Introduction to the Integration of Animal Tracking and Remote Sensing

Part 1: Introduction to Animal Tracking and Remote Sensing at NASA

Juan Torres-Pérez (NASA), Justin Fain (BAERI), Sativa Cruz (BAERI)
Invited Speakers: Morgan Gilmour (NASA), Claire Teitelbaum (USGS/Univ. of Georgia)

About ARSET

About ARSET

- **ARSET provides accessible, relevant, and cost-free training on remote sensing satellites, sensors, methods, and tools.**

- Trainings include a variety of applications of satellite data and are tailored to audiences with a variety of experience levels.

About ARSET Trainings

- Online or in-person
- Live and instructor-led or asynchronous and self-paced
- Cost-free
- Bilingual and multilingual options
- Only use open-source software and data
- Accommodate differing levels of expertise

- Visit the ARSET website to learn more.

Training Learning Objectives

By the end of this training attendees will be able to:

1. Identify the types of animal tracking tags and sensors that are commonly used in animal tracking.
2. Identify the types of remote sensing data and products that can be used for species distribution models and step-selection functions.
3. Recognize the process for integrating remote sensing and animal tracking data in species distribution models and step selection functions to facilitate an understanding of animal movements in relation to their environment.
4. Recognize key takeaways from examples of terrestrial and marine applications that inform and characterize animals' habitats.

Prerequisites

- Fundamentals of Remote Sensing

Training Outline

Part 1

Introduction to Animal Tracking and Remote Sensing at NASA

May 20, 2025

12:00 - 13:30 EDT (UTC-4)

Part 2

Integration of Animal Tracking and Remote Sensing Data

May 22, 2025

12:00 - 13:30 EDT (UTC-4)

Homework

Opens May 22, 2025 – Due June 5, 2025 – Posted on Training Webpage

A certificate of completion will be awarded to those who attend all live sessions and complete the homework assignment(s) before the given due date.

Part 1 – Trainers

Juan Torres-Pérez
Research Scientist
NASA Ames

Sativa Cruz
Research Scientist
BAERI/NASA Ames

Justin Fain
Research Scientist
BAERI/NASA Ames

How to Ask Questions

- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.

Introduction to the Integration of Animal Tracking and Remote Sensing - Guest Instructors

