# Coastal Lagoon Monitoring in the Southern Chukchi Sea National Park Units

## Fieldwork and Sampling Summary

## 2015, 2016, 2017

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A report led by Wildlife Conservation Society, in partnership with US National Park Service, Native Village of Kotzebue, and University of Alaska, Fairbanks, submitted to US National Park Service's Arctic Network.

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Cover Photo: Fyke net soaking (photo credit - WCS).

## Table of Contents

## Executive Summary

Wildlife Conservation Society (WCS) worked with the National Park Service from 2012 to design and implement the Coastal Lagoon Vital Sign component of the Inventory and Monitoring Program. This program is intended to establish biotic and abiotic reference conditions for assessing long-term changes in the coastal lagoons of Cape Krusenstern National Monument and Bering Land Bridge National Preserve. The Vital Signs program focuses on monitoring both the structure and ecological function of lagoons, as well as the fish resources used for subsistence by coastal communities. A standardized Vital Sign Protocol has now been completed for these coastal lagoons (Jones and Apsens, 2017), informed by work initiated in the early 2000s (Reynolds, 2012), followed by our four years of field efforts during 2012 (reported in Robards, 2014), 2015, 2016, and 2017 (reported here).

Our 2015, 2016, and 2017 Vital Sign field efforts were supplemented by funding from the National Park Foundation in support of a project called "Kotzebue Sound Whitefish Ecology and Seasonal Dynamics." This allowed for a more in-depth temporal and spatial investigation of whitefish ecology in these lagoons. We collected seasonal physical and biological data (rather than a rapid single visit) in Cape Krusenstern National Monument, assessed the feasibility of adding Cape Espenberg as another focal lagoon (Bering Land Bridge National Preserve), and collected additional Traditional Ecological Knowledge to inform a more comprehensive "Story of the Lagoons," which has been a priority for the Native Village of Kotzebue. Our field efforts in 2015-2017 focused on whitefish and other species of ecological importance. We sampled community composition, and assessed seasonal and spatial patterns of lagoon use, trophic dynamics, and fish health. A summary of this work encompassing both the Vital Sign and whitefish ecology project is a video summarizing field efforts published by the National Park Service (https://www.youtube.com/watch?v=Fb5yo2vxvNw&feature=youtu.be&t=6m47s), and the Vital Sign Protocol for monitoring efforts in coastal lagoons, with suggestions for further more in-depth research has been published (Jones and Apsens, 2017). Results from 2015-2017 field efforts have been synthesized into several publications and posters.

There are nine coastal lagoons described in the boundary of Cape Krusenstern National Monument – Aukulak, Imik, Ipiavik, Kotlik, Krusenstern, Port, Sisualik, Tasaycheck, and Atilagauraq; and four coastal lagoons within the boundary of Bering Land Bridge National Preserve – Espenberg, Kupik (also called Cowpack), Shishmaref, and Ikpek.

We monitored physical water parameters at three lagoons in Cape Krusenstern throughout the 2015, 2016 and 2017 field seasons (3-5 times total per lagoon) – Aukulak, Krusenstern, and Kotlik lagoons. During 2017, these lagoons were also sampled in winter as a part of an associated MSc graduate research project at the University of Alaska, Fairbanks (Tibbles, 2018). During the 2016 field season we also collected data at Tasaycheck and Atilagauraq lagoons, which were identified as potential sample sites based upon on-the-ground observation during the 2016 season, but had not been included in previous field efforts. Additionally, we conducted sampling in the Tukrok River, a marsh and riverine matrix which acts as the connection between Krusenstern Lagoon and the Chukchi Sea, with the outlet to the marine environment located 15 km away from the main body of the lagoon. Given the significant distance between the two sampling locations we treated the Tukrok channel as a distinct sampling site, rather than a part of Krusenstern lagoon.

While ease of access and logistics allow frequent sampling at Cape Krusenstern, high flight costs out of Kotzebue, the need for fixed wing planes on floats or a helicopter to get to the actual lagoon edge rather than the outer beach along the Bering Land Bridge coast, and limited freshwater supplies, limited sampling opportunities in 2015, 2016, and 2017. Consequently, Bering Land Bridge lagoons were only visited a single time per season during 2015 and 2016, and were not visited in 2017 (no float plane and no authorization permitted for helicopter logistics). Water quality data was collected at two lagoons in Bering Land Bridge during the 2015 and 2016 field seasons – Kupik and Ikpek. During the 2016 season, we sampled water quality in the lagoon waters at Cape Espenberg; however, extremely shallow water throughout (< 30cm) precludes standardized data collection consistent with other lagoons.

We generally accessed the various Park unit lagoons via fixed-wing plane (equipped with tundra tires or floats). Within each visited lagoon, we used a small inflatable boat equipped with a 9.9 horsepower outboard motor. Four long-term (Center, Outflow, Inflow, and Adjacent-to-the-Ocean stations) and three random sampling stations where sampled at each lagoon. At each station we collected data on primary productivity (YSI Sonde) and fish population (beach seine, fyke net, gillnet, minnow trap). Additionally, certain stations were sampled for mysid abundance (dip net), and zooplankton abundance (Wisconsin plankton tow net), while at all times opportunistic observations of avifauna and animal communities surrounding the lagoons were collected.

The data compiled in this report reflect findings from sample efforts across all three field seasons which include a total of 115 beach seine sets, 19 fyke net sets, 234 gillnet sets, 10 mysid transects, 9 hook and line sampling sessions and 25 minnow traps. These provide context for results from in-depth laboratory analyses of zooplankton and fish samples in collaboration with the University of Alaska, Fairbanks, and NOAA's Recruitment Energetics and Coastal Assessment group based in Juneau. Of key interest in this collaboration with NOAA is to place the characteristics of the lagoons of the southern Chukchi Sea, which we assess here in context of those further to the north.

Lagoons vary greatly in their seasonal connectivity with the ocean. Initial analysis of water quality data indicates that physical water properties varied by lagoon and season. Seasonal salinity levels vary in relation to a lagoon's connection with the marine environment; the more directly connected the lagoon is to the Chukchi Sea, the higher its salinity. A comparison between salinity levels recorded during the 2015/2016 field seasons and the 2017 field season, during which none of the lagoons sampled had an open connection to the Chukchi, reveals significantly lower salinity levels throughout all three Cape Krusenstern lagoons (Krusenstern, Aukulak and Kotlik). In most cases, mean temperature of the three Cape Krusenstern lagoons peaked in July and steadily decreased throughout the rest of the season, with the exception of Kotlik Lagoon in 2016. Mean temperatures in the generally shallower Bering Land Bridge lagoons were higher during the 2015 field season than the 2016 season, and results from data collection at Kupik and Ikpek show similar mean pH values for 2015 and 2016.

During the 2016 field season we began to develop a methodology for assessing seasonal variability of physical parameters in order to understand long-term variability within our sample sites. In order to establish the most effective and logistically realistic methodology for long-term data collection, we tested two methods of monitoring including deployment of the multiparameter Sonde at Aukulak Lagoon and installation of Onset Hobo Pendant pressure/salinity loggers at Krusenstern lagoon. We continued to experiment with long term monitoring during the 2017 field season and installed Onset Hobo Pendent temperature/light loggers around Krusenstern lagoon. Of the two methodologies to monitor short-term seasonal variability of water quality parameters within the lagoons we experienced more success with Sonde deployment rather than the Onset Hobo loggers. While the smaller pendant loggers were logistically simpler to install, poor retrieval success during the 2017 field season due to storm surge and drift prevented us from exploring any of the data collected. However, the 2016 deployment of the Sonde apparatus provided insight into seasonal variability within Aukulak lagoon, showing trends in both salinity and temperature.

Results from late winter sampling indicate that the physicochemical properties of water in the three lagoons varied widely. The water conditions beneath the ice were within ranges expected to be lethal to fishes, with hypersaline conditions, low temperatures and low dissolved oxygen. Average ice cover was thickest at Krusenstern Lagoon and thinnest at Aukulak Lagoon. The range of ice thicknesses across the lagoons corresponded with their salinities, with Krusenstern Lagoon being the freshest and having the thickest ice and Aukulak Lagoon being the most saline with the thinnest ice.

Results of blue green algae monitoring were initially anecdotal during 2015 and 2016 field seasons. In 2015 we experience the highest concentration of algae in Kupik Lagoon which, based on conversations with local fishermen, was a common occurrence and effected fishing success throughout the summer months. During the 2016 field season the most significant concentration of algae occurred at Aukulak Lagoon during the September sampling period. During the 2017 season we preemptively calibrated the Sonde with the objective of collecting blue green algae (BGA) and chlorophyll readings at water quality data collection sites. Units of collection changed during the 2017 season for BGA with µg/L being the unit of collection for all future sampling efforts. We were able to establish general seasonal trends in BGA in each individual lagoon, we were unable to make comparisons between lagoons due to inconsistent units in data collection.

Results from mysid transects taken during the 2016 field season indicate that there is no strong correlation between mysid density and depth using distance from shore as a proxy. Average mysid density was highest at Kotlik Lagoon while samples taken from Aukulak Lagoon yielded zero individuals (although not precluding they were elsewhere in the lagoon). Mysid sampling techniques that are adequate for these fast-moving species still need to be developed for comprehensive species composition assessment and potential quantitative assessments (see Porter, 2016 for review of some of the challenges).

Over three field seasons we recorded a total of 29 fish species, including several different types of whitefish: sheefish, humpback whitefish, least cicso and Bering cisco. In addition, we recorded several important forage species including Pacific sand lance, Pacific herring, pond smelt, ninespine stickleback, threespine stickleback and juvenile saffron cod. Species abundance varied from season to season and between lagoons.

We collected length and weight data on the majority of fish captured and, during the 2015 and 2016 field seasons, pulled otolith samples to examine fish growth rates for resident and migratory species. During the 2015 field season we assessed stomach contents on 14 species, and with mysids, chironomids and ninespine stickleback, three major prey items. Results of diet work are published in Tibbles and Robards, 2018.

While our focus was on seasonal characterization of water properties and whitefish ecology, during the 2015 field season we had the opportunity to gather a comprehensive set of length-weight measurements and otoliths from pond smelt (*Hypomesus olidus*), which is a poorly studied species found in Cape Krusenstern and Bering Land Bridge lagoons. Pond smelt is a locally abundant species in Krusenstern Lagoon and consequently may play an important role in the trophic dynamics.

In 2015 and 2016 we partnered with the State of Alaska to analyze contaminants (metals and persistent organic pollutants) in 9 species (Bering cisco, fourhorn sculpin, humpback whitefish, least cisco, ninespine stickleback, Pacific herring, saffron cod, sheefish, starry flounder), collected from the three lagoons in Cape Krusenstern (Appendix 4). During the 2017 field season we collaborated with Dr. Todd O'Hara and Dr. Maggie Castellini at University of Alaska Fairbanks to further develop contaminants sampling into our field protocol. We collected blood, organ and muscle tissue samples from 9 different species for a total of 94 samples. Species include fourhorn sculpin, pink salmon, Pacific herring, least cisco, saffron cod, sheefish, starry flounder, humpback whitefish and Bering cisco

Our research included collaboration with members of the local community who shared their Traditional Ecological Knowledge. Traditional knowledge of local ecosystems should be a key component of future lagoon monitoring systems, supplementing scientific data collection. Many residents of the areas surrounding Cape Krusenstern, who rely on the lagoons for subsistence purposes, have observed a range of significant changes to these resources, potentially linked to climate change. In the effort to construct a thorough and comprehensive picture of lagoon ecology and the subsistence resources the lagoons provide, we include these first-hand accounts from local residents. During the 2016 field season our field crew spent several days fishing the Wulik River with residents of the village of Kivalina (a full blogpost describing this trip can be found at: https://arcticberingia.wordpress.com/2016/10/21/fishing-in-kivalina-putting-research-in-context/). During this trip the team learned about local knowledge of the population dynamics of major subsistence species as well as how these species use the river and the lagoons surrounding Kivalina. We continue to make use of Traditional Ecological Knowledge to help guide our research efforts and make note of interactions with local community members in the findings summarized below.

Overall, our research builds on prior traditional knowledge and scientific research, providing ecological information vital for understanding long-term change, monitoring and managing Arctic lagoons of these Park units, helps prioritize spill contingency planning (by establishing the most productive lagoons), and will continue to inform a comprehensive understanding of the *Story of the Lagoons* – a key priority for the Native Village of Kotzebue, Wildlife Conservation Society, and the National Park Service.

# Introduction

In order to fulfill the National Park Service (NPS) mission of conserving parks unimpaired, National Park Managers are directed by federal law and NPS policies and guidance to know the status and trends in the condition of natural resources under their stewardship. The 2006, NPS Management Policies specifically directs the NPS to inventory and monitor natural systems. NPS has used the term "Vital Signs monitoring" since the early 1980s to refer to a relatively small set of information-rich attributes. This subset of physical, chemical, and biological elements and processes of park ecosystems are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. Vital Signs can provide managers with an early warning of situations that require intervention in National Parks. The mission of the NPS Arctic Network (ARCN) Inventory and Monitoring Program includes monitoring 28 specific Vital Signs in the five northern Alaska park units, including the coastal lagoons of Cape Krusenstern and Bering Land Bridge (Lawler et al., 2009).

In 2007, the Arctic Network Inventory and Monitoring Program began developing a monitoring protocol for coastal lagoons located in Cape Krusenstern. Using monitoring data to inform management decisions is clearly outlined in both the General Management Plan (GMP) for Cape Krusenstern National Monument (NPS, 1986a): "…monitoring will be conducted so that thorough information about the condition of resources will be available to monument managers," and Bering Land Bridge National Preserve (NPS, 1986b) which notes the: "positive effects on natural and cultural resources within the preserve as a result of natural resource research and monitoring." More specifically, the Cape Krusenstern National Monument GMP states the importance of monitoring water quality within the monument. The National Park Service will establish a monitoring program: "…to provide baseline data on water quality of the monument against which future sampling can be compared."

Coastal lagoons are a dominant landscape feature of the Arctic coastline; over a third (37%) of the coastline between Wales and the Canadian border is adjacent to coastal lagoon habitat (Figure 1, Appendix 1). The coastal lagoons of the NPS Arctic Network represent a critically important ecosystem in the region, and are vulnerable to both climatic change and development impacts. They are also highly dynamic, with both intra- and inter-lagoon dynamics are poorly understood. From a climate change perspective, increased coastal erosion and ocean acidification has the potential to profoundly alter the physical and biological dynamics of the lagoons. New dynamics of lagoon opening and closing will alter fish community patterns and the availability of important subsistence fish species. Projected changes in pH are projected to be most drastic in Arctic surface waters (Steinacher et al., 2009). This projected acidification has the potential to have a strong negative impact to calcifying organisms including mollusks and phytoplankton (Comeau et al., 2009). Coastal lagoons are also facing potential threats from increased development in the Arctic including potential oil and gas development in the northern Chukchi Sea, deep-water ports in the northern Bering Sea and increased international shipping along the Northern Sea Route. Lagoon Vital Sign efforts address the need for baseline information about the structure and function of lagoons, as well as the dearth of information about the local fish resources utilized for subsistence (Lentz et al., 2001). Without a clear understanding of baseline conditions in the lagoons, including the seasonality and inter-annual variability of physical and biotic components, and relative productivity, it is impossible for managers to detect long-term changes that result from climate change, to quantify the impacts of accidents, or develop appropriate management plans (including prioritization of sites) that protect the key functions that these lagoons have on local ecosystems and subsistence economy.


Figure 1: Map of the coastal lagoon habitat found in Alaska from Wales to the Canadian border. Coastline adjacent to lagoons is shown in blue, which amounts to 37% of the total coastline length.

*Coastal Lagoons in Northern Alaska*

Lagoons on the northern Chukchi and Beaufort Sea coastlines have been more comprehensively studied due to the relatively greater interest as part of oil and gas environmental assessment activities in that region. Common to all the more northern studies is the significant interannual, seasonal, and geographical differences in physical conditions and fish catches. Lagoon conditions can vary from fresh to saline, sometimes within a season dependent on connectivity (or loss of it) with the Beaufort Sea. Jarvela and Thorsteinson (1999) found Arctic cod, capelin, and liparids (snailfish) to be the most abundant marine fishes in catches, while arctic cisco was the only abundant diadromous (life cycles in fresh water and in marine water) freshwater species. Johnson et al. (2010) found capelin, Arctic cod, juvenile pricklebacks and juvenile sculpins to be the most common taxa in the Beaufort Sea around Cooper Island. In Elson Lagoon (Beaufort Sea coast), least cisco and juvenile sculpin were most common. Johnson et al. (2010) also concluded that species occupying coastal waters of the Beaufort Sea remained relatively unchanged over the past 25 years. Currently, Kevin Boswell, Brenda Norcross, Ron Heintz and colleagues are conducting a multi-year project funded by North Pacific Research Board looking at fish species composition and physical conditions in Kasegaluk Lagoon and Peard Bay on the northern Chukchi Coast. A new Long Term Ecological Monitoring (LTER) effort was also initiated in 2017 for the coastal Beaufort led by Dr. Ken Dunton – "The Beaufort Lagoon LTER and Arctic Coastal Ecosystem in Transition."

Between the North Slope efforts and the Cape Krusenstern and Bering Land Bridge NPS units, the most significant lagoon research efforts have been between Kivalina and Cape Thompson in the 1950s as part of the Project Chariot environmental assessment (Johnson, 1961; Willimovsky and Wolfe, 1966; Tash and Armitage, 1967; Tash, 1971) and at Port Lagoon just to the south of Kivalina as part of the Environmental Assessment for the Red Dog Mine port facility.

Within the focal National Park Service land units, there are nine coastal lagoons described within the boundary of Cape Krusenstern National Monument – Aukulak, Imik, Ipiavik, Kotlik, Krusenstern, Port, Sisualik, Tasaycheck, and Atilagauraq; and four coastal lagoons within the boundary of Bering Land Bridge National Preserve – Espenberg, Kupik, Shishmaref, and Ikpek (Table 1, Figure 2). We note that Sisualik and Espenberg may not fulfill all the requirements of being classed as lagoons, being more of a marine embayment or estuary (Durr et. al., 2011; Tagliapietra et. al., 2009).


Figure 2. Map of the Western Alaska coastal lagoons from Point Hope to Wales.

Villages in proximity to Cape Krusenstern National Monument include the Native villages of Kivalina (17 km northwest of the monument boundary), Noatak (13 km east of the monument boundary), and Kotzebue (15 km southeast of the monument boundary). For Bering Land Bridge National Preserve, proximal villages include the Native villages of Deering (20 km east of the preserve boundary), Shishmaref (surrounded by the preserve at a distance of about 20-30 km), and Wales (36 km southwest of the preserve boundary). Many residents of these villages use camps along the coastline, including around several of these lagoons. Red Dog Mine, one of the world's largest lead and zinc mines is located just north of Cape Krusenstern's boundary.

Of the lagoons in Cape Krusenstern, Atilagauraq is the smallest (<0.5 km$^2$) and Krusenstern Lagoon is the largest (56 km$^2$). Lagoons vary in the amount of water exchange with the surrounding marine environment. Aukulak, Krusenstern, and Sisualik are connected to Kotzebue Sound and Imik, Ipiavik, Kotlik, Tasaycheck, Atilagauraq and Port are connected to the more open Chukchi Sea. Aukulak, Imik, Kotlik, and Port are all intermittently open. Krusenstern, Atilagauraq, and Tasaycheck lagoons are typically seasonally closed. Krusenstern Lagoon is connected to the ocean at the mouth of the Tukrok River, which is 15 km away from the main body of the lagoon itself. The mouth of the Tukrok opens in springtime as a result of snow and ice breakup in the rivers and lagoons feeding the river, which builds pressure at the beachhead, and ultimately in some years breaking through (sometimes helped by local fishermen who recognize that the opening of the lagoons allows fish to enter (and grow). The mouth of the Tukrok River routinely closes in mid to late summer as gravel is pushed up by wave action resulting from strong storms. Sisualik, and Ipiavik are open year-round.

*Prior Coastal Lagoon Research in ARCN National Park Units and Overall Picture of Lagoons*
There have been a number of prior research efforts investigating the ARCN national park units that include this report's study areas. Throughout the 1970's, reports outlined avifaunal community composition and behavior surrounding the lagoons at Cape Krusenstern and Bering Land Bridge National Park. Additional insight from these predominantly avian studies included information on zooplankton community composition, which was found to be less diverse inside rather than outside the lagoons (Connors and Risebrough, 1977, 1978).

During the 1980's several reports were compiled that explored basic physical water quality parameters and fish and invertebrate community composition as well as fish abundance and size at study sites at Cape Krusenstern, Kotzebue Sound and the Turkrok River Channel (Raymond et al., 1984; Dames and Moore, 1983: Baylock and Erikson, 1983). Additional areas reported in these and associated literature include lagoon epibenthic regions, which were discovered to be highly variable and attributed to specific lagoon assemblages, timing, and location within lagoons by Blaylock and Erikson (1983). Findings from reports completed during this time period also suggested greater fish species diversity occur in lagoons open to marine environments rather than those that are closed off (Dames and Moore, 1983).

Research and data collection at lagoons in northwest Alaska National Park units continued into the 1990's, with one major study conducted at Krusentern Lagoon by Schizas and Shirley (1994). This study was in conjunction with a larger survey on benthic and epibenthic invertebrates of lagoons in Cape Krusenstern, and identified a new species of harpacticoid copepod (*Onychocamptus krusensterni)* among the benthic community at Krusenstern lagoon.

During the early 2000's, additional information on physiochemical (e.g. nutrients) and biological (e.g. zooplankton, epibenthos and fish) parameters was collected at six of the eight coastal lagoons located in Cape Krusenstern (Imik, Kotlik, Krusenstern, Aukulak, Sisualik,) (Reynolds et al., 2005). However, determining the general status and trends in conditions for these lagoons, in a manner comparable with future years, was not a feasible product of these studies, which acknowledged the absence of comprehensive baseline data for many coastal lagoons in the southern Chukchi Sea (Reynolds, 2012). A more limited sampling effort for the Cape Krusenstern National Monument Lagoons in 2009 was conducted by Reynolds, utilizing preexisting sampling sites with the intent of utilizing this in addition to data collected by Reynolds et al. (2005) to act as baseline information for Cape Krusenstern lagoons. Reynolds had sought to monitor coastal lagoons of Cape Krusenstern National Monument to document the long-term status and trends of physical, chemical, and biological components. In order to achieve that objective, Reynolds planned to collect: 1) physicochemical data in the five lagoons, 2) nutrient and chlorophyll a samples in five lagoons, 3) zooplankton samples in five lagoons, 4) benthic samples in three lagoons (Kotlik, Krusenstern, and Sisualik), 5) pelagic fish species in three lagoons (Kotlik, Krusenstern, and Sisualik), and 6) geomorphological data in five lagoons. These data, along with those previously collected (Reynolds et al. 2005), were intended to contribute to baseline water quality and species data for the five coastal lagoons in Cape Krusenstern. Additionally, field efforts during this sampling period were to be used to determine the feasibility of field-sampling methods for long-term sampling of these remote lagoon ecosystems (i.e., to develop a Vital Sign protocol).

Reynolds' efforts to seasonally sample multiple lagoons were ambitious given their remote nature and profound variability. While providing some valuable baseline data on basic conditions, a greater focus was still needed on a few lagoons to understand their temporal and spatial variability. Reynolds' protocols were not fully operationalized, and efforts to conduct in–field monitoring were thwarted by challenging logistics, creating a need and opportunity for NPS and Wildlife Conservation Society to collaborate towards common objectives.

The protocol and recommendations are beneficial for land management agencies. For example, lagoons and their marsh areas are particularly sensitive to climate change or oil that once entrained in the lagoon system would be very difficult to remediate; so, assessing the ecological or subsistence value of different lagoons supports both an understanding of change in lagoons as well as prioritized contingency planning in the case of an oil spill.

Traditional knowledge of local lagoon ecosystems has developed from a long history of subsistence fishing and is a vital monitoring system that can synergistically complement scientific data collection. Many residents of areas surrounding Cape Krusenstern rely on the lagoons for subsistence purposes, and have observed a range of significant changes to these resources linked to climate change (Moerlin et. al., 2015). These observations work to emphasize the importance of scientifically evaluating ecological functionality and health of lagoon systems, and incorporating local observations and expertise into these efforts. As Boswell et al. (2012) highlight for lagoons on the North Chukchi Sea coast, there is great importance in "developing a firm understanding of the value and role of these sensitive habitats with respect to fisheries productivity in the Arctic and their function as sources of nutrition and refuge for important fish, birds and mammals is imperative, especially in context of climate and environmental change."

# 2015, 2016 and 2017 FIELD EFFORTS

## Objectives

The objectives of the Wildlife Conservation Society-led activities throughout the 2015, 2016, and 2017 field seasons included the following:

1. Develop field protocols that can be included in a coastal lagoon Vital Sign;
2. Update objectives for coastal lagoons sampling to reflect a sampling period easily adapted to the Vital Signs monitoring program and that reflects the seasonal and interannual variability of lagoons;
3. Streamline logistics and field operations to provide guidance for future field efforts within the coastal lagoons of the NPS Arctic units;
4. Collect data from lagoon sites in Cape Krusenstern National monument and Bering Land Bridge National Preserve including:
    a. Water quality parameters: temperature, pH, salinity, dissolved oxygen, turbidity, and specific conductivity;
    b. Primary Productivity including blue green algae and chorophyll concentrations;
    c. Zooplankton abundance and community composition;
    d. Fish distributions, abundance, community composition, diet, and growth rates;
    e. Species composition and behavior of animal communities interacting with lagoon ecosystems;
5. Produce a cumulative report on findings from the 2015, 2016 and 2017 field seasons.

## Study Design

We built our sampling design based on Reynolds' prior work (Reynolds et al., 2005; Reynolds, 2012) and that of Robards et al., (2014). Reynolds' sampling sites were based on Blaylock and Houghton (1983). Four of Reynolds' five criteria were used for choosing sampling locations: 1) on the shoreline-side of the lagoon ("Marine Edge"); 2) in the middle of the lagoon ("Central"); 3) near creek and river inlets ("Inflow"); 4) at outlets ("Outflow"). Reynolds used one additional =l criteria: "near any known anomalies such as springs." We did not include this designation, as most lagoons could be designated with some unique feature. Robards et al., (2014) added 3 randomly chosen sites in each lagoon to facilitate statistical inference of results over time.

## Field Methodologies

*Water Quality*

Sampling methods used to collect physicochemical data were based on the Environmental Protection Agency (EPA) National Coastal Assessment Field Operations Manual (U.S. EPA 2001). At each sampling point (7 sites per lagoon per month) and at a depth of 50 cm, the following core water quality parameters were measured in situ using a YSI EXO 2 multiparameter Sonde: water temperature, dissolved oxygen, salinity, specific conductivity, turbidity, and pH. Water depth was measured with a hand-held depth sounder.

During the 2016 field season we began to develop a methodology for assessing continuous seasonal variability of physical parameters in order to better understand short- versus long-term variability within our sample sites. In order to establish the most effective and logistically realistic methodology for long-term data collection, we tested two methods of monitoring including deployment of the multiparamter Sonde at Aukulak Lagoon and installation of Onset Hobo Pendant pressure/salinity loggers at Krusenstern lagoon. We recorded water quality parameters in Aukulak Lagoon from 3-July to 13-

September. The probe was set to record data every fifteen minutes over the two-month period, collecting values for temperature, pH, dissolved oxygen, salinity, turbidity, specific conductivity, chlorophyll and blue green algae in the lagoon throughout the sampling period. During the 2017 field season we experimented with Hobo Pendent temperature/light loggers. We installed the Pendant loggers at intervals around the perimeter of Krusenstern lagoon, including the freshwater inlet and the outlet of the lagoon, at an approxinmate depth of 1m. We anchored loggers with duckbill anchors and connected buoys to the other end of the line so that the loggers were suspended in the water column. We installed loggers at the beginning of the season and attempted to retrieve them during the last sampling period. At the end of the season we were only able to relocate a few loggers due to storm surges and tidal drift. Future use of this technique would need to better establish a secure mode of mooring loggers.

*Primary Production*

Primary production was estimated using the YSI EXO 2 Sonde to measure chlorophyll and blue-green algae in the lagoons during the 2017 season. Reynolds (2012) and Robards et al., (2014) had used laboratory analysis for chlorophyll. However, the expenses for conducting this work are preclusive for a long-term monitoring project, particularly given the large number of below-detection samples over the course of a season reported by Robards et al., (2014).

*Zooplankton*

During the 2017 field season we developed a methodology for sampling zooplankton communities in three of the Cape Krusenstern lagoons (Aukulak, Krusenstern and Kotlik). Using an 80μm mesh Wisconsin plankton net with a 12" diameter mouth, we collected zooplankton samples in the area around the freshwater inlet and the outflow of each lagoon in addition to two other sample points corresponding with water quality data collection points. Due to the size of Krusenstern Lagoon we increased the number of samples from two to six for a total of eight sample sites, including additional points at the terrestrial edge and the marine edge as well as several water quality points, which were selected with the objective of maximizing area of the lagoon sampled. We collected samples by boat when depth required, but were able to walk tow nets at all near shore locations. We measured flow rate during sample collection using a General Oceanics Mechanical Flowmeter, which was towed at a fixed point along with the zooplankton net.

Standard sampling procedure is as follows:

1) Rinse plankton net and collection cup in ambient water

2) Attach collection cup. Record numerical value displayed on flow meter on data sheet under "flow start".

3) Throw the net from a stationary point and tow the net slowly behind a boat or, if performing a nearshore walking tow sample, behind body for 50m (aim for obtaining a sample size of ~ 5-10 cubic meters of water, distance can be measured with GPS unit).  Prevent the net from coming in contact with the bottom, particularly when sampling from shore. Care needs to be taken that flow meter does not turn backwards while conducting the tow. Make sure the net is constantly moving through the water without pauses when collecting sample; the recommended tow speed is 0.75-1 m.

4) Pull net from water in one motion, shake out excess water and drain the sample into collection bottle using squirt bottle filled with filtered water to remove any sample remaining in collection cup. Samples should have an approximate volume of 16 oz including lagoon water.

5) Record information on data sheet including: date, time, location, sample name and flow meter numerical value at end of tow.

6) Samples should be preserved in 5-10% formaldehyde/(sea) water solution. For a 16 oz sample, add 50 ml of 40% formaldehyde using syringe. Invert container to mix thoroughly. Write sample number information on piece of write in the rain paper (with pencil), add label to the bottle along with sample.

7) Store sample in a cool, dark place, such as a cooler.

8) Perform 3-5 sample tows per lagoon to account for spatial variation.

We completed zooplankton sample collection during the July and August sampling periods of the 2017 field season. Future samples should be collected throughout the field season with the objective of creating a more complete picture of zooplankton activity throughout the summer. Additionally, a protocol should be developed to investigate diurnal zooplankton activity within these lagoons. All these factors will need to be incorporated if results are to be compared over seasonal, annual and decadal time scales.

*Mysid Sampling*

During the 2016 field season we developed two different techniques for sampling mysids in the water column. This was initiated due to the clear importance of mysids in fish diets (see below). To evaluate mysid abundance in the area around fish sampling sites, we performed one pull with a 36 inch crab ring net lined with fine mesh mosquito netting in the area directly surrounding a fishing net (e.g. a gill or fyke net) or a beach seine pull site. Samples were taken by sinking the net into the water column until fully submerged, soaking the net for 10 minutes, then pulling the net vertically out of the water.

To judge mysid concentration gradients at different depths we performed sampling transects, taking samples in a straight line perpendicular from the shoreline with sampling stations at 1m, 10m, 50m, 100m and 500m offshore, with an occasional additional sample taken at 1000m offshore in large lagoons. At each sample site, we deployed two mysid nets simultaneously (for replication) to the benthos and soaked for 5 minutes before retrieval. The 1m station (approximately 1m from the shoreline) can be deployed without a boat while the other stations require a boat. If the 1m location was not sufficiently deep to properly deploy the net, we moved the station out 2-3 m from the shoreline. We retrieved the net in one smooth, quick motion, allowing the outer ring to rise rapidly and the mysids to remain on the surface of the net during retrieval. After pulling the nets we recorded the number of mysids collected as well as any other species present in the net.

*Fish Sampling*

We sampled fish in all lagoons using a beach seine, fyke nets, minnow traps, and experimental gill nets.

The 37-m bag beach seine was used to sample fish at any location where beaches allowed for deployment (e.g., sandy with no protruding rocks). The net was set parallel and 20 m from shore, and then retrieving the net in a symmetrical manner with people drawing the net in with lines attached to the net's ends (per Robards et al., 1999).

We used fyke nets to collect larger volumes of fish in locations where the depth and substrate were favorable. Our fyke net was constructed with 3.1 mm stretch mesh, a 91.5 x 122 cm frame made of two rectangular conduit frames, 5 steel hoops, 2 throats, and a 15.2 m lead. The wings were anchored using rebar with the main line attached perpendicular to shore and the wings set at approximately 45˚. Set time for fyke nets was more standardized than scientific gillnets throughout the three field seasons, however soak time still varied between sets to avoid mortality where catches were large. During the 2015 field season, our target set time for each fyke net was 3 hours (mean = 3.22 hours, standard deviation = 1.44 hours). We maintained the same target set time throughout the subsequent seasons, with mean a mean set time in 2016 of 3.47 (standard deviation = .7h) and in 2017 2.5 (standard deviation = .67h)

We used fine mesh minnow traps, which we set near shore at a depth of approximately 50 cm and were checked each day. Our success sampling with minnow traps varied greatly during the 2015 field season and we did not incorporate this sampling method in subsequent field seasons, apart from once in 2016.

Experimental gill nets consisted of 5 panels, each 25ft in length, for a total net length of 125ft. Stretch measurement of the individual panels were: 1 inch, 1.5 inch, 2 inch, 3 inch, and 4 inch. Set sites were selected in areas near the inflow/outflow (regardless of whether the connection was open or closed), and points next to water quality sample points through the lagoon (e.g., central, marine edge). Soak time varied greatly due to close attention to nets in order to minimize risk of a) birds or other unintended animals being caught, and b) unnecessarily heavy fish mortalities. Gill nets were therefore primarily used to help assess community composition and to catch target fish for further analysis, rather than for rigorous quantitative assessment. During the 2015 field season nets were set for 0.3 to 3.9 hours (mean = 1.7 h, standard deviation = 0.8 h). During the 2016 field season nets set for 0.15 hours to 4.25 hours (mean= 1.65, standard deviation = .9 h) and in 2017 set times varied between .25 and 3.25 hours (mean = 1.86, standard deviation = .9 h).

We identified all fish samples to species and measured each individual to fork length. We collected otoliths from various whitefish species including: sheefish, humpback whitefish, and least cisco; as well as starry flounder and 11 other fish species to determine age distributions. During the 2015 and 2016 field seasons we were able to perform most otolith extractions while in the field. Samples taken during the 2015 field season have been analyzed for age and we aim to complete similar analysis for 2016 samples. We do not plan on pulling otoliths from samples taken during the 2017 season. We had the opportunity to gather a comprehensive set of length-weight measurements and otoliths from pond smelt (*Hypomesus olidus*), which is a poorly studied species found in Cape Krusenstern and Bering Land Bridge lagoons.

During the 2015 and 2016 field season we partnered with the State of Alaska to analyze contaminants (metals and persistent organic pollutants) in samples collected from Krusenstern, Kotlik and Aukulak lagoons in Cape Krusenstern. We collected whole fish samples, which were removed from fishing apparatuses using latex gloves and immediately bagged then frozen. We developed a more focused in-field protocol at the beginning of the 2017 field season with the assistance of Drs. Todd O'Hara and J Margaret Castellini at the University of Alaska Fairbanks who provided contaminants sampling kits. Each kit contained one cardboard comb for collecting blood samples, one vial for an organ tissue sample and one Whirlpack for collecting a muscle tissue sample.

To perform gastric lavage, we anesthetized fish using a solution of 20-50 mg/L of Aqui-S 20E, depending on size class, as per the manufacturer's recommendations (www.aqui-s.com). Once fish were anesthetized, an appropriately sized, sterilized blunt piece of tubing was carefully inserted into the stomach of the fish. For fish less than 300 mm, plastic tubing with a diameter of 1mm was attached to a syringe; for fish larger than 300 mm, a copper tube with a diameter of 3 mm was attached to a pressurized container. We injected water into the stomach of the fish through the tubing to flush the entirety of the stomach contents. For larger fish, two to three flushings were often needed. We flushed the stomach contents into a 250μm sieve and the contents were then transferred to a Whirl-Pack and preserved in a 95% ethanol solution.

Fish and tissue samples were also collected for analysis at the NOAA facility in Juneau. These analyses include: Bio data, energetics, stable isotopes, and RNA/DNA. We selected a sub sample of fish that gives us a good representation of a species across size, harvest time and location to perform testing on. Stomach contents are removed, weighed, and sex, maturity, and gonadal somatic index determined. During this process some fish have small muscle plugs removed for either RNA/DNA ratio assays or stable isotope (C/N) analysis. We took a subsample of tissues for energetics and fish condition analysis, including carbon and nitrogen ratios, which will provide information on trophic structures in lagoon populations.

*Traditional Ecological Knowledge Surveys*

Traditional Ecological Survey interviews were performed in both a structured and informal capacity. Informal interactions occur in the field when, while collecting data, we encounter members of the local community. These encounters are documented the sampling descriptions below. More structured interviews include a formal questionnaire and are recorded and transcribed later on. Questionnaires on subsistence fishing include sections on the individual's current use of the resource, their experience of the state of the resource through time, the ecology of the resource, the cultural context of the resource and resource use through time, and a final miscellaneous section.

Table 1. Location of metadata for corresponding topic.

| | |
|---|---|
| *Water Quality Data* | Appendix 2 – Tabs 6-12 and 19; Appendices 8 and 9 |
| *Primary Production* | Appendix 2 – Tabs 7 and 9-12 |
| *Zooplankton* | Appendix 2 – Tabs 22 and 23 |
| *Mysid Sampling* | Appendix 2 – Tab 18 |
| *Fish Length Weight* | Appendix 2 – Tab 2, 4 and 5 |
| *Fish Abundance* | Appendix 2 – Tab 3 |
| *Pond Smelt Data* | Appendix 2 – Tab 20 |
| *Otoliths Collection* | Appendix 2 – Tabs 15-17 |
| *Diets Collection* | Appendix 2 – Tabs13 and 14 |
| *Contaminants Collection* | Appendix 2 – Tabs 25-28; Appendix 4 |
| *Traditional Ecological Knowledge Surveys* | Appendix 3 |

*Implementation*

We spent the majority of each field season sampling lagoons located in Cape Krusenstern due to the simplified field logistics of using the NPS Ranger Station at Anigaaq as a base for a field camp. With our field camp at Anigaaq we were able to store and secure food and gear, operate a propane freezer for biological samples throughout the season, make quick commutes to Kotzebue and, have access to outhouse, cooking, and sleeping facilities. Lagoons sampled in Cape Krusenstern included Krusenstern, Aukulak, Kotlik, Atilaguaraq and Tasaycheck.

To reach Krusenstern Lagoon, we boat up the Tukrok River and through the adjacent wetland. There are two navigable routes through the network of waterways, islands, shallows that make up the wetland. Both routes are approximately equal in travel time; however, as the season proceeds the increase in aquatic vegetation slows travel by fouling the propeller of the 9.9 hp outboard engine. To reach Aukulak, we boat from Anigaaq Ranger Station to the mouth of the Tukrok River, then approximately 2.5 km SE along the Chukchi coast. When Aukulak is open to the Chukchi Sea, we drive the boat to the mouth of the lagoon and enter there. When Aukulak is not open, we portage the boat and gear across the marine berm and into the lagoon. Due to its location 50 km north of Anigaaq ranger station, we access Kotlik Lagoon by plane or charter boat depending on the season. While Kotlik Lagoon is close enough to access by four-wheeler from Anigaaq ranger station, exposed beach below the high-water mark does not consistently occur throughout the route, making safe travel along the coast ephemeral. Furthermore, some of the route requires transit over private lands which was we had not authorized for this project (due to the former challenges of four-wheeler use). While visiting Kotlik we set up camp and stage gear on the beach near the outlet or on the terrestrial edge of the lagoon. We traveled to both Tasaycheck and Atilaguaraq Lagoon by four wheelers, driving north up the beach from Anigaaq and staging gear on the marine beach of each lagoon.

Sampling for the Tukrok River and the Chukchi Sea was performed directly from our base at the ranger station. For ocean sampling, we drove the boat to the mouth of the Tukrok River and back up the beach to the ranger station when the river was open to the marine environment. When the Tukrok River was closed, we portaged the boat from the channel to the marine side beach. We sampled predominantly in the area directly surrounding the ranger station on both the ocean and channel side.

The lagoons in Bering Land Bridge were less frequently visited due to limited access and challenging logistics. A Cessna-205 with tundra tires was used to transport gear and personnel to Bering Land Bridge from Anigaaq as well as between lagoons. We had used a Cessna-185 on floats during 2012; however, this plane was not available in 2015 through 2017. We camped and staged gear on the marine edge of the lagoons (increasing visibility and reducing chances of bears getting close without detection), however establishing a base for a field camp at Bering Land Bridge was made difficult by the fact that we were unable to land adjacent to the lagoon itself. Unable to travel to the lagoons by boat and without access to a floatplane, we had to transport most of our gear (engine, boat, water etc) up to half a mile by hand from the landing strip to our base at the marine edge. Furthermore, the inability to navigate the very shallow (often less than half a meter) Bering Land Bridge lagoons limited effectiveness of the standard sampling protocol. We were unable to access many sample sites and conduct accurate water quality data measurements in Ikpek, Kupik and Espenberg lagoons. In the future we hope to explore alternative methods of accessing and navigating these lagoons to improve feasibility of data collection. These lagoons were not visited during the 2017 field season due to logistic constraints.

