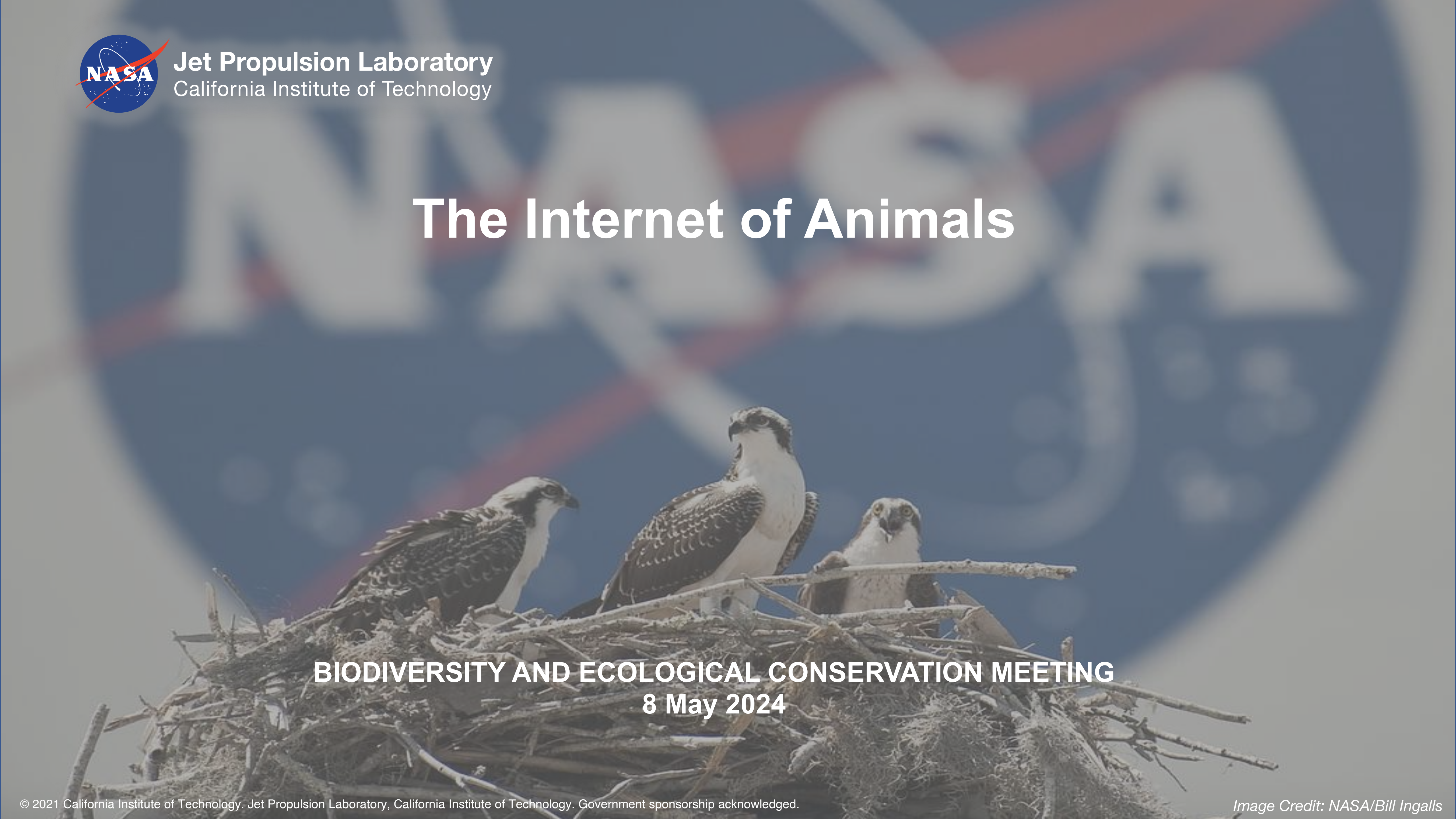


Jet Propulsion Laboratory
California Institute of Technology

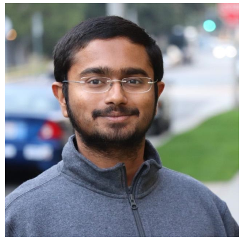
The Internet of Animals

BIODIVERSITY AND ECOLOGICAL CONSERVATION MEETING
8 May 2024

Image Credit: NASA/Bill Ingalls

Jet Propulsion Laboratory
California Institute of Technology

Ryan Pavlick
Antonio Ferraz
Darmin Arumugam
Srinivas Prasad


Ames Research Center

USGS
science for a changing world

Ian Brosnan
Susan De La Cruz
Claire Teitelbaum
Morgan Gilmour




MAX PLANCK INSTITUTE
OF ANIMAL BEHAVIOR

Martin Wikelski

Yale

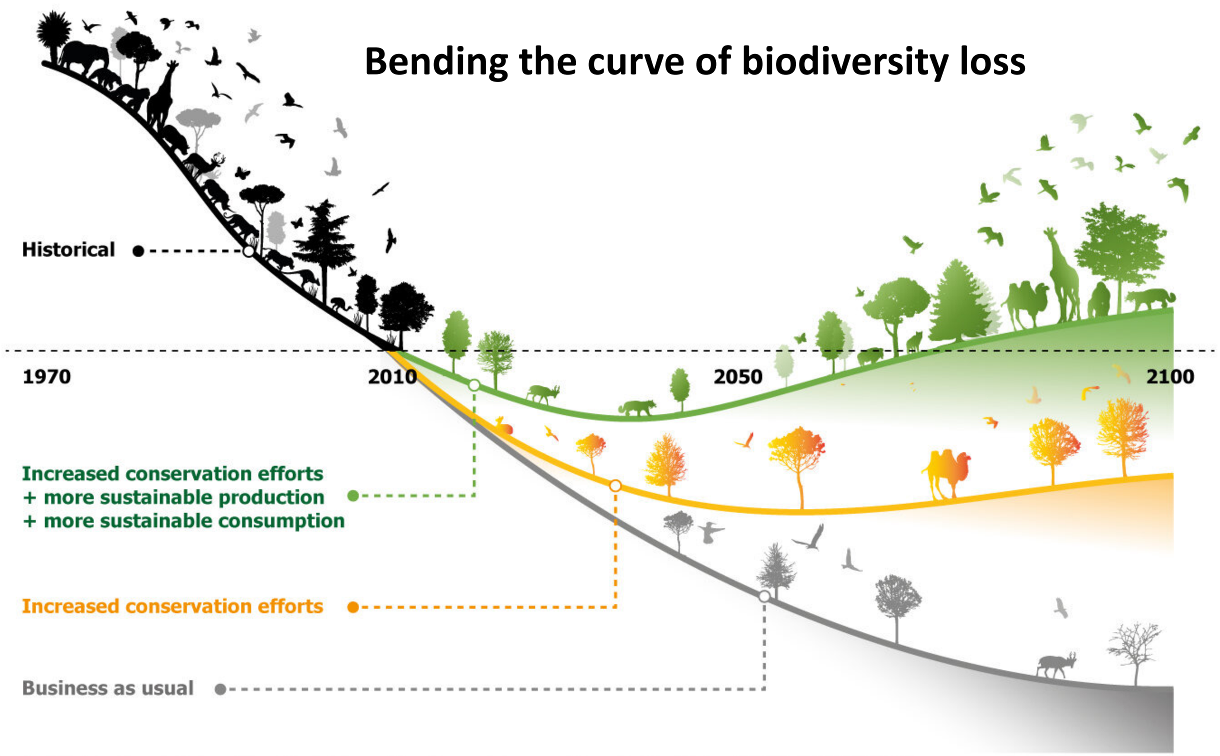
Walter Jetz
Scott Yanco
Ben Carlson

Leila Fouda
Alexander Killion
Diego Ellis Soto






Biodiversity changes rapidly



This artwork illustrates the main findings of the article, but does not intend to accurately represent its results (https://doi.org/10.1038/s41586-020-2705-y)

Leclère et al. (2020) *Nature*

Wildlife species play a critical role in the diversity, health and survival of natural ecosystems


Pest control

Nutrient cycling

