Protecting Coastal Lagoons in the Southern Chukchi: Project Chariot Revisited

Fieldwork Summary for Summer 2018

March 2019

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Executive Summary

The southeastern Chukchi Sea is a highly productive marine ecosystem. Nearshore habitats are heavily used by local people for commercial and subsistence harvest; they also provide important foraging habitat, proximity to shelter, and overwintering habitat for all life stages of many ecologically and locally/economically important fish species (Craig 1984; George et al. 2007; Johnson et al. 2007; Logerwell et al. 2015; Whiting et al. 2011). Coastal lagoons are a dominant landscape feature in this region, comprising over a third (37%) of the Arctic coastline between Wales and the Canadian border (Figure 1). These bodies of water provide critical habitat for migratory fish (e.g., salmon, whitefish) and other ecologically important forage fish (e.g., herring, smelt), as well as staging habitat for migratory shorebirds and waterfowl. Coastal community members are increasingly interested in documenting the ecology and importance of fish and invertebrates in these lagoons due to concerns about potential impacts from climate change, increased economic development, and the potential for coastal oil spill impacts (LGL 2011; Rand and Logerwell 2011).

Our research efforts during summer 2018, included a focus on the coastal areas around Cape Thompson in the North Slope Borough of Alaska, addressing the need for baseline information on the structure and function of lagoons in the area. Three lagoons were visited within the boundary of the North Slope Borough: Kemegrak, Akoviknak and Atosik. We also sampled one additional lagoon just south of the boundary of the North Slope borough, Singoalik, which is in Northwest Arctic Borough.

Previously, the most significant lagoon research efforts between Kivalina and Cape Thompson occurred 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. Apart from these research efforts, little research has been published about the presence and timing of habitat use by fishes in the coastal habitats of this area, despite their importance for food security and ecosystem health in the region.

We collected data on physical water parameters including primary productivity, with samples at 4-7 individual sites per lagoon. These sites included: the marine edge, the terrestrial edge, fresh water inlets, the outlet of the lagoon to the marine environment, and three random sample sites based on established protocols developed as part of the National Park Service's Arctic Lagoon Vital Sign (Jones and Apsens, 2017). We sampled fish community composition and abundance using a beach seine and experimental gill net, and performed zooplankton tows at each study site. We performed 3-5 tows per lagoon. We opportunistically recorded observations made by Point Hope community members who we encountered during sampling efforts.

We spent one day sampling at each lagoon, with the exception of Akoviknak which we sampled over the course of two days. We traveled to Cape Thompson aboard the US Fish and Wildlife vessel the R/V *Tiglax* which we used as a base of operations. The *Tiglax* provided us with food and accommodations as well as a place to process and store samples. During the day we loaded sampling gear on to a larger inflatable boat and were taken to shore in the general vicinity of the target lagoon. Within each visited lagoon, we used a small inflatable boat equipped with a 9.9 horsepower outboard motor.

Preliminary results from the 2018 field season reflect findings from 16 beach seine sets and 20 gill net sets, as well as point data on physiochemical water properties taken at each lagoon. These data on community composition and relative abundance will supplement laboratory analysis of zooplankton and fish samples in collaboration with the University of Alaska, Fairbanks, and other collaborators. Laboratory analysis will address several central research themes including genetic relationship between fish from closely separated study sites, mercury levels in fish from closely separated study sites, variation in stable isotope values in whitefish with geographic region, age, sex, and fork-length, and total mercury levels in relationship to trophic level.

Lagoons varied in their physical water parameters. None of the lagoons sampled were open to the marine environment at the time of sampling. Temperature readings varied between lagoons, with the highest overall temperature occurring at Kemegrak Lagoon (16.35 ± 1.82°C) and the lowest at Mapsorak (8.86 ± 0.25°C). Salinity levels at all lagoons were relatively low, ranging from 0.60 ± 0.07 ppt at Mapsorak to 9.47 ± 0.45 ppt at Singoalik. Low salinity levels and higher temperature readings likely reflect the absence of recent influxes of colder saline water from the marine system. This exchange generally exists in lagoons around Cape Krusenstern (Smith et al., 2019), which are open to the marine environment at the beginning of the open water season, but gradually close as the summer progresses. Temperature readings recorded in the 1983 report by Dames and Moore, for instance, revealed lower overall temperatures at lagoons open to the marine environment particularly at sample stations directly inside the mouth of the lagoon, indicating that influx of colder water from the ocean has significant impact on the overall temperature in the main body of the lagoon. Primary production was highest at Kemegrak lagoon.

We recorded seven species of fishes and one unidentified larval fish. Highest species diversity occurred at Singoalik Lagoon with six species captured. Fishes of the largest size class (100-199mm and 200+ mm) were found at Akoviknak, all of which were Least cisco. Sampling at both Atosik and Mapsorak did not catch any fish. Important forage species captured included ninespine stickleback, pond smelt and threespine stickleback.

We conducted informal interviews with members of the local community through chance encounters on the beach during sampling events. Conversations with members of the Point Hope community indicate that the community is keen to see more scientific monitoring in the area.

Introduction

The southeastern Chukchi Sea is a highly productive marine ecosystem (Springer and McKay, 1993). Nearshore habitats are heavily used by local peoples for commercial and subsistence harvest; they also provide important foraging habitat, proximity to shelter, and overwintering habitat for multiple life stages of many fish species (Craig 1984; George et al. 2007; Johnson et al. 2007; Logerwell et al. 2015; Whiting et al. 2011). In turn, these fishes are an important food source for marine birds and mammals (Piatt et al. 1991) and local residents. Residents of the region obtain up to 70% of their annual wild food harvest from the fish, marine mammals, and birds that depend on nearshore habitat (Whiting et al. 2011; Jones, 2006). Coastal lagoons in particular are a focal area where fishing for important subsistence species such as humpback whitefish takes place within these coastal ecosystems (Haynes et. al., 2017).

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). These bodies of water provide critical habitat for migratory fish (e.g., salmon, whitefish) and other ecologically important forage fish (e.g., herring, smelt), as well as staging habitat for migratory shorebirds and waterfowl. Coastal community members are increasingly interested in the ecology of fish and invertebrates in nearshore Arctic waters, including those associated with coastal lagoons, due to concerns about potential impacts from climate change, increased economic development, and the potential for coastal oil spill impacts (LGL 2011; Rand and Logerwell 2011). However, variation in both intra- and inter-lagoon dynamics remain poorly understood. Previous surveys of Chukchi Sea coastal waters emphasized the abundance and diversity of Arctic Ocean fishes, and more recently, the slow intrusion of Bering Sea species (e.g., Norcross et al. 2010; Eisner et al. 2013; Logerwell et al. 2015). Large-scale studies have been conducted throughout the southern Chukchi Sea over the past 10 years, but they have typically focused on offshore waters (>5 m deep). A comprehensive synthesis of fish surveys conducted in the eastern Chukchi Sea during 2007-2012 highlights the tremendous gap for nearshore and beach habitats, identifying "surveys of the lagoons of the Chukchi Sea" as a key need (Logerwell et al. 2015).

