Evaluating Novel Assessment Approaches for Coastal Ice Seal Haulout Areas and Behavior in the Alaska Chukchi and Beaufort Seas

Principal Investigators: Donna D. W. Hauser[1] & Andrew L. Von Duyke[2]

[1] College of Fisheries and Ocean Sciences, University of Alaska Fairbanks
[2] Department of Wildlife Management, Alaska North Slope Borough

March 2023
Final Report
OCS Study BOEM 2022-080

Contact Information:
uaf-cmi@alaska.edu
https://www.uaf.edu/cfos/research/cmi

This study was funded by the U.S. Department of the Interior, Bureau of Ocean Energy Management Alaska OCS Region and the University of Alaska Fairbanks under cooperative agreement M19AC00017. This report, BOEM 2022-080, is available through the Coastal Marine Institute and electronically from https://www.boem.gov/akpubs.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Recent decades in Alaska's Arctic marine regions have been marked by unprecedented sea ice loss, contributing to widespread marine ecosystem changes and concerns about impacts on Arctic marine mammals. Understanding how environmental conditions and anthropogenic factors affect the distribution, abundance, and behavior of Arctic marine mammals is relevant to the health of regional ecosystems and the coastal Alaskan communities that rely on these species as subsistence, cultural, and spiritual resources. This information also has implications for the management of marine and coastal environments potentially affected by oil and gas development in the Beaufort Sea and Chukchi seas. Spotted seals (*Phoca largha*) are an ice-associated pinniped that is seasonally abundant throughout the Chukchi and Beaufort coastal regions during open water periods. Spotted seals haul out in the dozens to thousands on barrier islands, sandbars, spits, shoals, rocks, and reefs from approximately July until mid-November. Here, we report on a pilot study using time-lapse cameras and other monitoring to describe the relative abundance and presence of spotted seals at four terrestrial haulout sites in the Chukchi and Beaufort seas during the 2020–2022 open water seasons. Spotted seals were observed on 19.3% of 330 days (5469 hours) monitored, across all sites and years. Seals were observed at all sites except the Paisuq River mouth site in Smith Bay. The presence and number of seals varied across sites, years, and months, with the most consistent and highest (69) numbers hauled out at the Oarlock Island site in 2020. Seals were not observed annually at every site, however, when present, we estimated a mean of ~10 seals across all sites and years. A single anthropogenic disturbance event was detected in three years of monitoring, occurring at Oarlock Island in July 2022. We applied generalized linear models to the 2020 Oarlock Island site data and found that three factors, date, wind speed (or alternatively Beaufort scale), and wind direction, affected the presence and numbers of seals at the haulout. We experienced some limitations to our monitoring approach due to the effects of interannual environmental variations on seal haulout behavior, impacts on our fieldwork due to the COVID-19 pandemic, and equipment disruptions due to extreme weather and wildlife damage. We describe our results in the context of local environmental observations from community-based observers in Utqiaġvik, Alaska. Overall, we conclude that time-lapse cameras provide a novel opportunity to learn about the behavior, distribution, and relative abundance of a poorly understood ice seal species within a region experiencing profound environmental change.

INTRODUCTION

Recent decades in Alaska's coastal Arctic regions, such as in the Chukchi and Beaufort seas, have been marked by unprecedented reductions in sea ice extent, thickness, and duration of seasonal cover (Stroeve et al., 2014). In turn, these changes have contributed to shifts in wind and storm patterns, ocean heat and currents, marine productivity, and coastal erosion affecting the entire regional ecosystem including the Indigenous people reliant on it (Danielson et al., 2020; Huntington et al., 2020; Moore & Stabeno, 2015; Thoman et al., 2019; Wood et al., 2015). Rapid environmental change and associated sea ice loss are expected to directly impact ice-associated Arctic marine mammals (Laidre et al., 2015), and complicated responses are increasingly observed in the Pacific Arctic region (Crawford et al., 2015; Hauser et al., 2017, 2018; Rode et al., 2014). Coastal change and its effects on traditional subsistence resources such as Arctic marine mammals are a concern for the coastal Iñupiat communities (Hauser et al., 2021; Huntington et al., 2017) as is the prospect of increasing anthropogenic activity throughout various portions of the Alaskan Arctic (Hauser et al., 2018; Reeves et al., 2014).

Understanding how environmental conditions and anthropogenic factors affect the distribution, abundance, foraging ecology, health, and behavior of Alaskan Arctic marine mammals is relevant to understanding shifts in regional marine ecosystems and impacts on coastal Alaska Native communities and to the management of marine and coastal environments potentially affected by oil and gas development. Marine mammals are key components of Arctic marine ecosystems as consumers and predators, and as important traditional subsistence resources. Ice-associated Arctic marine mammals are sentinels of Arctic environmental change (Moore, 2008), reflecting ecosystem health and affecting the food security and well-being of Alaska Native subsistence communities (Moore & Gulland, 2014; Moore & Hauser, 2019).

The spotted seal (*Phoca largha*) is an ideal focal species for addressing questions related to the cumulative impact of climate-related habitat change and increasing anthropogenic disturbance. Spotted seals are ice-associated pinnipeds seasonally abundant throughout coastal regions of the Chukchi and Beaufort seas during the summer and fall open water periods. The Alaska stock of spotted seals, the only stock recognized in U.S. waters, is estimated at 461, 625 seals (Conn et al., 2014). They frequently use coastal terrestrial habitats for hauling out, where it is common for dozens to thousands of spotted seals to aggregate on barrier islands, sandbars, spits, shoals, rocks, and reefs from approximately late July until mid-November (Frost et al., 1993). Alaska Native communities along the coastal margins of the Chukchi and Beaufort seas have long understood and relied upon predictable seasonal occurrences of spotted and other ice seals along the coast (Gryba et al., 2021). Despite their seasonal abundance and importance to coastal residents, there have been few systematic studies of spotted seal summer-fall abundance and distribution in the Chukchi or Beaufort seas. Aerial surveys of spotted seal coastal haulouts have not been conducted since the 1980s and 1990s (Frost et al., 1993), partially due to the cost and logistical challenges of surveys by manned aircraft, but especially because hauled-out spotted seals are particularly sensitive to disturbance by manned aircraft (Rugh et al., 1997).

Use of Novel Technologies

The proposed goal of this project was to examine the environmental and anthropogenic factors that might affect late summer-fall haulout patterns of ice seals in coastal regions of the Chukchi Sea and Beaufort Sea regions using environmental observations by Indigenous Experts and weather stations, time-lapse cameras, and short-duration surveys by small unmanned aerial systems (UAS). In January 2020, the Department of Interior (DOI) temporarily grounded all non-emergency UAS operations. In anticipation of a lift or modification to the cessation order, our team completed certification as FAA Part 107c small UAS pilots. We then evaluated using the “Blue UAS” platforms approved by DOI in 2021. However, consultation with our BOEM project officers, DOI scientists, and the DOI Office of Aviation Services confirmed these alternate UAS platforms were cost-prohibitive and not ideal to achieve our research objectives, and we dropped the UAS component of our research plan.

This study evaluated the potential for time-lapse game cameras to assess the seasonal presence, behavior, and numbers of spotted seals at known summer-fall coastal haulouts in the Chukchi and Beaufort seas. While remote photography for wildlife applications is well-developed (Cutler & Swann, 1999), there have been relatively few applications with pinnipeds or in Arctic coastal environments. We used high-resolution time-lapse cameras installed at four spotted seal haulout sites, in conjunction with measurements and observations of other environmental conditions and anthropogenic activity, to understand spotted seal use in the region and assess factors that might influence seal haulout presence, relative abundance, and behavior.

Local Involvement

Coordination, involvement, and outreach with coastal communities, subsistence hunters, regional managers, and the Ice Seal Committee (ISC; Alaska Native organization federally recognized as an ice seal co-management partner) were also critical components of this work. We enlisted local residents to help install weather stations and coordinated observations from Utqiaġvik observers who are part of a coastal environmental observing network of Indigenous experts (AAOKH; the Alaska Arctic Observatory and Knowledge Hub) to provide local context on the ice, ocean, and weather conditions that might be related to haul-out behavior. Collaborations with the North Slope Borough Department of Wildlife Management (NSB-DWM) provided additional local scientific expertise, logistical support, local coordination, hiring of Alaska Native field technicians, and the ability to build on existing studies focused on the movements and behavior of ice seals.

Objectives

Our proposed goals required modification during the period of performance. Given the DOI UAS cessation order and additional travel restrictions due to COVID-19, we revised our fieldwork strategy to focus on and expand the use of time-lapse camera data collection approaches. We added a site at the Topagoruk River in 2021 and extended the work for another year of data collection in 2022. Our specific goals, reported on here, focused on assessing the feasibility of new monitoring techniques for spotted seals at terrestrial haulout sites in the Chukchi and Beaufort Sea regions, including:

1. Test and refine remote camera survey methods to assess counts, presence/absence, and behavior of ice seals at haulout sites,
2. Quantify the effects of environmental conditions on ice seal summer-fall haul-out behavior,
3. Assess the combined effects of environmental conditions and human disturbance on counts and behavioral responses of hauled-out ice seals,
4. Assess the feasibility of using remote cameras to survey ice seal abundance and coastal haulouts,
5. Engage Indigenous communities and hunters in ice seal research, and
6. Build capacity for scientific operations by Indigenous communities and hunters.

METHODS

Study Area

Previous work suggests that spotted seals use a number of regular coastal and estuarine haulout locations to rest between foraging excursions in the Chukchi and Beaufort seas (Crawford et al., 2018; Lowry et al., 1998, 2000). For example, satellite tracking by the North Slope Borough (NSB, unpublished data) showed that spotted seals tagged in Dease Inlet remained in the general vicinity, revisiting haulout sites region within a few weeks of capture and before leaving the area on their seasonal migration. Longer-lasting flipper-mounted tags revealed seals had high fidelity to the Oarlock Island sites over two sequential years (NSB, unpublished data). In this project, we monitored well-known spotted seal haulout locations in Dease Inlet, Peard Bay, and Smith Bay that are accessible from Utqiaġvik (Figure 1, Table 1).

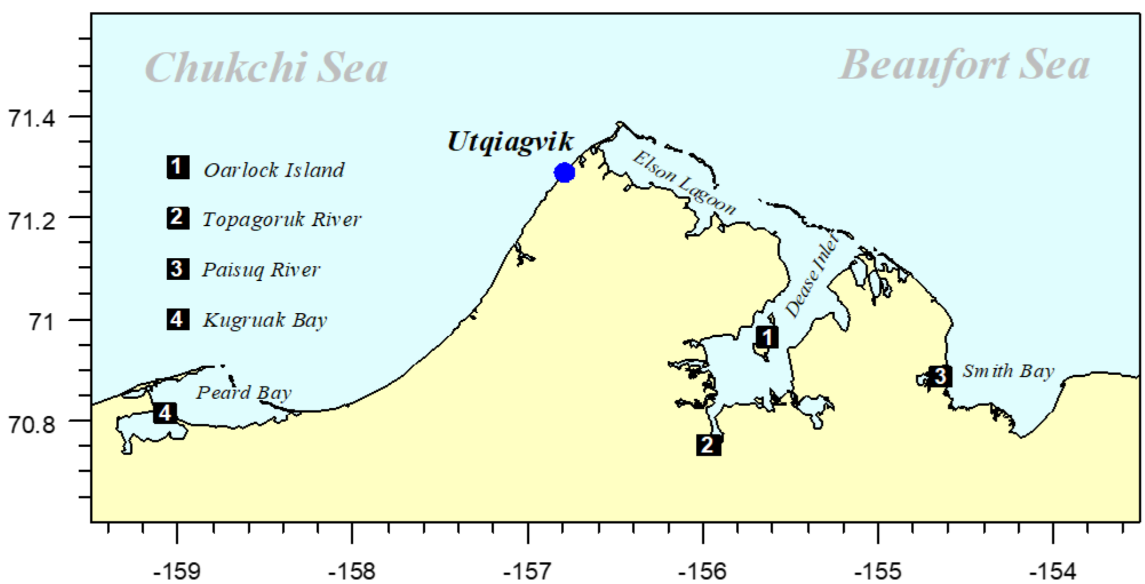


Figure 1. Map coastal haulout sites monitored in the study.

Table 1. Spotted seal haulout locations monitored in this study. These sites were expected to be occupied by 10s to 100s of hauled-out seals, based on observations by Co-PI Andrew Von Duyke (who has worked at these sites for nearly a decade), local marine mammal experts, and Utqiaġvik subsistence hunters who regularly transit near these sites. Estimates of Anticipated abundances change over the open-water period and in response to environmental and habitat variables.

Site	Anticipated numbers of seals	Comments
Dease Inlet Tiny Island and Oarlock Island	10s to 100+	Three main haulouts: One on Tiny Island and two on Oarlock Island. It appears that only one is typically used at any given time, with Oarlock Island being preferred. Seal numbers and haulout locations vary on daily and seasonal scales.
Dease Inlet Mouth of Topagoruk River	10s to 50+	Spotted seals are often found at entrances to creek and river systems in this region. As with Dease Inlet, seals tend to shift use among several different haulouts. During past seal capture efforts in this area, NSB researchers would search several other well-known areas if seals were not located at the initial site.
Smith Bay Two sites at the mouth of the Paisuq River	10s to 100+	This is the least known of haulout sites, with no previous research effort and the lowest levels of anthropogenic activity. Estimated numbers are based on evidence of use by a subset of tagged seals, which use the area in a way similar to Dease Inlet (Lowry et al. 1998, North Slope Borough, unpublished data, Richard Glenn, personal communication).
Peard Bay Junction of Peard and Kugruak Bays	200 to 1000+	Very large aggregations are common in this area.

The frequency, duration, and timing of haulout use can vary with local conditions, including wind, water level, fish movements, seasonality, and human disturbance. While some coastal haulouts used by spotted seals are rather ephemeral, others are used regularly, and several well-known sites can be accessed in the vicinity of Utqiaġvik, AK (71.3° N, 156.8° W; Figure 1). Previous studies confirm our selected sites were regularly used as haulout sites in the past (e.g., Citta et al., 2018; Gryba et al., 2019; Lowry et al., 1998, 2000; Morris et al., 2017; Von Duyke et al., In Preparation). Dease Inlet is a well-known haulout location, and satellite tag data and Traditional Ecological Knowledge both document the use of Peard Bay and Smith Bay as haulout locations for spotted seals (Morris et al. 2017).

Dease Inlet, in the Beaufort Sea southeast of Utqiaġvik, is important to the local ecology and traditional resource users. In the summer and fall open-water period (~July–October), this region is frequented by small vessels and subsistence hunters from Utqiaġvik as it provides access to and connects many inland rivers and lakes and several river systems that drain into Dease Inlet. Two monitoring sites were located in Dease Inlet, a spit on the northern extremity of Oarlock Island (central Dease Inlet) and the mouth of the Topagoruk River (southern Dease Inlet). Although subsistence hunters near Utqiaġvik do not commonly harvest spotted seals relative to bearded seals (*Erignathus barbatus*) or ringed seals (*Phoca hispida*) (Gryba et al., 2021), the Dease Inlet sites were expected to receive higher levels of anthropogenic activity than other sites. At Oarlock Island, passing boat traffic tends to follow deeper water channels that are relatively distant from these haulouts. Haulouts at the narrow entrance to Topagoruk River could receive closer approaches because boat traffic may pass closer to the banks.

