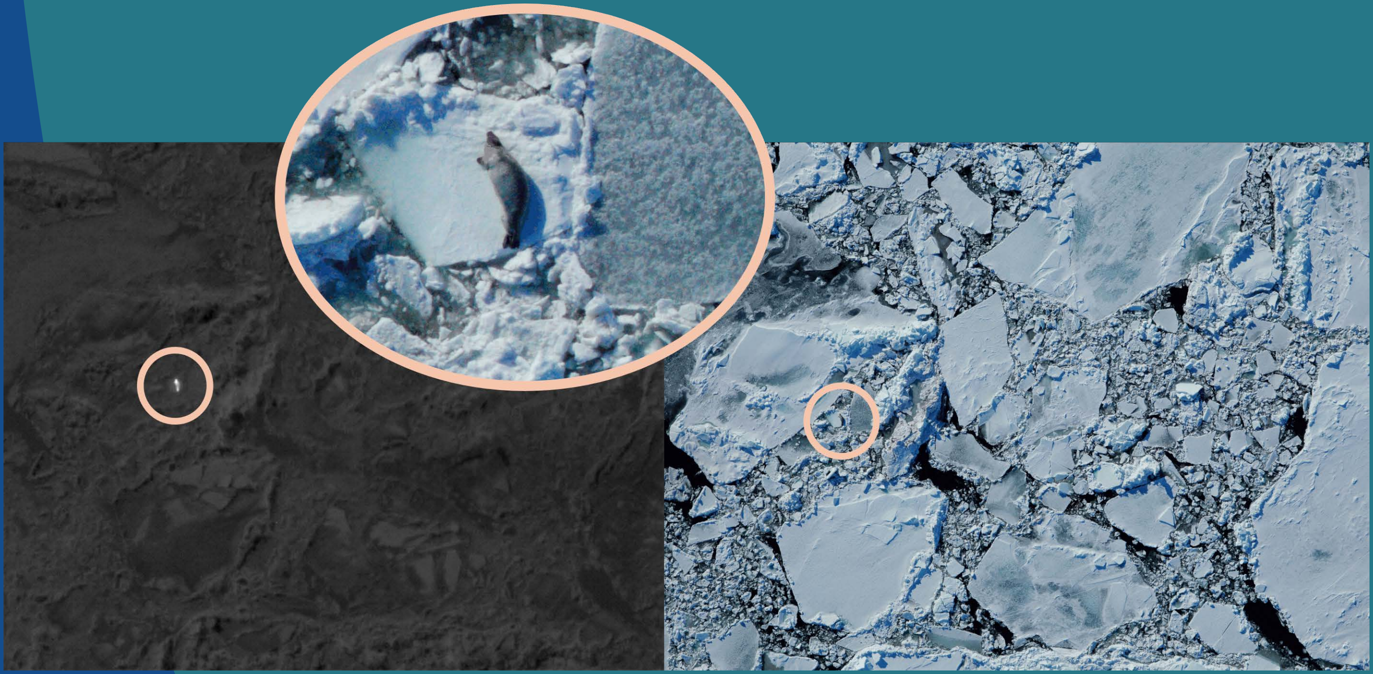
AFSC PROCESSED REPORT 2026-05

Alaska Fisheries Science Center
Marine Mammal Laboratory
Polar Ecosystems Program

2025 Aerial Survey of Ice Seals Field Report

JUNE 2026



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AFSC Processed Report

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Cover photo: Bearded seal hauled out on sea ice in the Bering Sea in May during the 2025 Aerial Survey of Ice Seals. Left: image shows the seal's heat signature detected in the thermal imagery; right: image shows the seal in the corresponding color imagery; and, center: image shows high-resolution color imagery zoomed in to identify the species. NMFS Permit No. 23858.

2025 Aerial Survey of Ice Seals Field Report

Cynthia L. Christman [3], Erin E. Moreland [1], Stacie M. Koslovsky [1], Benjamin X. Hou [1], Adam Romlein [2], Jessica M. Lindsay [1], Josh M. London [1], Erin L. Richmond [1], Skyla M. Walcott [3], Heather L. Ziel [1], Gavin M. Brady [3], Michael F. Cameron [1], Shawn P. Dahle [1], and Paul B. Conn [1]

[1]Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, WA 98115-6349

[2]Kitware, Inc.
1712 Route 9, Suite 300
Clifton Park, NY 12065

[3]Cooperative Institute for Climate, Ocean, & Ecosystem Studies
University of Washington
3737 Brooklyn Ave NE
Seattle, WA 98105

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Abstract

In the U.S., four species of ice-associated seals occupy the Arctic and sub-Arctic waters around Alaska: bearded (*Erignathus barbatus*), ringed (*Pusa hispida*), ribbon (*Histriophoca fasciata*), and spotted (*Phoca largha*) seals. Although all species of ice-associated seals are protected under the Marine Mammal Protection Act (MMPA) and ringed and bearded seals are listed as threatened under the Endangered Species Act (ESA), the first comprehensive abundance estimates of these species have only recently become available over the past decade. Previous survey efforts focused on one sea basin at a time, with surveys conducted in the Bering Sea in 2012 and 2013, the Chukchi Sea in 2016, and the Beaufort Sea in 2021. In 2025, the Alaska Fisheries Science Center's Polar Ecosystems Program conducted flights over the Bering, Chukchi, and Beaufort seas to survey available sea ice habitat throughout these species' geographic range in U.S. waters in a single season.

Aerial surveys were conducted from early April to early June to coincide with the seals' reproductive and molting period during which a large portion of animals would be hauled out on sea ice. Two aircraft conducted survey operations, each equipped with a multimodal imaging system composed of a six- or nine-camera array including long-wavelength infrared, high-resolution color, and, on one aircraft, ultraviolet monochrome cameras, all controlled by onboard computers used to collect and process imagery over ice covered regions. In 2025, a total of 84 flights were conducted, including transits, instrument tests, calibrations, and surveys over the Bering, Chukchi, and Beaufort seas. Of the 84 flights, 58 included an on-effort survey mode, covering approximately 39,663 km of ice seal habitat with a survey swath of 430–450 meters from a target altitude of 305–350 meters. Over three million images were collected, totaling 23 terabytes of data.

Thermal detection models were used either in flight or after the survey effort to identify thermal signatures of potential seals. Detections were reviewed by biologists and animals were classified to species using the color imagery. After hotspot classification and species identification is complete, data from this study will be used to estimate the abundance of bearded, ringed, spotted, and ribbon seals across their entire geographic range in U.S. waters of the Bering, Chukchi, and Beaufort seas. The updated abundance estimates will help provide the first estimates of population trends for these species and will be used in their management, which will be particularly important as their habitat continues to change. All data will be made publicly available.

Acknowledgments

This project would not have been possible without the generous support of many people, organizations, and communities.

We gratefully acknowledge all administrative support that we received from AFSC's Marine Mammal Laboratory including Nancy Friday, Jayme Charlson, AJ Renney, and Billie McCorkle.

NOAA's Aircraft Operations Center was instrumental in helping us collect all scientific data while keeping us safe in the air. We are especially indebted to Aircraft Maintainers Brent Schoumaker, Ron Pauley, Michael Peterson, John Benedict, David McGee, and Casey O'Toole; Twin Otter Pilots Max Anderson, Devin Schaefer, Davis Benningfield, Justin Miyano, Thomas Smith, and Kieran Viggiano; and King Air Pilots Casey Marwine, Elias Shiheiber, Kennieth Brewer, Denielle Stillwagon, James Siebert, and Jamie Park.

We thank the Department of the Interior's Bureau of Land Management for daily flight following, as well as Bering Air and the Alaska Flight Service Stations for their hospitality, support, and aviation guidance.

This research was conducted under the authority of NMFS Permit No. 23858 and USFWS Permit No. MA84399D, and was approved by the Alaska Native Ice Seal Committee.

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Contents

Introduction

Seals that rely on sea ice for important life history events, such as pupping, nursing, resting, and molting, are often collectively referred to as ice-associated seals, or simply ice seals. In the U.S., four species of ice seals occupy the Arctic and sub-Arctic waters around Alaska: bearded (*Erignathus barbatus*), ringed (*Pusa hispida*), ribbon (*Histriophoca fasciata*), and spotted (*Phoca largha*) seals (Young et al. 2023). Ice seals are not only key components of Arctic marine ecosystems, but they also serve as an important nutritional and cultural resource for many Indigenous people of Arctic coastal communities. Although all species of ice seals in U.S. waters are protected under the Marine Mammal Protection Act (MMPA) and ringed and bearded seal populations that occur in U.S. waters are listed as threatened under the Endangered Species Act (ESA), the first comprehensive abundance estimates of these species have only recently become available over the past decade (Boveng et al. 2025). Obtaining reliable estimates of the abundances and distributions of ice seals is necessary for developing sound plans for the management and conservation of these species, and for providing adequate responses to potential impacts from a rapidly changing environment and increasing human activity in the Arctic.