Dr. Morgan Gilmour

Research Scientist

NASA Ames Research Center

Claire Teitelbaum

Assistant Unit Leader

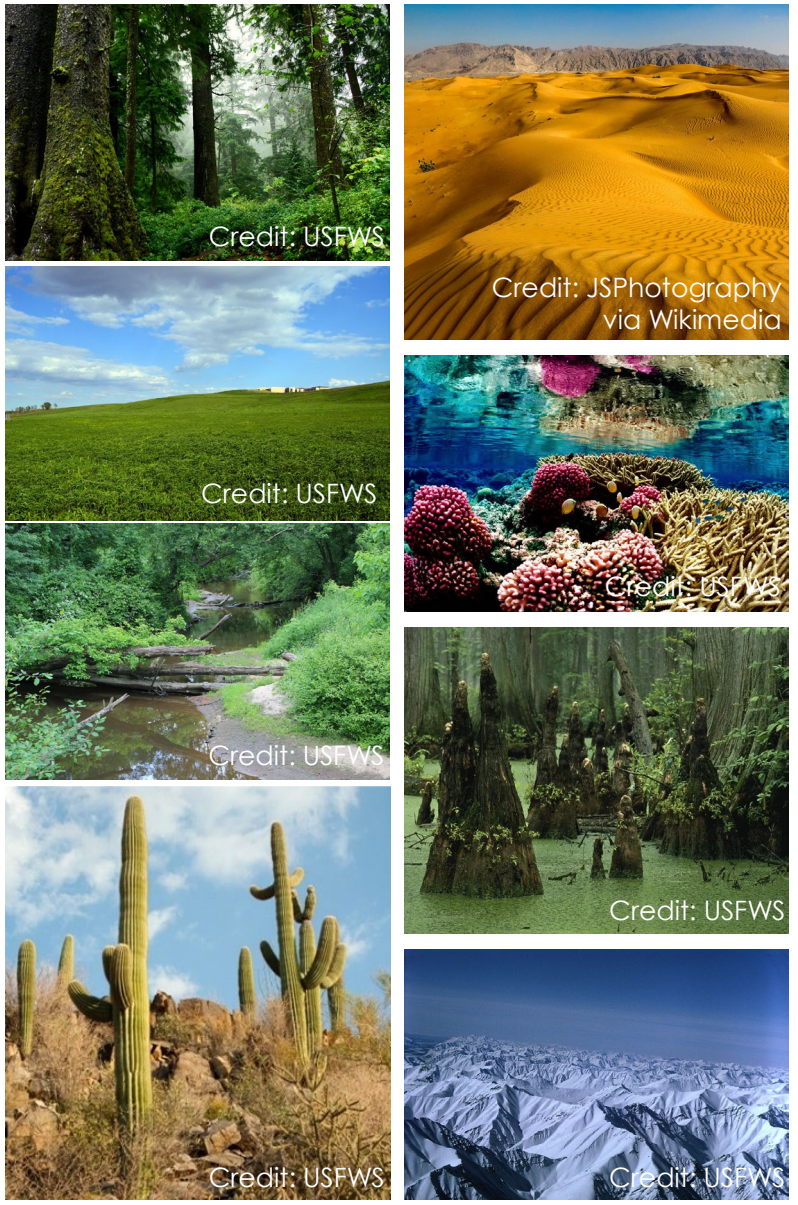
USGS

University of Georgia

Section 1: Overview of Animal Tracking

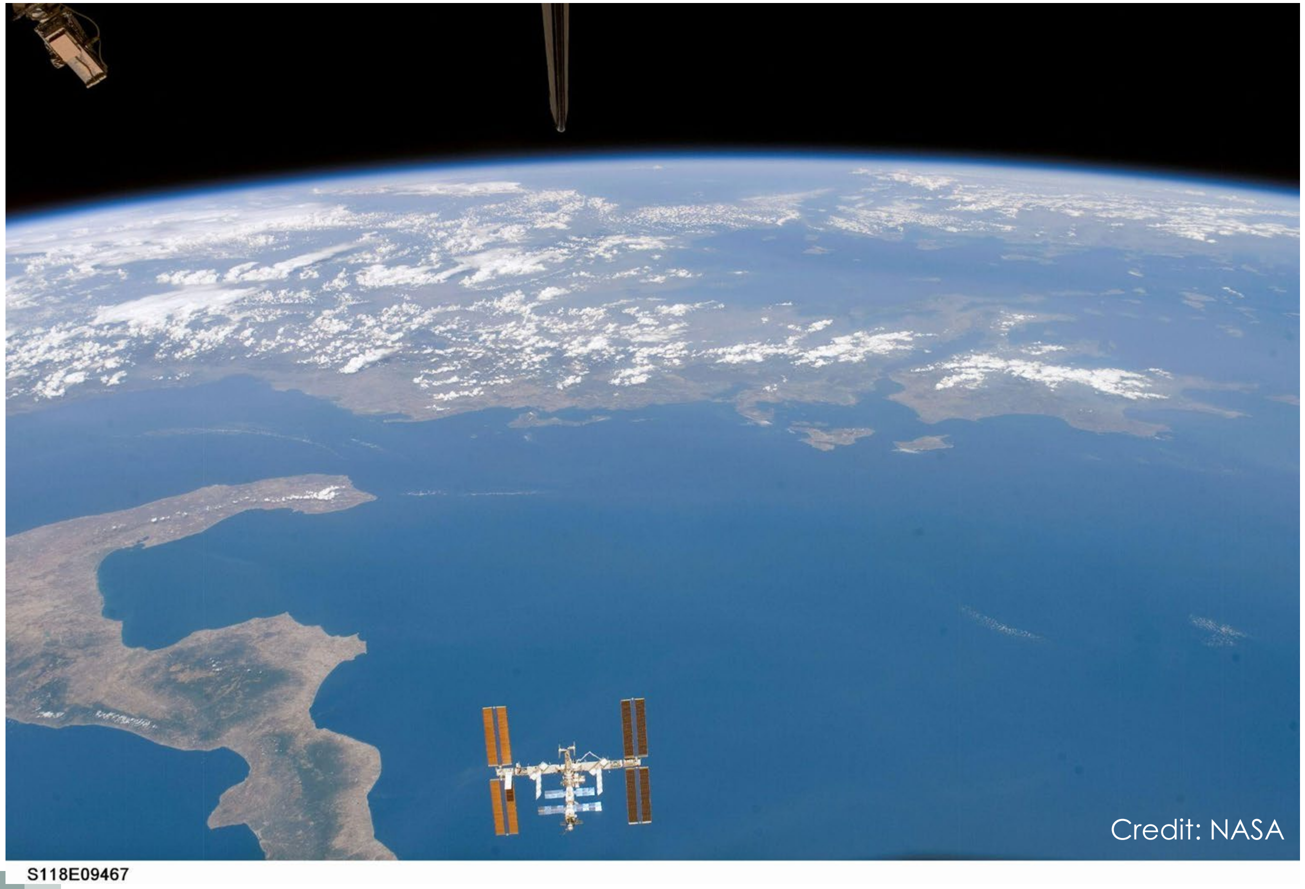
Why Track Animals?

- Earth is composed of complicated, integrated ecosystems.
- Understanding how to manage these systems requires diverse, integrated approaches & tools.



Why Track Animals?

- Animals use these ecosystems too!
- Animals provide a unique perspective on habitat use



Credit: NASA


Credit: USFWS


Credit: USFWS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Why Track Animals: Playing a Critical Role

Animals play a critical role in:

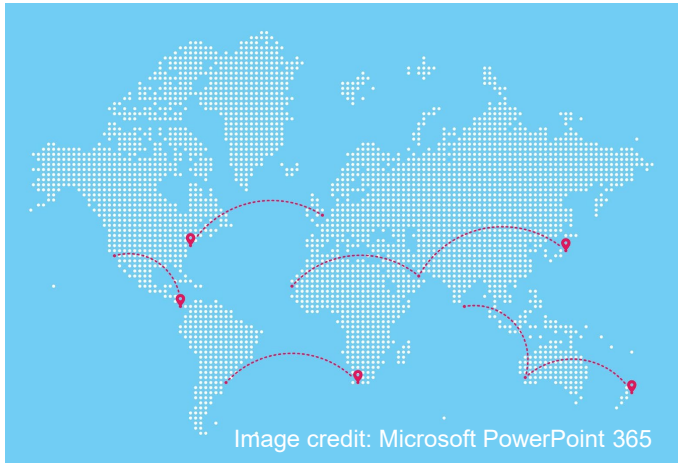
- Ecosystem diversity, health and survival
  - Pest control
  - Nutrient cycling
  - Pollination
  - Seed dispersal
  - Food

- Ancient and modern societies
  - Food
  - Disease dispersal
  - Sensor platforms
  - Navigation hazards
  - Spiritual
  - Tourism

