Project Proposal: Calibrating Drone-Based Mass Estimates of Northern Elephant Seals
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Course: BIOE-128L

Measure a Seal (Without Crushing Your Field Team):

Calibrating Aerial Morphometrics Measurements in Northern Elephant Seals

INTRODUCTION

As technology advances, new tools are emerging to help researchers study wildlife in ways that are more efficient and less invasive. In recent years, drones have become increasingly common in ecological research, especially for observing species that are difficult to monitor using traditional ground based methods.(Linchant et. al., 2015, Lyons et. al 2019, Schad & Fisher, 2023) Drones offer a bird's-eye view that allows for large scale data collection, with minimal disturbance to the animals being studied. One growing area of interest is using drone imagery to collect morphometric data, such as body length, width, and weight on marine mammals like seals. Accurate morphometric measurements are crucial for understanding individual health, reproductive potential, and overall population dynamics. However, while drones can provide detailed aerial images, the measurements taken from these images must be validated to ensure their accuracy. Without proper calibration, estimates of body size and shape may be skewed due to camera angles or flight height. (Dawson et al., 2017, Johnston 2019) To make these drone-based methods reliable, it is necessary to compare them with ground taken measurements taken from the same animals. (Krause et. al 2017, Carroll et. al, 2024, Stone & Davis, 2024) Our project focuses on calibrating the drone derived morphometrics with direct ground measurements of seals to test the accuracy and reliability of using drones for large scale morphometric studies. By calculating drone-estimate inaccuracy, we aim to use it as a tool for calibration to improve the scientific validity of drone based monitoring and open the door for future research that can gather colony wide data more efficiently and with less impact on the animals.

BACKGROUND

General Background:

As drone technology becomes more accessible, its use in ecological research continues to expand, particularly for collecting data on species that are difficult or sensitive to human approach. Drones offer a promising alternative to traditional methods for measuring animal size and condition, as they can capture morphometric data from a safe distance without disturbing the animals.(Stepien et. al. 2024) These data, including body length, width, and surface area, are essential for evaluating health, growth, and reproductive success in wild populations. However, the accuracy of drone taken measurements depends on several factors, such as camera angle, altitude, and image resolution. Without proper calibration, these aerial estimates may be unreliable. (Larsen, 2022) To address this challenge, researchers have started calibrating drone based morphometric estimates with the ground collected measurements. (Krause et. al 2017, Carroll et. al, 2024, Stone & Davis, 2024) This process helps validate aerial data and fine tune measurement techniques, improving confidence in using drones for long term wildlife monitoring.

Studies in pinniped species like harbor seals (*Phoca vitulina*) and leopard seals () have demonstrated the value of this calibration approach, showing that with appropriate correction, drone imagery can reliably estimate size and condition. (Carroll et. al, 2024, Krause et. al 2017) Calibrating these measurements allows researchers to expand from small, individual data collection to assessments of entire haul-out colonies. This shift has the potential to reveal broader patterns in health and body condition across time, helping to track ecological change at the population level. (Hodgson et. al, 2020, Carroll et. al, 2024, Stone & Davis, 2024)

Species Specific Background:

Northern elephant seals (*Mirounga angustirostris*) are large, sexually dimorphic marine mammals that haul out in dense colonies for breeding and a catastrophic molt. During both periods, animals do not feed unless they are pups during the breeding season, and can be aggressive to field teams. Their size and behavior make traditional morphometric methods, such as using measuring tapes, logistically difficult and potentially disruptive unless chemically immobilized, and the largest animals (adult males) are unable to be weighed on sling scales. (Beltran & Robinson, personal communication,)Using drones to estimate their body measurements could be especially useful during these sensitive haul out periods, where minimizing potentially dangerous human-wildlife interaction is a priority.

Accurate morphometric data from elephant seals are vital for studying life history traits such as fasting endurance, maternal investment, and reproductive success. These traits are directly linked to body condition and size, which in turn reflect foraging success and environmental variability. (Crocker et al., 2012; Carroll et al., 2024; Krause et al., 2017) By calibrating drone taken estimates with ground measurements from individual seals, researchers can create accurate, repeatable tools for monitoring seal health and body condition across entire colonies. <u>We aim to quantify the level of accuracy of drone-based, machine learning aided estimate measurements compared to physically measured procedure animals, in order to explore whether these methods are a viable alternative to invasive procedures when researching how seal mass/size relate to other behavioral, ecological and environmental conditions.</u> We are also interested in examining if error within drone estimates of mass and length are regularly over- or underestimated, to see if it can be accounted for, and to see if colony-level drone assessments of mass and length match correlative patterns observed in physically examined seals (e.g, mass is shown to correlate with oceanographic conditions), but it is a secondary focus compared to accuracy assessments, and is time-dependent.

This approach not only enhances our understanding of individual physiology but also allows for broader ecological questions to be addressed, such as how environmental changes may affect population growth patterns or how body condition varies across space and time. Developing a reliable calibration framework will allow researchers to use drone data with greater confidence and could significantly expand the scope of morphometric monitoring in pinniped populations.

