Movement Ecology

Project updates: Wednesday Nov 9

Written report: updated proposal, 4 items below, emailed to us by 11am

Presentation: <6 minute, 4 slides (one slide per topic)

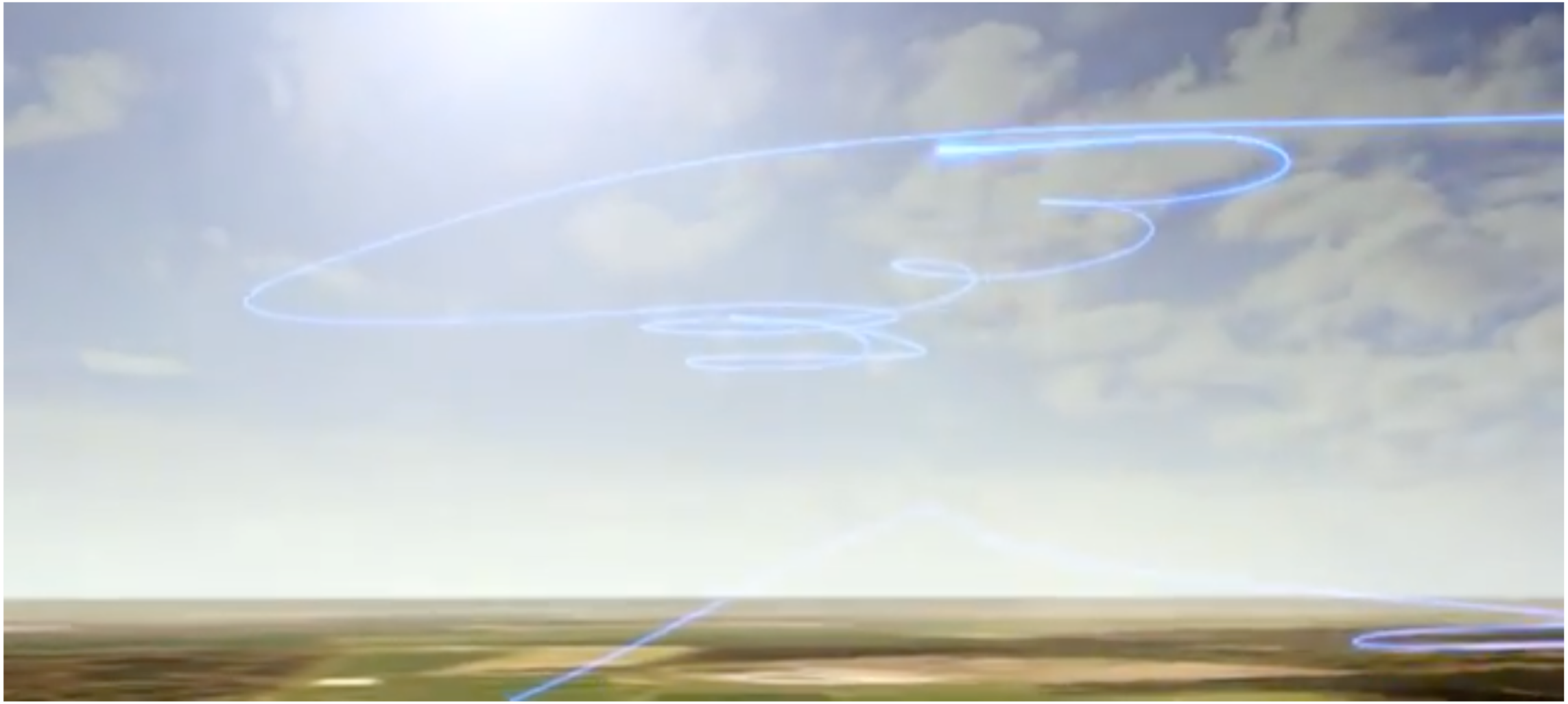
Topics:

1. statement of specific prediction(s)
2. data: sample sizes, spatial & temporal distribution/ resolution
3. justification for the analytical approach (R packages, functions)
4. progress/ current status, planned workflow

NETHERLANDS FROM ABOVE - the flight of a stork

3D flight of a solo stork as it first follows a farmer's plough before soaring upwards on a thermal

did they program a drone to follow the path of the stork's tracks and then add in the light animation?



What is movement?

- Change in spatial position over time
- Study of the movement of plants and animals is not new
- Movement is a fundamental and basic feature of life
- Includes all life at one stage or another

Why study movement?

- Critical to life, major component of fitness
- Key process in evolution, selection to facilitate (sea to land)
- Central to all questions in spatial ecology because movement is the process which brings the spatial aspect to population dynamics (the taxa are where they are because they get to move there)
- Applications such as monitoring, managing, and conserving populations, often requires an understanding of movement

Why study movement?