Peard Bay, located in the Chukchi Sea southwest of Utqiaġvik and northeast of the community of Wainwright, Alaska (70.6° N, 160.0° W), is a shallow bay with sandy spits, barrier islands, shoals, and capes where spotted seals sometimes haul out in the hundreds (Frost et al. 1993). Peard Bay can have hundreds of spotted seals hauled out along the entrance to a smaller bay known as Kugruak Bay (NSB, unpublished data). Peard Bay is accessible from Wainwright and Utqiaġvik but is farther than Dease Inlet from Utqiaġvik. With fewer cabins and less marine mammal subsistence activity than other regional sites, intermediate levels of anthropogenic activity, primarily use by local hunters and boaters, were expected at this site.

Smith Bay, a shallow estuary in the Beaufort Sea southeast of Dease Inlet, is fed by several river and creek systems, supports a number of fish, bird, and wildlife species, and is considered a "hotspot" for spotted seals (Kuletz et al., 2015). The mouth of the Paisuq River in Smith Bay was anticipated to have the lowest levels of anthropogenic activity, given the area is not commonly visited by subsistence hunters (Billy Adams, personal communication). This area is not used extensively for subsistence activities nor is it a major thoroughfare for travel. For now, Smith Bay receives relatively less disturbance than Dease Inlet or Peard Bay at times that are important to seals. However, Smith Bay is an area of interest for oil and gas exploration and extraction, particularly following major oil discoveries as part of the Tuliminiq discovery. As such, anthropogenic disturbance levels in this region may increase substantially.

The haulout sites selected for this study have broad applicability across the Chukchi and Beaufort seas, particularly for regions that have similar substrates, environmental characteristics, and range of human disturbance. Locations chosen for this study included low, intermediate, and high anthropogenic disturbance levels and haulout substrates common across the Chukchi and Beaufort coastal regions. The substrate at the Topagoruk River and Paisuq River mouths tends to be tundra with areas of exposed mud where the plant cover has been killed off, and Oarlock Island and Kugruak Bay haulouts are narrow spits composed of sand, gravel, and mud. Notably, wind-driven water levels can impact substrate availability in this region. For example, spotted seals haul out on a shoal near Oarlock Island, but only at exceptionally low water levels, illustrating the behavioral plasticity of spotted seals in selecting haulout locations.

Field Season

Spotted seals can access and use the selected haulout sites following landfast sea ice break-up, as early as mid-July, until landfast sea ice begins to freeze up, as late as October or November. We maintained monitoring sites during the open water seasons of 2020, 2021, and 2022, ranging from mid-July to late October. Fieldwork was also scheduled before and after the whaling season in coordination with the local whaling captains.

The Alaska stock of spotted seals gives birth to pups on marginal sea ice in the southern Bering Sea from late March to early May, followed by an intense 3–6 week nursing period

(Quakenbush et al., 2009). Approximately coincident with weaning, pups molt their birth lanugo, disperse from their mother, become independent, and aside from their somewhat smaller size are largely indistinguishable from adults. Our field activities occurred after the pup-dependent period, so all observations combine non-pup life stages and males and females as sex and age (via counts of claw bands) cannot be identified without capture.

Establishing Monitoring Stations

Monitoring stations deployed at spotted seal haulout sites (Figure 1) centered on the use of remote time-lapse cameras to photograph seals to address questions regarding the environmental and anthropogenic factors that affect spotted seal haul-out behavior, distribution, and numbers. Monitoring stations at each site in Peard Bay, Dease Inlet, and Smith Bay consisted of one or two time-lapse cameras, an acoustic recorder to monitor airborne sounds, a water-level marker, and a weather station.

We deployed remote time-lapse wildlife game camera systems (Reconyx Hyperfire2 or GameKeeper Covert cameras) with visible and infrared imaging and the ability to set schedules for image capture. Cameras were programmed for regular sampling during daylight hours, from 05:00–23:45. Reconyx cameras took a photograph every minute and GameKeeper cameras took a photograph every five minutes. Each camera had motion-sensing capabilities and would shoot a burst of three images upon detecting motion. Cameras were mounted on a t-post and positioned to monitor a portion of the haulout area (Figure 2). Two cameras were positioned at each site to record as much of the site area as possible. Cameras were serviced with fresh batteries and SD memory cards multiple times each season. An acoustic digital audio recorder (Wildlife Acoustics Song Meter SM4) was maintained at each of the haulout sites to continuously record the nearby passage of aircraft, boats, or other activities. The audio recorders were positioned on the same T-post as one of the cameras (Figure 2) so they were within the audio detection range of hauled-out seals (Sills et al., 2014). The acoustic systems had two built-in low-noise microphones with two-channel stereo sound configured with custom sampling schedules to match that of the cameras. We recorded airborne sounds continuously. A stick with standardized level markings was also placed in the foreground of one camera’s view to document changes in water level (Figure 3). HOBO Basic Weather Station kits were placed in central locations on the tundra above haulout sites in Peard Bay, Dease Inlet, and Smith Bay (Figure 4) to provide more localized weather data than available from the National Weather Service monitoring station in Utqiaġvik. Each station had data logging capabilities and sensors to collect site-specific wind speed and direction, precipitation, relative humidity, and air temperature data.

Figure 2. Monitoring equipment installed at Oarlock Island in Dease Inlet in July 2021. Each monitoring station included a time-lapse camera, acoustic recorder, and water-level marker. The arrow illustrates the direction of the camera angle toward the water-level marker and the rest of the spit where seals haul out. A second camera was placed to monitor seals hauling out on another section of the spit. A weather station was located on the tundra bluff above the spit. Photo courtesy D. Hauser (UAF).

Figure 3. Image captured at Oarlock Island, on 27 August 2020. This example shows that images can capture numbers and locations of spotted seals and displays of alert or other behaviors at a haulout. The marker in the foreground was used to track water levels.

Figure 4. Weather station deployed at Oarlock Island in August 2020. Co-PI Von Duyke stands next to two T-posts supporting the camera. Acoustic recorder equipment can be seen on the spit in the background. The weather stations were positioned at the same location across the three field seasons. Photo courtesy K. Scheimreif, NSB-DWM.

The placement and functioning of equipment were assessed each time a study site was serviced. Servicing included changing batteries and SD cards in the cameras. All recovered data were stored on at least two external hard drives and backed up to a secure Google drive maintained by UAF following return from the field. Upon return from the field each year, data were manually reviewed and entered into standardized data sheets by UAF undergraduate students. Each student was trained on extracting data from the images, once per hour from dawn to dusk. Data entry for each camera and site was suspended upon detecting the presence of shore ice forming since seals would no longer be expected to use or have access to the site. Data included:

- water level on the marker: noting any change from the previous observation,
- sea state: visually estimated Beaufort scale,
- weather: particularly visibility and glare, fog, or precipitation that obscured the image,
- presence of sea ice: floating ice floes, landfast ice forming, or no ice,
- seal presence: present or absent,
- seal numbers: visual count estimate and categorical estimate,
- reactionary behavior: flushing from the haulout, alert behavior (multiple seals' heads raised in a common direction),
- notations on the status and quality of the camera equipment,
- presence of other bird or wildlife species within the image was also noted,
- disturbances: passing vessel, humans, aircraft, etc.

Analysis and Modeling of Monitoring Data

Each image was classified as 'excellent' (i.e., no issues and the haulout site was completely visible), 'good' (e.g., there could be an issue with weather or equipment but the haulout site is still fully visible), 'questionable' (e.g., some portion of the haulout is obscured due to an issue with weather or equipment prevents the haulout site from being fully visible), or 'poor' (e.g., the haulout site is obscured and it is not possible to detect the presence of seals). Questionable and poor observations were excluded from the analysis. Questionable or highly uncertain seal identification was also noted in the comments.

We analyzed the hourly presence and number of seals detected relative to environmental conditions monitored in situ and by the National Weather Service (NWS) monitoring site in Utqiaġvik. Wind data were analyzed using the R packages 'openair' (to estimate windrose figures) and 'circular' (to assign wind direction as a circular variable, with units in degrees). Seals were most consistently present, and in the highest numbers, at the Oarlock Island site in 2020, so these data were used to explore quantitative relationships with environmental data. We fit generalized linear models (GLM) that applied a binomial or quasipoission error structure for presence/absence and count data, respectively (Zuur et al., 2009). Full models included environmental factors that might affect seal haul-out behavior, including weather variables (temperature, wind speed, wind direction, relative humidity, visibility, Beaufort scale), water levels (and any changes), hour, and date. We used variance inflation factors to screen for multicollinearity between covariates, and correlated covariates were disallowed from candidate models (Zuur et al., 2009). We then used Akaike's Information Criterion to identify the best model, applying stepwise model selection to determine the final model structure.

Sound levels at each site were processed and estimated using Wildlife Acoustics Kaleidoscope Pro Sound Analysis Software, which is designed to provide seamless sound processing of acoustic data from the Song Meter SM4. The analysis of airborne sounds at the haulout site was intended to serve two purposes: (1) inform the sound levels of any disturbance event detected in the haulout data, and (2) monitor ambient noise levels at each site and in association with weather conditions. During data entry of camera data, observers visually scanned each image for evidence of alert behavior and flushing from the haulout by seals that would be indicative of a disturbance event. If any events were detected, the continuously monitored sound levels would be analyzed for 10 minutes before and after the disturbance. Hourly ambient sound levels were analyzed relative to the number of seals, wind speed and direction, and Beaufort scale using the Oarlock 2020 observations.

Community Engagement and Partnerships

We were committed to coordinating this research in partnership with Alaska Native hunters in Utqiaġvik as well as elevating the use of holistic environmental monitoring by Iñupiaq Indigenous Knowledge holders. We hired two hunters to assist field operations in 2021 and 2022; field participation was limited in 2020 due to the COVID-19 pandemic. We also coordinated and shared our proposed plans and provided regular biannual updates to the Ice Seal Committee (ISC), the Alaska Native Organization that is the federally recognized ice seal co-management partner in Alaska. In particular, we presented our research plans to the ISC to ensure that coastal subsistence communities were consulted and to solicit advice from local and Indigenous Knowledge holders. Collaborations with the NSB-DWM and their biologists and subsistence experts provided further local scientific expertise, logistical support, local coordination, and the ability to build on existing studies focused on the movements and behavior of ice seals, including spotted, bearded, and ringed seals. The NSB-DWM Ice Seal Research Program works in partnership with six Arctic Alaskan coastal communities, including Utqiaġvik and Wainwright, to conduct ecological research on ice seals. The information collected since the inception of the NSB-DWM Ice Seal Research Program in 2011 provides an in-depth perspective on the phenology and locations of movements and haul-out behavior of spotted seals and other ice seal species.

To obtain regular (e.g., daily-weekly) holistic environmental monitoring of the coastal realm near Utqiaġvik, we coordinated with a network of coastal observers through the Alaska Arctic Observatory & Knowledge Hub (AAOKH). AAOKH is a community-based observing program representing a collaboration between the University of Alaska Fairbanks (UAF) and five Arctic Alaska communities (Hauser et al. In Press, *Arctic Science*). Utqiaġvik observers Joe Mello Leavitt and Billy Adams have regularly reported ocean, sea ice, and wildlife observations since 2007 and 2014, respectively. AAOKH observations provided context on localized environmental conditions from a hunter’s perspective, including wind speed and direction, air temperature, water levels, ocean and sea ice conditions, observations of fish, birds, and wildlife, and community activities. Observers also document any unusual events or presence of novel wildlife or shifts in the timing of regularly observed species. AAOKH observations are archived and accessible per the current data use agreement with Indigenous observers (Adams et al. 2022; Eicken et al. 2014) and housed with the Exchange for Local Observations & Knowledge of the Arctic (ELOKA), accessible at: https://eloka-arctic.org/sizonet/.

Permitting

Several permits and associated trainings were required to conduct our field research campaigns, including a Marine Mammal Protection Act General Authorization for Scientific Research, an Institutional Animal Care and Use authorization, and a Land Use Permit. Our Land Use Permit was modified in 2021 to allow for a limited number of helicopter landings to access sites (provided by NSB Search and Rescue as non-mission training flight opportunities for their pilots).

RESULTS

We monitored spotted seals at a total of four sites over a total of 436 days, including a cumulative of 41 days at two sites in 2020, 165 days at four sites in 2021, and 230 days at three sites in 2022 (Table 2). However, the operational periods for each monitoring device varied due to battery life, SD card capacity, weather, equipment malfunctions or errors, or wildlife interactions.

Table 2. Monitoring periods by site. Each site was equipped with 1–2 Reconyx Hyperfire2 time-lapse cameras for high-definition photos (one per minute) of the haulout area, a Wildlife Acoustics SongMeter4 recorder to detect ambient airborne sound, and a HOBO weather station (centrally positioned in Peard Bay, Dease Inlet, and Smith Bay) to continuously record local wind speed and direction, max wind gusts, precipitation, temperature, and relative humidity in each area (Peard, Dease, and Smith).

Year	Site	Total number of days monitored	Monitoring dates
2020	Dease Inlet: Oarlock	17	20 Aug – 5 Sept
2020	Smith Bay	24	31 Aug – 24 Sept
2021	Peard Bay	59	14 July – 22 Aug; 17 Sep – 7 Oct
2021	Dease Inlet: Oarlock	1	12 July – 13 July
2021	Dease Inlet: Topagoruk	30	17 Sep – 17 Oct
2021	Smith Bay	75	12 July - 23 Aug; 17 Sep – 20 Oct
2022	Peard Bay	77	12 July – 27 Sep
2022	Dease Inlet: Oarlock	76	13 July – 27 Sep
2022	Dease Inlet: Topagoruk	77	12 July – 27 Sep

Impacts of the COVID-19 Pandemic

We proposed field seasons in the autumn of 2019 and summer-autumn of 2020. However, funding was received too late to conduct the 2019 fieldwork so we revised our plan to conduct field seasons in summer-autumn 2020 and 2021. Due to Covid-19 restrictions, our 2020 field plans changed to a shortened season (August–October) with deployment at only two sites, the 'high' disturbance site at Oarlock Island in Dease Inlet and the low disturbance site at the mouth of the Paisuq River in Smith Bay. Both sites were accessible with a reduced field crew led by Co-PI Andrew Von Duyke. In 2021, we modified our Land Use Permit to allow a limited number of helicopter landings at each site, which facilitated access to the sites when weather conditions and limited staff availability made boat access impossible.

We used multiple channels to communicate with the Ice Seal Committee (ISC) and North Slope community members during the project. Project plans were introduced to the ISC for review during their January 2020 meeting, before COVID-19 closures happened, and ongoing updates were provided through virtual meetings and updates to their website (www.iceseals.org). Regular updates about the project were shared in the biannual *AAOKH News* (see Study Products), which is broadcast widely by email, social media, a website, and by direct mailings to all mailbox holders in the seven contributing AAOKH communities. AAOKH observing continued during the pandemic because Indigenous Knowledge holders from Utqiaġvik maintained their traditional subsistence activities and recorded their observations.

Monitoring Limitations and Adaptations

Factors associated with weather, wildlife, and equipment limitations affected our monitoring abilities each year. To ensure that visits to the study sites (regardless of whether the goal was to service or decommission a site) did not overlap with or cause disturbance to fall subsistence whaling activities in Utqiaġvik, we coordinated with the local whaling captains' association and agreed to attend to the sites either before or after whaling. In 2020, a firmware bug resulted in the weather stations failing to record data so we used Utqiaġvik National Weather Service data for that year. Additionally, cameras were displaced sideways at Oarlock Island starting on 5 September 2020 and at Smith Bay toward the end of the deployment; it was unclear what displaced each camera.