Throughout all three field seasons our team partnered with several individuals based in Kotzebue village representing different organizations and agencies. We collaborated with Alex Whiting and Cyrus Harris of the Native Village of Kotzebue, who provided extensive information on local fishing practices, logistical assistance and insight into these study sites. Additionally, Bill Carter of the U.S. Fish and Wildlife Service's Selawik National Wildlife Refuge Office provided invaluable logistical support as well as knowledge on and information about subsistence whitefish species included in our research. Collaboration was further supplemented by in-the-field interviews with members of the local community who provided traditional ecological and subsistence knowledge to guide our research. These interactions are touched upon in the following report. More structured interviews were performed in Kotzebue during 2016. Additionally, during the 2016 field season our field crew spent several days fishing the Wulik River with residents of the village of Kivalina during which they conducted informal interviews regarding traditional knowledge of population dynamics of major subsistence species.

We also conducted winter sampling in Aukulak, Krusenstern and Kotlik lagoons as part of a wider project to assess overwintering habitat for fishes in lagoons. The technician (Marguerite Tibbles) from the 2015 and 2016 field seasons enrolled at UAF for a MSc program with overwintering ecology of whitefish as a focus of her studies. Her work included field activities in 2017, which are noted below and in Appendix 4 for completeness.

## Field Notes for Sampled Lagoons

Below, we document some aspects, or noted events from our field logs, for each of our field efforts at each lagoon by sampling event and year. These accounts are included as a means to provide some greater context than the data tables or summarized data in publications provides. Consequently, the accounts include some speculative or anecdotal comments and thoughts from those working in the field, which may provide some help for future efforts considering different options for addressing specific needs.

Table 2. Name, location, field season sampled (x) and alternate names for sample sites. Names have been updated and standardized to reflect preferred names of local partners.

| Park Unit | Lagoon* | Alternate Spelling of Name | Field Season | | |
|---|---|---|---|---|---|
| | | | 2015 | 2016 | 2017 |
| Cape Krusenstern National Monument | Krusenstern | | x | x | x |
| | Atilaguaraq | | | x | |
| | Aukulak | Aqalaaq, Akulak | x | x | x |
| | Kotlik | | x | x | x |
| | Tasaycheck | Tasaychek | | x | |
| Bering Land Bridge National Preserve | Ikpek | | x | x | |
| | Kupik | Cowpack | x | x | |
| | Espenberg | | x | | |

*Note: Atilaguaraq and Tasaycheck were opportunistically sampled rather than being a part of the Vital Sign protocol. Espenberg was assessed as a candidate for the Vital Sign, but was omitted after 2015 due to the extreme shallows in this lagoon.

### Cape Krusenstern National Monument


Figure 3. Sampling sites at Cape Krusenstern National Monument

## Aukulak

### 2015 Field Season

Table 3. Field sampling dates for Aukulak Lagoon during the 2015 field season.

| July | August | September |
|---|---|---|
| 5 | 31 | 12 |
| 22 | | |

*July*

Aukulak is a relatively small lagoon (surface area = 9 $km^2$; Table 23) that was not open to the ocean during the 2015 field season. However, the salinity of the water was much higher than the previous field sampling conducted in 2012 (23.74 ppt in July 2015 versus 4.03 ppt in July 2012), suggesting that it had been open earlier that year (which was confirmed by local contacts and fish community data). Sampling on 5-July included water quality measurements, 2 gill nets and 2 beach seine replicates. Approximately 10,000 larval fish were caught in a beach seine at the eastern end of the lagoon and 6 new species were recorded on 5-July. Mysids were observed in Aukulak, and we collected a dip net sample. At the end of July the water level in the lagoon was low in comparison to the beginning of the month, having dropped approximately 50 cm. Both days we sampled Aukulak in July had clear sky conditions and calm winds.

*August*

We sampled Aukulak only once in August 2015, due to high seas preventing us from safely accessing the lagoon on several planned attempts (the journey requires transit through open water between Tukrok River and the Aukulak lagoon). The water temperature had decreased by 13ºC compared with temperatures measured on 22-July (5.9˚C versus 19.2˚C). The water level appeared to have returned to the height we noted at the beginning of July. We took water quality measurements and set 2 gill nets. We caught Arctic flounder for the first time on 31-August. The 31-August sampling day was calm (permitting travel to Aukulak via the Chukchi Sea) with clear skies.

*September*

Rough seas made landing on the beach near Aukulak difficult in September; however, conditions in the lagoon were calmer. We collected water quality measurements, and completed 1 gill net and 2 beach seine replicates. Unlike previous months, we did not capture saffron cod. Weather was overcast with intermittent rain showers and the water in the lagoon was approaching freezing temperatures.

### 2016 Field Season

Table 4. Field sampling dates for Aukulak Lagoon during the 2016 field season.

| June | July | August | September |
|---|---|---|---|
| 19 | 2 | 21 | 1 |
| 22 | 22 | | 4 |
| 30 | | | |

*June*

We visited Aukulak for the first time in the 2016 field season on 19-June to collect water quality data. The lagoon was open with a strong outgoing current and the channel at a depth of around 1.3 meters. We revisited the lagoon on the 22-June and set gillnets and performed one beach seine replicate at the area around the mouth of the lagoon. The weather was clear with light wind blowing northwest up the coast. On 30-June we returned to the lagoon with winds blowing from the north at 10 mph, at which time the channel of the lagoon was beginning to close. We set two gillnets along the northeast side of the lagoon in deep water (approximately 3m) and a fyke net in the area around the mouth. When pulled, the fyke net was full of juvenile sculpin averaging around 3-4mm, as well as flounder, ninespine stickleback and pond smelt.

*July*
On 2-July 2016, the mouth of the lagoon was further closed with a strong current flowing out to the ocean in the narrow remaining channel. We set an offshore gillnet near the marine edge and experimented with the mysid net close to shore but found a relatively low abundance of mysids in the area. We pulled the gillnet after two sets and collected otoliths and diet samples. Winds picked up as the day progressed with seas in the lagoon reaching two feet by the end of the day. We returned to Aukulak again on 22-July. The day was sunny and calm and the mouth of the lagoon was closed, forcing us to portage the boat across the marine edge to access the lagoon. We collected water quality data, set one fyke net and pulled one beach seine in the area around the mouth of the lagoon, catching a high abundance of juvenile herring in the beach seine. As the day progressed the wind picked up and it began to rain. We set a gillnet at the mouth which was checked a total of four times and caught a relatively low abundance of fish compared to previous fishing efforts that field season.

*August*
We sampled Aukulak once during August. Weather on 21-August was overcast and calm with showers. We set two gillnets at the west end of the lagoon, one offshore and one onshore. While they were soaking we completed water quality data collected. After pulling the gillnets we performed one beach seine replicate onshore in proximity to where we had set the gillnets. We performed an additional two beach seine replicates one the marine edge of the lagoon.

*September*
When we traveled to the lagoon in September we were accompanied by the videography crew from the Park Service (https://arcticberingia.wordpress.com/2017/08/17/dynamic-lagoons-of-arctic-alaska-getting-a-baseline/). We traveled to the lagoon with the two four wheelers and both boats to accommodate our numbers. We set a fyke net at the northwestern end of the lagoon catching eight different species including arctic flounder, Bering cisco, fourhorn sculpin, and Pacific herring. We traveled to the southern end of the lagoon where we set two gillnets and performed one beach seine replicate near the mouth of the lagoon. We caught six sculpin of an unidentified species, which we collected for identification later on. We observed a high abundance of algae in the water column, indicating a recent and significant bloom. We were visited during the day by two members of the local community who we spoke to us about traditional techniques of subsistence fishing that they generally used at Aukulak and around Cape Krusenstern. We returned to Aukulak on 4-September to collect water quality data and perform one beach seine replicate. The weather was calm, clear and unseasonably warm.

**2017 Field Season**

Table 5. Field sampling dates for Aukulak Lagoon during the 2017 field season.

| March | June | July | August |
|---|---|---|---|
| 11 | 25 | 14 | 15 |
| | | | 16 |
| | | | 18 |

*March*
We traveled to Aukulak Lagoon in March via snow machine from Kotzebue to determine abiotic conditions beneath the ice and identify potential overwinter habitat for fishes in the lagoon. Several holes were drilled through the ice using a gas-powered ice auger and a smaller drill-powered auger. The water depth, ice thickness and snow depth were measured at each site. Water quality was measured beneath the ice where liquid water was found.

*June*
Aukulak lagoon was not open during the first sampling period of the 2017 field season and we received information from local communities confirming that it had not opened at any point so far that season. On 25-June we collected water quality data throughout the lagoon, which revealed a lower overall salinity than historically common (Table 27), supporting reports that the lagoon had not opened that season. We

set 4 total gillnets at random points across the lagoon, each for three hour sets, and performed eight beach seine replicates on the marine edge however were unsuccessful in catching any fish. We observed a large amount of algae in the water column which had somewhat fouled the gillnets. The weather throughout the day was calm, clear and sunny.

*July*
Aukulak was closed throughout the second sampling period of 2017, and again only required one day of sampling. We used four wheelers to access the lagoon the morning of July-14, when the weather was sunny and clear with low winds. We collected water quality data when we first arrived at the lagoon and performed four zooplankton tows during which we observed a similar concentration of algae in the water column as the first round of sampling. We set two gillnets, one for two hours and one for three hours, but did not catch any fish. Taking into consideration similar results from fishing efforts during the first sampling period we did not set any more nets that day.

*August*
We revisited Aukulak for the final sampling round on 15 and 16-August of 2017. On the 15$^{th}$ we completed water quality data collection and four zooplankton. The next day we set two gillnets and performed two beach seine replicates. Weather on the 15$^{th}$ was sunny and clear with low wind while, on the 16$^{th}$, rain and high winds moved in. We conducted further sampling on 18-August with weather conditions similar to that of the 16$^{th}$ and seas at 2-4 feet. We set one fyke net for two hours, performed two beach seine replicates and two gillnet sets. We did not catch any fish on either day of sampling. Water levels in the lagoon did not appear changed (observation based) however water temperatures had decreased by around 5-6 ºC from the last sampling period.

## <u>Krusenstern</u>

### 2015 Field Season

Table 6. Field sampling dates for Krusenstern Lagoon during the 2015 field season.

| July | August | September |
|---|---|---|
| 1 | 10 | 1 |
| 2 | 11 | 3 |
| 3 | | 6 |
| 4 | | 7 |
| 6 | | 13 |
| 24 | | 14 |
| 25 | | 15 |
| | | 17 |

*July*
Krusenstern Lagoon is open to the wetland, the Tukrok River, and ultimately to the Chukchi Sea via a small (~4 m in width) breach on the eastern lagoon shore. We visited Krusenstern Lagoon 7 times in July (Table 6). Sampling in Krusenstern near the channel was affected several times by a strong current. The current frequently switched directions, flowing into the lagoon one day, and out the next creating a challenging environment for setting gill nets, fyke nets and beach seines (note lunar tides are low; however, freshwater runoff, marine circulation patterns, and wind drive strong flows of water within lagoons). Heavier weights on the gill nets helped stabilize the nets in the set location. Our water quality sampling done at the end of the month was challenged by strong winds, which caused large waves in the lagoon. Mysids were abundant within the lagoon throughout the field season; we took a dip net sample on 2- July to identify mysid species later in the lab. Also, there was an abundance of bird life in the lagoon and in the surrounding wetlands. Arctic terns were observed feeding on ninespine stickleback in the lagoon. Several small herds of caribou were observed in the wetlands in July.

*August*
We visited Krusenstern Lagoon twice in August of 2015. On 10-August, we measured water quality, set 2 gill nets and 3 beach seine replicates. The following day, we set 2 gill nets, a fyke net and 2 beach seine replicates. The current out of the lagoon was weaker, making beach seining at the outlet easier. Our efforts were focused on the mouth of the lagoon, and we captured 2 new species that have not been recorded in Krusenstern Lagoon previously. The weather for the August sampling was much cooler than the previous month, and sample days were overcast with showers.

*September*
We visited Krusenstern Lagoon 8 times in September 2015 (Table 6). September was characterized by strong winds, which created challenging conditions in the lagoon. Large wind waves (sometimes exceeding a meter) made sampling difficult; however, beach seining was sometimes possible on the leeward side of the lagoon. For days with high winds, collecting water quality measurements became exceedingly difficult because of spray and waves washing over the side of the boat. These conditions prevented us from beach seining, but gill net catches appeared unaffected in these conditions. The turbidity measurements taken during these storms were much higher than on calm days (mean turbidity = 11.0 and 22.0 NTU for August and September, respectively). Despite the challenging conditions, we increased our sampling efforts via beach seining in September to obtain larger sample sizes for our fish collections, where samples were the objective rather than quantitative comparison of individual uniform sets.

### 2016 Field Season

Table 7. Field sampling dates for Krusenstern Lagoon during the 2016 field season.

| June | July | August | September |
|---|---|---|---|
| 18 | 3 | 5 | 2 |
| 23 | 5 | 18 | |
| | 23 | 20 | |
| | 26 | 23 | |
| | 27 | 24 | |

*June*
We sampled Krusenstern for the first time in the 2016 field season on June 18$^{th}$ (Table 7). That day we completed water quality data collection and set two gillnets close to the mouth of the lagoon. We performed two beach seine replicates and set a fyke net north of the mouth, catching humpback whitefish along with several thousand ninespine stickleback and pond smelt. When we returned on the 23$^{rd}$ the weather was clear and sunny. We set two gillnets and completed one beach seine.

*July*
We visited Krusenstern three times during the month of July in 2016. Early in the month (3-July) we were delayed leaving Anigaaq due to heavy fog in the area. The fog lifted around noon and we were able to travel to Krusenstern. We set one gillnet near the marine edge of the lagoon and, while waiting for the one hour set, traveled to KR-R2 to assess the pond west of the ridge in which we discovered the presence of juvenile stickleback. While traveling back to the gillnet, we observed a brown bear swimming towards the shore close to the freshwater inlet. We returned to Krusenstern on the 5$^{th}$ in high winds gusting west at around 20 knots. We set two gillnets in the offshore area near the mouth and completed three beach seine replicates just north of the mouth, catching a large number of ninespine stickleback, pond smelt, and humpback whitefish. When we revisited the lagoon again at the end of the month (23-July), the weather was clear and sunny and we split up into two sampling teams. One team collected water quality measurements and traveled to the freshwater inlet to set two gillnets. The other team remained at the mouth and set one fyke net for approximately four hours and performed one beach seine. On the 25-July we brought gear to camp at the lagoon overnight, eliminating travel time from Anigaaq and enabling longer sampling days at the lagoon. During the next two days we collected bathymetry data, set five

gillnets and collected mysid samples. Additionally, we monitored Caspian tern and Glaucous gull activity at the nesting site located at the northern end of the lagoon near the marine edge. On the final day of sampling (27-July) it was raining with winds gusting at 10-15 knots.

*August*

On 5-August two crew members traveled to Krusenstern to beach seine and caught a large number of mysids. When we returned on the 18th the weather was overcast with intermittent showers and winds at 10-15 knots. We set a total of three gillnets and attempted to collect water quality readings but were unable to due to failure of the Sonde. We revisited the Caspian Tern nesting site and observed one recently fledged chick. We fixed the Sonde and revisited the lagoon on the afternoon of the 20th to complete water quality data collection. We noted that water was flowing rapidly into the lagoon and water was higher than previously seen that season (observation based). We returned twice more to Krusenstern that month (Table 7) with both visits characterized by overcast weather, lower temperatures and intermittent rain as well as high water levels in the lagoon. We continued to monitor the nesting Caspian Tern colony and completed bathymetry data collection throughout the lagoon. We set a total of three gillnets (one of which had fish hit the net immediately after having been set) as well as one fyke net for a three and a half hour set.

*September*

We returned to Krusenstern one time in September 2016 with a large crew of eight, including the videography crew from the Park Service. We set one onshore and one offshore gillnet, collected mysid samples and set a fyke net north of the mouth of the lagoon. We took the film crew to see the nesting tern colony, which we were able to observe briefly before they fled the nesting area. The weather was calm and clear with unseasonably warm temperatures.

**2017 Field Season**

Table 8. Field sampling dates for Krusenstern Lagoon during the 2017 field season.

| March | June | July | August |
|---|---|---|---|
| 16 | 22 | 15 | 17 |
| 17 | 23 | 16 | 19 |
| | | 18 | |
| | | 19 | |

*March*

We traveled to Krusenstern Lagoon on two separate occasions in March. Krusenstern was challenging to sample as there were consistently high winds (≥20 mph). The high winds led to large areas of glare ice on the lagoon as well as very hard, wind-shaped snow everywhere else which made travel across the lagoon challenging. We also found a pressure ridge across the lagoon that was up to 1 m high. Multiple holes were drilled through the ice using the 10-inch gas powered auger and the 2-inch drill-powered auger to measure water depth, ice thickness and snow depth. Water quality was also measured beneath the ice at these locations. Some sampling also took place in the Tukrok River and Clear Creek, which are part of the Krusenstern watershed.

*June*

We sampled Krusenstern Lagoon two times during the month of June 2017. On both days of sampling the weather was overcast and breezy, with swells on the 23rd reaching two feet. On 22-August we set two gillnets, one onshore and one offshore, and beach seined once on the terrestrial edge of the lagoon near the outlet. Pulling the beach seine was difficult due to high winds and silt levels in the water column, and we did not catch any fish. We observed high avifauna activity around the outlet of the lagoon including various feeding shorebirds. The next day we set out water quality probes at the fresh water inlet and the outflow of the lagoon. We set two gillnets at the terrestrial edge southwest of the inlet, one onshore and one offshore. We revisited the lagoon on the 27th to collect water quality data but were only able to collect data at five out of the seven water quality points due to a fatal error occurring with the hand held apparatus.

*July*
On 15-July 2017, we boated to Krusenstern Lagoon from the Anigaaq ranger station. That morning we collected water quality data, performed four zooplankton tows at water quality sites KR7, KR-R3, the mouth of the lagoon and the freshwater inlet where we also set one gillnet. The weather was overcast and windy, creating choppy water conditions and making it difficult to navigate between water quality points. The next day we set two gillnets on the western side of the mouth of the lagoon. The weather was clear with little wind. We pulled both nets on the first check and caught predominantly humpback whitefish and Pacific herring in addition to two sheefish. We performed two beach seine replicates, one on the western side of the mouth one on the eastern side. Due to the amount of silt covering the benthos on the western side of the mouth we pulled in mostly mud and one starry flounder. However, upon transitioning to the eastern side of the mouth we were able to complete a more successful pull, collecting around 300 ninespine stickleback in addition to humpback whitefish, herring, starry flounder and pond smelt. We returned to Krusenstern on the 18th and beach seined once at the mouth of the lagoon and set one gillnet offshore near the mouth of the lagoon. We caught a large amount of mysids and larval fish in the beach seine as well as pond smelt. We revisited the lagoon again on the 19th to perform four more zooplankton tows. Additionally, we observed that, throughout July, avifaunal activity around the lagoon mouth had decreased significantly since the previous sampling period.

*August*
On the first day of August sampling in 2017 (17-Aug) we split up into two separate teams, one traveling to the northwestern marine edge of the lagoon and one remaining at the mouth of the lagoon. The team traveling to the marine edge performed 8 zooplankton tows throughout the day but was unable to collect water quality data due to a failure of the hand held recorder. We set two gillnets at the marine edge, one onshore and one offshore as well as completing two beach seine replicates. We checked both nets twice at one-hour intervals for a total set time of 3 hours and caught almost exclusively humpback whitefish and Pacific herring. At the mouth of the lagoon we set two gillnets and one fyke net for a three-hour set. We returned to Krusenstern on 19-August to collect water quality. The weather was calm and overcast with heavy rain beginning towards the end of the day. We performed one beach seine pull at the mouth of the lagoon and caught predominantly juvenile Pacific herring.

## Kotlik

### 2015 Field Season

Table 9. Field sampling dates for Kotlik Lagoon during the 2015 field season.

| July | August | September |
|---|---|---|
| 8 | 6 | **19** |
| 9 | 7 | **20** |
| 10 | 8 | |
| 11 | 9 | |

*July*
Kotlik Lagoon is an 8.4 km long lagoon with several fresh water sources draining into it and a marine connection at the south end, which is intermittently open. We arrived at Kotlik Lagoon by boat and were dropped off at the outlet of the lagoon in July. The outlet was approximately 10 m across and there was a strong current flowing out of the lagoon. The area where the lagoon waters mix with the Chukchi Sea are an apparently productive feeding area for animals including large salmonids (pink salmon and Dolly Varden) and an abundance of birds (Arctic terns, Aleutian terns, parasitic jaegers, black-legged kittiwakes, glaucous gulls) feeding at the mouth on small fish (appeared to be salmonids) and mysids (based on high mysid densities and Arctic tern feeding behavior). We also observed a pair of grey whales (cow and calf) and an individual adult on 9-July feeding in this mixing zone in the shallows just outside of the lagoon outlet. We observed 3 brown bears throughout the course of our time at Kotlik. On the

evening of 8-July, we began taking the water quality measurements and set one gill net at KO_RAN_2. We later set a gill net near the marine mouth. The following morning, we completed the water quality measurements, and set 2 gill nets inside the main body of the lagoon, neither of which caught fish. We beach seined on the south shore of the outlet, catching 11 species. We observed mysids while beach seining, and took dip net sample. We were unable to leave for 2 days due to fog grounding the pilot in Kotzebue.

*August*
When we arrived in August, the outlet had completed closed, changing the dynamics of the lagoon. However, there was still flow coming from the ocean through the sand. There was an abundance of avifauna, with many shorebirds (e.g. black turnstones, red necked phalaropes) foraging near the outlet. We took water quality measurements that evening and set 2 gill nets and 7 minnow traps. The following day, we set 4 gill nets and completed 2 beach seine replicates. We captured 5 species not previously recorded at Kotlik. The day was overcast with strong winds and waves from the ocean were washing over the beach into the lagoon. The water level in the lagoon increased rapidly throughout the day, rising approximately 50 cm. The high winds continued for another 2 days, with intermittent rain showers.

*September*
The outlet was still closed when we visited Kotlik in September 2015. The water level in the lagoon had risen about 1 m since August, and water temperatures were close to freezing, and the lagoon was beginning to freeze (shorefast ice had formed). We completed water quality measurements and set 2 gill nets on the afternoon of 19-Sept. By the following morning, the lagoon was further frozen over. This made beach seining difficult because of the ice we caught in the net. Only 4 juvenile sculpin were caught beach seining. We observed a possible walrus carcass on the beach just south of the lagoon. The weather was clear and around freezing temperature.

### 2016 Field Season

Table 10. Field sampling dates for Kotlik Lagoon during the 2016 field season

| June | July | August |
|---|---|---|
| 25 | 31 | 1 |
| 26 | | 2 |
| 27 | | 3 |
| | | 26 |
| | | 27 |
| | | 28 |
| | | 29 |
| | | 30 |

*June*
We traveled to Kotlik for the first time in the 2016 field season via four-wheeler. When we arrived on 25-June, the lagoon was open to the ocean with currents switching from out flowing to inflowing approximately every six hours (observation based). We set the first gillnets and performed one beach seine close to the mouth of the lagoon, but did not catch many fish. At this time there was a strong current flowing into the lagoon, which may have affected the overall success of our fishing effort. Later in the afternoon we observed spawning capelin on the marine side beach with hundreds washing up onto shore with the surf. Rain and high winds made for large swells in the lagoon the next day, however we were able to complete water quality data collection and set gillnets at the mouth of lagoon. The same day we deployed two Onset Hobo pendant loggers around the lagoon and one on land near the wetland close to the mouth of the lagoon. The next day the weather was clear with winds around 5-10 knots. We completed two beach seine replicates and set one gillnet at the mouth of the lagoon. We observed two grey whales feeding in the ocean area just offshore near the mouth of the lagoon.

*July/August*
We revisited Kotlik at the end of July at which point the lagoon had closed to the ocean. The first day (31-July) we collected water quality data, mysid samples, and set gillnets at the outlet of the lagoon. We found that the mysid samples taken at near shore locations yielded the highest abundance while samples taken off shore had fewer of mysids. The next day (1-August) was mostly cloudy with winds at 10-15 knots and rain starting later in the day. We collected bathymetry measurements throughout the main lagoon, performed a mysid transect and two beach seine replicates. Throughout the next two days we performed an additional mysid transect and set four more gillnets in the area close to the mouth of the lagoon catching a high abundance of Pacific herring throughout all sets. The weather remained mostly cloudy with winds ranging from 5-15 knots.

*Late August*
The lagoon remained closed for the late August sampling period in 2016. We arrived at Kotlik on 26-August, collected water quality readings, performed a mysid transect and completed bathymetry data collection. The water level of the lagoon was significantly higher that previous visits and salinity readings at water quality points were noticeably lower (Table 26). Weather the next day was overcast with winds at 10 knots and intermittent showers. We traveled to the mouth of the lagoon where marine waves were breaking over the gravel bar separating the lagoon from the ocean. We completed another mysid transect and performed a beach seine replicate off the gravel bar, catching a profusion of least cisco, Bering cisco and humpback whitefish. We sampled at the north end of the lagoon the next day. We set two gillnets and beached seined once on the marine edge and at the fresh water inlet, respectively. We completed another round of mysid sampling near the northern marine edge with similar results as previous transect, finding the highest abundance of mysids at sample sites closer to shore. The next day (29-August) we planned to fish in the morning and leave Kotlik by tundra plane in the afternoon. However, having completed one beach seine replicate and one gillnet set, we discovered we were not able to be picked up at Kotlik that afternoon and were forced to dispose of the samples we had collected due to lack of refrigeration available to preserve the samples. The next day we were picked up by tundra plane in the afternoon but had the chance to replace the samples we had disposed of the day before by setting two gillnets near the mouth of the lagoon.

**2017 Field Season**

Table 11. Field sampling dates for Kotlik Lagoon during the 2017 field season

| March | June | July | August |
|---|---|---|---|
| 13 | 30 | 1 | 23 |
| 18 | | 2 | 24 |
| | | 21 | 25 |
| | | 22 | |

*March*
We traveled to Kotlik Lagoon via snowmachine on two occasions. Travel to Kotlik Lagoon was very challenging due to its distance from Kotzebue as well as the trail conditions. Due to the persistent high winds in this region, trails were bare and tussocks were exposed, leading to slow travel. Multiple holes were drilled through the ice using the 10-inch gas powered auger and the 2-inch drill-powered auger to measure water depth, ice thickness and snow depth. Water quality was also measured beneath the ice at these locations.

*June/July*
We arrived at Kotlik Lagoon by tundra plane on June 30$^{th}$ 2017 for the first round of sampling. The first day we collected water quality data at nine water quality points throughout the lagoon. There was light wind and intermittent rain showers mixed with sunshine. The same afternoon we set two gillnets at water quality points KO1 and KO2, respectively. The next morning was foggy and overcast with a west wind and we set a gillnet at the mouth of the lagoon. The net was in the water for a total of six hours, with three intermittent checks, and we caught a total of three different species. (starry flounder, Pacific

herring, and humpback whitefish). We set three more gillnets that day at the water quality points KO-ME, KO-4 and KO-R2 respectively. The wind and chop picked up throughout the day. The following day we set three gillnets. The first net, which we set at water quality point KO-R1, caught a total of three different species (threespine stickleback, Pacific herring and Bering cisco) and 5 individuals. The second gillnet, set at water quality point KO-R3 caught three individuals of two different species. We set the third gillnet at water quality point KO-5 for a total set time of three hours and caught four different species. At the marine edge we performed one beach seine, catching mostly saffron cod. We observed a high concentration of algae in the water column at this site.

*July*
The second round of sampling for the 2017 season began in late July. We arrived by tundra plane and were dropped on the marine edge of the lagoon. The lagoon remained unopened and the area around where the outlet has historically occurred had a high abundance of fish including concentrations of saffron cod. On the afternoon of July 21st we collected water quality data and performed four zooplankton tows. There was a strong breeze blowing northwest across the lagoon making navigation to water quality points difficult. At the northern end of the lagoon we observed avifauna activity surrounding the freshwater inlet, including flocks of various waterfowl species. The next morning (22-July) was overcast and breezy and we observed a brown bear sow and two yearlings cross the lagoon to the terrestrial edge and pass beyond the ridge. We took the boat to the marine edge towards the northern end of the lagoon (close to water quality point KO4) and set one onshore and one offshore gillnet. While waiting to check these nets we observed another bear walking along the marine edge of the lagoon. Fish were in lower abundance in this area and we caught a total of seven individuals of three different species types (saffron cod, humpback whitefish and least cisco). After pulling the two gillnets we beach seined in the same area but did not catch any fish. In the afternoon we motored to the outlet area of the lagoon and set two gillnets. Both nets were pulled at the first check due to the high number of saffron cod hitting the net. We caught a total of three different species types in these nets with the predominant species being saffron cod. Additionally, we beach seined off the gravel bar blocking outflow from the lagoon into the ocean, an area in which we observed significant shorebird activity. We captured four different species including a high proportion of juvenile pink salmon. We were picked up by tundra plane that same day and flew back to Kotzebue.

*August*
For the third and final sampling effort of the 2017 field season the lagoon was still closed and the water level in the lagoon has risen significantly since July (observation based). We completed water quality measurements and zooplankton sampling the first day, but experienced engine difficulty towards the end of water quality data collection. Due to engine limitations, we were unable to sample in any far offshore locations within the lagoon. The day of August 24th was sunny and clear with a slight breeze. We set two gillnets and a fyke net at the mouth of the lagoon and, after a three and a half hour fyke net set, caught five different species, including over 10,000 juvenile stickleback and around 500 pond smelt. We pulled one beach seine in which we caught over 50 juvenile flounder and 250 nine-spine stickleback. Later in the day the wind picked up and we set one more gill net onshore at the marine edge. During our final sampling session at Kotlik we observed many different species of birds migrating through the area. Species observed include: northern harrier hawk, cassia crossbill, pectoral sandpiper as well as the more commonly seen sandhill crane and common raven We were transported out of the field the next morning by tundra plane.

## Tasaychek

### 2016 Field Season

Table 12. Field sampling dates for Tasaycheck Lagoon during the 2016 field season

| August |
|---|
| 7 |
| 31 |

*August*

Tasaycheck is a small lagoon located 7.5 km south of Kotlik Lagoon in Cape Krusenstern National Monument. The lagoon is 1.9 km long with one main freshwater source at the southern end of the lagoon and a marine mouth located on the northwestern side. We traveled to Tasaychek on 7-August and the lagoon was closed. We collected water quality data, set a gillnet and performed one beach seine replicate. We noted a high abundance of fish in the area around the gillnet made evident by the fact that we observed several humpback whitefish hit the net while we were setting it. We returned to Tasaychek again at the end of the month and the lagoon was still closed. We set a gillnet and collected water quality data on the afternoon of 31-August, noting that salinity in the lagoon had decreased from 14 ppt to 2 ppt since the last round of sampling. Additionally, water quality data collection revealed the presence of a gradient in salinity concentration across the lagoon, with lower concentrations close to the fresh water inlet and increasing northward up the lagoon to the highest concentration around the mouth of the lagoon. Water levels in the lagoon were higher (observation based) and we set another gillnet and performed one beach seine replicate but did not catch many fish.

## Atilagauraq

### 2016 Field Season

Table 13. Field sampling dates for Atilagauraq Lagoon during the 2016 field season

| July |
|---|
| 28 |

*July*

Atilagauraq is a small lagoon of less than 0.5 $km^2$ size located just south of Battle Rock in Cape Krusenstern National Monument. We performed a preliminary round of sampling at Atilagauraq at the end of July in 2016. We traveled to the lagoon by four-wheeler and ran into two local people from Kivalina village on the way. We spoke to them briefly about local subsistence fishing locations and species that they commonly harvested. The lagoon was closed when we arrived and salinity levels were high compared to other lagoons in Cape Krusenstern (20ppt.). We caught seven different species including two species of sculpin, humpback whitefish and starry flounder. The weather was cold with wind at 10 knots.

## Tukrok River and Chukchi Sea


Figure 4. Sampling sites for the Chukchi Sea and Tukrok River channel off of Anigaaq.

### 2015 Field Season

Table 14. Sampling dates for Chukchi Sea and Tukrok River for 2015 field season.

| Month | Chukchi Sea | Tukrok River Channel |
|---|---|---|
| *September* | 5,11 | 5,11 |

During the field season of 2015, we began sampling the Chukchi sea and Turkrok River channel to develop insight into the differences between fish communities of each sample site (Figure 15). The channel of the Tukrok River flows through wetlands and discharges in the ocean; however, water flow directionality is weak and can often go upriver with the direction of flow is linked to tidal cycle, storm surge, and potentially shelf wave propagation (T. Jones, pers. comm.). The sampling location near the marine mouth has brackish water that is a mixture of marine water from the Chukchi Sea (when flow is upriver), Krusenstern lagoon, and freshwater from the Tukrok River itself. We sampled the channel of the Tukrok River and the Chukchi Sea on either side of the spit of land where the Anigaaq ranger station resides. Two beach seine replicates and one gill net were set for each sampling event to standardize effort in each location. This was a pilot sampling effort to determine the feasibility of adding an updated version of this sampling procedure to next year's sampling protocol. Nine species were caught in the Chukchi Sea, 3 of which were also caught in the channel during the same sampling event.

### 2016 Field Season

Table 15. Sampling dates for Chukchi Sea and Tukrok River for 2016 field season.

| Month | Chukchi Sea | Tukrok River Channel |
|---|---|---|
| *June* | | 20, 21 |
| *July* | 1 | 1 |
| *August* | 4,22,30,31 | 3, 20, |

We continued to sample the Tukrok River channel and Chukchi Sea during the 2016 field season to develop a more comprehensive picture of the differences in species composition between the two habitats. On 20-June we sampled the channel at Anigaaq for the first time. With a strong current moving southeast down the channel and out to the ocean, we set a gillnet for one hour catching two Humpback whitefish. On 21-June we attempted a trip to Aukulak but were forced to remain at Anigaaq due to high winds and seas of 2-4 ft. That day we performed two beach seine replicates in the channel and caught predominantly juvenile salmon and some Starry flounder. We sampled in the area around Anigaaq again at the beginning of the next month. On 1-July there was a strong wind pushing a heavy current in the direction of the mouth of the channel. We set a gillnet in the channel which was displaced by the current, however we were able to retrieve the net and caught Starry flounder and one Pacific herring. We attempted a gillnet set on the marine side as well but were prevented by the large swell.

We did not sample at Anigaaq again until the beginning of August. On 3-August, upon our return from Kotlik, we collected bathymetry data throughout the channel up to the inlet of Clear Creek. The next day we set two gillnets on ocean side parallel to shore for one hour. We pulled the nets at the first check but had only caught three fish. We set another 4 nets on the ocean side, with two running parallel and two running perpendicular to shore. We pulled the nets after the second check and caught a total of 13 different species. The same day we took water quality readings at 3 points and found salinity in the offshore marine area above 20ppt.We set a gillnet in the Tukrok channel again on 20-August for 1.5 hours, catching mostly jellyfish. Two days later (22-August) we set 2 offshore gillnets on the marine side. The weather was mostly calm however heavy wave action tangled the nets. We performed two beach seine replicates off the marine shore and caught mostly pond and rainbow smelt. We set another two gillnets 30 yards offshore on the marine side. Rain moved in throughout the evening. We sampled the ocean twice more at the end of August, navigating strong northward currents to set a total of three more gillnets. On 30-August we caught predominantly Pacific herring in high abundance, however were not so successful with the two nets set on 31-Augst, catching a total of only nine individuals.

**2017 Field Season**

Table 16. Sampling dates for Chukchi Sea and Tukrok River for 2017 field season.

| Month | Chukchi Sea | Tukrok River Channel |
|---|---|---|
| *June* | 26,27 | 21,23,28 |
| *July* | | 17,20 |
| *August* | 18,20 | 16,18,19 |

During the 2017 field season we sampled the channel of the Tukrok River and Chukchi Sea with the objective of further exploring the differences in fish communities between the two, particularly taking into consideration the absence of significant mixing between fresh and marine water at the mouth of the channel. While the channel had remained open to the influence of tidal inflow from the ocean during previous seasons, the mouth of Tukrok Channel was closed all throughout the 2017 field season, directly influencing salinity concentrations in what had historically been a brackish area (Table 27). This phenomenon may have had significant effect on fish population composition within the channel and we aimed to reveal any changes through repeated sampling of the river channel. During the beginning of the 2017 season we collected water quality data for the channel starting at the mouth and working our way towards the Anigaaq ranger station, collecting data points every 250m. We conducted a similar procedure in the Chukchi during the third sampling period (20-August), collecting data at four points at 250m intervals offshore.

We sampled the channel for the first time on 21-June, setting one gillnet in the area around the mouth of the river and pulling it at the first check. Two days later we set one gillnet near the boat launch site next to the Anigaaq Ranger station for a one-hour long set, catching mostly humpback whitefish and Pacific herring in relatively low abundance. On 26-June we set one gillnet on the marine side at Anigaaq ranger station for a total set of three hours, checking it at one hour intervals and catching predominantly Pacific herring and saffron cod. Weather the next day was calm and clear and we sampled the ocean again, setting a total of three gillnets. We set the first two nets in the morning, successfully completing one shorter fifteen-minute set first to test for relative abundance in that area of the Chukchi. Later that afternoon we set another gillnet on the marine side, which we pulled after one hour due to the high number of Pacific herring, saffron cod and ninespine stickleback hitting the net. The next day remained clear and we traveled to the mouth of the Tukrok to perform five beach seine replicates along the gravel bar blocking outflow from the channel. Humpback whitefish were in high abundance in this area and were the predominant species throughout all five replicates. During the first field session we observed a muskoxen herd of around 20 individuals move through the area around the Anigaaq Ranger station up the beach towards Krusenstern lagoon. The herd grazed the area around Anigaaq for four days before migrating up the beach. Additionally, we observed several herds of female and juvenile Caribou in the areas close to the channel as we traveled to and from Krusenstern lagoon.

In July we sampled the channel again, setting one gillnet at the site close to the ranger station and beach seining once near the mouth of the channel, off the gravel bar blocking the channel from the ocean. We did not sample the ocean during the July effort due to consistently high winds and swells. In August we sampled the channel a total of three times. On 16-August the weather was windy and rainy, with strong currents pushing water towards the mouth of the channel. We set one gillnet in the channel close to the ranger station, pulling it at the first check, processing samples and resetting the net in the same location for another hour long soak. On the 18$^{th}$ we set a gillnet in the channel for three hours, checking the net and collecting samples at hour-long intervals. That same day we set a net on the ocean side of the ranger station, which we pulled at the second check. We set a final gillnet in the channel on the 19$^{th}$, which we pulled at the first check after one hour. The 20-August we sampled the ocean again, setting three gillnets and performing two beach seine replicates throughout the day. It should be noted that the first gillnet set (set time 10:50) was washed ashore prematurely by the current and did not complete a full one-hour set. During the final round of sampling we observed one male muskox move through the area around Anigaaq. We also observed several different species of birds migrating south through the area including gyrfalcon, northern wheatear, yellow warbler and longbilled dowitcher.

## BERING LAND BRIDGE NATIONAL RESERVE

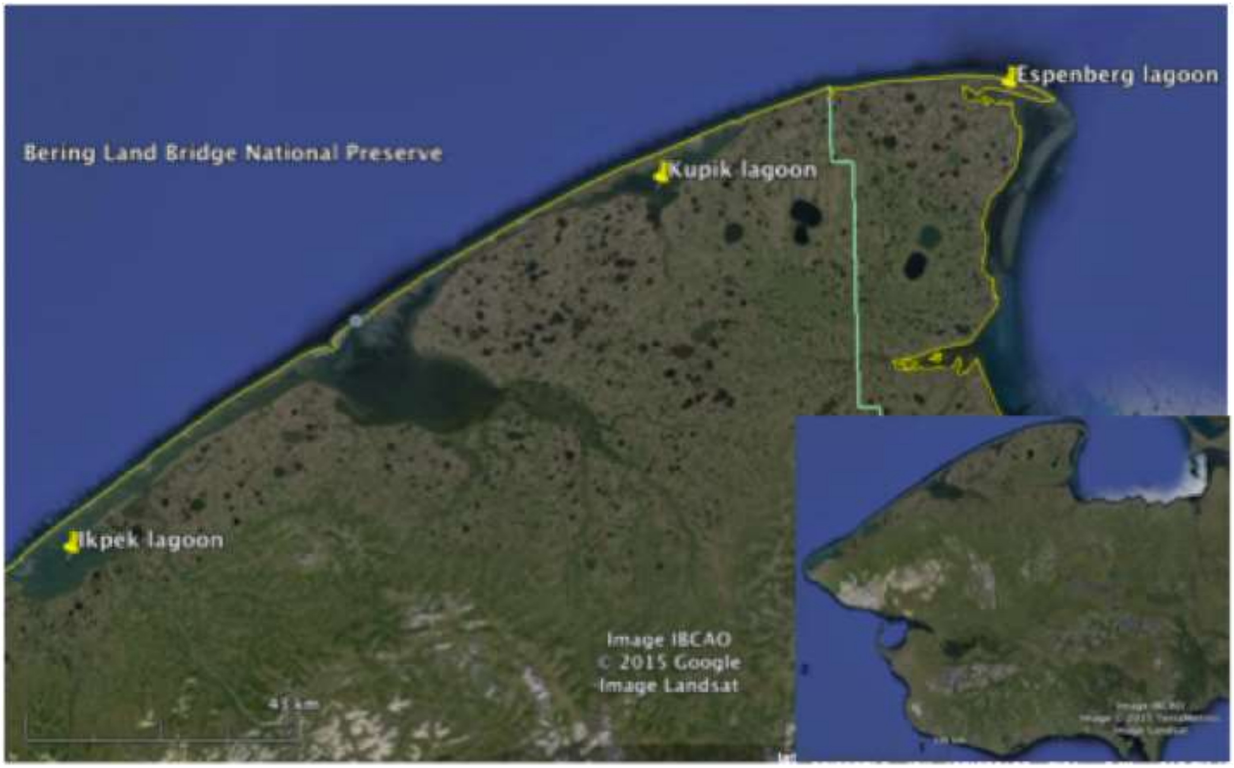


Figure 5. Lagoons sampled in Bering Land Bridge National Preserve

### Kupik

**2015 Field Season**

Table 17. Sampling dates for Kupik Lagoon for 2015 field season.

| July |
|---|
| 13 |
| 14 |
| 15 |
| 16 |

*July*

Kupik (also referred to as “Cowpack”) is a long, narrow lagoon with extensive shallows in the western end (Figure 4). We were dropped off via tundra wheeled airplane on a beach on the marine side, approximately 2.4 km west of the marine mouth. The drop-off was about 0.25 km away from the lagoon, necessitating multiple trips across the tundra staging gear (approximately 2 hours of transferring gear). We observed a seal carcass 20 m away from where the plane landed and the beach was covered in bear tracks.

