### Thesis Prospectus 2023-24

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**Student Final Submission (date):** 12/11/2023

**Faculty Reader Approval (date):**

**MES Director Approval (date):**

1. Working title of your thesis[[1]](#endnote-1).

Zoo Animal Movement: Assessing Habitat Use with Artificial Intelligence

1. **In 250 words or less, summarize the key background information needed to understand your research problem and question.**

The habitat of a captive animal is very influential on their welfare, often suppressing or encouraging behaviors that researchers interpret as positive and natural (Hediger, 2013). Thus, the ways in which animals use the space they occupy can be quite indicative of how suitable their environments are for the animals in question. Artificial Intelligence (AI) software is revolutionizing the way that zoo managers monitor their collection by integrating with pre-existing camera feed to derive precise location data of monitored animals. This information can be used to determine how animals are using their human-constructed spaces and, potentially, how these spaces may be improved upon. Lidar uses light which is typically invisible to humans to image objects and environments. Terrestrial lidar can provide detailed 3D modeling of the objects and environments that it senses such that a near infinite amount of structural data can be derived from the model. By pairing the movement data of animals with a model of their environment, one can derive possible relationships between space use and present habitat features. Behavioral observation is often the go-to tool for zoo faculty trying to understand how the animal feels, their general health condition, what the animal is thinking, etc. Such information is usually recorded in the form of ethograms: a species-specific inventory of behaviors that the animal may exhibit under observation. Used in tandem with space use and habitat feature information, a holistic understanding of the way in which zoo animals utilize their space and why could be deciphered.

1. **State your research question(s).**

Can Al movement tracking technology integrate with habitat modeling to answer the following questions:

* Is there a relationship between space use and habitat features in the lynx exhibit?
* Is there a relationship between observed behaviors and habitat features, particularly in '' hot spot'' locations?
1. **Situate your research problem within the relevant literature. What is the theoretical and/or practical framework of your research problem?**

Managers of zoological facilities and the zoo-attending public care about the welfare of exotic animals held in captivity (Veasey, 2022). The habitat of a captive animal poses an incredible influence on their welfare, with an animal’s ability to perform behaviors that are natural to them dependent in large part on their constructed environment (Hediger, 2013). However, one of the most promising methods of assessing habitat interaction by an animal is not widely implemented in zoological settings. Animal movement tracking has been used extensively in the wild to varying ends for decades–one article details the ever-growing interest in research utilizing biotelemetry by the number of relevant publications over the past 20 years (Weaver, Westphal, and Taylor, 2021). Movement data in such contexts has indeed been used to analyze habitat qualities and space use by animals (Winker, Rappole, and Ramos, 1995; Bjørneraas et al., 2012). Movement data is rich in information, and spatial analysis has the potential to uncover insurmountable behavioral patterns of captive animals concerning their environment. What’s more, such data is becoming less costly to attain, the technology for collecting data is less bogged down by clunky hardware, and results are more accurate in terms of the positionality of target animals. Movement tracking data analyzed in tandem with habitat modeling, highlighting well-used spaces, could provide zoo managers with a tool capable of informing a blueprint for optimal enclosure designs.





1. **Explain the significance of this research problem. Why is this research important? What are the potential contributions of your work? How might your work advance scholarship?**

The study of movement in captive animal environments tends to be limited to uncovering the efficacy of different technological approaches to biotelemetry, such as the use of accelerometry to derive albeit informative data on physiological parameters as well as behavior in studied animals (Shepard et al., 2008; Norris, 2019). Accelerometers, not equipped to measure location in space, are not applicable for studies looking to derive meaningful information from the use of space by animals. Location tracking devices for companion animals, tracking systems for locating farm animals, and UAV-enhanced GPS technologies for tracking small animals are all examples of movement data collection methods being investigated contemporarily (Yoon and Yoon, 2023; Ramesh et al., 2021; Tinghao et al., 2022), however, the applications of these methods in the available literature do not appear to extend to the realm of zoo animals and their habitats. Seemingly, only a single publication exists describing zoo animal movement tracking using existing technologies (Scott et al., 2016), and the application of movement tracking to inform habitat use appears nonexistent. The marriage of animal movement and habitat feature analyses could not only provide effective insights into the use of the habitat by the study subjects but also a framework from which to construct a more optimal habitat for the subjects, thereby addressing a major component of the animals’ welfare. Biotelemetry is extremely information-dense, and the resulting data of movement tracking can be analyzed with great precision, leaving little room for doubt when the variable interactions are appropriately assessed.

