



Coastal Lagoon Community and Ecological Monitoring in the Southern Chukchi Sea National Park Units

~ 2015 Field Sampling Report ~



Trevor Haynes (UAF), Martin Robards (WCS), Marguerite Tibbles (WCS),
Tahzay Jones (NPS), Alex Whiting (Native Village of Kotzebue), Mark Wipfli
(UAF)

Xx, xx, 2016

Coastal Lagoon Community and Ecological Monitoring in the Southern Chukchi Sea National Park Units ~ 2015 Field Sampling Report ~

A report by Wildlife Conservation Society to US National Park Service
Arctic Network (in collaboration with the University of Alaska, Fairbanks).

XX XX, 2015

Cooperative Ecosystem Studies Unit Agreement #: xxxxxxxx

Cover Photo: T. Haynes and M. Tibbles gastric lavaging a sheefish (*Stenodus nelma*) at Krusenstern Lagoon to obtain a diet sample (photo credit – M. Robards).

Contents

EXECUTIVE SUMMARY.....	4
INTRODUCTION	6
2015 FIELD EFFORT	9
Objectives	9
Study Design.....	11
Field Methods.....	11
Lagoon Specific Sampling Descriptions.....	16
Kupik.....	16
Ikpek.....	18
Eспенberg.....	18
Kotlik.....	20
Krusenstern.....	23
Aukulak	25
Tukrok River and Chukchi Sea.....	26
RESULTS	27
Water Quality	27
Fish Catches.....	27
Fish Diets.....	28
Laboratory work	30
Literature Cited.....	32

EXECUTIVE SUMMARY

Wildlife Conservation Society (WCS) provides assistance to the National Park Service with the design and implementation of the Coastal Lagoon Vital Sign component of the Inventory and Monitoring Program. Our 2015 field effort was a continuation of the Vital Sign Program. This program is intended to establish biotic and abiotic reference conditions for coastal lagoons in Cape Krusenstern National Monument and Bering Land Bridge National Preserve. The Vital Sign Program is still being developed for lagoons, and our 2015 effort will be used to inform the creation of a standardized protocol to monitor lagoon vital signs. These vital signs will focus on monitoring the structure and function of lagoons and fish resources used for subsistence by coastal communities. Our 2015 sampling was supplemented by Coastal Settlement Funds focused on better documentation of whitefish ecology in the lagoons, and provided the additional capacity necessary for collecting seasonal (rather than a rapid single visit) water quality data; fish sampling and assessing the feasibility of adding coverage of the vital sign program to the lagoon at Cape Espenberg. Fish research focused on whitefish and species of ecological importance and included sampling of community composition, seasonal and spatial patterns of use, trophic dynamics, and fish health.

As part of the Vital Signs program, we monitored water quality through the season (3-5 times total per lagoon) at the 3 lagoons in Cape Krusenstern, and once for the 2 lagoons in Bering Land Bridge. At each lagoon visit, we used a small inflatable boat equipped with a 9.9 horsepower outboard motor to visit four long-term (Center, Outflow, Inflow, and Adjacent-to-the-Ocean stations) and three random stations in each lagoon and accessed Park units via fixed-wing plane (tundra tire or float). We also sampled water quality in the protected waters at Cape Espenberg; however, extremely shallow water throughout (< 30cm) limited our ability to conduct standardized data collection at that site.

Ease of access and logistics allowed us to sample the lagoons in Cape Krusenstern more frequently, whereas, we sampled the lagoons in Bering Land Bridge only once, due to both challenging access and the costs of dedicated long flights out of Kotzebue.

Physical water properties varied by lagoon and season. The salinity of the lagoon appears to be related to its connection with the marine environment; the more connected the lagoon is to the Chukchi Sea, the higher its salinity. For example, Krusenstern Lagoon, which has a small connection that is intermittently open to the marine, is far more fresh (2.1 ppt) compared with lagoons that have large connections to the Chukchi Sea that remain open throughout the year, such as Espenberg Lagoon (31.9 ppt). For the three lagoons that were monitored periodically throughout the summer (Krusenstern, Aukulak and Kotlik) we noted general seasonal trends, included a decrease in temperature and pH, and an increase in dissolved oxygen from July to September.

Whitefish captured during the 2015 field season included sheefish, humpback whitefish, least cisco and Bering cisco. We collected fish length and otolith samples to examine fish growth rates for resident and migratory species. While our focus was on standardized seasonal characterization of water properties and of whitefish ecology, we also gathered length-weight measurements and otoliths from pond smelt (*Hypomesus olidus*), a poorly studied species which we recorded in Cape Krusenstern and Bering Land Bridge lagoons for the first time this season. Pond smelt were locally abundant and consequently may play an important role in the trophic dynamics in certain lagoons, such as Krusenstern Lagoon.

We assessed stomach contents on 14 species, focusing on key species in the lagoons. For larger fish, to minimize research mortality, we used gastric lavage. Our preliminary findings show that mysids, chironomids and ninespine stickleback are the three major prey items consumed by fish.

To examine fish health, we are partnering with the State of Alaska to analyze contaminants (metals and organic contaminants) 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.

Data we collected in 2015 builds on prior traditional knowledge and scientific research, provides ecological information vital for 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. 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 breaching 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 molluscs 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 above Siberia. 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 economies.

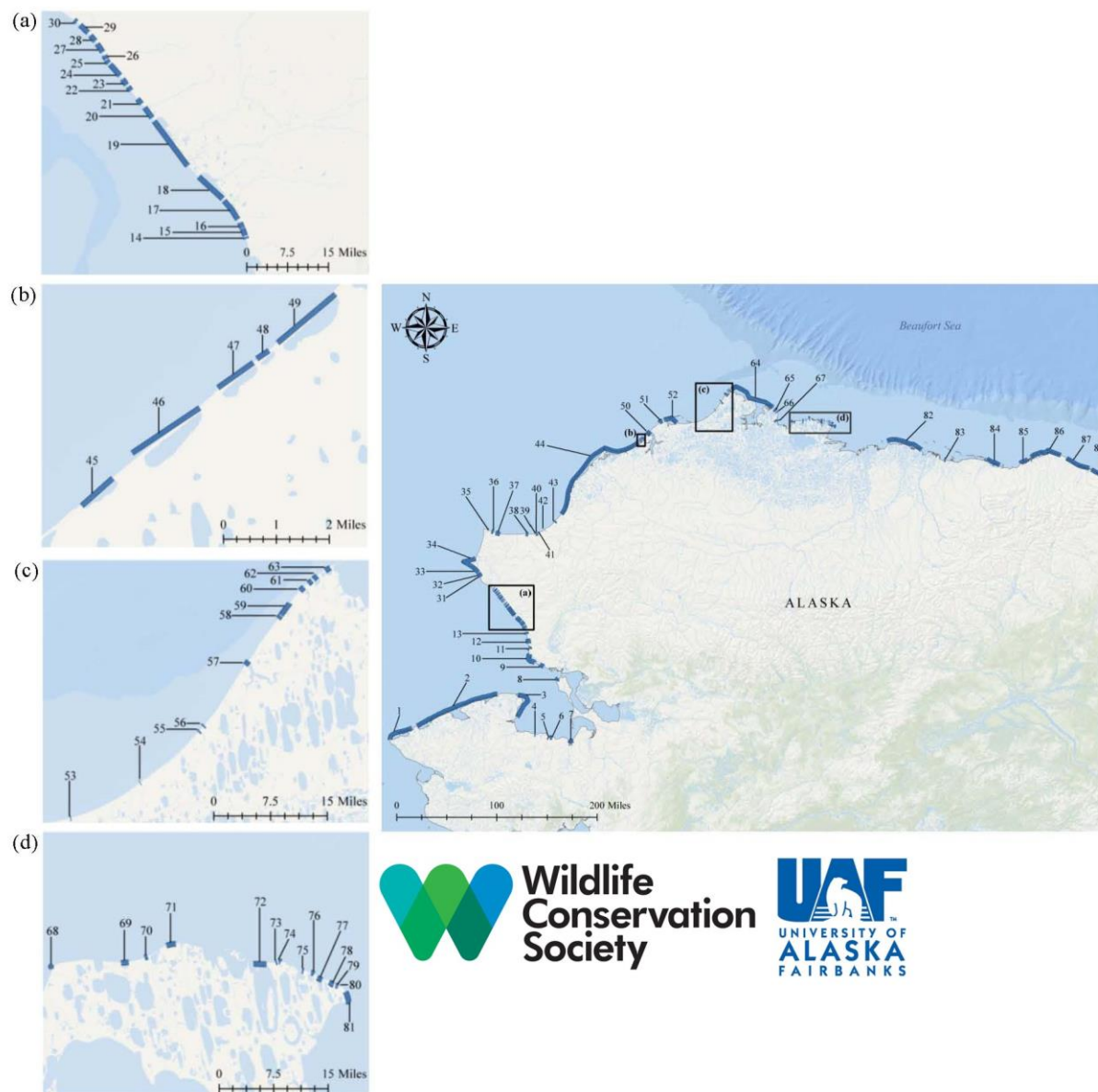


Figure 1: Map of the coastal lagoon habitat found in Alaska from Wales to the Canadian border. Coastline adjacent to lagoons is shown in blue, which amounts to 37% of the total coastline length.

Coastal Lagoons in Northern Alaska

Work in the coastal lagoons of Cape Krusenstern National Monument (hereafter “Cape Krusenstern”) and Bering Land Bridge National Preserve (hereafter “Bering Land Bridge”) will eventually be placed in the context of similar work on the northern Chukchi and Beaufort Sea coastlines where the composition and spatial and temporal dynamics of coastal fish assemblages have been relatively well described (e.g., Jarvela and Thorsteinson, 1999; Johnson et al., 2010). 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 (\$1.1 million) looking at fish species composition and physical conditions in Kasegaluk lagoon and Peard Bay on the northern Chukchi Coast.

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 (Willimovsky and Wolfe, 1966) 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 seven coastal lagoons described within the boundary of Cape Krusenstern National Monument – Aukulak, Imik, Ipiavik, Kotlik, Krusenstern, Port, and Sisualik; and four coastal lagoons within the boundary of Bering Land Bridge National Preserve – Espenberg, Kupik, Shishmaref, and Ikpek (Table 1). We note that Sisualik and Espenberg may not fulfill all the requirements of being classed as lagoons, being more of a fully marine embayment.