Pollination

Food

Seed dispersal


and ancient and modern human societies


Food

Disease dispersal

Sensor platforms

Navigational hazards

Spiritual

Tourism


Understanding **where, when, how** animals interact with and move through/between habitats is essential to crafting successful management plans to conserve Earth's wildlife, preserve vital ecosystem services, and safeguard human well-being and livelihoods.

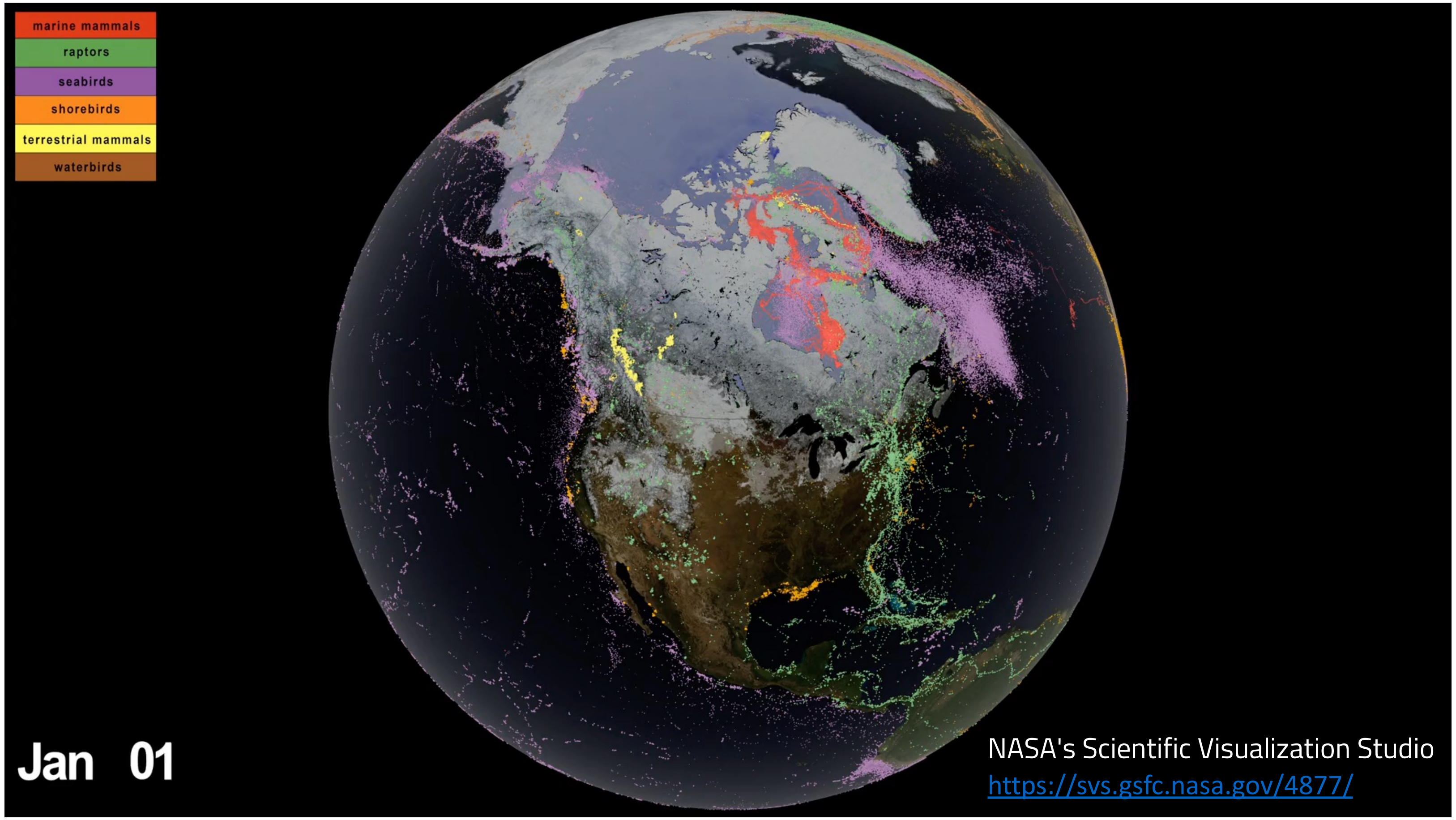
USGS science for a changing world

U.S. FISH & WILDLIFE SERVICE DEPARTMENT OF THE INTERIOR

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

The Internet of Animals

1) Understand observation needs for spaceborne animal telemetry
2) Architect a next-generation space-based animal tracking system to meet those needs
3) Integrate animal movement data with remotely sensed habitat dynamics
4) Develop science use cases



1) Understanding Observation Needs for Spaceborne Animal Telemetry

1.1) Compile a comprehensive set of animal movement **science questions and application objectives**