On the morning of July 14th, we sampled for fish using gill nets within the marine mouth of the lagoon. This proved to be challenging because of the large amounts of floating algae present in the water, which fouled the gill nets and greatly decreased their effectiveness (Figure 6). We spoke with Shishmaref residents, who were passing through the area, about the logistics of fishing Kupik. They informed us that they restricted fishing set-nets to just after ice-out because floating algae is not an issue for nets at that stage of the season. They also stated that there are whitefish that use Kupik lagoon. Besides issues with algae, there was also a strong current out of the lagoon, which caused gill nets to drift. We set a fyke net point CP_OF, with some success in capturing fish, despite current affecting the set. The fyke net caught 45 pond smelt (*Hypomesus oledus*), a species not previously recorded in the lagoon. We noticed an abundance of mysids drifting along the benthos near shore west of the outlet. We took a dip net sample for identification. By that evening, there was dense fog, large waves and high winds, making boating across the lagoon to collect water quality measurements difficult and slow. We observed four brown bears (1 sow and 2 cubs, 1 adult) while collecting water quality data. The next day, we did 2 beach seine sets on the west side of the marine mouth, though this was difficult because of mud fouling the net. We caught hundreds of crangon shrimp (*Crangon spp.*) while beach seining.

### 2016 Field Season

Table 18. Sampling dates for Kupik Lagoon for 2015 field season.

| June |
|---|
| 20 |
| 21 |

*June*

We traveled to Kupik Lagoon once during the 2016 field season. On 20-June we were flown into Bering Land Bridge and set up camp on a sandbar close to the mouth of the lagoon. The weather was clear and calm and we collected water quality data. We set one gillnet in the lagoon and caught predominantly herring. The next day we set four gillnets, catching a total of four different species. We harvested stomachs from four horned sculpin and attempted to do the same with herring samples with less success. That day we observed a muskoxen herd of around 35 individuals as well as a herd of around 12 reindeer.

## Ikpek

### 2015 Field Season

Table 19. Sampling dates for Ikpek Lagoon for 2015 field season.

| July |
|---|
| 16 |
| 17 |
| 18 |

*July*

Ikpek is a large, shallow lagoon connected to the ocean via a wide channel in the northwest corner (Figure 7). We were dropped off via tundra wheeled airplane on the marine beach south of the marine mouth on 16-July. There are many sand banks within the lagoon, running perpendicular to the marine edge, which create extensive shallows that required us to drag the boat for a substantial portion of the lagoon. It took approximately 5 hours to complete the water quality measurements on 16-July because of the large size of the lagoon and the shallows where the engine could not be used. When the water depth was less than 50 cm, water parameters were measured mid-column instead of at the target 50 cm depth.

On 17-July, we sampled for fish near the outlet of Ikpek, but still within the lagoon. Gill nets set in the marine mouth caught less algae compared with Kupik Lagoon. Similar to Kupik, we noted a strong current around the marine mouth of the lagoon which negatively affected our first gill net set. The west shore of the marine mouth had ideal conditions for beach seining and we captured 5 fish species that have not been previously recorded in Ikpek. We observed a herd of reindeer (*Rangifer tarandus)* on the north side of the outlet and hunters from Brevig Mission successfully hunted multiple reindeer. Both days at Ikpek were partly cloudy with rain showers.

### 2016 Field Season

Table 20. Sampling dates for Kupik Lagoon for 2016 field season.

| June |
|---|
| 22 |
| 23 |
| 24 |

*June*
We sampled Ikpek Lagoon throughout one three-day sampling period at the beginning of the 2016 field season. We traveled to the lagoon via tundra plane and were dropped off on the morning of 22-June. That day we completed water quality data collection, which took approximately six hours due to a significant increase in wind speeds making navigation difficult throughout the larger lagoon. The weather was mostly cloudy with intermittent rain showers and winds at 10 knots. We set a gillnet in the area around the mouth of the lagoon, which caught a large number of Pacific herring after soaking for under 15 minutes indicating high abundance of this species in the area. We observed high avifauna activity near the mouth of the lagoon including a large number of various gulls and tundra swans. The next day we set another gillnet and, once again, caught predominantly Pacific herring. In the afternoon we performed two beach seine replicates near the mouth of the lagoon, catching mostly juvenile sheefish and Dolly Varden. That afternoon we met two men from the village of Shishmaref with whom we discussed local subsistence hunting and fishing practices. The next morning we set two gillnets near the mouth of the lagoon with the objective of collecting more pacific herring samples. However, these sets were largely ineffective due to a strong inflowing current at the mouth of the lagoon forcing the nets to drift away from the original set location.

## Espenberg

### 2015 Field Season

Table 21. Sampling dates for Espenberg Lagoon for 2015 field season.

| **July** |
|---|
| 18 |
| 19 |

*July*
Espenberg is 12 $km^2$, a tenth of the size of Kupik and Ikpek, and is more saline (31.9 *versus* 26.6 for Kupik and 27.8 ppt for Ikpek). We were dropped off via tundra wheeled airplane on the marine beach next to a channel that connects the Chukchi Sea to the western end of the lagoon. The channel was extremely shallow, and composed of anoxic muds. Espenberg Lagoon itself was also very shallow at the time of sampling, with depths rarely exceeding 45 cm. Our first attempt to reach Espenberg from our camp took approximately 2hrs due to the shallow water preventing use of the outboard. On 19-July, we traveled back to Espenberg and measured water quality parameters at three sites. Water depth, which was only about 1.5m at its maximum and generally < 1m, decreased as we travelled east towards the marine mouth, and we observed a large mud bank that spanned the entire width of the lagoon. This mud bank blocked our passage and prevented further sampling towards the marine mouth. We did not sample for fish because there were no suitably deep locations to deploy gillnets and the extensive shallow waters did not appear to be good fish habitat. We observed a herd of reindeer on the mudflats of Espenberg and four musk oxen on the beach near our camp near the outer coast. We located fresh water near our camp, which was suitable for drinking. The weather was overcast with rain showers.

# RESULTS AND DISCUSSION

## Water Quality

Lagoons varied greatly in their seasonal connectivity with the ocean and an initial analysis of water quality data indicates that physical water properties varied by lagoon and season.

Table 22. Status of lagoons during each field season.

| Lagoon | 2015 | 2016 | 2017 |
|---|---|---|---|
| Aukulak | Closed for the duration of the season | Open until late July | Closed |
| Krusenstern | Open to Tukrok River channel | Open to Tukrok River channel | Open to Tukrok River channel |
| Kotlik | Open until August sampling | Open until August sampling | Closed |
| Tasaycheck | Not Sampled | Closed | Not Sampled |
| Atilagauraq | Not Sampled | Closed | Not Sampled |
| Turkrok River | Open to Chukchi | Open to Chukchi | Closed |
| Kupik | Open | Open | Not Sampled |
| Ikpek | Open | Open | Not Sampled |
| Espenberg | Open | Open | Not Sampled |

*Salinity/Specific Conductivity*

Salinity levels appear to be related to the lagoon's connection with the marine environment; the more connected the lagoon is to the Chukchi Sea, the higher its salinity. During the 2017 field season, none of the three consistently sampled Cape Krusenstern lagoons (Aukulak, Krusenstern and Kotlik) had the direct link to the marine environment of the Chukchi Sea that had occurred in both the 2015 and 2016 field seasons. As a result, all three lagoons displayed significantly lower mean monthly salinity levels, indicating the direct relationship between connectivity to the marine environment and salinity levels within the lagoons (Table 27). Highest spatial variability of salinity levels at Krusenstern (Table 28) and Aukulak lagoons (Table 30) occurred during the 2017 season, indicating that mixing was lowest during this season. At Kotlik Lagoon however, the 2017 season reflected the lowest variability in salinity levels throughout the lagoon with highest variability occurring in 2015 (Table 29). During the 2015 field season specific conductivity was highest at Espenberg lagoon, which also had the highest mean salinity of any of the lagoons sampled. Specific conductivity was highest at Aukulak Lagoon during the 2016 season and Krusenstern Lagoon during 2017, both of which had the highest mean salinity of the season, respectively.

*Temperature*

In most cases, mean temperature at the three Cape Krusenstern lagoons peaked in July and steadily decreased throughout the rest of the season, with the exception of Kotlik Lagoon in 2016, which steadily decreased throughout the season. During 2015, water temperature in these three lagoons decreased an average of 11.6 ±1.6˚C throughout the season. During the 2016 season the average decrease in temperature was 5.32 ± 3.47˚C. In 2017 temperatures in Kotlik and Krusenstern lagoons decreased an average of 4.5 ±1.44˚C. While temperatures in Aukulak Lagoon peaked in July, following a similar overall trend to Krusenstern lagoon, mean temperature recorded at the end of the season was slightly higher than at the beginning, increasing from 11.42˚C to 11.75˚C. It should be noted that mean seasonal temperatures of these lagoons were not significantly higher during the 2017 field season, during which all lagoons lacked an open connection to the marine environment. Preliminary analysis of these results indicate that water entering the lagoons from the colder marine environment does not seem to have a significant effect on temperature dynamics within these lagoons however a more in depth study is required to further examine the effects of marine mixing on overall temperature.

Mean temperatures in Bering Land Bridge lagoons were higher during the 2015 field season than the 2016 season. While we were able to begin to create a baseline picture of water parameters in these lagoons, their shallow nature made successful water quality data collection difficult during both field seasons. Due to the inability to navigate the very shallow (often less than half a meter) lagoons, the standard sampling protocol was not as successful at Bering Land Bridge as it had been at Cape Krusenstern. We were unable to access many sample sites and conduct accurate water quality data measurements in Ikpek, Kupik and Espenberg lagoons. In addition to logistic complications, lack of data from the 2017 field season makes it difficult to establish seasonal trends in temperature or any water quality parameters. Further monitoring and development of a more successful methodology should be a priority in the future to establish any significant trends in temperature or any other water quality parameters.

*pH*
During the 2015 field season pH in all three Cape Krusenstern lagoons decreased an average of 0.96 ±0.10. In 2016 pH at Kotlik and Krusenstern decreased by an average of 0.75 ±0.33. While Aukulak followed a similar general trend in temperature over time, pH in the lagoon increased towards the end of the season rather than decreasing with readings at the beginning of the season starting at an average pH of 7.87 and increasing by the end of the season to an average of 8.32. In 2017 trends in pH throughout the three lagoons did not follow a similar pattern to previously recorded years, with readings reaching the lowest point in July (average, 6.3 ±0.92) and increasing again towards the end of the season.

Due to the fact that lagoons at Bering Land Bridge were visited only once during the 2015 and 2016 field seasons we are unable to establish any seasonal trends in pH at these lagoons. Mean pH at Kupik and Ikpek lagoons were similar during the 2015 field season while pH at Espenberg was noticeably lower (Table 25). While Espenberg was not sampled again during the 2016 field season, results from data collection at Kupik and Ikpek show similar mean pH values to 2015 (Table 26).

*Dissolved Oxygen*
Results from 2015 monitoring show an increase in overall dissolved oxygen over the course of the season for Cape Krusenstern lagoons. Similar results were recorded at Aukulak lagoon during the 2016 season, however dissolved oxygen levels fluctuated in both Krusenstern and Kotlik and did not display any noticeable trend. In 2017 dissolved oxygen decreased at all three major Cape Krusenstern lagoons. While we can establish seasonal trends in dissolved oxygen concentration, it is difficult to compare between seasons due to the fact that 2015 data was recorded in mg/L with other years taken as % readings. A comparison between 2016 and 2017 however shows overall lower mean dissolved oxygen levels throughout all lagoons in the 2017 field season. This could potentially be related to an increase in blue green algae concentration during the 2017 field season however, without accurate data on BGA concentration from 2016 we cannot make a direct comparison.

Changes in temperature, pH and dissolved oxygen trends during the 2017 field season may be attributed to lack of connectivity to the ocean and, consequently, a more significant influence from the freshwater sources at each lagoon on water quality parameters. Diminishing dissolved oxygen levels may be a product of reduced mixing within the lagoons caused by the lack of tidal influence that occurs during seasons with open outlets to the Chukchi however further research is required to establish the connection between marine tidal dynamics and lagoon water quality parameters.

*Turbidity*
In 2015 turbidity increased steadily throughout the season at Krusenstern Lagoon from 8.31 NTU in July to 27.49 NTU in September. At Aukulak there were no noticeable trends in turbidity, with values fluctuating significantly throughout the season. Turbidity values at Kotlik remained low throughout the season, with a slight increase during the September sampling period (mean, 2.78 ±1.3 NTU). During the 2016 turbidity was relatively high at Kotlik Lagoon at the beginning of the season (60.36 NTU) with values dropping as the season progressed to a final measurement of 2.43 NTU. At Krusenstern Lagoon mean turbidity dropped to a low during the July sampling period (10.97 NTU) then increased into September to reach a high of 65.93 NTU. Turbidity at Aukulak was low in the beginning season then peaked noticeably in August, increasing from 1.88 NTU in July up to 34.25 NTU. In 2017 turbidity at

Aukulak Lagoon remained low throughout the June and July sampling periods but increased in August up to 11.83 FNU. Values at Kotlik remained relatively low with negative readings taken throughout the season. Mean turbidity at Krusenstern Lagoon was higher than Aukulak and Kotlik, with values increasing as the season progressed to a high of 42.06 mean FNU in August.

*Late winter conditions (2017)*

The physicochemical properties of water in the three lagoons varied widely (Table 31). Aukulak Lagoon had a mean water depth of 0.2 m at the two sampling sites where liquid water was found. The water conditions beneath the ice were lethal to fishes, with hypersaline conditions (52.70 ± 0.27 ppt), low temperatures (-3.41 ± 0.09˚C) and low dissolved oxygen levels (1.85 ± 0.42 mg/L). Krusenstern Lagoon had a mean water depth of 1.2 m (SD, 0.45 m) remaining beneath the ice. The water conditions beneath the ice were marginal as fish habitat, with relatively low salinities (6.65 ± 1.07 ppt), moderately cold temperatures (-0.54 ± 0.08˚C) and low levels of dissolved oxygen (4.33 ± 1.02 mg/L). Kotlik Lagoon had a mean water depth of 0.86 m (SD, 0.39 m), moderate salinity (12.73 ± 6.95 ppt), and moderately cold temperature (-0.73 ± 0.73˚C) and dissolved oxygen levels (5.55 ± 1.68 mg/L). The salinity varied greatly within Kotlik Lagoon, from 0.53 ppt near freshwater inflows to 17.92 ppt in the center of the lagoon. Dissolved oxygen levels were highest near the outlets of creeks entering the frozen lagoons. At the confluence of a small creek entering Kotlik Lagoon, dissolved oxygen levels were 7.43 mg/L. Less within-lagoon variability in physical parameters was found in Krusenstern and Aukulak lagoons.

The average ice thickness across all the lagoons was 1.34 m (SD, 0.23 m), with the thickest ice found in Krusenstern Lagoon (1.47 m) and the thinnest ice found in Aukulak Lagoon (1.25 m). The range of ice thicknesses across the lagoons corresponded with the range salinities, with Krusenstern Lagoon being the freshest and having the thickest ice and Aukulak Lagoon being the most saline with the thinnest ice.

*Short Term Variability Monitoring*

Of the two methodologies to monitor short-term seasonal variability of water quality parameters within the lagoons we experienced varying degrees of success between Sonde deployment during the 2016 season, 2016 Onset Hobo pressure/salinity loggers and 2017 light/temperature Hobo loggers. While the smaller pendant loggers were logistically simpler to install, during the 2017 we experienced poor retrieval success due to storm surge and drift preventing us from exploring any of the data collected. The 2016 season had a higher retrieval success rate and preliminary results from pressure/salinity monitoring can be found in appendix 9. Monitoring by the Sonde apparatus provided insight into seasonal variability within Aukulak lagoon, showing significant trends in both salinity and temperature. While temperature in Aukulak was variable during the month of July, we saw the beginning of a decrease in temperature at the beginning of August with overall variability in temperature decreasing as the season progressed (Figure 14). Data collected throughout this same season also provides insight into the relationship between connectivity to the marine environment and salinity levels in the lagoons. During the beginning of the season mean daily salinity was highly variable, however, over the course of the season we see a general decrease in concentration with a significant drop close to the time period in which the lagoon closes off completely to the Chukchi (22-July) and a further significant decrease towards the end of September (Figure 14). In future sampling seasons we hope to increase implementation of short-term monitoring with the Sonde apparatus to develop a more in depth picture of seasonal variability within our study sites.

In the effort to develop a baseline profile of water quality parameters along-side fish population and density data, we collected water quality data from the Tukrok River channel and the Chukchi for the first time during the 2017 field season. We took water quality readings every 250m along the Tukrok, beginning at the sandbar blocking outflow from the river into the sea and ending in the area around our base camp at Anigaaq Ranger Station (Table 32). Results from sampling show a higher mean salinity and lower mean temperature along the channel that feeds into Krusenstern Lagoon than the lagoon itself (Table 27). Furthermore, we observed that salinity levels gradually decreased with distance from the mouth of the channel with highest salinity concentration, as predictable, taken directly off the gravel bar separating the channel from the ocean. While these preliminary readings provide a valuable baseline for physical water parameter dynamics along the Tukrok channel, further sampling is required to develop a more in depth profile of the river. In the future we hope to continue to monitor water quality in the Tukrok to build a more comprehensive picture of the influence that the Chukchi has on physical parameters of the channel and aim to include seasons during which the channel remains open to inflow from the marine side throughout a larger portion of the season.

**Primary Productivity**
Results from blue green algae monitoring were mostly observation based during 2015 and 2016 field seasons. During the 2015 and 2016 field seasons the Sonde apparatus was not calibrated correctly to collect accurate blue green algae and chlorophyll readings. While the Sonde was calibrated during the 2017 season, data units were not kept consistent between lagoons making a comparison of general trends in values difficult. We observed algae in the water column of at least one lagoon in all three field seasons. In 2015 we experience the highest concentration of algae in Kupik Lagoon which, based on conversations with local fishermen, was a common occurrence and effected fishing success throughout the summer months. During the 2016 field season the most significant concentration of algae occurred at Aukulak Lagoon during the September sampling period. High concentration of algae in the water column indicated a recent bloom and alerted our team to the need of further development of a standardized protocol for assessing algae presence at our study sites. During the 2017 season we preemptively calibrated the Sonde with the objective of collecting blue green algae (BGA) and chlorophyll readings at water quality data collection sites. At Aukulak Lagoon concentrations in algae peaked in July at a mean value of 1.42 RFU (standard deviation, 0.50) and decreased into August to 0.60 RFU (standard deviation, 0.70). Kotlik Lagoon followed a similar general trend with values in July reaching a mean of 0.63 µg/L (standard deviation, 0.33) and decreasing to 0.45µg/L (standard deviation, 0.31) in August. Similarly, at Krusenstern Lagoon mean BGA concentration peaked during July (mean, $4.37 \pm 3.76$ µg/L) and decreased into August (mean,$1.16 \pm 0.40$ µg/L).

We had similar results with Chorophyll measurements and unit consistency. Furthermore there are no discernable trends within lagoons, with values from all three Cape Krusenstern lagoons fluctuating throughout the season. Development of a more streamlined protocol on primary productivity sampling should be made a priority for future field efforts, particularly taking into consideration of the effects that algal activity has on subsistence use of the lagoons.

**Mysid Sampling**
Results from mysids transects taken during the 2016 field season indicate that there is no strong correlation between mysid density and depth based on distance from shore. Average mysid density was highest at Kotlik Lagoon while samples taken from Aukulak Lagoon yielded zero individuals. Mysid densities were not recorded during the 2017 field season, however we did observe an abundance of mysids caught in many of the beach seines we performed at Krusenstern Lagoon. Future field seasons should continue to monitor mysid densities in proximity to fish sampling sites in the effort to provide insight on feeding behavior and context for results from diet analysis.

**Zooplankton Sampling**
We sampled zooplankton during the second and third sampling periods of the 2017 field season. We are partnering with the National Park Service and NOAA to process and analyze these samples, and hope to develop a preliminary profile of zooplankton community composition at Aukulak, Krusenstern and Kotlik Lagoons. In the future we plan to develop the protocol for zooplankton sampling that is robust in these shallow systems, and includes a methodology for evaluating diurnal activity within these communities.

**Fish Sampling**
*Length/Weight and Species Richness/Composition*

Species abundance and concentration in lagoons fluctuated during the course of each field season with population composition and density varying between both season and lagoon. We recorded a total of 29 different species, including several important subsistence whitefish species and key forage species. Overall, this represents a significantly greater biodiversity than had previously been reported – 29 species compared to 9 reported by Robards et al. (2014). Subsistence species included humpback whitefish, sheefish and Dolly Varden.

Forage species that we captured included Pacific sand lance, capelin, Pacific herring, pond smelt, ninespine stickleback, threespine stickleback and juvenile saffron cod. Of these species, ninespine stickleback, Pacific herring, and pond smelt appeared most frequently in the diets of piscivorous fish and were most commonly caught in fish sampling with the beach seine. In 2015, Krusenstern and Kotlik Lagoons were the most species rich, having a seasonal richness of 14 (Table 40) and 18 (Table 39) species respectively. During the 2016 Kotlik Lagoon had the highest species richness of 20 different species, followed closely by Aukulak with 19 (Table 38). In 2017, the highest species richness was at Kotlik Lagoon with a total of 11 different species caught. During the 2017 field season we recorded a total of 19 different species, which was lower than previous seasons with the highest richness occurring in 2016 (25 species) followed by 2015 (23 species). In a comparison of all three field seasons the lowest species abundance overall was in Aukulak Lagoon during the 2017 field season, wherein all fishing efforts during the season were consistently unsuccessful and did not yield any fish. The noticeably low seasonal species richness encountered during the 2017 field season may be attributed to an extremely short period in which the lagoons were open to the marine environment, limiting the number of species able to enter the lagoon before it was closed off to the ocean. Furthermore, the results may also be indicative of Aukulak having no associated overwintering habitat in feed rivers or deep-water habitats.

Sampling efforts in the Turkrok River channel and the Chukchi seas were increased in the 2017 season. Although the mouth of the channel was closed, preventing migration of fish between the river and the ocean, we experienced a larger overlap of species between the two sites than we had during the 2015 sampling period. We found a total of ten species in both locations compared with only seven in 2015. Due to the logistical ease of sampling the Chukchi and the Turkrok channel, we hope to continue to build upon our preliminary profile of fish communities at these two sample sites. In additional to providing insight on fish migration into and of the ocean, we can begin to develop a picture of migratory patterns between the Tukrok and Krusenstern lagoon. While we identified 14 different species in the channel during the 2017 field season, we found only 11 in the main body of Krusenstern lagoon. Ten total species were found in common between the main body of the lagoon and the Tukrok channel (Figure 15). Four species including juvenile chum salmon, Dolly Varden, fourhorn sculpin and saffron cod were found only in the Turkrok while threespine stickleback were only found in the main body of Krusenstern Lagoon. While further monitoring is required to build a more comprehensive of species movement between the Tukrok channel and Krusenstern lagoon, a preliminary comparison of species differences between the two locations provides insight on migration between the main body of the lagoon and the marine mouth located 15km away.

Preliminary analysis of results from all our fishing efforts indicates that fish community composition changes as the physical dynamics and characteristics of the lagoons undergo seasonal changes. During the 2015 field season, we observed that catches of migratory species (e.g. sheefish, humpback whitefish) generally decreased towards the end of the season as fish left the lagoons, likely in response to the potential loss of connectivity to overwintering habitat as freeze-up approached. Traditional knowledge and past research suggest that humpback whitefish likely move back into river systems to overwinter, explaining the species increased absence from the lagoon environment as the season progressed. Furthermore, variation in lagoon connectivity to the Chukchi Sea directly affects the timing and duration that lagoons are accessible to marine species, defining when, where and for how long these species are able to remain in lagoons. While results from our 2017 sampling efforts did not indicate a decrease in migratory species, sampling towards the end of the field season showed a high concentration of fish around the outflow area of the lagoon. These results may be explained by the fact that, in an attempt to exit the lagoon and access overwintering habitat as freeze-up approached, migratory species became aggregated at the outlet of the lagoon but were unable to leave due to lack of connectivity to the Chukchi.

**Lab Analysis**

*Diets*

Preliminary diet results from samples taken in 2015 provide valuable insight into the diet composition of many important subsistence species. In 2015 we gastric lavaged or removed stomach samples from fish representing 14 species (Table 41). Diets taken during the 2015 season suggest that mysids, Chironomidae larvae and ninespine stickleback are critical for transferring energy from secondary producers to top predators (Figure 16). Mysids were present in the stomachs of every species we sampled for diet, and some species were found to have fed on mysids almost exclusively. Additionally, results from 2015 diets analysis shows that ninespine stickleback, which were highly abundant in the lagoons, were fed on heavily by piscivorous fish (e.g., sheefish) and birds (e.g. Arctic terns) and analysis of 2015 fish diets found 8 new instances of invertebrates in the lagoons (Table 42). Results are summarized in Tibbles and Robards, 2018.

*Otoliths*

Otoliths collected throughout the 2015 were analyzed by Marguerite Tibbles to establish age and growth rate (Appendix 2, Tabs 8 and 9). Samples from the 2016 field season (Table 43) will be analyzed at the NOAA lab in Juneau to examine the growth rates of resident and migratory species. During the 2015 field season we gathered length-weight measurements, stomach samples and otoliths from 500 pond smelt (Figure 17). Results from these data will be synthesized into a manuscript summarizing the basic ecology of this poorly studied species.

*Contaminants*

Contaminants samples taken from the 2015 and 2016 field seasons were sent to the State of Alaska to analyze contaminants (metals and persistent organic pollutants). In 2015 we collected a total of 64 samples representing 9 species including Bering cisco, fourhorn sculpin, humpback whitefish, least cisco, ninespine stickleback, pacific herring, saffron cod, sheefish and starry flounder (Table 44). During 2016 we took 67 samples from a total of 6 different species including Pacific herring, saffron cod, starry flounder, humpback whitefish, Bering cisco, and arctic flounder (Table 45). Results from contaminants analysis for the 2015 and 2016 season can be found in Appendix 4.

In the 2017 field season we collected a total of 94 samples from 9 different species including fourhorn sculpin, pink salmon, Pacific herring, least cisco, saffron cod, sheefish, starry flounder, humpback whitefish and Bering cisco (Table 46). We sent these samples to be analyzed for metals and organic contaminants by the lab at the University of Alaska Fairbanks.

*NOAA Tests*

Sample processing at NOAA labs in Juneau will be completed winter of 2017/2018. Results from these tests will be synthesized into a manuscript summarizing results from all aspects of laboratory analysis.

**Traditional Ecological Surveys**

Traditional ecological surveys have been conducted in both a formal and informal capacity. Formal interviews have been conducted with several Kotzebue residents including: Bob Schaeffer, John and Pearl Goodwin, Cyrus Harris and Johnson Stalker, and Chuck Schaeffer. A complete transcript of the interview with Bob Schaeffer can be found in Appendix 4 along with documentation of all other interviews conducted.

During the 2016 trip up the Wulik River with residents of the village of Kivalina, the lagoons crew focused on gathering local knowledge regarding population dynamics of major subsistence species. A predominant theme of responses from interviewees included reports from many Arctic Circle locals of increasingly warmer winters, longer ice-free seasons and an overall change in the flora and fauna seen in the region. Our team's time on the Wulik revealed that local communities have noticed that many subsistence resources have been subject to change as climate change has progressed, altering the patterns that they have been following for thousands of years.

**Future Directions**

Data compiled throughout the 2015, 2016 and 2017 field seasons provides valuable information enabling us to begin to form a baseline profile of Arctic lagoon ecology. While our research encompasses many aspects of lagoon ecology and provides valuable insight into the complexity of these systems, there remain important knowledge gaps that we hope to address in future field efforts.

1. In an effort to continue to develop knowledge of feeding behavior and diet contents of fish species that exist in these lagoons, it is important to further expand our understanding of mysid abundance at our study sites. Preliminary analysis of diet contents indicates the significance of mysids in most species' diets. A more comprehensive understanding of the movement of mysid populations throughout the lagoons has the potential for providing further insight into feeding habits of major subsistence species that feed in these lagoons.
2. While we have acknowledged the importance of monitoring animal activity associated with the lagoons, a workable protocol has still not been developed. During the 2017 field season we compiled a preliminary list of bird species observed at study sites (Appendix 2, Tab 15). In future field seasons, we aim to develop techniques for ensuring the longevity and retrieval success of game cameras that in pilot efforts have frequently been moved by animals or inundated by profoundly changing water levels.
3. While we have attempted in previous field seasons to incorporate bathymetric data collection into our field protocol, we were unable to retrieve suitable data (either in extent or accuracy). During the 2016 season we reviewed multiple sampling protocols from various studies that incorporated bathymetry mapping in river channels to form a bathymetry data collection protocol. Ultimately we developed a protocol that involved traversing the study area by boat in a grid formation at slow speeds while collecting bathymetry data readings at standard intervals along the sampling grid. Because bathymetric features are important to hydrology and fish community dynamics, it will be important to further develop data collection techniques during future field seasons.
4. In the future we will continue to build on the preliminary profile of fish communities in the Tukrok River and the Chukchi Sea in order to establish a better understanding of movement of species between the marine and lagoon environment.
5. To develop a further understanding of overwintering habitat in these lagoons, we will continue to develop protocol and expand sampling efforts during the winter and early spring.
6. Detection of timing and location of seasonal berm breaching.
7. Based on poor success with the Ponar Grab in past years, we did not attempt to sample the benthos during the 2015, 2016 and 2017 field seasons. Benthic and epibenthic sampling is still of interest, but should be a collaboration with experts in this field.
8. Future versions of Vital Signs Monitoring Protocol should include standard operating procedures for mysid community evaluation and Traditional Ecological Knowledge surveys both of which provide valuable insight into lagoon ecology. Berm breaching should be a part of this protocol too.

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## TABLES AND FIGURES

Table 23. Lagoon size, general salinity, and water exchange for southern Chukchi Sea lagoons (ordered north to south). Data from Reynolds, 2012; Blaylock and Houghton, 1983; Robards, 2014; current study.

| NPS Unit | Lagoon | ~Size ($km^2$)[1] | Physical Tendency[2] | Connection |
|---|---|---|---|---|
| CAKR | Ipiavik | 4.7 | Fresh/Brackish | Open Channel |
| | Port | 1 | Fresh | Closed |
| | Imik[4] | 5 | ? | Intermittently Open |
| | Kotlik | 24 | Brackish | Intermittently Open |
| | Tasaycheck | 0.5 | Fresh/Brackish | Intermittently Open |
| | Atilagauraq | < 0.5 | Fresh/Brackish | Intermittently Open |
| | Krusenstern | 56 | Fresh | Seasonally-Closed |
| | Aukulak | 6 | Fresh/Brackish[3] | Intermittently Open |
| | Sisualik | 34 | Fresh | Open |
| | Espenberg | 12 | Marine | Open |
| | Kupik | 109 | Brackish | Open Channel |
| BELA | Shishmaref[4] | 370 | ? | Open |
| | Arctic | 430 | Brackish | Open Channel |
| | Ikpek | 128 | Brackish | Open Channel |
| | Lopp | 176 | Brackish | Open Channel |

[1] We recognize the subjectivity in describing boundaries– our estimates delineate the main water body (for example not including the long channel connecting Krusenstern Lagoon to the ocean).
[2] Based on average salinity within lagoon: <11 fresh; >11 - <30 brackish; >30 marine (see Table 3)
[3] Physical tendencies depend on the dynamics of the seasonal opening. In 2015, Aukulak was brackish due to an early season connection with the marine environment.
[4] Imik and Shishmaref lagoons have not been visited during any field season so far.

Table 24. Fish species inventory for Kotzebue Sound lagoons (Note data represents vastly different fishing efforts, both within and between sampling periods, and not all lagoons were sampled in all sampling periods. Data should be used as the basis for inventory efforts, rather than inter-lagoon or temporal comparisons of composition or abundance).

| | | | Cape Krusenstern[1] | | | | | | | Bering Land Bridge[1] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Family | *Latin Name* | Common Name | Ipiavik | Port | Aukulak | Imik[3] | Kotlik | Krusenstern | Sisualik | Kupik | Ikpek |
| Ammodytidae | *Ammodytes hexapterus* | Pacific sand lance | | | | | **6** | | | | |
| Agonidae | *Pallasina barbata* | Tubenose poacher | | | | | **6** | | | | |
| Clupeidae | *Clupea pallasii* | Pacific herring | | | **6** | | 3,5,6 | 4,5,6 | 1,3 | 5 | **6** |
| Umbridae | *Dallia pectoralis* | Alaska blackfish | | | 3 | | | | | | |
| Osmerideae[5] | *Mallotus villosus* | Capelin | | | | | 5 | 5 | | 5 | |
| | *Osmerus mordax* | Rainbow smelt | 2 | | **6** | | **6** | 3 | | **6** | **6** |
| | *Hypomesus olidus* | Pond smelt | | | | | | **6** | | **6** | **6** |
| | | Unidentified smelt | | | | | | | 1,3 | | |
| Salmonidae | *Coregonus laurettae* | Bering cisco | | | 3 | | 5,6 | 3,6 | 3 | | |
| | *C. nasus* | Broad whitefish | | | 3 | | | 3 | | | |
| | *C. pidschian* | Humpback whitefish | 2[4] | | 3,6 | | 3,6 | 3,4,5,6 | 3 | | |
| | | Unidentified whitefish | | | | | | | 1 | | |
| | *C. sardinella* | Least cisco | | | 3,6 | | **6** | 3,4,6 | 3 | | |
| | | Unidentified cisco | | | | | | | 1 | | |
| | *Stenodus leucichthys* | Inconnu | | | | | **6** | **6** | 3 | | |
| | *Thymallus arcticus* | Arctic grayling | 2 | | | | | 3,6 | | | |
| | *Oncorhynchus gorbuscha* | Pink salmon | 2 | | | | **6** | **6** | | | |
| | *O. keta* | Chum salmon | | | | | | | 1,3 | | |
| | *Salvenlinus alpinus* | Arctic char | 2 | | | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *S. malma* | Dolly Varden | | | | | 3,6 | **6** | | | |
| Gadidae | *Eleginus gracilis* | Saffron cod | 2 | | **6** | | 5,6 | **6** | 1,3 | | **6** |
| Gasterosteidae | *Gasterosteus aculeatus* | Threespine stickleback | | | | | **6** | 3,4,6 | 3 | | |
| | *Pungitius pungitius* | Ninespine stickleback | 2 | 2 | | | 3,5,6 | 3,4,5,6 | 1,3 | | **6** |
| Cottidae | *Cottus cognatus* | Slimy sculpin | 2 | | | | | | | | |
| | *Megalocottus platycephalus* | Belligerent sculpin | | | | | 3,6 | | | | |
| | *Myoxocephalus quadricornis* | Fourhorn sculpin | 2 | | 3,6 | | 3,5,6 | **6** | 3 | **6** | **6** |
| | | Unidentified sculpin | | | **6** | | **6** | | 1 | | |
| Pleuronectidae | *Limanda aspera* | Yellowfin sole | | | | | | | 3 | | |
| | *Limanda proboscidea* | Long head dab | | | **6** | | | | | | |
| | *Platichthys stellatus* | Starry flounder | 2 | | **6** | | 5,6 | 3,5,6 | 1,3 | **6** | |
| | *Pleuronectes glacialis* | Arctic flounder | | | **6** | | **6** | | 3 | **6** | **6** |
| | *Pleuronectes quadrituberculatus* | Alaska plaice | | | | | 5 | | | 5 | 5 |
| | | Unidentified flatfish | | | 3[2] | | | | 1 | | |
| **TOTAL SPP.** | | | **10** | **1** | **14** | **0** | **20** | **17** | **14** | **8** | **8** |

[1]For each lagoon, presence is denoted by **1** (1979/1980 data - Raymond et al. 1984); **2** (1982/1983 data – Blaylock and Houghton, 1983); **3** (2003/2004 data – Reynolds, 2012); **4** (2009 data – Reynolds and Clough, 2010); **5** (2012 data – Robards, 2014); **6** (2015 data- This report).
[2]Reynolds (2012) and Reynolds et al. (2005) indicate catches of unidentified Lepidopsetta spp. However, this is out of range for the genus so we classed more broadly as unidentified flatfish.
[3]Imik was only been sampled with a single gill net set on one occasion (catching no fish; Reynolds, 2012).
[4]1982 sampling effort.
[5] Osmerid identification is can be very challenging and the lack of pond smelt in previous sampling efforts may be a result of species misidentification

Table 25. Mean physical water parameters for the seven sample sites in each lagoon in 2015

| Lagoon | Temperature (°C) | Dissolved $O_2$ (mg/L) | pH | Specific conductivity (mS/cm) | Salinity (ppt) | Turbidity (NTU) | Chlorophyll (RFU) | Bluegreen algae (RFU) |
|---|---|---|---|---|---|---|---|---|
| Kotlik | 11.44 | 11.87 | 7.89 | 28558 | 19.6 | 9.43 | 2.21 | -0.59 |
| Krusenstern | 12.71 | 11.83 | 8.02 | 3505 | 2.1 | 9.73 | 2.14 | -0.67 |
| Aukulak | 13.291 | 11.76 | 7.97 | 26728 | 18.3 | 7.25 | 1.78 | -0.75 |
| Kupik | 14.991 | 10.93 | 8.55 | 38515 | 26.6 | 2.65 | 0.16 | -1.4 |
| Espenberg | 13.829 | NA | 7.88 | 46167 | 31.9 | 0.7 | 0.4 | -0.99 |
| Ikpek | 15.77 | 11.04 | 8.37 | 40310 | 27.8 | 1.64 | 1.14 | -1.44 |

Table 26. Mean physical water parameters for seven sample sites in each lagoon in 2016

| Lagoon | Temperature (°C) | Specific conductivity (mS/cm) | Salinity (ppt) | Dissolved $O_2$ (%) | pH | Chlorophyl (µg/L) | Bluegreen algae (µg/L) |
|---|---|---|---|---|---|---|---|
| Aukulak | 15.16 | 39794.61 | 25.37 | 122.13 | 8.1 | 3.6445 | 0.48 |
| Ikpek | 13.16 | 29537.3 | 18.26 | 122.84 | 8.3 | 1.185 | 0.23 |
| Kotlik | 12.834 | 35916.41 | 22.58 | 117.67 | 8.28 | 2.77 | 0.3847 |
| Krusenstern | 12.079 | 11644.39 | 4.719 | 119.94 | 8.6 | 29.30 | 1.50 |
| Kupik | 11.415 | 23564.1 | 14.34 | 114.38 | 8.06 | 3.65 | 0.34 |
| Tasaycheck | 14.607 | 12802.38 | 7.471 | 128.78 | 8.90 | 2.049 | 0.26 |

Table 27. Mean physical water parameters for seven sample sites in each lagoon in 2017

| Lagoon | Temperature (°C) | Specific conductivity (mS/cm) | Salinity (ppt) | Dissolved $O_2$ (%) | pH |
|---|---|---|---|---|---|
| Aukulak | 13.33 | 13282.78 | 3.51 | 100.8236842 | 7.36 |
| Kotlik | 13.81 | 5499.04 | 3.10 | 104.664 | 7.7004 |
| Krusenstern | 12.97 | 3601.84 | 2.05 | 112.725 | 8.79 |
| Tukrok River | 11.48 | 15130.3 | 8.84 | 94.083 | 7.92 |
| Chukchi Sea | 10.10 | 6176.5 | 3.38 | 100.725 | 10.6325 |

Figure 6. Mean monthly salinity (ppt) of each of the three Cape Krusenstern lagoons consistently sampled throughout each field season.

| Krusenstern | | | |
|---|---|---|---|
| **Month** | **2015** | **2016** | **2017** |
| June | - | 2.85 | 7.55 |
| July | 1.29 | 5.17 | 0.22 |
| August | 1.88 | 4.90 | 0.21 |
| September | 2.31 | 5.95 | - |

| Kotlik | | | |
|---|---|---|---|
| **Month** | **2015** | **2016** | **2017** |
| June | - | 23.61 | 7.15 |
| July | 11.82 | 23.70 | 0.43 |
| August | 21.69 | 16.84 | 1.32 |
| September | 11.24 | - | - |

| Aukulak | | | |
|---|---|---|---|
| **Month** | **2015** | **2016** | **2017** |
| June | - | 22.01 | 8.86 |
| July | 15.12 | 26.99 | 0.42 |
| August | 15.34 | 26.64 | 0.37 |
| September | 14.34 | - | |

Table 28. Mean salinity (ppt) at each water quality data sample point at Krusenstern Lagoon by year.

| Sample Site | 2015 | 2016 | 2017 |
|---|---|---|---|
| KR_1 | 1.73 | 4.81 | 2.66 |
| KR_2 | 2.01 | 3.23 | 2.68 |
| KR_3 | 1.93 | 2.47 | 7.43 |
| KR_4 | 0.94 | 5.08 | 0.22 |
| KR_5 | 1.69 | 4.42 | 0.22 |
| KR_6 | 1.84 | 4.86 | 0.2 |
| KR_RAN_1 | 1.83 | 4.78 | 0.22 |
| KR_RAN_2 | 1.86 | 5.69 | - |
| KR_RAN_3 | 1.84 | 4.45 | 2.68 |

Figure 7. Water quality sample sites at Krusenstern lagoon.