Table 1. 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	14	Fresh/Brackish	Open Channel
	Port	2	Fresh	Closed
	Imik	5	?	Intermittently Open
	Kotlik	24	Brackish	Intermittently Open
	Krusenstern	56	Fresh	Seasonally-Closed
	Aukulak	9	Fresh/Brackish ³	Intermittently Open
	Sisualik	34	Fresh	Open
BELA	Espenberg	12	Marine	Open
	Kupik	109	Brackish	Open Channel
	Shishmaref	370	?	Open
	Ikpek	128	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.

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, Port Lagoon is the smallest (2 km²) and Krusenstern Lagoon is the largest (56 km²). Lagoons vary in the amount of water exchange with the surrounding marine environment. Aukulak,

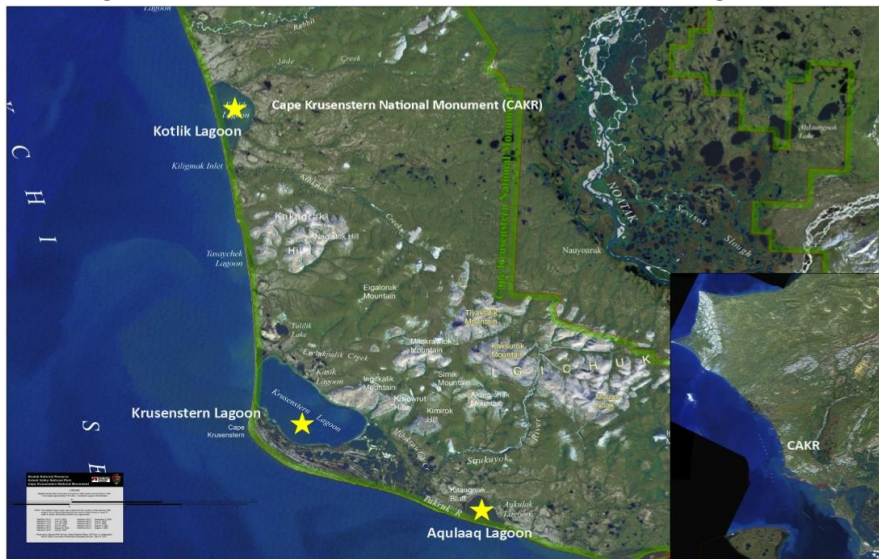
Krusenstern, and Sisualik are connected to Kotzebue Sound and Imik, Ipiavik, Kotlik, and Port are connected to the more open Chukchi Sea. Aukulak, Imik, Kotlik, and Port are all intermittently open. Krusenstern Lagoon is usually seasonally closed at the mouth of the Tukrok River, although this connection with the marine environment is still 15 km away from the lagoon itself. The mouth of the Tukrok is opened in springtime as a result of ice breakup and the pushing of the ice down the river and out to the ocean. The mouth is closed in mid-July as gravel is pushed up by strong wave action resulting from strong storms. Sisualik, and Ipiavik are open year-round.

2015 FIELD EFFORT

Objectives

The objectives of the Wildlife Conservation Society-led activities in 2015 included the following:

1. Provide updated field protocols for the 2015 field season;
2. Oversee logistics and field operations for the 2015 field season (6/28/15-9/28/15);
3. Collect water quality data for Vital Signs Program from 8 sampling locations in each of 5 lagoons - 3 lagoons in Cape Krusenstern (Figure 2) and 2 lagoons in BELA (Figure 3). Water quality data includes: water temperature, dissolved oxygen, salinity, specific conductivity, turbidity, pH, chlorophyll, and blue green algae;
4. Collect data on fish distributions, abundance, community composition, diet, and growth rates;
5. Determine the feasibility of adding Espenberg Lagoon to the vital signs program;
6. Provide guidance for future field efforts within the coastal lagoons of the NPS Arctic units;



7. Figure 2. Lagoons sampled in Cape Krusenstern National Monument
communicate results and recommendations.

Prepare a report to



Figure 3: Lagoons sampled in Bering Land Bridge National Preserve

Study Design

SAMPLING SCHEMATIC FOR COASTAL LAGOONS

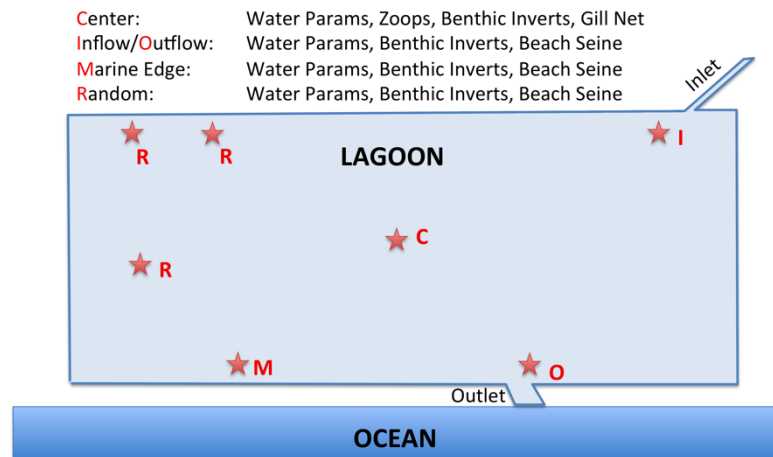


Figure 4. Sampling Strategy for Coastal Lagoon Monitoring

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 the work of Blaylock and Houghton (1983). Four of Reynolds' 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"); and 5) 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 (Figure 4).

Field Methods

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 and at a depth of 50 cm, the following core water quality parameters were measured in situ using a YSI EXO Sonde multiparameter probe: water temperature, dissolved oxygen, salinity, specific conductivity, turbidity, pH, chlorophyll, and blue green algae. Water depth was measured with a hand-held depth sounder. We did not repeat Reynolds' use of a Secchi disk for water clarity due to the shallow nature of these lagoons and the unattainable precision that would be needed for comparisons across sites and years.

Primary Production

Primary production was estimated using the YSI EXO Sonde to measure chlorophyll and blue-green algae in the lagoons. 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 the season. Given the rapid development of sonde technology, we will work over the next years to provide a conversion for sonde measurements of chlorophyll and that of original filter methodology; while continuing to focus on the use of a multi-parameter sonde which is a more efficient way to collect long-term samples than the complexities and costs of in-field filtering, freezing of samples, and laboratory analysis.

Benthic Community

Based on poor success with the Ponar Grab in past years, we did not attempt to sample benthos. This will be a future priority in collaboration with experts in this area.

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). Reynolds set beach seines by anchoring one end on land and then having two-team members drag the net first perpendicular to the shore, and then back to the beach in a U pattern. We used a more common protocol of setting the net 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).

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. Nets were set for 0.3 to 3.9 hours (mean = 1.7 h, standard deviation = 0.8 h) 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).

We used fyke nets to collect larger volumes of fish in certain locations where the depth and substrate were favorable. The net had 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°. The nets were set for 3-hour periods (mean = 3.22 hours, standard deviation = 1.44 hours).

Fine mesh minnow traps were set nearshore at a depth of approximately 50 cm and were checked every 23 hours.

We identified all fish to species and measured fork length. To analyze for fish growth rates in the laboratory, we collected fish otoliths from whitefish, including sheefish (5), humpback whitefish (42), least cisco (26) and starry flounder (19) as well as 11 other fish species (Table 2). We gathered length-weight measurements and otoliths from >500 pond smelt (*Hypomesus olidus*), a poorly studied species, which we identified in Cape Krusenstern and Bering Land Bridge lagoons for the first time this season.

Table 2. 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).

Family	Latin Name	Common Name	Ipiavik	Port	Cape Krusenstern ¹					Bering Land Bridge ¹	
					Aukulak	Imik ³	Kotlik	Krusenstern	Sisualik	Kupik	Ikpek
Ammodytidae	<i>Ammodytes hexapterus</i>	Pacific sand lance					6				
Agonidae	<i>Pallasina barbata</i>	Tubenose poacher					6				
Clupeidae	<i>Clupea pallasii</i>	Pacific herring			6		3,5,6	4,5,6	1,3	5	6
Umbridae	<i>Dallia pectoralis</i>	Alaska blackfish			3						
Osmeridae ⁵	<i>Mallotus villosus</i>	Capelin					5	5		5	
	<i>Osmerus mordax</i>	Rainbow smelt	2		6		6	3		6	6
	<i>Hypomesus olidus</i>	Pond smelt						6		6	6
		Unidentified smelt							1,3		
Salmonidae	<i>Coregonus laurettae</i>	Bering cisco			3		5,6	3,6	3		
	<i>C. nasus</i>	Broad whitefish			3			3			
	<i>C. pidschian</i>	Humpback whitefish	2 ⁴		3,6		3,6	3,4,5,6	3		
		Unidentified whitefish							1		
	<i>C. sardinella</i>	Least cisco			3,6		6	3,4,6	3		
		Unidentified cisco							1		
	<i>Stenodus leucichthys</i>	Inconnu					6	6	3		
	<i>Thymallus arcticus</i>	Arctic grayling	2					3,6			
	<i>Oncorhynchus gorbuscha</i>	Pink salmon	2				6	6			
	<i>O. keta</i>	Chum salmon							1,3		
	<i>Salvelinus alpinus</i>	Arctic char	2								
Gadidae	<i>S. malma</i>	Dolly Varden					3,6	6			
	<i>Eleginus gracilis</i>	Saffron cod	2		6		5,6	6	1,3		6
Gasterosteidae	<i>Gasterosteus aculeatus</i>	Threespine stickleback					6	3,4,6	3		
	<i>Pungitius pungitius</i>	Ninespine stickleback	2	2			3,5,6	3,4,5,6	1,3		6
Cottidae	<i>Cottus cognatus</i>	Slimy sculpin	2								
	<i>Megalocottus platycephalus</i>	Belligerent sculpin					3,6				
	<i>Myoxocephalus quadricornis</i>	Fourhorn sculpin	2		3,6		3,5,6	6	3	6	6
		Unidentified sculpin			6		6		1		
Pleuronectidae	<i>Limanda aspera</i>	Yellowfin sole							3		
	<i>Limanda proboscidea</i>	Long head dab			6						
	<i>Platichthys stellatus</i>	Starry flounder	2		6		5,6	3,5,6	1,3	6	

<i>Pleuronectes glacialis</i>	Arctic flounder	6	6	3	6	6				
<i>Pleuronectes quadrituberculatus</i>	Alaska plaice		5		5	5				
	Unidentified flatfish	3 ²		1						
TOTAL SPP.		10	1	14	0	20	17	14	8	8

¹For 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).