Critical for human life:

global warming and habitat loss & alteration are changing the environment:

1) not clear if animals and plants will be able to shift and adjust in time and

2) increasing movement of pathogens and invasive species

White Storks (*Ciconia Ciconia*) in Germany in 1822, *Pfeilstorch*

Movement Models

Parameter Estimation

statistical model of movement parameters such as speed or turtousity
(many packages)

Home Range Estimation

want to know where an animal is spending time
(adehabitatHR, ctmm)

Behavior Segmentation

what behavioral state the animal was in at each time step
(moveHMM, momentuHMM)

Path Reconstruction

how to reconstruct a path from data that are noisy?
(crawl, foieGras)

Step Selection Analyses

understand how animals make movement decisions based on the environment
(amt, adehabitatLT, others)

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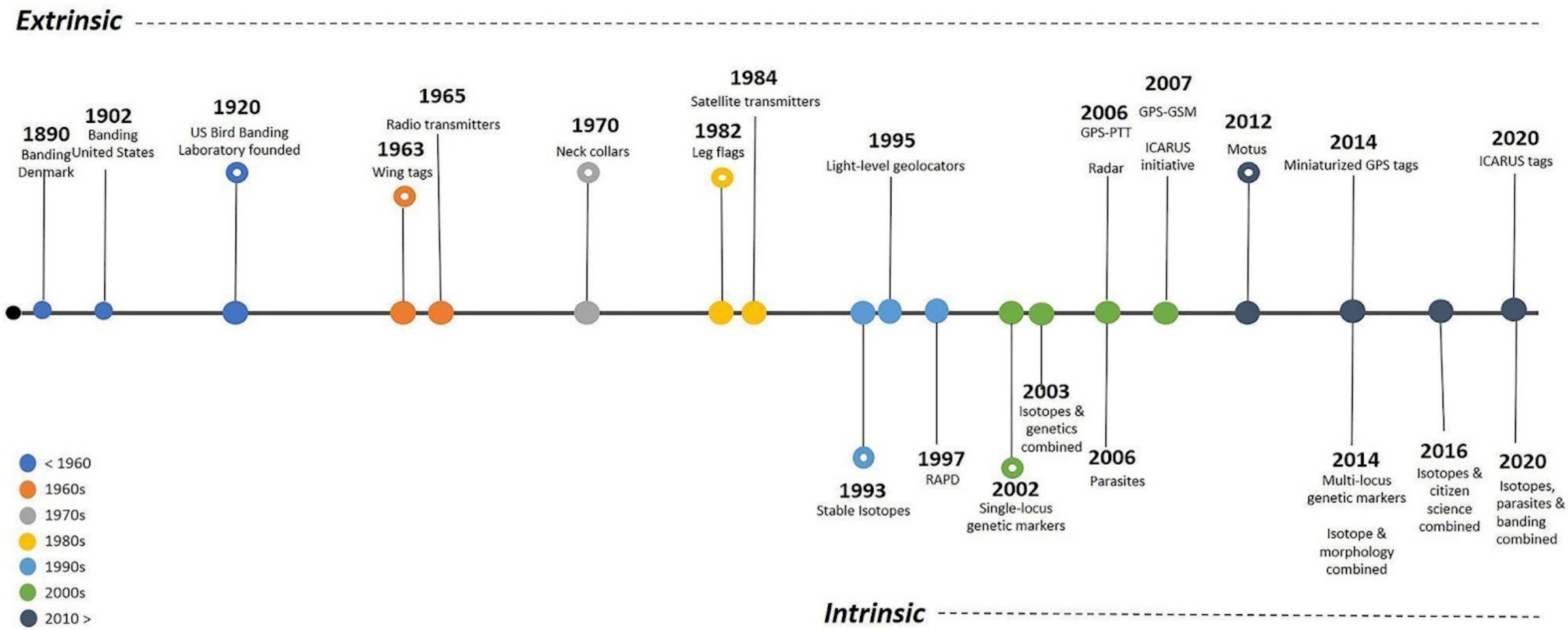
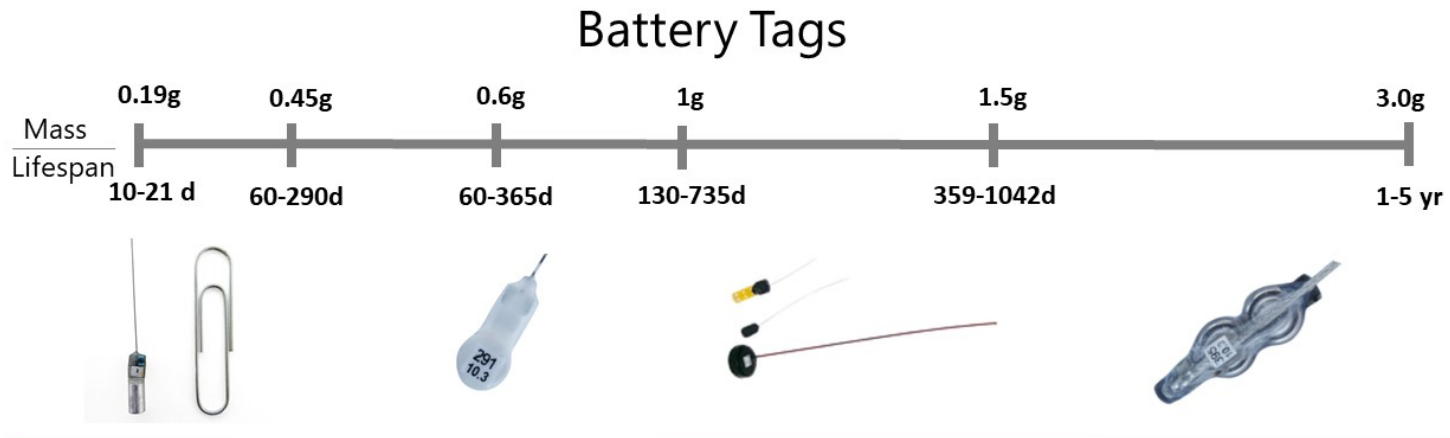
The Renaissance of Animal Tracking