Other factors impacted monitoring in 2021. The Oarlock Island site degraded in early August 2021, shortly after we deployed monitoring equipment. Specifically, the sand spit, a persistent feature that was frequently used as a spotted seal haulout site, was partially eroded and submerged when we redeployed equipment in July 2021 (Figure 5). Persistent strong winds and high-water levels continued into August, eventually leading to the complete erosion of the site. The camera and acoustic recording equipment disappeared, apparently washed into the water as the substrate continued to erode. No seals were seen at this site, nor was there substrate available for haul-out purposes (A. Von Duyke, pers. comm). To continue monitoring in the region, a fourth site was established at the mouth of the Topagoruk River in Dease Inlet from September–October 2021.

Figure 5. Oarlock Island haulout site on 24 July 2021. The water-level marker is in the background along the far side of the spit, while Co-PI Von Duyke replaces the time-lapse camera. The acoustic recorder is located on the post below the camera. Wind-driven erosion of the spit occurred after this photograph, and the spit was underwater and unavailable as a haulout for seals by August 2021. Photo by D. Hauser.

In 2021, low temperatures and the offshore sea ice pack persisted into August, which affected the battery life of cameras and acoustic recorders deployed in July. We switched from nickel-cadmium to lithium batteries for cameras, which effectively prolonged monitoring periods. We also affixed power cables and connected deep-cycle marine batteries to the acoustic recorders to prolong battery life. These upgrades to battery life were also used in 2022.

Wildlife also affected the functioning of our sites in 2021 and 2022, particularly at the Peard Bay site. On 8/4/2021, 7/31/22, and 9/18/22, motion-sensed images captured photos that have been confirmed as brown bears (*Ursus arctos*) by several bear and wildlife scientists (Figure 6). Following each image, the camera angle shifted away from the haulout. A similar disruption of a camera occurred on 7/31/21 at the Smith Bay site, though there was no photographic evidence of what caused the camera to turn. The weather station at Oarlock Island, including the wind speed and direction sensors, was also damaged during the 2020 field season, presumably by a bear, and no in situ weather data was recorded in 2020. The weather station at Peard Bay was knocked down in July 2022, likely by a bear, and repaired and reset when the site was serviced on 8/8/2022.

Figure 6. Motion-activated camera images from Peard Bay in 2021 and 2022. Each appears to capture an image of a brown bear investigating the camera.

Spotted Seal Observations

Spotted seals were observed on 19.3% of 330 days (and 5469 hours) monitored across all sites and years (Table 3). Spotted seals were observed on 32.6% of 89 days monitored at Oarlock

Island, including on 89.5% of 19 days monitored at Oarlock Island in 2020, 0% of 1 day in 2021, and 17.4% of 69 days in 2022. At the Topagoruk River mouth site, seals were observed 9.5% of 84 days monitored, including 0% of 7 days in 2021 (shorefast ice formed soon after the gear was deployed) and 10.4% of 77 days in 2022. Seals were detected 20.5% of 132 days at the Kugruak Bay site in Peard Bay, including 10.2% of 59 days in 2021 and 28.8% of 73 days in 2022. However, seal identification was very difficult to confirm at the Peard Bay site, so we consider these observations as 'questionable' and highly uncertain. The Smith Bay site was not deployed in 2022, because we did not observe seals on the cameras in 2020 or 2021. The highest number of seals hauled out was 69 seals on 8/26/20 at Oarlock Island in 2020, followed by an observation of 50 ('questionable') seals on 7/30/21 at Peard Bay in 2021, and an observation of 16 ('questionable') seals on 8/11/22 at Peard Bay in 2022. A total of 83 images were classified as "poor" or "questionable" image quality and excluded from analyses. We also excluded observations within one hour of site visits by our team.

Table 3. Seal observations from cameras at each site and across all years.

Year	First-last dates of observations[a]	# days with seals; monitored	# hourly observations with seals	# of hourly observations 05:00–23:00	Min-max # seals	Date max # seals	# of hourly observations excluded[b]
Oarlock Island							
2020[c]	8/20–9/5	17; 19	182	305	0–69	8/26	3
2021[c]	7/12–7/12	0; 1	0	11	0	-	0
2022	7/12–9/19	12; 69	59	988	0–15	9/2	21
Site Total		29; 89	241	1293	0–69	8/26	24
Topagoruk							
2021	9/17–9/24	0; 7	0	161	0	-	0
2022	7/12–9/27	8; 77	47	1357	0–5	8/20	57
Site Total		8; 84	47	1518	0–5	8/20	57
Peard Bay[d]							
2021	7/14–8/22	3; 39	25	741	0–50	7/30	1
2021	9/17–10/7	3; 20	10	300	0–6	10/5	0
2022	7/12–9/23	21; 73	51	1175	0–16	8/11	1
Site Total		24; 112	86	1916	0–50	7/30	2
Smith Bay							
2020	8/31–9/23	0; 20	0	367	0	-	0
2021	7/12–7/16	0; 5	0	75	0	-	0
Site Total		0; 25	0	442	0	-	0
Total All Sites		64; 330	371	5469	0–69	8/26	83

[a] Longest camera operational period, from first hourly observation to last hourly observation collected (when the haulout site was observable and open water was available before shorefast ice formation). Equipment may have been operating after this date, but haulout substrate was unavailable upon shorefast ice formation.

[b] Observations that were classified as 'questionable' or 'poor' were excluded from analysis.

[c] Only 1 camera was deployed. All other years and sites, two cameras were deployed.

[d] Seal presence and counts at the Peard Bay site were questionable, due to distance from the spit and the regular presence of large waterfowl and other birds that made identification difficult.

Overall, when seals were present (n=374 hourly observations), we observed an estimated mean number of 10.4 seals across all sites and years; however, estimated numbers varied by site, year, and date (Table 4, Figure 7). On average, August had the highest mean number of seals (13.2 seals) compared to July (8.6 seals, biased high by 'questionable' Peard Bay counts of 50 seals), September (3.9 seals), and October (4.3 seals). Across sites where seals were detected, some number of seals were present from mid-August into early September (note that operational monitoring periods varied; Figure 7). Except for observations at Oarlock Island in 2020 and at Peard Bay on August 1, 2021, the estimated number of seals was generally 10 seals or less.

Table 4. Estimated mean numbers of seals, when present, from cameras at each site and across months. No seals were detected at the Smith Bay site.

Site	Month*	Mean (standard deviation) number seals	Number of hourly observations with seals present
Oarlock Island	July	6.6 (4.4)	31
Oarlock Island	August	17.2 (18.1)	161
Oarlock Island	September	3.8 (4.3)	49
Oarlock Island	Overall	13.1 (16.1)	241
Topagoruk	August	2.6 (1.4)	45
Topagoruk	September	1.0 (0)	2
Topagoruk	Overall	2.5 (1.4)	47
Peard Bay	July	12.9 (14.1)	14
Peard Bay	August	8.2 (5.6)	35
Peard Bay	September	4.4 (3.8)	28
Peard Bay	October	4.3 (1.4)	9
Peard Bay	Overall	7.3 (7.5)	14
All sites combined		10.4 (14.0)	374

*Seals were present during monitoring at Oarlock in 2020 and 2022, Topagoruk in 2022, and Peard Bay in 2021 and 2022 (see Table 3). Identification of seals at the Peard Bay site was considered 'questionable' with a high degree of uncertainty.

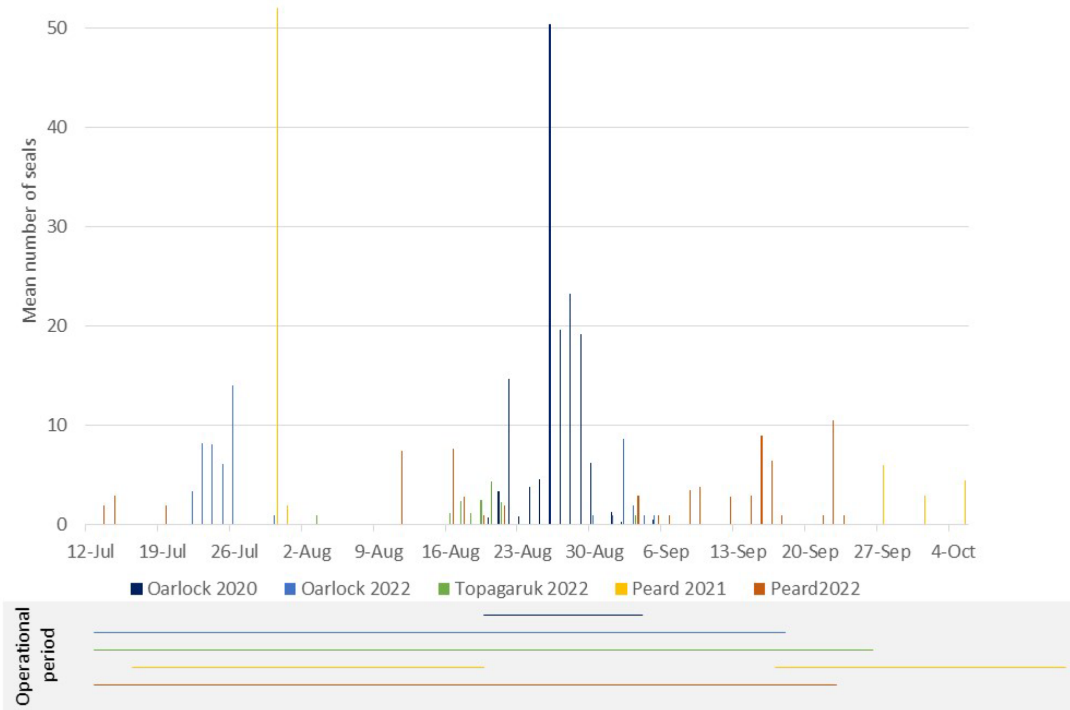


Figure 7. Estimated mean number of seals across date at each site and year. The operational monitoring period for each site is illustrated in the grey box.

Identification of seals at the Peard Bay site was considered ‘questionable’ with a high degree of uncertainty. We anticipated that human disturbance would be a factor affecting spotted seal haul-out behavior. However, we only detected a single disturbance event across all years and sites, which is documented in a series of photos from Oarlock Island on 7/23/22 (Figure 8). First, we estimated 13 seals at the end of the spit at 14:52, then by the next minute all seals had completely deserted the site, and then the next photo shows two small boats just coming into range. Although swimming seals were periodically observed in subsequent images, no seals returned to the haulout site until the next day, 7/24/22.

Figure 8. Photo sequence of vessel disturbance event at Oarlock Island on 7/23/2022.

Additional analysis focused on the monitoring period at Oarlock Island in 2020 when seals were regularly detected nearly daily, and at the highest numbers, over most days of the monitoring period. There was no significant trend or pattern in the time of day and the number of seals hauled out, so the time of day was not included in the final models, though slightly higher numbers of seals were observed at the very beginning and end of the daylight period (Figure 9). We used binomial and quasipoisson GLM to identify environmental covariates associated with seal presence and numbers, respectively. There was limited collinearity among predictor variables except for relative humidity, which was excluded from candidate models following Zuur et al. (2019). Following model selection procedures, date, wind speed, and wind direction were found to affect the probability that seals would be present at Oarlock Island (Figure 10). Seals were present for some proportion of the hourly periods on nearly every day (Figure 11), but attendance varied over the monitoring period and was more common in late August than early September. Wind also affected the presence of seals with a greater probability of observing hauled-out seals during observations with low wind speeds and northeasterly or easterly wind directions (Figure 12). Date, Beaufort scale, and wind direction were included in the final model describing the number of seals observed at the haulout. The number of seals at the haulout peaked during 26–30 August, with a higher number of seals observed in late August than in early September (Figure 13). More seals were observed in calm sea state conditions (although wind speed was not a factor in the final model) and northeasterly or easterly wind directions (Figures 12 and 14). Thus, wind direction and wind speed (or an indirect measure of speed, as sea state) were included in both final models. Wind direction during the 2020 monitoring period was predominantly from the east, regardless of whether seals were present at the haulout, but seals were present ~10% more often when winds were greatest (Figure 12).

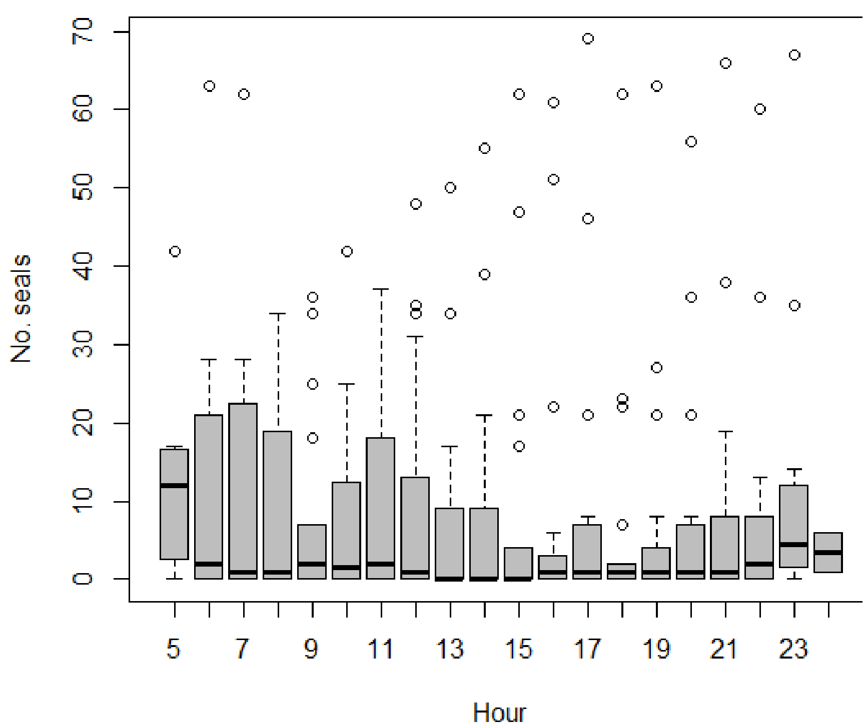


Figure 9. Boxplot of the number of seals observed, by hour, at the Oarlock Island site during the August–September 2020 monitoring period.