²Reynolds (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.

³Imik was only been sampled with a single gill net set on one occasion (catching no fish; Reynolds, 2012).

⁴1982 sampling effort.

To examine fish health, we are partnering with the State of Alaska to analyze contaminants (metals and organic contaminants) 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.

We gastric lavaged or removed stomach samples from 796 fish representing 14 species (Table 3). Our sampling was opportunistic in 2015 and aimed at informing a more focused protocol in 2016. 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 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.

Table 3: Diet samples collected in the 2015 field season.

Species	Number of samples
Pond Smelt	575
Pacific Herring	70
Saffron Cod	50
Humpback Whitefish	46
Starry Flounder	20
Least Cisco	17
Sheefish	12
Rainbow Smelt	10
Fourhorn Sculpin	7
Dolly Varden	5
Threespine Stickleback	3
Arctic Grayling	2
Bering Cisco	2
Pink Salmon	2

Implementation

The majority of the field season was spent in Cape Krusenstern because of the simplified field logistics when using the NPS Ranger Station at Anigaaq as a base for field camp. Using Anigaaq as a base allowed us to store and secure food and gear, operate a propane freezer through the season for freezing biological samples, make quick commutes to Kotzebue and, have access to outhouse, cooking, and sleeping facilities. We sampled Krusenstern Lagoon on 17 days, compared with 10 visits for all other lagoons combined. To reach Krusenstern Lagoon, we boated up the Tukrok River and through the adjacent wetland. We found two navigable routes through the network of waterways, islands, shallows that made up the wetland. Both routes were accessible all season and were approximately equal in travel time; however, as the season proceeded, aquatic vegetation increased and slowed travel by fouling the propeller of the 9.9 hp outboard engine. We visited Aukulak on 4 occasions throughout the season. To reach Aukulak, we boated from Anigaaq Ranger Station to the mouth of the Tukrok River, then approximately 2.5 km SE along the Chukchi coast. Because Aukulak was not open to the Chukchi Sea, we staged the boat and gear across the marine edge berm into the lagoon. We sampled Kotlik on 3 visits, one visit each month of July, August, and September. Access to Kotlik in 2015 was either by plane or charter boat because it is approximately 50 km north of Anigaaq.

The lagoons in Bering Land Bridge were only visited once for 2-3 days each in July. A Cessna-205 with tundra tires was used to transport gear and personnel to the lagoons. In these lagoons we sampled water quality at the 8 sampling locations; and at a minimum set 2 gill net and two beach seine sets.

LAGOON SPECIFIC SAMPLING DESCRIPTIONS

Below we briefly summarize the sampling layout and effort at each lagoon and then describe collective results for all lagoons.

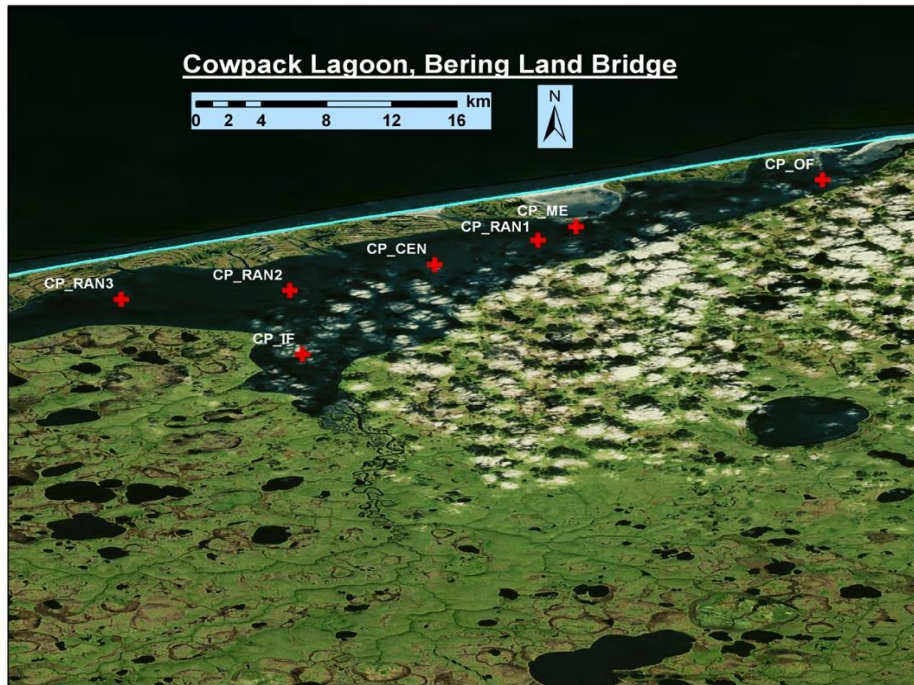


Figure 5. Kupik Lagoon and Sampling Sites (RAN = Random, CEN = Central, OF = Outflow, ME = Marine Edge, IF = Inflow).

Kupik (7/13/15-7/16/15)

Kupik (also referred to as “Cowpack”) is a long, narrow lagoon with extensive shallows in the western end (Figure 5). 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 hrs 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.



Figure 6. A gill net pulled from Kupik Lagoon after 3.5 hours on 14-July was fouled by algae (Photo credit: T. Haynes).

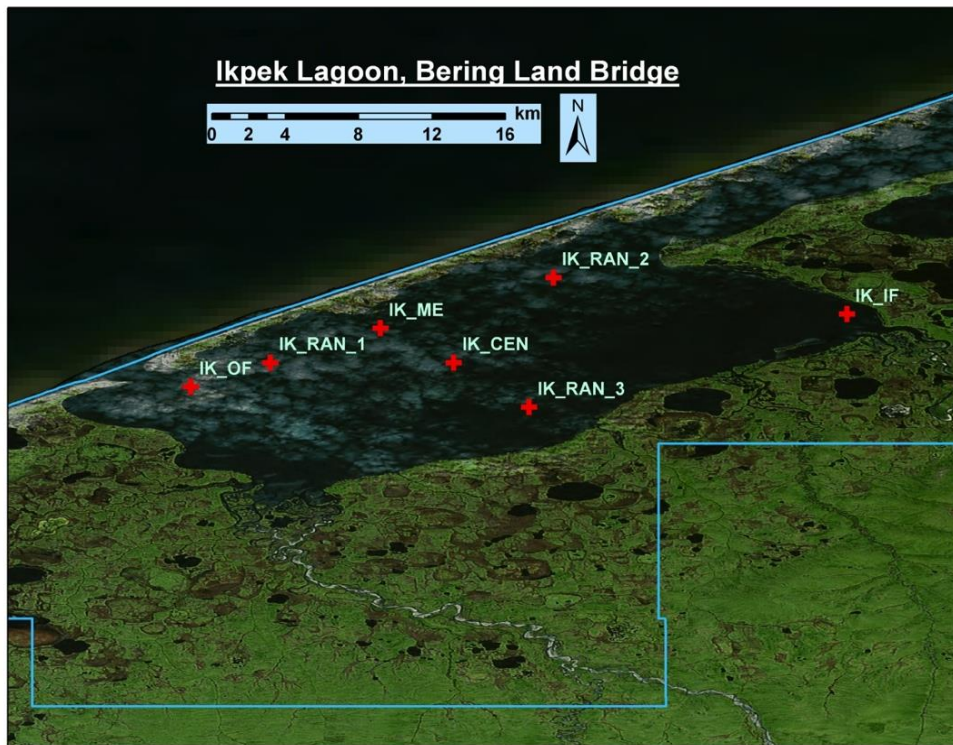


Figure 7. Ikpek Lagoon and Sampling Sites (RAN = Random, CEN = Central, OF = Outflow, ME = Marine Edge, IF = Inflow).

Ikpek (7/16/15-7/18/15)

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 local hunters from Brevig successfully hunted multiple reindeer. Both days at Ikpek were partly cloudy with rain showers.

Espenberg (7/18/15-7/19/15)

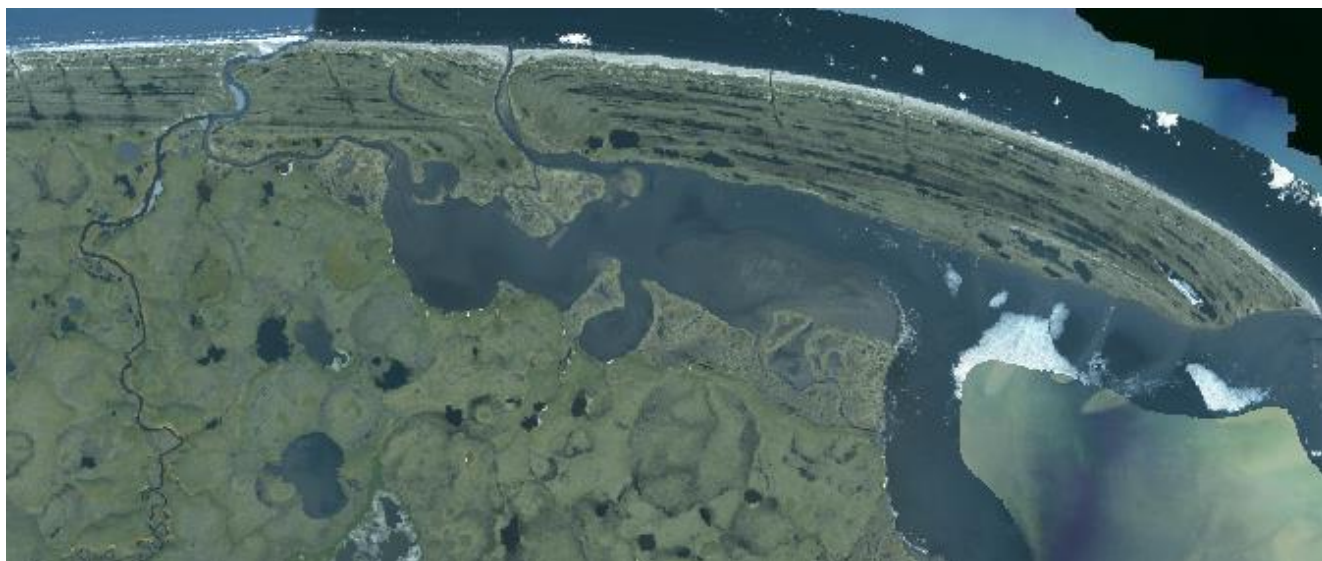


Figure 8. Espenberg Lagoon

Espenberg is 12 km², 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 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 muskoxen 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.