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 mollusks and phytoplankton (Comeau et al., 2009) that are key trophic elements within these Arctic foodwebs.

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 and through the Northwest Passage. The southern Chukchi is located just north of Bering Strait, an area already experiencing increasing shipping traffic, with significant volumes of transported petroleum products (particularly in Russian waters) and lead/zinc from the Red Dog mine located close to Kivalina. Regardless of place of origin, be it Russian or American waters, accidental oil spills from vessels transiting this area would most likely impact the Alaska coast due to the circulation of currents in the region. Consequently, baseline information is needed in order to directly inform coastal protection by the Alaska Department of Environmental Conservation's (ADEC) Geographic Response Strategies (GRS) and the NOAA-hosted Arctic Environmental Response Management Application (ERMA).

Baseline data will be critical for providing the on-the-ground information that can aid in the logistics and prioritization of the different areas within a prospective spill zone that are documented by these efforts. Limited response resources will require an approach that combines diversion of oil away from some key habitats and sacrifice of those that are less ecologically important (and consequently avoiding those areas important for food security). Furthermore, many of the sites currently within strategic planning documents are the result of tabletop exercises, and do not reflect on-the-ground conditions or equipment deployment practicalities. Firsthand experience with local conditions and addressing these practicalities of equipment deployment prior to a real event will avoid wasting both time and resources during the critical moments after an accident.

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 (sites >44 in Figure 1) have been more comprehensively studied due to the relatively greater interest as part of oil and gas environmental assessment activities. 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. Kevin Boswell, Brenda Norcross, Ron Heintz and colleagues are currently finalizing 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."

In 2007, the Arctic Network Inventory and Monitoring Program began developing a monitoring protocol for coastal lagoons located in Cape Krusenstern and Being Land Bridge NPS units (Sites 1 to 11 in Figure 1). An ongoing field effort at these lagoons, led by Wildlife Conservation Society in partnership with the National Park Service, seeks to gather baseline information in the effort to inform a standardized sampling protocol for coastal lagoon ecosystems (Robards, 2014; Haynes et. al., 2017; Jones and Aspens, 2017).

Within the focal study area (the coastal area south of the village of Point Hope extending to the border of the North Slope Borough) there are five lagoons: Aiautak, Kemegrak, Akoviknak, Atosik and Mapsorak (Figure 2; Table 1). We also included in our area of interest, lagoons just south of the boundary of the North Slope Borough, including Singoalik due to the in-place logistics for sampling additional lagoons. The closest village to all study sites is Point Hope (approximately 32 km north of Kemegrak Lagoon, our northernmost study site). The closest village to the south is Kivalina (approximately 40 km south of Singoalik). Many residents of these villages use camps along the coastline, including around several of these lagoons. The port for Red Dog Mine, one of the world's largest lead and zinc mines, is located approximately 70 km south of Singoalik.

Of the focal lagoons, Atosik is the smallest (<0.5 km^2) and Kemegrak the largest (3.6 km^2) (Table 1). All five lagoons share coastline directly with the ocean environment rather than a sound or other protected marine environment as is the case with some lagoons at the Cape Krusenstern.

Prior Coastal Lagoon Research in the Lagoons of Cape Thompson

The most significant lagoon research efforts between Kivalina and Cape Thompson occurred 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. While a study by Dames and Moore (1983) performed extensive data collection on fish communities, physiochemical properties, bird community composition and behavior as well as sediment composition and benthos/invertebrate communities in lagoons between Kivalina and Cape Thompson, this study only included one of the study sites included in this report – Singoalik. Dames and Moore (1983) captured mostly Arctic char and grayling at Singoalik Lagoon as well as a small number of anadromous and freshwater species. Additionally, they encountered a large number of juvenile pink salmon. The lagoon was open to the ocean at the time of the Dames and Moore sampling effort. Singoalik, Kemegrak, Akoviknak, Atosik and

Mapsorak lagoons were also sampled for zooplankton community composition and physiochemical properties by Johnson (1961) as well as Tash and Armitage (1967). Results from Johnson (1961) reveal significant differences in community composition between lagoons depending on their relationship with the marine edge and influx of fresh water. Tash and Armitage (1967) profiled a series of study sites which included lakes and pools in addition to lagoon habitat. Results from their study show that three major species preferred lagoon habitats. These included: *Daphnia middendorffiana*, *Limnocalanus johanseni*, and *Cyclops vernalis*. While the study was able to establish habitat preferences for several species, physiochemical water data was insufficient to provide conclusions about the relationship with zooplankton abundance.

Little further work has been published about the presence and timing of habitat use by fishes in the coastal habitats of the southern Chukchi Sea, despite their importance for food security and ecosystem health in the region. Through their Traditional Knowledge holders, residents of the region have identified some of this information, but much work is still needed to quantifiably prioritize lagoons based on seasonal productivity and fish community composition (Georgette and Shiedt 2005; Jewett et al. 2009; Whiting et al. 2011; Raymond-Yakoubian 2013). Our work represents a strategic expansion of efforts with NPS farther to the south, that will build on a solid foundation of local knowledge of the importance of the area and prior site assessments. Building from such data offers unique opportunities to assess trends and understand change at both local and regional scales.

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

2018 Field Effort

Objectives

The objectives of the Wildlife Conservation Society led field effort at Cape Thompson during the 2018 field season are:

1. To streamline logistics and field operations to provide guidance for future field efforts.
2. Assess physical and biological parameters of four lagoons during three sample periods spanning the open water season (early July, early August, September) involving data collection on:
    a. Water quality parameters: temperature, pH, salinity, dissolved oxygen, turbidity, and specific conductivity;
    b. Primary Productivity including blue green algae and chlorophyll concentrations;
    c. Zooplankton abundance and community composition;
    d. Fish distributions, abundance, community composition, genetics and life history.
    e. Species composition and behavior of animal communities interacting with lagoon ecosystems;
2. To build upon preexisting knowledge base of lagoon ecology of the area in order to inform management agencies.
3. To incorporate community and stakeholder engagement in prioritizing local lagoon habitats.

Study Design

In partnership with National Park Service, Wildlife Conservation Society has developed a protocol for comprehensive lagoon sampling which has been formatted as a standardized operating protocol (Jones and Apsens, 2017). We adapted this protocol for the rapid assessments of these sites.

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 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. NOTE: the YSI EXO 2 sonde collects salinity measurements based on temperature and conductivity readings and records data with the use the of the Practical Salinity Scale, making measurements unitless. For the purposes of this paper however, values are recorded in "part per thousand" (ppt), which is an equivalent reading in this case to practical salinity units (psu).