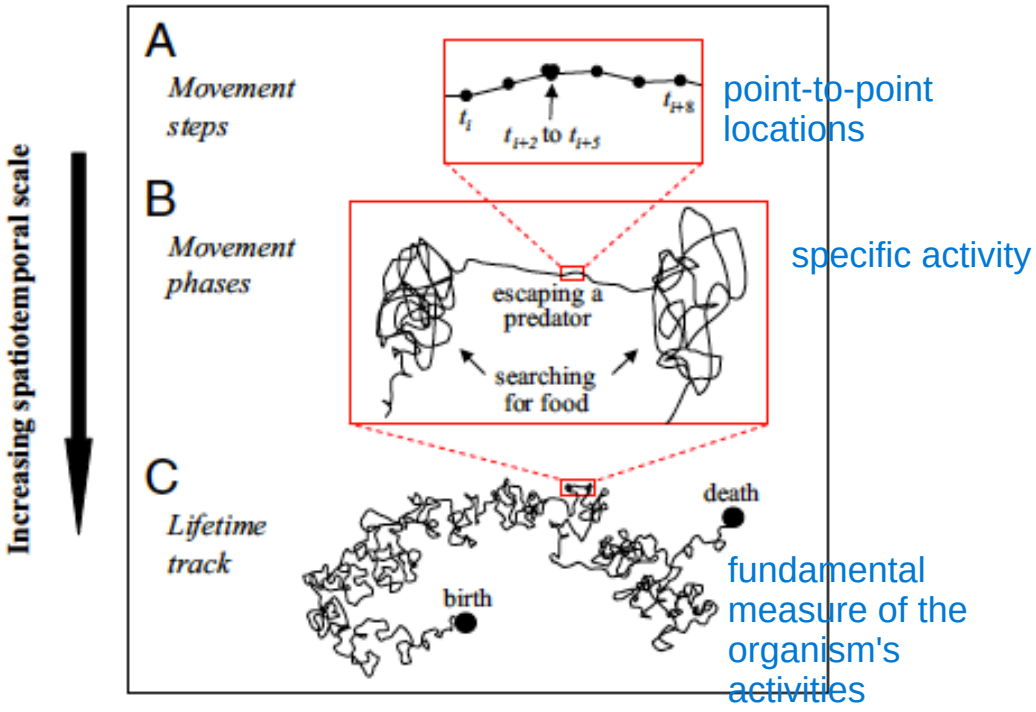
Movement Data



- Tracking in unprecedented detail and duration, paired with environmental data and over time
- Facilitate new insights into the mechanisms underlying patterns
- Promise of more data: more details, more discoveries, quicker
- Peril: hard to manage, analytics more complicated
- Challenges of big data: Volume (storage), Variety (data types), Velocity (live data), Veracity (how accurate)

Movement Ecology

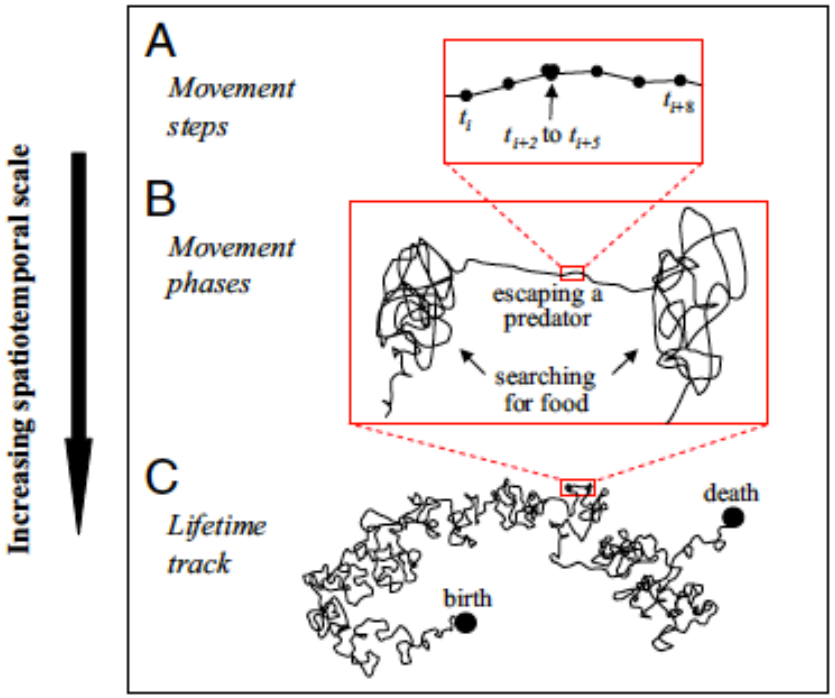
- Development of a general theory
- Emerged as a sub-discipline of ecology following technological revolution in tracking and mapping, and greater spatial awareness in community
- Understanding the patterns, causes, mechanisms, and consequences of movement phenomena