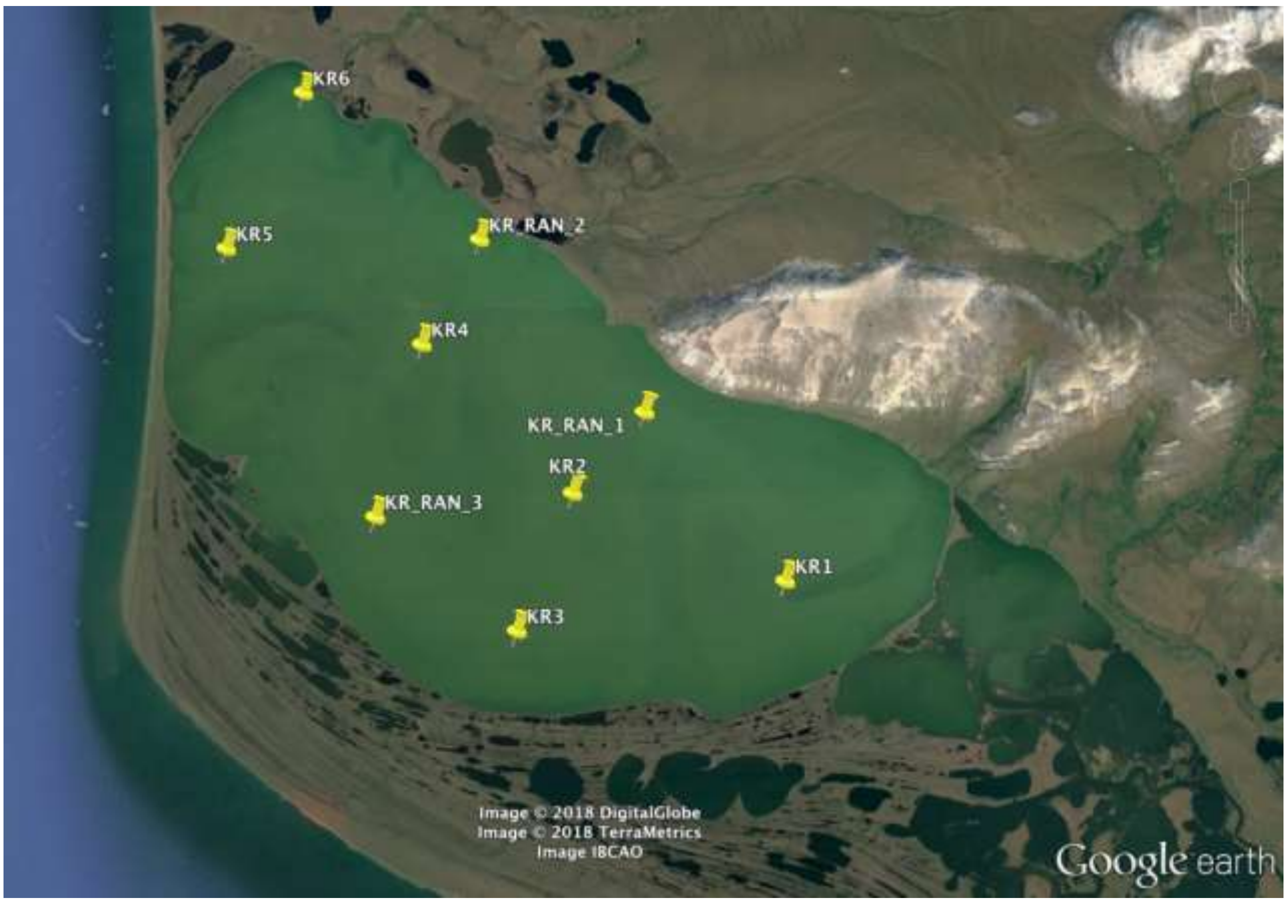

Table 29. Mean salinity (ppt) at each water quality data sample point at Kotlik Lagoon by year.

| Sample Site | 2015 | 2016 | 2017 |
|---|---|---|---|
| KO_1 | 15.97 | 24.13 | 2.6 |
| KO_2 | 17.15 | 22.48 | 3.79 |
| KO_3 | 15.2 | 23.26 | 3.05 |
| KO_4 | 15.33 | 21.58 | 2.96 |
| KO_5 | 14.95 | 20.7 | 3.78 |
| KO_ME | 15.24 | 22.07 | 4.32 |
| KO_OUT | 14.21 | 24.11 | 1.01 |
| KO_RAN_1 | 11.70 | - | 3.83 |
| KO_RAN_2 | 15.15 | 23.55 | 3.05 |
| KO_RAN_3 | 11.87 | 23.4 | 3.01 |

Figure 8. Water quality sample sites at Kotlik lagoon.

Table 30. Mean salinity (ppt) at each water quality data sample point at Aukulak Lagoon by year.

| Sample Site | 2015 | 2016 | 2017 |
|---|---|---|---|
| AK_1 | 16.56 | | 0.37 |
| AK_2 | 14.80 | 24.22 | 0.39 |
| AK_3 | 15.21 | 25.14 | 4.63 |
| AK_4 | 14.75 | 24.62 | 3.23 |
| AK_5 | 15.12 | 26.64 | 8.87 |
| AK_RAN_1 | 15.24 | 26.58 | 3.21 |
| AK_RAN_2 | 14.88 | 24.8 | 3.23 |
| AK_RAN_3 | 12.82 | 26.02 | 3.167 |

Figure 9. Water quality sample sites at Aukulak lagoon.

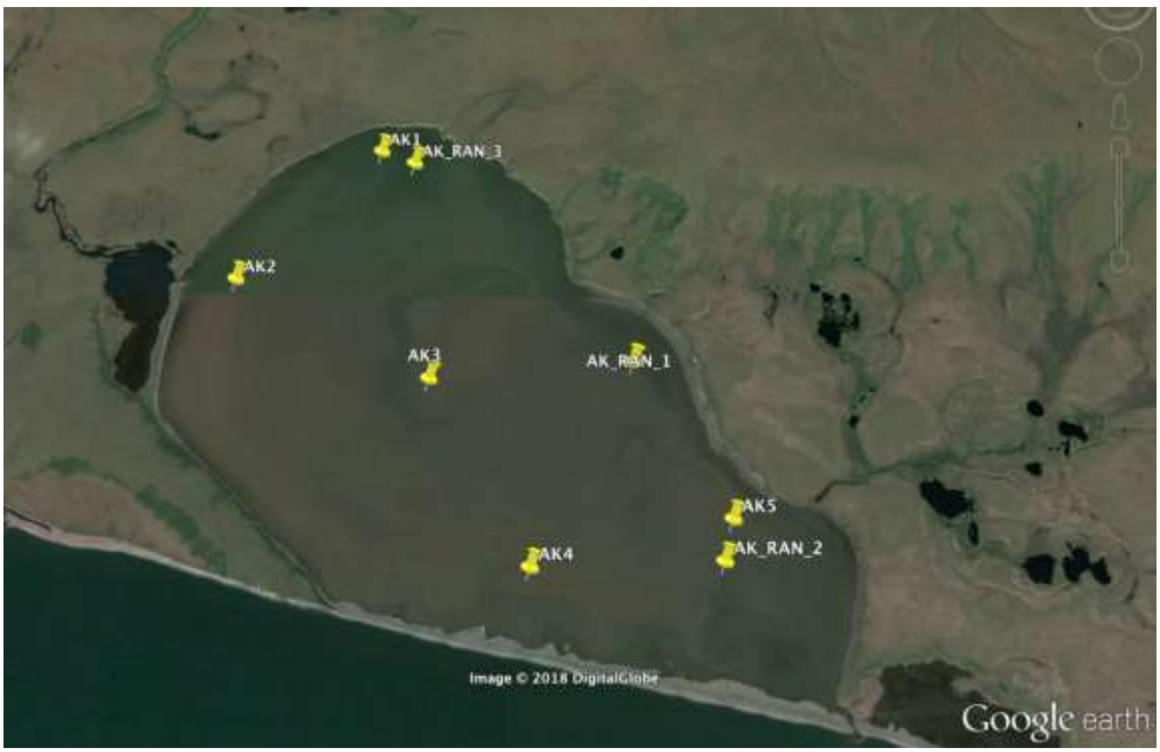

Figure 10. Mean monthly temperature (˚C) of each of the three Cape Krusenstern lagoons consistently sampled throughout each field season.

| Krusenstern | | | |
|---|---|---|---|
| **Month** | **2015** | **2016** | **2017** |
| June | - | 14.30 | 13.13 |
| July | 15.18 | 16.32 | 16.67 |
| August | 12.24 | 12.67 | 9.64 |
| September | 5.84 | 5.03 | - |

| Kotlik | | | |
|---|---|---|---|
| **Month** | **2015** | **2016** | **2017** |
| June | - | 15.07 | 15.13 |
| July | 15.55 | 11.21 | 15.76 |
| August | 13.95 | 11.14 | 9.6 |
| September | 2.69 | - | - |

| Aukulak | | | |
|---|---|---|---|
| **Month** | **2015** | **2016** | **2017** |
| June | - | 15.86 | 11.42 |
| July | 18.35 | 16.62 | 17.15 |
| August | 5.91 | 13.10 | 11.75 |
| September | 4.17 | - | |

Figure 11. Mean monthly pH of each of the three Cape Krusenstern lagoons consistently sampled throughout each field season.

| Krusenstern | | | |
|---|---|---|---|
| **Month** | **2015** | **2016** | **2017** |
| June | - | 8.70 | 8.30 |
| July | 8.58 | 8.36 | 7.35 |
| August | 8.26 | 8.69 | 10.36 |
| September | 7.73 | 8.56 | - |

| Kotlik | | | |
|---|---|---|---|
| **Month** | **2015** | **2016** | **2017** |
| June | - | 8.54 | 7.76 |
| July | 8.12 | 8.15 | 5.64 |
| August | 7.84 | 7.95 | 10.28 |
| September | 7.27 | - | - |

| Aukulak | | | |
|---|---|---|---|
| **Month** | **2015** | **2016** | **2017** |
| June | - | 7.88 | 7.41 |
| July | 7.90 | 8.10 | 5.91 |
| August | 7.35 | 8.32 | 8.75 |
| September | 7.38 | - | - |

Figure 12. Mean monthly dissolved oxygen of each of the three Cape Krusenstern lagoons consistently sampled throughout each field season. Values for the 2015 season are recorded in mg/L while 2016 and 2017 values are recorded in %.

| Krusenstern | | | |
|---|---|---|---|
| **Month** | **2015** | **2016** | **2017** |
| June | - | 115.40 | 120.74 |
| July | 10.70 | 129.86 | 114.50 |
| August | 11.22 | 120.34 | 106.16 |
| September | 12.44 | 114.17 | - |

| Kotlik | | | |
|---|---|---|---|
| **Month** | **2015** | **2016** | **2017** |
| June | - | 123.84 | 109.38 |
| July | 9.45 | 111.49 | 104.96 |
| August | 10.23 | 117.63 | 98.23 |
| September | 12.10 | - | - |

| Aukulak | | | |
|---|---|---|---|
| **Month** | **2015** | **2016** | **2017** |
| June | - | 106.95 | 102.96 |
| July | - | 126.47 | 102.93 |
| August | 11.14 | 130.79 | 96.23 |
| September | 11.48 | - | - |

Figure 13. Mean monthly turbidity of each of the three Cape Krusenstern lagoons consistently sampled throughout each field season. While turbidity was measured in NTU during the 2015 and 2016 field seasons, readings were recorded in 2017 using FNU.

| Krusenstern | | | |
|---|---|---|---|
| **Month** | **2015** | **2016** | **2017** |
| June | - | 21.34 | 19.73 |
| July | 8.31 | 10.97 | 21.15 |
| August | 13.00 | 17.31 | 42.06 |
| September | 27.49 | 65.93 | - |

| Kotlik | | | |
|---|---|---|---|
| **Month** | **2015** | **2016** | **2017** |
| June | - | 60.36 | -5.37 |
| July | 3.55 | 3.92 | -4.98 |
| August | 1.14 | 2.43 | -6.58 |
| September | 3.64 | - | - |

| Aukulak | | | |
|---|---|---|---|
| **Month** | **2015** | **2016** | **2017** |
| June | - | 2.66 | -2.04 |
| July | 6.81 | 1.88 | -0.96 |
| August | 14.79 | 34.25 | 11.83 |
| September | 9.82 | - | - |

Table 31: Mean water quality parameters and standard deviations (SD) for the three study lagoons for March 2017.

| | Aukulak | | Krusenstern | | Kotlik | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD |
| Ice thickness (m) | 1.25 | 0.04 | 1.47 | 0.43 | 1.31 | 0.13 |
| Temperature (°C) | -3.41 | 0.09 | -0.54 | 0.08 | -0.73 | 0.73 |
| Dissolved oxygen (mg/L) | 1.85 | 0.42 | 4.33 | 1.02 | 5.55 | 1.68 |
| Salinity (ppt) | 52.70 | 0.27 | 6.65 | 1.07 | 12.73 | 6.95 |
| pH | 7.73 | 0.11 | 8.15 | 0.10 | 7.90 | 0.64 |

Table 32. Salinity and temperature readings in the Tukrok river channel. Highest salinity readings were recorded at sample sites closest the mouth with readings decreasing in value further down the channel.

| Distance from Channel Mouth (m) | Salinity (ppt) | Temperature (°C) |
|---|---|---|
| Mouth-marine side | 9.38 | 10.944 |
| Mouth-Channel side | 8.93 | 11.93 |
| 250 | 8.88 | 11.15 |
| 500 | 8.82 | 11.8 |
| 750 | 8.80 | 11.056 |
| 1,000 | 8.60 | 11.625 |
| 1,250 | 8.49 | 11.888 |

Figure 14. Mean daily temperature (above) and salinity (middle) and pH (below) from July 2 to September 13, 2016 for Aukulak Lagoon.

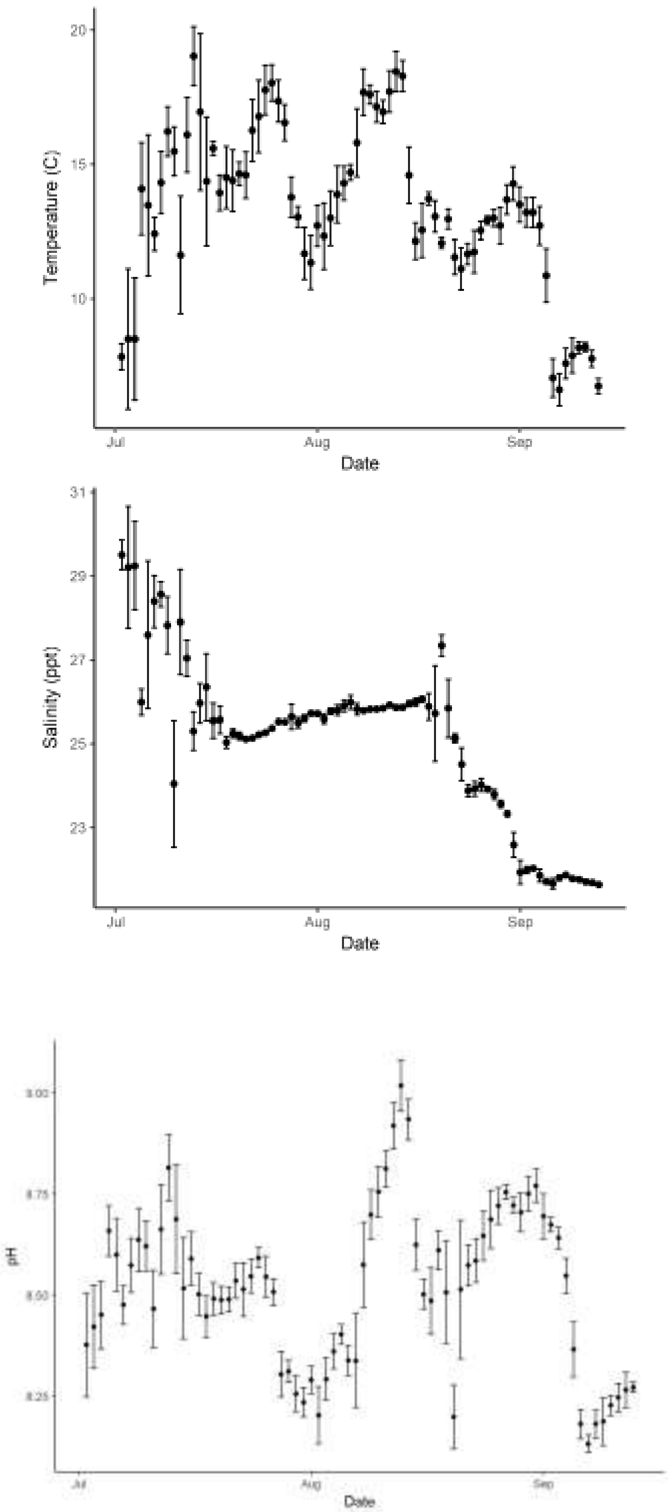

Table 33. Number of sets per year by gear type and total fishing time per year.

| Gear Type | Year 2015 | 2016 | 2017 |
|---|---|---|---|
| | Number of Sets | | |
| Beach Seine | 40 | 41 | 39 |
| Fyke Net | 8 | 7 | 3 |
| Gill Net | 68 | 110 | 50 |
| Dip Net | 0 | 1 | 0 |
| Hand and Line | 0 | 9 | 0 |
| Minnow Trap | 25 | 0 | 0 |

Table 34. Mean (standard deviation) set time for active sampling methodology (hours)

| Gear Type | Year 2015 | 2016 | 2017 |
|---|---|---|---|
| Fyke Net | 3.22 (1.44) | 3.47 (0.7) | 2.5 (0.67) |
| Gill Net | 1.7 (0.8) | 1.65 (0.9) | 1.86 (0.9) |

Table 35. Total Set time (hours) for active sampling methodologies by year

| Gear Type | Year 2015 | 2016 | 2017 |
|---|---|---|---|
| Fyke Net | 21.88 | 20.82 | 10 |
| Gill Net | 56 | 161.4 | 100.25 |

Table 36. Total number of individuals per species caught by field season.[1]

| Family | *Latin Name* | Common Name | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|
| Ammodytidae | *Ammodytes hexapterus* | Pacific sand lance | 109 | 31 | 4 |
| Agonidae | *Pallasina barbata* | Tubenose poacher | 14 | 152 | 0 |
| | *Ocella dodecaedron* | Bering poacher | 0 | 32 | 0 |
| Clupeidae | *Clupea pallasii* | Pacific herring | 1041 | 21248 | 1438 |
| Osmerideae | *Mallotus villosus* | Capelin | 1 | 77 | 0 |
| | *Osmerus mordax* | Rainbow smelt | 30 | 82 | 2 |
| | *Hypomesus olidus* | Pond smelt | 11350 | 2699 | 751 |
| Salmonidae | *Coregonus laurettae* | Bering cisco | 7 | 29 | 15 |
| | *C. pidschian* | Humpback whitefish | 84 | 317 | 507 |
| | *C. sardinella* | Least cisco | 16 | 54 | 37 |
| | *Stenodus leucichthys* | Sheefish | 21 | 13 | 34 |
| | *Oncorhynchus gorbuscha* | Pink salmon | 38 | 115 | 82 |
| | *O. keta* | Chum salmon | 0 | 3 | 4 |
| | *S. malma* | Dolly Varden | 7 | 39 | 6 |
| | | Unidentified whitefish | 1 | 1 | 0 |
| | *Thymallus arcticus* | Arctic grayling | 3 | 0 | 0 |
| Gadidae | *Eleginus gracilis* | Saffron cod | 118 | 157 | 425 |
| Gasterosteidae | *Gasterosteus aculeatus* | Threespine stickleback | 6 | 30 | 141 |
| | *Pungitius pungitius* | Ninespine stickleback | 11962 | 6027 | 1060 |
| | | Unidentified stickleback | 0 | 0 | 10202 |
| Cottidae | *Chitonotus pugetensis* | Roughback sculpin | 17 | 0 | 0 |
| | *Enophrys bison* | Buffalo sculpin | 0 | 17 | 0 |
| | *Megalocottus platycephalus* | Belligerent sculpin | 0 | 76 | 8 |
| | *Myoxocephalus quadricornis* | Fourhorn sculpin | 58 | 220 | 15 |
| | *Myoxocephalus polycanthocephalus* | Great sculpin | 56 | 0 | 0 |
| | *Gymnocanthus tricuspis* | Arctic Staghorn sculpin | 0 | 14 | 0 |
| | | Unidentified sculpin | 73 | 144 | 0 |
| Pleuronectidae | *Limanda proboscidea* | Long head dab | 1 | 4 | 0 |
| | *Platichthys stellatus* | Starry flounder | 154 | 419 | 118 |
| | *Pleuronectes glacialis* | Arctic flounder | 177 | 178 | 20 |
| | | Unidentified flatfish | 8 | 170 | 43 |
| Stichaeidae | *Acantholumpenus mackai* | Blackline prickleback | 1 | 1 | 0 |

[1] Unidentified classification includes juvenile individuals who could not be identified to species.

Table 37. Species sampled in the Chukchi Sea, Tukrok River and those found in both locations.

| Tukrok | Chukchi | Both Locations |
|---|---|---|
| Bering Cisco | Capelin | Arctic Flounder |
| Chum Salmon | Rainbow smelt | Fourhorn Sculpin |
| Dolly Varden | Threespine Stickleback | Pacific Herring |
| Sheefish | Blackline prickleback | Humpback Whitefish |
| Tubenose Poacher | | Least Cisco |
| | | Saffron Cod |
| | | Starry Flounder |
| | | Ninespine Sticklback |
| | | Pink Salmon |
| | | Pond Smelt |
| | | Pacific Sand Lance |
| | | Capelin |

Figure 15. Venn Diagram showing species found in the Tukrok River channel, the main body of Krusenstern Lagoon, and the Chukchi Sea.

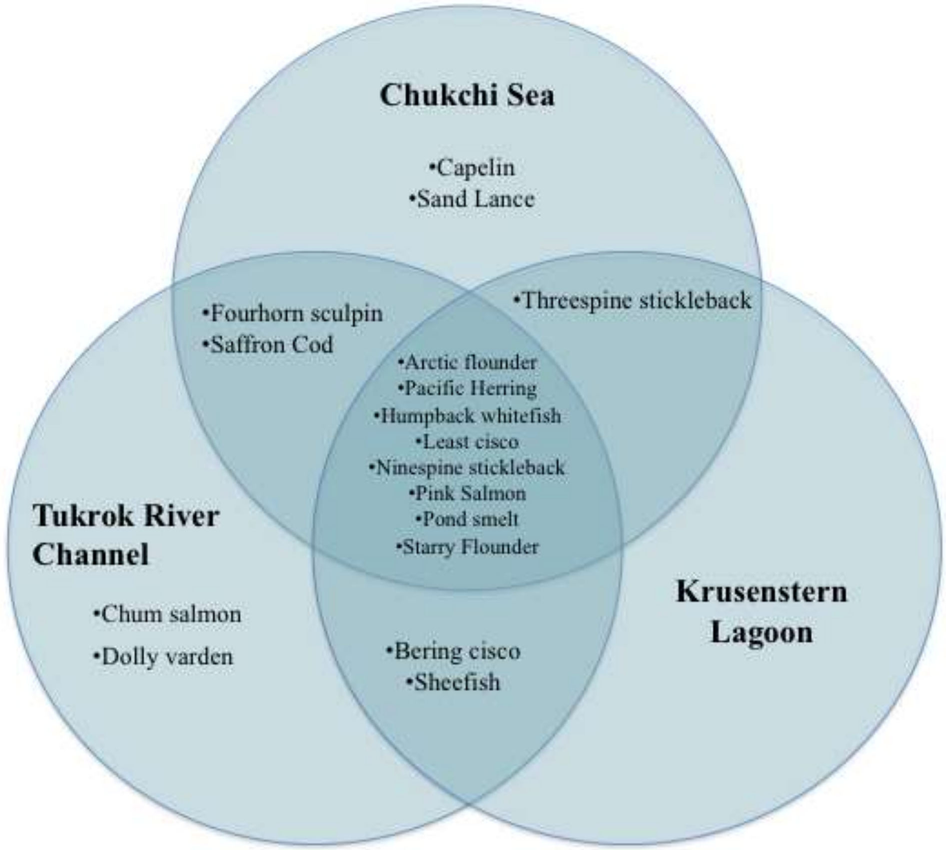

Table 38. Species richness in Aukulak lagoon by field season. X indicates species was sampled in the lagoon during the corresponding field season.

| Family | *Latin Name* | Common Name | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|
| Ammodytidae | *Ammodytes hexapterus* | Pacific sand lance | | | |
| Agonidae | *Pallasina barbata* | Tubenose poacher | | x | |
| | *Occella dodecaedron* | Bering poacher | | x | |
| Clupeidae | *Clupea pallasii* | Pacific herring | x | x | |
| Umbridae | *Dallia pectoralis* | Alaska blackfish | | | |
| Osmerideae[5] | *Mallotus villosus* | Capelin | | x | |
| | *Osmerus mordax* | Rainbow smelt | | x | |
| | *Hypomesus olidus* | Pond smelt | x | x | |
| Salmonidae | *Coregonus laurettae* | Bering cisco | | x | |
| | *C. pidschian* | Humpback whitefish | | x | |
| | *C. sardinella* | Least cisco | x | x | |
| | *Stenodus leucichthys* | Sheefish | x | | |
| | *Oncorhynchus gorbuscha* | Pink salmon | | x | |
| | *O. keta* | Chum salmon | | | |
| | *S. malma* | Dolly Varden | x | | |
| | | Unidentified whitefish | x | x | |
| | *Thymallus arcticus* | Arctic grayling | | | |
| Gadidae | *Eleginus gracilis* | Saffron cod | | x | |
| Gasterosteidae | *Gasterosteus aculeatus* | Threespine stickleback | | x | |
| | *Pungitius pungitius* | Ninespine stickleback | | | |
| | | Unidentified stickleback | | | |
| Cottidae | *Chitonotus pugetensis* | Roughback sculpin | x | | |
| | *Enophrys bison* | Buffalo sculpin | | x | |
| | *Megalocottus platycephalus* | Belligerent sculpin | | x | |
| | *Myoxocephalus quadricornis* | Fourhorn sculpin | | x | |
| | *Myoxocephalus polycanthocephalus* | Great sculpin | x | | |
| | *Gymnocanthus tricuspis* | Arctic Staghorn sculpin | | x | |
| | | Unidentified sculpin | | x | |
| Pleuronectidae | *Limanda proboscidea* | Long head dab | | x | |
| | *Platichthys stellatus* | Starry flounder | | x | |
| | *Pleuronectes glacialis* | Arctic flounder | x | x | |
| | | Unidentified flatfish | | x | |
| Stichaeidae | *Acantholumpenus mackai* | Blackline prickleback | | | |

Table 39. Species richness in Kotlik lagoon by field season. X indicates species was sampled in the lagoon during the corresponding field season.

| Family | *Latin Name* | Common Name | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|
| Ammodytidae | *Ammodytes hexapterus* | Pacific sand lance | x | x | |
| Agonidae | *Pallasina barbata* | Tubenose poacher | x | x | |
| | *Occella dodecaedron* | Bering poacher | | x | |
| Clupeidae | *Clupea pallasii* | Pacific herring | x | x | x |
| Umbridae | *Dallia pectoralis* | Alaska blackfish | | | |
| Osmerideae[5] | *Mallotus villosus* | Capelin | | x | |
| | *Osmerus mordax* | Rainbow smelt | x | x | |
| | *Hypomesus olidus* | Pond smelt | | x | x |
| Salmonidae | *Coregonus laurettae* | Bering cisco | x | x | x |
| | *C. pidschian* | Humpback whitefish | x | x | x |
| | *C. sardinella* | Least cisco | x | x | x |
| | *Stenodus leucichthys* | Sheefish | x | | |
| | *Oncorhynchus gorbuscha* | Pink salmon | x | x | x |
| | *O. keta* | Chum salmon | | | |
| | *S. malma* | Dolly Varden | x | x | |
| | | Unidentified whitefish | | | |
| | *Thymallus arcticus* | Arctic grayling | | | |
| Gadidae | *Eleginus gracilis* | Saffron cod | x | x | x |
| Gasterosteidae | *Gasterosteus aculeatus* | Threespine stickleback | x | x | x |
| | *Pungitius pungitius* | Ninespine stickleback | x | | x |
| | | Unidentified stickleback | | | x |
| Cottidae | *Chitonotus pugetensis* | Roughback sculpin | x | | |
| | *Enophrys bison* | Buffalo sculpin | | | |
| | *Megalocottus platycephalus* | Belligerent sculpin | | x | |
| | *Myoxocephalus quadricornis* | Fourhorn sculpin | x | x | |
| | *Myoxocephalus polycanthocephalus* | Great sculpin | x | | |
| | *Gymnocanthus tricuspis* | Arctic Staghorn sculpin | | x | |
| | | Unidentified sculpin | x | | |
| Pleuronectidae | *Limanda proboscidea* | Long head dab | | | |
| | *Platichthys stellatus* | Starry flounder | x | x | x |
| | *Pleuronectes glacialis* | Arctic flounder | x | x | x |
| | | Unidentified flatfish | | x | x |
| Stichaeidae | *Acantholumpenus mackai* | Blackline prickleback | | x | |

Table 40. Species richness in Krusenstern lagoon by field season. X indicates species was sampled in the lagoon during the corresponding field season.

| Family | *Latin Name* | Common Name | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|
| Ammodytidae | *Ammodytes hexapterus* | Pacific sand lance | | | |
| Agonidae | *Pallasina barbata* | Tubenose poacher | | | |
| | *Occella dodecaedron* | Bering poacher | | | |
| Clupeidae | *Clupea pallasii* | Pacific herring | x | x | x |
| Umbridae | *Dallia pectoralis* | Alaska blackfish | | | |
| Osmerideae[5] | *Mallotus villosus* | Capelin | | | |
| | *Osmerus mordax* | Rainbow smelt | | | |
| | *Hypomesus olidus* | Pond smelt | x | x | x |
| Salmonidae | *Coregonus laurettae* | Bering cisco | x | x | x |
| | *C. pidschian* | Humpback whitefish | x | x | x |
| | *C. sardinella* | Least cisco | x | x | x |
| | *Stenodus leucichthys* | Sheefish | x | | x |
| | *Oncorhynchus gorbuscha* | Pink salmon | x | x | x |
| | *O. keta* | Chum salmon | | x | |
| | *S. malma* | Dolly Varden | x | x | |
| | | Unidentified whitefish | | x | |
| | *Thymallus arcticus* | Arctic grayling | x | | |
| Gadidae | *Eleginus gracilis* | Saffron cod | x | | |
| Gasterosteidae | *Gasterosteus aculeatus* | Threespine stickleback | x | x | x |
| | *Pungitius pungitius* | Ninespine stickleback | x | x | x |
| | | Unidentified stickleback | | | |
| Cottidae | *Chitonotus pugetensis* | Roughback sculpin | | | |
| | *Enophrys bison* | Buffalo sculpin | | | |
| | *Megalocottus platycephalus* | Belligerent sculpin | | | |
| | *Myoxocephalus quadricornis* | Fourhorn sculpin | x | | |
| | *Myoxocephalus polycanthocephalus* | Great sculpin | | | |
| | *Gymnocanthus tricuspis* | Arctic Staghorn sculpin | | | |
| | | Unidentified sculpin | | | |
| Pleuronectidae | *Limanda proboscidea* | Long head dab | | | |
| | *Platichthys stellatus* | Starry flounder | x | x | x |
| | *Pleuronectes glacialis* | Arctic flounder | | x | x |
| | | Unidentified flatfish | | x | |
| Stichaeidae | *Acantholumpenus mackai* | Blackline prickleback | | | |

Table 41. Number of diet samples by species taken during the 2015 field season.

| Family | *Latin Name* | Common Name | Number of Samples |
|---|---|---|---|
| Osmerideae | *Osmerus mordax* | Rainbow smelt | 10 |
| | *Hypomesus olidus* | Pond smelt | 575 |
| Clupeidae | *Clupea pallasii* | Pacific herring | 70 |
| Gadidae | *Eleginus gracilis* | Saffron cod | 50 |
| Salmonidae | *Coregonus laurettae* | Bering cisco | 2 |
| | *C. sardinella* | Least cisco | 17 |
| | *C. pidschian* | Humpback whitefish | 46 |
| | *Stenodus malma* | Dolly Varden | 5 |
| | *Oncorhynchus gorbuscha* | Pink salmon | 2 |
| | *S. leucichthys* | Sheefish | 12 |
| | *Thymallus arcticus* | Arctic grayling | 2 |
| Pleuronectidae | *Platichthys stellatus* | Starry flounder | 20 |
| Gasterosteidae | *Gasterosteus aculeatus* | Threespine stickleback | 3 |
| Cottidae | *Myoxocephalus quadricornis* | Fourhorn sculpin | 7 |

Figure 16. Preliminary diet results from 2015 field season for a. sheefish (n=10), b. humpback whitefish (n= 30), c. saffron cod (n=39) and d. starry flounder (n=9). These percentages represent the percent composition by number of prey items, not by weight (Graphic updated in Tibbles and Robards, 2018).

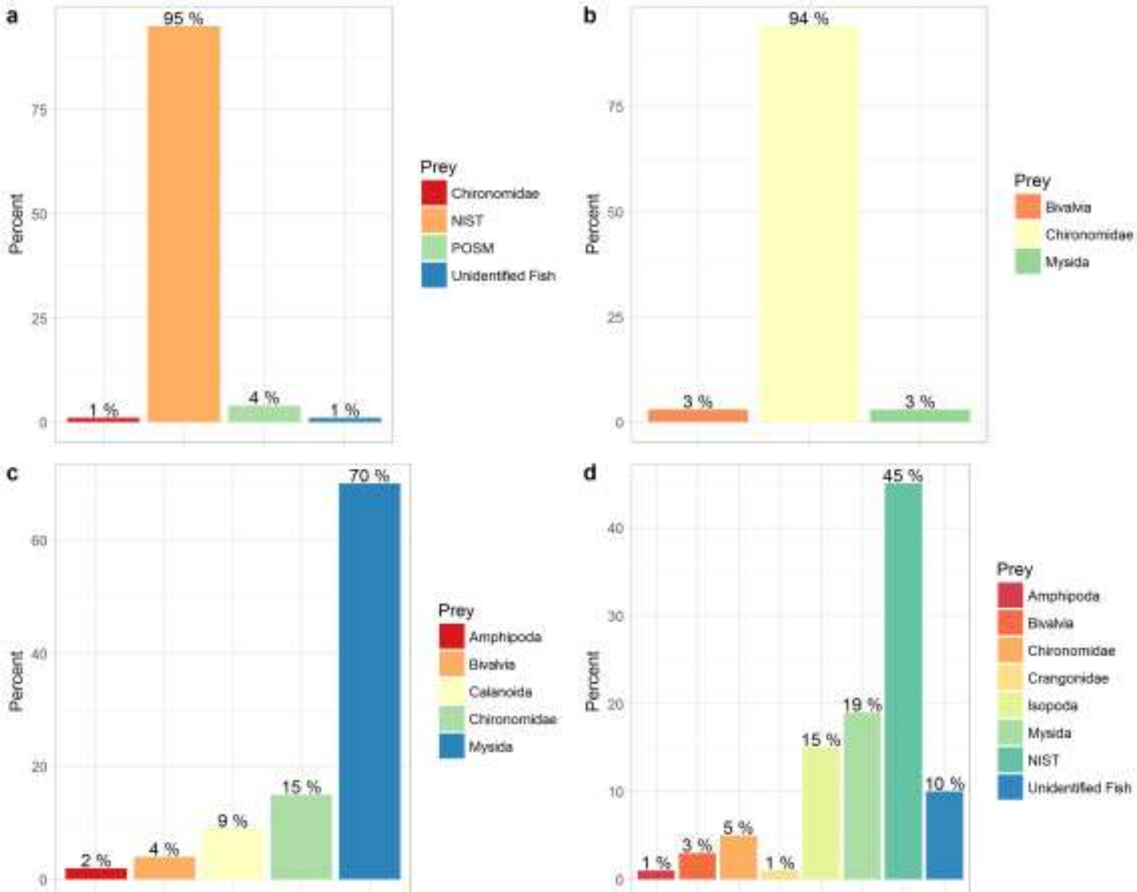

Table 42. Invertebrate Species Inventory for Kotzebue Sound Lagoons based on four sampling periods since 1979[3]

| | | | Cape Krusenstern[1] | | | | | Bering Land Bridge[1] | |
|---|---|---|---|---|---|---|---|---|---|
| Family | *Latin Name* | Common Name | Aukulak | Imik | Kotlik | Krusenstern | Sisualik | Kupik | Ikpek |
| | *C. septemspinosa* | Sand Shrimp | | | | | 1 | | 4 |
| | *Crangon Spp* | Unidentified Crangon Shrimp | 2, 5[4] | | 5[4] | 5 | 2 | 4,5 | |
| Mysidae | *Neomysis rayii* | | 5 | | | 5 | | | |
| | *Acanthomysis dybowski*[5] | | 5 | | 5 | | | 5 | |
| | *Mysid Spp.* | Unidentified Mysid Shrimp | | | | 2 | 2 | | 5 |
| | *Macoma Spp* | Clam[2] | 2, 4, 5[4] | 2 | 2, 4, 5[4] | 2 | 2 | 4 | 4 |
| | *Mytilus Spp.* | Mussel | | | 2, 4 | | | | |
| | | Polychaete | 2 | | | 2, 4 | 2 | | 4 |
| | | Tunicate | | | | | | 4 | |
| | | Chironomid Larvae | 2, 5[4] | 2 | 3, 5[4] | 2, 5[4] | 2 | | |
| | | Isopod | 2, 5[4] | 2 | | | | | |
| | | Amphipod | 5[4] | | 5[4] | 2, 5[4] | 2 | | 4, 5[4] |

[1]For each lagoon presence is denoted by 1 (Raymond et al., 1984), 2 (Reynolds et al., 2005), 3 (Reynolds, 2012), 4 (Robards, 2014), 5 (Haynes et al., 2017).

[2]*Macoma balthica* are reported by Dames and Moore (1983) for Red Dog study lagoons (just north of the National Park Service Cape Krusenstern unit).

[3]Additional invertebrate data is available in Erikson (1983) for Port Lagoon in Cape Krusenstern National Preserve, but have not been compiled into the NPS database yet.

[4] Data from the analysis of fish diet samples.

[5] There is ambiguity as to the taxonomic classification of this species. Pillia (1961) refers to it as *A. dybowski* while Petryashov (2009) has classified it as *Neomysis awatschensis*.

Table 43. Otoliths pulled by species per season

| Family | *Latin Name* | Common Name | 2015 | 2016 |
|---|---|---|---|---|
| Ammodytidae | *Ammodytes hexapterus* | Pacific sand lance | 68 | |
| Agonidae | *Pallasina barbata* | Tubenose poacher | | |
| | *Occella dodecaedron* | Bering poacher | | |
| Clupeidae | *Clupea pallasii* | Pacific herring | 93 | 30 |
| Umbridae | *Dallia pectoralis* | Alaska blackfish | | |
| Osmerideae[5] | *Mallotus villosus* | Capelin | | |
| | *Osmerus mordax* | Rainbow smelt | 3 | |
| | *Hypomesus olidus* | Pond smelt | 569 | 17 |
| Salmonidae | *Coregonus laurettae* | Bering cisco | | |
| | *C. pidschian* | Humpback whitefish | 42 | 26 |
| | *C. sardinella* | Least cisco | 26 | |
| | *Stenodus leucichthys* | Sheefish | 5 | |
| | *Oncorhynchus gorbuscha* | Pink salmon | 1 | 1 |
| | *O. keta* | Chum salmon | | |
| | *S. malma* | Dolly Varden | 1 | |
| | | Unidentified whitefish | | |
| | *Thymallus arcticus* | Arctic grayling | 3 | |
| Gadidae | *Eleginus gracilis* | Saffron cod | 23 | 18 |
| Gasterosteidae | *Gasterosteus aculeatus* | Threespine stickleback | 1 | |
| | *Pungitius pungitius* | Ninespine stickleback | 86 | |
| | | Unidentified stickleback | | |
| Cottidae | *Chitonotus pugetensis* | Roughback sculpin | | |
| | *Enophrys bison* | Buffalo sculpin | | |
| | *Megalocottus platycephalus* | Belligerent sculpin | | |
| | *Myoxocephalus quadricornis* | Fourhorn sculpin | 2 | |
| | *Myoxocephalus polycanthocephalus* | Great sculpin | | |
| | *Gymnocanthus tricuspis* | Arctic Staghorn sculpin | | |
| | | Unidentified sculpin | | |
| Pleuronectidae | *Limanda proboscidea* | Long head dab | | |
| | *Platichthys stellatus* | Starry flounder | 19 | 27 |
| | *Pleuronectes glacialis* | Arctic flounder | | |
| | | Unidentified flatfish | | |
| Stichaeidae | *Acantholumpenus mackai* | Blackline prickleback | | |

Figure 17. Relationship between weight and fork length for pond smelt (*Hypomesus oledus*) for samples collected during the 2015 field season.