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 the season.

Zooplankton

We used an 150µm mesh Wisconsin plankton net with a mouth diameter of 50 cm to sample each lagoon one time during the sample period. When possible, we collected samples in the area around fresh water inlets. We measured flow rate during sample collection using a General Oceanics Flow Meter Model 2030 series, standard model attached to zooplankton net at opening. Flow rate data is used to calculate volume of water filtered/distance traveled during tow for data quality assurance purposes.

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.

While we performed zooplankton sampling once during the 2018 field season (due to logistic considerations), future field efforts should aim to sample several times throughout the open water 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.

Fish Sampling

We sampled fish in all lagoons using a beach seine and experimental gill nets.

The 3.1x15 m beach seine was used to sample fish at any location where beaches allowed for deployment (e.g., sandy with no protruding rocks). We walked the net out to about 20 m into the water then drew it parallel to shore the retrieved the net in a symmetrical manner with people drawing the wing lines attached to the net's ends simultaneously at a constant rate (per Robards et al., 1999). When the depth of the lagoon did not allow a walk set we performed a similar tow using the boat to drag the net and pull it parallel to the shore.

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 (i.e., central, marine edge, terrestrial edge and freshwater inlet). Soaking nets are monitored in order to minimize risk of a) birds or other unintended animals being caught, and b) unnecessarily heavy fish mortalities. Set times varied based on success rate at the sample site and ranged from 0.72 hours to 2.37 hours (mean = 1.21 hours, standard deviation = 0.43 hours).

We identified all fish to species and measured each individual to fork length. We collected otoliths from the larger whitefish species as well as fin clip and muscle tissue samples. Otoliths were extracted and placed in a small coin envelope, labelled and stored in a dry case. We took one fin clip from each individual (right pelvic fin) and placed the sample in a 1.8 mL cryo tube containing desiccant beads for storage. Muscle tissue samples were taken using a sterile biopsy punch. We biopsied three 6 mm samples from the side of each fish at the thickest part of the body. Samples were weighed and placed small coin envelopes. We stored envelopes in a large dry case lined with desiccant beads.

Traditional Ecological Knowledge

Informal interactions occur in the field when, while collecting data, we encounter members of the local community. These encounters are documented in the sampling descriptions below.

Access Logistics

We traveled to Cape Thompson aboard the US Fish and Wildlife vessel the R/V *Tiglax*, which we used as a base of operations. The *Tiglax* provided us with food and accommodations as well as a place to process and store samples. During the day we loaded sampling gear on to an inflatable boat and were taken to shore in the general vicinity of the target lagoon. Once at shore we portaged our gear across the gravel berm separating the lagoon from the marine and assembled the 14' Saturn inflatable boat which, equipped with a 9.9 Yamaha outboard engine, we used to navigate the lagoon. We spent one day sampling at each lagoon with the exception of Akoviknak Lagoon, which was sampled over the course of two days. We were dropped off at Singoalik Lagoon on the last day with sampling and camping gear and took the day to complete data collection at Singoalik. We were picked up the following day by fixed wing airplane and flown out of the field directly to Kotzebue.

Assessment of Geographic Response Strategies

Nuka Research and Planning Group, LLC has been working with the Alaska Department of Environmental Conservation to develop Geographic Response Strategies (GRS) for areas of ecological sensitivity around the coast of Alaska. The GRS provide site-specific guidance for responding in the event of an oil spill. None of the North Slope Borough Lagoons that are the focus of this project have current strategies in place. However, during our field efforts, we also visited the northernmost coastal lagoons in the Northwest Arctic Borough, including Singoalik Lagoon, which is an established GRS site (GRS NWA-N01). We provide an assessment of GRS opportunities for the North Slope Borough lagoons as well as the Northwest Arctic Borough lagoons that were visited during the same field logistics as this project.

Field Notes for Sampled Lagoons

Kemegrak Lagoon

[1]FW: Fresh Water; ME: Marine Edge; TE: Terrestrial Edge; TE2: Terrestrial Edge2 MO: Mouth

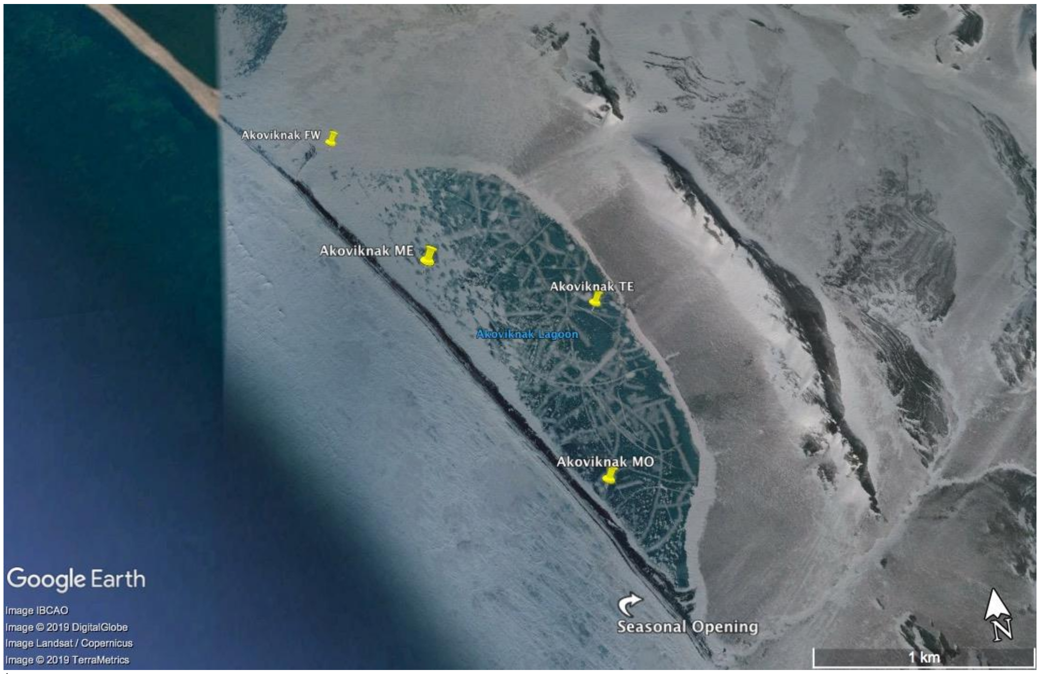
Figure 3. Water quality data sample sites (not including randomly generated points) at Kemegrak lagoon.