METHODS

Available Data:

The UCSC elephant seal program has been collecting data from the Año Nuevo colony since 1964. Every year, seals that undergo procedures also are measured for morphometrics including lengths, girths, blubber depth, and mass (when possible, directly via sling, or estimated from other morphometrics). With our focus on colony-level drone flights, data has been collected at least once a breeding season from 2016-2025, with three surveys a year collected during 2023-2025. Images collected on these flights are analyzed in Picterra software, and data collected as a result of human and machine-learning based analysis includes date, latitude, longitude, seal polygon area, perimeter, length, and width, and potential sex.

Analysis Approach:

We will be compiling datasets from drone-flight imagery, and from procedure animals. In order to accurately assess measurement accuracy, we will focus on data for seals with both known measurements and drone-based estimates. To do this, we must narrow our procedure animal data to the period of smaller drone dataset, which includes the 2016-2025 seasons, and then look at animals that were weighed on the same day as the drone flight, or are otherwise noted as being procedure animals in the drone-derived data. We will be pulling seal ID, polygon length/standard length, width, and mass estimates to analyze, and do paired comparisons between procedure data and drone-derived data of each seal, aiming to quantify the deviation of drone derived data from known-measurement data for seals across all years of drone flight data. We can also use statistical models (such as an LMM or GLMM) in order to quantify the statistical significance of the inaccuracy we find in drone vs procedure measures. <u>We predict that drone derived metrics of the seals will fall below a 20% margin of accuracy compared to actual morphometrics, and that it will not be significant.</u> Similarly calibrated studies note accuracy ratings normally between 10-15% of actual measurements, and that differences in data between collection methods are not statistically significant enough to mean that drones are not viable collection methods. However, it is of note that the percent inaccuracy does appear to fluctuate with age class.(Krause et. al 2017, Hodgson et. al, 2020, Carroll et. al, 2024, Stone & Davis, 2024)

If we find no animal matching one-to-one between these data sets, we will shift gears to analyze general morphometrics (length, width, and mass) trends between procedure and drone-derived datasets, to see how well they match with each other. In either case, we will be analyzing and visualizing the trends in our data and the accuracy of drone-derived data in R.

Reference List:

Carroll, D., Infantes, E., Pagan, E. V., & Harding, K. C. (n.d.). Approaching a population-level assessment of body size in pinnipeds using drones, an early warning of environmental degradation. *Remote Sensing in Ecology and Conservation*, *n/a*(n/a). https://doi.org/10.1002/rse2.413

Crocker, D. E., Houser, D. S., Tift, M. S., & Williams, T. M. (2012). Fasting physiology of the pinnipeds: The challenges of fasting while maintaining high energy expenditure. *Physiological and Biochemical Zoology, 85*(3), 223–230. https://doi.org/10.1086/663679

Hodgson, J. C., Holman, D., Terauds, A., Koh, L. P., & Goldsworthy, S. D. (2020). Rapid condition monitoring of an endangered marine vertebrate using precise, non-invasive morphometrics. *Biological Conservation*, *242*, 108402. https://doi.org/10.1016/j.biocon.2019.108402

Johnston, D. W. (2019). Unoccupied aircraft systems in marine science and conservation. *Annual Review of Marine Science, 11*, 439–463. https://doi.org/10.1146/annurev-marine-010318-

Krause, D. J., Hinke, J. T., Perryman, W. L., Goebel, M. E., & LeRoi, D. J. (2017). An accurate and adaptable photogrammetric approach for estimating the mass and body condition of pinnipeds using an unmanned aerial system. *PLOS ONE*, *12*(11), e0187465. https://doi.org/10.1371/journal.pone.0187465

Larsen, G. D. (2022). *Advancing Drone Methods for Pinniped Ecology and Management* [Ph.D., Duke University]. https://www.proquest.com/docview/2716558733/abstract/613681700170420DPQ/1

Linchant, J., Lisein, J., Semeki, J., Lejeune, P., & Vermeulen, C. (2015). Are unmanned aircraft systems (UASs) the future of wildlife monitoring? A review of accomplishments and challenges. *Mammal Review*, *45*(4), 239–252. https://doi.org/10.1111/mam.12046

Lyons, M. B., Brandis, K. J., Murray, N. J., Wilshire, J. H., McCann, J. A., Kingsford, R. T., & Callaghan, C. T. (2019). Monitoring large and complex wildlife aggregations with drones.

Methods in Ecology and Evolution, *10*(7), 1024–1035. https://doi.org/10.1111/2041-210X.13194

Schad, L., & Fischer, J. (2023). Opportunities and risks in the use of drones for studying animal behaviour. *Methods in Ecology and Evolution*, *14*(8), 1864–1872. https://doi.org/10.1111/2041-210X.13922

Stone, T. C., & Davis, K. J. (2025). Using unmanned aerial vehicles to estimate body volume at scale for ecological monitoring. *Methods in Ecology and Evolution*, *16*(2), 317–331. https://doi.org/10.1111/2041-210X.14457