Workshop at Yale University

- 33 participants from academia, US federal Agencies and NGO's

Workshop website

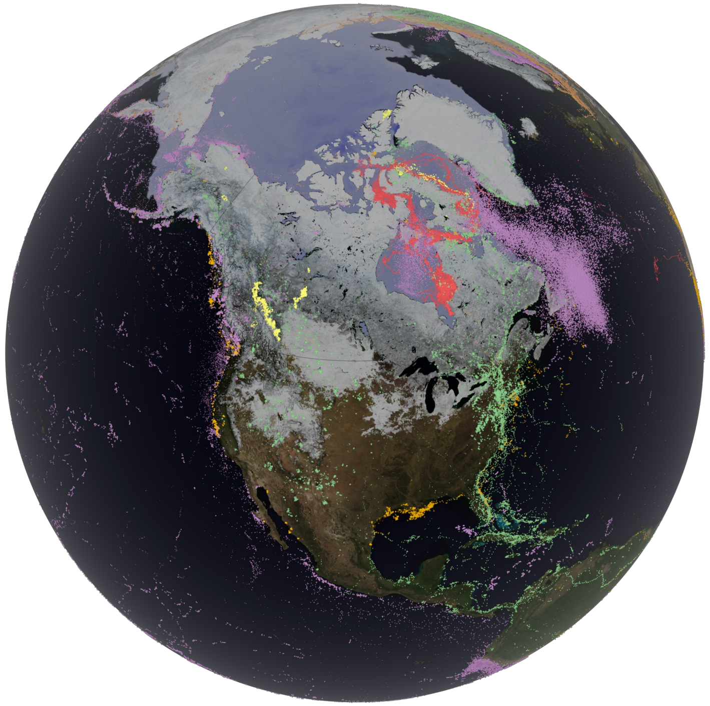


Image credit: NASA's Scientific Visualization Studio

Focus themes identified

T1: Migratory routes of small animals
T2: Sensing mortality
T3: Disease transmission
T4: Animal-borne sensors
T5: Local abundance
T6: Responses of animals to human activity
T7: Managing human-animal conflict
T8: Responses of animals to human development

Community of Practice interviews

What US Agencies use movement data to make decisions, and what are their needs

1) Understanding Observation Needs for Spaceborne Animal Telemetry

1.2) Associate each question and objective identified in 1.1) with the <u>requirements of a new observing system</u>

Observing system requirements identified by movement ecologists that are <u>not currently available</u>

Tag mass	Tag Duration	Measurements rate	Data latency	Spatial accuracy
< 1 gram	> 10 years	1 x/min	1 min	5 meters

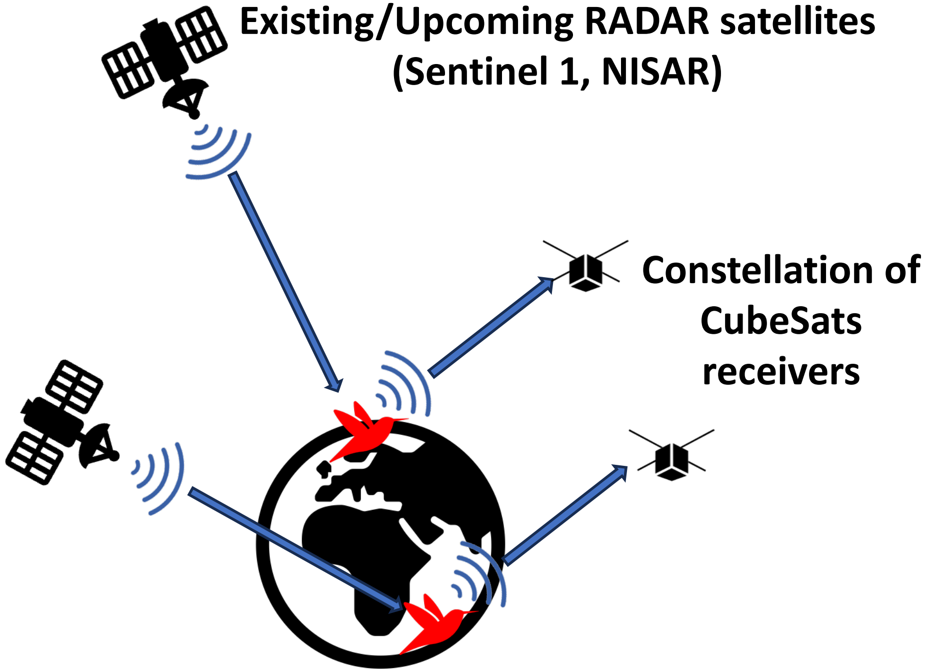
Credits image: Max Plank Institute

2) Architecting a next-generation space-based animal tracking system to meet those needs

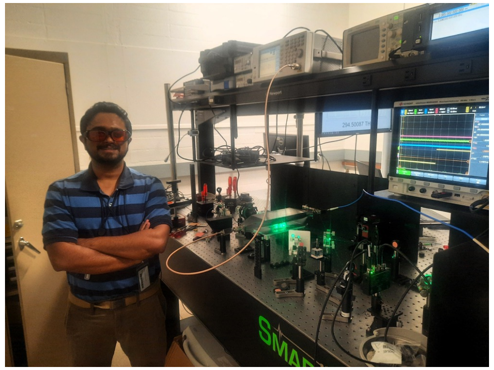
Evaluating the technical and financial feasibility of developing new spaceborne animal tracking technologies

Step 1: Exploring signals of opportunity to develop **< 1 gram** tags

Prototyping passive or semi-passive RFID tags
reflecting RADAR signals to a constellation of CubeSats receivers



RADAR Concepts and Formulation Group, NASA Jet Propulsion Laboratory



Srinivas Prasad Mysore Nagaraja
Engineer (JPL)