Why Track Animals: Insights

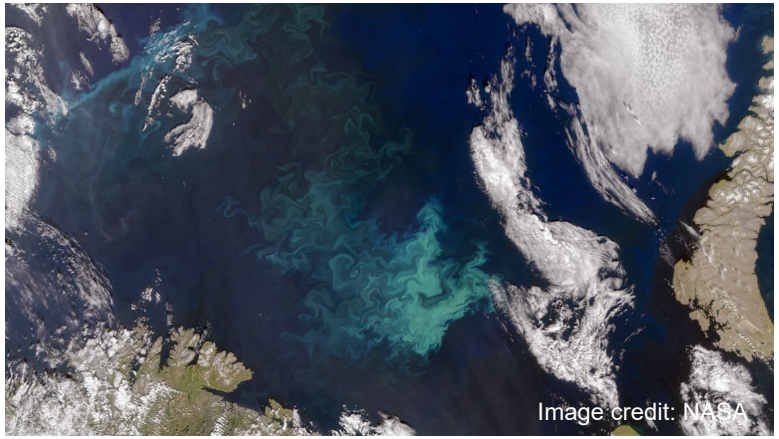
Animal tracking data can reveal information about:

Movement Ecology



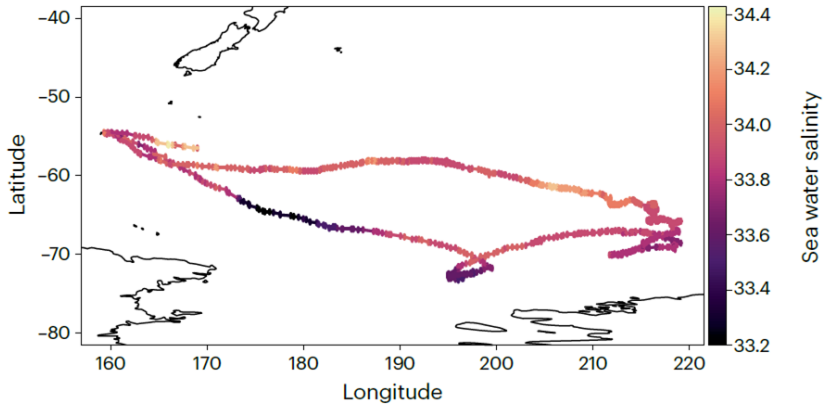
Where do animals go?
Why do they go there?

Habitats



What is the environment like?

The Environment



What else can they tell us?

Ellis-Soto et *al*. 2023 *NatClimChg*

Animal Tracking Tags & Sensors

We discern animal behaviors from commonly used tracking tags.

- Presence
- Hotspots
- Transit speed
- Mortality
- Interactions with human infrastructure
- Interactions with resources, the environment
- Responses to environmental change


Credit: USFWS


Credit: Mike Baird via Wikimedia Commons


Credit: USFWS

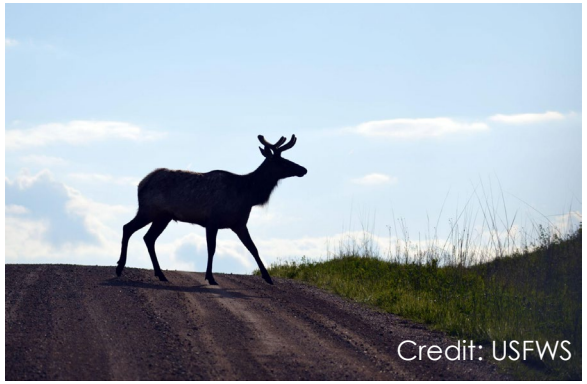
Animal Tracking Tags & Sensors

Tag selection depends on taxon and application

- Tag size: *body mass, locomotion method*
- Latency: *location remoteness, application*
- Location precision & accuracy: *habitat type, tag size*
- Auxiliary sensors: *application*


Credit: USFWS


Credit: Mike Baird via Wikimedia Commons


Credit: USFWS

Animal Tracking Tags & Sensors: Transmission Mode

Tracking tags are often defined by their data transmission mode:

- Radio
- Satellite
- Archival
- Combination archival/satellite
- Cell phone network (GSM)
- MOTUS
- Remote download (via UHF)

Radio antenna

Limitations of Biologging

- Size, Weight, and Power (SWaP)
- Presence-only information
- Spatio-temporal resolution
- Information on a small subset of a group/population/species

Animal tracking at NASA

- NASA has supported animal tracking efforts since 1970
  - Missions
  - Sensors
  - Tracking tags
  - Communication networks
  - Biodiversity monitoring
  - Contribute in-situ observations to models, satellite validation

NASA tracked elk in 1970!

NASA's Internet of Animals Project: Goals

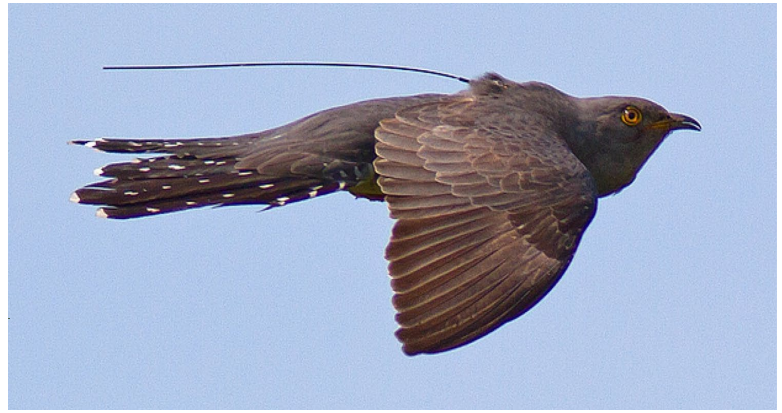
1. **Understand observation needs for spaceborne animal telemetry**
   - Workshop
   - Community of Practice

2. **Architect a next-generation space-based animal tracking system**

3. **Remote sensing of animal movement**
   - What are the tracking community's remote sensing needs?
   - What & where can animals fill gaps in remote sensing?