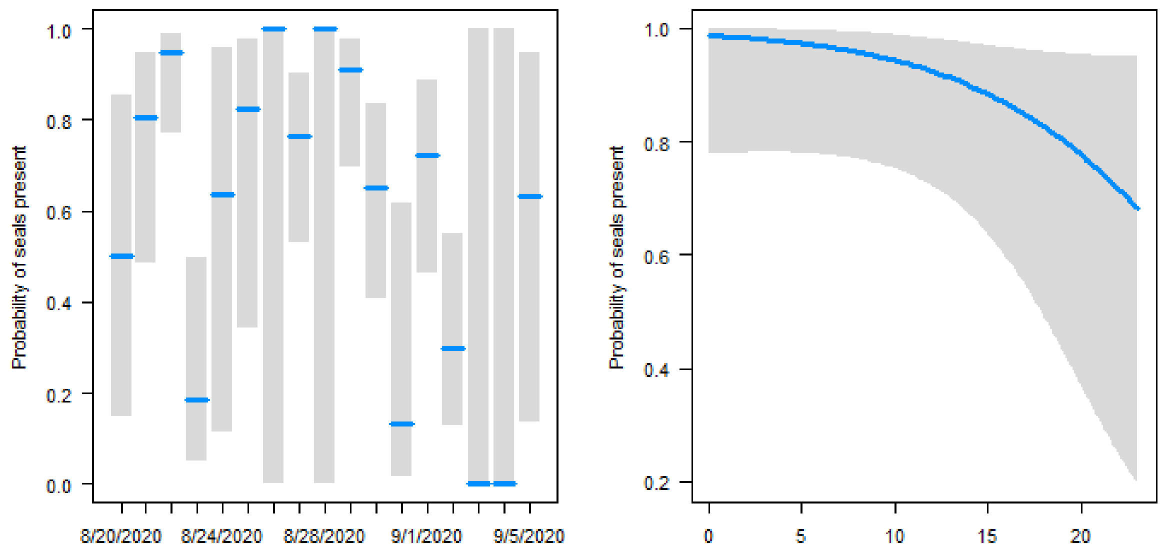


Figure 10. Binomial GLM model results describing the probability of spotted seals being present at Oarlock Island during the 2020 monitoring period relative to date (left panel) and wind speed (knots, right panel).

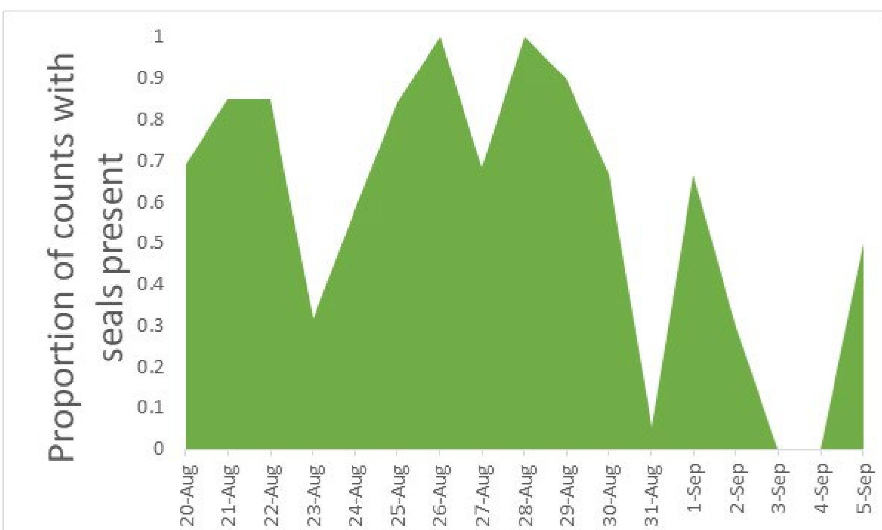


Figure 11. Proportion of the daily counts of seals present by date at the Oarlock Island site during the August–September 2020 monitoring period.

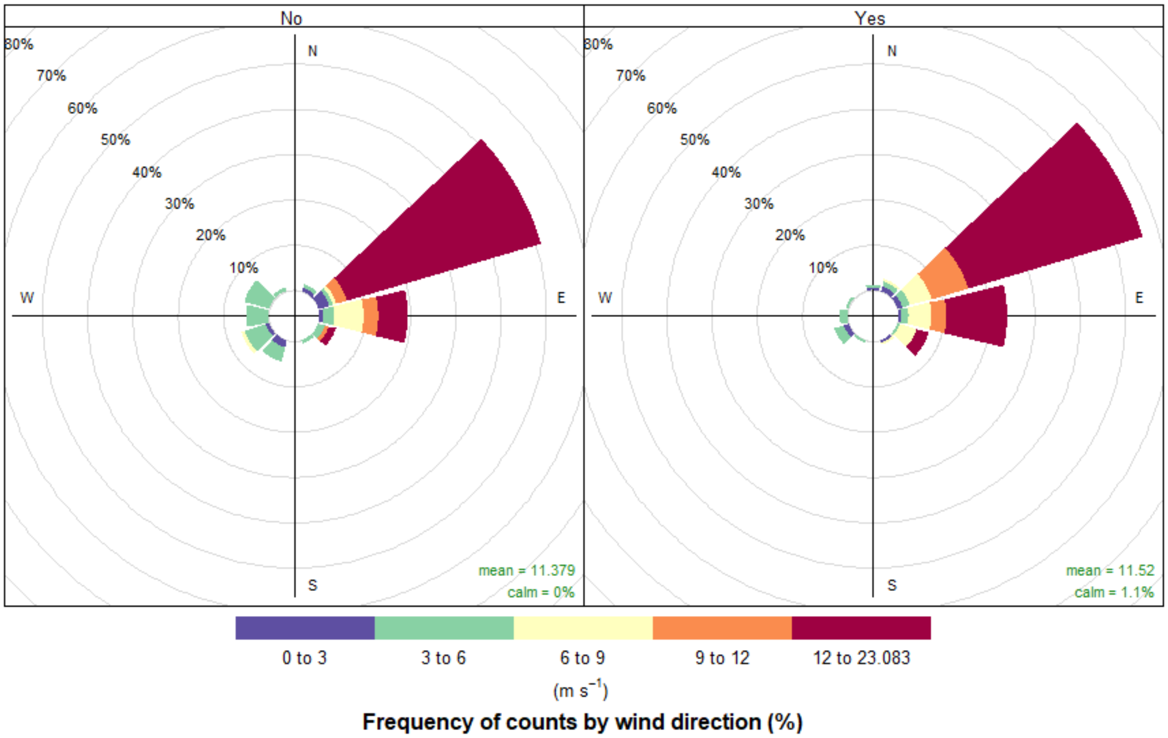


Figure 12. Windroses for observations at the Oarlock Island site when seals were absent (left) and present (right) during the August–September 2020 monitoring period. The direction of wind conditions is shown in the percentage of observations, and colors indicate the magnitude of wind speed at different wind directions.

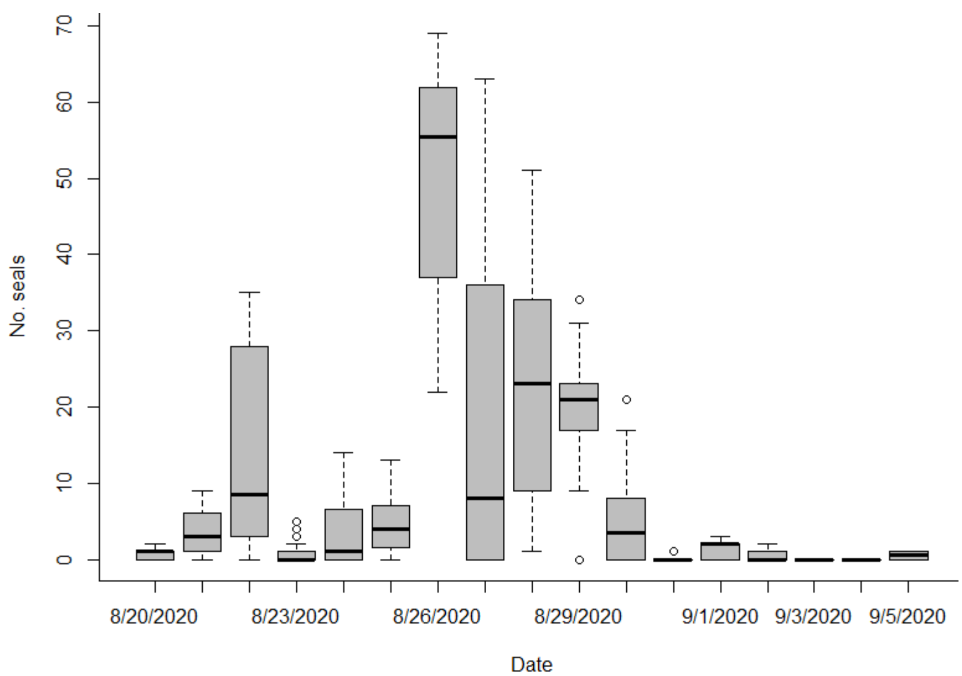


Figure 13. Number of seals hauled out by date at the Oarlock Island site during the August–September 2020 monitoring period.

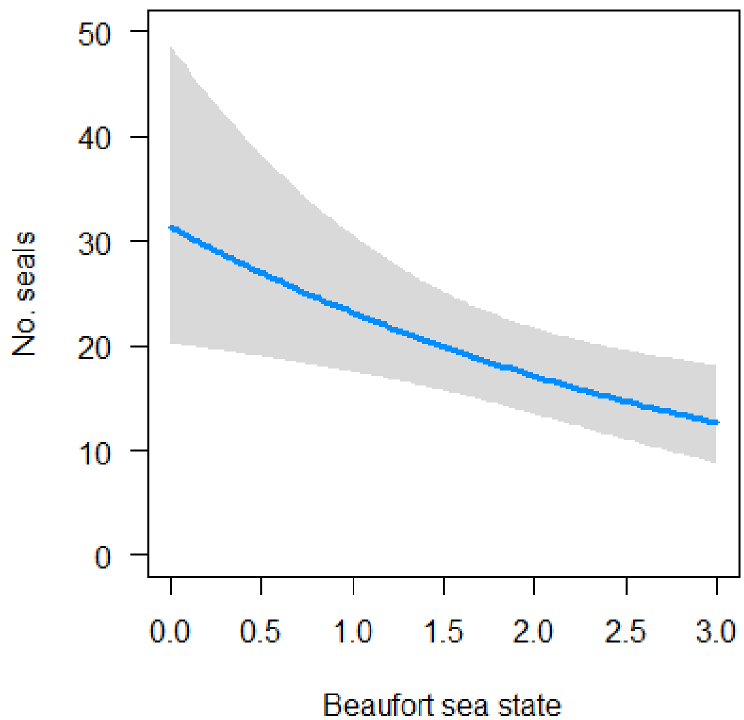


Figure 14. Model results of the number of seals hauled out relative to Beaufort scale (left) at the Oarlock Island site during the August–September 2020 monitoring period. Wind direction (see Figure 14) was also included in the final model.

There were no clear disturbance events, described as multiple seals in "alert" behavior, observed during the 2020 monitoring period at Oarlock Island. Alert behavior includes head up, vigilant, preparing to enter the water, or flushing/fleeing from the haulout. Ambient airborne sound levels collected during 20–24 August also showed relatively limited variability as well as limited correlation with the number of seals observed (Figure 15). However, for a ~6-hour period on the morning of 24 August, sound levels dipped before returning to previous stable levels. The drop in sound levels corresponded with calm wind conditions followed by a rapid increase in wind speed, Beaufort scale, and change in wind direction.

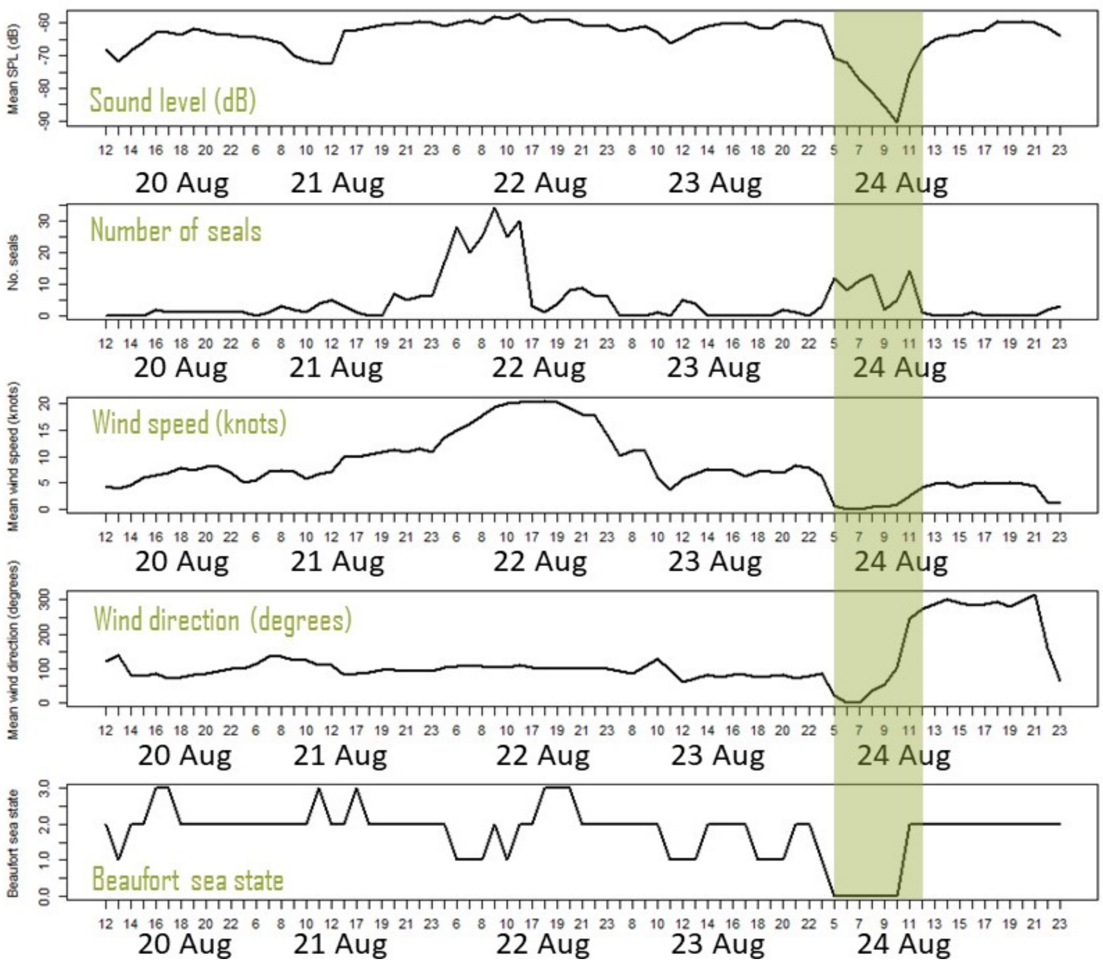


Figure 15. Mean hourly ambient airborne sound levels at Oarlock Island during daylight hours on 20–24 August 2020. The mean number of seals observed at the haulout, wind speed and direction, and Beaufort scale are also shown for the corresponding hours. The morning of 24 August, from ~5:00–12:00, is highlighted for comparison purposes.

Weather Data

A total of 65,298 weather observations (every 10 minutes) were collected from Peard Bay (on Oarlock Island) and Smith Bay in 2021 and 2022 (Table 5). In 2020, both stations failed to record due to a firmware bug, so we used Utqiaġvik NWS weather data for our analyses for that year. Bears and weather also contributed to the damage of sensors in some years and sites, such that not all sensors were functional or operational for the entire monitoring periods listed in Table 5.

Table 5. Field weather station observations collected in 2021 and 2022. No in situ weather data was collected in 2020 due to programming errors.