The best way to estimate the abundances of ice seals is to conduct aerial photographic surveys during the reproductive and molting period when the greatest proportions of the populations are hauled out on sea ice (Hammond 2010; London et al. 2024). The distributions of these animals are often broad and patchy, requiring surveys to cover extremely large geographic areas that are remote and difficult to access. Similarly, the extent, location, and condition of their sea ice habitat is constantly changing, necessitating that surveys be conducted in a relatively short period of time and requiring sophisticated analyses. The expense, logistical complexity, and technological limitations of these surveys have been the primary impediments to acquiring comprehensive and reliable estimates of ice seals in the past.

NOAA Fisheries initially began surveys of Alaskan Arctic ice seals through the Loss of Sea Ice (LOSI) initiative, which was a multi-disciplinary research plan led by the Habitat and Ecological Processes Research (HEPR) Program at the Alaska Fisheries Science Center. Surveys of ice seals were first conducted in the Bering and Okhotsk seas as part of an international effort during the Bering-Okhotsk Seal Surveys (BOSS) in 2012 and 2013 (Moreland et al. 2013). The Chukchi Sea was surveyed during the Chukchi and East Siberian Surveys (ChESS) in 2016 (Boveng et al. 2025), and the Beaufort Sea was surveyed during the Joint Beaufort Sea Surveys (JoBSS) in 2021. The objective of these surveys was to provide baseline distribution and abundance data for breeding populations of bearded, ringed, ribbon, and spotted seals.

In 2025, NOAA conducted flights over the Bering, Chukchi, and Beaufort seas to survey ice seals over their entire geographic range in U.S. waters in a single season (NOAA Fisheries 2025). Due to the large volume of photographic data collected, images are currently being analyzed and only preliminary results are available. Formal abundance estimates will eventually be derived from these data and published accordingly.

Methods

Survey Area & Timing

The survey area encompassed the Bering, Chukchi, and Beaufort seas from the Alaskan coastline to the borders of the U.S. Exclusive Economic Zone (EEZ). The area was divided into a sampling grid, which consisted of 25 x 25 km grid cells with center points, or centroids, used both for flight planning and analysis (Fig. 1). The grid was created to mirror the scale and resolution of various sea ice products used in the abundance analyses. A similar grid was used during ice seal surveys flown in previous years. To minimize potential impacts to Alaska Native subsistence hunting, 30 nautical mile (nmi) buffers were placed around the communities of Wainwright, Point Lay, Point Hope, Kivalina, Wales, Diomede, Savoonga, and Gambell (Fig. 1), which are communities with relatively little air traffic. These buffers were guided by discussions with community members during planning meetings prior to the start of the field season. The overall target sampling effort was approximately 45,000 km of on-effort transect line flown, with effort spread across the three ocean basins as follows: 20,000 km of effort (44%) in the Bering Sea, 15,000 km (33%) in the Chukchi Sea, and 10,000 km (22%) in the Beaufort Sea.

Surveys were planned for April through early June to balance the timing of pupping at the southernmost ice edge with the timing of ringed seals emerging from their snow caves, or lairs (Lindsay et al. 2021), and the timing of molting throughout the range (London et al. 2024). Areas covered in sea ice were targeted using the most current satellite-derived imagery available (Melsheimer & Spreen 2026; NASA Worldview Snapshots 2025; NOAA NESDIS STAR 2025), and effort was spread out in space and time to support sampling of each region’s changing habitat throughout the study period.

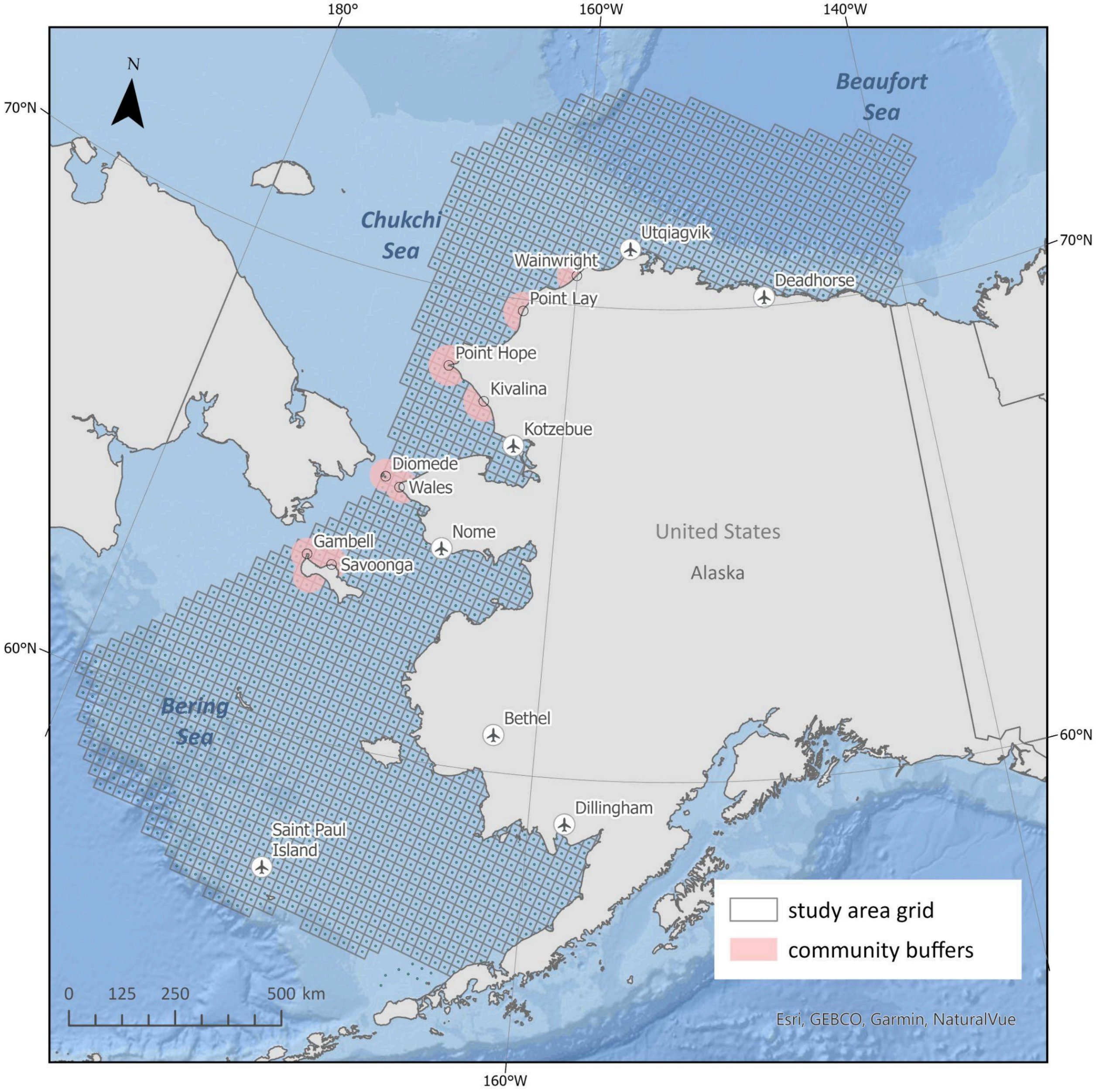


Figure 1. -- Map of study area for the 2025 Aerial Survey of Ice Seals. The survey grid consisted of 25 x 25 km cells that covered all anticipated ice-covered waters extending from the Alaska coastline offshore to the U.S. Exclusive Economic Zone. The community buffers were 30-nmi areas around subsistence hunting villages where no surveys would occur and transit altitude would exceed 3,000 ft (914 m).

Survey Platform

Flights were conducted in two fixed-wing aircraft modified for extended range capabilities that were owned and operated by the NOAA Aircraft Operations Center (AOC): a DeHavilland Twin

Otter DHC-6 and a Beechcraft King Air 350CER. Each aircraft was crewed by two AOC pilots and a maintainer (i.e., mechanic), who traveled with the plane to each staging location. Surveys were flown at a target groundspeed of 120 to 150 knots and an altitude of 1,000 ft (305 m) with the ability to adjust altitude by +/- 200 ft as needed, depending on cloud ceilings and visibility. The altitude range was chosen to 1) maximize the area covered, 2) maintain the ground sampling distance required to detect heat signatures in the thermal imagery (20–30 cm/pixel), 3) maintain the resolving power required to distinguish between species of ice seals in the color imagery (2 cm/pixel), and 4) minimize the potential of disturbance to seals and other wildlife. Field operations were staged from multiple locations along the Alaskan coastline including Nome, Kotzebue, Utqiagvik, Bethel, and Deadhorse. Locations were adjusted as weather and sea ice conditions changed and as survey effort progressed.