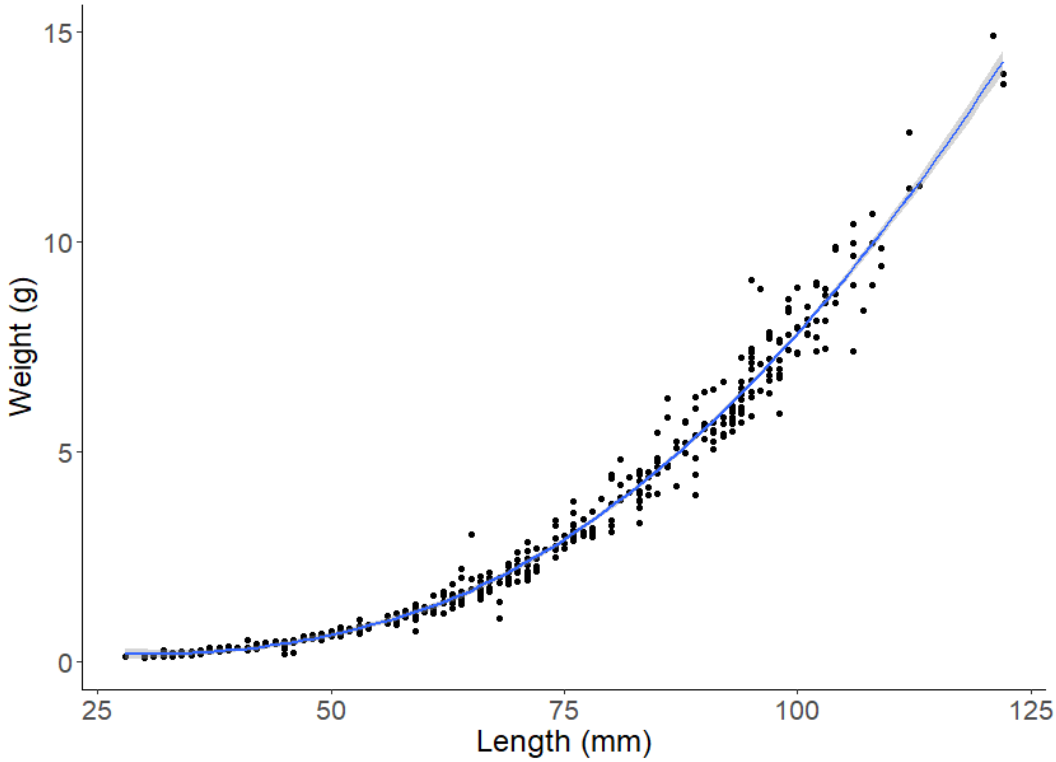

Table 44. Contaminants samples taken in 2015 field season from lagoons in Cape Krusenstern by species.

| Family | *Latin Name* | Common Name | Krusenstern | Aukulak | Kotlik |
|---|---|---|---|---|---|
| Salmonidae | *Coregonus laurettae* | Bering Cisco | 5 | 0 | 0 |
| | *Stenodus leucichthys* | Sheefish | 3 | 0 | 0 |
| | *C. sardinella* | Least Cisco | 3 | 2 | 0 |
| | *C. pidschian* | Humpback Whitefish | 6 | 4 | 0 |
| Cottidae | *Myoxocephalus quadricornis* | Fourhorn Sculpin | 2 | 0 | 5 |
| Gasterosteidae | *Pungitius pungitius* | Ninespine Stickleback | 5 | 0 | 0 |
| Clupeidae | *Clupea pallasii* | Pacific Herring | 5 | 0 | 0 |
| Gadidae | *Eleginus gracilis* | Saffron Cod | 0 | 5 | 5 |
| Pleuronectidae | *Platichthys stellatus* | Starry Flounder | 5 | 4 | 5 |

Table 45. Contaminants samples taken in 2016 field season from lagoons in Cape Krusenstern by species.

| Family | *Latin Name* | Common Name | Kotlik | Krusenstern | Aukulak |
|---|---|---|---|---|---|
| Cottidae | *Myoxocephalus quadricornis* | Fourhorn Sculpin | 0 | 0 | 0 |
| Clupeidae | *Clupea pallasii* | Pacific Herring | 5 | 0 | 0 |
| Salmonidae | *Coregonus sardinella* | Least Cisco | 0 | 0 | 0 |
| | *Oncorhynchus gorbuscha* | Pink Salmon | 0 | 0 | 0 |
| | *Stenodus leucichthys* | Sheefish | 0 | 0 | 0 |
| | *C. pidschian* | Humpback Whitefish | 2 | 14 | 11 |
| | C. *laurettae* | Bering Cisco | 0 | 2 | 2 |
| Gadidae | *Eleginus gracilis* | Saffron Cod | 0 | 0 | 3 |
| Pleuronectidae | *Platichthys stellatus* | Starry Flounder | 0 | 0 | 22 |
| | *Pleuronectes glacialis* | Arctic Flounder | 0 | 0 | 6 |

Table 46. Contaminants samples taken in 2017 field season from lagoons in Cape Krusenstern by species.

| **Family** | *Latin Name* | **Common Name** | **Anigaaq Ocean** | **Tukrok River Channel** | **Kotlik** | **Krusenstern** | **Aukulak** |
|---|---|---|---|---|---|---|---|
| Cottidae | *Myoxocephalus quadricornis* | Fourhorn Sculpin | 2 | 0 | 0 | 0 | 0 |
| Clupeidae | *Clupea pallasii* | Pacific Herring | 1 | 6 | 7 | 2 | 0 |
| Salmonidae | *Coregonus sardinella* | Least Cisco | 1 | 1 | 10 | 3 | 0 |
| | *Oncorhynchus gorbuscha* | Pink Salmon | 2 | 0 | 0 | 0 | 0 |
| | *Stenodus leucichthys* | Sheefish | 0 | 5 | 0 | 3 | 0 |
| | *C. pidschian* | Humpback Whitefish | 0 | 5 | 7 | 19 | 0 |
| | C. *laurettae* | Bering Cisco | 0 | 0 | 1 | 1 | 0 |
| Gadidae | *Eleginus gracilis* | Saffron Cod | 0 | 0 | 0 | 0 | 3 |
| Pleuronectidae | *Platichthys stellatus* | Starry Flounder | 2 | 0 | 1 | 0 | 0 |

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# Appendix 1. Catalogue of Coastal Lagoons Including their Coastline Length, Latitude and Longitude

Appendix 1: Coastal lagoons located between Wales, Alaska and the Canadian border. Lagoons were characterized as coastal bodies of water that are separated from the ocean by barrier islands. Lagoons are typically parallel to shore, and are connected to the ocean, at a minimum, seasonally.

| Lagoon Name | Adjacent coastline length | Centroid latitude (DD) | Centroid longitude (DD) | Notes |
|---|---|---|---|---|
| Lopp Lagoon | 42 | 65.748483 | -167.900311 | |
| Ikpek | 28.3 | 65.970459 | -167.052476 | |
| Arctic | 29.4 | 66.125899 | -166.53867 | |
| Shishmaref | 44.7 | 66.3373 | -165.72313 | |
| Kupik | 36 | 66.480387 | -165.070989 | |
| Espenberg | 52.4 | 66.444181 | -163.661938 | |
| NoName1 | 2.11 | 66.058733 | -163.139605 | |
| NoName2 | 2.15 | 66.042369 | -162.645261 | |
| NoName3 | 3.6 | 66.042214 | -162.561935 | |
| Kiwalik | 7.66 | 66.023826 | -161.840787 | |
| Swan Lake | 4.98 | 66.884352 | -162.611331 | |
| Aukulak | 5.5 | 67.056001 | -163.243076 | |
| Krusenstern | 18.4 | 67.108306 | -163.700997 | |
| Tasaychek | 1.94 | 67.272593 | -163.770781 | |
| Kotlik | 7.88 | 67.379310 | -163.844472 | |
| Imik | 3.77 | 67.489363 | -163.951627 | |
| NoName4 | 0.66 | 67.552509 | -164.024668 | |
| Tasaitsat Angayukangnk | 2.3 | 67.565977 | -164.044756 | |
| Tasaitsat Lagoons | 1.73 | 67.583075 | -164.070738 | 2 connected lagoons |
| Ipiavik | 6.9 | 67.618856 | -164.149012 | |
| Imikruk | 9.6 | 67.667769 | -164.311815 | |
| Kivalina | 14.9 | 67.770818 | -164.643601 | |
| Asikpak | 3.79 | 67.840518 | -164.826582 | |
| Kavrorak | 1.92 | 67.86671 | -164.902347 | |
| Tugak | 1.4 | 67.895806 | -164.985171 | |
| Pusaluk | 2.1 | 67.911242 | -165.027188 | |
| Tasikpak | 4.42 | 67.939176 | -165.105690 | |
| Seppings | 1.19 | 67.957169 | -165.169963 | |
| NoName5 | 1.26 | 67.967568 | -165.189258 | |
| Singoalik | 2.97 | 67.988782 | -165.234006 | |
| Pusigrak | 2.19 | 68.012182 | -165.296525 | |
| Mapsorak | 3.27 | 68.032874 | -165.368762 | |
| Atosik | 0.95 | 68.049464 | -165.439273 | |
| Akoviknak | 4 | 68.198634 | -166.039193 | |
| Kemegrak | 3.65 | 68.226709 | -166.094108 | |
| Aiautak | 22 | 68.295192 | -166.335853 | |

| | | | | |
|---|---|---|---|---|
| Marryat Inlet | 27.5 | 68.384677 | -166.605426 | Inlet |
| NoName6 | 0.39 | 68.872420 | -166.061326 | |
| NoName7 | 3.43 | 68.863471 | -165.88084 | |
| Ayugatak | 7.29 | 68.853329 | -165.665783 | |
| Agiak | 4.12 | 68.915184 | -164.510214 | |
| NoName8 | 1 | 68.936217 | -164.203152 | |
| Punuk | 2.63 | 68.943676 | -164.158533 | |
| NoName9 | 0.45 | 68.959567 | -164.10389 | |
| NoName1 | 0.44 | 69.013299 | -163.878301 | |
| Omalik | 2.73 | 69.153922 | -163.512556 | |
| Kasegaluk | 192 | 70.072922 | -162.510958 | |
| NoName11 | 1.27 | 70.474762 | -160.452178 | |
| NoName12 | 2.46 | 70.493079 | -160.402229 | |
| NoName13 | 1.32 | 70.510563 | -160.351475 | |
| NoName14 | 0.44 | 70.517039 | -160.331407 | |
| NoName15 | 2.3 | 70.527595 | -160.300487 | |
| Wainwright Inlet | 7.68 | 70.609905 | -160.102942 | Inlet |
| NoName16 | 6.44 | 70.796702 | -159.638709 | |
| Kugrua Bay | 23.7 | 70.859339 | -159.186895 | |
| NoName17 | 0.2 | 70.830809 | -158.032372 | |
| NoName18 | 0.15 | 70.90792 | -157.649591 | |
| NoName19 | 0.37 | 71.012984 | -157.329269 | |
| NoName2 | 0.37 | 71.023969 | -157.303946 | |
| Walakpa Bay | 1.18 | 71.149696 | -157.073476 | Bay |
| NoName21 | 0.83 | 71.242443 | -156.89706 | |
| Nunavak Bay | 3.16 | 71.257147 | -156.867126 | Bay |
| Isatkoak Lagoon | 1.18 | 71.298577 | -156.774715 | |
| South Salt Lagoon | 0.98 | 71.312638 | -156.72843 | |
| Middle Salt Lagoon | 1 | 71.321977 | -156.699845 | |
| North Salt Lagoon | 1.21 | 71.338904 | -156.629586 | |
| Elson | 71.3 | 71.206394 | -155.714796 | |
| NoName22 | 3.87 | 71.050867 | -154.708879 | |
| NoName23 | 1.98 | 71.019459 | -154.623771 | |
| NoName24 | 2.66 | 70.894597 | -154.604693 | |
| NoName25 | 0.81 | 70.876470 | -153.944175 | |
| NoName26 | 1.68 | 70.883862 | -153.50672 | |
| NoName27 | 0.71 | 70.894415 | -153.381249 | |
| NoName28 | 2.1 | 70.919568 | -153.23415 | |
| NoName29 | 2.9 | 70.876765 | -152.706467 | |
| NoName3 | 0.39 | 70.880279 | -152.611343 | Embayment |
| NoName31 | 0.55 | 70.881513 | -152.590295 | |
| NoName32 | 0.43 | 70.861887 | -152.455718 | |
| NoName33 | 0.75 | 70.856469 | -152.396868 | |

| | | | | |
|---|---|---|---|---|
| NoName34 | 1.15 | 70.844408 | -152.356676 | |
| NoName35 | 1.16 | 70.834400 | -152.287882 | |
| NoName36 | 0.63 | 70.829505 | -152.255953 | |
| NoName37 | 0.0045 | 70.827394 | -152.243445 | |
| NoName38 | 2.75 | 70.80571 | -152.193914 | |
| Simpson | 59 | 70.518307 | -149.190945 | Bounded by barrier islands |
| NoName39 | 2.54 | 70.205753 | -147.571076 | |
| NoName40 | 22.2 | 70.091894 | -145.589101 | |
| NoName41 | 14.2 | 70.039956 | -144.332312 | Barrier island lagoon |
| Arey | 52.4 | 70.128326 | -143.388220 | |
| NoName42 | 39.9 | 69.867907 | -142.169887 | |
| NoName43 | 19.8 | 69.704395 | -141.451472 | Inlet |
| **Total length adjacent to coastline** | **986.0745** | | | |
| **Total coastline length** | **2690** | | | |

## Appendix 2. Metadata for Excel Archive

**Tab 1: Robards 2012 Ponar Grab Results**

Includes results from ponar grabs taken during the 2012 field season.

Field 1: Lagoons
Field 2: Site
Field 3: Depth
Field 4 Date
Field 5: Time
Field 6: Notes
Field 7: Invertebrates

**Tab 2: Fish Data 2012**

Includes data from 2012 field season fishing efforts.

Field 1: Sampling lead
Field 2: Date
Field 3: Month
Field 4: Time
Field 5: Lagoon
Field 6: Location ID
Field 7: Collection Method
Field 8: Common Name
Field 9: Scientific Name
Field 10: Total Length

**Tab 3: Abundance**

Includes relative species abundance for every gear set throughout all three field seasons.

Field 1: Location = Lagoon the gear was set in
Field 2: Day
Field 3: Month
Field 4: Year
Field 5: Latitude
Field 6: Longitude
Field 7: Set Time
Field 8: Gear Type
Field 9: Rep Date = Date on which the set (replicate) of gear type was performed
Field 10: Rep = replicate (set number)
Field 11: Rep Time
Field 12: Species
Field 13: Abundance = Number of individuals of the same species found in that replicate

**Tab 4: Length and Weight**

Includes length and weight information on individuals captured.

Field 1: Location
Field 2: Site Type = Area of lagoon sample was taken from
Field 3: Day
Field 4: Month
Field 5: Year

Field 6: Latitude
Field 7: Longitude
Field 8: Set time
Field 9: Check 1 = time of the first check of the net (note: beach seine check 1= set time)
Field 10: Check 2
Field 11: Check 3
Field 12: Check 4
Field 13: Check 5
Field 14: Gear
Field 15: Rep
Field 16: Species
Field 17: Length
Field 18: Mass
Field 19: Count
Field 20: Sex
Field 21: Sin/Code = number or code assigned for bookkeeping purposes
Field 22: Sample Type Taken (includes: whole fish, contaminants, DNA/RNA, Diet, Otolith
Field 23: Notes (I.D. Numbers in this field starting in FP indicate sample was taken for contaminants analysis)

**Tab 6: Length and Weight for 2018 Field Season**

Field 1: Date
Field 2: Lagoon
Field 3: Site
Field 4: Latitude
Field 5: Longitude
Field 6: Gear type
Field 7: Set time
Field 8: Check Number
Field 9: Check time
Field 10: Species
Field 11: Count
Field 12: Length
Field 13: Weight
Field 14: Sample Number
Field 15: Sample Type
Field 16: Notes

**Tab 7: 2012 Physiochemical Data**

Inculdes water quality parameters for 2012 field season.

Field 1: Lagoons
**Field 2: Site**
**Field 3: Depth**
**Field 4: Date**
Field 5: Time
Field 6: Time of Chlorophyll filtration

Field 7: Temperature
Field 8: Conductivity
Field 9: Salinty
Field 10: Sonde depth
Field 11: pH
Field 12: PAR
Field 13: NTU
Field 14: Chlorophyll Concentration
Field 15: Dissolved oxygen %
Field 16: Dissolved Oxygen mg/L
Field 17: TSS
Field 18: Comments

**Tab 8: Laboratory Chlorophyll Data**

Field 1: Sample ID
Field 2: Client Sample Numner
Field 3: Field ID
Field 4: Site ID
Field 5: Lagoon
Field 6: Depth
Field 7: Matrix
Field 8: Collection Date
Field 9: Chlorophyll A

**Tab 9: Total Suspenedd Solids for 2012 Field Season**

Field 1: Date
Field 2: Lagoon
Field 3: Field Site
Field 4: Initial Filter Weight
Field 5: Filtrate Volume
Field 6: Final Filter Weight
Field 7: Total Weight
Field 8: Total Suspended Solids

**Tab 10: Water Quality Data 2015**

Field 1: Date
Field 2: Year
Field 3: Latitude
Field 4: Longitude
Field 5: Time
Field 6: Total Depth
Field 7: Temperature
Field 8: Dissolved Oxygen mg/L
Field 9: pH
Field 10: SPC = Specific Conductivity
Field 11: Salinity
Field 12: ORP = Oxidation Reduction Potential
Field 13: Turbidity
Field 14: Chlorophyll RFU = Relative Fluorescent Units

Field 15: Chlorophyll µg/L
Field 16: BGA RFU = Blue green algae relative fluorescent units

**Tab 11: Water Quality Data 2016**

Field 1: Location
Field 2: Date
Field 3: Year
Field 4: Latitude
Field 5: Longitude
Field 6: Time
Field 7: Total Depth
Field 8: Temperature
Field 9: Dissolved Oxygen %
Field 10: pH
Field 12: SPC = Specific Conductivity
Field 13: Salinity
Field 13: ORP = Oxidation Reduction Potential
Field 14: Turbidity
Field 15: Chlorophyll µg/L
Field 16: BGA µg/L

**Tab 12: Water Quality Data 2017**

Field 1: Location
Field 2: Date
Field 3: Year
Field 4: Latitude
Field 5: Longitude
Field 6: Time
Field 7: Total Depth
Field 8: Temperature
Field 9: Dissolved Oxygen %
Field 10: pH
Field 12: SPC = Specific Conductivity
Field 13: Salinity
Field 13: ORP = Oxidation Reduction Potential
Field 14: Turbidity
Field 15: Chlorophyll µg/L
Field 16: BGA

**Tab 13: Water Quality Data 2018:**

Field 1: Lagoons
Field 2: Date
Field 3: Water Quality Point
Field 4: Time
Field 5: Depth
Field 6: SPC
Field 7: Salinity
Field 8: Dissolved Oxygen %
Field 9: Dissolved Oxygen mg/L

Field 10: pH
Field 11: Chlorophyll
Field 12: BGA
Field 13: Turbidity
Field 14: Grab sample name
Field 15: Notes

**Tab 14: Diets Contents 2015**

Field 1: Initials = Initials of processor
Field 2: Vial Number
Field 3: Process Date
Field 4: Predator = species of fish from which diet was taken
Field 5: Prey Taxon
Field 6: Live Stage
Field 7: Length
Field 8: Quantity
Field 9: Approximate Length
Field 10: Weights
Field 11: Comments

**Tab 15: Sheefish Diets 2015**

Field 1: Initials = Initials of processor
Field 2: Vial Number
Field 3: Process Date
Field 4: Predator = species of fish from which diet was taken
Field 5: Prey Taxon
Field 6: Live Stage
Field 7: Length
Field 8: Quantity
Field 9: Approximate Length
Field 10: Weights
Field 11: Comments

**Tab 16: Otoliths Collected 2015**

Field 1: Identification Number
Field 2: Code
Field 3: Species
Field 4: Length
Field 5: Sex
Field 6: Mounted = whether or not the sample was mounted on a slide
Field 7: Notes
Field 8: Mounted By = Initials of person who mounted the sample

**Tab 17: Otoliths Ages 2015**

Field 1: Sample
Field 2: Age

**Tab 18: Otoliths Collected 2016**

Field 1: Species
Field 2: Day

Field 3: Month
Field 4: Year
Field 5: Site = lagoon that sample was taken from
Field 6: Trip
Field 7: Number
Field 8: Weight
Field 9: Length
Field 10: Cooler = Number of cooler sample was stored in
Field 11: Temporal Comparison
Field 12: Spatial Comparison
Field 13: Size Comparison
Field 14: Otolith Extraction
Field 15: Count

**Tab 19: Mysid Data 2016**

Field 1: Location
Field 2: Transect Code
Field 3: Latitude
Field 4: Longitude
Field 5: Check Point (meters) = place in transect where sample was taken
Field 6: Set Time
Field 7: Number of Mysids
Field 8: Number of Amphipods
Field 9: Number of Ninespine Stickleback
Field 10: Number of Arctic Flounder
Field 11: Number of Choronomids
Field 12: Number of Marine Worms
Field 13: Number of TUPO
Field 14 Number of Belligerent Sculpin

**Tab 20: Sonde Data, Aukulak 2016 Field Season**

Field 1: Date
Field 2: Time
Field 3: Dissolved Oxygen (%)
Field 4: Dissolved Oxygen mg/L
Field 5: Temperature
Field 6: Specific Conductivity
Field 7: Salinity
Field 8: Turbidity
Field 9: Chlorophyll
Field 10:Blue Green Algae
Field 11: pH

**Tab 21: Pond Smelt Raw Data:**

Field 1: Bag Weight
Field 2: Sample ID
Field 3: Length
Field 4: Bag and Fish Weight
Field 5: Fish Weight

Field 6: Gear Type
Field 7: Notes

**Tab 22: Bird Species List 2017**

Field 1: Date
Field 2: Species
Field 3: Location
Field 4: Comments

**Tab 23: Zooplankton Data 2017**

Field 1: Date
Field 2: Location
Field 3: Sample number
Field 4: Location = Name designated to sample site
Field 5: Flow Start = Number reading on flow meter before sample was taken
Field 6: Flow Stop = Number reading on flow meter after sample was taken
Field 7: Notes

**Tab 24: Zooplankton Data 2018:**

Field 1: Date
Field 2: Lagoon
Field 3: Site
Field 4: Latitude
Field 5: Longitude
Field 6: Time
Field 7: Sample Name
Field 8: Flow Start
Field 9: Flow Stop

**Tab 25: Pesticides, % Lipids**

Field 1: Number
Field 2: Lab Number
Field 3: Species
Field 4: Collection Date
Field 5: Sample Number
Field 6: Latitude
Field 7: Longitude
Field 8: Location
Field 9: Collection Method
Field 10: Length
Field 11: Weight
Field 12: Sex
Field 13: Age
Field 14: Comments
Field 15: Tissue Type
Field 16: Percent Lipid
Fields 17- 48: Analysis Results

**Tab 26: PBDE's**

Field 1: Lab Number
Field 2: Species
Field 3: Total

**Tab 27: PCB's**

Field 1: Lab Number
Field 2: Species
Fields 3-220: Result totals

**Tab 28: Metals Results**

Field 1: Tissue Type
Field 2: Number Fish in Composite
Field 3: Length
Field 4: Weight
Field 5: Sex
Field 6: Age
Field 7: Site
Field 8: Area
Field 9: Arsenic
Field 10: Cadmium
Field 11: Copper
Field 12: Lead
Field 13: Mercury
Field 14: Selenium

## Appendix 3: Traditional Ecological Knowledge Interviews

Interviews:

- Bob Schaeffer interviewed by Deb Lawton
- Lee Harris interviewed by Alex Whiting
- John and Pearl Goodwin interviewed by Alex Whiting
- Cyrus Harris and Johnson Stalker interviewed by Alex Whiting
- Chuck Schaeffer interviewed by Alex Whiting

| | |
|---|---|
| *Interviewer:* | This is Deb Lawton and I'm here in Kotzebue with Bobby Schaeffer and we're going to talk about whitefish tonight for a research project on Kotzebue Sound ecology that's being done by Martin Robards, Trevor Haynes and Alex Whiting. Bobby, if you would just introduce yourself and tell us a little bit about how long you've lived in Kotzebue and maybe a little bit about your subsistence activities. |
| *Interviewee:* | I'm Bobby Schaeffer Pouya, Eskimo name. I've lived here all my life. I was born in 1949, so that was 67 and a half years ago. Of course, I went off to school for four years of my life, but for the rest of the time, I've always lived here, summer and winter, never lived any place else. When I was born in '49, the reliance on subsistence was really, really strong. It was not a money, a cash economy, it was a subsistence economy. Money didn't mean nothing to us at the time. It was how your father went out on a seasonal basis, based on the type or the certain time of the year, the gathering of our subsistence resources was critical for us to last the winter, to feed us for the winter. So for hundreds and hundreds of years, people have always figured out where the most fruitful areas are at any given specific time of the year and a long time ago before the missionaries came up and schools were established, the people moved from one settlement to the next based on the _____ availability and abundance of subsistence resources.<br><br>When I was born, that was pretty much gone. The schools were here, so that's where we were stuck. We weren't nomadic anymore. We didn't travel from site to site, we pretty much lived here but we continued our subsistence lifestyle when I was very young 'cause there was no board motors, there was no electricity, there was no vehicles in Kotzebue except for, probably, the FAA and they made one road down into our little town of probably 300 or 400 at the time. So that was our lifestyle. The summertimes, of course, were a little bit more robust, simply because people from the villages came down and fished for the salmon and we did a lot of bartering with the local folk amongst themselves. So that's pretty much how my life started and so far as subsistence was concerned. |
| *Interviewer:* | Did your parents and grandparents fish for whitefish? |
| *Interviewee:* | Oh yes. Whitefish was always a really important resource for us. I remember because when I was a kid, my introduction to fishing for whitefish was out here when my father was cutting salmon or we'd bring in a beluga and there'd be a lot of blood on the water and the white fish would always come. So they'd give us kids little, small hooks and put a little piece of meat on it and you'd throw it out and you'd catch whitefish and we'd pile 'em up and then you cut a bunch and my mother would cut them up and dry them for us so that we can put the in oil for the winter. So we played an important part when we were kids. So that was my introduction to fishing for whitefish on our frontier. So also, my dad, every fall, after the first freeze-up, him and his friends would always take a dog team ride and they'd take their picks and take their gunny sacks and then they'd go to the different lagoons nearby Kotzebue. Anigak was one of them, right past Cape |

Blossom, there's two lagoons past there. Some would go out as far as the Arctic Circle, 50 miles down there, some 40 miles down. I forgot what the distance is but they could go to all the various lagoons and they would make, they called taliaks or little small channels with picks since the top of the gravel was frozen.

So they'd dig it out and then they make a little catch area for it so that they can use their nets and catch all the fits that were coming out of all these lagoons in the fall time. So they'd all stack up with sacks of whitefish and the whitefish was very important. We've got probably four or five different species from all of the lagoons, but probably the most plentiful was the skipjack or calosak, we call it. I'm not sure if the calosak is here, but I guess that's calosak right here. It must be -- cisco, never heard of that one before. We just call 'em skipjacks but that's what we do but there's an abundance of those but the skipjack, in the fall time, would have a lot of eggs in 'em. So they're absolutely great. I also spent some time with friends in Kiana when I was young and they'd seen them in Kiana, in certain parts of the river, there'd be only skipjacks and certain parts of the rivers there'd be kosayuk. So you'd go _____ and get about 20 tubs and we'd separate the males and the females and then they'd sack all the females in one and then keep the males mostly for dog feed and then they'd put the sacks and kind of age them so that they can become tiplaka, fermented, sort of, amongst themselves and that made them really, really tasty and especially the eggs but you go further up the next bend in the river and we'd get Kosayuks and the Kosayuks in late fall are full of eggs as well.

So you'd separate them out and do the same thing. Nowadays, it's not done as much as when a lot of elders that did it all the time are now gone, so a lot of the young folks don't do this, hardly, anymore. It's just a few of us that are still kicking that are still around, that love to go out and do this. I know in the years I spent at camp after I got married back in the early 80s, I moved up to camp for a while and I spent some time on the mouth of the Kobuk fishing for whitefish. What I would target with a bigger mesh net, of course, would be the Kosayuk because like I said, they're full of eggs in the late fall and are delicious. It has a delicious texture to the meat and it's a really, a good _____. Of course, we always loved having eggs, eggs with seal oil and it was really a heck of a treat. We also like to bag those and then ferment them as well because you can't ask for a better cooked meal than fermented Kosayuk with the eggs in them. So there's always a real treat for us.

*Interviewer:* And do you still fish for whitefish? Do you still fish for whitefish?

*Interviewee:* Yeah, I still fish for whitefish all the time. I spend a lot of time at camp now that I'm retired and I put my nets out on the little creek near my home and I catch, pretty much, what do they call, humpback whitefish, I guess they call them. Most of them, in my little creek, are pretty much humpback whitefish. We get the skipjack or the cisco as well, I guess, but I don't -- you have to have a smaller mesh net, like a herring net, like the size of a herring for them and I don't normally get them. I spent a lot of time on those, especially when I moved into Kotzebue in the 80s and 90s, raising my family here, after we moved back from camp and I still go out to those lagoons and dig 'em out, even if I'm by myself and then once in a while, my daughter would come by with her kids and we'd just have a ball, getting a couple of sacks a piece and then we'd close up after we were done.

*Interviewer:* And is it humpbacks that you're getting from those --?

*Interviewee:* We get a few humpbacks. Most of them would be a skipjack or the Calosak. The ciscos, I guess you'd call 'em, Crisco, cisco.

*Interviewer:* Yeah, they're ciscos and is this across the Sound here over --

*Interviewee:* No, I do it locally. We got lagoons down here, too, but for years, my dad used to like to go down to Anigak because as a major, it always closes up and the fish, as they grow and the lagoons back, all the way through all the creeks in that area, the lakes that feed it out of the Anigak. The entire lagoon on Krusenstern lagoon is also a great place for fish to grow and then they get blocked off when the ocean covers and blocks off the mouth of the Anigak River. So a lot of fish pile up in there, absolute millions and a lot of the local people used to go over there before there were dog teams and they'd go there because it's a place that you can fill up what you were gonna be required for the winter and they'd get 15-20 sacks and then take their dog teams and go home and they'd get what they need. They wouldn't try to get too much or too little but you'd get all different species. We get all five species of whitefish in all those lagoons.

*Interviewer:* And so did you say you're mostly fishing with nets?

*Interviewee:* Oh no. We fish 'em with a taliak 'cause all the fish wanna come out but they can't because even though the river rises, it just feeds through the gravel and goes out to the ocean. So it stays closed and when it freezes, you go over there and you make a little -- what would you call that thing? You make a little stream, you dig it down until the water starts flowing from the high water in the back and like in the Anigak and on the bottom, you'd put a catch or you can put a net or a small dip net or whatever you want down under there and some people used to put their gunny sacks right there and when the fish start coming out, they'd come out by the millions, by the thousands. You'd just fill up your gunny sack and you'd just have a little scoop until _____ and you just close it when you're done and then you tie up your sack and you put another sack under there, open it up, and fish will come scooping out into your sack and you just fill 'em and you get what you need and sometimes there'd be 15-20 guys over there doing that kind of stuff and enjoying the heck out of it and drinking coffee and smoking cigarettes and enjoying. So that's what they did.

*Interviewer:* Any idea how many fish in each of those sacks?

*Interviewee:* Probably at least 200 to 300, I guess. We never counted them, we just filled them 'cause gunny sacks are a pretty good size, the old ones that we had that they sell but you could get as many as you wanted. Everybody got what they wanted over there but the local ones, I know my dad spent a little time over at the one over by Ningle Point. It's about, I'd say, 20 miles from here, following the beach and he said they went and dug it out and they started flowing but they floated out in the ice and when they float out in the ice, they're just right there. _____ small boots on and they just let 'em fill up and then when they think they had about 3,000-4,000 sitting out there and a little bit of the water came out into the ice and they just plugged it up, went out there with a shovel and scooped 'em into their gunny sacks. There was three other guys there. He said they just had the fun of their lives, you know, just chasing fish out on the ice right there and throwing 'em in sacks. So it's not done. I was probably the last person that ever went over there and did that over by Ningle Point just 'cause it's a pretty good sized lagoon.

*Interviewer:* Mm-hmm and you said you're doing that early winter?

*Interviewee:* Yeah, early, very early, yeah. When the ice gets probably four or five inches thick and you're able to go through the edge. I went there with a four wheeler the last time and I dug a small little channel but I didn't dig it all the way out, I just dug a hole right there and at the end, when they started funneling into the hole, I just scooped 'em out with my little net scooper that I have and got a sack that I wanted and left and plugged it back up.

*Interviewer:* And the other place that you were talking about where you dug the channels and the fish, where you had the dip net at the bottom of the channel, was that over around Krusenstern?

*Interviewee:* That's by Anigak, yeah. We do the same thing over there but when there's more people, like there used to be years ago, we'd put plywood or some kind of wood on our side and make it so that we have a little slot at the end that we can close it when we have to but there were little ones that when I go out to get my two sacks, I don't even bother with it, I just have a little dip net, I make a little waterfall, so when the fish go over, they're right there and I slowly fill up my sack and when I get done, I just plug it up, I got enough, it don't take that long.

*Interviewer:* And do you feel like the way that you catch your whitefish has any impact on how they taste or their desirability?

*Interviewee:* Not really. When I look at a whitefish, I look at the seasons because the most fruitful, most tasteful, I should say, whitefish are the ones that have suvak or eggs in 'em and you get eggs and whitefish at different times of the year. Late fall for the kosayuk and I think the skipjack or the cisco, is the same thing, late fall. I know the skipjacks, when you get a female right there, we used to break 'em in half and the eggs come squirting out and you just suck 'em right down. That was always a real treat when we were fishing those little animals but in lagoons, we also get the tipuk, which is kind of a prize to get. There's not as many as there are with the ciscos or the Humpback whitefish. There's a lot of them but it's a rare treat for us to get the tipuk or the Bering cisco because it's really a fat fish and it's kind of rich when you cook it and it's one of those fishes where you don't need too much of it but it's a good tasting fish but it's a very fat fish and it's very round. Sometimes when you get' em, it looks like a little butterball but they're very health fish but all the fish that we get when we're fishing down here are all the humpbacks.

We got all humpback down here, we never got no kosayuk. Kosayuks are pretty much more at the mouths of the rivers and at all the tributaries that feed into the different Noatak, the Kobuk and the Selawik get a lot of those but there's a difference. I think they're all, for some reason, the ones that are Kobuk, when you go up to the Kobuk and fish, you use probably a four inch mesh. When you go up to Noatak to fish the same species, you have to use a five-and-a-half inch mesh otherwise you'll get all small ones. So the ones in the upper Noatak are huge compared to the other rivers that we have around here. That was one of the things that I noticed, the size of them are -- sometimes you put a salmon net out and you get a bunch and they'll fit into salmon net because there's such a huge fish up there.

*Interviewer:* Do you think, from what I've heard other people say that the Noatak is a lot clearer than other rivers. Do you think that --

*Interviewee:* It is. It's not as a deeper river. I think it shallows a lot quicker than the Kobuk, 'cause I could even go up to Kiana pretty good until you get probably five or six miles above Kiana, that first area where it gets kind of shallow and then you get past the shallows and you can go all the way up, probably up past coal mine pretty easily with a tug, but if you go up to Noatak, you go up here, right past Aggie and it's real difficult now because it gets pretty shallow from then on. You get past Aggie, you could go up, probably 15 mile and then after that, it's good in summertime. Sometimes it's only a foot deep in the deepest part and then you'll walk across it. So it's a different river altogether. There’s five villages up to Kobuk and there's only Noatak up the Noatak River but for some reason, a lot of the fish that go up there are a lot bigger. I'm not sure why that is but I noticed that with the kosayuk, that when I'm fishing kosayuk on the Kobuk for most of my days, 'cause that's where my camp is, my dad's camp, which I know. We lived in that area and my dad was born up toward the mouth of the Kobuk area. They fished the kosayuk up there but we also did fishing up in the Noatak as well and let me tell you, I don't know what the difference is and why they grow so big up there but they're a pretty good size up there.

*Interviewer:* And do you think the number of whitefish have increased or decreased or maybe stayed the same since you've been fishing?

*Interviewee:* In certain areas, I think they've decreased because the beaver has come back by the millions and they're damming all the creeks so the spawning grounds of most of our whitefish species are in jeopardy, so they're having very few places to go to spawn. So I think, like, in the Selawik area, there are millions of beavers up there. There's a creek they call Singatuk. I used to go up there all the time and you could drive quite a ways up there. To just give you an example, two years ago, I went up there for the first time in years and you couldn't get more than a half mile up that creek. There's so many beaver dams. The whole creek was beaver dammed out and that's when it was a real prime spawning area for a number of species of whitefish that feed into the Selawik River and the Selawik tributaries and that river is gone. You could not cross. When you tried to break it, it was impossible 'cause the next bend, there was another one across, all the way across Quintera Creek. So the beavers have, pretty much, fenced off all the areas that were prime spawning areas for all the species of whitefish on the Selawik and it's the same thing happening in the Kobuk now. The beavers are coming into the Kobuk with strength. There's a lot of beaver up the Noatak for the first time, there was never a beaver problem ever before until now. They're expanding their bounds by leaps and bounds and it's unfortunate but that's probably the biggest threat I see to our whitefish.

*Interviewer:* In the lagoons surrounding here, have you noticed any changes in the types of whitefish that you find in them compared to 20 years ago or 10 years ago.

*Interviewee:* Not really. I think they're pretty healthy. I've gotta mention, you talked about a threat. I think the major threat is -- there are two threats. I think that one is global warming, I think is having a tremendous impact on it because the lagoons won't be there, they're gonna be part of the ocean here in a few years and some of the area's getting quite critical because the erosion is washing closer and closer to the lagoon that was there. As the waters rise and erosion intensifies, I think a lot of those areas were the young fish that come after spawning come down and spend the time in the lagoon feeding and growing, those areas will be gone and I'm not sure where they're gonna go. So they could go back into the ocean prematurely but of course, they become more accessible to predators out there and there's a lot of them.

*Interviewer:* Do you think there's been a change in the size of the whitefish you catch over the years?

*Interviewee:* No.

*Interviewer:* No?

*Interviewee:* No, I think they're pretty much the same, but I did notice that a lot of the -- when we opened the taliak or those creeks in different lagoons, we get a lot of the smaller kosayuk and some of the humpbacks are pretty much the same but we get a lot of smaller ones that are still growing. So those lagoons were very critical for the growth of these fish for the growth of these fish, but the ciscos, the least ciscos, especially the skipjacks are the ones that are always plentiful. I've never seen a change in them, they're always on time.

*Interviewer:* And do the fish seem healthy?

*Interviewee:* We run into a few that have -- you could tell by the skin, they have a little red coming out of them, I've always noticed that and there's always some that are sick 'cause whitefish have parasites and you gotta watch. I know when we're up at the Kobuk, one out of two sometimes would be full of tapeworm and those other ones you don't cut look too dry because you don't want that bug in you. So we're very careful about being selective and sometimes there's less, sometimes there's more, depending on the year. Sometimes you can't find one that's good but most of the time, one out of three, one of four will have tapeworms inside and you just have to throw them aside, you have no choice. So I'm not sure if that's been like that forever but I've noticed that in my lifetime of cutting whitefish.

*Interviewer:* And ever see any large numbers of dead fish anywhere?

*Interviewee:* Yes, they're on Kotzebue. I've never seen it any place else. I think, mostly, because of the pollution coming from the Kotzebue dump and the entire mile of the sediment lagoon that we have for all the sewage discharge, it's right past the airport there. We've got one, two, four lagoons just to support the Kotzebue and it's a _____ system. It goes into the lagoons and it's fed enzymes to eat it but enzymes work fine in the summertime, but when you get long winters that we have, they don't work very fine so the lagoons build up and they grow. So almost every year, they have to go out with big pumps in the springtime and pump out millions of gallons of sewage into the ocean. So that has impact on something, I'm sure it does and it's raw sewage. That's just the way the system works around here and I think there was massive dead fish on a Kotzebue lagoon and we expect it because of the Kotzebue dump. Everything is dumped in the Kotzebue dump and it's built on a hill and it's a baler system, where all of our garbage, every week they pick up my garbage and it goes to the baler building and they have huge compressors and they compress it and then bag it and they take it up to the hillside up there.

Where the dump is, it's a hillside that's Permafrost, so they have to _____ the gravel to cover stuff and by the time they dump it, all the birds and plenty of bears, even, go over there and start digging around 'cause everybody throws from batteries to food to body parts to you name it, goes into the dump. So there's a lot of pollution in that dump and then all of it just compressed and it goes down and it flows down into the water shed below the hill and then it flows into the Kotzebue lagoon. I walk it all the time and I look down at that creek where it comes from the dump and it's like watching Mask, the show Mask. Everything is so polluted and you look down and you see the sheen, like there's oil or something flowing, but they put oil up there too. Everything that is dumped in Kotzebue, they don't separate it and it all pretty much flows right into that stream and that was the only massive whitefish mortality I've ever witnessed is that. For some reason, I guess there was so much pollution that year during the rainy days 'cause if it rained, more pollutants go into the creek, into that June creek and into the Kotzebue lagoon than anytime else. So I saw that twice in my life.