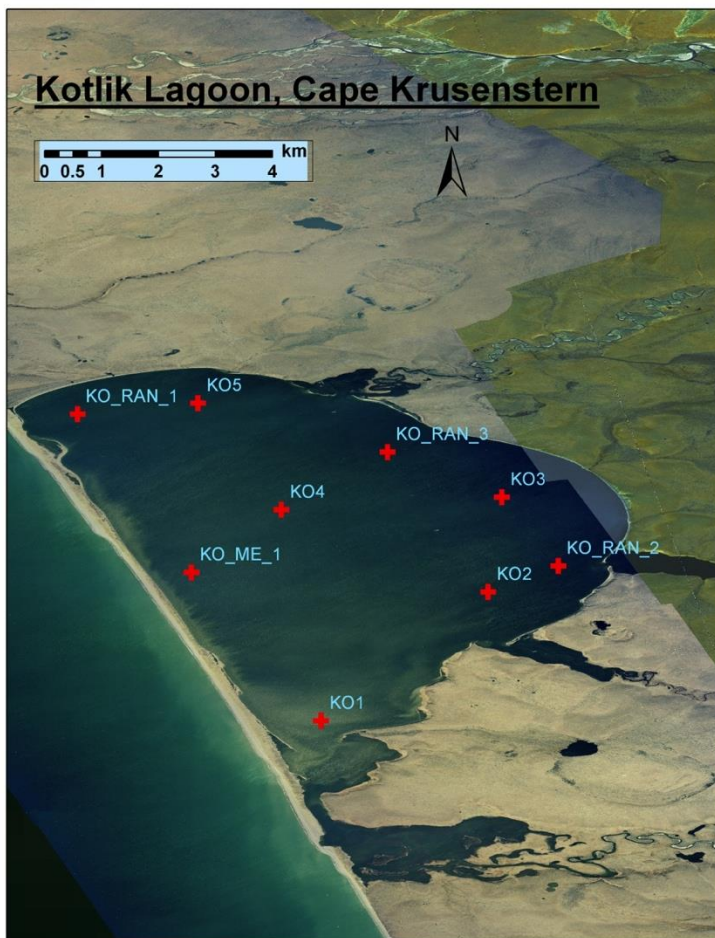


Figure 9. Kotlik Lagoon and Sampling Sites (RAN = Random, CEN = Central, OF = Outflow, ME = Marine Edge, IF = Inflow).

Kotlik

July (7/8/15-7/11/15):

Kotlik lagoon is an 8.4 km long lagoon with several fresh water sources draining into it and a marine mouth at the south end, which is intermittently open (Figure 9). 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 mixed with the Chukchi Sea was a highly 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 (8/6/15-8/9/15):

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 (including unidentified sculpin as one 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 (9/19/15-9/20/15):

The outlet was still closed when we visited Kotlik in September, the water level in the lagoon had risen about 1 m since August, and water temperatures were close to freezing (Table 4), 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 (Figure 10). 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.

Table 4. Mean water quality parameters per month in Kotlik lagoon.

Month	Temperature °C	Dissolved O ₂ (mg/l)	pH	Conductivity mS/cm	Salinity	NTU	Chloro phyll RFU	BGA RFU
July	15.57	9.45	8.12	32252	22.18	3.55	-0.06	-1.44
August	15.34	10.23	7.84	32634	22.45	1.14	0.38	-1.04
September	2.69	12.10	7.27	18430	12.5	3.64	0.80	-0.66



Figure 10. A beach seine set in Kotlik Lagoon on 9-September yielded ice and few fish (Photo credit: M. Tibbles).

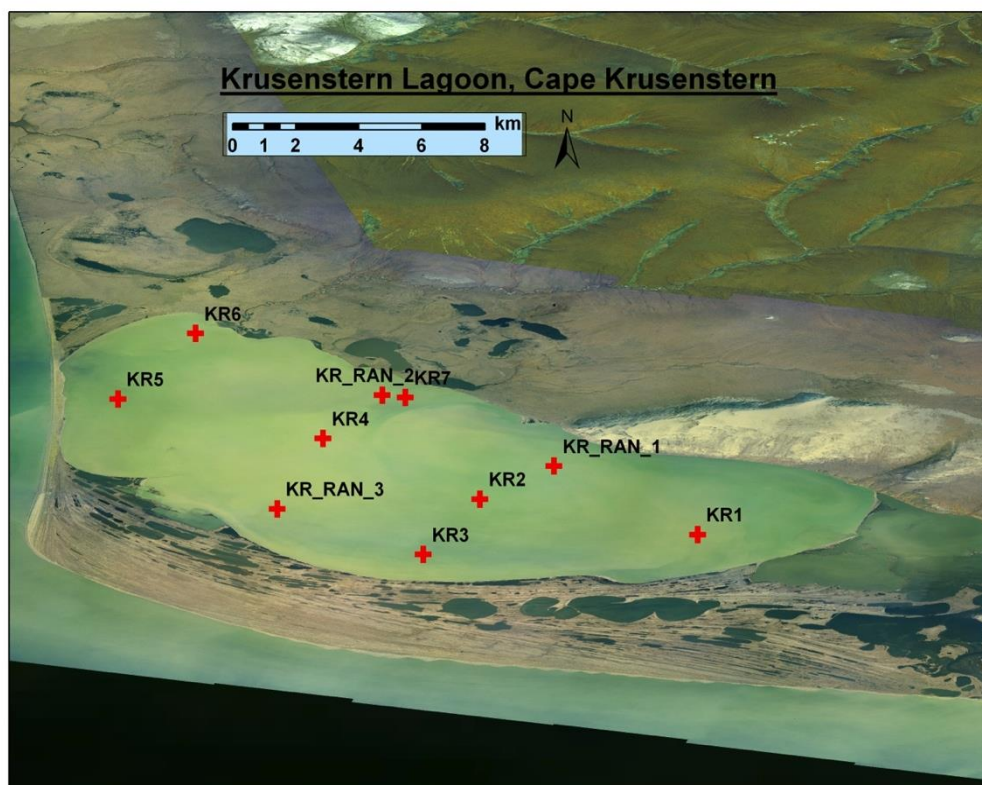


Figure 11. Krusenstern Lagoon and Sampling Sites (RAN = Random, CEN = Central, OF = Outflow, ME = Marine Edge, IF = Inflow).

Krusenstern

Table 5. Sampling dates for Krusenstern Lagoon for 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) channel on the eastern lagoon shore (Figure 11). We visited Krusenstern lagoon 7 times in July (Table 5). 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. This created challenges for setting gill nets, fyke nets and beach seines. Heavier weights on the gill nets proved to help with stabilizing 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 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 (Table 5). 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 (Table 5). 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; Table 6). Despite the challenging conditions, we increased our sampling efforts via beach seining in September to obtain larger sample sizes for our fish collections (Table 7).

Table 6. Mean physical water quality parameters per month for Krusenstern lagoon

Month	Temperature	Dissolved O ₂	pH	Conductivity	Salinity	NTU	Chlorophyll	BGA
	°C	(mg/l)		mS/cm			RFU	RFU
July	15.27	10.70	8.58	2929.1	1.68	8.31	1.746	-0.68
August	12.24	11.22	8.26	3396.0	1.978	13.00	5.23	-0.02
September	5.49	12.13	7.62	4138.5	2.5	22.04	4.442	0.16

Table 7. Fishing effort over the season in Krusenstern for the three main gear types. Note, fishing hours for beach seine is not displayed, as this is an active sampling gear (each seine replicate takes approximately 15 minutes to set).

Number of Replicates (Fishing hours)	July	August	September
Beach seine	2	2	11
Fyke net	3 (13:19)	1 (3:35)	2 (4:50)
Gill net	12 (15:53)	4 (7:03)	15 (33:07)

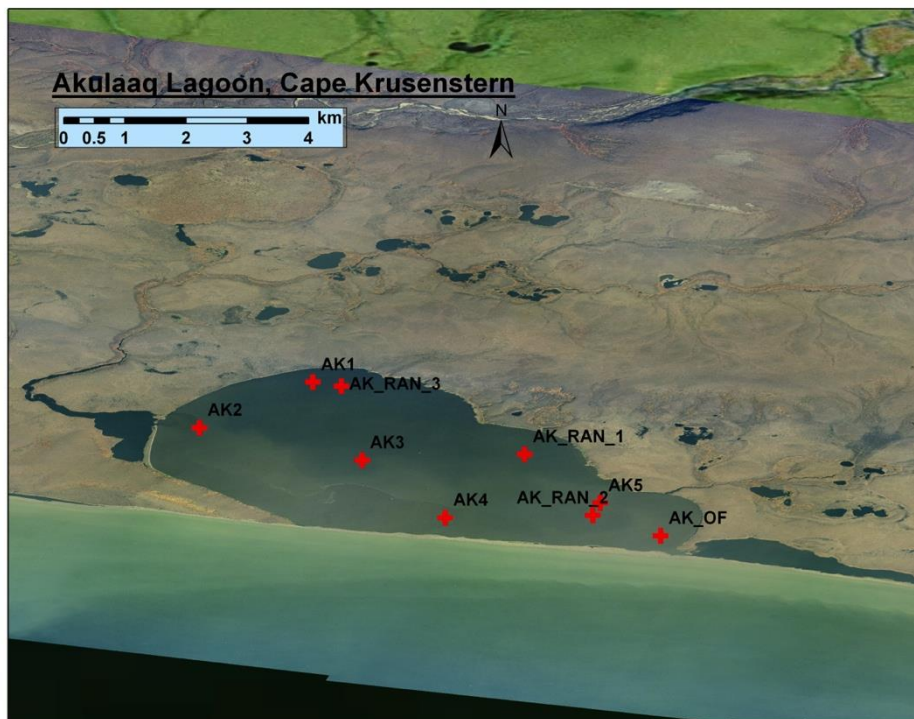


Figure 12. Aukulak Lagoon and Sampling Sites (RAN = Random, CEN = Central, OF = Outflow, ME = Marine Edge, IF = Inflow).