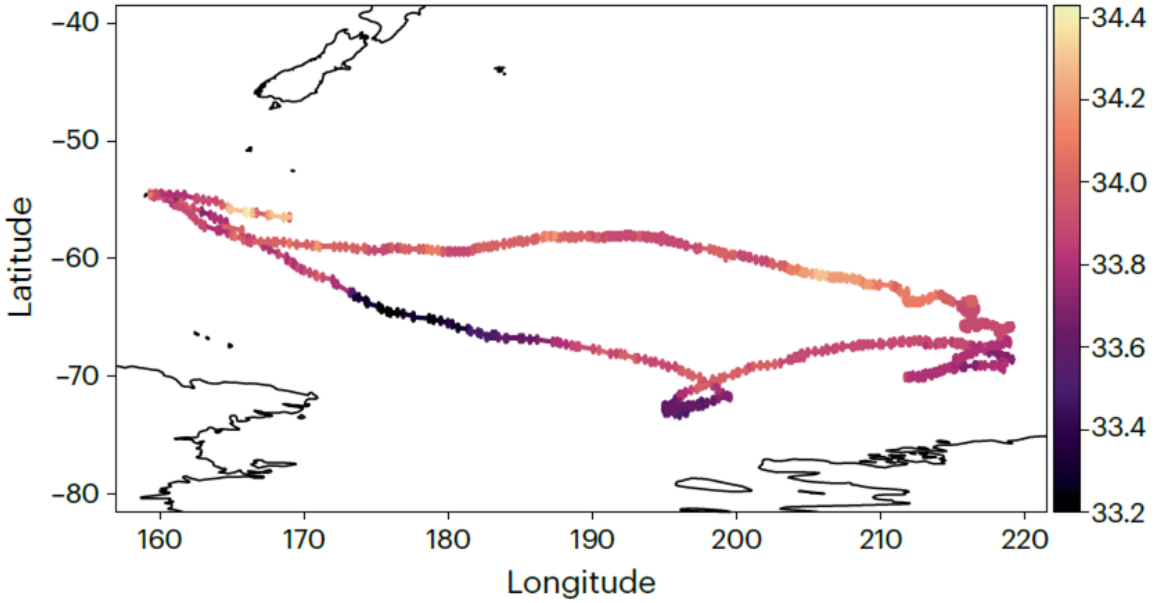
4. **Case studies**
   - Remote sensing can improve disease ecology research
   - Species distribution models quantify efficacy of marine protected area


Credit: NASA GSFC

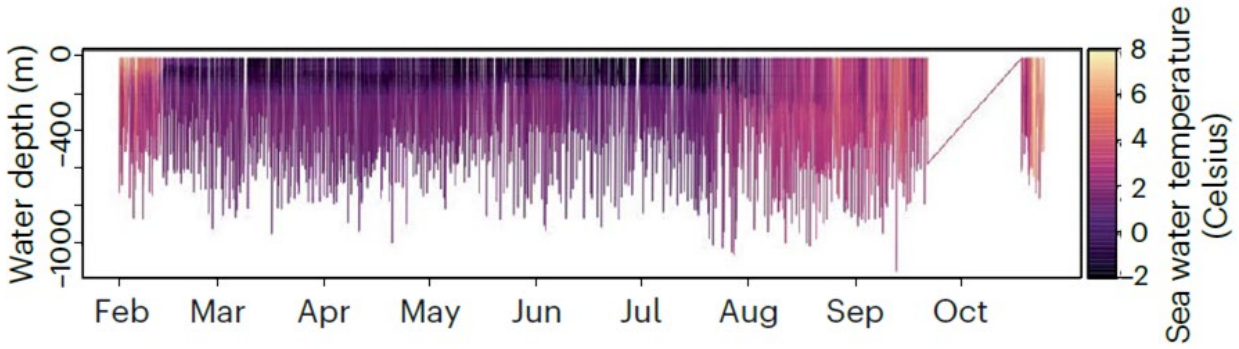


Animals as Sensors of the Environment: Elephant Seals

Elephant seals collect salinity and temperature.