Camera Systems

Images were collected using an array of cameras mounted in the open-air belly port of each aircraft (Figs. 2 and 3). The array mounted in the Twin Otter open-air belly port carried nine cameras including three medium format, high-resolution color cameras (Phase One iXM-GS120, fitted with Schneider-Kreuznach RS-110 mm lenses), three cooled, long-wavelength infrared (LWIR) thermal imagers (FLIR A6751sc SLS fitted with 25 mm IR lenses) that recorded data in the 7.5–9.5 micrometer (µm) wavelength, and three ultraviolet (UV) cameras (Prosilica GT4907, fitted with Jenoptik 105 mm UV lenses and a UV bandpass filter centered around 380 nanometers [nm]). The array mounted in the King Air open-air belly port carried three of the same color and thermal cameras and was covered by a pressure dome that allowed the aircraft to pressurize in order to transit at higher altitudes. We also affixed a closeout panel at the bottom of the array near the skin of the aircraft to encourage laminar air flow over the fuselage and to reduce vibration induced by the Helmholtz effect (i.e., the phenomenon of air vibrating in a cavity).

The King Air camera array did not have UV cameras installed for two reasons. Primarily, this was because the Prosilica GT4907 cameras had been discontinued, but it was also because the purpose of the UV cameras was to measure the absorption of UV light by polar bears, and the Twin Otter aircraft was superior to the King Air for this purpose. A secondary objective of the survey was to perform targeted flights over polar bears that we visually detected during the flights. The goal of these targeted flights was to increase the number of multimodal images of polar bears that were collected to develop more refined object detectors for bears. The King Air was a low-wing aircraft with flat windows, which made it more difficult to locate bears and keep them in sight for additional image collection. The Twin Otter, however, was a high-wing aircraft equipped with panoramic observation windows (bubble windows), which made it easier to visually detect polar bears and direct the aircraft over them. Thus, integrating the UV cameras into the Twin Otter aircraft maximized our ability to collect additional imagery of polar bears.

The color (RGB), thermal (IR), and ultraviolet (UV) cameras were arranged in three sets, each connected to an onboard computer that managed image acquisition for that swath. All cameras were simultaneously triggered via a hardware signal produced by a specialized data-acquisition device ([DAQ]; MCC USB-2408-2AO). The center cameras were mounted straight down (nadir), while the left and right cameras were pivoted inward at 30 degree angles, such that there was an approximately 40 m gap between the center and left or right images. This was done to eliminate duplicate counts of seals in side-to-side images and to simplify data processing and analyses. The combined theoretical swath of the three thermal cameras, excluding the gaps, captured approximately 432 m (1,417 ft) underneath the aircraft at a resolution of approximately 19–25 cm/pixel. The combined theoretical swath of the three color cameras, excluding the gaps, covered a slightly larger area at approximately 451 m (1,480 ft) at a resolution of approximately 1–1.3 cm/pixel. An integrated Inertial Navigation System ([INS]; Applanix POS AVX 210) was installed on the camera mount plate with the antenna mounted on the top of the aircraft fuselage, and it provided data on aircraft location, GPS altitude, and attitude, which were stored as a JSON file for each set of images.

All metadata and images were processed on the aircraft by three image processing computers equipped with graphics processing units (GPUs) and then archived to a Networked Attached Storage (NAS) device (Figs. 2 and 3). The computers used in the Twin Otter were Neousys 6108GC rugged, industrial computers equipped with Intel i7-6700 central processing units (CPUs) and NVIDIA 4060TI GPUs with 16 gigabytes (GB) of video memory. The computers in the King Air were Neousys 10208GC rugged, industrial computers equipped with Intel i9-14900 CPUs and NVIDIA 4080TI GPUs with 16 GB of video memory. The NAS used was a Synology DS1621+ with solid-state drives and a four-port 10 gigabit ethernet card.

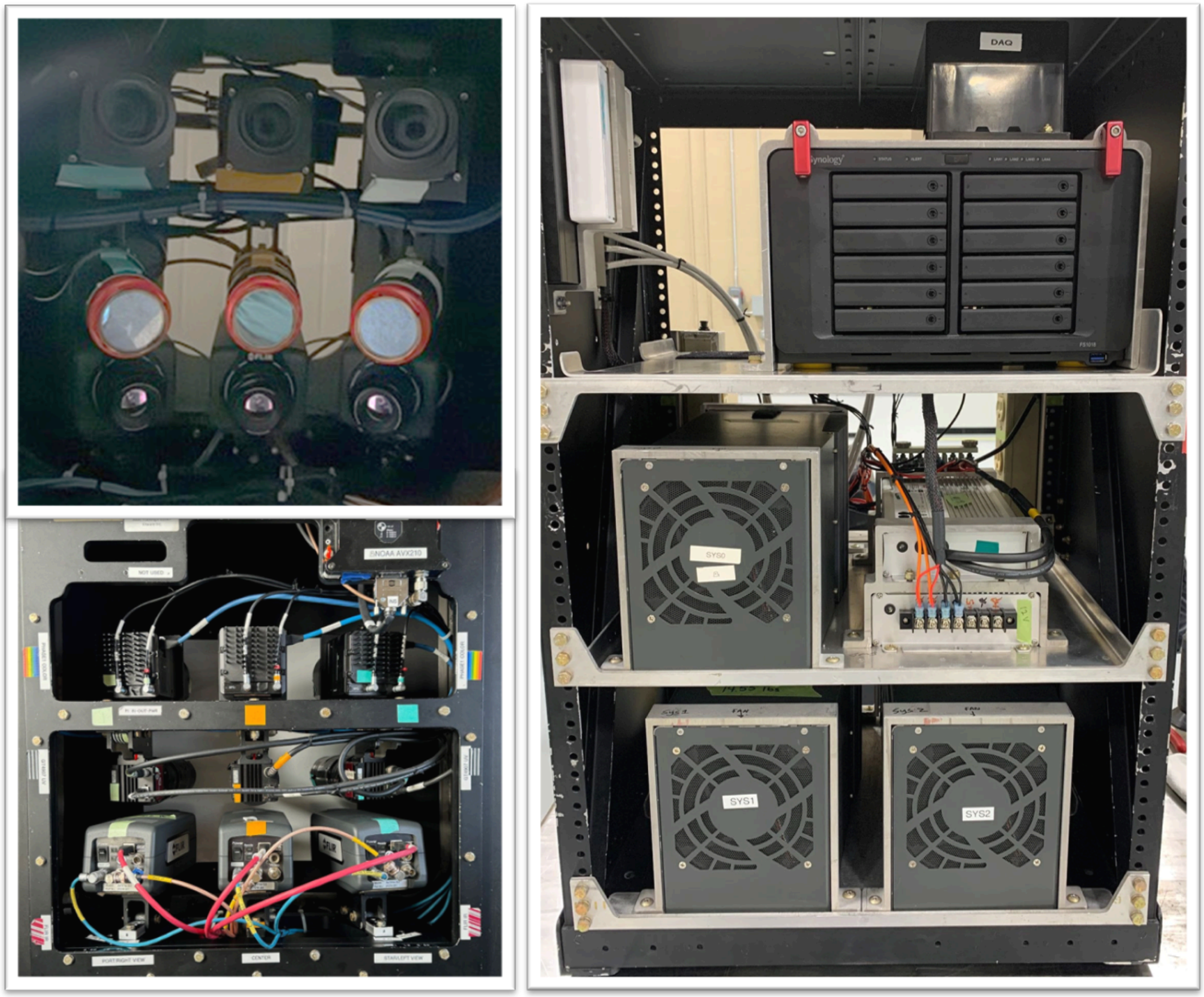


Figure 2. -- Camera system used in the Twin Otter aircraft during the 2025 Aerial Survey of Ice Seals. Left top: underside view of the camera mount through the open-air belly port. Left bottom: topside view of the camera mount from inside the aircraft cabin. The mount includes three color cameras (top), three ultraviolet cameras (middle), and three thermal cameras (bottom). Right: view of rack containing the Networked Attached Storage unit and three image processing computers inside the aircraft cabin.