Aukulak

July (7/5/15, 7/22/15):

Aukulak is a small lagoon (surface area = 9 km²; Figure 12) that was not open to the ocean during our 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 2015), indicating that it had been open earlier that year (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 also noted 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. We captured two species in gill nets on 22-July that had not previously been recorded in Aukulak lagoon. Both days we sampled Aukulak in July had clear sky conditions and calm winds.

August (8/31/15):

We sampled Aukulak once in August, due to high seas preventing us from accessing the lagoon on several planned attempts (the journey requiring transit through open water between Tukrok River and the Aukulak lagoon). The water temperature had decreased by 12 °C compared with temperatures measured on 22-July (5.9°C versus 19.2°C; Table 8). The water level appeared to have returned to the height we noted at the beginning of July (note, this was not measured). 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 a calm (permitting travel to Aukulak via the Chukchi Sea) with clear skies.

September (9/12/15):

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.

Table 8. Mean physical water quality parameters per month for Aukulak lagoon

Month	Temperature	Dissolved O ₂	pH	Conductivity	Salinity	NTU	Chlorophyll	BGA
	°C	(mg/l)		mS/cm			RFU	RFU
July	16.33	-	8.13	34475.9	23.74	4.04	0.65	-1.26
August	7.34	10.82	7.55	24225.7	16.6	14.57	3.94	0.00
September	4.17	11.48	7.38	22815.5	15.57	9.82	3.20	-0.22

Tukrok River and Chukchi Sea (9/5/15, 9/11/15):



Figure 13. Tukrok River and Chukchi Sea sampling locations on either side of the Anigaaq ranger station.

During the field season of 2015, we designed a new sampling protocol looking at the differences in fish communities between the Tukrok River and the Chukchi Sea (Figure 13). The channel of the Tukrok River flows through wetlands and discharges in the ocean; however, water flow can often go upriver and the direction of flow is likely linked to 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 (Table 9).

Table 9. Species caught in the Chukchi Sea and Tukrok River during our sampling.

Chukchi Sea	Tukrok River	Both locations
Rainbow smelt	Capelin	Fourhorn sculpin
Blackline prickleback	Pacific herring	Ninespine stickleback
	Humpback whitefish	Pond smelt
	Least cisco	Saffron cod
	Pink salmon	Pacific sand lance
	Sheefish	Starry flounder
	Tubenose poacher	Unidentified sculpin

RESULTS

Below we briefly present summary results of the 2015 field effort. Raw data is included in the associated database with ARCN at National Park Service in Fairbanks, Alaska (Metadata in Appendix 2).

Water Quality

Water quality was likely a result of lagoon connectivity to the marine environment and the amount of freshwater input (Table 10). There were large differences in the salinities found between lagoons (ranging from 0.07-32.06 ppt). Krusenstern lagoon had the lowest salinity (1.78 ± 0.39 ppt), and was the least connected to the ocean; Kupik and Ikpek were the most saline, and both have multiple openings to the ocean. We did not find seasonal trends in salinities for Krusenstern, Aukulak and Kotlik lagoons, which were monitored through the season. Water temperature in these three lagoons decreased an average of 11.6°C (standard deviation= 1.6°C), pH decreased an average of 0.96 (standard deviation= 0.10) and dissolved oxygen increased, likely due to the decrease in water temperature.

Table 10. Mean physical water parameters for the seven sample sites in each lagoon in 2015

Lagoon	Temperature	Dissolved O₂	pH	Conductivity	Salinity	NTU	Chlorophyll	BGA
	°C	(mg/l)		mS/cm			RFU	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

Fish Catches

We captured 20 of the 33 species of fish that have been identified to date in the lagoons that we sampled this summer. We also caught 33 species new to specific lagoons. Krusenstern and Kotlik Lagoons were the most species rich of the lagoons we sampled, having a seasonal richness of 14 and 18 species respectively (Table 2).

Fish community composition correlated with the physical dynamics and characteristics of the lagoons. Variation in lagoon connectivity to the Chukchi Sea also affected the timing and duration lagoons were accessible to marine species. 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.

Fish Diets

Our preliminary observations of fish diets suggest that mysids, chironomid larvae and ninespine stickleback are critical for transferring energy from secondary producers to top predators (Figure 14). We will be creating length-weight regressions for the prey items found in the diets to find the percent compositions by weight.

Mysid densities in the lagoons were remarkable (based on anecdotal observations), and this was reflected in the diets of fish. Mysids were present in the stomachs of almost every species we sampled for diet, and some species fed on mysids almost exclusively. However, ninespine stickleback, which were also highly abundant in the lagoons, were fed on heavily by piscivorous fish (e.g., sheefish) and birds (e.g. Arctic terns). With the analysis of the fish diets, we have also found 8 new instances of invertebrates in the lagoons (Table 11).

Table 11. Invertebrate Species Inventory for Kotzebue Sound Lagoons based on four sampling periods since 1979³

Family	Latin Name	Common Name	Aukulak	Imik	Cape Krusenstern ¹			Bering Land Bridge ¹	
					Kotlik	Krusenstern	Sisualik	Kupik	Ikpek
Mysidae	<i>C. septemspinosa</i>	Sand Shrimp					1		4
	<i>Crangon Spp</i>	Unidentified Crangon Shrimp	2, 5 ⁴		5 ⁴	5	2	4,5	
	<i>Neomysis rayii</i>		5			5			
	<i>Acanthomysis dybowskii</i> ⁵		5		5			5	
	<i>Mysid Spp.</i>	Unidentified Mysid Shrimp				2	2		5
	<i>Macoma Spp</i>	Clam ²	2, 4, 5 ⁴	2	2, 4, 5 ⁴	2	2	4	4
	<i>Mytilus Spp.</i>	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

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

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).

³Additional 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. dybowskii* while Petryashov (2009) has classified it as *Neomysis awatschensis*.

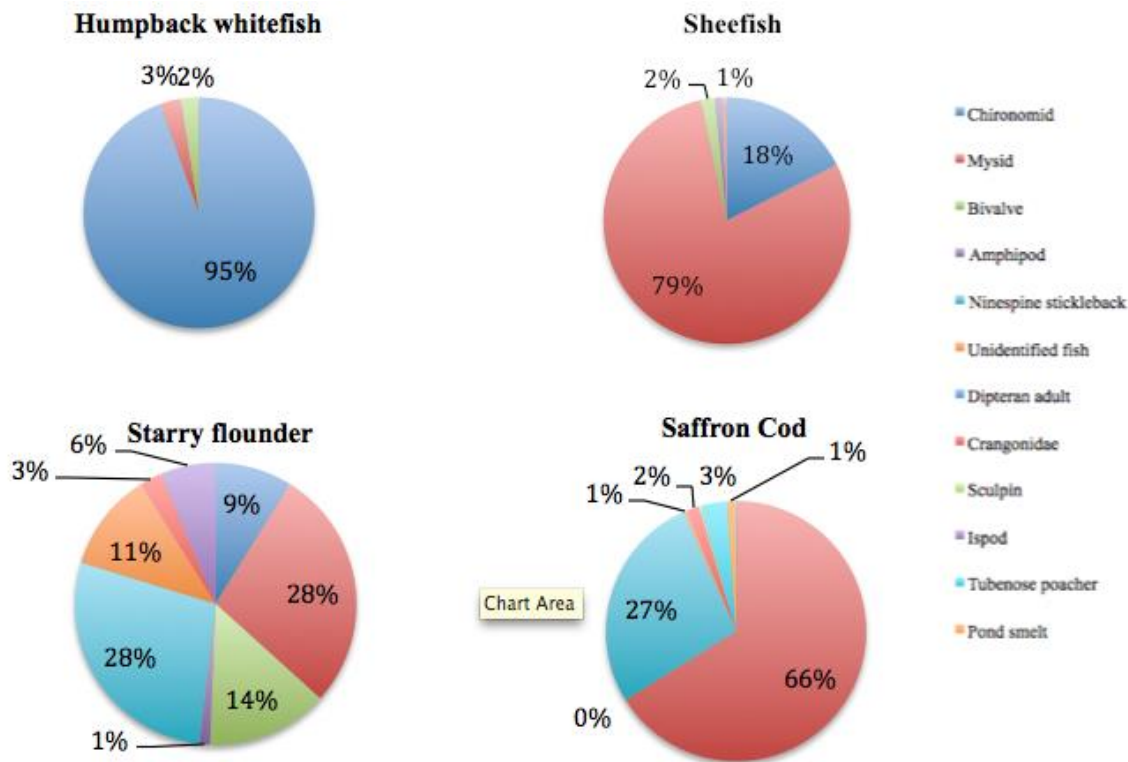


Figure 14. Preliminary diet results for humpback whitefish (n= 30), sheefish (n=10), starry flounder (n=9) and saffron cod (n=39). These percentages represent the percent composition by number of prey items, not by weight.

Laboratory work

During the winter of 2015-2016, we plan to complete the lab work for all the samples collected in the 2015 field season including diet samples from stomachs, otoliths, and fish tissue samples. The gastric lavage and stomach samples are being analyzed to determine the percent composition of the prey items in each diet sample. The otoliths collected (Table 12) will be analyzed to examine the growth rates of resident and migratory species. Microchemistry analysis of otoliths can provide key information on fish life history, age structure and migratory patterns. Sixty-four samples representing 9 species collected in the 3 Cape Krusenstern lagoons (Table 13) were sent to the State of Alaska Division of Environmental Health State Veterinarian laboratory for a contaminants analysis, including metals and organic contaminants (<https://dec.alaska.gov/eh/vet/fish.htm>). Opportunistically, and based on existing collaboration with Darcie Neff (NOAA affiliate) who is studying pond smelt in the Yukon River drainage, we gathered length-weight measurements, stomach samples and otoliths from 500 pond smelt, a poorly studied species. These samples will be used to help explain the basic ecology of this poorly studied species (Figure 15).