Year	First-last date of observations	# of observations (every 10 min)	Operational sensors
Oarlock Island			
2021	7/12–10/21	14,583	Wind direction (degrees)
2022	7/13–9/27	10,966	Wind speed (mph), Maximum gust speed (mph) Wind direction (degrees), Rain (inches) Air temperature (°F), Relative humidity (%)
Site Total		*25,549*	
Peard Bay			
2021	7/14–10/21**	14,257	Wind speed (mph), Maximum gust speed (mph) Wind direction (degrees), Rain (inches) Air temperature (°F), Relative humidity (%)
2022	7/12–9/27	11,053	Wind speed (mph), Maximum gust speed (mph) Wind direction (degrees), Rain (inches) Air temperature (°F), Relative humidity (%)
Site Total		*25,310*	
Smith Bay			
2021	7/12–10/20	14, 439	Wind speed (mph), Maximum gust speed (mph) Wind direction (degrees), Rain (inches) Air temperature (°F), Relative humidity (%)
Site Total		14,439	
Total All Sites		65,298	

** On 8/20/21, the wind speed, gust, and direction sensor were damaged, presumably by a bear, and stopped functioning for the remainder of the monitoring period.

We analyzed trends in weather data for 2021 and 2022, depending on the availability of each sensor among the sites. Temperature data were collected every 10 minutes at weather stations in Peard Bay (2021 and 2022), Smith Bay (2021), and Oarlock Island (2022), although daily mean temperatures provided a clearer interpretation of the variability in temperature among sites and years (Figure 16). On average, air temperatures during the monitoring period in 2021 were lower than those in 2022, particularly in August and September (Table 6).

Table 6. Mean monthly and overall air temperatures (°F) at monitoring sites at the NWS station at Utqiaġvik airport (PABR) in 2021 and 2022.

Month	Peard 2021	Smith 2021	PABR 2021	Oarlock 2022	Peard 2022	PABR 2022
July	48.2	46.6	41.4	39.0	40.7	37.8
Aug	40	40.9	37.9	41.5	41.4	39.6
Sep	34.1	34.2	33.5	35.4	37.6	35.6
Oct	25.8	26.6	27			
Mean	36.90	36.91	35.40	38.7	39.9	37.5

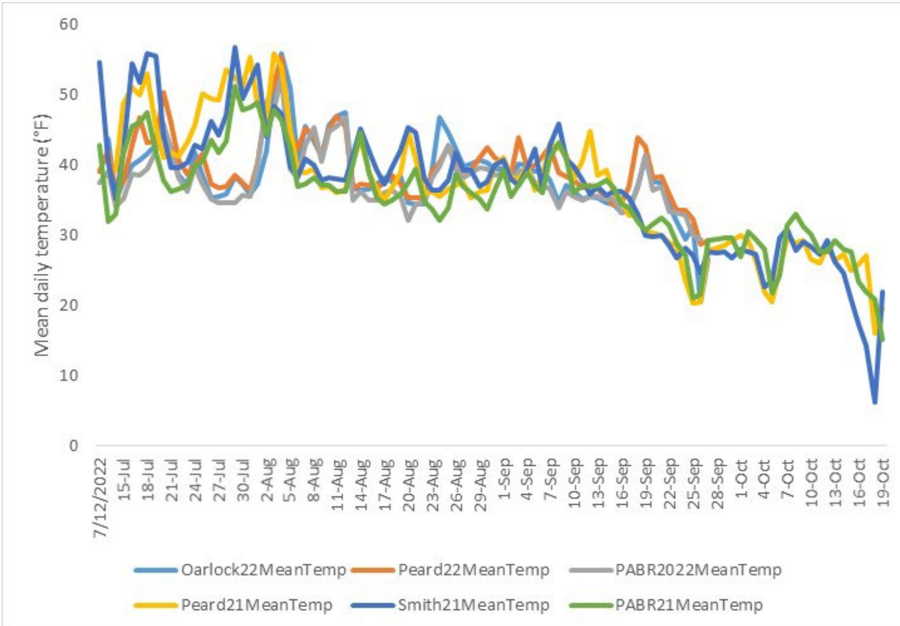


Figure 16. Mean daily temperatures at monitoring sites and the Utqiaġvik airport NWS station (PABR) in 2021 and 2022.

Wind speeds and directions varied among sites and years (Figures 17–19). Wind speed also varied monthly among sites, but was substantially higher in all months of 2021 based on data from the NWS station in Utqiaġvik (Figure 17). In Peard Bay, wind speeds were comparable between 2021 and 2022, with the lowest speeds in August (mean = 3.4 m/s in 2021, mean = 3.8 m/s in 2022) compared to July (mean = 4.5 m/s in 2021, mean = 4.9 m/s in 2022). Wind speeds in Smith Bay in 2021 were slightly higher on average than in Peard Bay, but both were substantially lower than wind speeds measured in Utqiaġvik. Similar or slightly higher wind speeds were measured in Utqiaġvik each month in 2022 and at Peard Bay in July and August 2022 (mean = 4.9 m/s and mean = 3.8 m/s, respectively). Wind direction also varied across sites and years (Figures 18 and 19). There were differences between 2021 and 2022 in the prevailing wind directions and across sites. The most complete wind direction data was collected by the NWS in Utqiaġvik, which showed easterly and northeasterly winds predominated in both years; however, winds were generally stronger in 2021 and westerly winds in 2021 were higher than westerly winds in 2022. Peard Bay winds were different in 2021 and 2022, although Peard Bay was only measured into August 2021 compared to measurements through September in 2022. In Peard Bay in 2021, winds were primarily either northeasterly or southwesterly whereas northeasterly winds prevailed in 2022. Northerly winds prevailed in 2021 at Smith Bay, and northeasterly winds prevailed at Oarlock Island in 2022.

Limited amounts of rainfall were recorded at each site in 2021 and 2022. During the 2021 monitoring periods, averages were 0.0006 inches of rain at Peard Bay, 0.0002 inches of rain at Smith Bay, and 0.002 inches of precipitation (rain and snow) at Utqiaġvik. During the 2021 monitoring periods, averages were 0.0002 inches of rain at Peard Bay, 0.0003 inches of rain at Oarlock Island, and 0.001 inches of precipitation (rain and snow) at Utqiaġvik.

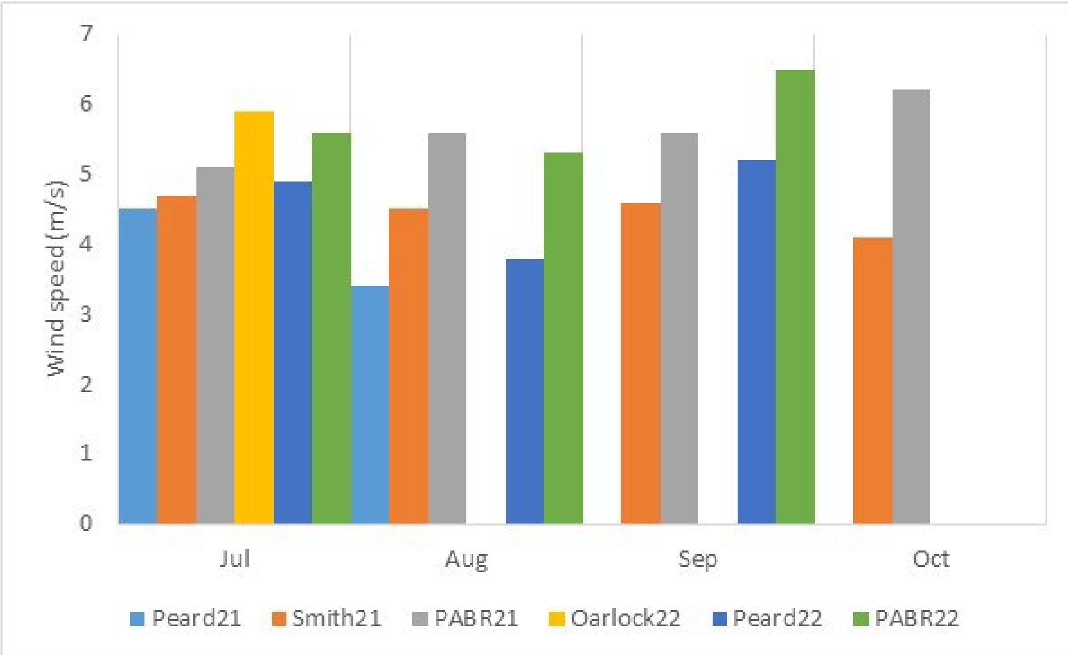


Figure 17. Mean monthly wind speed at each monitoring site in 2021 and 2022.

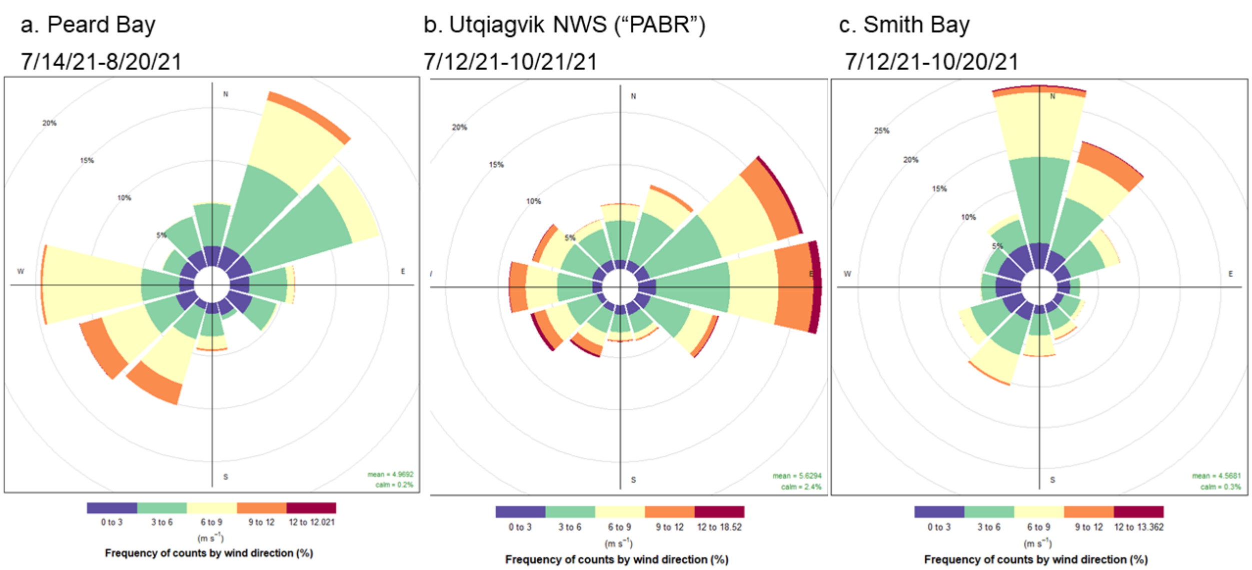


Figure 18. Windroses for 2021 sites operating both wind speed and direction sensors. Note differences in maximum wind speed categories among sites. Wind direction data was the only operational sensor at the Oarlock Island site in 2021.

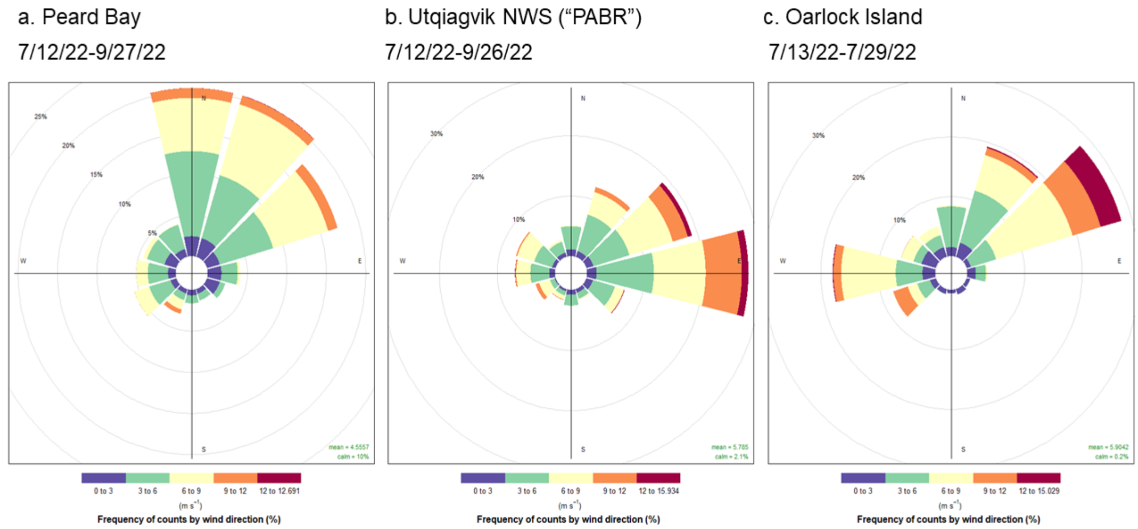


Figure 19. Windroses for 2022 sites operating both wind speed and direction sensors. Note differences in maximum wind speed categories among sites.

Information from Utqiaġvik Community-based Observers

Local weather and environmental observations at spotted seal haulout sites are also put in the context of holistic regional environmental conditions contributed by Utqiaġvik observers who are part of the Alaska Arctic Observatory & Knowledge Hub (AAOKH) community-based monitoring program at the University of Alaska Fairbanks (https://arctic-aok.org/). All AAOKH observations can be searched online via the AAOKH data portal (https://eloka-arctic.org/sizonet/) upon acceptance of the data use agreement and recognition of the data citation and context (Adams et al., 2022).

AAOKH observations were a valuable addition to our field data. For example, during the 2020 monitoring period at Oarlock Island, AAOKH observers described that fall whaling season coincided with the monitoring period, actually commencing earlier in 2020 than in past years. Observer Joe Mello Leavitt noted:

- 8/26/2020: “Whaling season for fall hunt open today. They want to get the whales while they are here. Two whales taken.”

The 2020 whaling season in Utqiaġvik was ultimately prolonged and successful in the number of whales landed, which likely focused subsistence activities away from the Oarlock Island site and limited human activity in the vicinity of the site during our operational period. The site was decommissioned following the end of whaling. Observer Billy Adams provided additional context and described how the fall 2020 environmental conditions and ecosystem functioning were consistent with past years:

- 9/5/2020: “Easterly winds are back…past few years we experienced more west or south winds Aug–Oct…this changed patterns in migratory animals…we had to travel much further in these past few years, many dangerous and long hours, many days at sea. Conditions this fall, beginning Aug, come back to normal…bowheads, seals, and seabirds are closer to shore to feed on what they need as well as the Indigenous Iñupiat."

In 2021, AAOKH observers in Utqiaġvik described a shift to different summer-fall conditions, which were more consistent with distant past conditions but cooler and windier than had been experienced over the past decade. Sea ice floes persisted along the shore and offshore in the Chukchi and Beaufort seas into August 2021. Billy Adams assisted with deployment of monitoring equipment (Figure 20) observing:

- 7/12/2021: "Went to Smith Bay which is about 60 miles to the east of Barrow to set a small camera system and weather recorder. You can see that the pack ice is endless."
- 7/14/2021: "It is 32°F, foggy, overcast, west winds at 5 mph, and visibility 1/4–2 miles at times. I hear this ice extends well over 700 miles out."

Since spotted seals are not adapted to pack ice (only marginal ice) habitats, the prolonged presence of pack and shore ice could prevent spotted seals from accessing areas they might otherwise use. Cool temperatures, offshore ice floes (Figure 21), and westerly winds persisted into August 2021, as Billy Adams observed:

- 8/20/21: "Barrow had its one day of summer …about 50f, calm, sunny and visibility to 10 miles or more. The ice came close and with it came plenty of healthy animals that will feed many people across the Arctic Slope." Also, on
- 8/23/21: "It is 31f, west winds have been persistent this month and snow flurries."
- 8/31/21: "It has been a cold windy wet month for August as it is 30f today but calm, overcast, and visibility to 6 miles."