August 1st, 2018

Kemegrak is a 3.6 km^2 lagoon with no clear freshwater source and no marine connection during the time of our visit. We arrived at Kemegrak in the morning having been ferried over from the *Tiglax* by dinghy with sampling gear. The weather was overcast and calm. The lagoon was closed to the marine side with significant vegetation growth on the berm separating the ocean and the lagoon suggesting that it had not opened earlier in the season. Throughout the course of the day we set four gillnets and performed four beach seine pulls catching only ninespine stickleback. During the afternoon the wind picked up and it started to rain. We collected water quality data and performed four zooplankton tows, one at the marine edge, two distributed along the terrestrial edge of the lagoon and one at what we believed to be the periodic mouth of the lagoon at the southern end. While there were some swales leading in to the lagoon from the terrestrial edge we did not observe any permanent fresh water source into the lagoon. A camp is situated at the southern end of the terrestrial side of the lagoon with four-wheeler tracks observed running north-south along the beach.

WCS Arctic Beringia
A Wildlife Conservation Society Program

Akoviknak Lagoon



[1]FW: Fresh Water; ME: Marine Edge; TE: Terrestrial Edge; MO: Mouth

Figure 4. Water quality data sample sites (not including randomly generated points) at Akoviknak lagoon.

August 2nd and 3rd, 2018

Akoviknak is a 1.8 km^2 lagoon with one major fresh water inlet and several seasonal tributaries. While this lagoon was not open to the marine side, we observed what appears to be a periodic connection location at the southern-most end of the lagoon. We traveled to Akoviknak on the morning of the 2nd August, the weather was calm with light rain. We collected water quality data and performed five zooplankton tows at the marine edge, terrestrial edge, the fresh water inlet, one random site and at what we believe to be the mouth. We performed five beach seine pulls catching juvenile stickleback (individuals were too small to identify to species), ninespine stickleback and least cisco. We found high densities of copepods, mysid shrimp and isopods in each of our beach seine pulls. We set five gill nets which only caught least cisco. We returned to Akoviknak the following day and set four gillnets catching more least cisco. We extracted otoliths from all least cisco in addition to taking fin clip samples and muscle tissue plugs. The weather on the 3rd was windy and clear.

Mapsorak Lagoon

[1]FW: Fresh water; ME1: Marine Edge1; TE/FW2: Terrestrial Edge/Fresh Water2; ME2: Marine Edge2

Figure 5. Water quality data sample sites (not including randomly generated points) at Mapsorak lagoon.

August 4th, 2018

Mapsorak is a 0.8 km^2 lagoon with freshwater from two obvious inputs and was not connected to the marine at the time of our visit. Potential breach of the berm separating the lagoon from the ocean appears to occur at the northern end of the lagoon. We traveled to Mapsorak the morning of the 4th August and collected water quality data and zooplankton samples. We collected four zooplankton samples: at the major freshwater inlet, the terrestrial edge (at what appeared to be a small seasonal fresh water input), the marine edge and one random site, respectively. Densities of zooplankton in samples taken here appeared higher than the prior lagoons sampled. We set a total of four gill nets pulling them all after one hour and pulled four beach seines. We did not catch any fish but noted high densities of tadpole shrimp as well as other invertebrates in all four beach seine pulls. After packing up sample gear, we ran into two groups of locals, both from the village of Point Hope. The larger group was a family collecting beach peas and riding down the beach for recreation; the second a couple out collecting beach peas, sour dox and wild onions. That night we were dropped off at Atosik to camp for the night intending to sample the lagoon the following day.

Atosik Lagoon

[1]ME: Marine Edge; TE: Terrestrial Edge

Figure 6: Water quality data sample sites (not including randomly generated points) at Atosik lagoon.

August 5th, 2018

Atosik Lagoon is small with an area of only .03 km^2. It is unclear whether the lagoon breaches seasonally to connect with the ocean and the lagoon does not appear to have any fresh water input other than groundwater. On the morning of the 5th August, we collected water quality data and zooplankton samples. Due to the size of Atosik we collected water quality data at fewer points than the other sampled lagoons, taking point readings at the northern end, southern end, terrestrial edge and marine edge of the lagoon. We collected a total of three zooplankton samples, one each at the north end, middle of the lagoon and southern end. Zooplankton appeared to be at high densities in the samples taken from all three tows. We performed two beach seine pulls and set three gill nets. The gill nets were long enough to span the width of the lagoon. We did not catch any fish and invertebrate densities were low in both beach seine pulls; however, a large number of Mare's Eggs were caught in the seine nets.

Singoalik Lagoon

[1]FW: Fresh Water; ME: Marine Edge; TE: Terrestrial Edge; MO: Mouth

Figure 7: Water quality data sample sites (not including randomly generated points) at Singoalik lagoon.

August 6th, 2018

Singoalik is 1.65 km^2 with two notable freshwater inlets. Breaching most likely occurs at the southernmost end of the lagoon; however, this lagoon was closed at the time of our visit. We collected water quality data and performed four zooplankton tows. Singoalik was more saline than other sampled lagoons. We performed one beach seine pull in which we caught a large number of juvenile sculpin and flounder as well as threespine stickleback. We set a total of three gillnets, none of which caught fish. We observed Glaucous gull fledglings at the edge of the lagoon.

RESULTS AND DISCUSSION

Water Quality

Lagoons at Cape Thompson varied in their physical water parameters. While more long-term monitoring is required to develop a thorough understanding of physiochemical properties, an analysis of data collected from the 2018 field season provides valuable insight on baseline information. We were able to gather from conversations with several Point Hope residents that these lagoons had been closed off by a strong storm the previous November and had not opened back up again with shore-fast ice breakup however there is no consistent recorded history of lagoon connectivity to the surrounding marine environment.

Depth and Temperature

Akoviknak Lagoon had the highest overall average depth (mean, 2.31m; SD, 1.08m) with the highest variability in depth readings (Table 2). Singoalik Lagoon had the shallowest overall depth (mean, 0.97m; SD, 0.10m).

Kemegrak Lagoon had the highest average temperature of all the sampled lagoons (16.35 ± 1.82°C); however, temperature varied considerably between data collection stations despite the absence of any potential sources of impact on the internal temperature of the lagoon. Temperature readings recorded in the 1983 report by Dames and Moore, were lower overall at lagoons open to the marine environment particularly at sample stations directly inside the mouth of the lagoon, indicating that influx of colder water from the ocean has significant impact on the overall temperature in the main body of the lagoon. Despite the absence of any connection of this type during the 2018 field season, high variability in temperature readings throughout the lagoon was likely caused by external factors such a fresh water inlet or springs within the lagoons.

Salinity and Specific Conductivity
Salinity levels across all sampled lagoons were low, reflecting the absence of connectivity to the marine environment. Average salinity level was highest at Singoalik Lagoon (9.47 ± 0.45 ppt). Singoalik had higher average conductivity (16,148.26 ± 704.61 S/m) than any other lagoon. However, salinity levels at Singoalik were significantly lower than those recorded in the 1983 report by Dames and Moore, in which values ranged from 2.00-22.00 ppt, depending on location of sample station within the lagoon. The Dames and Moore study recorded a noticeable increase in salinity levels throughout the duration of the sample period as water from the marine environment flowed into the lagoon through a breach in the marine side berm.