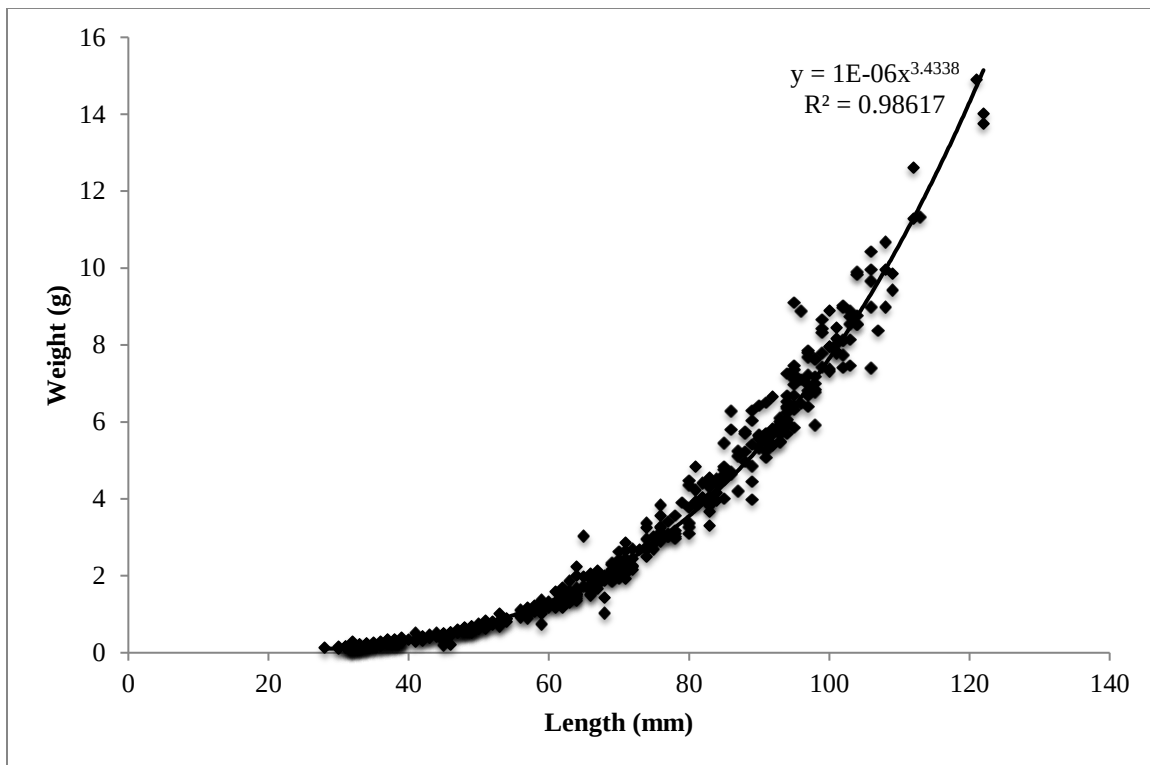


Figure 15. Relationship between weight and fork length for pond smelt (*Hypomesus oledus*).

Table 12. Number of otoliths collected per species per lagoon in the 2015 field season.

Species	Anigaaq	Aukulak	Kotlik	Krusenstern	Kupik	Ikpek	Total
Arctic Grayling	-	-	-	3	-	-	3
Dolly Varden	-	-	-	1	-	-	1
Fourhorn Sculpin	-	2	-	-	-	-	2
Humpback Whitefish	2	3	2	8	-	-	42
Least Cisco	1	24	1	-	-	-	26
Ninespine stickleback	36	-	-	5	-	-	86
Pacific Herring	1	1	1	7	-	2	93
Pink Salmon	1	-	-	-	-	-	1
Pond Smelt	19	-	-	535	15	-	569
Rainbow Smelt	-	1	1	-	-	1	3
Saffron Cod	-	18	5	-	-	-	23
Sandlance	2	-	48	-	-	-	68
Sheefish	-	-	2	3	-	-	5
Starry Flounder	16	-	1	2	-	-	19
Threespine Stickleback	-	-	-	1	-	-	1

Table 13. Number of contaminants samples collected per species for lagoons sampled in Cape Krusenstern National Monument. We did not sample for contaminants in Bering Land Bridge due to the logistic restrictions of keeping samples frozen.

Sample Size

Species	Krusenstern	Aukulak	Kotlik
Bering Cisco	5	0	0
Fourhorn Sculpin	2	0	5
Humpback Whitefish	6	4	0
Least Cisco	3	2	0
Ninespine Stickleback	5	0	0
Pacific Herring	5	0	0
Saffron Cod	0	5	5
Sheefish	3	0	0
Starry Flounder	5	4	5

Future Directions

The 2015 field season provided a better understanding of Arctic lagoon ecology, but also revealed some important knowledge gaps. The importance of mysids in the lagoon ecosystems. Mysids were highly abundant, were extremely important in the diets of fishes, and thus are likely key links between primary and secondary production and higher trophic levels within the lagoons. The importance of mysids raise several key questions: What do mysid diets consist of? How do mysid densities change through the season? How are mysids distributed within and among lagoons? Given their apparent importance, we aim to use our 2016 field efforts to help answering these questions.

The discovery of high densities of pond smelt in several lagoons was unexpected and led to several questions as what role this species plays in the lagoon aquatic ecosystem: What are the age structures of pond smelt populations and when and where are they spawning? How do pond smelt use lagoons? Are pond smelt present only seasonally or are they a resident species. Current laboratory work, coupled with further pond smelt collections in 2016 will aid in answering these questions.

Finally, through the fish diet samples collected during the 2015 season, we are gaining valuable insight into the trophic dynamics of these lagoons. In 2016, we hope to further investigate the spatial and temporal aspects of lagoon trophic dynamics. Using data from 2015, we will create a focused study design that will examine how diets of key species such as humpback whitefish vary seasonally and among lagoons. The temporal and spatial variation in lagoon connectivity to the marine environment may be reflected in fish diets and ultimately lagoon trophic dynamics.

Acknowledgements

We would like to acknowledge the National Parks Foundation for the funding supporting this research through the Coastal Settlement Fund and the Western Arctic National Parklands and NPS Alaska Regional Office for extensive logistical support. This work would not have been possible without the following people, who made substantial contributions to the project planning, fieldwork, laboratory work, and logistics for this project: Jim Lawler, Peter Neitlich, Tahzay Jones, Nicole Farnham, Ryan Sherman, Stacia Backensto, Marci Johnson, Dan Shelden, Bob Schaeffer, Dave Rosser, Carrie Haddad, Melanie Flamme, Cyrus Harris, Colin McKenzie, Ben Meyer, Kristin Rine, Kristin Sellmer, Erik Schoen and Mark Wipfli. This project was also supported by a host of staff from the Wildlife Conservation Society and UAF, to whom we are very grateful.

LITERATURE CITED

- Blaylock, W.M. and J.P. Houghton. 1983. 1983 Lagoon Investigations. In. Supplement to Environmental Baseline Studies, Red Dog Project. See Dames and Moore (1983b).
- Blaylock, W.M. and E.E. Erikson. 1983. Marine Biology. Chapter 4 in Environmental Baseline Studies. See Dames and Moore (1983a).
- Comeau, S., G. Gorsky, R. Jeffree, J. L. Teyssié, and J. P. Gattuso. 2009. Impact of ocean acidification on a key Arctic pelagic mollusc (*Limacina helicina*). *Biogeosciences*, 6, 1877-1882.
- Dames and Moore, 1983a. Environmental baseline studies, Red Dog Project. Prepared for Cominco Alaska, Inc. Available at University of Alaska, Fairbanks – Rasmussen Library.
- Dames and Moore, 1983b. Supplement to Environmental Baseline Studies, Red Dog Project. Dames and Moore. Available at University of Alaska, Fairbanks – Rasmussen Library.
- Erikson, D.E. 1983. Fall 1983 Bird Survey. In: Supplement to Environmental Baseline Studies, Red Dog Project. See Dames and Moore (1983b).
- Jarvela, L.E., and L.K. Thorsteinson. 1999. The epipelagic fish community of Beaufort Sea coastal waters, Alaska. *Arctic* 52(1): 80-94.
- Johnson, S.W., J.F. Thedinga, A.D. Neff, and G.A. Hoffman. 2010. Fish fauna in nearshore waters of a barrier island in the western Beaufort Sea, Alaska. U.S. Department of Commerce, NOAA Technical Memorandum: NMFS-AFSC-210, 28p.
- National Park Service (NPS) 1986a. Cape Krusenstern National Monument General Management Plan. U.S. Department of the Interior. 220p.
- National Park Service (NPS) 1986b. Bering Land Bridge National Preserve, Alaska. General Management Plan, Land Protection Plan, Wilderness Suitability Review. U.S. Department of the Interior.
- Petryashov, V.V. (2009). Illustrated keys to free-living invertebrates of Eurasian Arctic seas and adjacent deep waters, Vol. 1. *Rotifera, Pycnogonida, Cirripedia, Leptostraca, Mysidacea, Hyperidea, Caprellidea, Euphausiacea, Dendrobranchiata, Pleocyemata, Anomura, and Brachyura*. Alaska Sea Grant, University of Alaska Fairbanks.
- Raymond, J.P., M. Merritt, and C. Skaugstad. 1984. Nearshore fishes of Kotzebue Sound in summer. Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement and Development (FRED) Report. Number 37.
- Reynolds, M.J. 2012. Arctic Coastal Lagoons of Cape Krusenstern National Monument: Subsistence, Ecosystem Characterization, and Management. PhD Dissertation. East Carolina University. 290pp.
- Reynolds, M., T. Reynolds, C. Lean, and L. Clough. 2005. Cape Krusenstern National Monument: Year-round sampling to characterize water quality, species richness, and food web structure in five coastal lagoons. *Alaska Park Science* 4(1): 38-43.
- Reynolds, M. and L.M. Clough. 2010. The development of a long-term monitoring protocol for the coastal lagoons of Cape Krusenstern National Monument: Pilot sampling July 2009. National Park Service, Natural Resource Program Center. Fort Collins, Colorado. Natural Resource Data Series NPS/ARC/NRDS-2010/127. Published Report - 2167248.
- Robards, M.D., J.F. Piatt, A. Kettle, and A.A. Abookire 1999. Temporal and geographic variation in fish communities of Lower Cook Inlet, Alaska. *Fishery Bulletin* 97, 962-977.
- Robards, M.D. 2014. Coastal lagoon community and Ecological monitoring in the Southern Chukchi Sea National Park Unit over five decades – Status and 2012 Field Sampling Report. Report by the Wildlife Conservation Society for the US National Park Service, Cooperative Ecosystem Studies Unit Agreement #: P12AC14948.
- Steinacher, M., F. Joos, T. L. Frolicher, G. K. Plattner, and S. C. Doney. 2009. Imminent ocean acidification in the Arctic projected with the NCAR global coupled carbon cycle-climate model. *Biogeosciences* 6, 515-533.