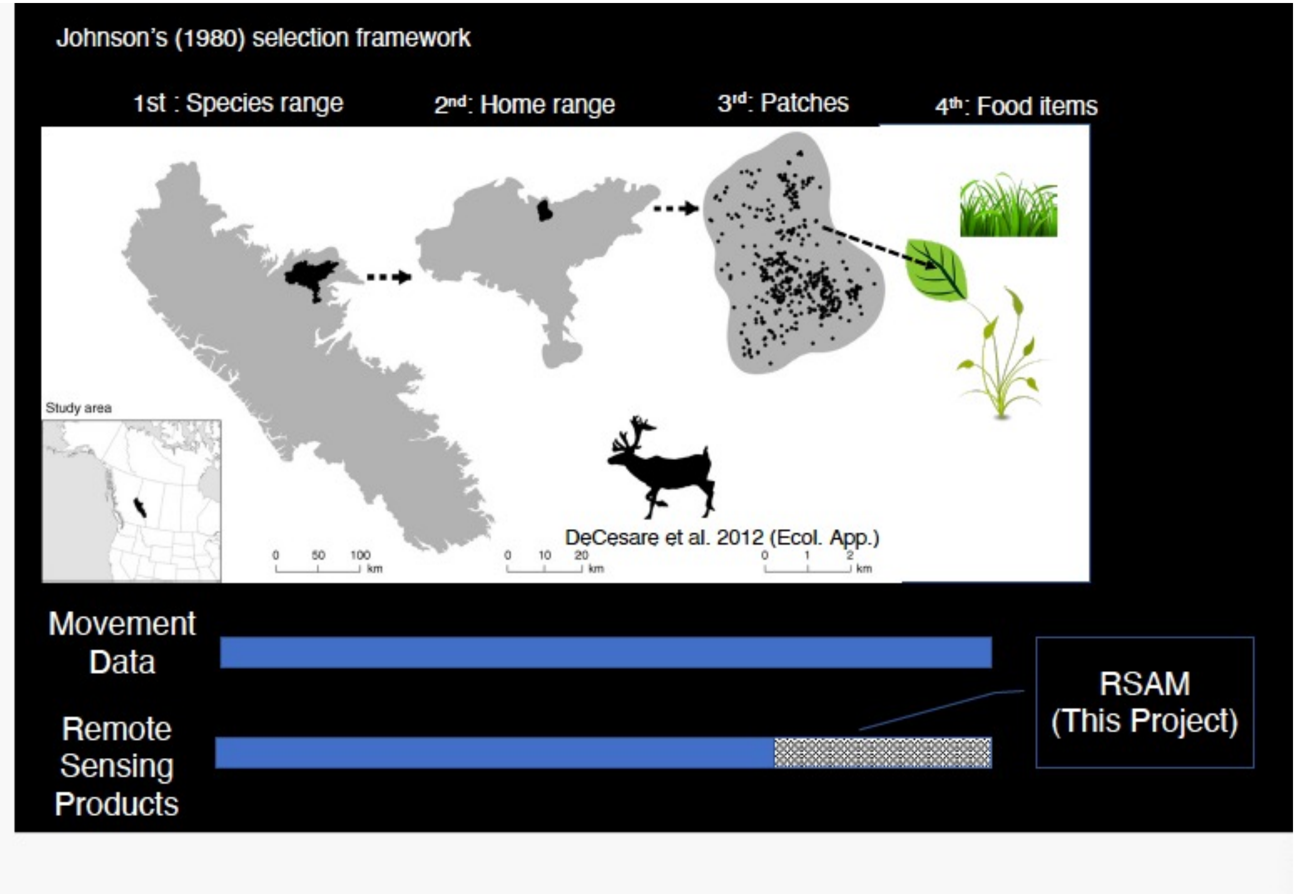
Darmindra Arumugam
Research technologist (JPL)

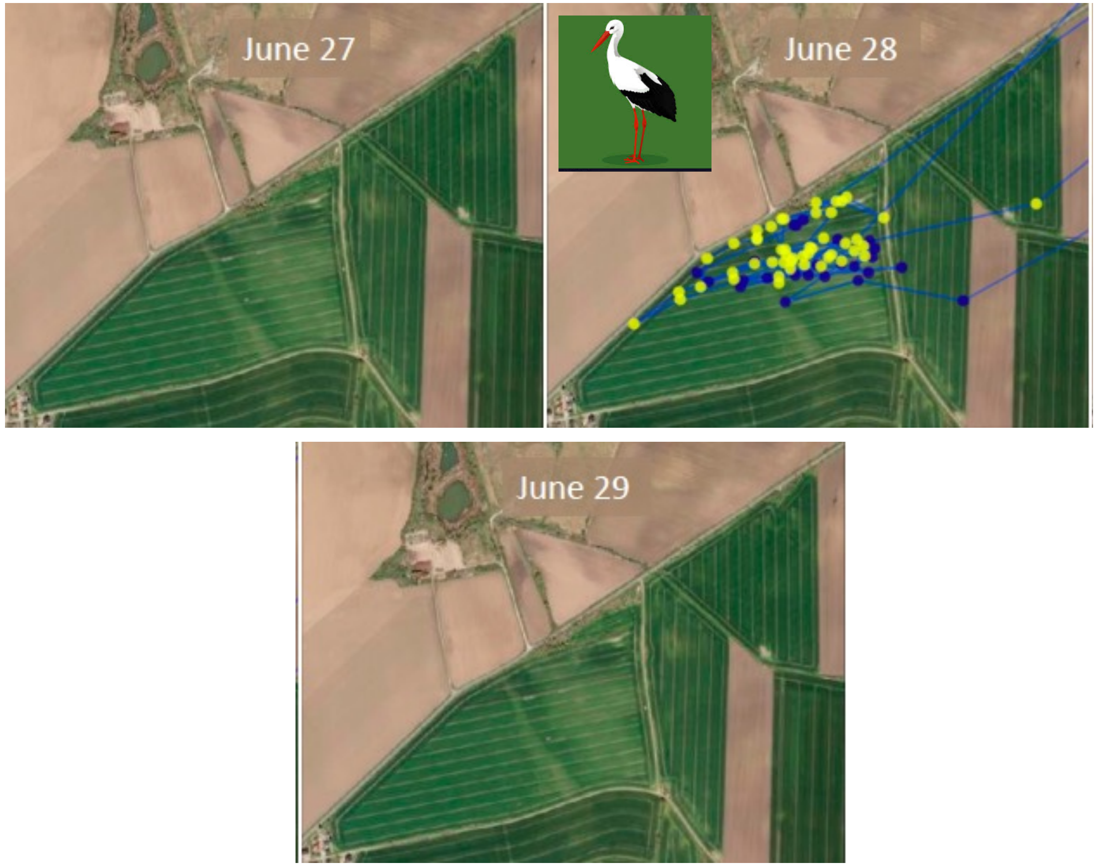
3) Remote Sensing for Animal Movement (RSAM)

Ben Carlson
Yale University

The problem: Animal movement datasets have been traditionally integrated with greenness indexes and coarse-resolution remote sensing (*e.g.* MODIS, 250 m –1 km resolution)

RSAM GOAL: stimulate the integration of advanced <u>habitat and biodiversity remote sensing</u> in movement ecology