*Interviewer:* Yeah, so I think you've talked about this a little bit but can you describe the seasonal movements of whitefish a little bit, between saltwater, freshwater and the lagoons?

*Interviewee:* Well, it's hard to because I know the whitefish we get out here, there's always whitefish and all over the beaches, they're trying to feed off mostly, you see the humpbacks always chasing the small, tiny little species of fish, millions that go through the beaches as a different species of herring and probably the ciscoes. There's also needlefish that go through there by the jillions. The cods spawn in the area, the tomcod, so everything spawns at pretty much the same time and then when they start filling up the beaches, you see these little fishes over there feeding on 'em all the time. I know that the Eskimos, the local folks have different times -- at different times they like to cut the kosayuk and the humpbacks because they're not spawning, especially during the spring, when they come out, they're not too fat so they make good, dried meat. Later on, during the fall, when they started getting pregnant or getting big and ready to lay their eggs, they get pretty fat and they get pretty healthy, so that's not a good time to cut but most of the time, in their villages up in the Noatak and the Kobuk and even the Selawik, they like 'em in the springtime because they're a lot leaner and they make a lot better dried product.

But of course, in the fall time, that's the real treat because you get the eggs with them and that is a real critical time for a lot of folks to stock up on a critical protein that is enjoyed by the Eskimo folks. As far as the ciscoes, God, there's just so many of those buggers. They prefer 'em in the fall, they don't prefer 'em any place else because they're such a tiny fish the eggs are a real delicacy, especially when they age 'em. Tipuks are always a treat, fall, spring, summer, it's good to have one once in a while. I know not too many people eat them 'cause they don't like the richness of 'em but they're a fat fish. Now, the round whitefish, that bugger, you don't see too many of them. Most of them, as we see up here, are the humpbacks and the kosayuk. The skipjacks are real popular. These, I see some but I don't know, for some reason, I can't recognize it as a real abundant fish as much as these right here because these are the ones that I prefer 'cause they're huge. They're delicious fish.

*Interviewer:* Do you have any sense of if there's a change when the lagoons open up to the chutchee in terms of ice and how that might affect the whitefish movements?

*Interviewee:* If the lagoons don't open up, then the whitefish have to stay either in the creeks or in the lagoon. They have no choice. I've seen a situation where they got cut and the egg on the creeks, like the _____ went over by Krusenstern, I just happened to be going by and I looked down and I saw an otter throwing up a fish and he looked at me and dove into the creek and disappeared. The fish was flopping there, so I stopped my snowmobile and I went down there and it was probably '85, 1985. I went over to the hole and I busted the hole and the fish couldn't go up river and they couldn't go down river and the smell was pretty strong but when I looked down, it was probably three or four foot deep and it was just like they were caught in a can of sardines. They were so close together, the river was flowing but it was too shallow for them to go up and it was flowing below and it was too shallow for them to go down and that whole bend right there was fish like sardines. I just reached down and grabbed one and threw it up and I reached down and grabbed another, threw it up and God, these are nice fish.

My father-in-law had a bunch of dogs and so I said, 'oh, I might be able to get some for his dogs.' His son came over, my brother-in-law came by and we just sat there and started throwing fish up. So I'm not sure how long -- we got two sled loads by the time we left there and there were still fish there. So they can get themselves in a pickle when the lagoons don't open in the fall, but the lagoon always opens in the spring. That's when they really come out and it's a real preference. People put nets out, I put nets out all the time but I put nets under the ice for whitefish when I was living at camp, two locations up in the mouth of the Kobuk River because I got fish there all winter and 'cause the kosayuk spawn probably November first. So you get 'em past November and they're skinny, they get skinny 'cause all the eggs are gone and they're spawned out and the lakes are all full of grass. So they spawn out. So on a different note, you look at the fish and where they spawn. Obviously, I know where these spawn. I'm not sure exactly where -- I think they go up rivers themselves, they pretty much live up there.

*Interviewer:* And that's least cisco.

*Interviewee:* Yeah, so they spawn in late fall along with the kosayuks but the celic and the blackfish spawn in the springtime, so it's opposite, they're different. The celic come up our creek and we catch 'em because when we catch 'em in the spring in May, late and early June, they're squirting eggs all over the place where you catch 'em. So they're from 30 pounders down to probably about eight or nine pounders. They're all spawning and then the blackfish also spawn up in the lakes where all the belugas are. They go up through the Kobuk Lake and then hit those lagoons or lakes that have access to the ocean and they go up there 'cause they're full of grass and they go up there and spawn huge. So different species of fish, pretty much, spawn at different times.

*Interviewer:* Do you have any sense of why the whitefish use the lagoons?

*Interviewee:* I think it's a good place to grow. They're very, very nutritious, they have a lot of nutrition in them. There's a lot of other species that spawn up those creeks and that feed into the lagoons and into the lakes that feed into the lagoons and that's where all the fish spawn. The springtime spawners go up there and millions of fry come out and these from small, they get huge, they get big in the lagoons. That's what I think.

*Interviewer:* That's the humpbacks.

*Interviewee:* Yeah and then the rivers, pretty much, they do the same thing. They all go up to the rivers and they go up to the lakes 'cause all the lakes feed into the creeks and then into the main river but they all spawn up in the grass areas. All the lakes are just full of grass, so pretty much all of them, they go up there and they spawn up in the grass up there little baby ones, the fry pretty much live in the lakes and grow in the lakes 'cause they got good protection from all the grass. The buggers right here, they feed off them and grow off them. So it's just a complete cycle. So they're pretty healthy. They used to be but I think with the beavers damming the whole world off, at least their world, I think it's gonna change and I think, then, we're gonna be in trouble.

*Interviewer:* And that's the humpback and the --

*Interviewee:* Yeah, the kosayuk and probably even the cisco but I don't know. They haven't come down into the oceanside, the beavers, they don't like saltwater much but all the city creek up here in Kotzebue, there's piles of beavers up here already. We never had beaver up in the Baldwin Peninsula before, but they're here. You go up _____ one of those creeks up there and he was up there trapping beaver back here, a friend of mine, anyway, and there's beavers back there. I've run into houses back there for God sake, I've never seen them before. Pretty good sized ones, big families up there.

*Interviewer:* Yeah, do you think whitefish are important to other animals in the region?

*Interviewee:* Yeah, when they get out of the lagoons, they become prey to the seals. The seals love 'em. When we used to get belugas here, they used to let us see what they eat and we've always found sheefish and the ones we got out here with the whitefish in 'em. The otters, of course, love them, especially up in the creeks and lagoons. They're easy to get for the waters, they're tremendous fisherman. Up here in the smaller creeks, there's a lot of the humpbacks and even the ciscos, otters just thrive on them out back here in the small creeks. So all over the mouth of Kobuk is full of waters. We go up to Selawik 'cause it's no different. The Noatak doesn't have as much of a Delta like the other rivers do but there's a lot of otter up there and they feed on everything else including trout. In fact, that's one of their favorite meals. You go to the upper Noatak and it's just amazing the number of otters that live up there.

*Interviewer:* Yeah, I didn't know that there were many otters in the region.

*Interviewee:* Yeah, lots of otters. People don't trap otters as much as they used to. It's just a hard animal to skin. It's a fat animal, just like trapping beaver. You have to like the work in order to trap a beaver because it takes so much time. They're so far and otters are the same way. They’re so much work for the skin, so that's why a lot of people don't bother with them. It's easier to trap a fox or a martin or a wolverine, a wolf, 'cause they're not far. Beavers and otters, they rely on that fat to keep 'em warm in the wintertime.

*Interviewer:* Do you have a sense of whitefish being affected by stuff like wind, rain, river levels, ice thickness --

*Interviewee:* Like I told you, I think global warming's gonna have an effect up here. We're ringside on this one. We see it every day. Our storms are becoming more fierce. We had tremendous erosion all over this entire area, especially around the villages or around the Kotzebue Sound and _____. Kivalina is a perfect example of one. Deering is another example that beaches are moving right toward the houses. In Kivalina, I don't know how much protection that little sea wall they built is going to -- and they're worried about that because the water -- we have 100 mile an hour winds up here for the last couple of years and as global warming intensifies, the storms intensify. My God, we had a hurricane up here two years that came through and beat the crap out of us but thank God it died down before it finally came up here but it was one of the lowest low pressures ever recorded that year was in the Bering Sea and we got the brunt of it. Like I said, the lagoons and the rivers, and the erosion in the rivers, this is happening all the time. If we have a wet fall, I hope we don't, it can happen like what happened a couple years, three years ago, you know, that massive erosion in the Noatak River. It was so huge and thick, _____ cruise ship up there, it was so high. So we can never tell from one year to the next how much rain we're gonna get in the fall, 'cause that's when our storms hit. So I don't know. I think just based on what I've seen and what I can predict, I think the lagoons are gonna disappear, at least some of them that are real critical to whitefish. I don't know. I can't predict what may happen with the ones up the river.

I think they're probably a little safer unless the beavers move in and start blocking off those. I've seen in Selawik and the people in Selawik are really concerned about that, too, the numbers of beavers in the winter, the creeks and the lakes that they're blocking off. I mean, it's just amazing, going up there and seeing the numbers of beavers and going up one creek that was always open all those years I used to go up to Selawik and all of a sudden, you go there and there's a dam across that thing that's impregnable. You cannot beat it to death, you have to blow it up or something to get rid of it 'cause we tried to open it up and it was just, pretty much, impossible. We thought we'd get past it and we'd be able to go up to where we normally go but there was another right around the bend and it's just like that all through the Selawik. They're damming little streams to create their own dam so that they can build houses back there. It's just amazing what they're doing up at every bend. They're going through there in the nighttime and you look at the number of beavers at every bend. Look at the number of eyes you see on the corners. Every bend. Hundreds and hundreds and hundreds of 'em. You can sit there and shoot them all day, it won't make a dent in the population, that's just the way it is and I think that's what's gonna happen in the Kobuk. It's happening now in a lot of the creeks, people tell me. So in between weather and the beavers, these animals might be in jeopardy, these little creatures.

*Interviewer:* So you've talked a bit about how you like the whitefish and I've certainly seen a lot of people drying whitefish here and you said they like to dry the whitefish when they’re thinner?

*Interviewee:* Yeah. When they get too oily, they get rancid too quick, so fall time before they spawn, they get pretty fat in the summer and people like to do it in the springtime because they're a lot thinner, they don't have eggs in 'em. A lot of people wait 'til the fall time and they make what they call -- what's the Eskimo word? I haven't thought about it for a while. They cut 'em and then they dry one side and they keep the eggs inside the carcass on the other side and when you hang 'em like that, one side dries and the other side ferments and it's really a good treat for a lot of folks in the villages.

*Interviewer:* And so it's the side with the eggs that ferments?

*Interviewee:* Yeah.

*Interviewer:* Yeah, wow.

*Interviewee:* You dry 'em like that, yeah, then you put 'em in the freezer. Sometimes, we do it the same with salmon but a lot of people do that with whitefish because that's a good time to do it, especially with the kosayuk because people in Noorvik, Kiana, all the way up to Kobuk do the same thing in the fall time to get the real treat, the fermented eggs. God, my mind -- the tip of my tongue, I forgot the Eskimo name for it. I haven't thought about it for a while.

*Interviewer:* It may come back to you and a _____ man that I knew said the best thing he learned during World War II was the Eskimo people that he met out in the Aleutians taught him to dip his whitefish in seal oil. He'd never had that.

*Interviewee:* Oh.

*Interviewer:* So he was always looking for seal oil because he said whitefish never tasted as good to him after.

*Interviewee:* We used to give some to some of our friends, I went to high school with some Indians from Galida and Galado, Calteg, those places and they come up and visit once in a while _____ that's the first thing they ask for, 'Bob, you got any seal oil?' 'Yeah, lots of it, I always have lots of seal oil.'

*Interviewer:* So do you eat whitefish sometimes with seal oil?

*Interviewee:* All the time.

*Interviewer:* Yeah.

*Interviewee:* All the time, that's a must. It's a dip for us. We take our black meat, 'cause it's all in oil, ook oil and we put it out and the oil comes and then we take our whitefish after we bake and then we just stick it inside there. Either that or we _____, eat it frozen. that's the way we prefer it, tiplaka, fermented perfect and it has that fermentation makes for a really great taste, otherwise it's bland if I eat it too fresh. So that's the way we like it. That's why we make it every year.

*Interviewer:* And do you have any idea how many meals of whitefish you and your family might eat in a year?

*Interviewee:* I don't know. Not as much as we used to, now that all my kids are grown up and done gone but I still get it. My brother gives me the -- he lives in Kiana, so he gives me some of that dried eggs that are not really dried, but they're fermented eggs along with the -- he gives me five or six of them and I'll eat five or six of them. Kosayuks, I like them, especially in the fall time when we bake 'em and I'll probably eat 10 or 15 of those things, I guess, 'cause I'm a fish man, I don't much care for meat other than caribou meat. I like fish. When you get older, you get to appreciate it more because meat's just too hard to process through an older body. My dad told me that when he got older he didn't much care for meat no more but he'd eat fish 'cause it's easier for him.

*Interviewer:* There's certainly lots of fish here. When you harvest whitefish, do you usually share the catch that you get, with people?

*Interviewee:* Yeah. When people have a product, I don't mind bartering, like when we get belugas right here, I send them to my friends up the Upper Kobuk and they get a nice box of their whitefish and all perfect and dried perfectly and I like that. They're not fat, they're not rancid, they're just perfect. So we barter and trade all the time with the different products. Henry sends me that stuff and I send him smelt from here because you don't get smelt up there in the winter time from here or I send him sheefish 'cause they don't get fresh sheefish, like I get fresh sheefish all winter. So we share what we have. I know sheefish is a good thing to share because you could share with other villages that don't get it and you can get other things, so it's a good thing to share.

*Interviewer:* I know that pretty much everyone I know in Kotzebue fishes for sheefish. You just see lots of people out there. Do you think that many other people in Kotzebue fish for the other kinds? Any of the other kinds of whitefish?

*Interviewee:* There's some that do, yeah. There's a few that -- most of the people that -- we used to go over and taliak Anigak, are gone now and there's not too many people living out there. I know the Harrisons, they're the only ones that live over there and they go there once a year now and they're pretty much loners when they go there, _____ a few other elders that go, that are local. If I had the chance, I'd go down again but I spend my falls up in my camp, _____ I put that out for my fish _____ after it freezes. I still do that.

*Interviewer:* But that's up on the Kobuk River, right?

*Interviewee:* Yeah, it's at the mouth of the Kobuk, yeah, but not on the lagoons. If I spend my fall here, I like to fish here. I don't mind, if it allowed for it, if it froze enough, I'd go down to one of those lagoons down there, close by, like one of the ones behind Cape Blossom. That was a good one because it was accessible and it was a good place to spend the day playing with fish and you get the fish that you need.

*Interviewer:* So through the course of your lifetime, how would you say that the number of people fishing for whitefish has pretty much -- how much is it diminished?

*Interviewee:* Well before, it was a really important species. I'm not sure how it's affecting people of Noorvik 'cause it was a real fish town. They had access to the mouth and whatever and they did a lot of fishing. I think they still do that. I think the younger people are learning what the old people used to do and they were always at the camps with their parents while they're putting fish away in the springtime. There's a lot of people still doing that up there. Down here, it's not as much of it because Kotzebue's become more of a cash economy rather than that. It's become the center for the government services and everything else. People work here now but I try to instill in my children the importance of our culture and what made our culture and our people strong and that's pretty much fish, you know? Of course, we would have access to the sea mammals and the caribou and moose that we get all the time but that'll probably be gone someday as the populations increase and pressure on the resource increases especially with the head hunters that come up here by the hundreds anymore. So the reliance in Kotzebue is not like it used to be. People don't -- either they're _____ get more money in the community and the poeple started working more. Their parents used to do this but they don't do it themselves 'cause they were never taught and they don't take them out. I was fortunate to raise my children out there and I never worry. They know how to cut fish, they know how to do stuff.

*Interviewer:* So the way that you taught your kids to catch and prepare fish, is that pretty much the same way that your dad or your mom taught you?

*Interviewee:* Yeah, mm-hmm, pretty much. My dad and I were like partners when he moved up here when I first got married. We did everything together and we knew where the fish were, we set nets together, we did the same thing where we wanted to make tiplaka white fish, fermented whitefish. He taught me how and I just ran with it and next thing I know, I'm teaching my children 'cause they're helping put the fish in the doggone hole so we could eat 'em, so we can age 'em. So something has to be passed down. My dad was very spiritual, so like his grandma, he believed everything has a spirit and a long time ago when we had celebrations, we celebrated the spirits of the plants, animals, whatever, that fish that gave us the privilege of taking them so we can sustain ourselves. I believe in that 'cause he taught us that.

*Interviewer:* And the fish that you're putting in the ground to ferment, is that for human consumption?

*Interviewee:* Yeah.

*Interviewer:* Yeah and so the eggs that you talked about, so the fish that you cut up half, dried and the other fish, would those go into a hole or would those be put away differently?

*Interviewee:* Oh, those were late fall fish. Sometimes people would just keep them out there until it froze and the ladies got really strong but it was a real treat because the fermentation was not rotted, it was fermented slowly, so the rot, it wasn't spoiled. Sometimes when we get wet weather, they all spoil, so those have to get thrown away 'cause they're dangerous to eat but those ones that survive are perfect, like say, we do this thing with salmon in the Upper Kobuk, they do it with sheefish, they don't cut 'em but they age 'em in the late summer when the sheefish go up there to spawn. They do the same thing with them. They ferment them and let me tell you, that's a heck of a treat. When I could trade something from down here for that fermented sheefish from the _____, boy, that's a treat for me. It's amazing.

*Interviewer:* So you've taught your kids to fish and so do you feel like there are many other families in Kotzebue who taught their kids how to --

*Interviewee:* Yeah, there's some, not as much as we were hoping. A perfect example, when we got the run of belugas, maybe 10 years ago or so, the young guys went out _____, they didn't know what to do with them. We had to go and show them what to do and that's because the parents were just too busy to take their children out to show them. I took my boys out very young when they were young to learn how to gut and take care of a caribou and that's our main source of protein and my goodness, it doesn't take too much effort and love to take your children out to show them how to do stuff. I was real proud of my brother when we got to his belugas and he had oogooks hanging and he invited the community to come over and had a lot of young folks, young married women that never did this before that couldn't wait to go learn something. So some of the elder showed them what to do, how to skin, how to cut everything and I took picture of that 'cause I was really amazed at some of the young ladies that came out here and wanted to learn and they learned. That's what we have to promote more of, I think, to get the young folks to appreciate, especially to learn what their parents _____ used to live by all the time.

They didn't have that opportunity as they were growing and they just grew up here and were stuck here and the next thing you know, they're married and what do I do? Somebody throws a hook in front of you, what do you? Somebody throws a caribou in front of you, what do you do? So it's happening. I think the realization of it is happening more. I think the tribe should get more involved. We have NATA, the nonprofit association to get more involved but they're not and the school district is so far from teaching kids the importance of being a subsistence user. It's sad. They pretty much dump their local programs mostly because of budget cuts, that's the first thing they touch and they try to maintain their emphasis on a _____. So they cut some really important Eskimo type programs that would teach children how to do all that stuff, how to, at least, recognize the importance of our culture and our traditions and those are not taught enough by the parents anymore 'cause the parents are too busy working. So I don't know. I worry about it in a way but I worry more that the new families, the new parents are not teaching their children, are not taking them out and having 'em learn how to cut fish or telling 'em stories about the importance of fish during the specific times of the year when they're the best to eat and things of that nature. I think we can do better with it and I just don't think we're doing much, enough.

*Interviewer:* I have to say, as an outsider, one of the most amazing things that I've ever seen in my life is when the smelt went through -- not this past spring, but the spring before, it felt like everyone in Kotzebue was out here and snagging smelt and there were kids that were --

*Interviewee:* I got a picture of a kid who was snagging a smelt and he was taking his catch home. It was a sheefish that was almost or bigger than him. He had it on his back on his shirt, in a jacket. He was walking by _____ over there and I think it was dragging. That was the cutest thing I ever saw. He was so proud, he was gonna take it home to his mama. That's what I'm talking about. I love it in the spring time when I see hundreds of people. All kinds of people, it don't make no difference what race, as long as they enjoy it. They're taking herring home and smelt and sheefish and they're doing the right thing with them. They're putting them away and it becomes food.

*Interviewer:* Yeah and I meant herring, I think I said smelts but yeah, they were snagging.

*Interviewee:* Yeah, we had a big run of herring smelt this year, too.

*Interviewer:* Well, is there anything else you would like to say about fish?

*Interviewee:* I think it's the education, just the knowledge of what whitefish do would be an education for me. I know where to get it, I know how to prepare it, I know when to get it, yet, I don't think -- nothing was ever written about where they are at any given time, when is the best time to get them 'cause if you take a local person that's been living here all his life, who wants to know something of where to get 'em this time of the year, I could probably tell them but that information, no one ever asks me, so I never ever give advice to folks 'cause it's not written anywhere, you know?

*Interviewer:* Yeah and when you were just saying about where, I realized that I did bring some maps. So I don't know if you see any of the lagoons here. We're looking at Baldwin Peninsula in Kotzebue.

*Interviewee:* There are some beautiful spots once you get past Kotzebue and you go over -- this is Sadie Creek, right? Is that right? Kotzebue, and you go over Sadie Creek, then you go past Sadie Creek over to, this is Riley Rec this is Blossom, there's a lagoon right in here, right before you get to Riley Rec. There's a nice lagoon in here I go to all the time and that's Blossom. Oh, this is Blossom here and that's

Sadie Creek and that's Blossom, right? Yeah, this is the lagoon right here, my favorite lagoon. I used to go there every year for years 'cause it's got a big, deep creek and there's a lot of different lakes that feed into it.

A lot of whitefish come out of here and then you got, on the other side, you got Dingle Point, this whole lagoon in Ningle Point right here, a very big lagoon right in here in Ningle Point. There's Akulak, it's really a nice spot, Akulak. This is Ningle Point right here. This is Kotzebue, _____ Pike's Peak. Okay, this is Ningle Point, this is the lagoon right here. My dad told me where to get a lot of fish and you go right past it, right down to Akulak, which is right around here somewhere. The clouds are covering it, I guess, but there's a real nice little creek that closes up every year or two. I've done that one, I've done this one, I've done this one by Cape Blossom. I never did the other ones, I never went to the Arctic Circle, 'cause there's _____ Arctic Circle _____ the same way. They're almost pretty much the same but this one here is a lot of fun because this one is kind of close to Kotzebue, you could drive right to it any time.

*Interviewer:* So this is East Kobuk Lake.

*Interviewee:* Oh yeah. That's my country. This is where we live. This is my dad's allotment right here. These two lakes, right in between, that's my little creek that comes out. I built it in 1982 and moved there with my wife when we first got married and this is fish heaven. Oh God, you just name it. Sheefish right out here, all you want all winter long. I had nets out here all winter and then I had nets at the _____ creek right here and then I always had a lot of whitefish at the time. Then of course, you got mouth of the Kobuk, this is the mouth of _____ right here that goes up and then you got _____ right here. I put nets in here and in here to get whitefish as they come out of this lake and going into the river.

*Interviewer:* And this is the North Kobuk Delta?

*Interviewee:* Oh yeah. This is the really healthy country. There's so many camps that Noorvik people have all through this area and they're all fish camps and _____ in here and _____ all that country, I used to trap in here _____ stuff, but I come here mostly for the fish because there's so much fish coming from the lagoon and going out.

*Interviewer:* And so what's this here? This little --

*Interviewee:* Oogwivik. It's the last channel on the right hand side that goes and feeds into the Melvin and goes down this way but you can go through here and you can go through Oogwivik and come out on the Yorks Bay and then straight to Kotzebue through the lake. A lot of people take that channel. Interesting. I like your photos.

*Interviewer:* My husband printed these out from Google Earth.

*Interviewee:* Oh wow.

*Interviewer:* This is Lower Krusenstern Lagoon.

*Interviewee:* Yeah. I know that country. You're showing me all my favorite spots. That's the creek that goes to the back of _____. I drove that quite a few times. A lot of little tributaries go through that. A lot of whitefish in this area. Mostly the sharp nose ones. Oh, this is Anigak. Yeah, this is Anigak River 'cause this is Tuktuk right here. _____ cabins right in here and then you go up into the lagoon back here but this is -- it's a perfect place for whitefish. It’s got a perfect, enclosed lagoon. It's shallow at one end and deep on one end and you got so many creeks and the little lakes and in the fall time, when you come out in Anigak over here, everything wants to come out and they just pile up in here, just dying _____. So that's when I said we want a Tuktuk right here, it wasn't very far up and that bend was just stuffed with whitefish 'cause the poor things had no place to go. They couldn't go up, they couldn't go down, the water dropped. So they were stuck and I'm sure most of them died. I'm sure the next bend was the same way.

*Interviewer:* So that's the place where you wound up getting fish for your father-in-law's dog team, right?

*Interviewee:* Yep, mm-hmm. Yeah, they weren't good for human consumption, because I think they were stuck there for so long but you could smell the death in the water. It was smelly 'cause a lot of them died already but we stuck 'em up there and he was so thankful that he something to put for his dog feed at the time. So it was pretty doggone cool. Yeah, that's Aukoolak.

*Interviewer:* Yeah, it is Aukoolak.

*Interviewee:* Oh yeah, Aukoolak Lagoon right there. People don't do much here as much as they used to. They used to have cabins. Not cabins, but little tents and stuff but I think the most important thing was going over to Anigak because Anigak was so rich. This whole lagoon right here is pretty shallow. There's a few creeks that feed off it but there's whitefish in it but accessibility, when you get whitefish, to get as many as you need was right here. Pretty doggone slick.

*Interviewer:* And then this is --

*Interviewee:* Nuvaruk. Looking at these things and trying to remember the names of things sometimes. Just the main things that you remember, the important stuff when you're young. You got Nuvaruk right here, of course, and that's Sistowik right here. All the cabins down here and then as quick as you go around this way, you go all the way up, all through these allotment, I got part of an allotment over here somewhere. And this is Paul Slu.

*Interviewer:* And this is the Noatak Delta.

*Interviewee:* Yeah, Noatak mouth. The Noatak, where things get big. We've been hunting muskrats in Selawik for years and Kobuk and we hunted muskrats later in the Noatak but out after the Kobuk went out and now we get muskrats, probably 200 or 300. At the time, we were always -- people really like muskrat. So we got quite a bit and then we go back to Kotzebue and then we go up to Noatak and hunt muskrat and the muskrats up the Noatak are twice as big as the ones at Kobuk and Selawik. Now go figure, everything is bigger in the Noatak for some -- it's gotta be biological, it's gotta be something. The kosayuks are bigger, the salmon, when you get the Noatak one, rather than eight and a half pounds, they're like nine and a half pounds. The average is huge. We get 26, 27, 28 pound dog salmon. Big monsters are coming, Noatak run. Everything is bigger.

*Interviewer:* It's the East Noatak, North Kobuk Lake.

*Interviewee:* The Noatak goes in there. That's Singatuk. No, that's Sivisuk. No, Sivisuk's up there. This is _____. God, I'm getting mixed up here. Places I've gone, holy cow, in my years. I can take off from here without taking Kobuk Lake, I can go up here, go around and come out at Selawik Lake, just following the small tributaries between all those rivers. I did that lots of times when I had my small boat, too rough to go across over here. I just come out here and then zip over to my camp. Pretty slick, huh?

*Interviewer:* Yeah.

*Interviewee:* You get to know the country pretty good when you're traveling all the time and doing these things for years and years. Of course, nowadays you can GPS your way through it but them days, we just knew the rivers.

*Interviewer:* Yeah, well I think that for a person from away from here, I look around and I think, 'okay, visibility here is often very, very limited. Like, how do you ever find your way anywhere?' And especially like right here because there aren't mountains or even many big hills and I think that I would get hopelessly lost.

*Interviewee:* Yeah, some people do. Let me tell you, it doesn't much. I never forgot. When I go some places, I just know where I'm going and after doing it for so many years, you just remember. Things change. The water levels have changed, there's a lot of places that were there that aren't there no more. Some islands have disappeared. Global warming is a real thing and it's really scary how it's intensified probably the last 10 years. We have six month summers for the first time. We've never had that before.

*Interviewer:* I've only experienced -- well, this summer is actually the first year I spent a full summer here and it was nice but it was not at all what I expected from having just looked at what whether you would typically expect in _____. It was warm. A lot of this summer it seemed like it was over 65 degrees and I had expected a lot more rain, a lot more like 50 degree weather.

| | |
|---|---|
| *Interviewee:* | We had a lot of that when I was growing up. By late September, one time it froze September 12, the whole Kobuk Lake and we thought that was just a fluke but it stayed. I had to pull my boat out of the water, I had to break ice, four inches of ice and the next thing you know, the ice was a foot thick. So you could never tell from one year to the next. That was back in the 80s when I was living at camp. so nowadays, you almost guarantee that it's gonna stay warm until November. |
| *Interviewer:* | Yeah, well it was Veteran's Day when the caribou were out here this fall and all of the seals were out here and -- |
| *Interviewee:* | I never saw that before in my lifetime. Poor caribou. We've lost a lot of caribou because they came in expecting winter and it wasn't here and a lot of them drowned. We had, about three years ago, about 200 drowned right by Pikes Peak and I went by them after it froze, about a foot, I drove by all those carcasses and I just shook my head. They just miscalculated and they tried to walk on that one inch of ice and all fell in at the same time, pretty much. It was pretty sad. |

*[End of Audio]*

**2016 Whitefish TEK Questionnaire - Lee Harris 55 years old**

1) **Use of the resource**

   *Questions about the contemporary harvest of whitefish including timing, location, methods, quantities, and uses.*

   1. Are you still actively fishing for whitefish, if not what time periods (years) did you fish for whitefish? Yes
   2. What times of year and where do you go fishing for whitefish? Aukulak and Anigaak before and during freezeup – October/November, sometimes springtime.
   3. What are the Inupiaq names of these places? (I can figure spelling out later, just write down the best you can)
   4. What methods do you use to harvest whitefish (gear type)? Whitefish net – 3"
   5. What species of whitefish do you harvest? Humback, round, bering cisco, least cisco
   6. How many whitefish do you usually catch during the different kinds of fishing and what affects this? (If measured in sacks, try to understand how many whitefish per sack) 100 a day – end up with sacks about 80 a sack
   7. When do whitefish taste best? Fall and spring
      When are they not as good to eat? Maybe summertime, but I think they are good year round.

2) **The state of the resource through time**

   *Questions about how have whitefish populations changed through time.*

   1. Have the number of whitefish increased, decreased or stayed the same compared with the past? Pretty much have stayed the same. Lots of whitefish
   2. What influences whitefish populations from year to year? DK
   3. Have you noticed changes in the types (species) of whitefish you find at the locations where you fish? Springtime they have parasites in the meat – a lot of them. White worm like parasites in the back.
   4. Have you noticed a change in the size of whitefish you catch? No - stay the same.
   5. Have you noticed any unhealthy whitefish or seen large numbers of dead whitefish? Parasites springtime when they come in from the ocean – when they come out of the lagoons in fall their clean.
   6. Do you have concerns about the health of whitefish? No not right now.

3) **Ecology of the resource**

   *Questions about the natural history of whitefish including, their habitat, seasonality, diet, reproduction, age, behavior, interactions with predators, changes to the hydrographic network.*

   1. Can you describe the seasonal movements of whitefish in saltwater, freshwater and lagoons? They come out of the lagoons in springtime when they open – they are born in the lagoons I believe. Go from Anigaak towards Sisualik and then go up the rivers someplace. Others stay in the lagoons during the summertime. Others come out of the lagoons in the falltime when they open up.

2. When do the lagoons open and close to the Chukchi sea and how does this affect whitefish movements? Open in the springtime. Then close again late summer until following spring, unless there is real high water in late summer or fall.
3. Where do whitefish spend the summer? Lagoons. Even in the Sisualik lagoon and up Kenworthy's creek (the creek that empties into the NW end of Sisualik Peninsula).
4. Where do whitefish spend the winter? Probably in the lagoons because they are stuck if they don't open – if they open they are probably spending time in the ocean – DK.
5. Why do whitefish use lagoons and when? Probably for spawning and their fry grow up there to avoid the ocean.
6. Where do whitefish spawn and when does this occur? Falltime - they are full of eggs and springtime they are just starting to grow eggs.
7. What type of habitat do young whitefish prefer and where do they go to grow? Lagoons.
8. How are whitefish important to other animals? Food for other animals.
9. What predators eat whitefish? Bears, seagulls, seals, whatever can get a hold of them. When there is lots we use them for dog food – good for them lots of oil/liquid.
10. How are whitefish affected by things like wind, rain, river levels, ice thickness, timing of ice-out, and other environmental conditions? If the ice gets thick and sucks up all he water in the lagoons then they can have a problem overwinter – but I think that Krusenstern Lagoon has a lot of water they can stay in. When Anigaak stays closed they get real thick in the channels, while boating late fall you can see them all around the boat.
11. Do whitefish ever get stranded on sand, beach, or ice? I seen one this summer strand itself on the beach after get chased by something (big humpback). I took it home and ate it.

**4) Cultural context of the resource and resource use through time**

*Questions about the cultural importance of fishing for whitefish including how family dynamics influence fishing activity, how subsistence traditions are being passed on, and how subsistence traditions are changing.*

1. How are whitefish preserved and what are the different ways people eat whitefish? 2 months aged and stink – in a burlap gunny sack in a sigluak or if cold enough just leave them outside – as long as the bugs are gone. Cover them with a board. They will freeze a little bit but they will stay good. Lately they have been having harder time because the weather gets too warm even during winter. I can keep mine in a little shack. Mice and weasels will mess them up if they get into them, chewing, urine and what not.
2. How many meals of whitefish do you and your family eat in a year? Once or twice a week. Quaq all winter - bake once a week.
3. When you harvest whitefish, do you share your catch with other community members? I share pretty much all of it, save enough for myself. If yes, how many people do you share with? Do you share with families other than your own? Yes. Especially the Elders they love the whitefish. A dozen or so families, I usually give them a quarter, or half a gunny sack.
4. Why are whitefish important to you and your community? They love the taste of it.

5. How widespread is whitefish harvest in your community? Mostly Sisualik people, a few people from Kotzebue will go get a load of whitefish.
6. How has the use of whitefish by your community changed through time? As they elders leave us, less people fish for them.
   If there is a decline in the number of people using whitefish, why is it declining? All the people that used to go get them and camp at Anigaak are mostly gone, they used to make bags out of grass – weave them up – long time ago.
7. How have the methods of whitefish harvest changed? Pretty much the same nets and fish traps.
8. How did you learn how to catch whitefish? Hanging around my parents.
9. Are the traditional techniques for harvesting and preparing whitefish being passed on to the young people? Yes, it was passed on to me.
10. Have you taught young people how to catch whitefish? Yes, kids always help me when they are around.
11. Do young people fish for whitefish? Not that I know of (by themselves).
12. As young people in your community get older, do you expect they will use whitefish as you do? If they find out how good they taste.
13. What could promote the tradition of subsistence harvest of whitefish in your community for future generations? Teach the young kids to keep it going.
14. What prevents more people in your community from harvesting whitefish? The logistics of getting to Anigaak in the fall and spring during freezeup and breakup.

**WCS Arctic Beringia**
A Wildlife Conservation Society Program

**2016 Whitefish TEK Questionnaire John Goodwin 73 and Pearl Goodwin 67**

1) **Use of the resource**
   *Questions about the contemporary harvest of whitefish including timing, location, methods, quantities, and uses.*

   1. Are you still actively fishing for whitefish, if not what time periods (years) did you fish for whitefish? Yes.
   2. What times of year and where do you go fishing for whitefish?(*show regional map)? September (see google map)
   3. What are the Inupiaq names of these places? (I can figure spelling out later, just write down the best you can)
   4. What methods do you use to harvest whitefish (gear type)? Net 4" for smaller whitefish and 5 5/8" for Qausiluk.
   5. What species of whitefish do you harvest? Coal mine/kobuk river have all the species. We fish for Quasiluk and use two different size nets to catch smaller ones and larger ones. All but round whitefish
   6. How many whitefish do you usually catch during the different kinds of fishing and what affects this? (If measured in sacks, try to understand how many whitefish per sack) About 40 or so.
   7. When do whitefish taste best? They are good all year. When are they not as good to eat?

2) **The state of the resource through time**
   *Questions about how have whitefish populations changed through time.*
   1. Have the number of whitefish increased, decreased or stayed the same compared with the past? No changes noticed, pretty much the same.
   2. What influences whitefish populations from year to year? The populations seems to stay the same the only difference is whether Anigaak opens in the fall or stays closed for fish that go to Singaruk, its likely they go up the creek and spawn and then turn around and come back out. The other places we fish are on their own lake systems where the fish grow eggs and get fat for the summer.
   3. Have you noticed changes in the types (species) of whitefish you find at the locations where you fish? Always the same.
   4. Have you noticed a change in the size of whitefish you catch? Seem the same.
   5. Have you noticed any unhealthy whitefish or seen large numbers of dead whitefish? No.
   6. Do you have concerns about the health of whitefish? No.

3) **Ecology of the resource**
   *Questions about the natural history of whitefish including, their habitat, seasonality, diet, reproduction, age, behavior, interactions with predators, changes to the hydrographic network.*

   1. Can you describe the seasonal movements of whitefish in saltwater, freshwater and lagoons? When the fish come out from the lakes in the falltime they spend the winter in Kobuk lake and Selawik Lake. The Humpack is different than the others one, they come

out of the lakes and down the Kobuk River in the springtime – they spend the winter in the lakes and then spend the summer in Kobuk and Selawik lakes – every slough that has lakes people camp on the Noorvik area/Kobuk delta. And then in late fall travel back to the lakes to spend the winter. Some of the qausiluks can come out in early fall right after the salmon stop running like early September, some people like to get them early – but if they get them too early then too hot to make quaq.

2. When do the lagoons open and close to the Chukchi sea and how does this affect whitefish movements? They open in the spring if there is high water and close when you have high waves. The whitefish likely spend the winters in Kobuk lake and Selawik Lake and travel to the summer feeding lakes and lagoons and then spawn in the fall time in Kobuk and Selawik lakes. If they get stuck in their summering areas because of closed off lagoons they will spawn in the lagoons because they have no choice.
3. Where do whitefish spend the summer? See above
4. Where do whitefish spend the winter? See above
5. Why do whitefish use lagoons and when? They use the lagoons in the summertime to feed, get fat and grow their eggs.
6. Where do whitefish spawn and when does this occur? Spawning happens in the late fall around freezeup – October in Kobuk lake - at least for the Qausiluk that are always running down the Kobuk River/delta in the fall. The least cisco, at least some of them go to Singaruk and run up the river to spawn and then come back down before freezeup to overwinter in the Kobuk and Selawik Lakes.
7. What type of habitat do young whitefish prefer and where do they go to grow? Not sure, but likely all over the area in the lakes, lagoons, sloughs, rivers.
8. How are whitefish important to other animals? Their food.
9. What predators eat whitefish? All predators that eat fish – we notice whitefish in sheefish stomachs all year.
10. How are whitefish affected by things like wind, rain, river levels, ice thickness, timing of ice-out, and other environmental conditions? The most likely being thick ice influencing how they pick their overwinter spots, also its likely they are all over in different area for winter so they have sufficient oxygen and not bunched all together.
11. Do whitefish ever get stranded on sand, beach, or ice? Never seen it.

**4) Cultural context of the resource and resource use through time**

*Questions about the cultural importance of fishing for whitefish including how family dynamics influence fishing activity, how subsistence traditions are being passed on, and how subsistence traditions are changing.*

1. How are whitefish preserved and what are the different ways people eat whitefish? Paniktaq spring and fall, in the fall they dry broad and humpback whitefish with eggs dried whole skeins on one side with meat on the other (amachaiq). In the spring time they make igamaqluk (half dried) with humpback then boiled and eaten with seal oil. In the fall time they make quaq, especially with qausiluq and eat it frozen with seal oil.
2. How many meals of whitefish do you and your family eat in a year? Twice a month or so – we would have more if it was more available – it would be a regular diet but hard to catch (the timeframe is such a small part of the year).

3. When you harvest whitefish, do you share your catch with other community members? Yes, definitely – that's why we never have enough for ourselves. If yes, how many people do you share with? About half a dozen all elders. Do you share with families other than your own? Yes.
4. Why are whitefish important to you and your community? It's a delicacy and hard to get because they only are available for catching for a small window and far away places from Kotzebue.
5. How widespread is whitefish harvest in your community? Just a few – see above.
6. How has the use of whitefish by your community changed through time? If there is a decline in the number of people using whitefish, why is it declining? Way less people now use and fish for whitefish – when we were growing up pretty much everybody fished and used one of our main diets.
7. How have the methods of whitefish harvest changed? Same.
8. How did you learn how to catch whitefish? Parents and grandparents – followed them fishing.
9. Are the traditional techniques for harvesting and preparing whitefish being passed on to the young people? Not really.
10. Have you taught young people how to catch whitefish? Yes, our granddaughters.
11. Do young people fish for whitefish? When they follow older fishers.
12. As young people in your community get older, do you expect they will use whitefish as you do? No probably not.
13. What could promote the tradition of subsistence harvest of whitefish in your community for future generations? Run out of hamburgers – showing the younger how to catch and eat whitefish.
14. What prevents more people in your community from harvesting whitefish? The long distances from the community and short catch window.

