Hanenburg, M., Goertz, C., Reichmuth, C. All about the curves: Cooperative body condition measurements of Arctic seals support health assessments for wild populations. *2023 Joint Conference of the International Marine Animal Trainer's Association and the Animal Behavior Management Association*, Atlanta, Georgia, 5-10 March 2023. Oral Presentation.

ALL ABOUT THE CURVES: COOPERATIVE BODY CONDITION MEASUREMENTS OF ARCTIC SEALS SUPPORTS HEALTH ASSESSMENTS FOR WILD POPULATIONS

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INTRODUCTION

Four ice-associated seal species are found in the Arctic and sub-Arctic waters of Alaska: bearded (*Erignathus barbatus*), ribbon (*Histriophoca fasciata*), ringed *(Pusa hispida),* and spotted (*Phoca largha*) seals. As warming Arctic conditions accelerate the loss and retreat of seasonal sea ice, it is estimated that the foraging and haul out behaviors of these Alaskan ice seals will substantially change (Laidre and Regehr, 2017). Long-term research suggests an overall decline in the body condition of wild spotted and ribbon seals in the Bering Sea (Boveng et al., 2020), while ringed and bearded seals have been granted Threatened status in the United States due to rapid habitat loss (Gryba et al., 2021).

Studying Arctic seals presents numerous challenges (Boveng *et al*., 2020). These animals are cryptic and live in difficult to reach areas. Much of what we know about these species and their populations has been learned from a small number of live caught seals, annual aerial surveys, and sampling collaborations with Alaskan subsistence hunters. Animals in managed care provide us with unique and valuable opportunities to further knowledge of these species. Collaborations between scientists and animal care programs can further basic and applied knowledge about these species and their relationships with their environment, which in turn can support conservation efforts (AZA, 2023). In addition to observational studies, we have the powerful ability to use operant conditioning to support the participation of animals in meaningful research. With behavioral cooperation, we can increase access to data and information that would be unavailable otherwise. This approach also reduces stress for the animal, improves data quality, and minimizes potential aversive effects of the research tasks (O'Malley *et al*., 2022).

The Alaska SeaLife Center is an AZA-accredited aquarium in Seward, Alaska that focuses on education, marine research, and wildlife response. Within the Mammals team, resident Steller sea lions, harbor seals, ringed seals, and spotted seals give guests an up-close view of Arctic and sub-Arctic pinniped species. For the past eight years, our primary research partnership has been with the Pinniped Laboratory at the University of California Santa Cruz and associated collaborators. Our staff and animals support the PHOCAS program (Physiology and Health of Cooperating Arctic Seals). Through this unique collaboration, bearded, ringed, and spotted seals housed at the Alaska SeaLife Center and UC Santa Cruz participate in voluntary physiological and metabolic research to help further our understanding of these polar seals.

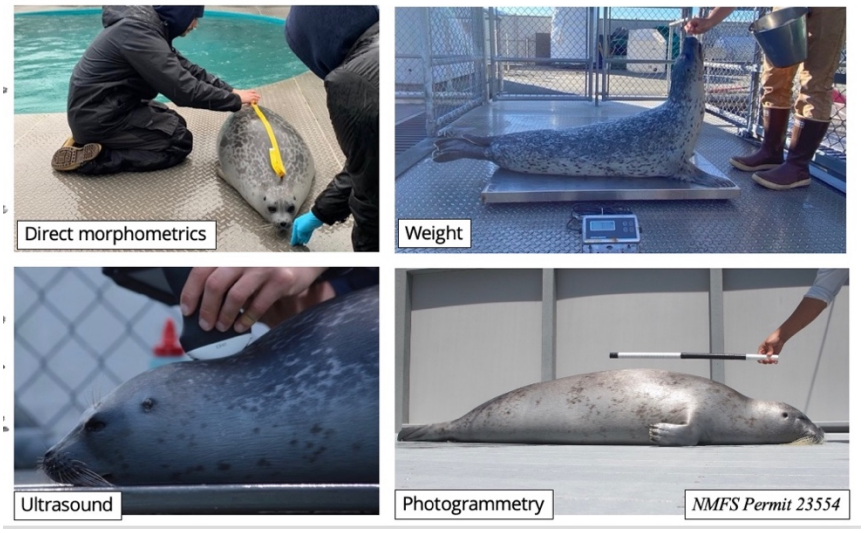
While research tasks can vary in difficulty and involvement, from relatively simple tasks to more challenging sequences requiring advanced training, an enormous amount of research can be facilitated through a few foundational behaviors. Three core behaviors we use within the PHOCAS program are Target, Down, and Roll (or ventral present), while incorporating tactile conditioning and significant extensions or holds. These behaviors are simple, versatile, and have innumerable applications. They are typically the most important learned behaviors to support voluntary medical examinations, and by allowing access to the animal's body, they can support a wide range of studies. For example, the seals involved in the PHOCAS program participate in an array of routine body condition monitoring tasks to support our understanding of their physiological changes associated with their growth and seasonality.