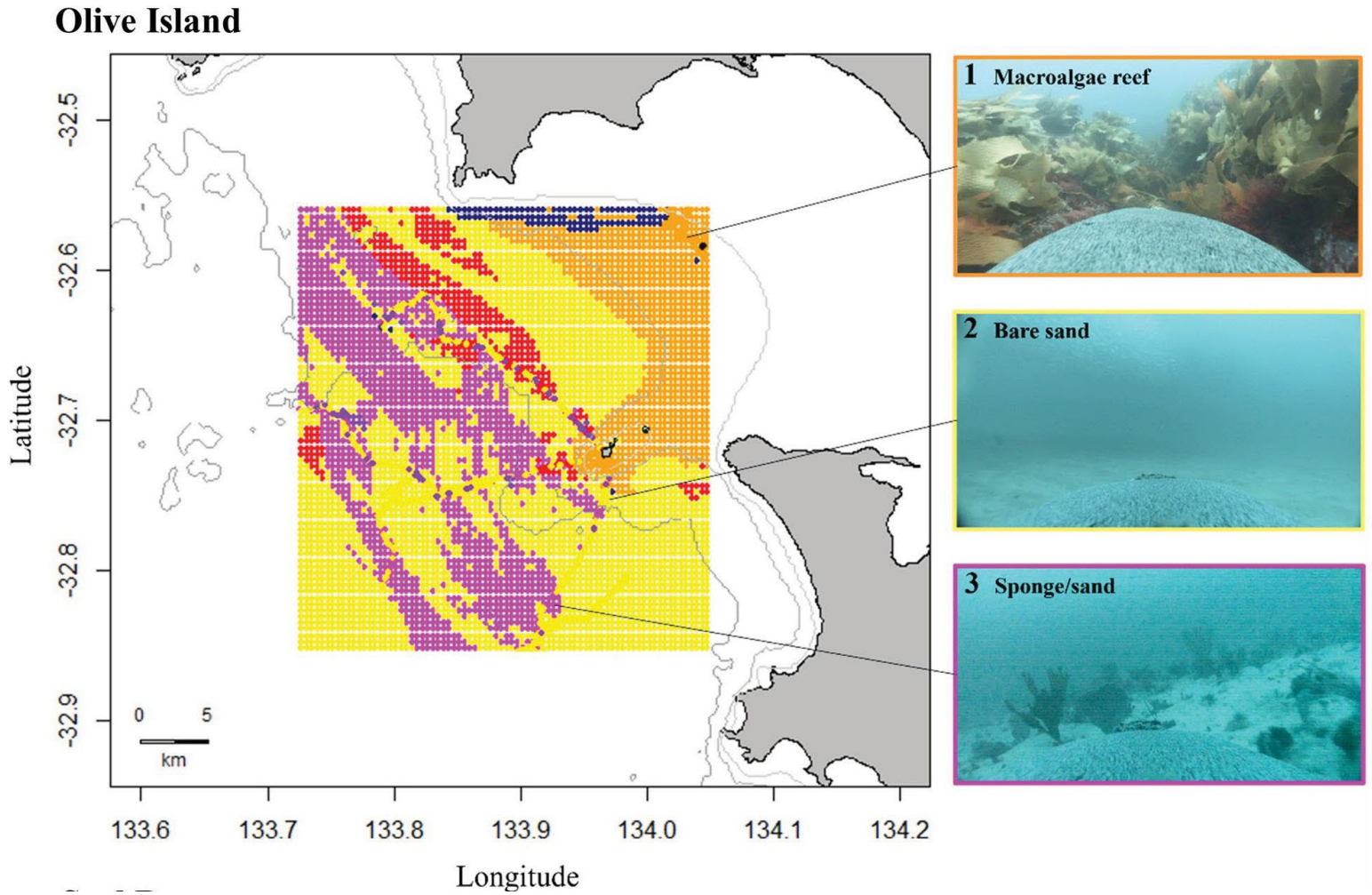
Advanced technology enables animals to collect ambient environmental data.



Ellis-Soto et *al*. 2023 *NatClimChg https://doi.org/10.1038/s41558-023-01781-7*

Animals as Sensors of the Environment: Sea Lions

Sea lions collect bathymetry and habitat information.



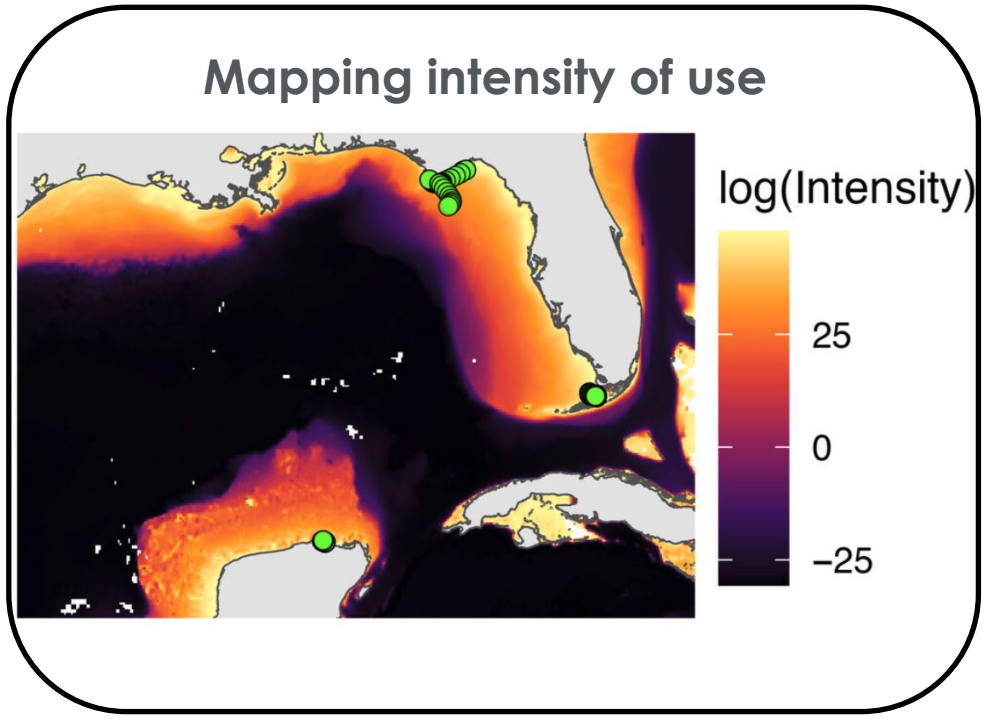
Angelakis et *al*. 2024 *FrontMarSci* https://doi.org/10.3389/fmars.2024.1425554

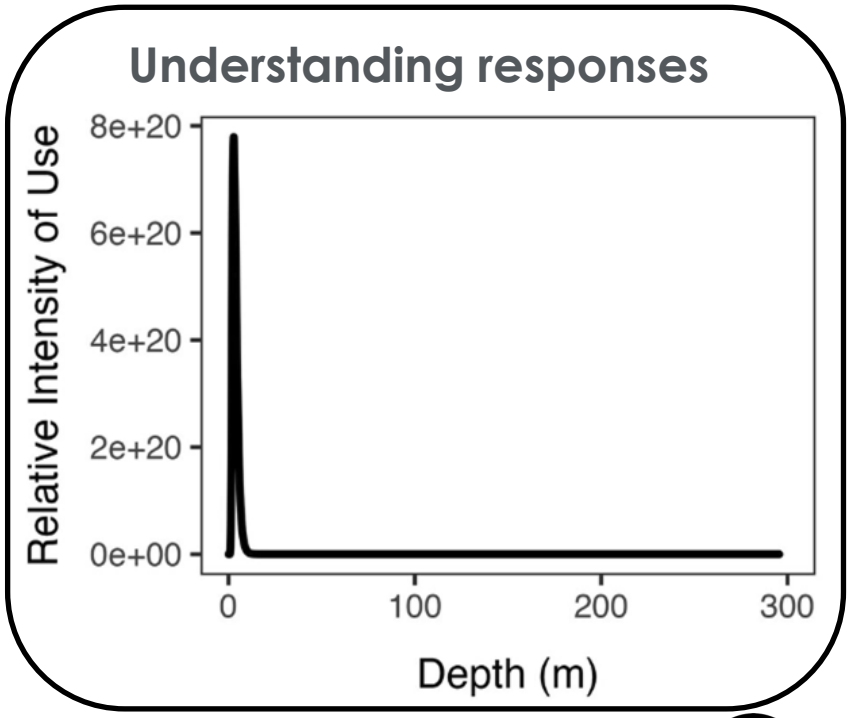
Section 2: How is Remote Sensing Related to Animal Tracking?