From Nathan et al. 2008
PNAS 105: 19052-19059

Movement Ecology

- Movement is done by individuals (not a population-level process), which affects the structure and dynamics of populations
- Considers the scale and phases of movement (lifetime track from birth to death broken into steps)



From Nathan et al. 2008
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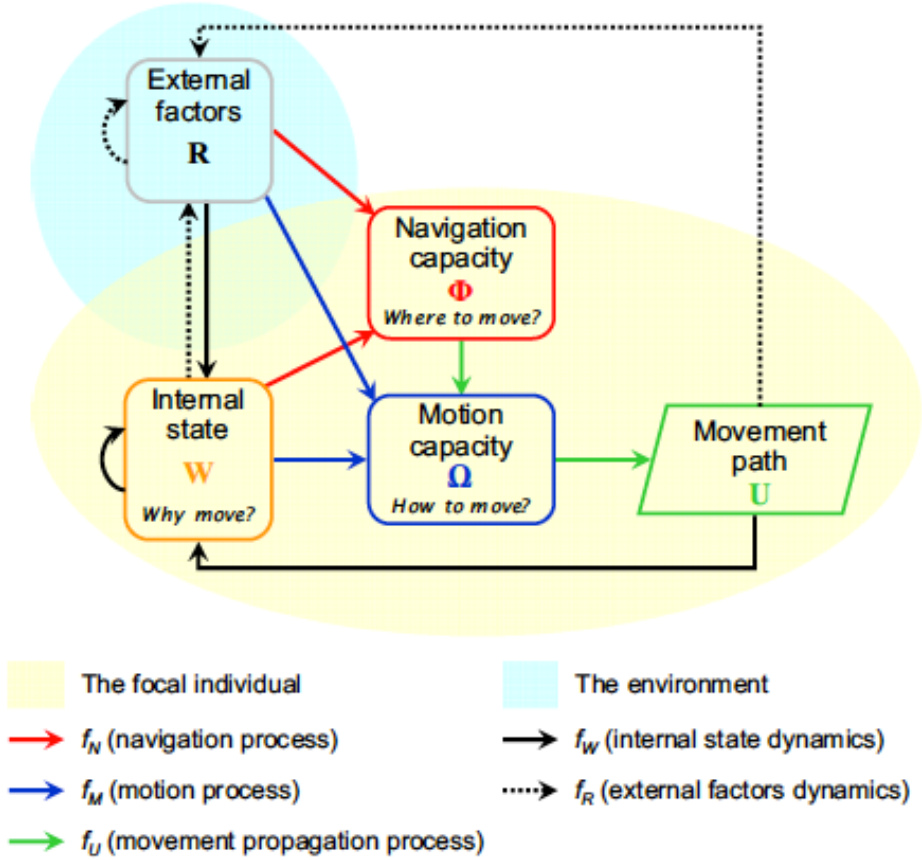
Movement Ecology

- Identify the changes in phases (segmentation into functional units) incorporating BOTH spatial and temporal dynamics
- 4 basic components can be applied to different movements (like primary colors)