1. **Summarize your study design[[2]](#endnote-2). If applicable, identify the key variables in your study. What is their relationship to each other? For example, which variables are you considering as independent (explanatory) and dependent (response)?**

This project attempts to use novel AI machine learning software and terrestrial LiDAR technology to draw meaningful connections between a zoo animal’s spatiotemporal use of their enclosure, the habitat features present within their enclosure, and the behaviors that the animal performs in response to high-use areas within the enclosure. The research will involve a small-scale, in-depth analysis of three captive Canadian Lynx within a single enclosure. The chosen study species' enclosure will be mapped in three dimensions from which habitat features, such as slope grade and foliage density, can be classified. Over 7-30 days, continuous movement data will be captured using Kibsi AI machine learning software overlaying the zoo’s surveillance video feeds. The movement data is to be paired with habitat feature data and behavioral observations to determine whether a relationship between space use and habitat features or observed behaviors can be deduced. This study aims to provide a foundation for data-driven enhancements to habitat design and animal welfare initiatives.

MOVEMENT (Dependent variable): Kibsi, a video intelligence and computer vision platform, collects geolocation data of animals by optically tracking them and measuring a depth of field using the zoo’s video feed.

\*\*Movement Classification\*\*

Movement will be quantified by the amount of time that an animal spends in any given area within the enclosure. This variable is termed “space use.”

BEHAVIORAL OBSERVATION (Dependent variable): Behavioral observations will be recorded by monitoring the zoo’s video feeds for behavioral expressions.

\*\*Ethogram and Behavioral Classification\*\*

Behaviors will be systematically recorded and categorized using an ethogram: an inventory of behaviors exhibited by the animal. The ethograms are created in reference to pre-existing behavioral manuals for the subject species (if applicable) and/or discussion with the zoo’s animal care team.

HABITAT FEATURES (Independent variables): The enclosure of the study subjects is qualified by existing features (foliage type, water features, enrichment items, terrain type, etc.), based on environmental models and/or imagery.

OUTCOMES:

When combined, movement data, habitat feature data, and behavioral observations may inform a relationship between animal presence within distinct areas of the enclosure and behavioral expression and habitat features. By measuring where the subjects are spending their time within their enclosure, and how this relates (or does not relate) to behavioral expression and present habitat features. This information can be used to inform how best to manipulate current habitat features with the goal of improving animal enrichment, or it can be used as a precedent for the designing of future exhibits for the study species.

1. **Describe the data that will be the foundation of your thesis. Will you use existing data, or gather new data (or both)? Describe the process of acquiring or collecting data[[3]](#endnote-3).**

The data to be collected:

* Animal Movement Tracking Data: The geolocations of the animals are collected continuously by Kibsi’s AI machine learning software using the zoo’s surveillance camera feed.
* Video Feed of Animals: This data will be gathered from the zoo’s active video feeds.
* Behavioral Observations: Using video feed, behaviors will be observed and noted on ethograms, which are catalogues of behaviors exhibited by the animal. Noting behavior in a continuous fashion over the entire course of the study may not be feasible for the scope of this research, in which case behaviors will be observed and noted during periods where the animal(s) occupy space in the spatiotemporal “hot spot” locations.
* Exhibit Models: The exhibit will be modeled in ArcGIS Pro using terrestrial LiDAR point cloud data collected by myself.
1. **Summarize your methods of data analysis. If applicable, discuss any specific techniques, tests, or approaches that you will use to answer your research question.**