Understanding Animals' Habitats

- Location data from animal tracking can tell us where animals go.
- Remotely sensed environmental data can tell us what the conditions were like in those places.
- We can characterize these habitats statistically
  - Species Distribution Models
  - Step-Selection Functions

Credit: Charles J. Sharp via Wikimedia Commons

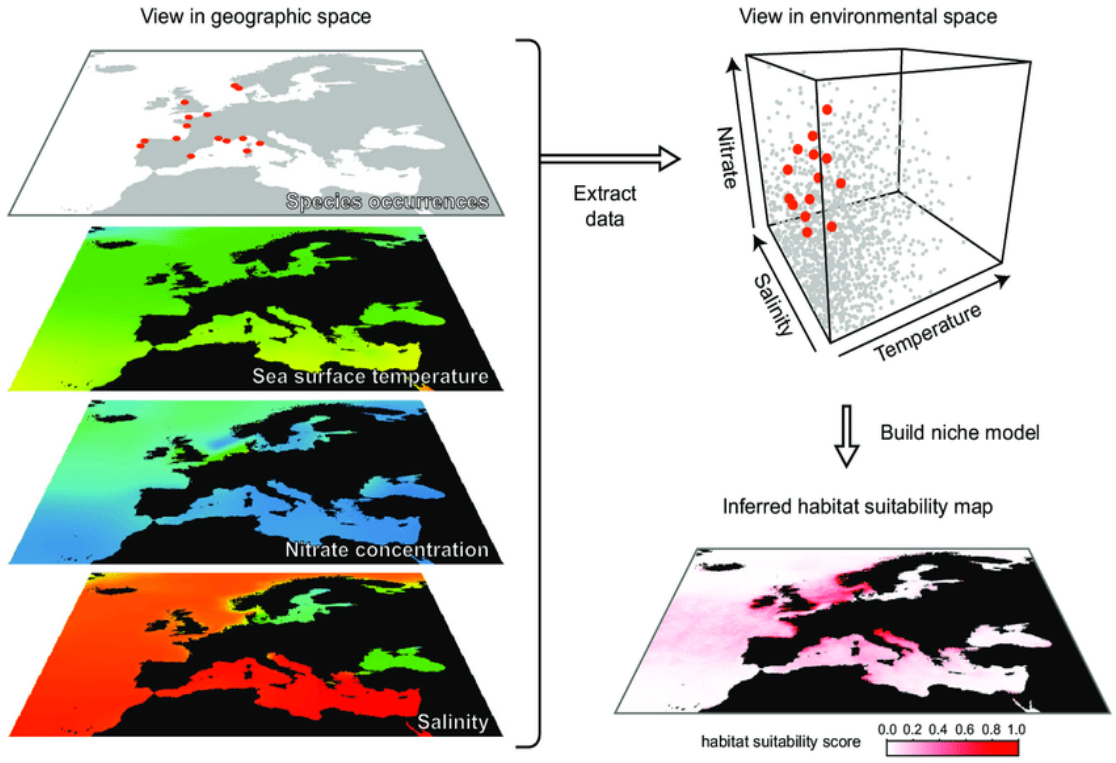




Figures from: Cullen et *al*. 2024 *Ecosphere* https://www.doi.org/10.1002/ecs2.70136

Characterizing Animals' Habitats: Species Distribution Models

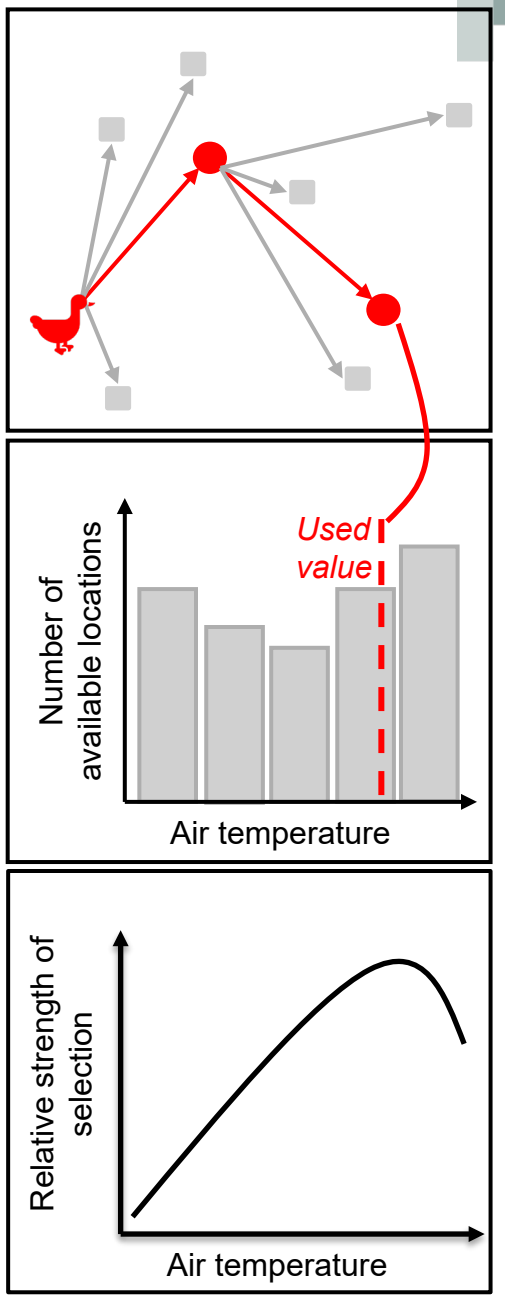
- Species Distribution Models (SDM)
  - Help us understand the likelihood of animals' presence in different habitat types.
  - Asks the question: **How did the environment differ between where the animal did and did NOT go?**
  - Result: Habitat suitability map
- Steps
  - Animal tracks
  - Define presence/absence points
  - Model
    - Binary response variable (present/absent) predicted by environmental covariates