One example of the positive impact of collaborations between zoos and aquariums and the scientific community is highlighted by the interaction between the PHOCAS research program and NOAA's Polar Ecosystems Program. NOAA scientists are working to develop non-invasive methods to collect scaled measurements of wild seals from uncrewed aircraft systems (UAS) launched from research vessels. To support this effort, information from our seals with known body condition values are used to validate NOAA's photogrammetric field methods, which in turn will improve health metrics for wild seal populations. This presentation highlights the successes and challenges of this collaborative project, demonstrating how applied research with healthy, trained individuals in zoological settings can support *in situ* conservation efforts.

APPROACH

Multiple methods are used by the PHOCAS program to monitor changes in body condition. In addition to obtaining regular weights to measure changes in body mass, the three main modalities used are photogrammetry, direct morphometric measurements, and blubber thickness measurements from ultrasound (Figure 1). Due to the natural history and behavior of Arctic seals, most known data has been collected during specific seasons when the seals are most accessible to scientists. Our analyses allow us to understand the seasonal changes these animals experience year-round.

Figure 1. *PHOCAS Program Methods for Body Condition Monitoring*



Note: In addition to participation in routine voluntary weights to measure body mass, body condition is measured through photogrammetry, direct morphometrics, and blubber thickness ultrasounds. All research and animals featured are authorized under NMFS Permit 23554.

Photogrammetry is an indirect way to measure growth and body condition of seals. Photos are taken of the seals with a scale bar that allows us to calculate the curvilinear and standard length, as well as body height at specific locations along the animals. The scale bar is simply a pole with a known length that is imaged next to the seal to allow the photos to be calibrated and analyzed. Seals within the PHOCAS program are trained to hold in both the prone or down position as well as the ventral present position while images are obtained from standard angles and distances. Photogrammetric data are collected weekly, allowing us to have a robust data set tracking changes over time and between individuals. The data we collect can be compared to existing images and data sets from free-ranging seals, allowing us to support the analysis and validation of data from wild populations.

While photogrammetry can be used with untrained or non-participating animals, direct morphometrics requires significant participation from the animal. Direct morphometrics allows us to measure body condition and growth using a measuring tape. For this task we directly measure standard and curvilinear lengths, as well as obtain a series of girth measurements at fixed points along the body. Seals are trained to maintain a relaxed down or prone position throughout the positioning and measurements. Data from direct measurements also allows us to gain information in three dimensions, whereas photogrammetry is only in two dimensions. By taking the circumference of the seal into consideration, we can have greater insight into total body total energy stores. Looking at this data long-term allows us to better interpret seasonal and developmental changes. As with photogrammetry, we collect morphometric data weekly for each of the seals in the PHOCAS program.

We use non-invasive ultrasound as a tool to measure how thick a seal's blubber layer is. Blubber is a specialized fat used for thermoregulation and energy storage, and is critical for survival in cold polar seas (Boveng *et al*., 2020). The blubber energy stores of seals typically make up 20 to 50% of their body mass. Seals typically bulk up in the fall leading into winter and lose much of their blubber following the breeding and molting season in spring. For this task, the seals are conditioned to relax in extended prone or ventral side up positions while we measure blubber depth at 13 positions along the animal's body.

By combining the three metrics of photogrammetry, direct morphometric measurements, and blubber depth ultrasounds, we know the animal's size and shape, and the thickness of the blubber layer at various points. This allows us to calculate the amount of fat contained in the body, which can be converted into units of energy, allowing us to determine the amount of energy an animal has stored in their blubber (Boveng *et al*., 2020). These measurements give us a better understanding of seasonal blubber energy stores, most importantly as they transition through their leanest and heaviest body conditions. It also allows us to monitor changes as they grow and age.

The seal body condition data collected within the PHOCAS program are used to support various research efforts including the NOAA UAS validation study. High-resolution paired color images and thermal images are obtained from eight set elevations from 50-280 feet using calibrated instrumentation. In-house, this project is nicknamed the "Drone Study."