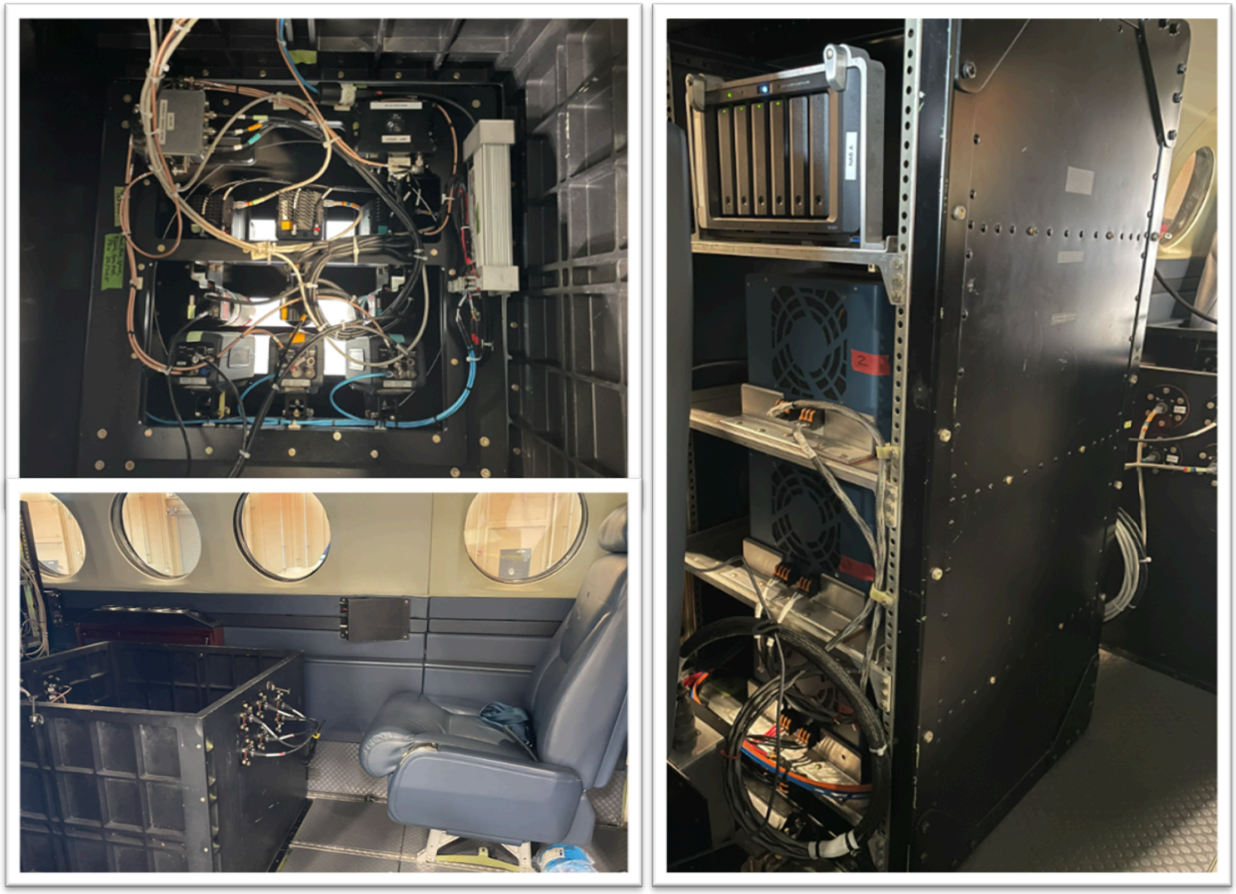
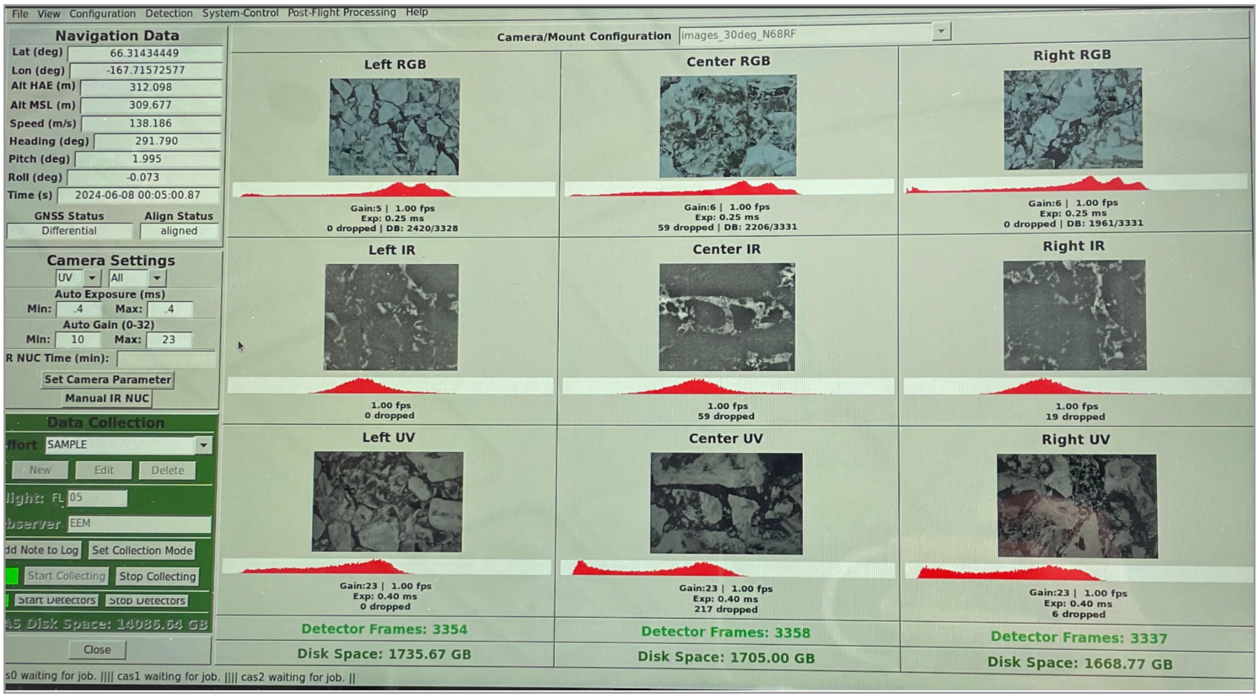


Figure 3. -- Camera system used in the King Air aircraft during the 2025 Aerial Survey of Ice Seals. Left top: topside view of the camera mount from inside the aircraft cabin and open pressure dome. Left bottom: view of the pressure dome covering the camera mount from inside the aircraft cabin (with lid removed). Right: view of rack containing the Networked Attached Storage unit and three image processing computers inside the aircraft cabin.

Data Collection

The science team collected data using custom, open-source software (https://github.com/Kitware/kamera) designed to collect, manage, and analyze images. The software, known as KAMERA (or, the Knowledge-Guided Image Acquisition Manager and Archiver), was developed by Kitware, Inc. (Clifton Park, NY) in collaboration with NOAA's Marine Mammal Laboratory (Romlein et al. 2025). Prior to the start of the field season, the KAMERA systems were configured with camera models that were developed for the specific cameras and mounts used in each aircraft, along with the Arctic Seals Detection model (YOLOv3) and pipelines developed to identify hotspots in the thermal imagery to enable real-time inference of seals (Boss 2021).

During survey flights, the KAMERA operator used a graphical user interface (Fig. 4) to start and stop image collection, enter effort types associated with each collection, and adjust exposure and gain on the color and UV cameras. The system operator also set the desired forward-to-aft overlap percent which allowed the system to determine the image capture rate based on the center color camera's projected footprint from the loaded camera model, and the aircraft's real-time GPS altitude and ground speed as provided by the INS on the camera mount. Survey images were collected at a rate to achieve 5% forward-to-aft overlap between images, while images collected during calibration flights were set to target 60% overlap. On the Twin Otter, imagery was collected on a sampling routine ("ON_SAMPLE" effort), allowing color images to be discarded if there were no detections in the associated thermal image, or if it was not selected as a 20th frame collected for later evaluation of detection probability. Because the detection model did not perform as expected on the thermal cameras in the King Air, all color images were collected ("ON_ALL" effort) for later analysis. Color imagery was debayered on board the aircraft and then converted from ~120 MB proprietary files to compressed ~20 MB jpegs.



Navigation Data

Lat (deg): 66.31434449
Lon (deg): -167.71572577
Alt HAE (m): 312.098
Alt MSL (m): 309.677
Speed (m/s): 138.186
Heading (deg): 291.790
Pitch (deg): 1.995
Roll (deg): -0.073
Time (s): 2024-06-08 00:05:00.87
GNSS Status: Differential
Align Status: aligned

Camera Settings

UV
All
Auto Exposure (ms) Min: .4 Max: .4
Auto Gain (0-32) Min: 10 Max: 23
R NUC Time (min):

Data Collection

ffort: SAMPLE
light: FL 05
bserver: EEM
AS Disk Space: 14086.64 GB

Camera/Mount Configuration: images_30deg_N68RF

Left RGB
Gain:5 | 1.00 fps
Exp: 0.25 ms
0 dropped | DB: 2420/3328

Center RGB
Gain:6 | 1.00 fps
Exp: 0.25 ms
59 dropped | DB: 2206/3331

Right RGB
Gain:6 | 1.00 fps
Exp: 0.25 ms
0 dropped | DB: 1961/3331

Left IR
1.00 fps
0 dropped

Center IR
1.00 fps
59 dropped

Right IR
1.00 fps
19 dropped

Left UV
Gain:23 | 1.00 fps
Exp: 0.40 ms
0 dropped

Center UV
Gain:23 | 1.00 fps
Exp: 0.40 ms
217 dropped

Right UV
Gain:23 | 1.00 fps
Exp: 0.40 ms
6 dropped

Detector Frames: 3354
Disk Space: 1735.67 GB

Detector Frames: 3358
Disk Space: 1705.00 GB

Detector Frames: 3337
Disk Space: 1668.77 GB

s0 waiting for job. |||| cas1 waiting for job. |||| cas2 waiting for job. ||

Figure 4. -- Screenshot of the KAMERA graphical user interface (GUI). The far left column displays navigation data, camera settings, and data collection. Remaining columns show left, center, and right image streams from each color (RGB), thermal (IR), and ultraviolet (UV) camera.