Marcelino & Verbruggen 2015 *J. Phycol* https://www.doi.org/10.1111/jpy.12322

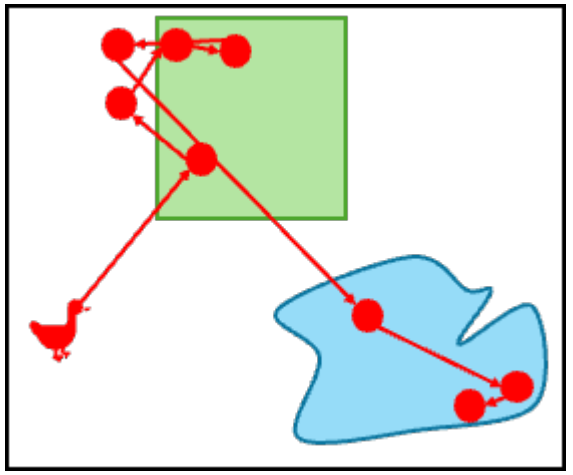
Characterizing Animals' Habitats: Step-selection Functions

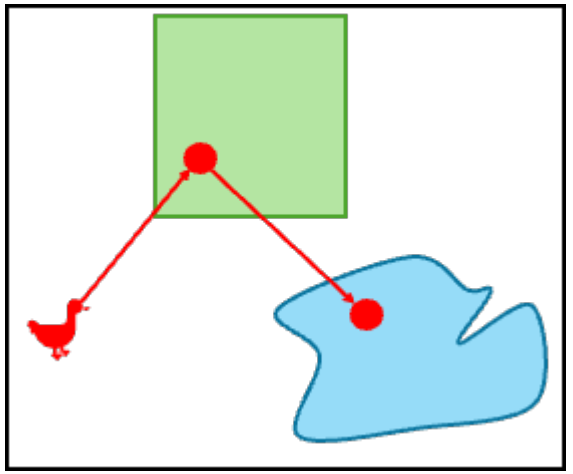
- Similar conceptually and statistically to SDMs
- Key differences
  - Specific way of defining "used" and "available" locations
  - Require regularly sampled locations
  - Analysis is at the level of an individual movement "step"
  - Remote sensing data can easily be time-matched
- Steps
  - Regularly sampled animal tracks
  - Define presence/absence points **by simulating alternative "steps" based on step lengths and turn angles**
  - Model
    - Binary response variable (case/control) predicted by environmental covariates using **conditional logistic regression**



Tracking Data

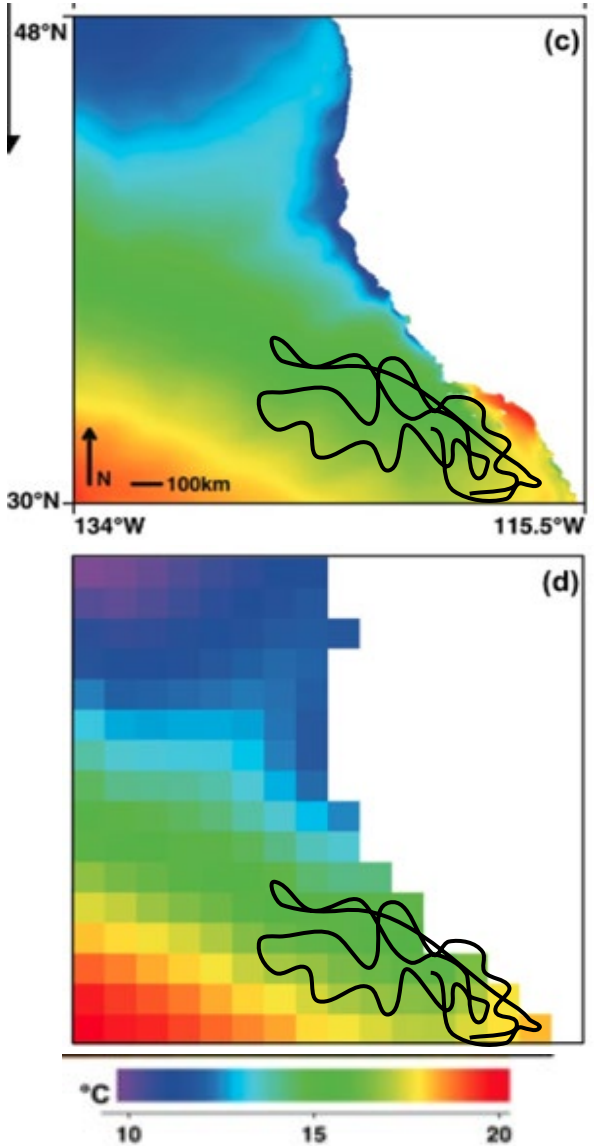
- Data must be regularly sampled
  - Within some ***tolerance***
  - Gaps are okay: analyze ***bursts***
  - Generally compatible: GPS, Argos, etc. (active)
  - Generally not compatible: MOTUS, RFID (passive)
- **Temporal resolution**: What questions can you answer?
  - Daily step: local dispersal/relocation
  - Hourly step: Function movement (foraging, etc.)
  - Minute step: Fine-scale habitat use
- Temporal and **spatial scale** are often related
  - What environmental conditions represent a *daily* location?
- **Multiple individuals** can be analyzed separately or together
  - Together: Population-level inference
  - Separately: Individual differences in habitat use