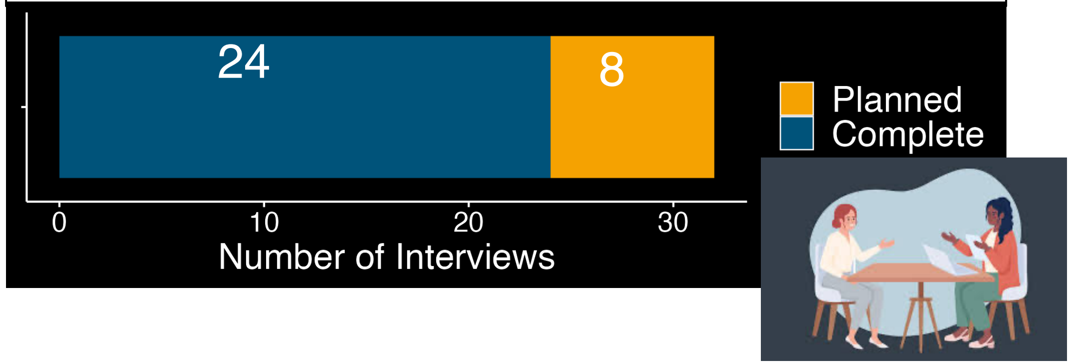


Ben Carlson
Yale University

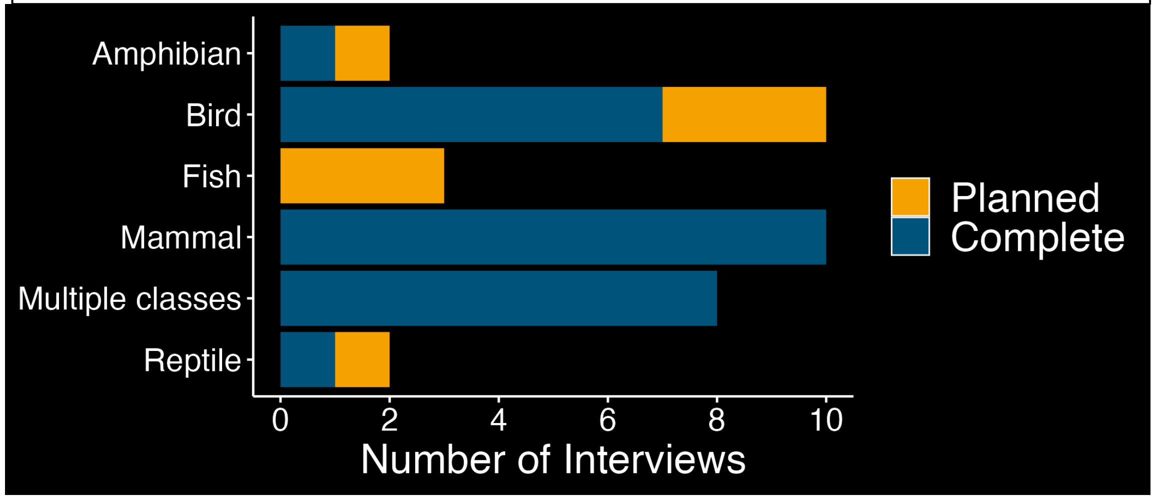
3) Remote Sensing for Animal Movement (RSAM)

a) **Requirements**. Wish list of habitat characteristics from ecologists

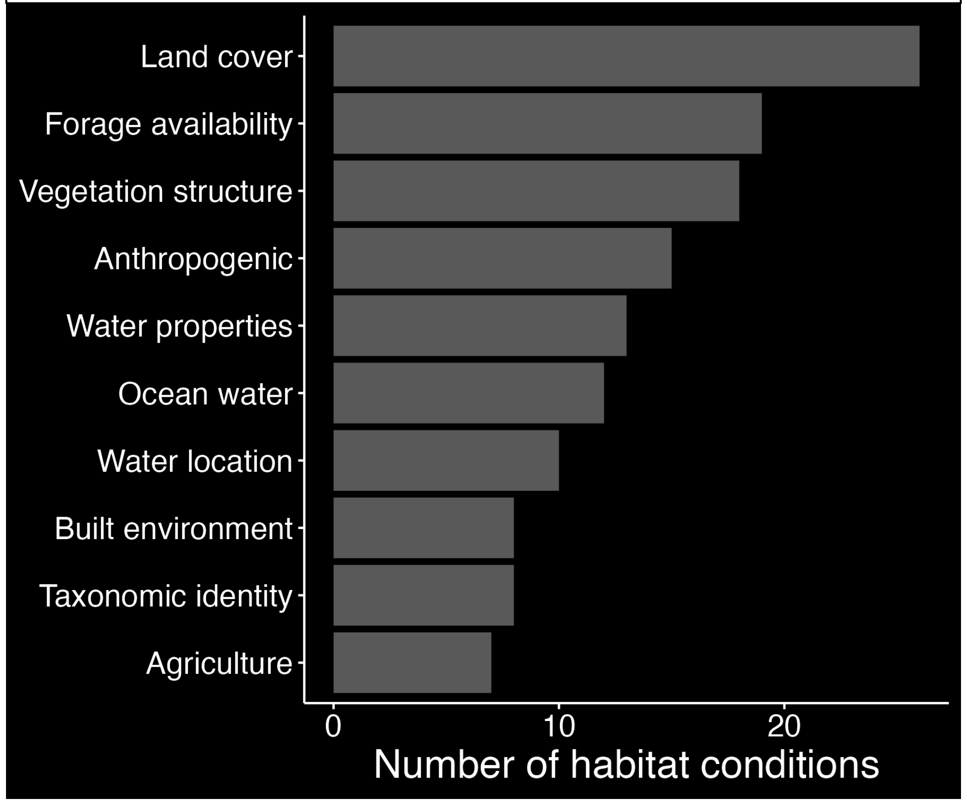
Progress: Interviews with animal ecologists



Progress by Taxon



Top 10 categories of habitats



3) Remote Sensing for Animal Movement (RSAM)

Ben Carlson
Yale University

b) Gap Analysis. What habitat requirements can be met by:

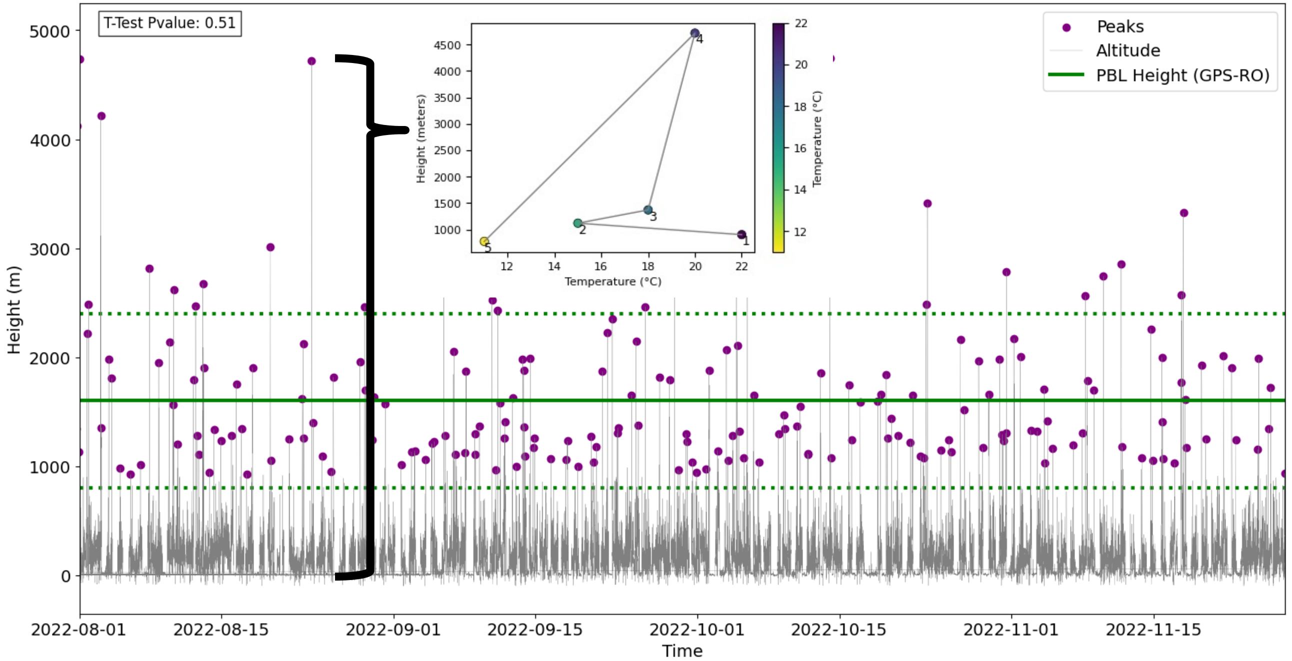
a) current remote sensing sensors
b) upcoming remote sensing sensors
c) require the design of new remote-sensing sensors