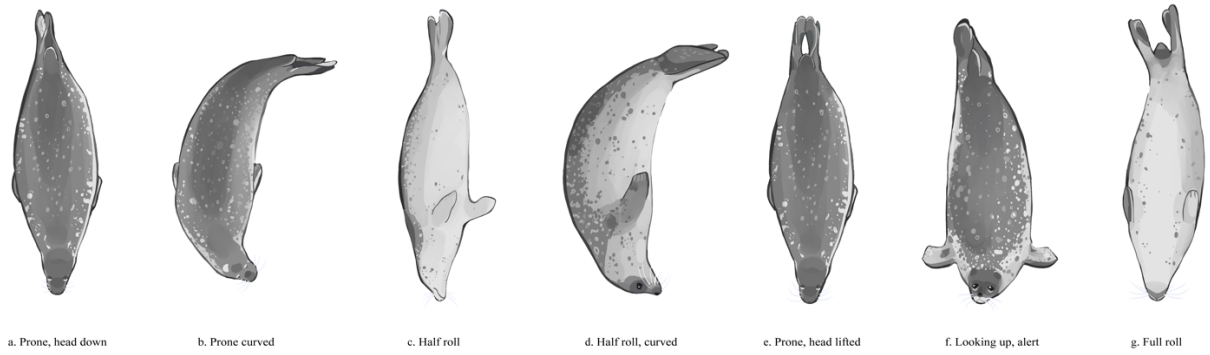
By pairing the images collected of our seals with the body condition data from our photogrammetry, direct morphometric, and ultrasound measurements, statistical models can be developed for estimated mass and length of wild seals as an index of their health. This information will be used to validate and improve these models. With this optimized approach,

NOAA plans to obtain similar measurements from thousands of seal images collected during aerial surveys of wild seals resting on sea ice in Alaskan waters.

The study design required that images would be taken of the PHOCAS seals "posing", or holding for extended intervals in specific body positions. Seven positions were selected to be trained. The positions were: down, curved down, half roll, curved half-roll, relaxed position looking straight ahead, alert position looking up, and a full roll or ventral present (Figure 2). An eighth position was also developed. Instead of being a set trained position, this position was called "free style" and involved a scan and capture approach to both training as well as imaging. For this position, the animals were reinforced for the novelty of the positions they offered, without a specific goal pose in mind. Images were of the seals moving or opportunistically holding in a variety of positions they naturally offered allowed further validation of wild seal images. Three spotted seals, five ringed seals, and two bearded seals participated in cooperative behavioral sampling for this project.

Figure 2

Body Positions utilized in support of the collaboration between NOAA's Polar Ecosystems Team and the PHOCAS program



Note: Seal Drone Positions. Meaghan Klos, 2023.

As previously highlighted, only a few core behaviors were used to train the behavorial tasks supporting photogrammetry, direct morphometrics, ultrasound blubber measurements, and to establish the 7 desired positions for the drone study. For the drone study in particular, trainers dedicated significant effort to desensitizing the seals to area distractions while they held the positions, taking special care to condition calm and relaxed affective states. Gradually, the time intervals for the positions were increased until the seals could hold each up to 5 minutes before reinforcement. During drone trials, seals were asked to hold a position for durations between 30 seconds and 5 minutes between reinforcement opportunities, depending on behavior and conditions. During free-style sessions, a more dynamic approach was used to capture the seals in motion.

To determine whether the final UAS approach would be sensitive enough to detect a known change in body condition, images of the same seals were collected in early summer, when the individuals were leanest, and in fall, when the seals were heavier (Rosen et al., 2021). During

sampling, multiple sets of images was collected for all desired position at each of the designated heights, and trials were repeated several times over successive days.

FINDINGS AND NEXT STEPS

Replicate trials in up to eight body positions were successfully obtained with seven ice seals at the Alaska SeaLife Center and three ice seals at UC Santa Cruz. During the fall data collection alone, over 59 drone flights were completed at the Alaska SeaLife Center, resulting in approximately 3,300 color and thermal image pairs. These data are being evaluated now to ensure accuracy of instrumentation and to generate calibrated morphometric information for each seal in different scenarios (positions). The UAS measurements will then be coupled with known information about seals' mass, lengths, widths, and blubber stores to provide a large data set that will allow significant progress to be made in the validation of this emerging population health assessment approach.

DISCUSSION

The highly trained seals of the PHOCAS program contribute to veterinary, physiology, and applied conservation studies. This collaboration between the PHOCAS program and NOAA's Polar Ecosystems Program is an example of a successful partnership between scientists and zoological institutions. This effort will enhance and support ongoing studies of Alaskan ice seal populations in an increasingly changing Arctic.

ACKNOWLEDGEMENTS

We share this presentation on behalf of the PHOCAS team, including our talented trainers, scientists, and seals. In particular, we thank the ASLC Mammal Team including Jamie Mullins, Shelby Burman, Jasmine Collier, and Madi Burgess and the UCSC Research Team including Madeline Meranda, Madilyn Pardini, Sebastian Caamaño, Kyle Kolda, Jenna Sullivan, and Micaela Garcia. We thank NOAA's Polar Ecosystems Program for the opportunity to contribute to their science program, and Kaiti Chritz, Lisa Hartman, and Meaghan Klos for their support and contributions to our presentation. This program was supported in part by NOAA's Alaska Pinnipeds Program and NOAA's Cooperative Institute for Marine, Earth, and Atmospheric Systems. Research was authorized under NMFS marine mammal research permit 23554 with the expressed consent of the Ice Seal Committee, a tribally authorized co-management organization. Activities were approved by the Institutional Animal Care and Use Committees of UC Santa Cruz and the Alaska SeaLife Center.

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