Salinity levels at all other lagoons were considerably lower with the next highest average salinity found at Akoviknak (1.89 ± 0.01 ppt) and the lowest average salinity at Mapsorak (0.69 ± 0.07ppt). Akoviknak, Mapsorak and Atosik lagoons all had relatively low spatial variability in salinity levels throughout each of the data sample stations (Table 2.), reflecting the absence of any saline or fresh water point source at any of the three sites and mixing throughout each lagoon.

Overall, salinity levels at the lagoons of Cape Thompson were significantly lower than their counterparts at Cape Krusenstern, an area where more extensive monitoring of physiochemical properties of the lagoons has been conducted (Smith et al., 2019). During the 2017 field season at Cape Krusenstern, it was confirmed that Aukulak Lagoon never breached and lacked any direct connectivity to the ocean for the duration of the field season. Accordingly, salinity levels at Aukulak were significantly lower than previous seasons with average readings ranging from 0.36 ppt to 8.92 ppt compared to the 2016 season's range of 22.01 ppt to 26.64 ppt. A comparison of salinity levels between Cape Thompson lagoons and those of Aukulak Lagoon during a closed season reveals similar concentrations between the two. Low salinity levels at Cape Thompson lagoons could, therefore, indicate the absence of any recent breaching events.

Dissolved Oxygen and Primary Production
Percent dissolved oxygen was highest at Atosik Lagoon (105.18 ± 0.79%) and lowest at Mapsorak Lagoon (101.20 ± 0.65%). Dissolved oxygen levels across all lagoons were sufficient for fishes. Primary production was highest at Kemegrak lagoon, with average chlorophyll levels reaching 10.57 µg/L (±6.94) and average blue green algae (BGA) levels of 94.02 (± 37.15 µ/L). Chlorophyll levels were lowest at Singoalik Lagoon with an average of 1.75 (± 0.93 µg/L). BGA was lowest at Akoviknak with an average of 16.99 (±3.61 µg/L). Despite relatively high primary production at Kemegrak lagoon, fish species diversity and abundance were the lowest of all sample sites. At sites with lower primary production, readings were highly variable throughout the lagoon (Table 2.).

Zooplankton Sampling
Zooplankton surveys were performed at all lagoons, with 3-4 samples taken per lagoon. Samples were sent to University of Alaska facilities in Juneau for processing and will be analyzed for species composition and relative abundance. Results from sample analysis will be compared to previous zooplankton surveys conducted by Johnson (1961) as well as Tash and Armitage (1967) to determine potential changes in community composition.

Fish Sampling

Species Richness/Composition and Length/Weight

Species richness and composition varied between lagoons. We recorded a total of eight different species across all lagoons including important forage and one whitefish species, least cisco (Table 4.). Singoalik Lagoon had the highest species richness with a total of six different species caught, the majority of which were smaller forage fishes. Sampling at Mapsorak and Atosik did not catch any fish. Lowest species diversity occurred at Kemegrak Lagoon with only one species captured, Ninespine stickleback.

A comparison of fish catches from the 2018 field season and results from species surveys conducted by Dames and Moore in 1983 indicate a change in community composition at Singoalik lagoon. The 1983 sampling caught mostly arctic char and grayling as well as a large number of juvenile pink salmon. A description of their findings indicates that Singoalik Lagoon was open to the ocean during sampling while the lagoon was closed off to the marine during our 2018 field effort. In their analysis, Dames and Moore suggest that the small number of fresh water and anadromous species caught in their surveys reflect the absence of large communities of these species in the Singoalik River, the larger of the two fresh water inlets observed at the lagoon (Dames and Moore, 1983). The overall absence of both grayling and Arctic char in the sampling effort during the 2018 season reflect findings from other recent sampling efforts in lagoons of the surrounding area. Sampling efforts in the lagoons of the southern Chukchi sea over the past three years have not produced grayling or Arctic Char, perhaps indicating a change in freshwater fish communities of the tributaries leading into these lagoon environments from the time of the Dames and Moore sampling effort.

The majority of fishes captured at Akoviknak Lagoon were least cisco, most of which ranged between 200 and 300mm fork length (Figure 8.). Other species included ninespine stickleback and juvenile unidentified stickleback species. Akoviknak Lagoon hosted a fish population with the broadest range in size profile (Table 5). Individuals captured at other lagoons did not exceed 99 mm fork length. Fishes collected at Kemegrak Lagoon were exclusively in the lowest size class (0-49mm) while fishes collected at Singoalik Lagoon were split almost equally between the lowest and second lowest (50-99mm) size classes.

Forage species captured included ninespine stickleback, pond smelt and threespine stickleback. The most frequently encountered species was threespine stickleback, accounting for 40% of the total number of forage species caught (Figure 9.).

Laboratory Analysis

Samples taken during the 2018 field season will be evaluated for stable isotopes, mercury levels, genetic information, and life history. Using results from these analyses we hope to answer several questions including:

- How genetically related or distinct are fish from closely separated study sites?
- Do mercury levels in fishes vary between study sites?
- Do stable isotope values in whitefish vary with geographic region, age, sex and length?
- Do total mercury levels vary with the relative trophic position of the whitefish?

Samples will be analyzed for mercury content at the University of Alaska laboratory in Fairbanks.

Traditional Ecological Knowledge

Chance encounters with members of the Point Hope community occurred during sampling efforts. Results from brief discussions with Point Hopers indicate that the community supports more scientific monitoring in the area. Conversations also revealed a persistent concern about the ecological and health impacts from Project Chariot. One individual described changes in subsistence practices in the areas where radioactive waste was dumped in the early 1970’s and voiced concern about potential health impacts on the community. We plan to perform further interviews in a more formal capacity in addition to presenting findings from the 2018 field season to the community of Point Hope.

Avifaunal Activity Monitoring

Avifaunal activity was more limited compared to lagoon counterparts at Cape Krusenstern. No large flocks of feeding waterfowl were observed at lagoon, which is a commonplace phenomenon at Cape Krusenstern lagoons. Differences may be attributable to the absence of larger, more diverse fish communities within most of the lagoons. Individual shorebirds occurred as well as frequent encounters with seabirds on the marine side of the lagoon. Commonplace on the marine side of the lagoon were glaucous gulls and Arctic terns. We also observed a feeding semipalmated plover along the shore of Kemegrak Lagoon as well as a feeding semipalmated sandpiper along the shore of Mapsorak.

Geographic Response Strategies

Only one of these lagoons currently has a draft Geographic Response Strategy: Singoalik Lagoon (Appendix 1). At the time of sampling, there was no risk to this lagoon from a marine oil spill due to being "closed."