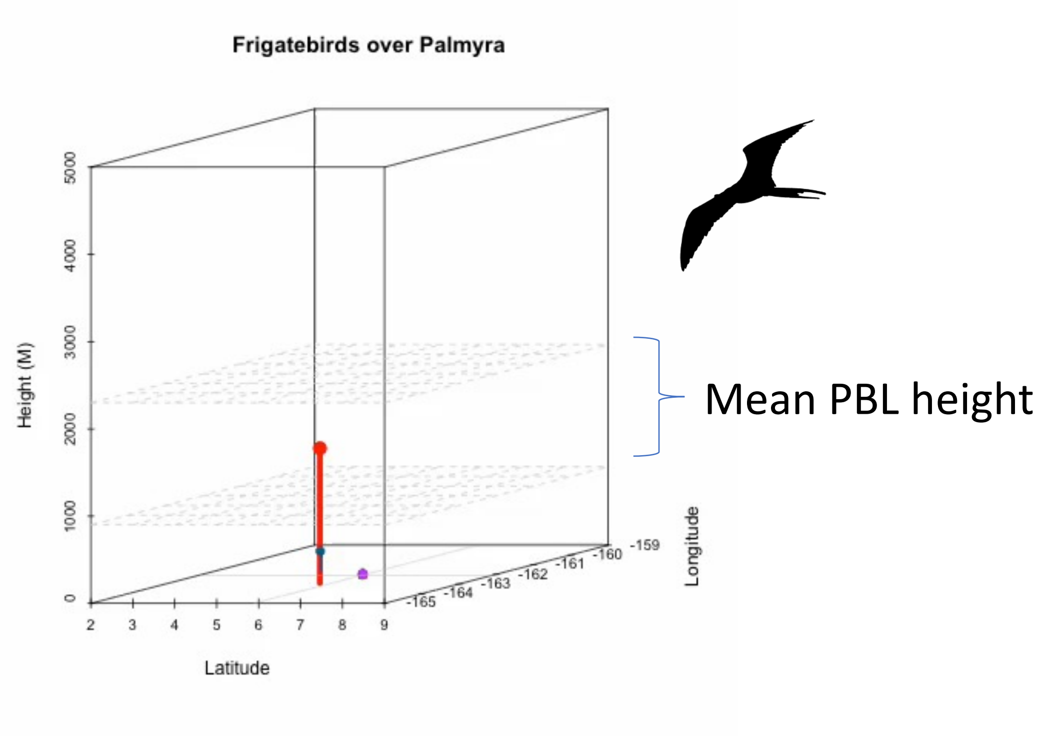
4) Science Use Cases

Morgan Gilmour
NASA AMES

Frigatebirds track the planetary boundary layer

- Telemetry tags collected altitude, geolocation & temperature data
- Great frigatebirds regularly fly up to 4,000 m in altitude. These heights track the movement of the planetary boundary layer, an important mediator of our climate





- Frigatebirds can collect in-situ meteorological data under clouds, in remote parts of the ocean, during the day and night