Figure 20. Photo of extensive pack ice extending well offshore of Utqiaġvik. Photo by AAOKH Observer Billy Adams accompanies his 7/12/2021 observation notes.

Figure 21. Photo of ice floes and windy conditions on 8/16/2021 near Utqiaġvik. Photo by Billy Adams accompanying his AAOKH observations.

Ice floes in the nearshore regions of the Chukchi and Beaufort seas cleared by September 2021, along with warmer air temperatures and more variable winds. Fall whaling in Utqiaġvik commenced on 9/28/21. Billy Adams observed:

- 9/2/21: "Winds are about 22 mph, temperature 40f, east winds have started finally after all summer of west winds."
- 9/21/21: "We have been having high winds from the west, snow and rain with warm temperatures melting the snow by mid afternoon. The temperatures have gotten lower the past 2 days and the snow have not melted since. "
- 9/30/21: " It is 39°F, north winds 14 mph, mostly cloudy, and visibility to 7 miles. It has been warm early in the month some days 40–50f, by mid-month 25–28f, and we are 28–30f today. The snow is still sticking and the lakes have a thin crust of ice with snow on top."

As Billy Adams noted, there were persistent west winds during summer 2021 and into September, which is known to result in higher water levels in the Elson Lagoon system, including Dease Inlet. By October, whaling ended and he noted how snow and slush ice were forming on lagoons:

- 10/12/21: "east winds at 25mph, temperature about 30°F, overcast and visibility to 5 miles. It has been blowing snow and the [Elson] lagoon is building up slush from the blowing snow. The bowhead whaling has been successful with unofficial results of 26 landed whales with 4 lost at an efficiency rate of 87% which is excellent. Congratulations to all..... "

Spotted seals would be expected to depart an area ahead of the establishment of shorefast or pack ice (Figure 22). Billy Adams helped retrieve equipment and decommission sites in October and noted:

- 10/20/21: "The weather has been in the mid 20's overcast, easterly winds at 20–25 mph, and the visibility has been about 5–8 miles. Dr. Von Duyke who is a biologist for the NSB is picking up his research equipment before the winter arrives."

Figure 22. Photo of Dease Inlet covered over with shorefast ice on 10/20/21. Photo by Billy Adams accompanying his AAOKH observations.

In 2022, there were temperatures, ice break-up, and wind conditions reported that were similar to those in 2020. In mid-July there was no shore ice remaining in Utqiaġvik, with the pack ice reported several miles offshore. Hunters were boating already, looking for caribou, seals (primarily bearded and ringed seals), and walruses. Observer Joe Mello Leavitt observed:

- 7/16/22: "Ice reported 10 miles out. Calm in the morning but wind picks up in the afternoon. Rough ride back. Pack ice has big pans, not many seals got."

Billy Adams also talked about broken ice and productive, healthy wildlife:

- 7/28/22: "From Gravel pit to NARL and Cake Eater road, 34f, west winds to 13 mph, overcast, and visibility to 5 miles. Some ice is going by and some smaller broken ice is ashore. Polar bears are with the ice going north, this morning some were spotted and a mother with 2 cubs look very healthy. Geese with their goslings are looking well too. A grey whale is also feeding nearshore." (Figure 23)

Figure 23. Photo of ice floes and “healthy” polar bears. Photo by Billy Adams accompanying his AAOKH observations.

August was reported as predominantly foggy and cool in Utqiaġvik; however, temperatures warmed by the end of August, as Billy Adams observed:

- 8/24/22: “It has been wet and foggy for the past few weeks with lower temperatures 34f to 38f normal prevailing winds east or west winds. This foggy wet condition is great for tuttu [caribou] and other herbivores as they benefit from it the most and are putting on fat. The fog for civilians who like to travel has not been good as many planes are canceling flights and the cargo that is needed in the communities has been very slow receiving products. Let us be patient and soon enough the sun will shine again!”
- 8/29/22: “Warmed up to 40+f light east winds, and overcast with areas of fog.”
- 9/5/22: “The fog and wet conditions continued till the 4th of September now we have some sun in our lives but there are still areas of dense fog. The winds have shifted and are coming from the west and wave action have developed where we call them ingulik (rolling waves; Figure 24) maybe a cruise ship in the fog and fuel vessel near Barrow. A bowhead whale about 10 miles north of Nuvuk [Point Barrow] also.”

Figure 24. Photo of windy conditions and rolling waves in Utqiaġvik on 9/4/22. Photo by Billy Adams accompanying his AAOKH observations.

On 9/21/22, Billy Adams observed the presence of krill and bowhead whales feeding near town, similar to patterns observed for decades by the Iñupiat:

- 9/21/22 "About 10 miles northeast of Nuvuk bowheads feed on krill. The krill are pushed up onto the shelf after a good east wind and are sort of trapped there to be eaten by whales, sea birds, and other marine animals. So bowheads know when this event happens and are quick to find their food."

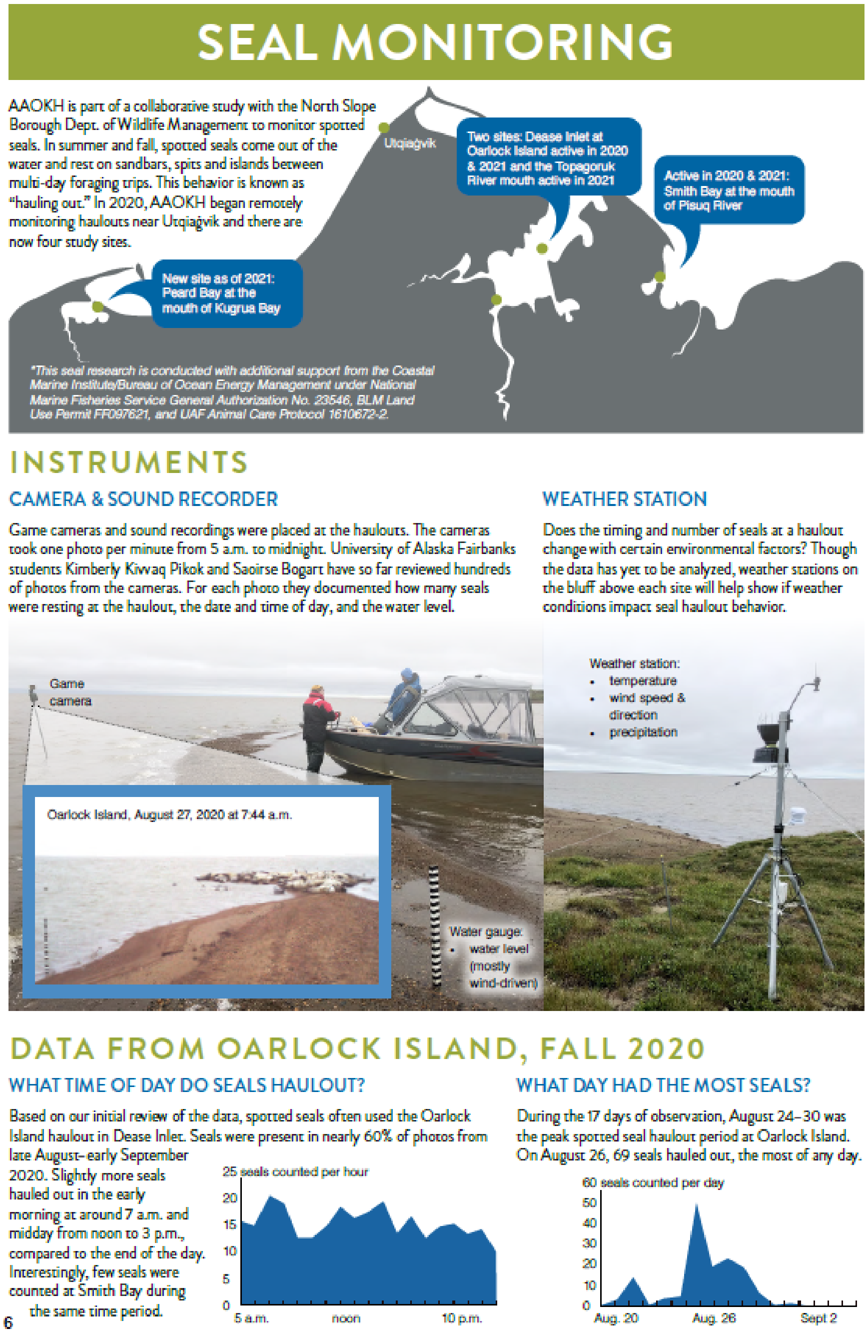
Our monitoring sites were decommissioned in late September 2022 in anticipation of fall whaling commencing on 9/24/22. This also coincided with lakes, rivers, and lagoons starting to freeze and some of the first snowfalls in Utqiaġvik, as Billy Adams observed:

- 9/23/22: "Late last night we got some Christmas greetings from above! Whale snow! Ugsrualaqigaatigut! Oil snow from above! It is a message from our Creator that we shall receive great gifts such as whales very soon!" (Figure 25)

Figure 25. Photo of snowfall in Utqiaġvik on 9/23/22. Photo by Billy Adams accompanying his AAOKH observations.

Outreach and Local Coordination

In coordination with the AAOKH and the NSB-DWM, we also shared project plans and updates with the community of Utqiaġvik and the co-management organization for Arctic seals, the Ice Seal Committee (ISC). Project plans were introduced to the ISC for review in 2020 and ongoing updates are provided via their website and annual meetings. Regular updates about this project have been shared in the biannual *AAOKH News* (e.g., Figure 26), which also features recent regional observations in each newsletter. *AAOKH News* is broadcast widely by email, social media, and the website in addition to direct mailings to all mailbox holders in the seven contributing AAOKH communities. Sharing updates and reports via the AAOKH newsletter has been acknowledged as a way to rapidly share our work with communities in an accessible and easily-digestible format that is appreciated by community members who are increasingly seeing researchers in their communities (Hauser et al. In Press, *Arctic Science*).


SEAL MONITORING

AAOKH is part of a collaborative study with the North Slope Borough Dept. of Wildlife Management to monitor spotted seals. In summer and fall, spotted seals come out of the water and rest on sandbars, spits and islands between multi-day foraging trips. This behavior is known as "hauling out." In 2020, AAOKH began remotely monitoring haulouts near Utqiaġvik and there are now four study sites.

*This seal research is conducted with additional support from the Coastal Marine Institute/Bureau of Ocean Energy Management under National Marine Fisheries Service General Authorization No. 23546, BLM Land Use Permit FF097621, and UAF Animal Care Protocol 1610672-2.

INSTRUMENTS

CAMERA & SOUND RECORDER

Game cameras and sound recordings were placed at the haulouts. The cameras took one photo per minute from 5 a.m. to midnight. University of Alaska Fairbanks students Kimberly Kivvaq Pikok and Saoirse Bogart have so far reviewed hundreds of photos from the cameras. For each photo they documented how many seals were resting at the haulout, the date and time of day, and the water level.

WEATHER STATION

Does the timing and number of seals at a haulout change with certain environmental factors? Though the data has yet to be analyzed, weather stations on the bluff above each site will help show if weather conditions impact seal haulout behavior.

DATA FROM OARLOCK ISLAND, FALL 2020

WHAT TIME OF DAY DO SEALS HAULOUT?

Based on our initial review of the data, spotted seals often used the Oarlock Island haulout in Dease Inlet. Seals were present in nearly 60% of photos from late August–early September 2020. Slightly more seals hauled out in the early morning at around 7 a.m. and midday from noon to 3 p.m., compared to the end of the day. Interestingly, few seals were counted at Smith Bay during the same time period.

WHAT DAY HAD THE MOST SEALS?

During the 17 days of observation, August 24–30 was the peak spotted seal haulout period at Oarlock Island. On August 26, 69 seals hauled out, the most of any day.

6

Figure 26. Study information published in the Fall–Winter *AAOKH News* (McFarland et al., 2020). Summaries in the newsletter each year provided updates on the spotted seal monitoring project and our research.

DISCUSSION

Research on spotted seals is in its relative infancy, and there are no recent or reliable estimates of population trends, abundance, movements, or habitat use for large segments of the population of spotted seals in Alaska. In this study, we combined remote camera monitoring of haulout locations, environmental monitoring, and community-based observations to describe seal presence and numbers and environmental conditions at a network of terrestrial haulout sites in the Beaufort and Chukchi seas. Monitoring was completed during the open water seasons of 2020, 2021, and 2022, collecting the first time-lapse camera data available for spotted seals at their haulouts in the region.

Presence and Relative Abundance at Haulout Sites

Our results suggest the importance of timing (i.e., date) and wind or sea state conditions for spotted seals to use haulouts. Seals were detected across all months monitored, from July-October, though the most consistent and peak numbers occurred from mid-August to early September. We also found that date was a significant predictor of both seal presence and abundance at Oarlock Island in 2020. Although some seals were present nearly every day of the monitoring period, peak counts (~69 seals) occurred on 8/26/20 and the mean number of seals was at least 20 seals for the next three days. Seal presence at the site varied non-linearly and was more common in late August than in September 2020.

Wind speed, or an indirect measure of it (Beaufort state), and wind direction were included in models of both seal presence and abundance at Oarlock Island in 2020. The wind was predominantly from the northeast or east regardless of whether seals were present or not, although seals were less likely to haul out when winds were >15 knots (7.7 m/s). Fewer than 10 seals would be predicted to haul out for a Beaufort scale of 3, which corresponds to wind speeds of 7–10 knots and waves ~2 ft in height. No seals were predicted to haul out at sea states greater than 3.

Seals may haul out less frequently at higher wind speeds and sea states to remain more vigilant to predators or disturbance, especially in the most trafficked site of our study. Polar bears (*Ursus maritimus*), one of the few natural predators of spotted seals, are also known to occur on Oarlock Island during the open water period (A. Von Duyke, personal communication). Grizzly bears were also documented as present at the Kugruak Bay study site, which may explain why a location previously overrun with hauled-out spotted seals was not used. Further, spotted seals are known to be particularly weary and responsive to human activity, including passing vessels (A. Von Duyke, personal communication) and aircraft (Frost et al., 1993). We only documented one human disturbance event during our three years and multiple sites of monitoring. Our data show that higher wind speeds and associated wave action create a noisier ambient soundscape that could affect a seal's ability to hear or detect perceived dangers. Seals may be less likely to haul out in windier conditions because wind and wave noise "mask" the sound of approaching predators, boats, or aircraft. Additional data will be useful to understand how wind affects seal haul-out behavior.

The inverse relationship of seal activity at the site relative to wind speed and sea state may also be related to thermoregulation. Other seal species, such as the closely related harbor seal (*Phoca vitulina*), prefer to haul out at warmer temperatures and lower wind speeds, presumably to reduce chill and promote thermoregulation (Simpkins et al., 2003). Higher wind speeds cause more wave spray at haulouts, which acts as a cooling factor in addition to windchill. Though the ambient temperature was not included in the final models, perhaps wind speed and sea state have a direct impact on thermoregulation in this Arctic coastal environment, and future studies could estimate windchill as a factor affecting haul-out behavior.