Tradeoffs When Combining Animal Tracking & Remote Sensing Data

- Mismatched spatio-temporal resolutions
  - Telemetry resolution > remote sensing resolution (satellites)
  - Remote sensing data: tradeoff between spatial and temporal resolutions
- Remote sensing often provides proxy variables:
  - Sea surface temperature → water temperature at 2 m
  - Vegetation indices → food availability
  - Air temperature → water temperature
  - etc.
- Computational power and time
  - Higher resolutions + more variables = more data



9 km resolution

111 km resolution

Scales et *al*. 2016 *Ecography* https://www.doi.org/10.1111/ecog.02272

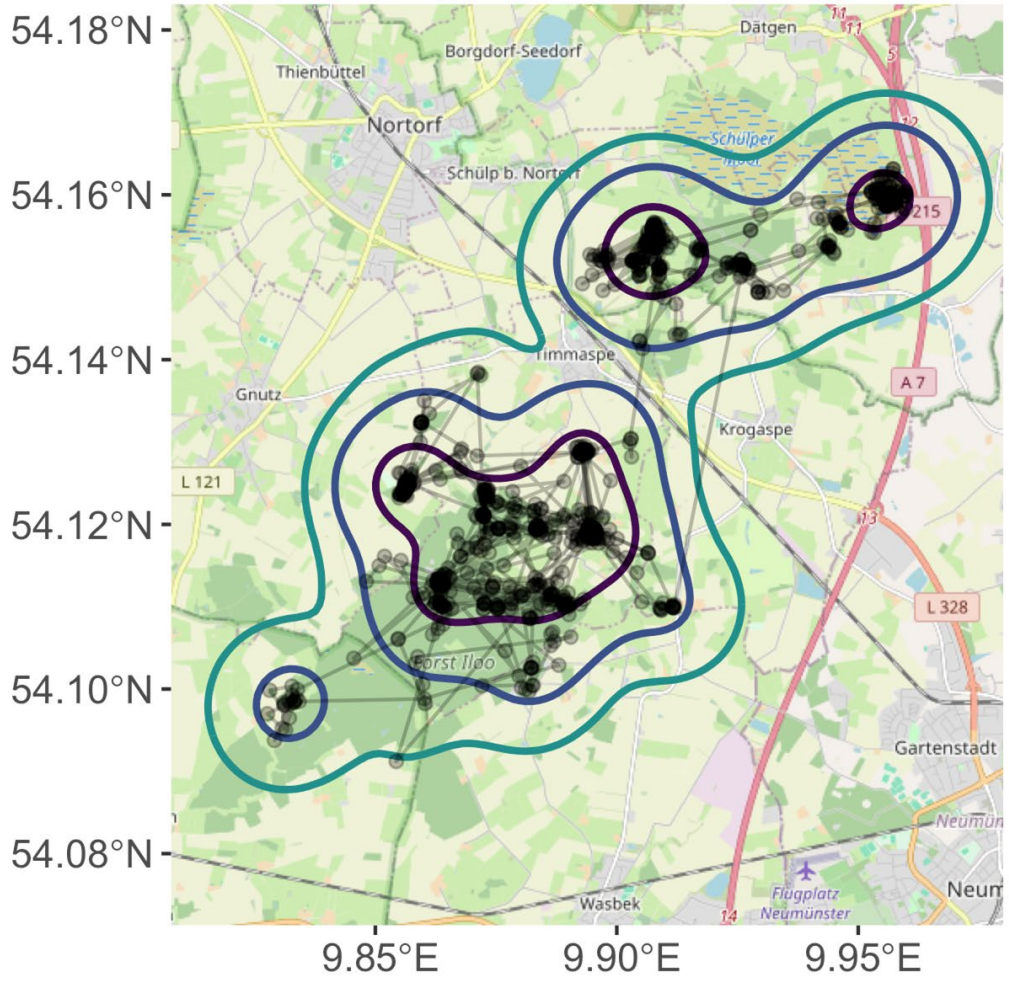
Section 3: Working with Animal Tracking Data

Working with Animal Tracking Data

Basic pre-processing steps often include:

- Clean data
  - Remove NA's and/or points with high error estimates (e.g., low Agos location class)
  - Remove erroneous points with species-specific speed threshold
  - Consider movements within context of life history stage and desired analysis
    - For example, remove migratory points if only interested in data from breeding season
- Visualize tracking data via plots
  - Allows assessment of data gaps
- Regularize track time-steps (not shown)
  - Can help smooth over short data gaps
- Quickly assess habitat use
  - Home range via utilization distributions (UD's)
    - UD: The probability that an animal occurs in a location

Calculate Home Range



Summary of Part 1

- Animal tracking techniques can help understand animal behavior and species' roles in ecosystem ecology.
- Biologging has its advantages and limitations. While it can serve to monitor specific animals for long periods of time and distances, it provides presence-only data, and size, weight, and power constraints limit the number of species that can carry tracking tags.
- NASA's Internet of Animals project integrates animal tracking observations with remote sensing data for a better understanding of ecosystem environments and how it influences the presence of diverse animal species.

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on 5/22/2025
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by 5/6/2025**

- **Certificate of Completion:**
  - Attend this live webinar (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.

Contact Information

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