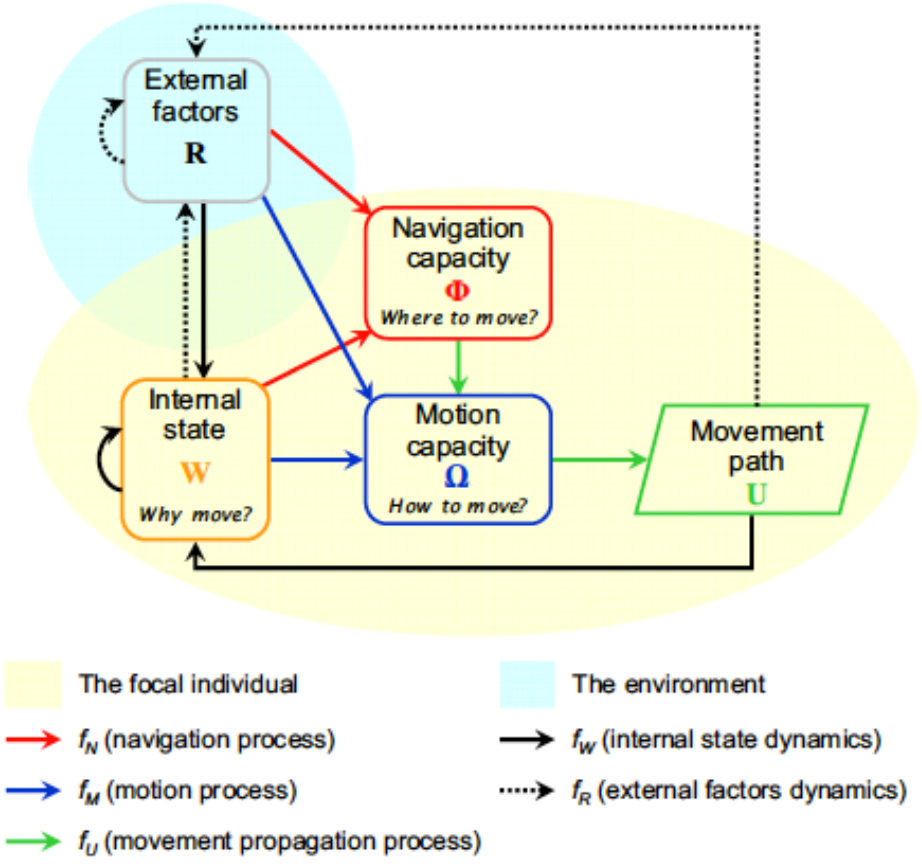


basic framework for interacting in multiple ways

From Nathan et al. 2008

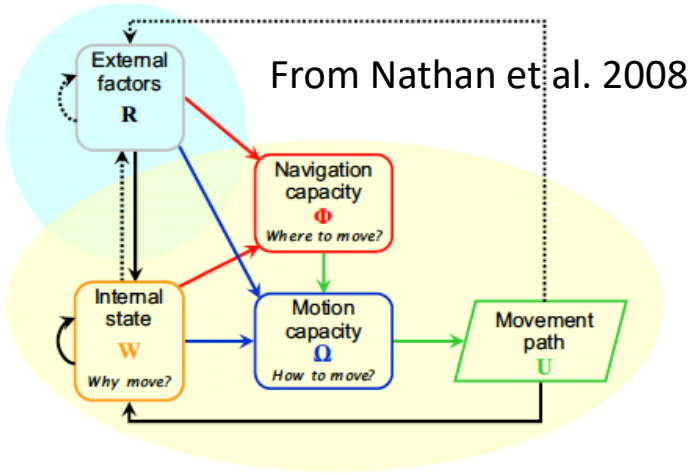
Components of Movement Ecology

- Why? Internal state– energy, physiology, mental state or motivation to move (hungry, afraid)
- How? Motion capacity - machinery, wings of birds or seeds
- When and where? Navigation mechanisms- movement is not random in space and time, need some machinery to decide when and where to move
- External factors abiotic and biotic environment
- Movement path From these 4 and feeds back to internal state that feeds into the next path
- Applies to everything from seed dispersal to bird migration, common language



From Nathan et al. 2008

Movement Fields of Study



From Nathan et al. 2008

Different ways of thinking brings together many fields

- Optimality (Foraging optimality, migration, under what conditions will an animal minimize time during migration or move away from a path, but the path itself is rarely part of the research)
- Biomechanics- motion capacity (How do seeds disperse, how horses are running, mechanical but rarely look into navigation capacity, external factors, movement path)
- Cognition (machineries of perception in the brain)
- Random path (look only on the path itself, mostly from physics, based on the movement itself, see Levy walk- see simplest possible track)

Movement Ecology in 2022

- Evolutionary Drivers of Animal Movement
- Origins of Individual Variation in Movement Strategies
- Interspecific Interactions that Motivate Movement
- Cues to Decide When and Where to Move
- Modelling Space Use: From the Individual to the Population
- Compiling Big Data to Understand the Movement Process
- Responses to a Changing Environment
- Invasions and Outbreaks