4) Science Use Cases

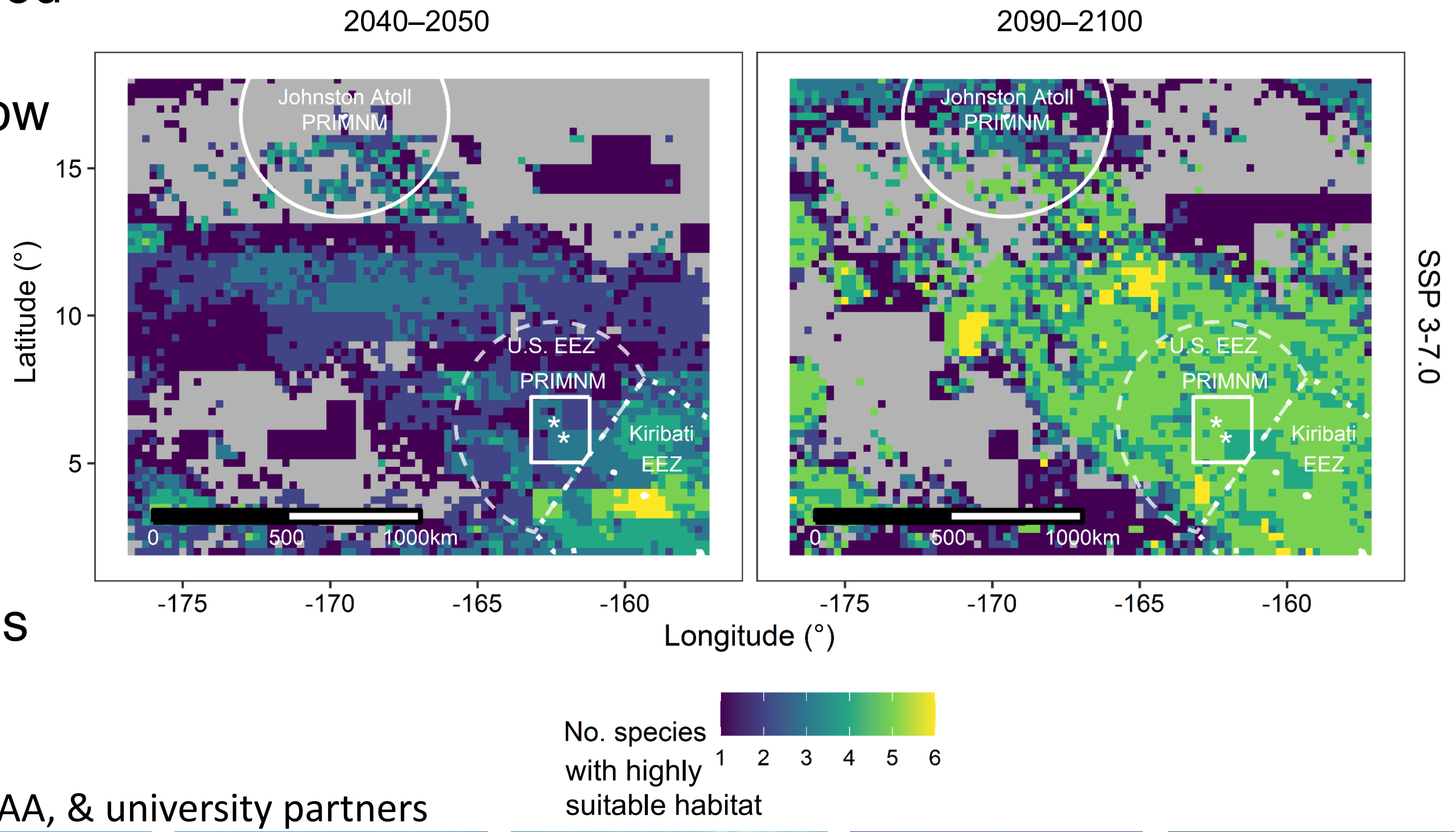
Morgan Gilmour
NASA AMES

Multi-species telemetry assesses effective MPA size

- Telemetry tags & remote sensing data used to quantify how Marine Protected Areas (MPAs) protect mobile marine animals now and under climate change scenarios

- MPA encompassed
  - 41% of species' movements
  - 73% highly suitable habitats

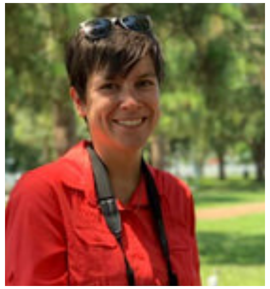
- Predicted habitat change
  - Greatest change: Reef-based species
  - Moderate changes: Pelagic species



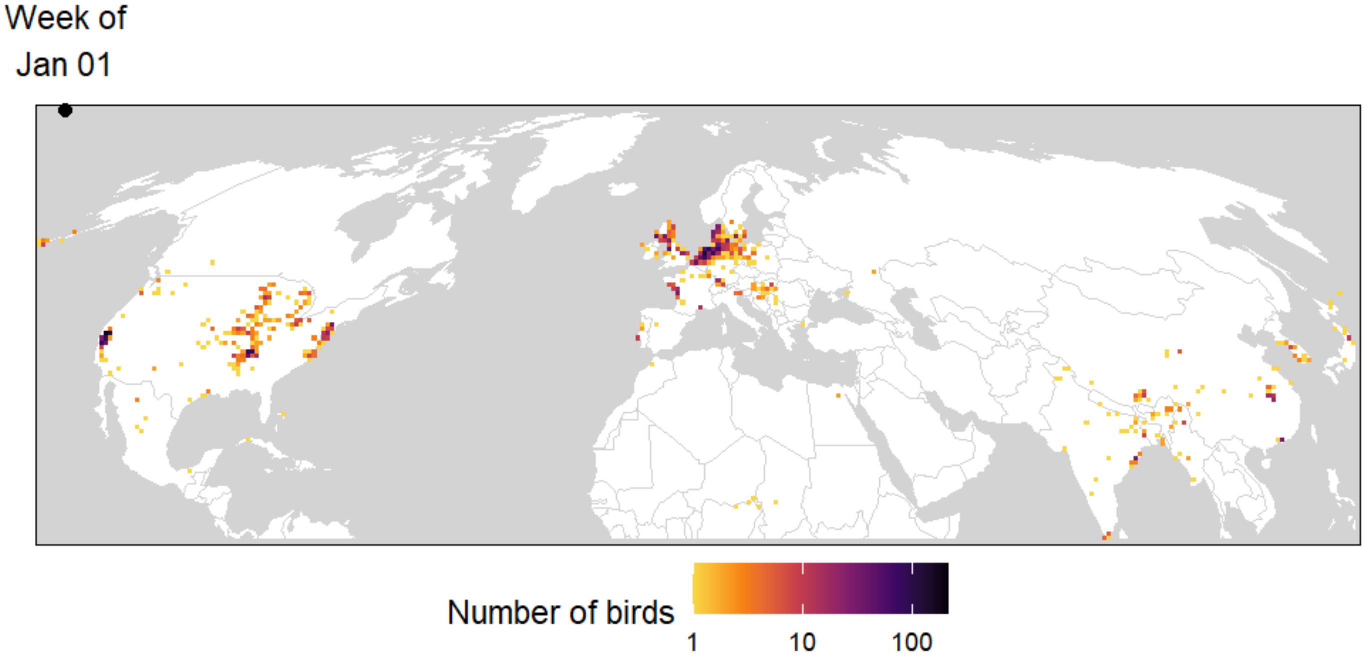
Collaborative project with: The Nature Conservancy, USGS, NOAA, & university partners