**2016 Whitefish TEK Questionnaire - Cyrus Harris (59 years old) and Johnson Stalker 80 years old interviewed together at Sisualik on August 21, 2016**

1) **Use of the resource**
   *Questions about the contemporary harvest of whitefish including timing, location, methods, quantities, and uses.*

   1. Are you still actively fishing for whitefish, if not what time periods (years) did you fish for whitefish? Yes
   2. What times of year and where do you go fishing for whitefish? Aukulak and Anigaak before and during freezeup – October/November. Springtime end of and right after breakup (May/June) off the south side of Sisualik Peninsula. Cyrus – some net fishing in the Sisualik lagoon during summer for dog food – mix of species, including salmon and sheefish – not specifically targeting whitefish for human food.
   3. What are the Inupiaq names of these places? (I can figure spelling out later, just write down the best you can)
   4. What methods do you use to harvest whitefish (gear type)? Whitefish net – 3" off Sisualik and in the Anigaak Channels/Tukrok River during the fall when Anigaak is closed and under the ice at the juncture of Tukrok River and Sitakuyak River, and fish trap when lagoons are closed in the falltime. The fish trap It depends on weather and timing – the good trap fishing needs the right kind of ocean water at the right level (below the level of the Anigaak slough) – so the current will run down through the sand at the pot – when the tide goes out the only opening is the trench leading to the pot. North wind is what draws them down the Krusenstern waterways to the mouth of Anigaak. During periods of lots of north wind and clear skies lots of whitefish can accumulate at the mouth if Anigaak is closed. When digging the trap it seems alomost crazy because you start digging from such a distance away – it takes a couple of days of work for 3-4 people. You dig a trench and a pot the pot will be on the ocean side and is where the fish fill up in. the trench will connect to the existing waterway at Anigaak and a board will be used at the mouth of the trench where it connects to the waterway it will be laid so water still flows rapidly over it and is used to block the retreat of the fish back to the Anigaak waterway. The board also can be used to close off the trench from the waterway once enough fish are in the pot. Then the water can drain down in the pot. The trap is closed when done for the day, unless an early morning check is planned. Pot is covered with tarp to keep birds and foxes out.
   5. What species of whitefish do you harvest? Humback, broad, bering cisco, least cisco in the Anigaak and Aukulak fall fishery and mostly humpback in the spring Sisualik/ocean fishery.
   6. How many whitefish do you usually catch during the different kinds of fishing and what affects this? (If measured in sacks, try to understand how many whitefish per sack) During the spring run Cyrus catches 50-100 or so a day for about a week in ocean net. Johnson catches 40 or so a day for about a week in ocean net. During the fall net fishery 100 a day at Anigaak and about 50 a day at Aukulak. At Anigaak fall trap fishery on a good day can fill 15 sacks – about 80 per sack. **Need to follow up on how many sacks total for average fall fisheries.**

7. When do whitefish taste best? Fall and spring
   When are they not as good to eat? They are always good, but better in spring and fall.

**2) The state of the resource through time**

*Questions about how have whitefish populations changed through time.*

1. Have the number of whitefish increased, decreased or stayed the same compared with the past? Same amount it seems like – just more sheefish – large abundance as long as the environmental conditions cooperate for fishing methods.
2. What influences whitefish populations from year to year? DK
3. Have you noticed changes in the types (species) of whitefish you find at the locations where you fish? No.
4. Have you noticed a change in the size of whitefish you catch? No - stay the same.
5. Have you noticed any unhealthy whitefish or seen large numbers of dead whitefish? No.
6. Do you have concerns about the health of whitefish? No.

**3) Ecology of the resource**

*Questions about the natural history of whitefish including, their habitat, seasonality, diet, reproduction, age, behavior, interactions with predators, changes to the hydrographic network.*

1. Can you describe the seasonal movements of whitefish in saltwater, freshwater and lagoons? In the spring it is unclear to us where they are going to or coming from – except know that they will go into the lagoons and then come back out of the lagoons in the falltime – then the likely go into the main rivers for the winter.
2. When do the lagoons open and close to the Chukchi sea and how does this affect whitefish movements? Spring from highwater/melt the lagoons will open, close in the summer during SW storms and high ocean water events. If the lagoons stay open for extended periods in the summer/fall all the whitefish will move out, sometimes the lagoons stay open all winter. If the lagoons stay closed for a couple of years ina row there will be dead water, with hardly any fish in them.
3. Where do whitefish spend the summer? Lagoons.
4. Where do whitefish spend the winter? In the rivers if they escape from the lagoons in the fall.
5. Why do whitefish use lagoons and when? Summer use for feeding.
6. Where do whitefish spawn and when does this occur? Early fall/September they are full of eggs later in October hardly any eggs left in the lagoon fish remaining. So sometimes they must spawn in the lagoons when they have no choice, otherwise likely the main rivers in the region.
7. What type of habitat do young whitefish prefer and where do they go to grow? Lagoons.
8. How are whitefish important to other animals? Food.
9. What predators eat whitefish? Foxes for sure at Anigaak especially if trap fishing when they will access the pots to eat whitefish – seagulls and bears, bears will also access traps and pick nets set at Anigaak.

10. How are whitefish affected by things like wind, rain, river levels, ice thickness, timing of ice-out, and other environmental conditions? Whitefish can get stranded up the Tukrok river during the winter inside deep eddies.
11. Do whitefish ever get stranded on sand, beach, or ice? NC

**4) Cultural context of the resource and resource use through time**

*Questions about the cultural importance of fishing for whitefish including how family dynamics influence fishing activity, how subsistence traditions are being passed on, and how subsistence traditions are changing.*

1. How are whitefish preserved and what are the different ways people eat whitefish? Baked fresh and aged in the fall time in gunny sacks. About 80 per sack which are laid on willows/ground in the fall when temperatures are cooler 30-40 degrees or so, turn them over everyday until they finally freeze all the way then keep frozen and eat as Quaq. If too early or too hot it will not work and they can spoil – changing climate in recent years has pushed the date back - too hot now at the same time of year. Can also crack open while catching them and eat the eggs from the belly. Springtime igamaaqłuk (half dried) and then boiled and eaten with seal oil. Dried fish split open and dried all the way to be eaten with seal oil.
2. How many meals of whitefish do you and your family eat in a year? Once a week or so will eat quaq (frozen whitefish peeled and chopped with seal oil). Will bake occasionally when fresh and a few meals of half dried during the year.
3. When you harvest whitefish, do you share your catch with other community members? Share all the time about 60% or so of the entire catch during the year.
4. If yes, how many people do you share with? A few dozen because of the providing to long term care center, community thanksgiving dinner and community Christmas dinner – at least sacks a piece for each event/place. Do you share with families other than your own? Yes, see above.
5. Why are whitefish important to you and your community? Whitefish are important as a main source of food.
6. How widespread is whitefish harvest in your community? Almost whoever is at Sisualik and occasionally a few boats from Kotzebue will travel to Anigaak to harvest a few sacks.
7. How has the use of whitefish by your community changed through time? In the dog team days lots more people, they would catch for both people and dogs, also a lot more people camping down the coast in the past so they were there during the best time.
   If there is a decline in the number of people using whitefish, why is it declining? See above.
8. How have the methods of whitefish harvest changed? Same methods now as in the past.
9. How did you learn how to catch whitefish? Learned by participating when younger.
10. Are the traditional techniques for harvesting and preparing whitefish being passed on to the young people? Some young people participate – family members follow – mostly Sisualikmiut.
11. Have you taught young people how to catch whitefish? Yes, when kids are around and follow.

12. Do young people fish for whitefish? Just help us.
13. As young people in your community get older, do you expect they will use whitefish as you do? Not clear – depends on if they stay at camp probably.
14. What could promote the tradition of subsistence harvest of whitefish in your community for future generations? Teach the young people when fishing.
15. What prevents more people in your community from harvesting whitefish? Less people camping now.

WCS Arctic Beringia
A Wildlife Conservation Society Program

**Chuck Schaeffer**

**2016 Whitefish TEK Questionnaire**

1) **Use of the resource**
*Questions about the contemporary harvest of whitefish including timing, location, methods, quantities, and uses.*

1. Are you still actively fishing for whitefish, if not what time periods (years) did you fish for whitefish? Yes, September & October or October November under the ice Iqalusaaq @ Putinikruaq
2. What times of year and where do you go fishing for whitefish?(*show regional map)?
3. What are the Inupiaq names of these places? Anigaak, Ivik, Putinikruaq
4. What methods do you use to harvest whitefish (gear type)? Qausiluk 4" gillnet, dig ditches, and 2" gillnet @ Anigaak for Iqalusaaq
5. What species of whitefish do you harvest? See above
6. How many whitefish do you usually catch during the different kinds of fishing and what affects this? Qausiluk 6 sacks (50 per sack), Iqalusaaq 12 sacks (100 per sack) one time I harvested a 100 or so sacks @ Anigaak (If measured in sacks, try to understand how many whitefish per sack)
7. When do whitefish taste best? Fall and winter. When are they not as good to eat? Summer they get mushy.

2) **The state of the resource through time**
*Questions about how have whitefish populations changed through time.*
1. Have the number of whitefish increased, decreased or stayed the same compared with the past? Stayed about the same.
2. What influences whitefish populations from year to year? No idea
3. Have you noticed changes in the types (species) of whitefish you find at the locations where you fish? No
4. Have you noticed a change in the size of whitefish you catch? No
5. Have you noticed any unhealthy whitefish or seen large numbers of dead whitefish? No
6. Do you have concerns about the health of whitefish? No

3) **Ecology of the resource**
*Questions about the natural history of whitefish including, their habitat, seasonality, diet, reproduction, age, behavior, interactions with predators, changes to the hydrographic network.*

1. Can you describe the seasonal movements of whitefish in saltwater, freshwater and lagoons? Iqalusaaq & Qausiluk spend the summer in lagoons they leave in the fall during north wind. Iqalusaaq run heaviest around midnight at Anigaak.

2. When do the lagoons open and close to the Chukchi sea and how does this affect whitefish movements? Depends on weather throughout the summer, it they open early in the summer whitefish leave before they can be harvested in the late fall.
3. Where do whitefish spend the summer? Lagoons.
4. Where do whitefish spend the winter? Wonder where they are, not sure.
5. Why do whitefish use lagoons and when? Summertime for feeding & developing eggs.
6. Where do whitefish spawn and when does this occur? October - spawn up the Kobuk River.
7. What type of habitat do young whitefish prefer and where do they go to grow? Shallow water where they can stay warm and escape predation.
8. How are whitefish important to other animals? Good food.
9. What predators eat whitefish? Birds, pike, sheefish, people, mink, otters.
10. How are whitefish affected by things like wind, rain, river levels, ice thickness, timing of ice-out, and other environmental conditions? The lagoons opening up early lets them out and the only way to fish them then is with nets.
11. Do whitefish ever get stranded on sand, beach, or ice? Yes, especially in the Noatak Delta sloughs after freezeup with high water they get frozen in through the cracks when water forces them up in the cracks, sometimes widespread and thousands die.

**4) Cultural context of the resource and resource use through time**

*Questions about the cultural importance of fishing for whitefish including how family dynamics influence fishing activity, how subsistence traditions are being passed on, and how subsistence traditions are changing.*

1. How are whitefish preserved and what are the different ways people eat whitefish? Dried, frozen, baked and fried – tip(l)aaq "stink" whitefish are kept in the sack outside during the fall covered with plywood or willows and then eaten throughout the winter as quaq – the freezing and thawing cycle lets them ferment some. To make really good quaq you try to get them a little early in the time around freezeup to allow for a little bit more "warmer" temps to ferment them a little more.
2. How many meals of whitefish do you and your family eat in a year? Once or twice a month.
3. When you harvest whitefish, do you share your catch with other community members? Yes. I always share quaq with a half dozen or so people (friends and family) .If yes, how many people do you share with? Do you share with families other than your own?
4. Why are whitefish important to you and your community? Food source and it has its own particular taste different than other kinds of fishes and food.
5. How widespread is whitefish harvest in your community? Very small number of people mostly campers.
6. How has the use of whitefish by your community changed through time? Definitely a lot less people that depend on whitefish. If there is a decline in the number of people using whitefish, why is it declining? Less dog teams, easier access to western foods, and less campers.
7. How have the methods of whitefish harvest changed? The methods are the same.

8. How did you learn how to catch whitefish? Learning where the areas were to set net from parent and other fishers – relatively few sites to set in any case.
9. Are the traditional techniques for harvesting and preparing whitefish being passed on to the young people? Absolutely not.
10. Have you taught young people how to catch whitefish? My boys have followed me.
11. Do young people fish for whitefish? Probably not.
12. As young people in your community get older, do you expect they will use whitefish as you do? No
13. What could promote the tradition of subsistence harvest of whitefish in your community for future generations? Get somebody like me to teach them
14. What prevents more people in your community from harvesting whitefish? Modernization makes it no longer necessary.

## Appendix 4: Contaminants Results for 2015 and 2016 Field Seasons

Table 1: Mean (SD) of select organic contaminants from DEC fillet samples of sheefish, humpback whitefish and starry flounder. Reported in ng/g wet weight.

| | Sheefish | Humpback Whitefish | Starry Flounder |
|---|---|---|---|
| n | 23 | 2 | 1 |
| Percent Lipid | 2.15 (1.34) | 3.85 | |
| Dieldrin | 0.172 (0.016) | ND | |
| HeptachlorEpoxide | 0.039 (0.013) | ND | |
| Hexachlorobenzene | 1.24 (0.125) | 0.58 | |
| Mirex | 0.099 (0.023) | ND | |
| PBDE47 | 0.010 (0.026) | 0.065 | |
| PCB153 | 0.741 (0.268) | 0.185 | 0.359 |
| SumChlordanes | 0.556 (0.114) | 0.13 | |
| SumDDT | 1.65 (0.497) | 0.53 | |
| SumNonachlor | 1.35 (0.375) | 0.444 | |
| TotalPBDE | 0.319 (0.113) | 0.143 | |
| TotalPCB | 6.51 (2.02) | 1.68 | 3.14 |
| Toxaphene | 7.71 (0.642) | NA | |

Table 1: Mean values (mg/Kg wet weight) of heavy metals for samples from NW Alaska lagoons by species and site.

| Species | Site | n | Mean Length (cm) | Mean Weight (Kg) | Mean Age | As | Cd | Cu | Pb | Hg | Se |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CISCO-BERING | KRUSENSTERN LAGOON | 5 | 32.00 | 0.6024 | 5.2 | 0.593 | ND | 0.457 | ND | 0.065 | 0.366 |
| CISCO-LEAST | AKULAK LAGOON | 2 | 29.50 | 0.242 | 8.0 | 0.692 | ND | 0.448 | ND | 0.037 | 0.722 |
| CISCO-LEAST | KRUSENSTERN LAGOON | 3 | 31.43 | 0.176 | 8.7 | 0.532 | ND | 0.564 | ND | 0.062 | 0.604 |
| COD-SAFFRON | AKULAK LAGOON | 5 | 22.38 | | 2.4 | 4.055 | 0.018 | 1.452 | 0.024 | 0.021 | 0.679 |
| COD-SAFFRON | KOTLIK LAGOON | 5 | 26.68 | | 3.0 | 2.986 | 0.011 | 0.973 | ND | 0.027 | 0.700 |
| FLOUNDER-STARRY* | AKULAK LAGOON | 1(5) | 19.68 | | 7.0 | 0.495 | 0.011 | 0.809 | 0.014 | 0.017 | 0.616 |
| FLOUNDER-STARRY* | KOTLIK LAGOON | 1(4) | 22.35 | | 7.3 | 0.637 | ND | 0.572 | ND | 0.016 | 0.720 |
| FLOUNDER-STARRY* | KRUSENSTERN LAGOON | 1(5) | 21.52 | | 5.4 | 0.269 | ND | 0.720 | 0.010 | 0.052 | 0.549 |
| PACIFIC HERRING | KRUSENSTERN LAGOON | 1(5) | | | | 0.213 | <0.05 | 1.89 | 0.0272 | 0.0573 | 0.608 |
| SCULPIN-FOURHORN* | KOTLIK LAGOON | 1(5) | 6.06 | | | 0.542 | ND | 1.850 | 0.023 | 0.014 | 0.625 |
| SCULPIN-FOURHORN | KRUSENSTERN LAGOON | 2 | 19.05 | | 2.0 | 0.130 | ND | 1.194 | 0.011 | 0.070 | 0.378 |
| SHEEFISH | KRUSENSTERN LAGOON | 3 | 63.83 | | 12.0 | 0.455 | ND | 0.389 | ND | 0.163 | 0.470 |
| STICKLEBACK-NINESPINE* | KRUSENSTERN LAGOON | 1(5) | 5.04 | | | 0.189 | ND | 1.530 | 0.031 | 0.055 | 0.549 |
| WHITEFISH-HUMPBACK | AKULAK LAGOON | 4 | 30.93 | 0.286 | 7.0 | 0.731 | ND | 0.376 | ND | 0.029 | 0.887 |
| WHITEFISH-HUMPBACK | KRUSENSTERN LAGOON | 6 | 30.48 | 0.414 | 6.2 | 0.174 | ND | 0.367 | ND | 0.030 | 0.373 |

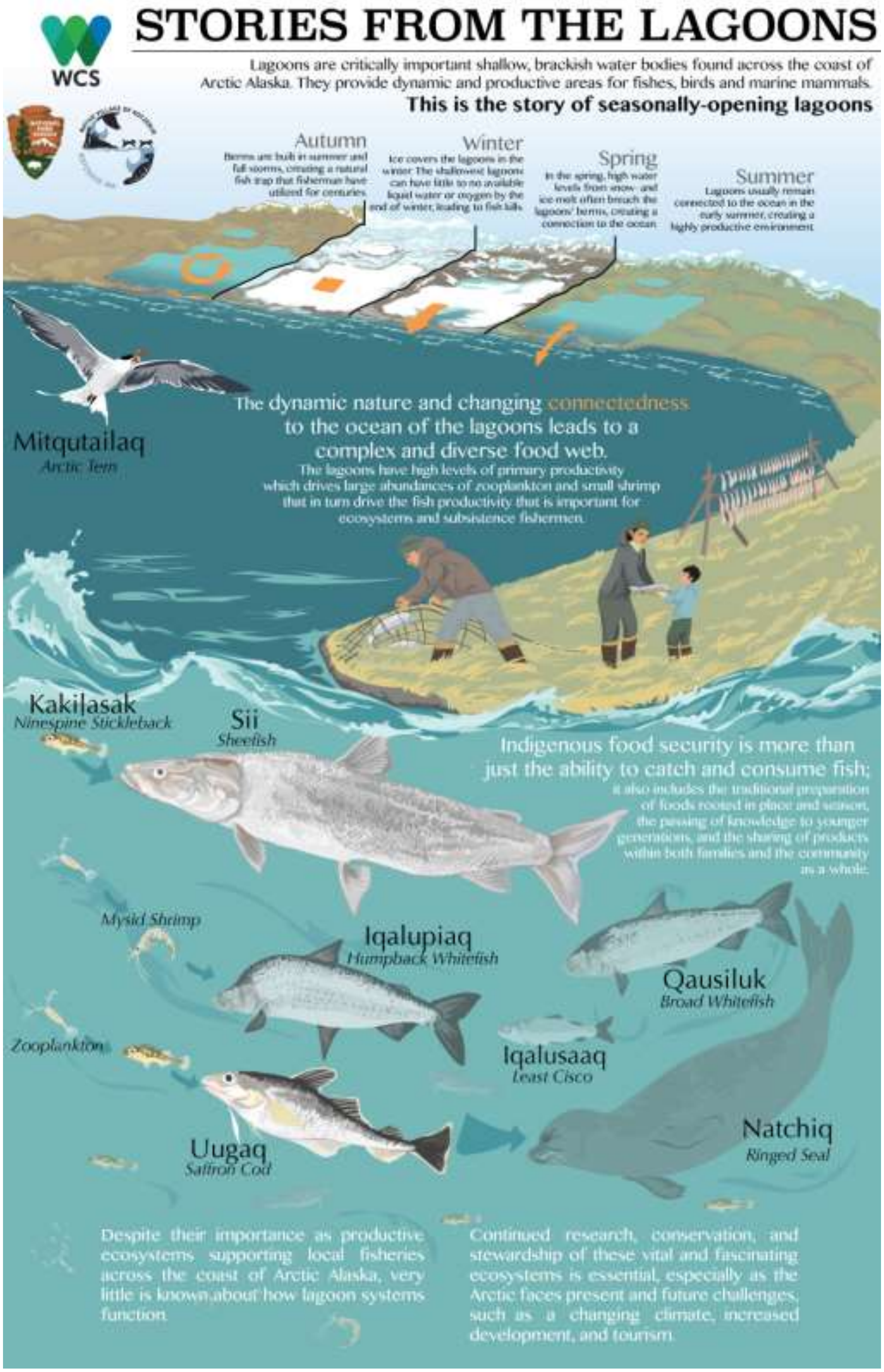
*Whole body composite sample

Table 2: Mean ± SD (sample size) for samples tested by the DEC fish tissue monitoring program provided for reference. Samples submitted by the client are not included. Results reported in mg/Kg wet weight.

| Department of Environmental Health Fish Tissue Monitoring Program | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Location** | **Mercury** | **Arsenic** | **Cadmium** | **Copper** | **Lead** | **Selenium** |
| **All DEC Least Cisco** | Various | 0.048±0.02 (27) | 0.768±0.41 (27) | NA | 0.287±0.10 (7) | ND (27) | 0.339±0.10 (27) |
| **All DEC Saffron Cod** | Various | 0.021±0.01 (12) | 5.77±1.6 (12) | 0.020±007 (12) | 0.842±0.26 (12) | ND (12) | 0.842±0.22 (12) |
| **All DEC Starry Flounder** | Various | 0.070 (2) | 2.25 (2) | ND (2) | 0.29 (2) | ND (2) | 0.305 (2) |
| ***All DEC Pacific Herring** | Various | 0.022±0.01 (14) | 2.14±0.81 (14) | 0.027±0.01 (14) | 0.884±0.14 (14) | ND (14) | 0.60±0.28 (14) |
| **All DEC Fourhorn Sculpin** | Kaktovik | 0.041±0.02 (4) | 1.3±0.42 (4) | ND (4) | 0.865±0.17 (4) | ND (4) | 0.91±0.07 (4) |
| **All DEC Sheefish** | Various | 0.131±0.05 (46) | 9.52±6.05 (46) | ND (46) | 0.396±0.20 (38) | ND (46) | 0.397±0.13 (46) |
| ***All DEC 9-spine stickleback** | Various | 0.046 (2) | 0.42 (2) | ND (2) | 1.43 (2) | 0.17 (2) | 0.41 (2) |
| **All DEC Humpback Whitefish** | Various | 0.067±0.3 (99) | 0.169±0.23 (99) | ND (99) | 0.326±0.20 (58) | ND (99) | 0.332±0.27 (99) |

*Composite samples (2-11 whole fish)

## Appendix 5: Stories from the Lagoons Outreach Project



## Appendix 6: Outputs

*Scientific Outputs*

Published

Haynes, T.B., M. Tibbles, K. Rodriguez, B. Haggerty Perrault, and M.D. Robards. 2017. Successful breeding of Caspian terns *Hydroprogne caspia* in the Arctic – Part of the new normal? *Marine Ornithology* 45: 143-148.

Mahoney, A.R. and M. Robards. 2017. Understanding Arctic Sea Ice in a Period of Rapid Climatic Change. National Park Service, Alaska Park Science Series, Volume 16, Issue 1: Science in Alaska's Arctic Parks.

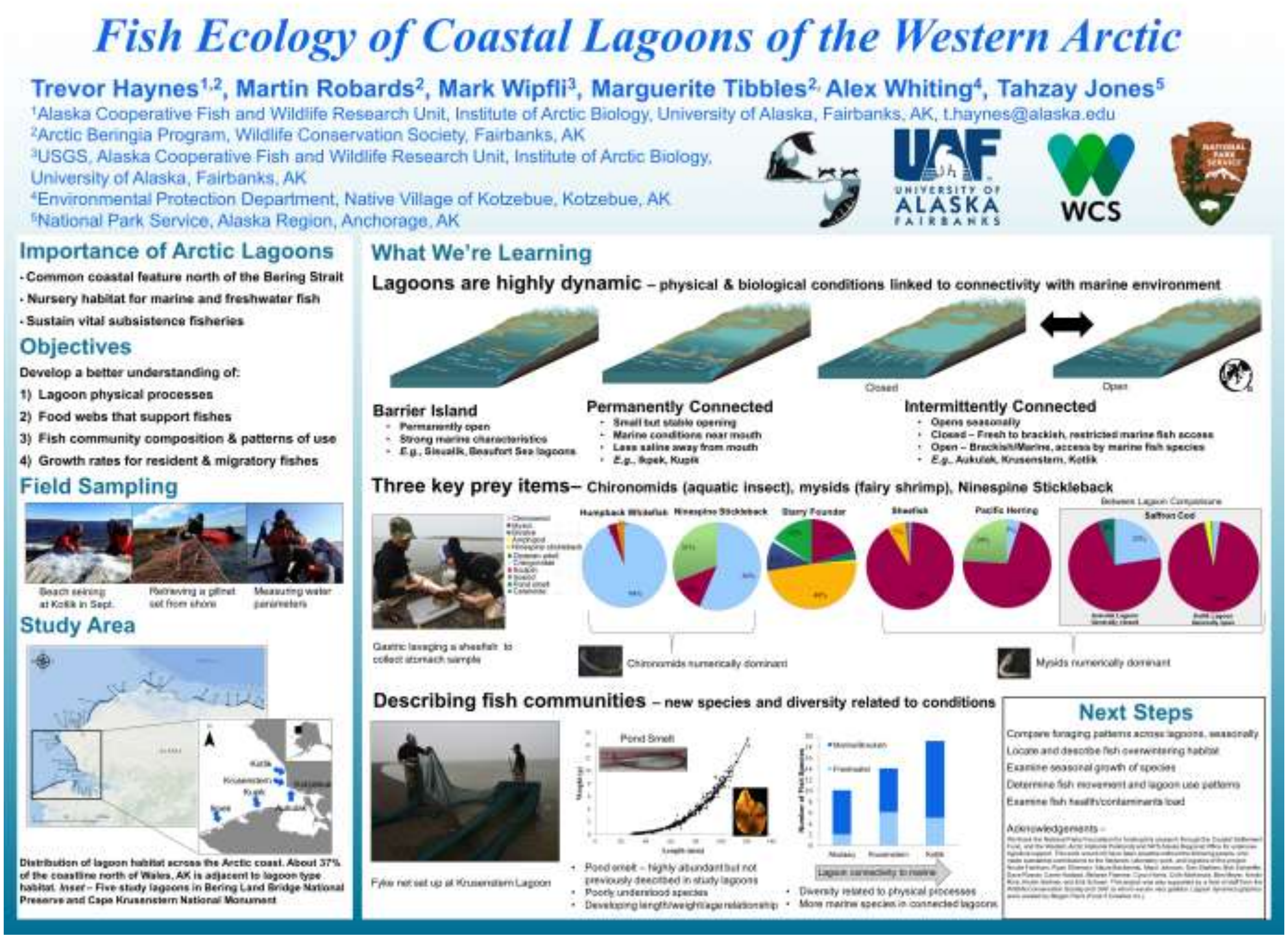
Tibbles, M., and M.D. Robards. 2018. Critical trophic links in southern Chukchi Sea lagoons. *Food Webs* 15. E00099.

Presentations

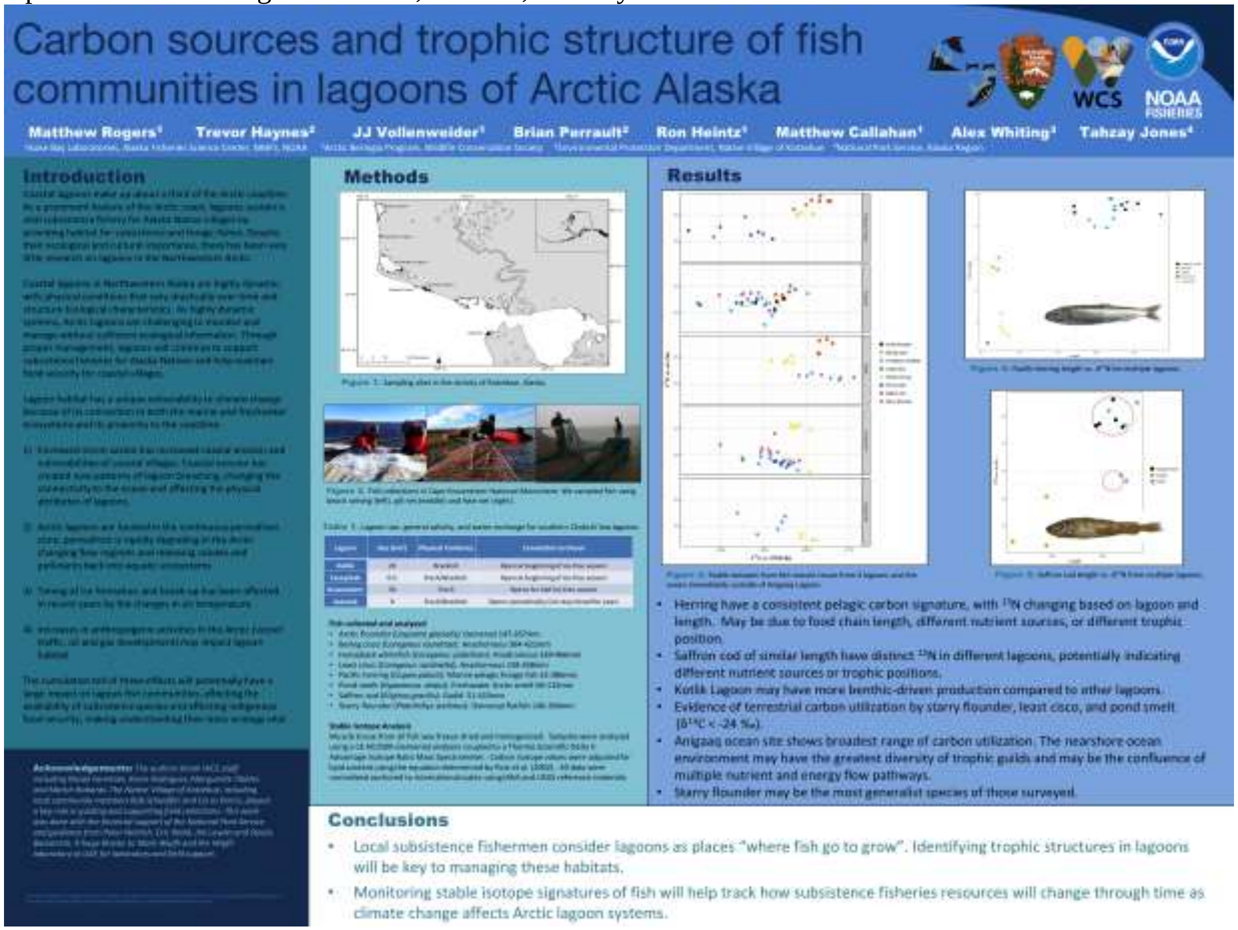
Haynes, T.B., M. Robards, M. Tibbles, T. Jones, and A. Whiting. 2017. Understanding the Physical and Ecological Dynamics of Arctic Coastal Lagoons [Presentation]. Lowell Wakefield Symposium. (DATE)

Posters

Haynes, T., M. Robards, M. Wipfli, M. Tibbles, A. Whiting and T. Jones. 2016. Fish Ecology of Coastal Lagoons of the Western Arctic [Poster]. Alaska Cooperative Fish and Wildlife Research Unit.



Rogers, M., T. Haynes, J.J. Vollenweider, B. Perrault, R. Heintz, M. Callahan, A. Whiting, and T. Jones. 2017. Carbon Sources and Trophic Structure of Fish Communities in Lagoons of Arctic Alaska [Poster]. The Ecosystem Studies of Subarctic and Arctic Seas Open Science Meeting. June 11-15, Tromso, Norway.



Pinchuk, A.E., M. Robards and B. Smith. 2018. Zooplankton Production in Arctic Coastal Lagoons: Preliminary Results of Biological Monitoring in the Cape Krusenstern National Monument. [Poster]

Tibbles, M., A. Seitz, T. Haynes, T. Jones and A. Whiting. 2017. Identifying overwintering habitat suitability for whitefishes using remote sensing [Poster]. International Coregonid Symposium. September 10, Bayfield, WI, USA.

*Media Outputs*

Park Service Video Summarizing Lagoons Field Effort: https://www.youtube.com/watch?v=Fb5yo2vxvNw&feature=youtu.be&t=6m47s)

Dynamic Lagoons of Arctic Alaska: Getting a Baseline Blog post:
https://arcticberingia.wordpress.com/2017/08/17/dynamic-lagoons-of-arctic-alaska-getting-a-baseline/

Algal Soup Blog post:
https://arcticberingia.wordpress.com/2017/01/07/algal-soup/

Caspian Terns Nesting in the Arctic Blog post:
https://arcticberingia.wordpress.com/2016/11/08/caspian-terns-nesting-in-the-arctic/

Fishing in Kivalina: Putting Research in Context Blog post:
https://arcticberingia.wordpress.com/2016/10/21/fishing-in-kivalina-putting-research-in-context/

Artist in Residency at Fish Camp Blog post:
https://arcticberingia.wordpress.com/2016/09/23/artist-in-residency-at-fish-camp/

Arctic Feeding Frenzy Blog post:
https://arcticberingia.wordpress.com/2016/07/16/arctic-feeding-frenzy/

Winter Lagoon Explorations Blog post:
https://arcticberingia.wordpress.com/2016/05/27/winter-lagoon-explorations/

Where Fish Come to Grow Blog post:
https://arcticberingia.wordpress.com/2015/11/12/where-fish-come-to-grow/

Whitefish Ecology in Coastal Lagoons Blog post:
https://arcticberingia.wordpress.com/2015/07/17/whitefish-ecology-in-coastal-lagoons/

WCS Arctic Beringia
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# Arctic Network

National Park Service
U.S. Department of the Interior

Alaska Region
Inventory & Monitoring Program

Bering Land Bridge N Pres. • Cape Krusenstern NM
Gates of the Arctic NP & Pres. • Kobuk Valley NP • Noatak N Pres.

January 2017

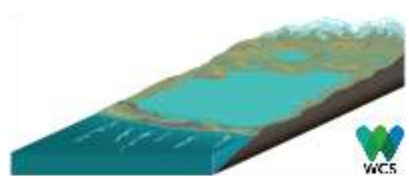
## Coastal Lagoon Resource Brief

### The Importance of Coastal Lagoons in the Arctic Network


Map: Coastal lagoons are being monitored in 2 Arctic Network parks: Bering Land Bridge N Pres. and Cape Krusenstern NM.

Images: (top) NPS monitoring efforts, (near right) juvenile ninespine stickleback, (far right) conceptual diagram of a lagoon when connection to the marine environment is closed (courtesy of the Wildlife Conservation Society).

Arctic lagoons make up about a third of the Arctic coastline. These dynamic coastal lagoons are a critically important ecosystem in the region because they support avian, fish, and invertebrate populations, and are used by both terrestrial and marine mammals. They also support seasonal traditional subsistence activities for Alaska Natives and serve as navigational pathways throughout the year by local village residents. Coastal lagoons are shallow, semi-enclosed, brackish waterbodies that have conditions between fresh and marine waters. There are eight major lagoons described within the boundary of Cape Krusenstern National Monument – Aukulak, Imik, Ipiavik, Kotlik, Krusenstern, Port, Taseycheck, and Sisualik. Five major lagoons are within the boundary of Bering Land Bridge National Preserve – Lopp, Kupik, Shishmaref, Ikpek and Arctic and sediment transport is beginning to form a sixth in the shallow, protected waters behind Cape Espenberg. Lagoons in both parks are vulnerable to climate change through increased coastal erosion and decreased ice cover. Lagoon breaching by marine waters is a part of the naturally functioning system, but these dynamics are changing due to beach erosion and changes in lagoon ice cover. This, in turn, alters fish community patterns and the availability of fish resources to subsistence fishers. Coastal lagoons also face threats from increased human activities in the region, such as oil and gas development, development of deep-water ports, and international shipping. Despite their ecological and cultural importance, there has been very little research on coastal lagoons in the western Arctic. The Arctic Network Inventory and Monitoring Program is developing long-term monitoring protocols for these lagoons with Wildlife Conservation Society and the Native Village of Kotzebue, along with input from local indigenous knowledge holders.



**What We Want To Know About This Vital Sign**

- Lagoon water chemistry and connectivity with the marine environment
- Fish community composition and patterns of use
- Fish growth rates for resident and migratory species
- Aquatic food web and trophic dynamics
- Contaminants levels in fish
- Extent of overwintering fish habitat
- The importance of fish species for subsistence fishers in specific lagoons and at specific times

**How We Monitor This Vital Sign**

- These lagoons are highly dynamic systems where water quality changes drastically as connections to the marine environment open and close. We monitor water quality parameters (temperature, dissolved oxygen, salinity, specific conductivity, turbidity, pH, chlorophyll, and blue green algae) through the season (3-5 times total per lagoon per season when logistically feasible).
- Lagoons in both parks range in size, connectivity and saltwater influence, allowing us to sample fish distributions, abundance, and community composition through the season and across selected environmental gradients. We sample fish using beach seines, fyke nets, and gill nets. Initial efforts show that key prey species include mysid shrimp, midge (fly) larvae, and ninespine stickleback.
- Documenting fish growth rates allows us to monitor long-term changes in fish condition, and ultimately changes to the lagoon conditions that affect fish growth. Examining fish diets establishes key trophic linkages among species in order to develop a broader understanding of Arctic lagoon food webs. We measure fish length and collect otolith (structures in the inner ear of fish) samples to examine fish growth rates for resident and migratory species.
- Levels of contaminants in the Arctic may increase. Although analysis of fish in these lagoons suggests they are healthy and low in contaminants, we collaborate with the state of Alaska to analyze contaminants (metals and persistent organic pollutants) in key fish species in order to establish a baseline for Arctic lagoons.

Dolly Varden, an important subsistence species for Kivalina. Courtesy of J.L. Bryant.

- We use Synthetic Aperture Radar (SAR) remote sensing techniques to locate available liquid water that may serve as overwintering habitat for whitefishes in watersheds of coastal Arctic lagoons.
- Subsistence fishers have a traditional understanding of the ecosystem that can provide crucial ecological and cultural insights. We work with local communities to combine our scientific findings with traditional knowledge to gain a more complete picture of whitefish subsistence use and whitefish ecology.

**How Monitoring This Vital Sign Can Help Park Managers**

- Provide baseline conditions of the lagoons to better detect long-term changes
- Characterize seasonal and inter-annual variability of physical and biotic components of lagoons
- Determine relative productivity of lagoons to better prepare for and quantify impacts of industrial marine accidents
- Provide information about the ecological role of lagoons to improve resource protection

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# Arctic Network Newsletter

## Alaska Region Inventory & Monitoring Program

National Park Service

### In this issue



*"Wetlands are considered the kidneys of the landscape– they clean the water. Wetlands are important rearing grounds for young of all kinds, whether it's birds or fish or insects."*
*- Amy Larsen on shallow lakes and wetland areas*

*"Other studies have shown that winter flow or baseflow has increased, presumably in response to permafrost thaw and increasing groundwater circulation. These hydrologic changes can have profound effects on the water quality of streams and rivers."*
*- Jon O'Donnell on rivers and streams*

*"When considering the potential impacts from oil spills, our baseline data allows us to build up an idea of which areas need priority protection. Where would we really want to try to keep oil away from and at what times of the year is that most important for fish, birds, marine mammals, and people?" - Martin Robards, on monitoring coastal lagoons*



**Arctic Network Inventory and Monitoring Program (ARCN)**

Our mission is to collect scientifically sound information through natural resource monitoring to contribute to park management and facilitate park preservation for future generations. We work in Bering Land Bridge National Preserve (BELA), Cape Krusenstern National Monument (CAKR), Gates of the Arctic National Park and Preserve (GAAR), Kobuk Valley National Park (KOVA), and Noatak National Preserve (NOAT).

**Our Network is Alaska's 5 northern National Parks**


**Arctic Network Staff (area code 907)**

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### Science for the stewardship of Arctic Parklands

To learn more about ARCN and our recent activities visit http://science.nature.nps.gov/im/units/arcn/. Check out our monitoring videos on the AlaskaNPS channel http://www.youtube.com/user/AlaskaNPS.



## Shallow Lakes

We are working to understand lake ecosystem dynamics and lake change over time across ARCN. Not all lakes will be impacted by climate warming, but many will, and our monitoring efforts will help us understand the various ways in which lakes will change and affect the lives of the people and animals who depend on them.

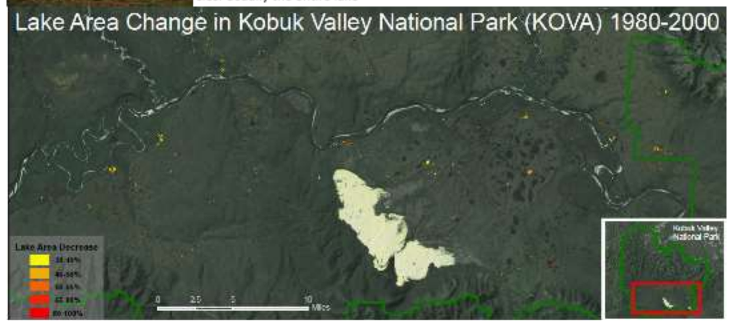
*This lake is expanding as near shore permafrost melts.*

**The mechanisms** by which lakes and ponds change over time are surprisingly complex. Each year, water level is affected by snow pack, the rate of spring melt, precipitation and ground water inputs, as well as numerous physical factors such as soil composition, permafrost, ice content, and watershed slope and size. Over the last five years, we observed permafrost melting around many lakes and ponds network-wide. Ice melting near the shoreline can affect lakes in several ways: 1) the lake may expand in size or merge with a nearby lake (pictured above), 2) large quantities of trees and sediment may slump into the lake, and 3) ice wedges near the shoreline can melt and allow more water to run out of the lake causing it to drain.