Appendix

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	

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

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	

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

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. Avian Species Inventory for Southern Chukchi Sea Lagoons based on opportunistic observations during field sampling 2012. Data table based on (unpublished data) documenting a full species inventory for coastal avifauna from Wales to Point Hope.

<u>Common Name</u>	<u>Scientific Name</u>	Cape Krusenstern					Be
		Aukulak	Imik	Kotlik	Krusenstern	Sisualik	
Greater White-fronted Goose	<i>Anser albifrons</i>						
Emperor Goose	<i>Chen canagica</i>						Me
Snow Goose	<i>Chen caerulescens</i>						
Brant	<i>Branta bernicla</i>				Medium		Me
Cackling Goose	<i>Branta hutchinsii</i>						
Canada Goose	<i>Branta canadensis</i>						
Trumpeter Swan	<i>Cygnus buccinator</i>						
Tundra Swan	<i>Cygnus columbianus</i>			Low	Low		
Whooper Swan	<i>Cygnus cygnus</i>						
Gadwall	<i>Anas strepera</i>						
Eurasian Wigeon	<i>Anas penelope</i>						
American Wigeon	<i>Anas americana</i>						
Mallard	<i>Anas platyrhynchos</i>						
Northern Shoveler	<i>Anas clypeata</i>						
Northern Pintail	<i>Anas acuta</i>						L
Green-winged Teal	<i>Anas crecca</i>						
Blue-winged Teal	<i>Anas discors</i>						
Canvasback	<i>Aythya valisineria</i>						
Redhead	<i>Aythya americana</i>						
Ring-necked Duck	<i>Aythya collaris</i>						
Greater Scaup	<i>Aythya marila</i>			Medium	Medium		
Lesser Scaup	<i>Aythya affinis</i>						
Steller's Eider	<i>Polysticta stelleri</i>						
Spectacled Eider	<i>Somateria fischeri</i>						
King Eider	<i>Somateria spectabilis</i>						
Common Eider	<i>Somateria mollissima</i>						Me
Harlequin Duck	<i>Histrionicus histrionicus</i>	Low			Low		Me
Surf Scoter	<i>Melanitta perspicillata</i>						
White-winged Scoter	<i>Melanitta fusca</i>						
Black Scoter	<i>Melanitta americana</i>						
Long-tailed Duck	<i>Clangula hyemalis</i>			Low	Very High		Very
Bufflehead	<i>Bucephala albeola</i>						
Common Goldeneye	<i>Bucephala clangula</i>						
Barrow's Goldeneye	<i>Bucephala islandica</i>						
Common Merganser	<i>Mergus merganser</i>						
Red-breasted Merganser	<i>Mergus serrator</i>						
Spruce Grouse	<i>Falcipennis canadensis</i>						
Willow Ptarmigan	<i>Lagopus lagopus</i>						
Rock Ptarmigan	<i>Lagopus muta</i>						
Red-throated Loon	<i>Gavia stellata</i>						
Arctic Loon	<i>Gavia arctica</i>						
Pacific Loon	<i>Gavia pacifica</i>	Low		Low	Low		Med
Common Loon	<i>Gavia immer</i>						

Appendix 2. Avian Species Inventory for Southern Chukchi Sea Lagoons based on opportunistic observations during field sampling 2012. Data table based on (unpublished data) documenting a full species inventory for coastal avifauna from Wales to Point Hope.

<u>Common Name</u>	<u>Scientific Name</u>	Cape Krusenstern					Be
		Aukulak	Imik	Kotlik	Krusenstern	Sisualik	
Yellow-billed Loon	<i>Gavia adamsii</i>				Low		L
Horned Grebe	<i>Podiceps auritus</i>						
Red-necked Grebe	<i>Podiceps grisegena</i>						
Northern Fulmar	<i>Fulmarus glacialis</i>						
Short-tailed Shearwater	<i>Puffinus tenuirostris</i>						
Fork-tailed Storm-Petrel	<i>Oceanodroma furcata</i>						
Brandt's Cormorant	<i>Phalacrocorax penicillatus</i>						
Pelagic Cormorant	<i>Phalacrocorax pelagicus</i>						
Osprey	<i>Pandion haliaetus</i>						
Bald Eagle	<i>Haliaeetus leucocephalus</i>						
Northern Harrier	<i>Circus cyaneus</i>				Low		
Sharp-shinned Hawk	<i>Accipiter striatus</i>						
Northern Goshawk	<i>Accipiter gentilis</i>						
Red-tailed Hawk	<i>Buteo jamaicensis</i>						
Rough-legged Hawk	<i>Buteo lagopus</i>						
Golden Eagle	<i>Aquila chrysaetos</i>						
American Kestrel	<i>Falco sparverius</i>						
Merlin	<i>Falco columbarius</i>						
Gyr Falcon	<i>Falco rusticolus</i>						
Peregrine Falcon	<i>Falco peregrinus</i>						
Sandhill Crane	<i>Grus canadensis</i>						L
Black-bellied Plover	<i>Pluvialis squatarola</i>						
American Golden-Plover	<i>Pluvialis dominica</i>						
Pacific Golden-Plover	<i>Pluvialis fulva</i>						
Lesser Sand Plover	<i>Charadrius mongolu</i>						
Semipalmated Plover	<i>Charadrius semipalmatus</i>						
Spotted Sandpiper	<i>Actitis macularius</i>						
Solitary Sandpiper	<i>Tringa solitaria</i>						
Wandering Tattler	<i>Tringa incana</i>						
Lesser Yellowlegs	<i>Tringa flavipes</i>						
Upland Sandpiper	<i>Bartramia longicauda</i>						
Eskimo Curlew	<i>Numenius borealis</i>						
Whimbrel	<i>Numenius phaeopus</i>						L
Bristle-thighed Curlew	<i>Numenius tahitiensis</i>						
Hudsonian Godwit	<i>Limosa haemastica</i>						
Bar-tailed Godwit	<i>Limosa lapponica</i>						
Marbled Godwit	<i>Limosa fedoa</i>						
Ruddy Turnstone	<i>Arenaria interpres</i>						
Black Turnstone	<i>Arenaria melanocephala</i>						
Surfbird	<i>Aphriza virgata</i>						
Red Knot	<i>Calidris canutus</i>						
Sanderling	<i>Calidris alba</i>						
Semipalmated Sandpiper	<i>Calidris pusilla</i>						H

Appendix 2. Avian Species Inventory for Southern Chukchi Sea Lagoons based on opportunistic observations during field sampling 2012. Data table based on (unpublished data) documenting a full species inventory for coastal avifauna from Wales to Point Hope.

<u>Common Name</u>	<u>Scientific Name</u>	Cape Krusenstern					Be
		Aukulak	Imik	Kotlik	Krusenstern	Sisualik	
Western Sandpiper	<i>Calidris mauri</i>						L
Red-necked Stint	<i>Calidris ruficollis</i>						
Least Sandpiper	<i>Calidris minutilla</i>	Medium		Medium			
Baird's Sandpiper	<i>Calidris bairdii</i>						
Pectoral Sandpiper	<i>Calidris melanotos</i>						
Sharp-tailed Sandpiper	<i>Calidris acuminata</i>						
Rock Sandpiper	<i>Calidris ptilocnemis</i>						
Curlew Sandpiper	<i>Calidris ferruginea</i>						
Dunlin	<i>Calidris alpina</i>	Low					H
Stilt Sandpiper	<i>Calidris himantopus</i>						
Spoon-billed Sandpiper	<i>Eurynorhynchus pygmeus</i>						
Buff-breasted Sandpiper	<i>Tryngites subruficollis</i>						
Ruff	<i>Philomachus pugnax</i>						
Long-billed Dowitcher	<i>Limnodromus scolopaceus</i>						
Wilson's Snipe	<i>Gallinago delicata</i>						
Red-necked Phalarope	<i>Phalaropus lobatus</i>			Low			
Red Phalarope	<i>Phalaropus fulicarius</i>						
Black-legged Kittiwake	<i>Rissa tridactyla</i>			Medium			H
Red-legged Kittiwake	<i>Rissa brevirostris</i>						
Ivory Gull	<i>Pagophila eburnea</i>						
Sabine's Gull	<i>Xema sabini</i>						
Bonaparte's Gull	<i>Chroicocephalus philadelphia</i>						Me
Ross's Gull	<i>Rhodostethia rosea</i>						
Mew Gull	<i>Larus canus</i>						
Herring Gull	<i>Larus argentatus</i>						
Iceland Gull	<i>Larus glaucoides</i>						
Slaty-backed Gull	<i>Larus schistisagus</i>						
Glaucous-winged Gull	<i>Larus glaucescens</i>						
Glaucous Gull	<i>Larus hyperboreus</i>	Low		Low			Me
Aleutian Tern	<i>Onychoprion aleuticus</i>			Low			
Arctic Tern	<i>Sterna paradisaea</i>			Medium	Low		Me
Pomarine Jaeger	<i>Stercorarius pomarinus</i>						
Parasitic Jaeger	<i>Stercorarius parasiticus</i>						L
Long-tailed Jaeger	<i>Stercorarius longicaudus</i>				Low		
Common Murre	<i>Uria aalge</i>						
Thick-billed Murre	<i>Uria lomvia</i>						
Black Guillemot	<i>Cephus grylle</i>						
Pigeon Guillemot	<i>Cephus columba</i>						
Kittlitz's Murrelet	<i>Brachyramphus brevirostris</i>						
Parakeet Auklet	<i>Aethia psittacula</i>						
Least Auklet	<i>Aethia pusilla</i>						
Crested Auklet	<i>Aethia cristatella</i>						
Horned Puffin	<i>Fratercula corniculata</i>						

Appendix 2. Avian Species Inventory for Southern Chukchi Sea Lagoons based on opportunistic observations during field sampling 2012. Data table based on (unpublished data) documenting a full species inventory for coastal avifauna from Wales to Point Hope.