Drivers of global waterfowl movements

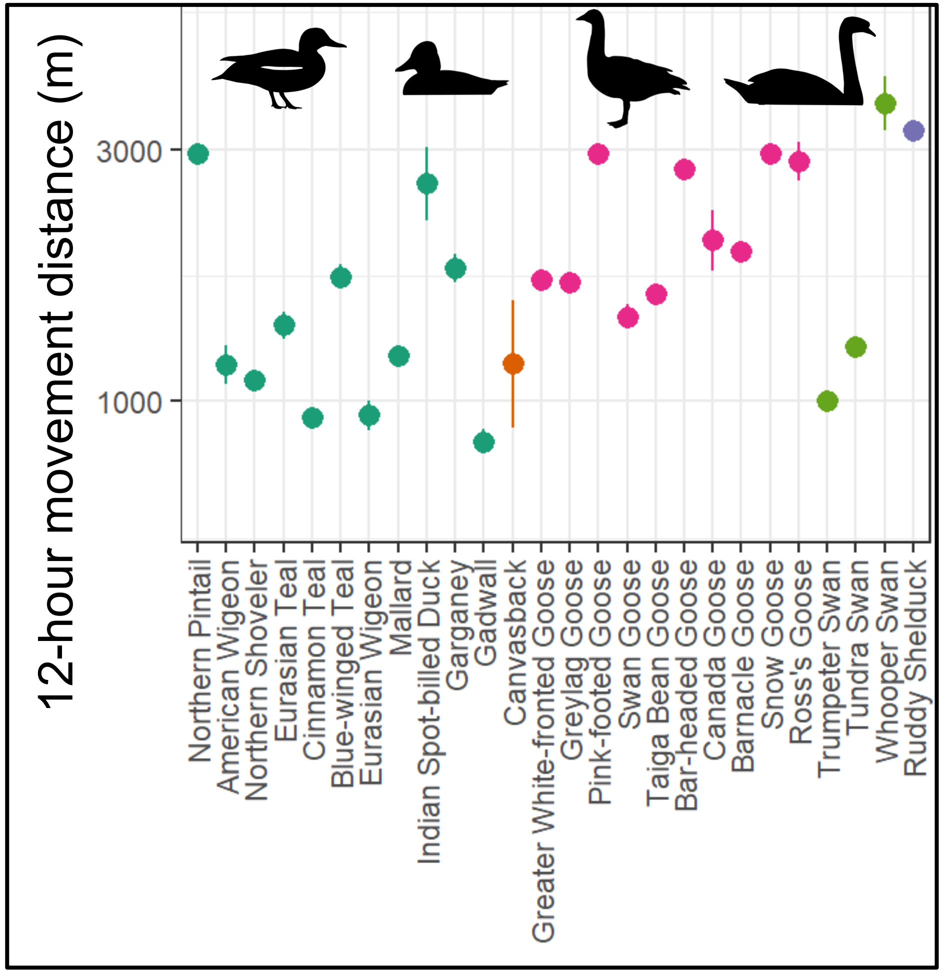
Claire Teitelbaum
NASA AMES



- Data from **26 waterfowl species** and 58 studies across the Northern Hemisphere
- Movement metrics relevant to influenza dispersal
- Environmental correlates of movement

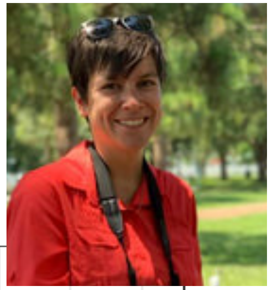


Weekly locations of tracked waterfowl compiled from >30 studies of >25 species.

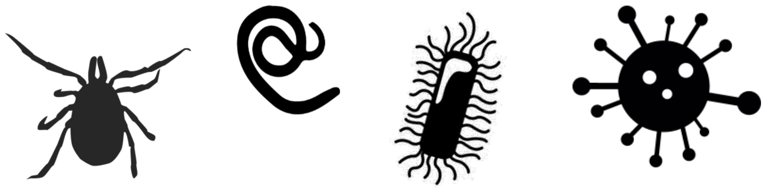


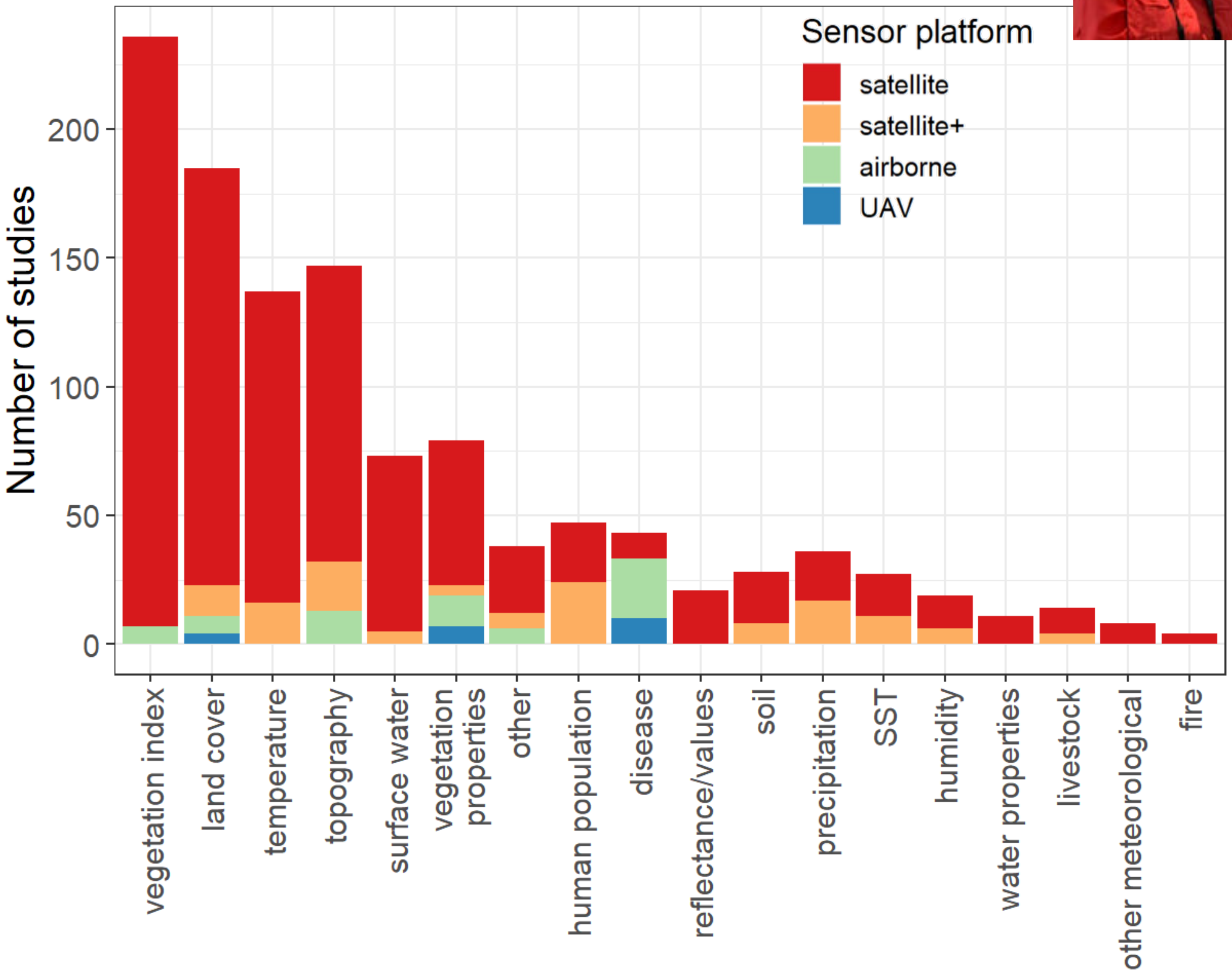
Remote sensing for disease ecology

Claire Teitelbaum
NASA AMES



- Systematic review of ~500 studies
- Catalog of remote sensing products used
- Opportunities for further integration





<u>Most common remotely sensed variables:</u>
- Vegetation indices
- Land cover
- Temperature
- Topography

…but <u>use varies across hosts and disease types</u>


THANK YOU