Studies of harbor seals and other seal species indicate that other environmental factors, such as water level, might have factored into the final models predicting seal presence or numbers at the Oarlock Island site in 2020. Harbor seals strongly prefer to haul out at low tide when optimal habitat is available (Hamilton et al., 2014; Simpkins et al., 2003). However, there are minimal tidal exchanges on Alaska's North Slope, so the tide is not an important factor for harbor seals that haul out on glaciers, sea ice (Hamilton et al., 2014; Jansen et al., 2015) or other areas where the tide does not affect the availability of haulout substrate (Stewart, 1984). The wind is the primary factor affecting water levels in the coastal regions of the Chukchi and Beaufort seas. During the 2020 monitoring period at Oarlock Island, haulout substrate was consistently available for seals, which may have contributed to a diminished effect of water level. In 2021, however, water levels were very high during July and August and little to no substrate was available at the Oarlock Island site. We discuss this in more detail below, and additional data across other sites and years could help further describe the impact of water level on haul-out behavior.

Time of day is also known to be a factor affecting the haul-out behavior of harbor seals and other pinnipeds. Across many parts of their range, the number of harbor seals hauled out increases around mid-day and declines towards sunset, particularly during the molting period (Simpkins et al., 2003; Stewart, 1984). However, the most northerly population of harbor seals in Svalbard, Norway does not exhibit diel haul-out patterns characteristic of more temperate populations (Hamilton et al., 2014), similar to other terrestrial species in the Arctic that are known to cease, or partially cease, circadian rhythms (van Oort et al., 2005). Yet understanding diel haul-out patterns, as well as other environmental factors, has become a critical aspect of population abundance surveys for harbor seals. We found time of day had a limited impact on the number of seals hauled out, except for a slight peak earlier and later in the day. The study was conducted when spotted seals were post-molt, so they may have been optimizing the brightest part of the day to forage as visual predators. Understanding diel haul-out patterns has the potential to inform broader survey efforts for ice seals by identifying environmental factors that affect when the greatest numbers of spotted seals are hauled out and therefore "available" to be observed by manned or unmanned aerial surveys focused on population abundance.

Interannual Variability

The use of terrestrial haulouts by spotted seals in the Chukchi and Beaufort seas also seems to be ephemeral. Locations historically known to be highly used by spotted seals (Table 1) appeared not to have been frequented by seals during our study. While water level was not directly included in our predictive models, it clearly impacts the availability and quality of substrate for hauling out. For example, the most reliable haulout in Dease Inlet, Oarlock Island, became wave-affected due to high water in July 2021 to the point that waves triggered motion-activated photo bursts, filling the SD card within one day (Figure 27). The spit and most of the other substrate available in earlier years was under water due to high water levels.

By early August, the high water levels, combined with wind and waves, caused erosion and the loss of our cameras, T-posts, and acoustic recorder at the site. These factors also resulted in the loss of the usual and predictable substrate available to seals for haul-out purposes compared to other years.

Figure 27. Photo taken on 7/12/21 as waves continuously activated camera motion sensors at Oarlock Island. The water-level marker location, underwater here, was at the water's edge during 2020.

During the July through September 2022 monitoring period at Oarlock Island, we observed periods with excellent available substrate rapidly shift to being underwater for hours to a few days, depending on wind direction and speed. For example, on 8/23/22 the Oarlock Island spit provided ample seal haulout substrate when NWS in Utqiaġvik recorded predominant easterlies and wind speeds averaging 7.1 m/s, yet on 8/26/23, the winds shifted to northerly, averaging only 4.4 m/s, and inundated the haulout spit (Figure 28). The wind sensor at Oarlock Island was not functioning at the time, but this suggests the importance of wind direction in particular.

Figure 28. Photos taken on 8/23/22 (left) and 8/26/22 (right) from the same camera on Oarlock Island. Images illustrate how shifts in wind direction and speed can affect the amount of substrate available for spotted seals to haul out.

It should be noted that in addition to the polar bear observed at Oarlock Island, the Smith Bay region is frequented by polar bears, with two observed nearby at the time that equipment was deployed. As previously noted, a grizzly bear was documented at the Kugruak Bay study site on multiple occasions. It cannot be determined whether these bears were hunting the hauled-out spotted seals. However, the presence of potential seal predators at three out of the four study sites suggests that predator behavior may be an important consideration with future deployments. Aggregations of prey may be attractive to large predators and therefore, monitoring methods may need to be adjusted to account for the chance that a bear will destroy field equipment and/or affect monitoring results by driving away seals that would normally be hauled out.

Physical environmental conditions likely affect the fine-scale selection of haulout sites by seals, while water level may be more important at a regional scale. Although there is not an established tidal or other water level station maintained by NWS in the region, our environmental monitoring and community-based observers indicated that 2021 was different from 2020 and 2022. Based on AAOKH observations and monitoring by western science (Meier et al., 2021), conditions in July–August 2021 seem to reflect historic conditions prior to the shift to earlier sea ice break-ups experienced in recent decades. For example, AAOKH Observer Billy Adams noted very cool temperatures and shore ice extending "for miles offshore" in Utqiaġvik into August. Prolonged pack and shorefast ice may have prevented spotted seals from accessing sites they otherwise may have used in July and into August 2021. Additionally, Traditional Ecological Knowledge from Utqiaġvik residents indicates that sustained west winds increase water levels in the Elson Lagoon and Dease Inlet region (NSB, unpublished data). High water levels and site erosion were observed at Oarlock Island in 2021.

Cooler air temperatures as well as prolonged sea ice cover (both shorefast and pack ice) correlate with cooler sea surface temperatures, differences in water chemistry (e.g., salinity), and later break-up of rivers used by fish prey of spotted seals. While there is no data on the distribution and abundance of prey species during the open water seasons monitored in this study, differences in physical environmental conditions would likely impact annual prey availability and the related foraging behavior and space use by spotted seals.

It is unclear where spotted seals were hauled out in 2021 since they were not observed on our cameras across the network of monitoring sites. We presume that the abundance and diversity of haulout sites in the region compensated for the loss of substrate at sites like Oarlock Island. Local observations document that spotted seals periodically will shift haulout locations among several sites in close proximity. For example, the channel between the south end of Dease Inlet and Pittalukruak Lake is frequented by spotted seals changing their haulout locations within this confined area.

Telemetry studies suggest that individual spotted seals tagged in northwest Alaska use several haulout sites within a season, with site fidelity varying among individuals (Lowry et al., 1998, 2000). The Chukchi and Beaufort Sea coastal regions include lagoon systems with extensive sand spits, small-large islands, and low-tundra substrates that are used by spotted seals (e.g., Figure 29). With an abundance of suitable haulout sites in the region, seals are likely opportunistic in choosing haulout sites that combine suitable substrate, the ability to be vigilant to disturbance or predators, and proximity to foraging opportunities. Telemetry work (NSB, unpublished data) suggests that spotted seals visit multiple haulout locations during the open water season, many of which are consistent from year to year, as they begin to make their annual migratory movements out of the Arctic and towards the Bering Sea. While they are locally situated, it is also possible that spotted seals shifted just enough to be out of the camera frame. As such, it may be necessary to employ a more extensive or sophisticated camera monitoring network to cover the suite of potential haulout sites that are selected by seals each season, particularly considering the unexpected limitations and equipment issues we experienced due to COVID-19, extreme weather, and wildlife.

Figure 29. Spotted seals hauled out on the small island at the Topagoruk River monitoring site on 8/20/22. This example illustrates the diversity of haulout substrate opportunistically used by spotted seals in the Chukchi and Beaufort Seas coastal regions.

Local Coordination and Community-based Observing

We believe that local participation and inclusion of broader perspectives enhance research efforts in Arctic regions. The holistic perspectives and extensive experience of Iñupiaq field assistants, AAOKH observers, and students broadened the scope of our work. The role of local and Indigenous Knowledge, particularly in the context of understanding the environmental conditions that might affect spotted seal haul-out behavior, was very valuable. Engagement with the Ice Seal Committee helped us to refine our project goals and share information and results during the project. We also communicated results to community members in the region through the AAOKH newsletter. These efforts helped us to meet our objective to engage with Indigenous communities and involve them in our research in ways that built capacity for scientific operations by community members in Utqiaġvik to support research while helping our scientific team understand the broader ecosystem.

CONCLUSIONS

This pilot project provided valuable and novel data about spotted seal haul-out behavior and environmental conditions in an area of the Arctic that is experiencing extreme physical and anthropological change. Spotted seals are important and abundant components of Arctic marine ecosystems. Their extensive and vast seasonal migrations make these species valuable as nutritional and cultural resources for coastal Indigenous people across northern, western, and southwestern Alaska, including both Iñupiat and Yup'ik coastal communities yet significant knowledge gaps remain regarding abundances, distribution, phenology, foraging ecology, health, and habitat use.

We have met our goals to improve the understanding of environmental factors affecting spotted seal use of terrestrial haulouts in the Chukchi and Beaufort seas, particularly when considering that spotted seals are probably the least studied Arctic marine mammal species in the Alaska Arctic. Similar to other pinniped studies (e.g., Stewart, 1984), we demonstrated the ability of time-lapse camera monitoring stations to detect and enumerate spotted seals and investigate the impacts of environmental conditions. As a pilot study, we also identified limitations to our methodology. There is extensive habitat within the region that may be utilized by spotted seals, which makes it logistically challenging to monitor all of the potentially suitable haulout sites. We also documented relatively small numbers of seals at haulouts in comparison to the thousands that have been documented elsewhere (e.g., Lowry et al. 2000). Interannual variability in environmental and ecological conditions can impact the ability to detect seals, as we saw in 2021.

Despite hauled-out spotted seals' sensitivity to human activities, there was only one disturbance event observed across all years and sites. The disturbance was at our 'high impact' site, Oarlock Island, which is closest to Utqiaġvik and a location that boaters pass by on their way to cabins and hunting sites around Dease Inlet. Details of that disturbance event were consistent with our experience that seals are alert to vessels that are miles away and will flush from a haulout substantially ahead of vessels passing or approaching (A. Von Duyke, personal communication). Thus, it is notable that only a single disturbance was recorded, suggesting that seals in the region may rarely be disturbed.

The pilot study offers opportunities for additional research. For example, vast volumes of data were created over three years and four sites of monitoring, and these data are slow to manually process. It is possible that machine learning or other automated methodologies could improve processing time, although we provided valuable work and research opportunities by involving undergraduate students in the review and entry of camera data. Future research could explore environmental and ecological factors that were identified as important to understanding haul-out behavior and combine other novel assessment techniques, such as unmanned aerial systems, to enhance data collection.

We met our goals to engage with Indigenous communities and build local capacity for scientific operations. Coordination with the Ice Seal Committee and partnerships with NSB-DWM and AAOKH were critical components to support this goal. We appreciate and value the engagement of AAOKH observers in this project to provide holistic perspectives and contribute knowledge that has been gained since time immemorial.

ACKNOWLEDGMENTS

We thank the Coastal Marine Institute and the Bureau of Ocean Energy Management for the support of this project, particularly project officers Dr. Richard Raymond, who graciously worked with us on modifications to the study, and Dr. Christina Bonsell. We appreciate the Alaska Arctic Observatory & Knowledge Hub (AAOKH) for providing matching funds. We thank the North Slope Borough Department of Wildlife Management for providing critical logistics for completing our field activities out of Utqiaġvik and in-kind cost-share including vessels and fuel, lodging, and salary support for local field assistants and Dr. Von Duyke. In addition, NSB Search and Rescue generously provided helicopter flights to our study sites which greatly increased accessibility when weather conditions or limited staff availability (i.e., due to the COVID-19 pandemic) impacted our ability to access sites by boat. We deeply appreciate the cooperation and enthusiasm from numerous NSB Search and Rescue pilots and crew, Director Heather Dingman, and former director April Brooks.

Several people contributed to the field and data entry components of this project. Joe Skin and Isaac Leavitt were essential field assistants for the vessel-based research activities. Joshua Jones from UAF assisted on several field trips and with equipment procurement, as did several North Slope Borough employees, including Billy Adams, Kayla Scheimreif, John Citta, and Craig George (retired). UAF undergraduate students also played important support roles, including Saoirse Bogart who entered data from camera images for many hours in addition to helping with fieldwork in 2022. Additional data entry help was provided by Kimberly Kivvaq Pikok, Emily Camp, Ashlynn Nakvinda, and Markayla Katchatag.

This work was funded under BOEM cooperative agreement M19AC00017, with cost-share from the University of Alaska Fairbanks. Work was permitted under the Marine Mammal Protection Act (NOAA General Authorization Letter of Confirmation No. 23546), the UAF Institutional Animal Care and Use Committee (UAF Protocol No. 1610672-2), and the Bureau of Land Management land use permit (NPR-A Permit No. F097621). Fieldwork was conducted within the traditional and ongoing territories of Alaska's Iñupiat people. We acknowledge their stewardship and appreciate the Iñupiaq hunters and students from Utqiaġvik who supported and contributed to this work. Dr. Hauser would also like to acknowledge that she lives, works, and conducts research from Fairbanks, Alaska, on the homelands of the Lower Tanana Dene.

STUDY PRODUCTS

Publications

Hauser, D.D.W., Glenn, R.T., Lindley, E.D., Pikok, K.K., Heeringa, K., Jones, J., Adams, B., Leavitt, J. M., Omnik, G.N., Schaeffer, R., SimsKayotuk, C., Sparrow, E.B., Ravelo, A.M., Lee, O., & Eicken. H. (In Press). Nunaaqqit Savaqatigivlugich - Working with Communities: Evolving Collaborations around an Alaska Arctic Observatory and Knowledge Hub. *Arctic Science*.

Von Duyke, A. L., Douglas, D. C., Crawford, J. A., & Gryba, R. (In Preparation). Seasonal movements, dives, and haul-out behavior of spotted seals (*Phoca largha*) in the Beaufort, Chukchi, and Bering Seas (2012-2020).

McFarland, H.R., D. Hauser, R. Thoman, C. SimsKayotuk, G. Omnik, S. Patkotak, R. Schaeffer, J. Leavitt, B. Adams, E. Lindley, K. Pikok, R. Glenn. 2021–2023. AAOKH News: Alaska Arctic Observatory & Knowledge Hub newsletter issues IV, V, and VI. International Arctic Research Center, University of Alaska Fairbanks. Available online.

Hauser, D.D.W. and A. Von Duyke. 2021–2022. Evaluating novel assessment approaches for coastal ice seal haulout areas and behavior in the Alaskan Beaufort Sea. Alaska Coastal Marine Institute Annual Reports for calendar years 2020, 2021.

Hauser, D.D.W. and A. Von Duyke. 2020. Novel assessment techniques for spotted seal coastal haulouts. Project Summary provided to the Ice Seal Committee for online distribution.

Presentations

Hauser, D.D.W., A. Von Duyke, and J. Jones. 2023. Novel assessment techniques for monitoring spotted seals at Alaska Arctic haulouts. Alaska Marine Science Symposium 2023 (poster).

Hauser, D.D.W. and A. Von Duyke. 2020–2023. Novel assessment techniques for spotted seal coastal haulouts. Project updates to the Ice Seal Committee Annual Meetings: February 2021 March 2022, and February 2023.

Hauser, D.D.W and A. Von Duyke. 2020–2023. Evaluating novel assessment approaches for coastal ice seal haulout areas and behavior in the Alaskan Beaufort Sea. Alaska Coastal Marine Institute Annual Research Reviews, January 2020, 2021, 2022, 2023.