Acknowledgements

The U.S. Fish and Wildlife Service provided logistical support and accommodations via the R.V. *Tiglax*; the National Fish and Wildlife Foundation provided funding for this effort; the National Park Service was a key collaborator in the development of a comprehensive lagoon sampling protocol. 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: Bill Carter of the U.S. Fish and Wildlife Service's Selawik National Wildlife Refuge Office, Sara Germain of the U.S. National Park Service, Golden Eagle Outfitters, Arctic Backcountry Outfitters of Kotzebue, Alexei Pinchuk of University of Alaska; and Carrie Haddad of the Wildlife Conservation Society; Thanks also to our awesome field crew Matthew Campbell and Zane Chapman.

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Tables and Figures

Table 1. Lagoon size for study sites at Cape Thompson.

Lagoon	Area (km^2)
Aiautak	32.90
Kemegrak	3.60
Akoviknak	1.80
Atosik	< 0.5
Mapsorak	0.79
Singoalik	15:36

[1] We recognize the subjectivity in describing boundaries– our estimates delineate the main water body (for example not including the long channel leading into Singoalik lagoon).

Table 2. Mean (standard deviation) for water quality parameters at Cape Thompson lagoons during the 2018 field season.

Lagoon	Depth (m)	Temp (°C)	SPC	Salinity (ppt)	ODO %	pH	Turbidity (FNU)	Chlorophyll (µg/L)	(BGA u/L)
Kemegrak	1.33 (0.48)	16.35 (1.82)	2019.91 (107.13)	1.13 (0.30)	104.97 (1.28)	8.80 (0.06)	7.39 (5.30)	10.57 (6.94)	94.02 (37.15)
Akoviknak	2.31 (1.08)	15.74 (0.16)	3571.90 (6.75)	1.89 (0.01)	101.59 (0.37)	8.30 (0.02)	2.43 (1.35)	1.35 (0.41)	16.99 (3.61)
Mapsorak	1.11 (0.21)	8.86 (0.25)	1323.67 (16.11)	0.69 (0.07)	101.20 (0.65)	7.86 (0.04)	14.49 (2.45)	2.64 (1.10)	54.38 (5.56)
Atosik	1.00 (0.08)	9.66 (0.21)	3098.90 (9.13)	1.62 (0.0)	105.18 (0.79)	7.79 (0.03)	2.34 (0.62)	2.02 (0.17)	30.06 (1.10)
Singoalik	0.97 (0.10)	10.76 (0.23)	16148.26 (704.61)	9.47 (0.45)	104.90 (1.29)	8.24 (0.01)	1.75 (0.93)	0.76 (0.10)	23.87 (1.06)

Table 3. Number of sets by gear type at each lagoon.

		Lagoon				
		Kemegrak	Akoviknak	Mapsorak	Atosik	Singoalik
Gear Type	Beach Seine	4	5	4	2	1
	Gill Net	4	6	4	3	3

Table 4. Species richness in lagoons sampled at Cape Thompson. x indicates species was encountered at corresponding lagoon.

Species	Lagoon				
	Akoviknak	Atosik	Kemegrak	Mapsorak	Singoalik
Juvenile Flounder					x
Juvenile Sculpin					x
Juvenile Stickleback	x				
Larval Fish					x
Least Cisco	x				
Ninespine Stickleback	x		x		x
Pond Smelt					x
Threespine Stickleback					x

Table 5. Number of individuals by size (fork length, mm) captured per lagoon. Note: Total Individuals includes individuals caught and measured for fork length.

Lagoon	Size Class				Total Individuals
	0-49	50-99	100-199	200+	
Akoviknak	3	1	3	18	25
Atosik	-	-	-	-	0
Kemegrak	21	14	-	-	35
Mapsorak	-	-	-	-	0
Singoalik	33	38			71

Figure 8. Relationship between weight (g) and fork length (mm) of least cisco caught at Cape Thompson lagoons (n=20).