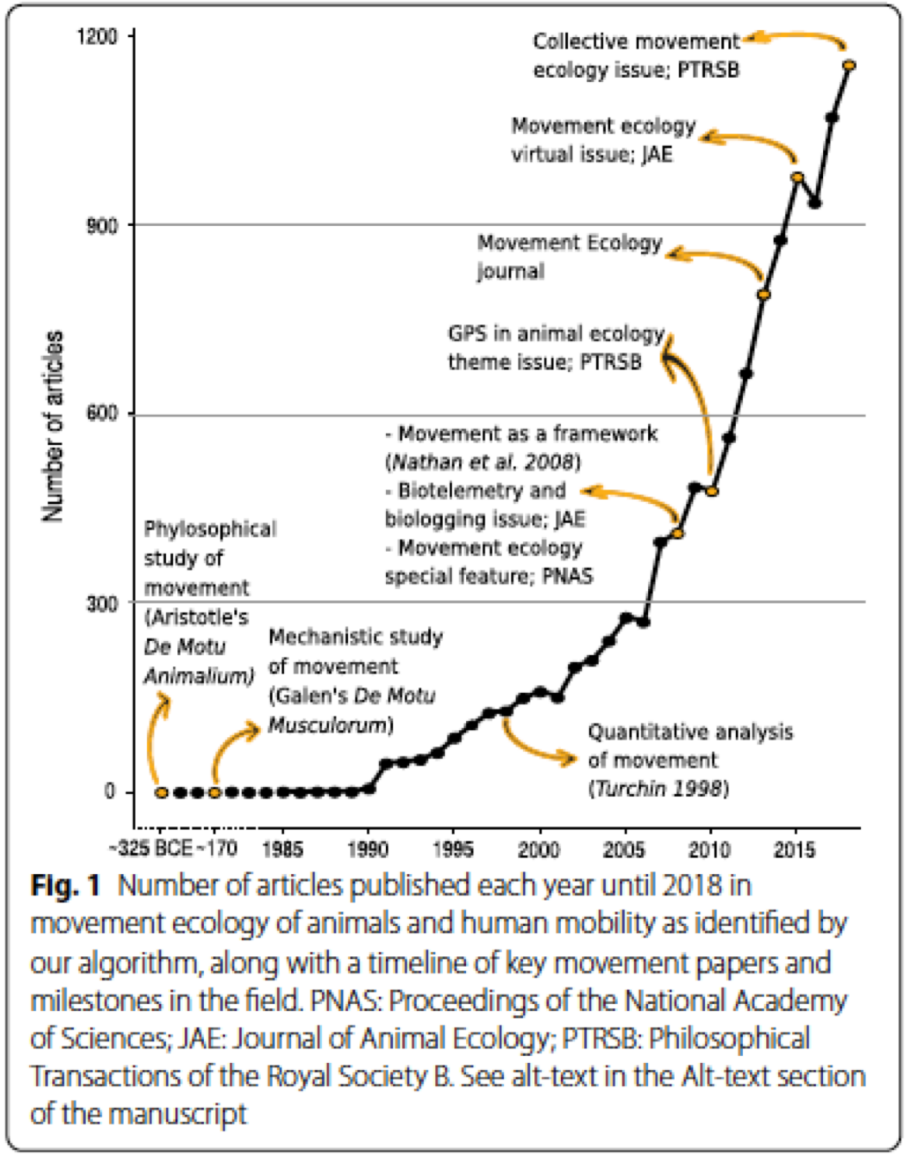
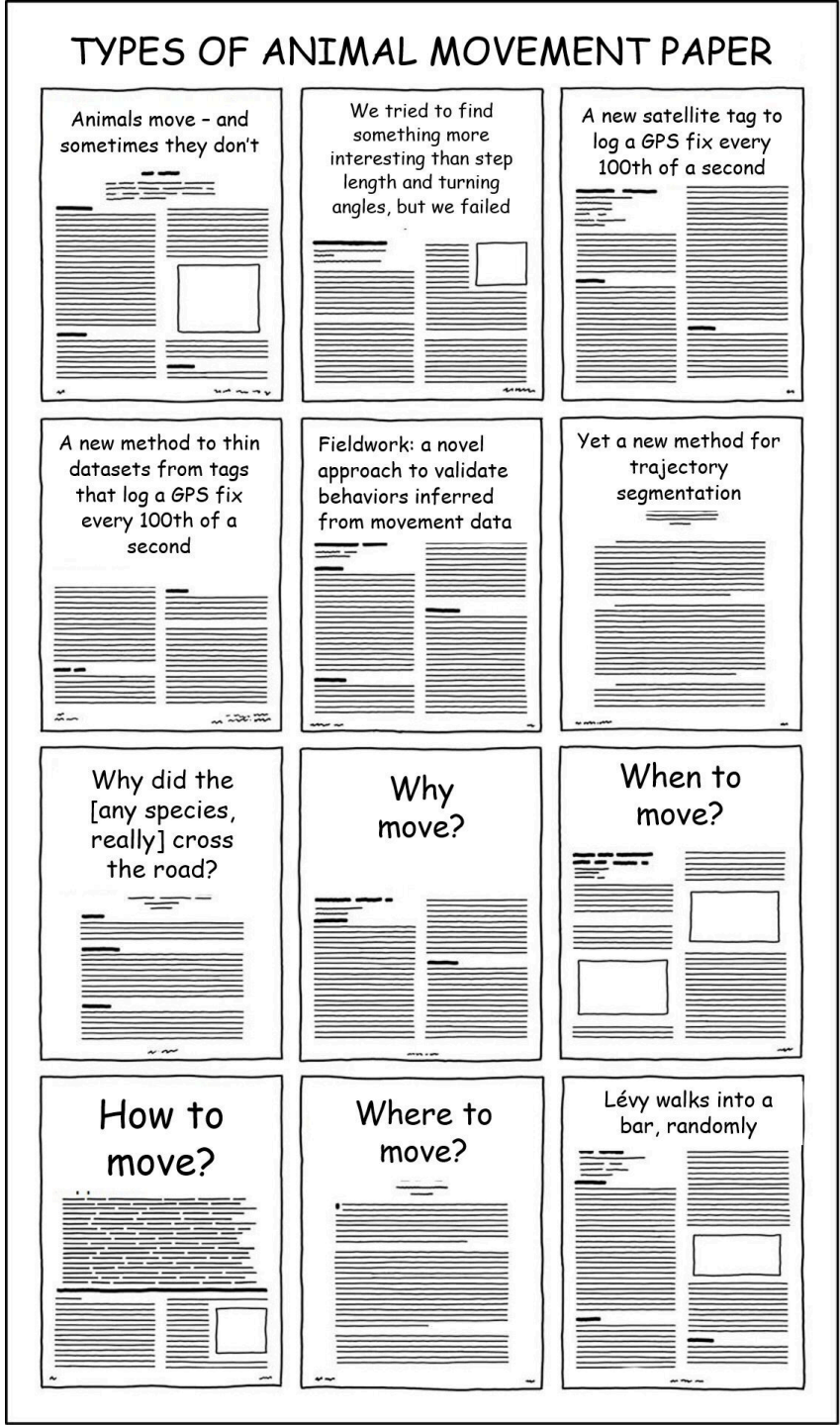