1. Relationship Between Space Use (Continuous) and Habitat Features (Categorical):

* Kernel Density Estimate: To identify high-use areas within the enclosure.
* One-Way Analysis of Variance (ANOVA): To determine if there are statistically significant differences in space use across different categories of habitat features.
* Post-Hoc Tests: If the ANOVA shows significant differences, it will be followed up with a post hoc test (like Tukey's HSD) to determine which specific habitat features differ from each other in terms of influencing space use.
* Check Assumptions: For the ANOVA, this will ensure assumptions such as normality and homogeneity of variances are met. If these assumptions are violated, a non-parametric equivalent like the Kruskal-Wallis Test will be used.

2. Relationship Between Behavioral Expression (Categorical) and Space Use (Continuous):

* Chi-Square Test for Independence (if behavioral categories are nominal): To determine if there is a significant association between different categories of behavior and levels of space use (which can be categorized into ranges for this analysis).
* Kruskal-Wallis H Test (if behavioral categories are ordinal and space use can be categorized): If the behaviors have an inherent order (e.g., low to high activity levels), the Kruskal-Wallis H Test will be used to determine if there are differences in space use across different behavior categories.

3. [Time Permitting] Relationship Between Behavioral Expression (Categorical) and Habitat Features (Categorical):

* Chi-Square Test for Independence: To examine whether there is a significant association between two categorical variables. A contingency table with habitat features as one dimension and behavioral expressions as another will be created.

4. Visualization and Interpretation:

* Bar Charts and Box Plots: Bar charts (for ANOVA) and box plots (for Kruskal-Wallis H Test) will illustrate how space use varies with different habitat features and behaviors.
* Mosaic Plots: To visually represent the data from the contingency table.
* GIS Mapping: A spatial representation of the results will be provided, including a heat map rendering as well as point pattern analysis.

Tools: R, ArcGIS Pro.

1. **Address the ethical issues[[4]](#endnote-4) raised by your thesis work. Include issues such as risks to anyone involved in the research, as well as specific people or groups that might benefit from or be harmed by your thesis work, perhaps depending on your results. List any specific reviews you must complete first (e.g., Human Subjects Review or Animal Use Protocol Form).**

Working with zoological facilities can be tricky. The research will determine how the space is being used by the study subjects, thus, the results could influence personal perception on how engaging, stimulating, boring, inadequate etc. the subjects’ environment is. The zoo itself may have incentive the influence the outcome of the research to promote its facility as a positive environment for captive animals. Additionally, the researcher has their own personal ideology regarding the ethics of zoological facilities and could be swayed by subsequent assumptions of these environments, whether positive or negative. While the purpose of this research is not at all to produce negative or positive assumptions whatsoever regarding the animals’ wellbeing, I cannot dissuade others from coming to their own conclusions in this way.

As a non-profit establishment, the zoo is supported by memberships and donations, and is interested in maintaining a good image for these stakeholders. The zoo as an establishment could be benefitted or harmed by my thesis work if these stakeholders are at all influenced by the outcome—whether the study subject(s) are determined to be appropriately stimulated by their environment at the zoo or not. Consequently, all staff would be impacted in this way if members and donors of the zoo took interest in the study results.

Prior to any research, the zoo’s welfare committee must review the intended methods of the research design for compliance with the zoo’s welfare standards. The general curator must also decide whether this research can be conducted based on its potential impact on the animals.