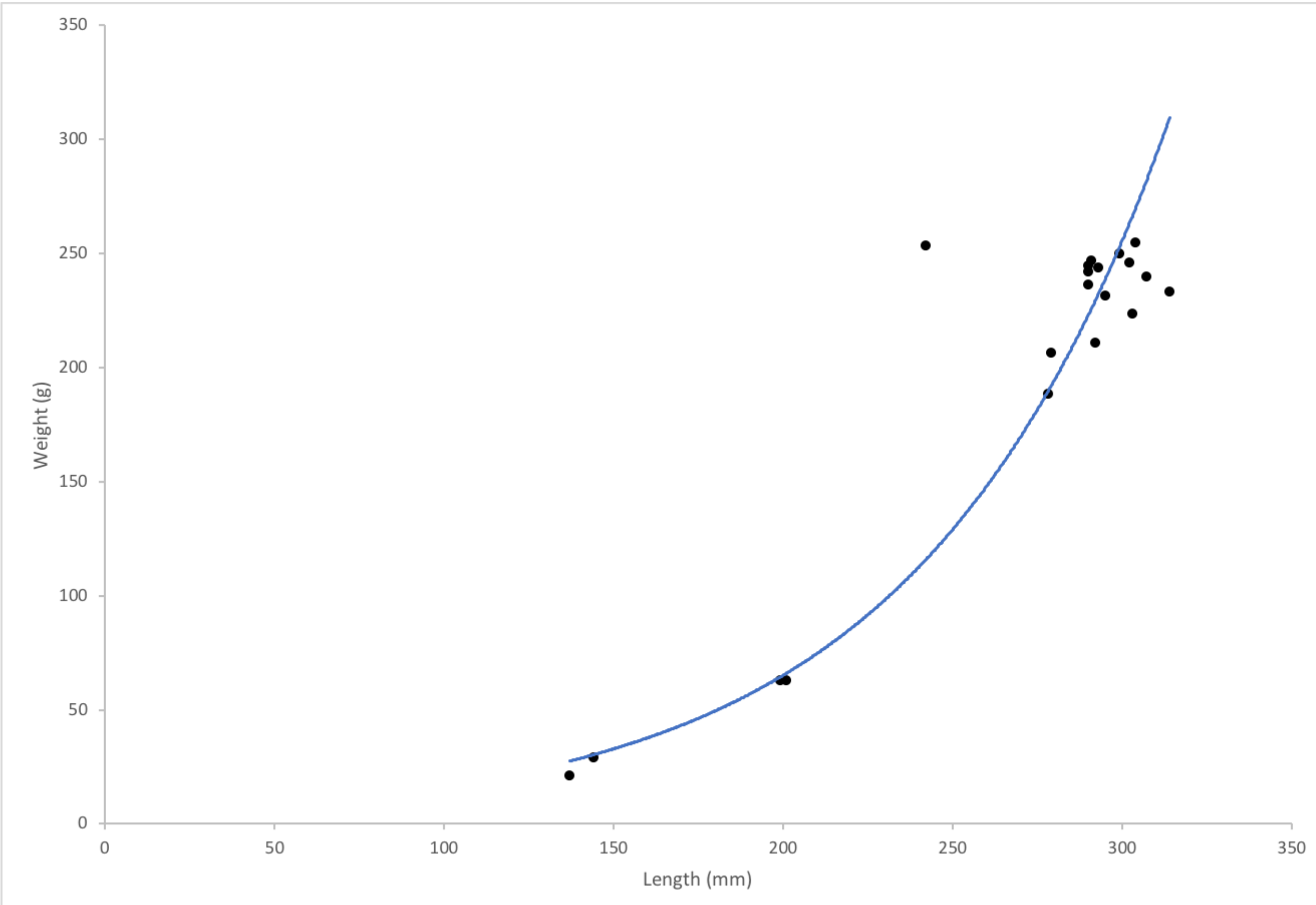
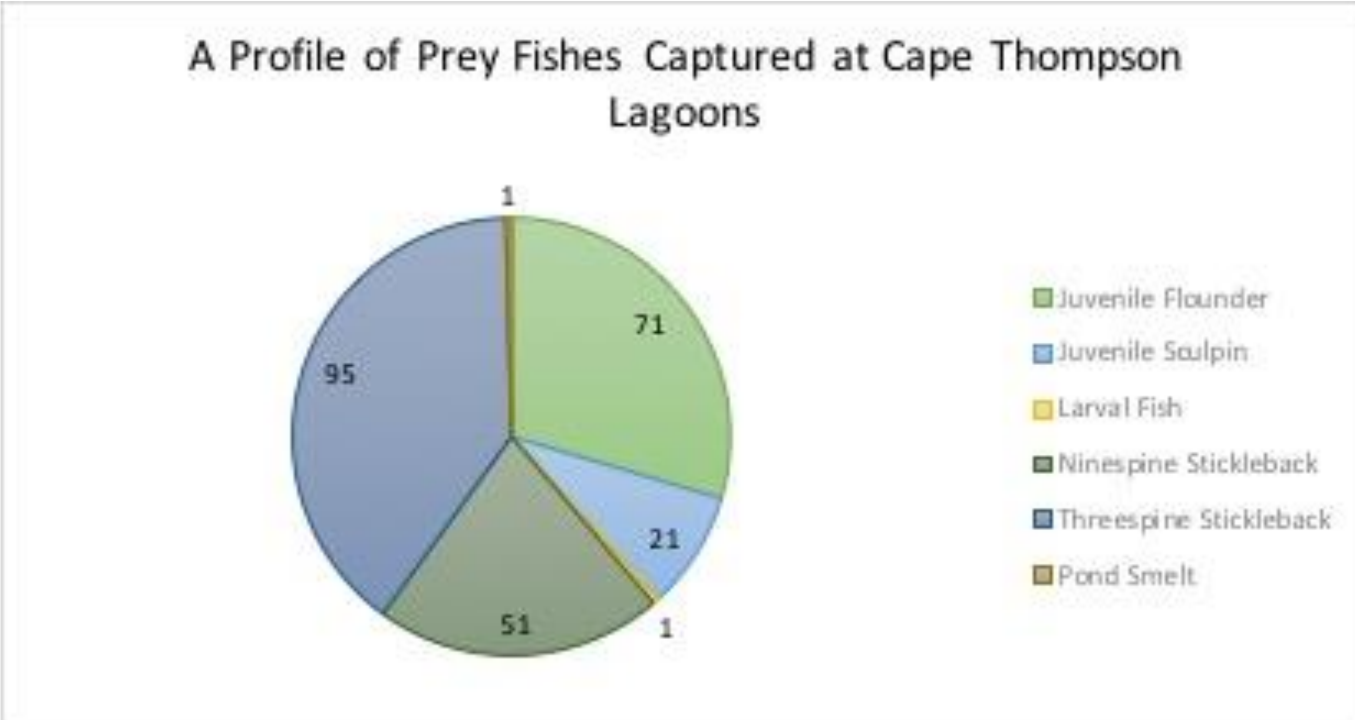


Figure 9. A profile of fish species caught at the lagoons of Cape Thompson (n=240).



Appendix 1. Metadata for 2018 field season

Tab 1: Water Quality
- Field 1: Lagoon
- Field 2: Date
- Field 3: Time
- Field 4: Water Quality Point
- Field 5: Depth (m)
- Field 6: Temperature
- Field 7: SPC
- Field 8: Salinity
- Field 9: Dissolved Oxygen (%)
- Field 10: pH
- Field 11: Turbidity (FNU)
- Field 12: Chlorophyll (mg/L)
- Field 13: Blue Green Algae (u/L)
- Field 14: Notes
- Field 15: Latitude
- Field 16: Longitude

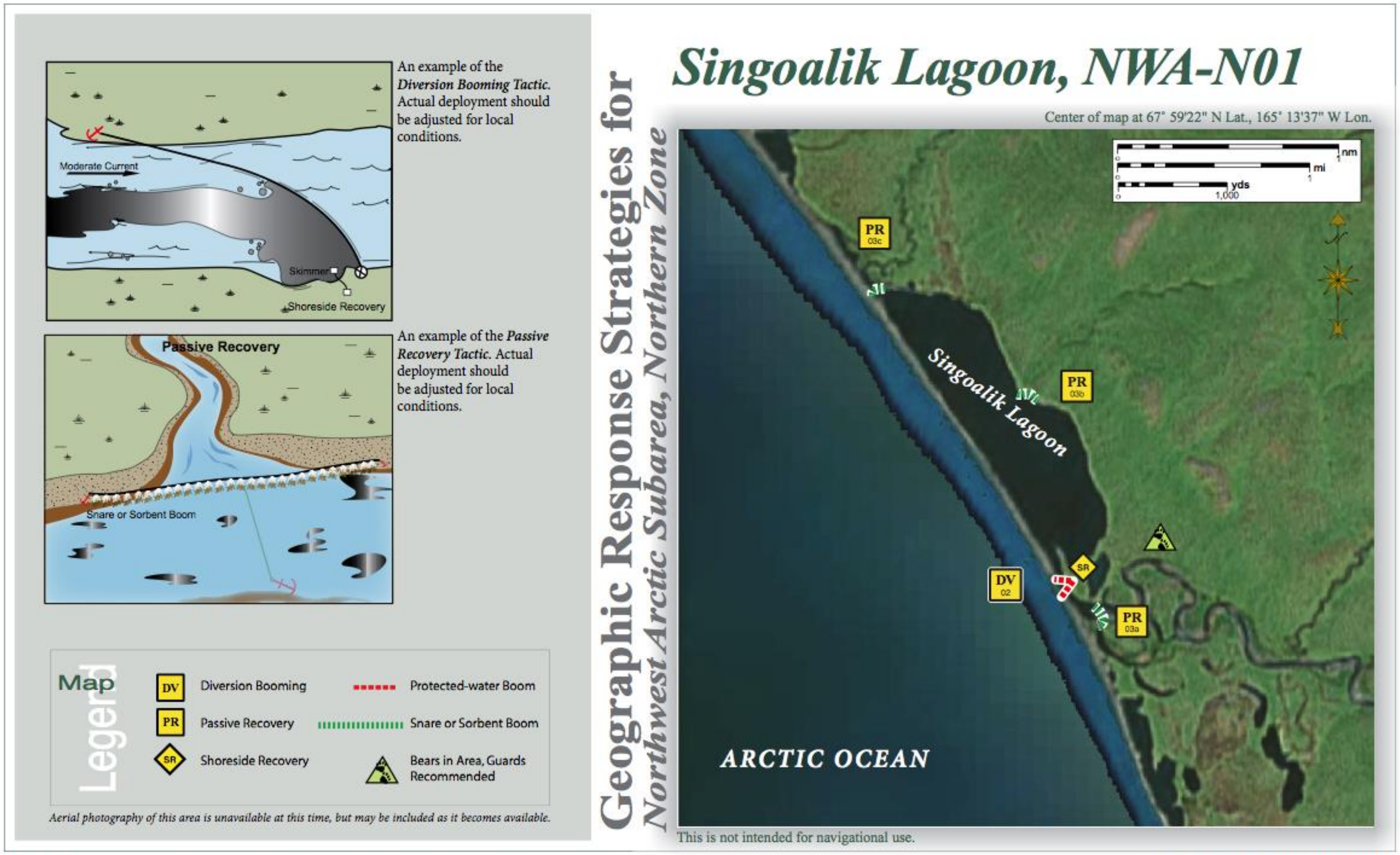
Tab 2: Zooplankton Data
- Field 1: Lagoon
- Field 2: Date
- Field 3: Site Name
- Field 4: Latitude
- Field 5: Longitude
- Field 6: Time
- Field 7: Sample Name
- Field 8: Flow meter starting value
- Field 9: Flow meter ending value