Effort was entered as one of six effort types: ON_ALL, ON_SAMPLE, BEAR, CALIBRATION, TEST, or OFF. Descriptions of each effort type are provided in Table 1.

In general, the following survey principles were used as a guide:

- On any given day, aim to get as wide of spatial coverage as possible.
- Over several days, aim to spread flights across all geographic regions, distributing effort as evenly in time and space as possible.
- Survey effort should represent the habitat within individual grid cells. Target cells that have sea ice, but effort should avoid oversampling sea ice in cells with sparse ice.
- Effort should begin and end at the border of a grid cell.
- Fly around unsurveyable weather and large groups of non-target wildlife species (e.g., walrus). Tracklines do not have to be straight, but try to keep the aircraft level.
- Tracklines can be modified in-flight to stay over grid cells that have ice or to avoid weather or large groups of birds or walruses. Tracklines cannot be modified to target seals that are visible or sea ice that looks like optimal habitat.
- Stop surveys if any concerns arise regarding interference with subsistence activities by our aircraft.

Table 1. -- Effort types used during the 2025 Aerial Survey of Ice Seals.

Effort Type	**Description**
ON_ALL	Imagery was being collected in a grid cell with sea ice. All imagery was saved. Used primarily on King Air flights.
ON_SAMPLE	Imagery was being collected in a grid cell with sea ice. All thermal and ultraviolet imagery was saved. Every 20th color image and every color image with a thermal detection was saved. Used primarily on Twin Otter flights.
BEAR	Imagery was being collected continuously during targeted flights over polar bears. The purpose of this effort was to collect additional imagery to develop detection models tailored for polar bears.
CALIBRATION	Calibration imagery was collected. Used during dedicated calibration flights to collect imagery with high forward-to-aft overlap for use in camera model development.
TEST	Test imagery was collected. Used for initial set-up, debugging, or troubleshooting. Images collected under TEST effort were not stored in the primary project folder on the NAS.
OFF	Used when transiting to survey areas, over land approaching the survey area, in poor survey conditions (e.g., low ceilings, fog, or preciptation), or when troubleshooting.

Results

Survey Effort

In the spring of 2025, NOAA conducted 84 flights over 313 flight hours for the Aerial Survey of Ice Seals project. Flights were conducted from 4 April to 10 June, and included transits, tests, calibrations, and surveys over the Bering, Chukchi, and Beaufort seas. Of the 84 flights, 58 included on-effort survey coverage, with approximately 39,663 km of trackline flown over the Bering, Chukchi, and Beaufort seas (Table 2). Effort was collected in each region as follows: 14,548 km (37%) were flown in the Bering Sea; 13,737 km (34%) were flown in the Chukchi Sea; and 11,378 km (29%) were flown in the Beaufort Sea (Table 3). Survey tracklines by aircraft, effort type, and month are shown in Figures 5 through 7.

To map changes in the distribution of sea ice throughout the survey period, Advanced Microwave Scanning Radiometer sea ice concentration files were obtained from the University of Bremen, Germany data archive (Spreen et al. 2008; Melsheimer & Spreen 2026). Satellite imagery showed ice extending south into the Bering Sea to Saint Paul Island from early April to early May (Fig. 8). Ice started to diminish from the Bering Sea from mid May to early June. Both the Chukchi and Beaufort seas remained mostly ice covered during the entire survey.

Table 2. -- Preliminary summary of each flight conducted during the 2025 Aerial Survey of Ice Seals. Flight numbers in the 100 series were conducted on a NOAA DeHavilland Twin Otter; flight numbers in the 200 series were conducted on a NOAA Beechcraft King Air.

Flight Number	Date (yyyymmdd)	Departure Airport	Arrival Airport	Flight Time (h)	On Effort (km)	Survey Area
201	20250404	Nome	Nome	2.4	477	Bering
101	20250404	Nome	Nome	4.2	0	Bering
202	20250405	Nome	Nome	5	927	Bering
102	20250405	Nome	Nome	4.7	0	Norton Sound
103	20250406	Nome	Nome	4.2	0	Bering
203	20250408	Nome	Nome	2.4	520	Norton Sound
104	20250408	Nome	Nome	1.5	0	Norton Sound, testing
105	20250408	Nome	Nome	1.3	0	Norton Sound, testing
204	20250410	Nome	Nome	5	1,170	Bering
106	20250410	Nome	Nome	1.7	0	Norton Sound, testing
205	20250411	Nome	Nome	4.3	663	Chukchi
107	20250411	Nome	Nome	4.3	954	Norton Sound
206	20250414	Nome	Nome	3.7	428	Bering
108	20250414	Nome	Nome	4.4	741	Bering
109	20250417	Nome	Nome	5	617	Chukchi
207	20250418	Nome	Nome	5.5	561	Bering
110	20250418	Nome	Kotzebue	1.3	0	Transit
208	20250419	Nome	Utqiagvik	1.6	0	Transit
209	20250419	Utqiagvik	Utqiagvik	4.8	1,157	Beaufort/Chukchi
111	20250419	Kotzebue	Kotzebue	4.9	895	Kotzebue Sound
210	20250420	Utqiagvik	Utqiagvik	5.4	1,075	Beaufort
112	20250420	Kotzebue	Kotzebue	5.4	520	Chukchi
211	20250421	Utqiagvik	Utqiagvik	4.8	1,153	Beaufort
113	20250421	Kotzebue	Kotzebue	4.4	636	Chukchi
212	20250422	Utqiagvik	Nome	2.3	0	Transit
114	20250422	Kotzebue	Utqiagvik	2.2	0	Transit
115	20250422	Utqiagvik	Utqiagvik	4.3	770	Chukchi

Flight Number	Date (yyyymmdd)	Departure Airport	Arrival Airport	Flight Time (h)	On Effort (km)	Survey Area
213	20250423	Nome	Nome	4.2	582	Bering
214	20250424	Nome	Nome	4.3	713	Bering
116	20250424	Utqiagvik	Utqiagvik	4	848	Chukchi
215	20250425	Nome	Nome	4.4	785	Bering
117	20250426	Utqiagvik	Anchorage	5	0	Transit
216	20250501	Nome	Nome	4.6	311	Norton Sound
118	20250503	Anchorage	Bethel	3.4	0	Calibration, transit
217	20250505	Nome	Nome	4.6	595	Chukchi
119	20250505	Bethel	Bethel	5.6	429	Bering
120	20250505	Bethel	Bethel	5.6	556	Bering
121	20250507	Bethel	Bethel	5.7	492	Bering
218	20250508	Nome	Nome	3.4	508	Kotzebue Sound
122	20250508	Bethel	Bethel	4.8	377	Bering
123	20250508	Bethel	Bethel	5.4	765	Bering
219	20250509	Nome	Nome	3.8	360	Bering
124	20250509	Bethel	Nome	1.8	0	Transit
220	20250510	Nome	Nome	3.8	185	Bering
221	20250510	Nome	Nome	3.8	207	Bering
125	20250510	Nome	Nome	5.1	750	Bering
126	20250510	Nome	Nome	3.9	468	Bering
222	20250511	Nome	Nome	3.5	391	Bering
127	20250511	Nome	Nome	4.6	655	Bering
128	20250512	Nome	Fairbanks	3.4	0	Transit
129	20250512	Fairbanks	Anchorage	1.9	0	Transit
223	20250513	Nome	Nome	4.3	655	Chukchi
224	20250514	Nome	Utqiagvik	1.9	0	Transit
225	20250515	Utqiagvik	Utqiagvik	4.1	885	Chukchi
226	20250519	Utqiagvik	Utqiagvik	4.7	1,188	Beaufort
227	20250520	Utqiagvik	Utqiagvik	4.8	1,054	Chukchi
228	20250521	Utqiagvik	Utqiagvik	4.9	1,254	Beaufort
229	20250521	Utqiagvik	Utqiagvik	5.1	1,061	Chukchi