1. **List specific research permits[[5]](#endnote-5) or permissions you need to obtain before you begin collecting data (e.g. landowner permissions, agency permits).**
* Clearance from the zoo’s welfare committee to conduct research on the resident animals.
* Clearance from the zoo’s general curator to conduct research on the resident animals.
* Clearance from the zoo’s animal welfare scientist to conduct research on the resident animals.
* Permission to conduct LiDAR scans within the Lynx exhibit.
* Permission to access video feed of the lynx exhibit.
* Permission to access Kibsi movement data.
* The Association of Zoos and Aquariums Research Proposal Form must be completed and submitted to the zoo for approval.
1. **Reflect on how your positionality as a researcher could affect your results and how you will account for this in the research process[[6]](#endnote-6).**

As a researcher of zoological animals, I recognize that my own biases regarding zoological facilities may be reflected in the data collected as well as subsequent findings. The behavioral observations are particularly vulnerable to such biases. In my personal life, I am philosophically opposed to the perpetuation of animal captivity and assume that, in many cases, captive exotic animals are afflicted with varying degrees of zoochosis. To ensure that my philosophy and assumptions are accounted for, I will structure my ethograms in a standardized, pragmatic fashion to eliminate as much subjectivity as possible in behavioral observation. I will also inform behavioral observations using pre-established, species-specific behavioral manuals to avoid unintended and/or incorrect characterizations of behaviors.

1. **Provide at least a rough estimate of the costs associated with conducting your research, if any.  Provide details about each budget item so that the breakdown of the final cost is clear.**

Terrestrial LiDAR Sensor: From $297 to over $1,000

Tripod for Sensor: ~$100

Travel Expenses: $65.58 - $87.24

* Combined average MPG for 2006 Toyota Scion xB: 29 MPG
* Miles from home to Woodland Park Zoo: 73.2 Miles
* Thurston county average cost of gas: $4.319/gallon
* Estimated number of excursions: 3-4

(73.2 x 2) / 29 = 5.05 gallons per excursion

5.05 \* 3 = 15.15 gallons \* 4.329 = $65.58

5.05 \* 4 = 20.2 gallons \* 4.329 = $87.24

Lowest Estimate: $462.58

Greatest Estimate: $1,187.24 +

1. **Provide a detailed working outline of your thesis.**

Title: Zoo Animal Movement: Assessing Habitat Use with Artificial Intelligence

Abstract:

A brief overview summarizing the objectives, methods, anticipated findings, and potential applications of the research.

1. Introduction

 - Rationale for the study

 - Importance of understanding animal movement and their environment

 - Overview of biotelemetry and its applications in zoological research and wildlife research

2. Objectives

 - To collect and analyze movement data of captive animals

 - To qualify habitat features within animal enclosures

 - To qualify behavioral expressions by the animals

 - To examine the relationship between animal movement patterns and habitat features

 - To examine the relationship between animal movement patterns and behavioral expression

 - To examine the relationship between habitat features and behavioral expression

3. Literature Review

 - Existing research on animal movement patterns in captivity

 - The role of habitat features in animal behavior and enrichment

 - The role of behavioral observation in animal welfare

 - Previous applications of biotelemetry in zoological studies and wildlife research

4. Methodology

 4.1. Study Area and Subjects

 Description of the zoological facility

 Selection criteria for animal subjects

4.2. Data Collection

 Movement Data - AI Software Use

 Utilization of 3D models and LiDAR data

 Ethogram recording

Space Use

 Measuring space use with Kibsi movement data and ArcGIS Pro

Habitat Features

 Classification and qualification of habitat features

Behavioral Observation

 Ethogram development and usage

 Video feed analysis

4.3. Data Analysis

 Analytical methods for movement patterns

 Comparative analysis of movement data and habitat features

 Comparative analysis of movement data and behavioral expressions

 Comparative analysis of habitat features and behavioral expressions

5. Results

 - Presentation of movement data findings

 - Qualitative and quantitative analysis of habitat features

 - Correlation between animal presence and habitat feature types

 - Correlation between animal presence and behavioral expressions

 - Correlation between habitat feature types and behavioral expressions

6. Discussion

 - Interpretation of the relationship between movement patterns and habitat features

 - Interpretation of the relationship between movement patterns and behavioral expressions

 - Interpretation of the relationship between habitat features and behavioral expressions

 - Implications for animal enrichment and exhibit design

7. Conclusions

 - Summary of key findings

 - Conclusions drawn from the research

 - Limitations of the study

 - Suggestions for future research

8. References

 - Cited works of literature and previous studies used throughout the research

9. Appendices

 - Additional material such as raw data, ethogram samples, and detailed maps of enclosures