Tab 3: Fish Length and Weight Data
- 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: Time at gear check 1
- Field 9: Time at gear check 2
- Field 10: Time at gear check 3
- Field 11: Haul number
- Field 12: Species Identification
- Field 13: Number of individuals
- Field 14: Fork Length (mm)
- Field 15: Weight (g)
- Field 16: Number of otoliths pulled
- Field 17: Fin clip taken
- Field 18: Muscle plug taken
- Field 19: Sample identification number
- Field 20: Muscle plug weight (g)
- Field 21: Sample notes

Tab 4: Bird Observations

Field 1: Date
Field 2: Lagoon
Field 3: Species
Field 4: Notes

Appendix 2. Graphic of Singoalik Lagoon Geographic Response Strategy



June 28, 2011

DRAFT This tactic map is a working draft being used to develop a Geographic Response Strategy at this location. The tactics represented here have not been approved by the Subarea Committee and should not be considered final. If you have questions or comments please contact us by email at contact@nukaresearch.com.

NUKA Research & Planning Group, LLC.

Site Information for Northwest Arctic, NWA-N01

ID	Location and Description	Response Strategy	Implementation	Response Resources	Staging Area	Site Access	Resources Protected (months)	Special Considerations
N-01-01 FO-S	**Singoalik Lagoon** Nearshore waters in the general area of: Lat. 67° 58.5 N Lon. 165° 14.15 W	**Free-oil Recovery** Maximize free-oil recovery in the offshore & nearshore environment of Singoalik Lagoon depending on spill location and trajectory.	Deploy free-oil recovery strike teams upwind and up current of Singoalik Lagoon. Use aerial surveillance to locate incoming slicks.	Deploy multiple free-oil recovery strike teams as required to maximize interception of oil before it impacts sensitive areas.	Kivalina	Via marine waters Chart 16005	Same as N-01-02	Vessel master should have local knowledge. Use extreme caution, shoal waters with numerous reefs and rocks.
N-01-02 DV	**Singoalik Lagoon** Lat. 67° 58.61 N Lon. 165°12.89 W	**Divert and Collect** Divert oil to shore-side collection points determined by spill source and trajectory. The entrance to the lagoon may change seasonally and large storms may open the lagoon in other areas on the barrier beach. Aerial survey recommended prior to deployment.	Deploy anchors and boom with skiffs (class 6). Place protected-water boom at proper angle to divert incoming oil to the collection site. Set-up collection site using shore-side collection units or if oil volume is minimal, use sorbent boom or snare line to provide collection of oil. Tend throughout the tide.	**Deployment** **Equipment** 650 ft. protected-water boom 7 ea. small anchor systems 8 ea. anchor stakes 200 ft.snare line or sorbent boom or 2 ea. shore-side collection units **Vessels** 1 ea. class 3 1 ea. class 6 1 ea. helicopter (if needed for N-01-03) **Personnel/Shift** 5 ea. vessel crew 2 ea. response techs **Tending** **Vessels** 1 ea. class 3 1 ea. class 6 **Personnel/Shift** 3 ea. vessel crew 2 ea. response tech	Vessel platform	Via marine waters Chart 16005	Birds- shorebird concentration Marine mammals- polar bears Habitat- Low lying tundra, marsh, sheltered tidal flats	Vessel master should have local knowledge. A population of bears may be present in the area. A bear guard is required during these periods. FOSC Historic properties specialist should INSPECT site prior to operations. Take appropriate measures as outlined in the STAR Manual to protect the beach at the collection site. Site Survey: not surveyed Tested: not yet
N-01-03 PR	**Singoalik Lagoon** a. Lat. 67° 58.83 N Lon. 165°12.89 W b. Lat. 67° 59.69 N Lon. 165°13.66 W c. Lat. 68° 00.07 N Lon. 165°15.68 W	**Passive Recovery** The lagoon in closed to direct ocean access. If storms have, or threaten to breach the barrier beach, place passive recovery across the channels of the streams in Singoalik Lagoon. The lagoon may not be accessible with skiffs. Helicopter deploy when not accessible.	Transport boom to the lagoon via helicopter. Place and anchor three 200 ft. sections of snare line or sorbent boom across the channels of streams in Singoalik Lagoon. Replace as necessary to maximize the recovery.	**Deployment** **Equipment** 600 ft. snare line or sorbent boom 3 ea. anchor systems 12 ea. anchor stakes **Vessels/Personnel/Shift** Same as N-01-02 **Tending** **Vessels/Personnel/Shift** Same as N-01-02	Vessel platform	Via marine waters Chart 16005	Same as N-01-02	Vessel master should have local knowledge. Threatened or endangered species/habitat is present or possible in the area. Consult with NOAA and DOI prior to deployment.

NOTE: Sensitive resource information can be found on other maps which can be accessed through the sensitive area section of the NWA Sub-Area Contingency Plan: http://dec.alaska.gov/spar/perp/plans/scp_nwa.htm.