<u>Common Name</u>	<u>Scientific Name</u>	Cape Krusenstern					Be
		Aukulak	Imik	Kotlik	Krusenstern	Sisualik	
Tufted Puffin	<i>Fratercula cirrhata</i>						
Great Horned Owl	<i>Bubo virginianus</i>						
Snowy Owl	<i>Bubo scandiacus</i>						
Northern Hawk Owl	<i>Surnia ulula</i>						
Great Gray Owl	<i>Strix nebulosa</i>						
Short-eared Owl	<i>Asio flammeus</i>						
Boreal Owl	<i>Aegolius funereus</i>				Low		
Belted Kingfisher	<i>Megaceryle alcyon</i>						
Downy Woodpecker	<i>Picoides pubescens</i>						
American Three-toed Woodpecker	<i>Picoides dorsalis</i>						
Northern Flicker	<i>Colaptes auratus</i>						
Northern Shrike	<i>Lanius excubitor</i>						
Olive-sided Flycatcher	<i>Contopus cooperi</i>						
Alder Flycatcher	<i>Empidonax alnorum</i>						
Say's Phoebe	<i>Sayornis saya</i>						
Eastern Kingbird	<i>Tyrannus tyrannus</i>						
Gray Jay	<i>Perisoreus canadensis</i>						
Clark's Nutcracker	<i>Nucifraga columbiana</i>						
Black-billed Magpie	<i>Pica hudsonia</i>						
Common Raven	<i>Corvus corax</i>						
Horned Lark	<i>Eremophila alpestris</i>						
Tree Swallow	<i>Tachycineta bicolor</i>				Low		
Violet-green Swallow	<i>Tachycineta thalassina</i>						
Bank Swallow	<i>Riparia riparia</i>						
Cliff Swallow	<i>Petrochelidon pyrrhonota</i>						
Barn Swallow	<i>Hirundo rustica</i>						
Black-capped Chickadee	<i>Poecile atricapillus</i>						
Boreal Chickadee	<i>Poecile hudsonicus</i>						
Gray-headed Chickadee	<i>Poecile cinctu</i>						
American Dipper	<i>Cinclus mexicanus</i>						
Ruby-crowned Kinglet	<i>Regulus calendula</i>						
Arctic Warbler	<i>Phylloscopus borealis</i>						
Bluethroat	<i>Luscinia svecica</i>						
Northern Wheatear	<i>Oenanthe oenanthe</i>				Low		
Mountain Bluebird	<i>Sialia currucoides</i>						
Townsend's Solitaire	<i>Myadestes townsendi</i>						
Gray-cheeked Thrush	<i>Catharus minimus</i>						
American Robin	<i>Turdus migratorius</i>						
Varied Thrush	<i>Ixoreus naevius</i>						
European Starling	<i>Sturnus vulgaris</i>						
Eastern Yellow Wagtail	<i>Motacilla tschutschensis</i>						
White Wagtail	<i>Motacilla alba</i>						
American Pipit	<i>Anthus rubescens</i>						

Appendix 2. Avian Species Inventory for Southern Chukchi Sea Lagoons based on opportunistic observations during field sampling 2012. Data table based on (unpublished data) documenting a full species inventory for coastal avifauna from Wales to Point Hope.

<u>Common Name</u>	<u>Scientific Name</u>	Cape Krusenstern					Be
		Aukulak	Imik	Kotlik	Krusenstern	Sisualik	
Red-throated Pipit	<i>Anthus cervinus</i>						
Bohemian Waxwing	<i>Bombycilla garrulus</i>						
Lapland Longspur	<i>Calcarius lapponicus</i>						
Smith's Longspur	<i>Calcarius pictus</i>						
Snow Bunting	<i>Plectrophenax nivalis</i>						
McKay's Bunting	<i>Plectrophenax hyperboreus</i>						
Northern Waterthrush	<i>Parkesia noveboracensis</i>						
Orange-crowned Warbler	<i>Oreothlypis celata</i>						
Yellow Warbler	<i>Setophaga petechia</i>						
Blackpoll Warbler	<i>Setophaga striata</i>						
Yellow-rumped Warbler	<i>Setophaga coronata</i>						
Wilson's Warbler	<i>Cardellina pusilla</i>						
American Tree Sparrow	<i>Spizella arborea</i>						
Savannah Sparrow	<i>Passerculus sandwichensis</i>	Low					
Fox Sparrow	<i>Passerella iliaca</i>				Low		
Lincoln's Sparrow	<i>Melospiza lincolnii</i>						
White-crowned Sparrow	<i>Zonotrichia leucophrys</i>						
Golden-crowned Sparrow	<i>Zonotrichia atricapilla</i>						
Dark-eyed Junco	<i>Junco hyemalis</i>						
Red-winged Blackbird	<i>Agelaius phoeniceus</i>						
Rusty Blackbird	<i>Euphagus carolinus</i>						
Common Grackle	<i>Quiscalus quiscula</i>						
Brambling	<i>Fringilla montifringilla</i>						
Gray-crowned Rosy-Finch	<i>Leucosticte tephrocotis</i>						
Pine Grosbeak	<i>Pinicola enucleator</i>						
White-winged Crossbill	<i>Loxia leucoptera</i>						
Common Redpoll	<i>Acanthis flammea</i>						
Hoary Redpoll	<i>Acanthis hornemanni</i>						
Hawfinch	<i>Coccothraustes coccothraustes</i>						

Seen at low (1-9 birds), medium (10-99 birds), high (100-999) or very high (>999) birds per sighting (including young).

*Confirmed as nesting or with flightless young denoted with

Appendix 3. Metadata for Excel Archive

Tab 1: Sample Locations

Includes all sites sampled by Melinda Reynolds and Martin Robards.

- Field 1: Park = National Park Unit
- Field 2: ID = Location Code
- Field 3: Latitude
- Field 4: Longitude
- Field 5: Source

Tab 2: Reynolds Thesis Sampling Dates

No sampling dates are provided in the thesis. These data provided by Melinda Reynolds (*pers. comm.*).

- Field 1: Sampling Period = Per thesis bins for data
- Field 2: Month
- Field 3: Lagoon
- Field 4: Sampling Dates = In some cases only a window of time available.

Tab 3: Reynolds Physio Data

Physical water attributes for Melinda Reynolds' sampling efforts in 2003/2004 and 2009.

- Field 1: Date
- Field 2: Lagoon
- Field 3: Station = Location (See Tab 1)
- Field 4: Salinity
- Field 5: Dissolved Oxygen
- Field 6: Water Temperature
- Field 7: Dissolved Oxygen (D.O.)
- Field 8: Conductivity (Cond.)
- Field 9: pH
- Field 10: Water Depth
- Field 11: Source

Tab 4: Robards Physical Data

All data from sonde (field readings) and time of filtering for Chlorophyll samples (for lab analysis). Note Chlorophyll samples taken at same time as sonde deployment.

- Field 1: Lagoon
- Field 2: Site = Location (see Tab 1)
- Field 3: Depth = Measured with hand-held depth sonar
- Field 4: Date
- Field 5: Time
- Field 6: Chlorophyll filtered (time in the field)
- Field 7: Temperature
- Field 8: MicroSiemens
- Field 9: Salinity

Field 10: Depth = measured with sonde
Field 11: pH
Field 12: PAR (aberrant readings in 2012)
Field 13: NTU
Field 14: Chlorophyll (aberrant readings in 2012)
Field 15: Dissolved oxygen (%)
Field 16: Dissolved oxygen (mg/l)
Field 17: TSS (samples taken for Total Suspended Solids – See Tab 11)
Field 18: Comments

Tab 5: Nutrients-pigments

Field 1: Date
Field 2: Month
Field 3: Year
Field 4: Lagoon
Field 5: Station or Sample
Field 6: Surface or Bottom Collection
Field 7: DKN (from Reynolds)
Field 8: DKN (from Reynolds)
Field 9: TKN (from Reynolds)
Field 10: TKN (from Reynolds)
Field 11: TKP (from Reynolds)
Field 12: TKP (from Reynolds)
Field 13: Average Chlorophyll a (ug/l)
Field 14: Chlorophyll a (SD)
Field 15: Average Phaeophytin (from Reynolds)
Field 16: Source
Field 17: Detection Limit for Chlorophyll a.

Tab 6: Robards_Lab Chl_Raw (Raw Laboratory Data for Chlorophyll analysis)

Field 1: Sample ID (lab assigned)
Field 2: ClientSample ID (lab assigned)
Field 3: Field ID and replicate (of 3) (per field protocol names)
Field 4: Site ID (location in lagoon – blind to replicate)
Field 5: Lagoon
Field 6: Depth (0 = surface)
Field 7: Matrix
Field 8: Collection Date and Time
Field 9: Chlorophyll a

Tab 7: Robards_Ponar

Field 1: Lagoon
Field 2: Site

Field 3: Depth
Field 4: Date
Field 5: Time
Field 6: Notes on Sample
Field 7: Taxa observed.

Tab 8: Beach Seines

Field 1: Date (needs completing from report)
Field 2: Month
Field 3: Lagoon
Field 4: Site
Field 5: Time
Field 6: Set number (replicate)
Field 7: Common Name
Field 8: Latin Name
Field 9: Catch (number caught)
Field 10: Archival Photograph
Field 11: Reporting (full details in which report).

Tab 9: Gill Nets

Field 1: Date
Field 2: Month
Field 3: Lagoon
Field 4: Site
Field 5: Set on Day
Field 6: Time into water
Field 7: Time out of water
Field 8: Soak time
Field 9: Fish (species)
Field 10: # fish (number caught)
Field 11: Fish observations and which mesh caught in.

Tab 10: Fish Data (Morphometrics etc)

Field 1: Sampling lead (Primary investigator)
Field 2: Date
Field 3: Month
Field 4: Time
Field 5: Lagoon
Field 6: Location ID (place in lagoon)
Field 7: Collection Method
Field 8: Common Name
Field 9: Scientific Name
Field 10: Total Length

Tab 11: TSS (Total Suspended Solids)

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 of TSS (mg)
Field 8: TSS (mg/l)