1. **Provide a specific work plan and a timeline for each of the major tasks in the work plan. Be as realistic and specific as you can at this point, including the deadlines for Spring quarter.**

Fall Quarter:

* Week 7
	+ Submit AZA Research Proposal to Woodland Park Zoo
	+ Storyline of Results
* Week 8
	+ Draft of literature review due
* Week 9
	+ Working draft of results due
	+ Finalized Thesis Prospectus to reader
	+ Tuesday: Thesis Poster due
* Week 10
	+ Revised draft of results to reader

Winter Break (December 16 – January 7):

* Work with Zoo on collecting 3D point cloud data using terrestrial LiDAR solution
* Establish research protocols with zoo
* Supply an example of intended ethogram for review to zoo

Winter Quarter:

* Week 1
	+ Conduct pilot study to ensure the resultant data is appropriate.
* Week 2
	+ Review pilot study results
		- Troubleshoot if required.
		- Conduct additional pilot study if required.
* Week 3
	+ Review second pilot study results if applicable
	+ Conduct research
		- Behavioral observations
	+ Retrieve movement data from the local server or cloud, depending on system used.
* Week 4
	+ Conduct research
		- Behavioral observations
	+ Retrieve movement data from the local server or cloud, depending on system used.
* Week 5
	+ Conduct research
		- Behavioral observations
	+ Retrieve movement data from the local server or cloud, depending on system used.
* Week 6
	+ Conduct research
		- Behavioral observations
	+ Retrieve movement data from the local server or cloud, depending on system used.
* Week 7
	+ Convene with curator and/or related management regarding research and forward momentum.
* Week 8
	+ Write thesis.
* Week 9
	+ Write thesis.

Spring Break (March 25 – March 30, 2024)

* Write thesis.

Spring Quarter:

* Week 1
	+ Complete draft of Results/Discussion due
* Week 2
	+ Complete draft due to reader
* Week 3
	+ Conclusion for peer review due
* Week 4
	+ Revised conclusion due to reader
* Week 5
	+ Friday: submit request to present or extent Thesis Research
* Week 8
	+ Possible thesis presentation
* Week 9
	+ Possible thesis presentation
	+ Friday: Final Draft of Thesis due to reader
* June 7, 2024
	+ Submit signed, final version of thesis.
1. **Who (if anyone), beyond your MES thesis reader, will support your thesis (in or outside of Evergreen)? Be specific about who they are and in what capacity they will support your thesis. If you are working with an outside agency or expert, be specific about their expectations for your data analysis or publication of results.**

The animal welfare scientist of the zoo will support in my thesis in that they will act as a liaison between I and other areas of zoo management. They will also oversee the research that is being conducted, ensuring that welfare standards and zoo policies are being met.

The Kibsi software company will support my thesis by providing guidance on how best to integrate their data into software for analysis and how to interpret the data. It may be that the data provided by Kibsi is also owned by Kibsi, which would require attaining permission from Kibsi to use the data for my intended purposes.

1. **Provide the 5 most important references you have used to identify the specific questions and context of your topic, help with issues of research design and analysis, and/or provide a basis for interpretation. Annotate these references with notes on how they relate to/will be helpful for your thesis. For any other sources cited in your prospectus in other answers, provide a complete bibliographic citation here as well.**

Hediger, H.. Wild Animals in Captivity. Netherlands: Elsevier Science, 2013.

This article is a comprehensive history of the keeping of wild animals by humans from the 1800s onward. The history provides a look into the goals of zookeeping, including welfare initiatives and how exhibit design is correlated with animal wellbeing.

Scott, Nancy L., Bernard Hansen, Chase A. LaDue, Carlson Lam, Albert Lai, and Lowell Chan. 2016. “Using an Active Radio Frequency Identification Real-Time Location System to Remotely Monitor Animal Movement in Zoos.” Animal Biotelemetry 4 (1): 16.