Flight Number	Date (yyyymmdd)	Departure Airport	Arrival Airport	Flight Time (h)	On Effort (km)	Survey Area
230	20250523	Utqiagvik	Deadhorse	0.8	0	Transit
231	20250524	Deadhorse	Deadhorse	2	120	Beaufort
232	20250525	Deadhorse	Deadhorse	4.6	861	Beaufort
233	20250526	Deadhorse	Kotzebue	1.4	0	Transit
234	20250527	Kotzebue	Kotzebue	4.9	814	Chukchi
235	20250528	Kotzebue	Nome	4.3	744	Bering
236	20250528	Nome	Kotzebue	0.7	0	Transit
237	20250530	Kotzebue	Kotzebue	4.6	1,230	Chukchi
238	20250531	Kotzebue	Utqiagvik	1.3	0	Transit
130	20250531	Anchorage	Fairbanks	1.7	0	Transit
239	20250601	Utqiagvik	Utqiagvik	4.3	954	Chukchi
131	20250601	Fairbanks	Deadhorse	2.4	0	Transit
132	20250602	Deadhorse	Deadhorse	4	451	Beaufort
240	20250603	Utqiagvik	Utqiagvik	2.7	20	Beaufort
241	20250604	Utqiagvik	Utqiagvik	4.6	995	Beaufort
133	20250604	Deadhorse	Deadhorse	3.6	270	Beaufort
134	20250605	Deadhorse	Deadhorse	4.5	863	Beaufort
242	20250606	Utqiagvik	Utqiagvik	4.1	909	Beaufort
243	20250607	Utqiagvik	Anchorage	2.9	0	Transit
244	20250607	Anchorage	Ketchikan	2	0	Transit
135	20250607	Deadhorse	Utqiagvik	4.3	606	Beaufort/Chukchi
136	20250607	Utqiagvik	Deadhorse	2.4	212	Beaufort
245	20250608	Ketchikan	Everett	2.7	0	Transit, calibration
137	20250609	Deadhorse	Deadhorse	3.5	393	Beaufort
138	20250610	Deadhorse	Deadhorse	4.4	883	Beaufort
139	20250610	Deadhorse	Anchorage	3.9	0	Transit
Total				313.4	39,663	

Table 3. -- Distribution of on-effort data collection in each sea during the 2025 Aerial Survey of Ice Seals.

	On Effort (km)	**On Effort (%)**
Bering Sea	14,548	37
Chukchi Sea	13,737	34
Beaufort Sea	11,378	29
Total	**39,663**	**100**

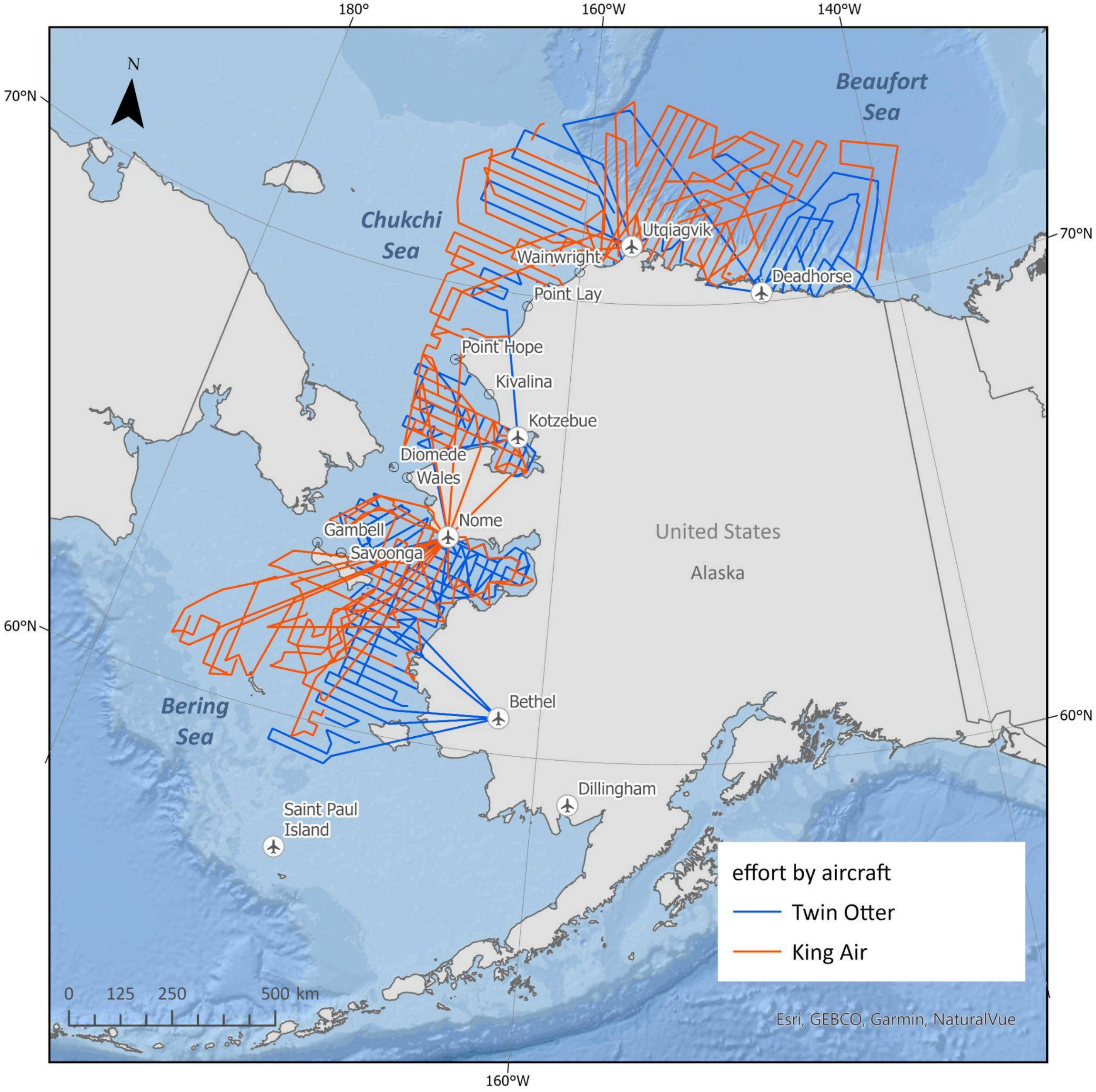


Figure 5. -- Map of tracklines flown by aircraft type during the 2025 Aerial Survey of Ice Seals.