**Lake drying** is a serious concern in the Arctic because the climate is cold and dry. When lakes drain (pictured left) the environment becomes drier and habitat is unavailable for wetland animals like waterfowl, muskrats, mink, beaver and many other species. Usually the entire lake doesn't disappear, but it can become considerably smaller. In KOVA, 240 lakes have drained (see figure below) by more than 30% over the past 30 years, and the total lake surface area in the park has decreased by about 14%.

**Melting permafrost** is partially responsible for these changes. Ice melting near the lake outlet allows more water than normal to flow out, and the lake level drops. Depending on the thickness and size of the ice wedge that melts, changes can range from small to catastrophic. Over 15 lakes in KOVA have drained catastrophically— virtually overnight. These drained lake bottoms are very obvious and look like a lunar landscape. Melting permafrost can also affect a lake when large ice wedges melt and cause sediment and trees to slump into the lake. The amount of ice in the frozen ground along the lake shore determines how much a lake may be impacted— the larger the ice wedge, the larger the potential impact to the lake. Thaw slumps can grow over several years and become very large, adding considerable amounts of soil and vegetation to the water column. This material increases the nutrient supply to the lake, often increasing animal production. Thaw slumps have occurred on many lakes in BELA, where there are large areas of Yedoma.

*Contact Amy Larsen for more information about shallow lakes amy_larsen@nps.gov.*



## Yedoma: a treasure trove of fossil remains

In the summer of 2012, we sampled lakes and ponds located in BELA. Looking at a USGS topographic map would lead one to view the park is a wasteland of lakes on a relatively flat plain. Upon further examination, one finds that the park is a complex mosaic of inactive volcanoes, lava flows, ancient sand dunes, low rolling hills of silt and a vast coastal plain. Amid these varied lakes live a vibrant waterfowl population, large herds of caribou, grizzly bears and muskox. Trees and shrubs are sparse in the region, and it is easy to imagine large mammals ambling across this open landscape. From the air, we often see animals or melting permafrost—perhaps a big exposed ice wedge—but last summer we stumbled across the ancient remains of several large mammoths! Our crews have sampled hundreds of lakes throughout Alaska, and rarely do we discover something so unique and massive. We found these bones exposed on the lake floor shortly after the lakes had drained.

The bones, from a distance, stuck out of the water just enough for an arctic tern to take a short rest. Our biggest find was a humerus and radius, together with some rib bones, vertebrae and several teeth. These objects were dated at 12,500 years old. This was the third youngest mammoth ever to be found in Alaska. This particular lake was in a large region of Yedoma, a special type of frozen ground where large ice lenses are hidden within a thick silt deposit. This experience has forever changed the way we look at the land. These discoveries have unleashed the treasure hunter in all of us; from the airplane, we excitedly scan the shorelines of lakes and ponds hoping to discover a bit of tusk, teeth or bone sticking out of the mud.

*Contact Amy Larsen for more information about shallow lakes amy_larsen@nps.gov*

**Yedoma** is a special type of permafrost that was formed in the Pleistocene, some 12,000 years ago. This type of permafrost is very rich in ice, large ice wedges can often be seen usually in silt, and there are large amounts of ancient plant material and often animal parts preserved in it. This past summer we found several lakes that had drained that contained mammoth and other fossilized bones.

**How we do it: Documenting lake change**

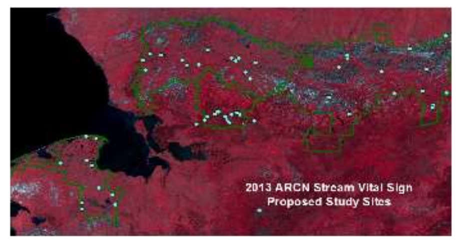
We use satellite photographs to measure changes in the size of lakes over time, and we visit a small portion of the lakes to record lake depth, the shape of the lake bottom, and basic soil features such as particle size and type (e.g., sand, silt, or gravel). We also sample the water to measure nutrients available for plants and animals. So far, the network has sampled 100 lakes in KOVA and 114 lakes in BELA. This summer we are planning to sample 100 lakes in NOAT.

## Stream and River Ecosystems

Recent climate change at high-latitudes is altering the hydrology, thermal characteristics, chemical composition, and ecology of streams and rivers. For instance, mean annual discharge in large arctic rivers has increased in recent decades in response to warming air temperatures. Other studies have shown that winter flow or baseflow has increased, presumably in response to permafrost thaw and increasing groundwater circulation. These hydrologic changes can have profound effects on the water quality of streams and rivers.

Still, very little is known about how stream ecosystems will respond to projected climate change in ARCN parks. Large uncertainties exist regarding the magnitude and nature of climate-driven impacts across space and time. To better understand stream and river dynamics in ARCN parks, we are developing protocols to detect changes in water quality over space and time. This summer, we will conduct a synoptic survey to provide a "snapshot" of current conditions. Streamwater samples will be analyzed for dissolved organic carbon (DOC) chemical composition (see sidebar) and a suite of other parameters. These tools will be used to "fingerprint" streams based on source-water type and watershed characteristics. Data from this pilot season will be used to guide and refine future protocol development and site selection for long-term inventory and monitoring efforts.

For more information contact Jon O'Donnell, jaodonnell@nps.gov.




**Seven of NPS Wild and Scenic Rivers flow through ARCN parks: Noatak, Alatna, John, Kobuk, Salmon, and Tinayguk. The Noatak is an International Biopreserve.**

### Assessing Water Quality

**Measures and Techniques**

**DOC** – organic matter in aquatic system that can pass through a 0.45-micron filter. DOC functions as a source of nutrients, regulator of pH, and mediator of microbial reactions.

**UV-visible absorbance** – provides information on DOC chemical structure and molecular weight.

**Fluorescence** – provides information on DOC origin (terrestrial vs. aquatic) and presence of different compounds (e.g. proteins, organic acids).

**Chemical fractionation** – a technique used to separate DOC into function groups (e.g. water-loving vs. water-fearing compounds).

### Learning from other watersheds in Alaska

Studies from interior and southeastern Alaska—where climatic conditions are substantially warmer than in ARCN—may serve as a proxy for what future conditions may hold. For example, in the Yukon River basin, the concentration of DOC has declined with recent warming and thawing of permafrost. Also, the molecular composition of DOC has shifted, reflecting changing permafrost extent and watershed hydrology. In southeast Alaska, shrinking glacial coverage in watersheds is driving higher concentrations of DOC and nitrogen in rivers, but lower phosphorous concentrations. These chemical shifts will likely modify growth rates of aquatic algae and mosses, which ultimately affect other organisms in the aquatic food-web, like fish and birds.

WCS Arctic Beringia
A Wildlife Conservation Society Program



**Coastal lagoons** are critically important ecosystems for wildlife and subsistence practices in northwestern Alaska, and are vulnerable to both climatic change and industrial development. In order to understand the status of Park resources in a rapidly changing environment and to mitigate threats of climate change and industrial development, we collaborate with the Wildlife Conservation Society (WCS) to gather baseline information and monitor lagoons in BELA and CAKR. Currently, our focal lagoons are Ikpek and Cowpack in BELA, and Aqulaaq, Krusenstern, and Kotlik in CAKR.

Our efforts will benefit not only NPS land managers but land management agencies elsewhere in Alaska. For example, we have already established that some lagoons (e.g., Krusenstern) are much more productive and of greater importance for subsistence fish.

We are also working with local residents to ensure that the information we collect is presented in a manner that is useful to them. This includes plans to portray "the story of the lagoons" in collaboration with the Native Village of Kotzebue.

We use high-tech digital equipment to monitor water quality, lab analyses to assess phytoplankton, and a range of nets to catch fish. Birds are monitored opportunistically as we travel around lagoons in a 4-person inflatable boat to our different sites. All of this equipment and the provisions for camping for a few days at each lagoon are carried in a Cessna 185. The logistics of visiting multiple coastal lagoons, the distances that must be traveled, and the challenges of collecting quality information in a diverse set of lagoons that change throughout the seasons make monitoring these water bodies very difficult. For more information contact Martin Robards, mrobards@wcs.org

The information we gather continues to inform us about the baseline conditions in lagoons, the most recent sampling being in July of 2012.

**Alaska Plaice** (*Pleuronectes quadrituberculatus*)

**Pacific Herring** (*Clupea pallasii*) and Humpback Whitefish (*Coregonus pidschian*)

**Northern Sand Shrimp** (*Pandalus borealis*)

Tools of the trade

We use a **ponar grab** to sample invertebrates from the lagoon floor.

We use **beach seine** and **gill nets** to sample the fish community.

This **water quality monitoring meter** measures water salinity, temperature, and turbidity.

**Birds** are also indicators of lagoon productivity because they feed in these areas to fuel up before and after migrating. Last summer, we observed thousands of Dunlin (*Calidris alpina*, pictured here) preparing for their southward journey at Cowpak lagoon.

This summer, NPS biologists and University of Alaska Anchorage will begin investigating shorebird use of BELA and CAKR lagoons during fall migration. Each summer, breeding shorebirds are monitored at Krusenstern lagoon by the Arctic Shorebird Demographic Network– a community of scientists working together to monitor shorebird populations across the North American Arctic from Nome to Churchill, Canada. Krusenstern lagoon is a sister site to neighboring Chukotka in the Russian Federation where the NPS Shared Heritage Beringia Program is active.

ARCN

# Arctic Network 2013 Summer Field Activities

### Streams and Large Lakes

Jon O'Donnell will be in BELA June 20 - 23 and NOAT June 24 - 30 to characterize stream and lake habitats and to collect water samples for chemical analysis. Later in KOVA, August 18 - 25, he will sample streams along the Kobuk river between Ambler and Kiana. *jaodonnell@nps.gov/907-455-0631*

### Shallow Lakes

In NOAT, from July 5 - 19, Amy Larsen, Heidi Kristenson and crew will collect information on water quality, shoreline vegetation and permafrost characteristics for 100 lakes in the Preserve.
*amy_larsen@nps.gov/ 907-455-0622*

### Serpentine Hot Springs

Linda Hasselbach and crew will study hydrology and monitor water quality at Serpentine Hot Springs in BELA, June 27 - 30.
*linda_hasselbach@nps.gov/509-996-8031*

### Climate Station Maintenance

Pam Sousanes and Ken Hill will maintain climate stations across ARCN. They will visit stations in GAAR, May 27 - 31; CAKR and NOAT, June 25 - 29; KOVA/NOAT, July 15 - 19; and BELA, August 5 - 9. The stations provide real-time and archived information on temperature and precipitation gradients, climate variability and extreme events.

*pam_sousanes@nps.gov/*
*907-455-0677*

### Exclosures

From July 21 - 23, Peter Neitlich will revisit 12 grazing exclosures installed in 2012 in BELA to monitor impacts of grazing on lichen communities.
*peter_neitlich@nps.gov/*
*509-996-3917*

**Vegetation Nodes** Dave Swanson and crew will sample vegetation plots from July 3 - August 13 in: BELA near Cowpack Lagoon and Devil Mountain Lake; NOAT near Radio Hill and Lower Noatak Lowlands; and in CAKR.

*dave_swanson@nps.gov/*
907-455-0665

### Fire

Jennifer Barnes will be in NOAT, June 24-30, monitoring fire plots, mapping fires, and reducing vegetation at the Kelly Ranger Station.
*jennifer_barnes@nps.gov/*
*907-455-0652*

### Brown Bears

From June 1 - 10 Brad Shults, in cooperation with ADF&G, will conduct aerial surveys across BELA for brown bears in order to estimate their abundance and occupancy.

*brad_shults@nps.gov,*
*907-455-0674*

### Dall's Sheep

Marci Johnson and Kumi Rattenbury will conduct aerial surveys for Dall's sheep in the western Baird Mountains in NOAT, June 29 - July 3 and in the Itkillik preserve area in GAAR, July 8 - 13.

The surveys provide data to estimate abundance, and sex and age composition. *kumi_rattenbury@nps.gov*
*907-455-0673*

### Yellow-billed loons

Melanie Flamme and Stacia Backensto will sample forage fish and yellow-billed loon eggs for contaminants in BELA, June 13 - 16—during which time two high school students (Max Dan from Anchorage and Sam Tocktoo from Shishmaref) will video document the field effort and loon nesting ecology. Aerial surveys with USFWS for nest occupancy will be conducted, June 18 - 28 in BELA and CAKR.
*melanie_flamme@nps.gov, 907-455-0627*

### Shorebirds

Jeremy Mizel and crew will assess shorebird abundance at Ikpek Lagoon in BELA from July 24 - August 30 to better understand lagoon use during fall migration. To complement this effort, Audrey Taylor (UAA) will conduct aerial surveys for shorebirds along BELA and CAKR coasts, July 27– August 4. *jeremy_mizel@nps.gov/907-455-0638 and artaylor@uaa.alaska.edu/907-786-6854*

# COMMUNICATIONS and MEDIA

## *Reports and Publications*

**Soil and Carbon Storage**: Hugelius G, Tarnocai C, Kuhry P, Harden J, Ping C-L, Schuur EAG, Schirrmeister L, **O'Donnell JA**, Mishra U, Palmtag J, Grosse G, Camill P, Michaelson G, Strauss J, Eberling B, Jorgenson T, Johnson K, Yu Z, Bockheim JG. 2013 (in press). Spatially distributed estimates of soil organic carbon storage between 1 to 3 m depth in the northern circumpolar permafrost region (an extension of the Northern Circumpolar Soil Carbon Database). Submitted to *Earth System Science Data.*

**Caribou**: 1) Joly, Kyle. 2012. Sea ice crossing by migrating Caribou, *Rangifer tarandus*, in northwestern Alaska. Canadian Field-Naturalist 126(3): 217–220.
2) Joly, K. 2012. Caribou Vital Sign Annual Report for the Arctic Network Inventory and Monitoring Program.

**Dall's Sheep**: Schmidt and Rattenbury. In press. Reducing effort while improving inference: Estimating Dall's sheep abundance and composition in smalls areas. Journal of Wildlife Management.

**Vegetation**: Swanson, D. 2012. Vegetation sampling in the Arctic Inventory and Monitoring Network, 2009-2012. http://science.nature.nps.gov/im/units/arcn/index.cfm?rq=12&vsid=24

**Landscape Change**: Swanson, D. 2012. Three decades of landscape change in Alaska's Arctic National Parks: Analysis of aerial photographs, c. 1980-2010. http://science.nature.nps.gov/im/units/arcn/index.cfm?rq=12&vsid=28

**Weather**: Wilson, Ryan R., Annett Bartsch, **Kyle Joly**, Joel H. Reynolds, Anne Orlando, and Wendy M. Loya. 2013. Frequency, timing, extent, and size of winter thaw-refreeze events in Alaska 2001–2008 detected by remotely sensed microwave backscatter data. Polar Biology 36: 419–426.

## *Outreach and Education*

**Fly ARCN parks with the new Interactive Web-Feature**: Satellite images and aerial photographs are combined with topography to simulate a 3D view from above! Fly to points of interest by selecting them from a menu that also provides a written narrative, and use interactive pan, zoom, and tilt to really investigate the landscape. Anyone with a WebGL-enabled browser, such as Google Chrome or Mozilla Firefox, and a reasonably fast Internet connection can use it. http://science.nature.nps.gov/im/units/arcn/owg/ For more information Contact: Dave Swanson, dave_swanson@nps.gov

**Yellow-billed Loon Youth Videography Project– Connecting Youth with Science through Art**

This June, two high school students– Sam Tocktoo from Shishmaref and Maxwell Dan from Anchorage–will join the yellow-billed loon monitoring team to video contaminants sampling and related field activities in BELA. After filming on location, both students will head to Alaska Teen Media Institute in Anchorage (ATMI) and work together to produce videos about yellow-billed loons, their conservation, and the ongoing monitoring efforts of breeding yellow-billed loons in BELA and CAKR. The videos are part of a larger effort to increase awareness about conservation issues facing the birds in light of the 2014 listing decision (when yellow-billed loons will considered for federal listing priority under the Endangered Species Act).

This collaboration with the students, ATMI and Alaska Geographic is possible from additional support provided by the Murie Science and Learning Center, NPS Biological Resource Management Division , and Wildlife Conservation Society. For more information contact: Melanie Flamme, Melanie_flamme@nps.gov or Stacia Backensto, stacia_backensto@nps.gov


**We plan to monitor wood frogs** in tandem with the Shallow Lake Monitoring Program by recording their vocalizations— all part of a larger collaboration with the Terrestrial Wetland Global Change Research Network (TWGCRN) and the Alaska Department of Fish and Game (ADF&G). TWGCRN developed an innovative technique using digital sound recorders to capture frog calls in lieu of ground surveys. Wood frogs call during a short breeding season, which depends on the timing of spring break up and is often less than two weeks. This makes surveying for frogs very difficult. By using sound recorders, we can collect around-the-clock data collection so we won't miss frogs that might begin calling early in the day or night.

**Frogs are a vital part of the wetland food chain and are excellent indicators of environmental health.** Frogs eat large quantities of insects, and in turn are eaten by fish, cranes, and waterfowl. By breathing through their skin, frogs readily absorb chemicals and gasses from the environment, making them highly susceptible to chemicals dissolved in water. Minor changes in temperature or water level directly affect the timing and duration of the breeding season, making frogs excellent indicators of climate change.

**Scientists everywhere are concerned** about the health of frogs because their populations are declining worldwide. These declines are linked to a variety of causes: habitat fragmentation and loss, chemical contamination, and increased ultraviolet radiation. Despite the fact that much of Alaska is remote and relatively pristine, frog populations in Alaska are at risk. ADF&G and U.S. Fish and Wildlife Service have observed unusually high numbers of deformed frogs throughout Alaska. What is causing the deformities is unknown. Environmental contaminants, genetic defects, infections and predation are all potential causes.

**If you have observed wood frogs in your area,** please let us know by contacting Amy Larsen, amy_larsen@nps.gov, 907-455-0662 or visit http://aknhp.uaa.alaska.edu/zoology/citizen-science/alaska-wood-frog-monitoring/.

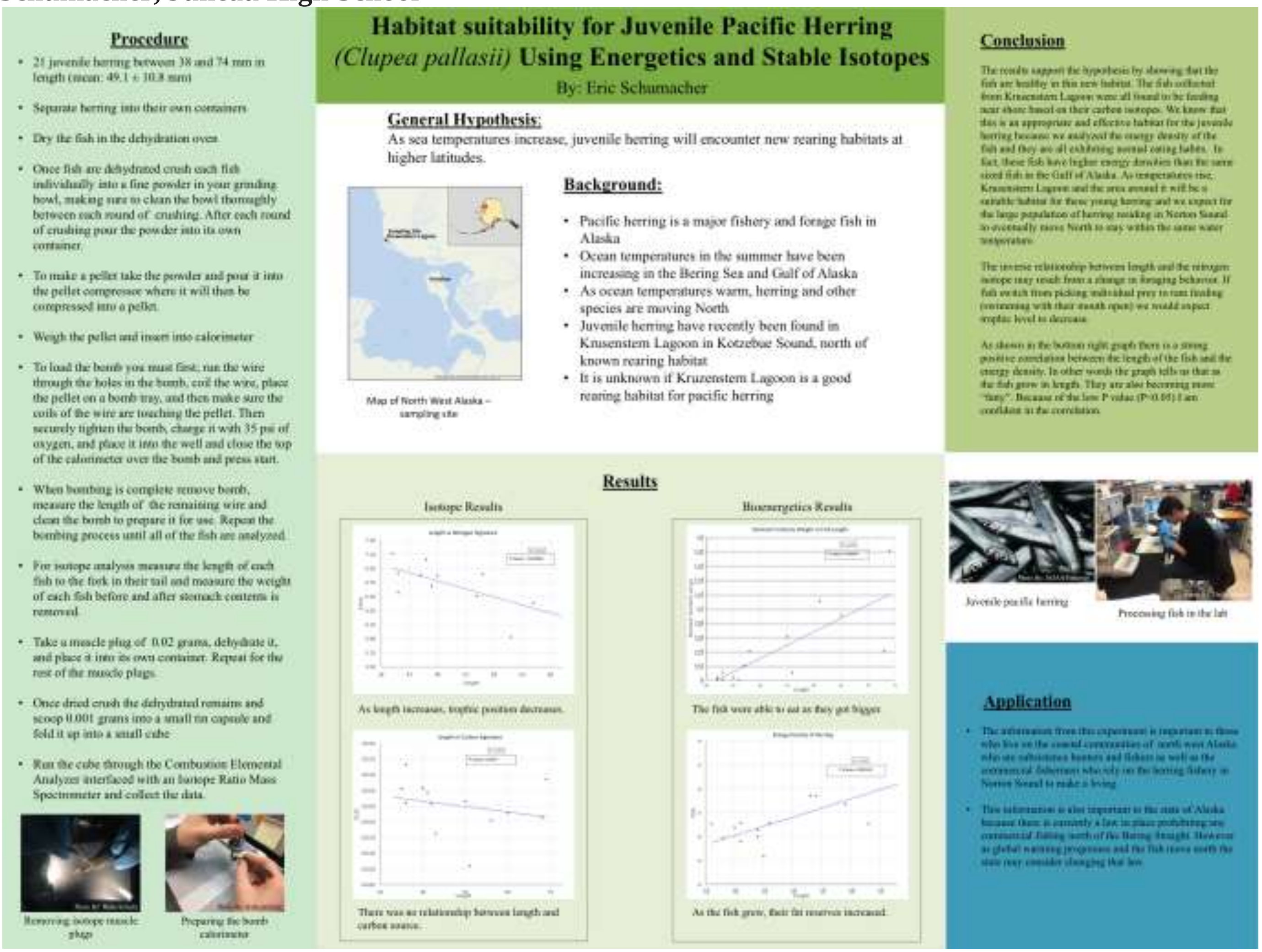
*Arctic Network*
*National Park Service*
*4175 Geist Road*
*Fairbanks, Alaska 99709*
*http://science.nature.nps.gov/im/units/arcn/*

**Science for the stewardship of Arctic Parklands**
Arctic Network Newsletter, June - September 2013

Check us out on youtube, facebook, and twitter

WCS Arctic Beringia
A Wildlife Conservation Society Program

**Appendix 7: Poster on Habitat Suitability for Juvenile Pacific Herring Using Energetics and Stable Isotopes, Eric Schumacher, Juneau High School**



**Appendix 8: Meta Data for Exel Archive: 2016 Hobo Loggers**

**Tab 1: Krusenstern 2016 Entrance: Plot Title 10684074**
Field 1: Number
Field 2: Date
Field 3: Pressure
Field 4: Salinity
**Tab 2: Krusenstern 2016 NE Corner Fresh: Plot Title 10684077**
Field 1: Number
Field 2: Date
Field 3: Pressure
Field 4: Salinity
**Tab 3: Krusenstern 2016 Entrance Land: Plot Title BELA-Lagoon Water Lever 4"**
Field 1: Number
Field 2: Date
Field 3: Pressure
Field 4: Salinity
**Tab 4: Kotlik North 2016: Plot Title 10684078**
Field 1: Number
Field 2: Date
Field 3: Pressure
Field 4: Salinity
**Tab 5: Kotlik Outlet 2016: Plot Title 10536713**
Field 1: Number
Field 2: Date
Field 3: Pressure
Field 4: Salinity
**Tab 5: Kotlik 2016 Land Water: Plot Title BELA Lagoon Water Level 5"**
Field 1: Number
Field 2: Date
Field 3: Pressure
Field 4: Salinity
**Tab 6: Plot Title 10684079**
Field 1: Number
Field 2: Date
Field 3: Pressure
Field 4: Salinity
**Tab 7: Plot Title 10684076**
Field 1: Number
Field 2: Date
Field 3: Pressure
FField 4: Salinity
**Tab 8: Plot Title 10684075**
Field 1: Number

Field 2: Date
Field 3: Pressure
Field 4: Salinity

**Tab 9: Plot Title 10684071**

Field 1: Number
Field 2: Date
Field 3: Pressure
Field 4: Salinity

**Tab 10: Plot Title 10569609**

Field 1: Number
Field 2: Date
Field 3: Pressure
Field 4: Salinity

**Tab 11: Plot Title 10536714**

Field 1: Number
Field 2: Date
Field 3: Pressure
Field 4: Salinity

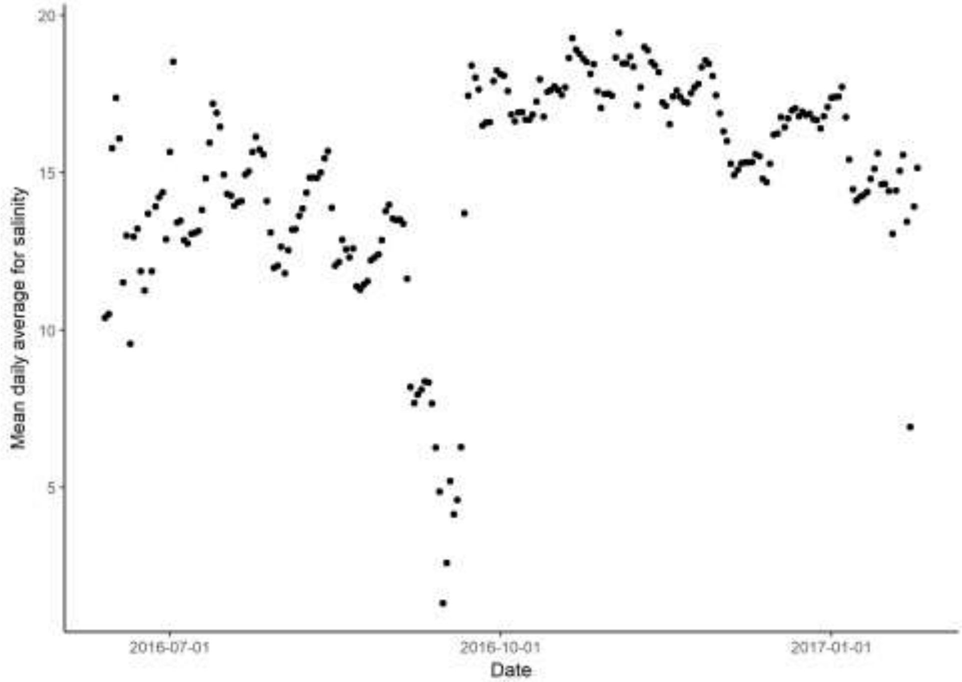
**Tab 12: Plot Title 10030843**

Field 1: Number
Field 2: Date
Field 3: Pressure
Field 4: Salinity

**Tab 13: Plot Title 9998504**

Field 1: Number
Field 2: Date
Field 3: Pressure
Field 4: Salinity

## Appendix 9: 2016 Hobo Logger Data Preliminary Results



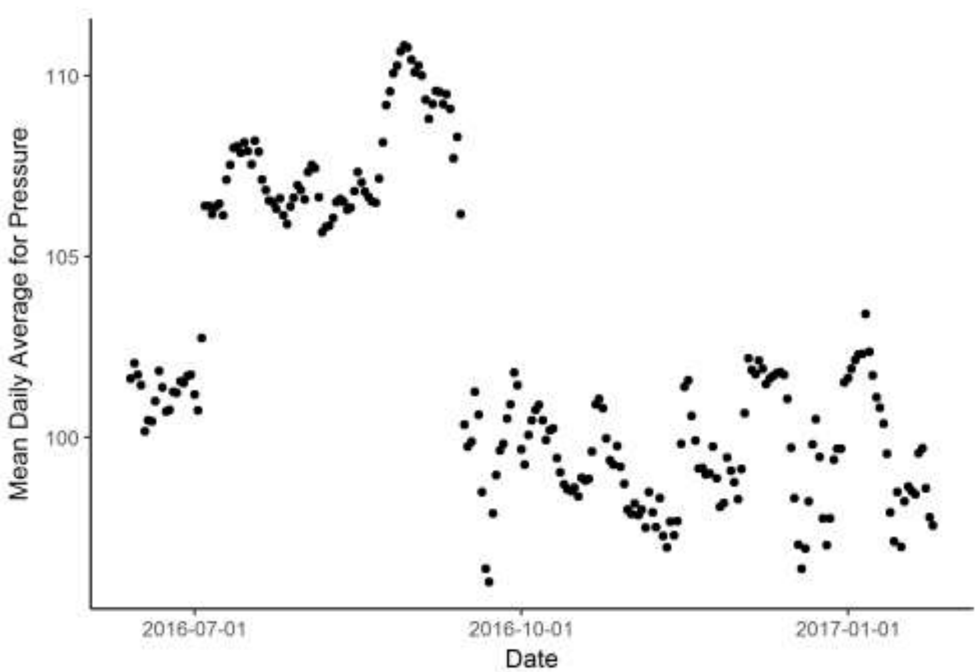




Figure 1. Mean daily salinity (top) and pressure (bottom) from hobo logger data taken at Krusenstern Lagoon entrance from June 2016 until January 2017.

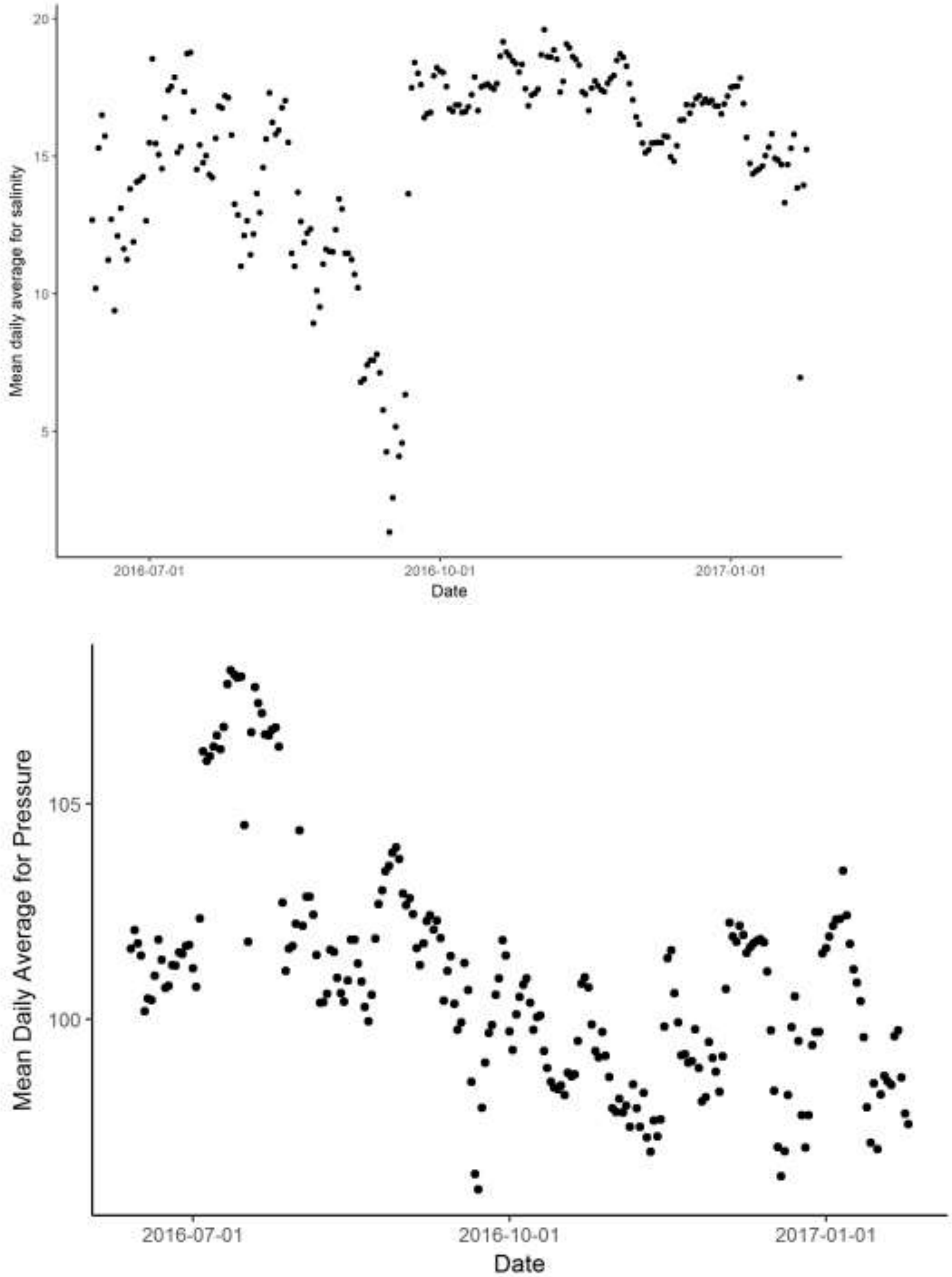
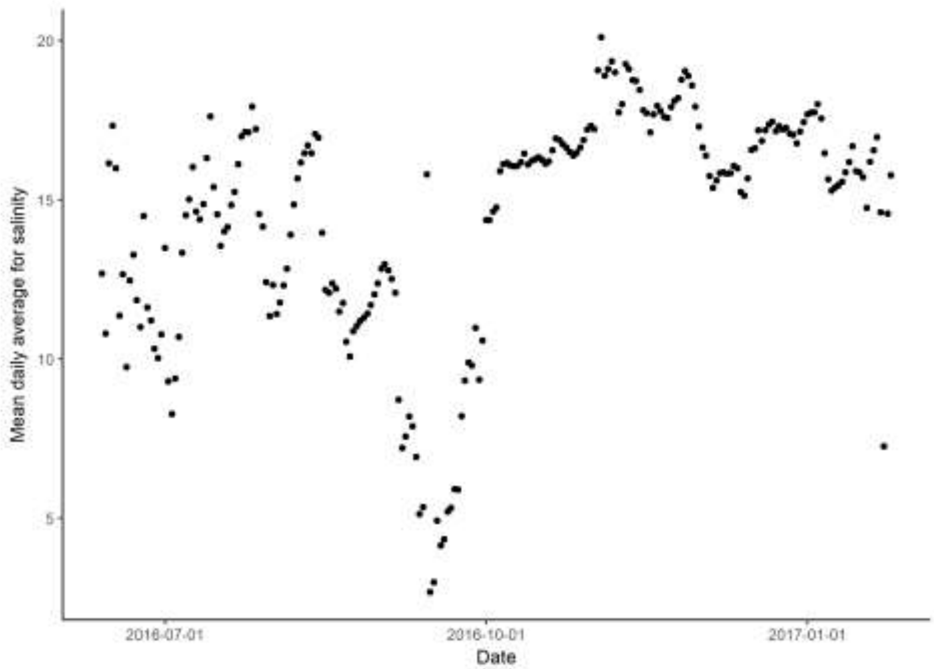



Figure 2. Mean daily salinity (top) and pressure (bottom) from hobo logger data taken at the northeast corner of Krusenstern Lagoon from June 2016 until January 2017.



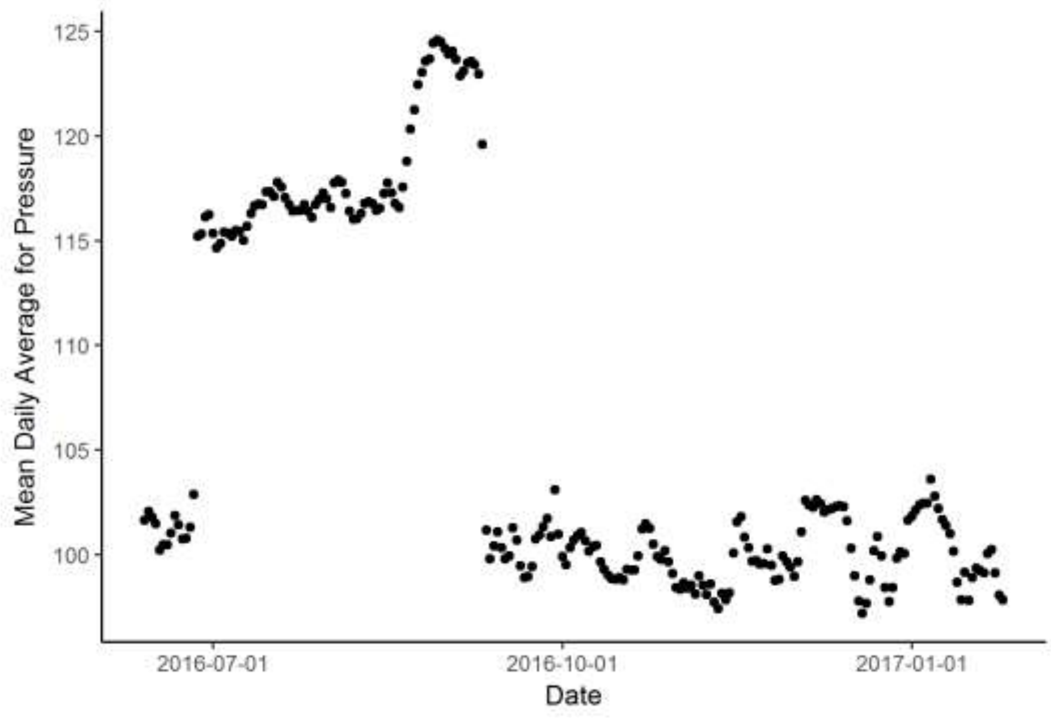
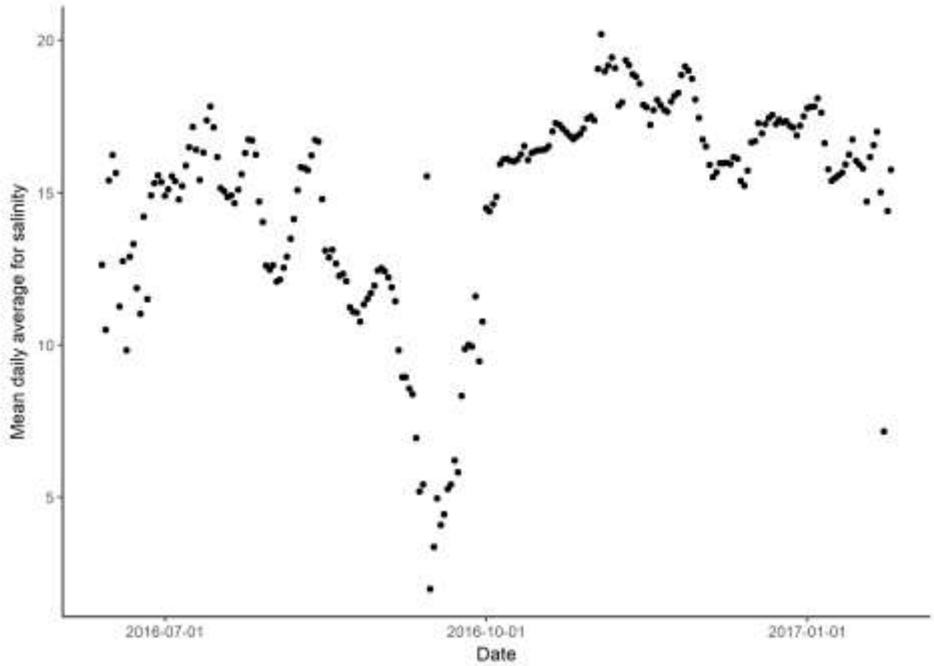




Figure 3. Mean daily salinity (top) and pressure (bottom) from hobo logger data taken at the outflow of Kotlik Lagoon from June 2016 until January 2017.



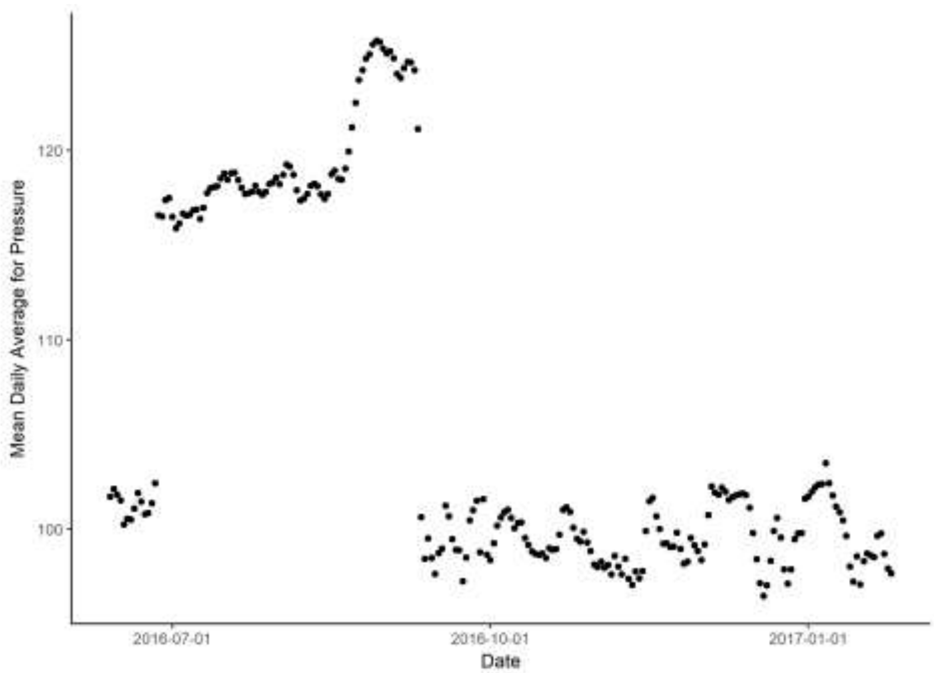




Figure 4. Mean daily salinity (top) and pressure (bottom) from hobo logger data taken at the north end of Kotlik Lagoon from June 2016 until January 2017.