REFERENCES

Adams, B., Apangalook, L., Apangalook, P., John, S., Leavitt, J., Omnik, G., Patkotak, S., SimsKayotuk, C., Schaeffer, R., Weyapuk, J., & other observers. (2022). *Local Observations from the Seasonal Ice Zone Observing Network (SIZONet) and Alaska Arctic Observatory and Knowledge Hub (AAOKH), Version 2.* Edited by H. Eicken, R. Glenn, D. Hauser, K. Heeringa, J. Jones, M. Kaufman, O. Lee, E. Lindley, K. Pikok, and A. Ravelo. National Snow and Ice Data Center, Boulder, CO. http://dx.doi.org/10.7265/N5TB14VT

Citta, J. J., Lowry, L. F., Quakenbush, L. T., Kelly, B. P., Fischbach, A. S., London, J. M., Jay, C. V., Frost, K. J., Crowe, G. O., Crawford, J. A., Boveng, P. L., Cameron, M., Von Duyke, A. L., Nelson, M., Harwood, L. A., Richard, P., Suydam, R., Heide-Jørgensen, M. P., Hobbs, R. C., … Gray, T. (2018). A multi-species synthesis of satellite telemetry data in the Pacific Arctic (1987–2015): Overlap of marine mammal distributions and core use areas. *Deep Sea Research Part II: Topical Studies in Oceanography*, *152*, 132–153. https://doi.org/10.1016/j.dsr2.2018.02.006

Conn, P. B., Ver Hoef, J. M., McClintock, B. T., Moreland, E. E., London, J. M., Cameron, M. F., Dahle, S. P., & Boveng, P. L. (2014). Estimating multispecies abundance using automated detection systems: Ice-associated seals in the Bering Sea. *Methods in Ecology and Evolution*, *5*(12), 1280–1293. https://doi.org/10.1111/2041-210x.12127

Crawford, J. A., Frost, K. J., Quakenbush, L. T., & Whiting, A. (2018). Seasonal and diel differences in dive and haul-out behavior of adult and subadult ringed seals (*Pusa hispida*) in the Bering and Chukchi seas. *Polar Biology, 42,* 65–80. https://doi.org/10.1007/s00300-018-2399-x

Crawford, J. A., Quakenbush, L. T., & Citta, J. J. (2015). A comparison of ringed and bearded seal diet, condition and productivity between historical (1975–1984) and recent (2003–2012) periods in the Alaskan Bering and Chukchi seas. *Progress in Oceanography*, *136*, 133–150. http://dx.doi.org/10.1016/j.pocean.2015.05.011

Cutler, T. L., & Swann, D. E. (1999). Using Remote Photography in Wildlife Ecology: A Review. *Wildlife Society Bulletin (1973-2006)*, *27*(3), 571–581.

Danielson, S. L., Ahkinga, O., Ashjian, C., Basyuk, E., Cooper, L. W., Eisner, L., Farley, E., Iken, K. B., Grebmeier, J. M., Juranek, L., Khen, G., Jayne, S. R., Kikuchi, T., Ladd, C., Lu, K., McCabe, R. M., Moore, G. W. K., Nishino, S., Ozenna, F., … Weingartner, T. J. (2020). Manifestation and consequences of warming and altered heat fluxes over the Bering and Chukchi Sea continental shelves. *Deep Sea Research Part II: Topical Studies in Oceanography*, *177*, 104781. https://doi.org/10.1016/j.dsr2.2020.104781

Frost, K. J., Lowry, L. F., & Carroll, G. (1993). Beluga whale and spotted seal use of a coastal lagoon system in the northeastern Chukchi Sea. *Arctic*, *46*(1), 8–16.

Gryba, R., Huntington, H. P., Von Duyke, A. L., Adams, B., Frantz, B., Gatten, J., Harcharek, Q., Olemaun, H., Sarren, R., Skin, J., Henry, G., & Auger-Méthé, M. (2021). Indigenous Knowledge of bearded seal (*Erignathus barbatus*), ringed seal (Pusa hispida), and spotted seal (*Phoca largha*) behaviour and habitat use near Utqiaġvik, Alaska, USA. *Arctic Science*, *7*(4), 832–858. https://doi.org/10.1139/as-2020-0052

Gryba R. D., Wiese F. K., Kelly B. P., Von Duyke, A. L., Pickart, R. S., & Stockwell, D. A. (2019). Inferring foraging locations and water masses preferred by spotted seals *Phoca largha* and bearded seals *Erignathus barbatus*. *Marine Ecology Progress Series*, *631*, 209–224.

Hamilton, C. D., Lydersen, C., Ims, R. A., & Kovacs, K. M. (2014). Haul-Out Behaviour of the World's Northernmost Population of Harbour Seals (*Phoca vitulina*) throughout the Year. *PLOS ONE*, *9*(1), e86055. https://doi.org/10.1371/journal.pone.0086055

Hauser, D. D. W., Laidre, K. L., Stafford, K. M., Stern, H. L., Suydam, R. S., & Richard, P. R. (2017). Decadal shifts in autumn migration timing by Pacific Arctic beluga whales are related to delayed annual sea ice formation. *Global Change Biology*, *23*(6), 2206–2217. https://doi.org/10.1111/gcb.13564

Hauser, D. D. W., Laidre, K. L., & Stern, H. L. (2018). Vulnerability of Arctic marine mammals to vessel traffic in the increasingly ice-free Northwest Passage and Northern Sea Route.

Proceedings of the National Academy of Sciences, *15*, 7617–7622. https://doi.org/10.1073/pnas.1803543115

Hauser, D. D. W., Laidre, K. L., Stern, H. L., Suydam, R. S., & Richard, P. R. (2018). Indirect effects of sea ice loss on summer-fall habitat and behaviour for sympatric populations of an Arctic marine predator. *Diversity and Distributions*, *24*(6), 791–799. https://doi.org/10.1111/ddi.12722

Hauser, D. D. W., Whiting, A. V., Mahoney, A. R., Goodwin, J., Harris, C., Schaeffer, R. J., Schaeffer, R., Laxague, N. J. M., Subramaniam, A., Witte, C. R., Betcher, S., Lindsay, J. M., & Zappa, C. J. (2021). Co-production of knowledge reveals loss of Indigenous hunting opportunities in the face of accelerating Arctic climate change. *Environmental Research Letters*, *16*(9), 095003. https://doi.org/10.1088/1748-9326/ac1a36

Hauser, D.D.W., Glenn, R.T., Lindley, E.D., Pikok, K.K., Heeringa, K., Jones, J., Adams, B., Leavitt, J. M., Omnik, G.N., Schaeffer, R., SimsKayotuk, C., Sparrow, E.B., Ravelo, A.M., Lee, O., & Eicken. H. (In Press). Nunaaqqit Savaqatigivlugich - Working with Communities: Evolving Collaborations around an Alaska Arctic Observatory and Knowledge Hub. *Arctic Science*.

Huntington, H. P., Danielson, S. L., Wiese, F. K., Baker, M., Boveng, P., Citta, J. J., De Robertis, A., Dickson, D. M. S., Farley, E., George, J. C., Iken, K., Kimmel, D. G., Kuletz, K., Ladd, C., Levine, R., Quakenbush, L., Stabeno, P., Stafford, K. M., Stockwell, D., & Wilson, C. (2020). Evidence suggests potential transformation of the Pacific Arctic ecosystem is underway. *Nature Climate Change, 10,* 342–348. https://doi.org/10.1038/s41558-020-0695-2

Huntington, H. P., Quakenbush, L. T., & Nelson, M. (2017). Evaluating the Effects of Climate Change on Indigenous Marine Mammal Hunting in Northern and Western Alaska Using Traditional Knowledge. *Frontiers in Marine Science*, *4*(319). https://doi.org/10.3389/fmars.2017.00319

Jansen, J. K., Boveng, P. L., Ver Hoef, J. M., Dahle, S. P., & Bengtson, J. L. (2015). Natural and human effects on harbor seal abundance and spatial distribution in an Alaskan glacial fjord. *Marine Mammal Science*, *31*(1), 66–89. https://doi.org/10.1111/mms.12140

Kuletz, K. J., Ferguson, M. C., Hurley, B., Gall, A. E., Labunski, E. A., & Morgan, T. C. (2015). Seasonal spatial patterns in seabird and marine mammal distribution in the eastern Chukchi and western Beaufort seas: Identifying biologically important pelagic areas. *Progress in Oceanography*, *136*, 175–200. http://dx.doi.org/10.1016/jpocean.2015.05.012.

Laidre, K. L., Stern, H., Kovacs, K. M., Lowry, L., Moore, S. E., Regehr, E. V., Ferguson, S. H., Wiig, Ø., Boveng, P., Angliss, R. P., Born, E. W., Litovka, D., Quakenbush, L., Lydersen, C., Vongraven, D., & Ugarte, F. (2015). Arctic marine mammal population status, sea ice habitat loss, and conservation recommendations for the 21st century. *Conservation Biology*, *29*(3), 724–737. https://doi.org/10.1111/cobi.12474

Lowry, L. E., Burkanov, V. N., Frost, K. L., Simpkins, M. A., Davis, R. A., DeMaster, D. P., Suydam, R. S., & Springer, A. (2000). Habitat use and habitat selection by spotted seals (*Phoca largha*) in the Bering Sea. *Canadian Journal of Zoology*, 1959–1971.

Lowry, L. E., Frost, K. L., Davis, R. A., DeMaster, D. P., & Suydam, R. S. (1998). Movements and behavior of satellite-tagged spotted seals (*Phoca largha*) in the Bering and Chukchi Seas. *Polar Biology*, *19*, 221–230.

McFarland, H., Hauser, D. D. W., Thoman, R., Jones, J. M., & Omnik, G. (2020). *AAOKH News: Alaska Arctic Observatory and Knowledge Hub, Issue IV*. International Arctic Research Center, University of Alaska Fairbanks, AK. available online: https://uaf-iarc.org/wp-content/uploads/2021/01/AAOKH-news-winter-2020.pdf

Meier, W. N., Perovich, D., Farrell, S., Haas, C., Hendricks, S., Petty, A. A., Webster, M., Divine, D., Gerland, S., Kaleschke, L., Ricker, R., Steer, A., Tian-Kunze, X., Tschudi, M., & Wood, K. (2021). *Sea Ice* (noaa:34474). https://doi.org/10.25923/y2wd-fn85

Moore, S. E. (2008). Marine mammals as ecosystem sentinels. *Journal of Mammalogy*, *89*(3), 534–540.

Moore, S. E., & Gulland, F. M. D. (2014). Linking marine mammal and ocean health in the 'New Normal' arctic. *Ocean and Coastal Management*, *102, Part A*(0), 55–57. http://dx.doi.org/10.1016/j.ocecoaman.2014.08.011

Moore, S. E., & Hauser, D. D. W. (2019). Marine mammal ecology and health: Finding common ground between conventional science and indigenous knowledge to track arctic ecosystem variability. *Environmental Research Letters*, *14*, 075001. https://doi.org/10.1088/1748-9326/ab20d8

Moore, S. E., & Stabeno, P. J. (2015). Synthesis of Arctic Research (SOAR) in marine ecosystems of the Pacific Arctic. *Progress in Oceanography*, *136*, 1–11. http://dx.doi.org/10.1016/j.pocean.2015.05.017

Morris, A., Von Duyke, A. L., Douglas, D. C., Gryba, R., & Herreman, J. (2017). *Spotted seal (Phoca largha) spatial use, dives, and haul-out behavior in the Beaufort, Chukchi, and Bering Seas (2012-2016).* [Poster presentation: Alaska Marine Science Symposium].

Quakenbush, L. T., Citta, J. J., & Crawford, J. A. (2009). *Biology of the spotted seal (Phoca largha) in Alaska from 1962 to 2008*. Report to the National Marine Fisheries Service. Alaska Department of Fish and Game, Fairbanks, AK. 66 p.

Reeves, R. R., Ewins, P. J., Agbayani, S., Heide-Jørgensen, M. P., Kovacs, K. M., Lydersen, C., Suydam, R., Elliott, W., Polet, G., van Dijk, Y., & Blijleven, R. (2014). Distribution of endemic cetaceans in relation to hydrocarbon development and commercial shipping in a warming Arctic. *Marine Policy*, *44*(0), 375–389. http://dx.doi.org/10.1016/j.marpol.2013.10.005

Rode, K. D., Regehr, E. V., Douglas, D. C., Durner, G., Derocher, A. E., Thiemann, G. W., & Budge, S. M. (2014). Variation in the response of an Arctic top predator experiencing habitat loss: Feeding and reproductive ecology of two polar bear populations. *Global Change Biology*, *20*(1), 76–88. https://doi.org/10.1111/gcb.12339

Rugh, D. J., Shelden, K. E. W., & Withrow, D. (1997). Spotted seals, *Phoca largha*, in Alaska. *Marine Fisheries Review*, *59*(1), 1–18.

Simpkins, M. A., Withrow, D. E., Cesarone, J. C., & Boveng, P. L. (2003). Stability in the proportion of harbor seals hauled out under locally ideal conditions. *Marine Mammal Science*, *19*(4), 791–805. https://doi.org/10.1111/j.1748-7692.2003.tb01130.x

Stewart, B. S. (1984). Diurnal Hauling Patterns of Harbor Seals at San Miguel Island, California. *The Journal of Wildlife Management*, *48*(4), 1459–1461. https://doi.org/10.2307/3801821

Stroeve, J. C., Markus, T., Boisvert, L., Miller, J., & Barrett, A. (2014). Changes in Arctic melt season and implications for sea ice loss. *Geophysical Research Letters*, *41*(4), 1216–1225. https://doi.org/10.1002/2013gl058951

Thoman, R. L., Bhatt, U. S., Bieniek, P. A., Brettschneider, B. R., Brubaker, M. Y., Danielson, S. L., Labe, Z., Lader, R., Meier, W. N., Sheffield, G., & Walsh, J. (2019). The record low Bering Sea ice extent in 2018: Context, impacts, and an assessment of the role of anthropogenic climate change. *Bulletin of the American Meteorological Society, 101*(1). https://doi.org/DOI:10.1175/BAMS-D-19-0175.1

van Oort, B. E. H., Tyler, N. J. C., Gerkema, M. P., Folkow, L., Blix, A. S., & Stokkan, K.-A. (2005). Circadian organization in reindeer. *Nature*, *438*(7071), 1095–1096. https://doi.org/10.1038/4381095a

Von Duyke, A. L., Douglas, D. C., Crawford, J. A., & Gryba, R. (In Preparation). Seasonal movements, dives, and haul-out behavior of spotted seals (*Phoca largha*) in the Beaufort, Chukchi, and Bering Seas (2012-2020).

Wood, K. R., Bond, N. A., Danielson, S. L., Overland, J. E., Salo, S. A., Stabeno, P. J., & Whitefield, J. (2015). A decade of environmental change in the Pacific Arctic region. *Progress in Oceanography*, *136*, 12–31. http://dx.doi.org/10.1016/j.pocean.2015.05.005

Zuur, A. F., Ieno, E. N., Walker, N. J., Saveliev, A. A., & Smith, G. M. (2009). *Mixed Effects Models and Extensions in Ecology with R*. Springer, New York, NY.

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the sound use of our land and water resources, protecting our fish, wildlife and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation.The Department assesses our energy and mineral resources andworks to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island communities.

The Bureau of Ocean Energy Management

The Bureau of Ocean Energy Management (BOEM) works to manage the exploration and development of the nation's offshore resources in a way that appropriately balances economic development, energy independence, and environmental protection through oil and gas leases, renewable energy development and environmental reviews and studies.