Fig. 1 Number of articles published each year until 2018 in movement ecology of animals and human mobility as identified by our algorithm, along with a timeline of key movement papers and milestones in the field. PNAS: Proceedings of the National Academy of Sciences; JAE: Journal of Animal Ecology; PTRSB: Philosophical Transactions of the Royal Society B. See alt-text in the Alt-text section of the manuscript

From Joo et al. 2022

Learning Objectives

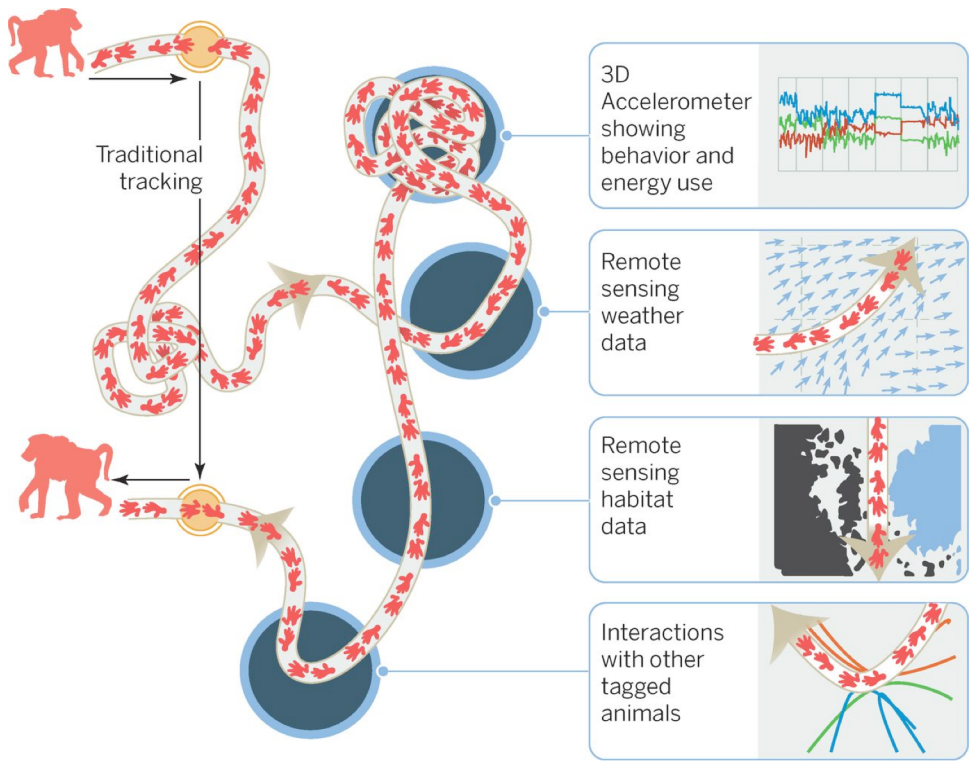
1. Describe and analyze how individuals move.
2. Calculate quantitative movement metrics.
3. Explain how the expected distance moved over time differs for correlated and biased random walks, and Lévy flight models.
4. Categorize which model best fits an animal's movement pathway.



24 hours in the life of a single gull. A GPS transmitter shows its route as it flies inland from his shoreline roost, checking out the garbage cans of urban Amsterdam before heading back out to sea and finally back to where it started.