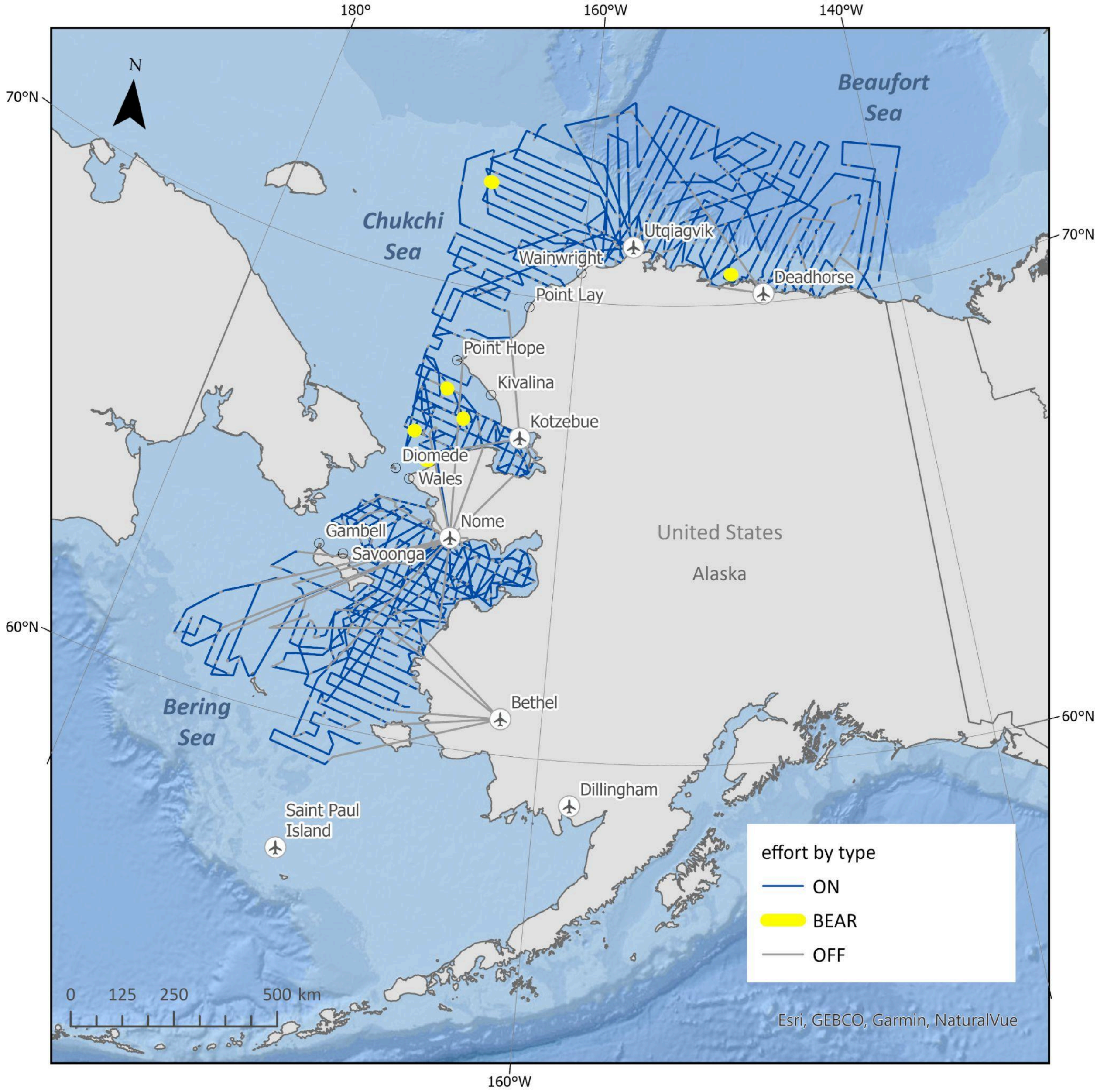


Figure 6. -- Preliminary map of tracklines flown by effort type during the 2025 Aerial Survey of Ice Seals. On-effort tracklines (blue) include both “ON_ALL” and “ON_SAMPLE” effort types. Limited “BEAR” effort (yellow) was conducted due to permit constraints and does not reflect the high encounter rate of bears during this survey.

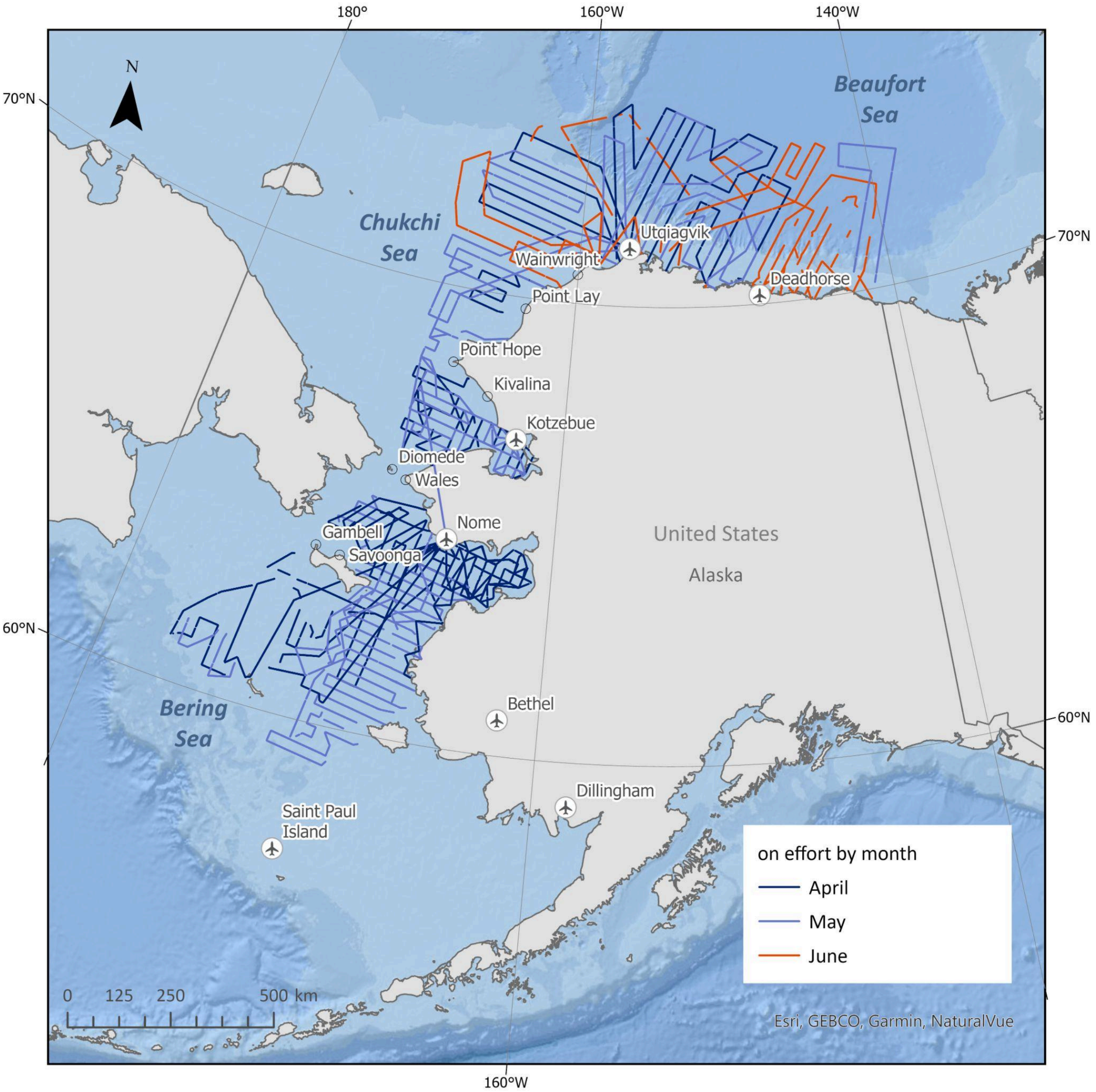
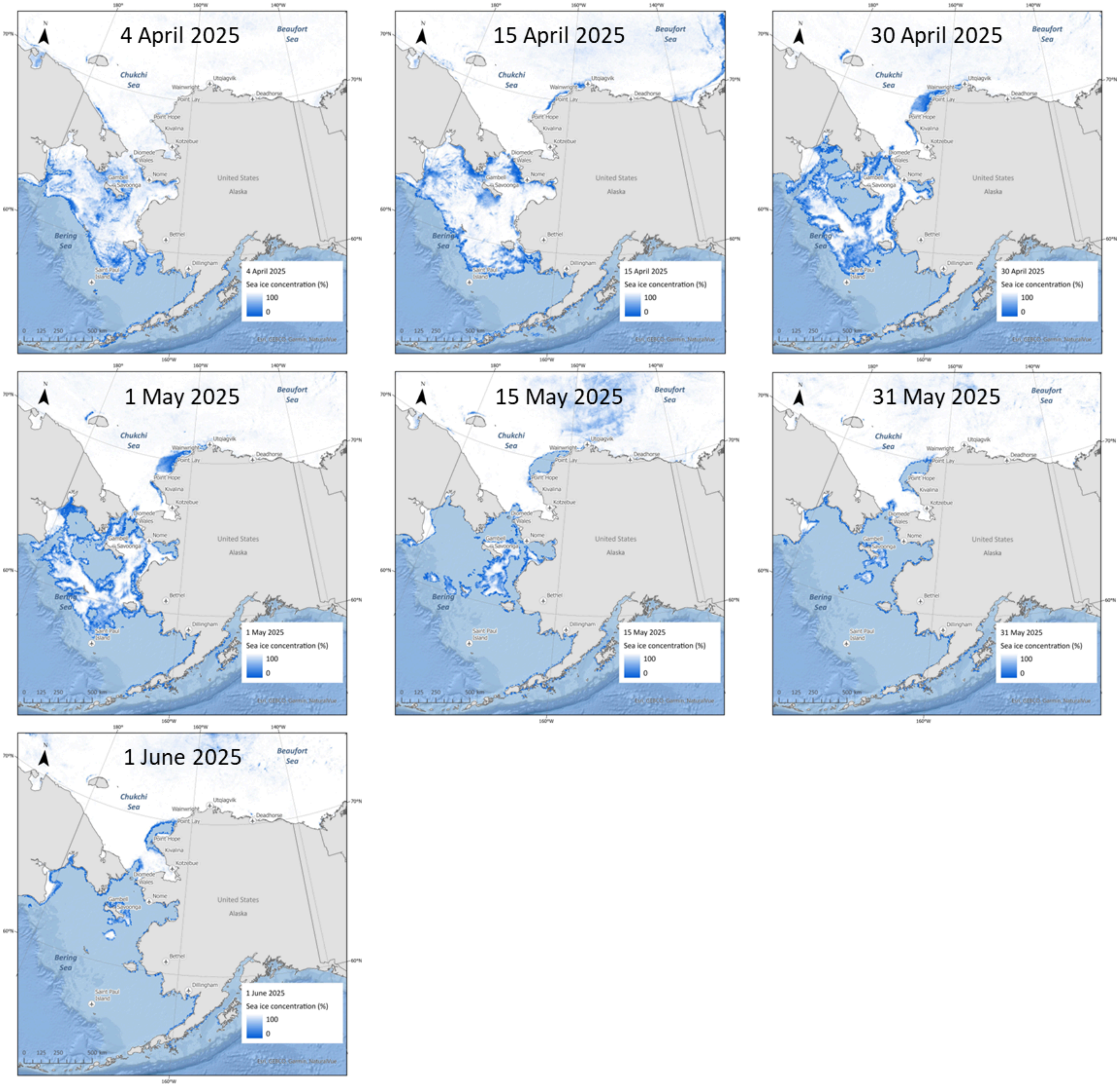


Figure 7. -- Map of on-effort tracklines flown by month during the 2025 Aerial Survey of Ice Seals. Surveys began on 4 April and ended on 10 June, 2025.