This source is of particular importance to me as it was the only application of biotelemetry technology for tracking animal movements in a zoological setting. As such, it details the insights of movement data in relation to zoo animals and their enclosures.

Yasmeen, Roheela, Irfan Aslam, Mubashar Ahmad, and Muhammad Hasan Ali Shah. 2023. “Zoochosis: A Short Review on Stereotypical Behavior of Captive Animals.” Journal of Wildlife and Biodiversity 7 (2): 8–20. <https://doi.org/10.5281/zenodo.7362442>.

This review article gives an overview of the effects of captivity on the exotic animal mind and how they are physically manifested. I’m using this article to help inform the significance of my research as indicators of welfare based on captive exhibit design are, in my opinion, of importance in managing artificial environments with the intent to suppress zoochosis.

Smith, Kirsten D., Richard J. Snider, Daniel P. Dembiec, Janice M. Siegford, and Ahmed B. Ali. 2023. “Effects of a Modern Exhibit Design on Captive Tiger Welfare.” Zoo Biology 42 (3): 371–82. <https://doi.org/10.1002/zoo.21746>.

This article is a case study on how environmental design impacts captive tigers’ abilities to simulate natural wild behaviors and the subsequent influence this has on their welfare. This informs both what to look for in large felid behavior and how the environment influences such behavior.

Mittal, S. K., R. J. Rao, Sanjay Shakya, and Symantak M. Tripathi. 2019. “Modern Naturalistic Enclosures: Comparatively an Enhanced Management Practice of Captive Felids in the Zoological Park,” February.<https://imsear.searo.who.int/handle/123456789/210796>.

This is another article that provides insight into the behaviors and welfare of captive felids based on exhibit design. This information can be used in my research to better understand the behaviors observed in response to the presence or absence of environmental stimuli as the animals move about their enclosures.

1. You are not locked into this title; we want you to identify the main point or topic of your thesis. [↑](#endnote-ref-1)
2. You might discuss a selection of case studies, sampling methods, experimental design, and/or specific hypotheses you will test. You should also address any specialized knowledge or skills that are necessary to complete the research. [↑](#endnote-ref-2)
3. If you are planning to use existing data, explain the specific source, contact information, arrangement with collaborating agencies, and expectations about use of data and final products of your research. If you are planning to gather new data, describe specific methods, time, place, and equipment that will be required. [↑](#endnote-ref-3)
4. If you’re not sure where to start, consult a ‘Code of Ethics’ or other similar document from an academic society in an applicable field of study. [↑](#endnote-ref-4)
5. If you are collecting ANY samples or data, even observational data, on public lands (city, county, state and/or federal) it is your responsibility to find out the permit requirements BEFORE you collect data. Conducting research with tribal members/on tribal lands will have different and additional requirements. [↑](#endnote-ref-5)
6. Your *positionality as a researcher* refers to the fact that one’s “…beliefs, values systems, and moral stances are as fundamentally present and inseparable from the research process as [one]’s physical, virtual, or metaphorical presence when facilitating, participating and/or leading the research project…” (The Weingarten Blog 2017).

**Bibliography**

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Weaver, Savannah J., Michael F. Westphal, and Emily N. Taylor. 2021. “Technology Wish Lists and the Significance of Temperature-Sensing Wildlife Telemetry.” Animal Biotelemetry 9 (1): 29. https://doi.org/10.1186/s40317-021-00252-0.

Winker, Kevin, John H. Rappole, and Mario A. Ramos. 1995. “The Use of Movement Data as an Assay of Habitat Quality.” Oecologia 101 (2): 211–16. <https://doi.org/10.1007/BF00317286>.

윤종화(Yoon, Jong Hwa), and Dal Hwan) 윤달환(Yoon. 2023. “반려동물을 위한 IoT 기반 이동식 캐리어 디자인과 위치추적장치 개발.” 안전문화연구, May, 109–22. https://doi.org/10.52902/kjsc.2023.22.109. [↑](#endnote-ref-6)