4 April 2025

15 April 2025

30 April 2025

1 May 2025

15 May 2025

31 May 2025

1 June 2025

Figure 8. -- Sea ice concentration from Advanced Microwave Scanning Radiometer data for seven days throughout the 2025 Aerial Survey of Ice Seals. Insets show data for early, mid, and late month periods for April (top row), May (middle row), and June (bottom row) that overlap with the survey period. Data are courtesy of the University of Bremen, Institute for Environmental Physics (https://seaice.uni-bremen.de).

Images Collected

Over three million images were collected during the survey (Table 4). Thermal imagery constituted the majority of imagery collected, followed by color imagery. The difference between counts of image types was in part due to the sampling approach on the Twin Otter where we only archived color images that were likely to contain animals based on detections in the thermal images, along with every 20th color image. Ultraviolet imagery constituted the least amount of imagery collected as it was only collected by the system on the Twin Otter. All data totaled a volume of approximately 23.6 terabytes.

Table 4. -- Number of color (RGB), thermal (IR), and ultraviolet (UV) images collected during the 2025 Aerial Survey of Ice Seals. *Color image count excludes 0-bit images collected during “ON_SAMPLE” effort which were retained to calculate the area surveyed.

	Number of images collected
RGB*	1,103,241
IR	1,491,754
UV	606,047
Total	**3,201,042**

Preliminary Detections

A preliminary review of detections was completed for flights that were conducted on the Twin Otter aircraft. Over 50,000 detections were analyzed, the majority of which (89%) were false positives (Table 5). Marine mammal detections included bearded seals, ringed seals, spotted seals, ribbon seals, walruses, and polar bears. Other animals detected included birds, caribou, and foxes. Review of detections from flights conducted on the King Air aircraft is still on-going.

Table 5. -- Preliminary number of detections by type from flights conducted on the NOAA Twin Otter aircraft during the 2025 Aerial Survey of Ice Seals. Some detections, particularly those of polar bears, may be duplicate detections from circling effort and/or image overlap.

Detection	**Count**
Bearded seal	590
Bird	875
Caribou	32
Fox	2
Polar bear	21
Ribbon seal	13
Ringed seal	1,643
Spotted seal	61
Unknown animal	7
Unknown seal	4
Walrus (groups)	369
False positive	44,602
Other (off frame, duplicate, etc.)	1,893
Total	**50,112**

Discussion

Planning for this project was greatly impacted by a number of extenuating circumstances. In response to DOGE (the Department of Government Efficiency; a U.S. federal initiative aimed at modernizing government technology, reducing waste, and improving efficiency), NOAA was taking drastic measures to restructure. Travel approval and all spending processes were undergoing policy changes, project budgets were undecided, and personnel were facing employment uncertainty. Additionally, we encountered technological and environmental obstacles that had to be overcome. In spite of these challenges, collaborative efforts among many people and agencies persevered, and the first survey of Arctic ice seals sampling their entire geographic range in U.S. waters was successfully completed. Below we describe some of the factors that affected the survey as well as future steps for this project.

To accommodate two aircraft flying these surveys, a second KAMERA system was assembled using three new thermal cameras which were initially installed on the Twin Otter aircraft. A preliminary review of the imagery and detections from the first few surveys in Alaska (flights 101-107 on the Twin Otter and 201-205 on the King Air) showed that our object detection model had unexpectedly poor performance, specifically when collected by the new thermal cameras. The new thermal camera sensors had high rates of pixel failure, and we were unable to reliably detect animals in the imagery. To address this, we made a number of changes to our thermal cameras and our expected survey methods. On 8 April, we reset the internal calibration on all of the thermal cameras which had been changed during servicing. On 13 April, we moved the new thermal cameras from the Twin Otter to the King Air in order to collect all color images rather than a subsample; the computers in the King Air system were better suited for a higher rate of image collection and debayering which is a computationally demanding process. In addition to the “ON_SAMPLE” effort type, we added an effort type of “ON_ALL” to account for the collection of all color images on the King Air. Lastly, we mapped the bad pixels in the new thermal cameras throughout the survey to reduce their impact on normalization routines used both for viewing imagery in the plane and processing it in the detection pipeline.

While the thermal cameras were removed from both systems on 13 April, prior to switching them between aircraft, we also took the opportunity to refine each camera's focus. In preparation for the surveys, all cameras had all been focused prior to installation at the NOAA Aircraft Operations Center in Florida, where atmospheric effects of the earth’s radiant heat distort the focal point. Refocusing the cameras in Alaska, where cold temperatures provided a clear focal point, helped correct for any temperature impacts on the lenses and achieve a sharper image. Focus can impact thermal detection by averaging temperature values from the target animals with the surrounding sea ice, thereby, diluting the overall thermal signature.

During surveys, we ran a custom-trained Arctic Seal Detection Model (Boss 2021) that was developed from a Darknet YOLOv3 framework. The model was developed using thermal images from the surveys of ice seals that were conducted in 2016 and 2019, and it demonstrated a 98% detection rate of known seals that were found in an independent review of color images from the ice seal survey conducted in 2021. The model was run in real-time on the Twin Otter aircraft which allowed us to identify thermal frames that likely contained animals. The in-flight detections informed the KAMERA system whether to archive or discard the associated color images. We also archived every 20th color frame in order to maintain a subsample of imagery across all cameras and flights from which to determine the final detection probability of the model. Because the Arctic Seal Detection Model did not perform as expected on the new thermal cameras, we collected all color images from the system on the King Air aircraft. After the field season ended, we developed an Ultralytics YOLOv11 model and reprocessed the thermal imagery collected from the new cameras. The additional time to develop a detection model in-house affected our ability to proceed with data processing, and consequently resulted in delays to the abundance analysis.

Environmental conditions also presented a significant challenge during the initial period of the field season. The ambient air temperature was often well below freezing, necessitating the use of a diesel forced-air heater inside of the aircraft to allow the team to work on the system and cameras. Additionally, we discovered that the computer systems would operate extremely slowly, if at all, when the temperature dropped below -10℃. The Twin Otter pilots also noted that the autopilot computer would often be in a faulty state until after takeoff, believing it to be temperature related. To help address these issues, the field team adopted a routine of preheating the aircraft’s interior using either a diesel or electrical heater. This process needed to be done cautiously and monitored closely to ensure that ambient air was mixed with the flow of warm air in order to avoid overheating the computers and cameras. This method proved to be effective for ensuring that the image processing computers operated correctly.

While the survey grid covered the entire potential ice-covered region of the Bering, Chukchi, and Beaufort seas in U.S. waters, actual survey effort was dictated by sea ice coverage and extent. We had planned to survey more of the Bering Sea, but by early April when surveys began, sea ice had already retreated north of Saint Paul Island. By late April, polynyas started to open in the Bering Sea south of Saint Lawrence Island and in the Bering Strait. From early May to early June, sea ice continued to decrease in the Bering Sea, and polynyas started to open in the Chukchi Sea near the coast between Point Hope and Utqiagvik. We expected more ice breakup in the Chukchi and Beaufort seas throughout the season, but both remained mostly ice covered through early June when surveys ended. Persistent, solid ice pack limited the benefits of extensively surveying the eastern portion of the Beaufort Sea as seals would be under ice cover or lairs. Unpredictable weather further restricted flights to the central Bering Sea ice edge. While this area is recognized as prime ribbon seal habitat, its extreme remoteness limited flight safety margins and crew comfort was a significant challenge during attempted flights. With rapid retreat of the ice edge, high pilot turnover, inclement weather, and the need to spread out effort spatially and temporally, achieving desired coverage of the central and southern Bering Sea was difficult.

Data from this study will be used to generate updated abundance estimates of bearded, ringed, spotted, and ribbon seals across their entire geographic range in U.S. waters of the Bering, Chukchi, and Beaufort seas. These data will be made publicly available in peer-reviewed publications and online data repositories, and they will be used to inform the management of these species, which will be particularly important as their habitat continues to change.

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Howard Lutnick

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