Analyzing movement data is challenging

- Movement is influenced by a lot of things
- Movements take place at multiple scales
- The processes that influence movements take place at multiple scales
- Movement steps are not independent
- The choice of model depends on the complexity of movement

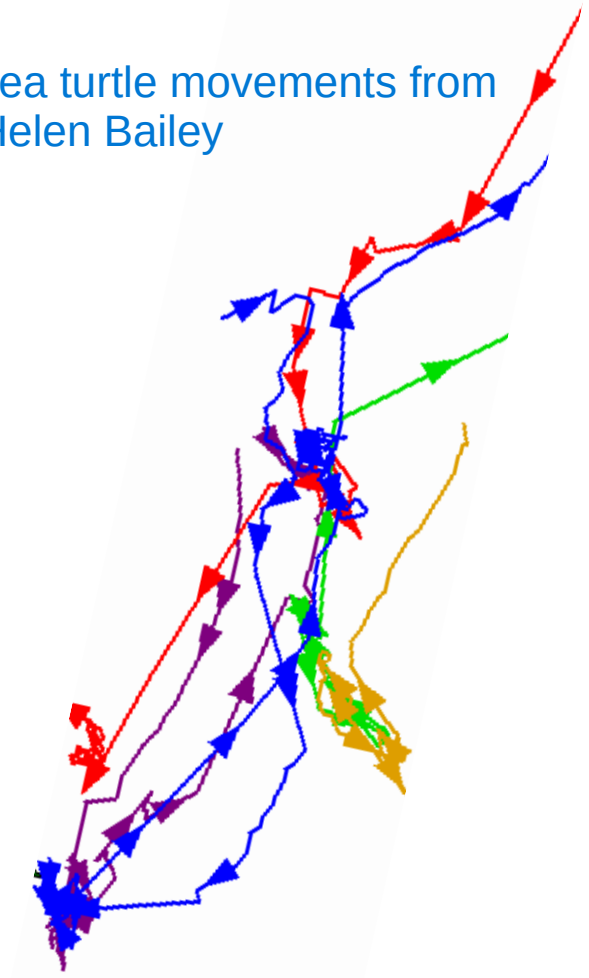


From Kays et al. 2015 Science

Characterizing Animal Movement

commonly used statistics

- Path- define characteristics of the walk
- Segment the trajectory into behavioral components (migration, foraging, mating)
- For each segment, reconstruct the distribution of displacement and turns
- Characterize the trajectory statistics by extracting parameters from a model fitting procedure (displacement distances, heading angles, turning angle)
- Brownian Walk– turning angel and step length



sea turtle movements from Helen Bailey

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BIOLOGGING: REVIEW

Journal of Animal Ecology

Navigating through the R packages for movement

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Abstract

1. The advent of miniaturized biologging devices has provided ecologists with unprecedented opportunities to record animal movement across scales, and led to the collection of ever-increasing quantities of tracking data. In parallel, sophisticated tools have been developed to process, visualize and analyse tracking data; however, many of these tools have proliferated in isolation, making it challenging for users to select the most appropriate method for the question in hand. Indeed, within the R software alone, we listed 58 packages created to deal with tracking data or 'tracking packages'.
2. Here, we reviewed and described each tracking package based on a workflow centred around tracking data (i.e. spatio-temporal locations (*x*, *y*, *t*)), broken down into three stages: pre-processing, post-processing and analysis, the latter consisting of data visualization, track description, path reconstruction, behavioural pattern identification, space use characterization, trajectory simulation and others.
3. Supporting documentation is key to render a package accessible for users. Based on a user survey, we reviewed the quality of packages' documentation and identified 11 packages with good or excellent documentation.
4. Links between packages were assessed through a network graph analysis. Although a large group of packages showed some degree of connectivity (either depending on functions or suggesting the use of another tracking package), one third of the packages worked in isolation, reflecting a fragmentation in the R movement-ecology programming community.
5. Finally, we provide recommendations for users when choosing packages, and for developers to maximize the usefulness of their contribution and strengthen the links within the programming community.

KEYWORDS
biologging, movement ecology, R project for statistical computing, spatial, tracking data

Joo et al. Movement Ecology (2022) 10:26
https://doi.org/10.1186/s40462-022-00322-9

Movement Ecology

REVIEW Open Access

Recent trends in movement ecology of animals and human mobility

Rocío Joo[1,2*], Simona Picardi[1,3], Matthew E. Boone[1], Thomas A. Clay[4,5], Samantha C. Patrick[4], Vilma S. Romero-Romero[6] and Mathieu Basille[1]

Abstract

Movement is fundamental to life, shaping population dynamics, biodiversity patterns, and ecosystem structure. In 2008, the movement ecology framework (MEF Nathan et al. in PNAS 105(49):19052–19059, 2008) introduced an integrative theory of organismal movement—linking internal state, motion capacity, and navigation capacity to external factors—which has been recognized as a milestone in the field. Since then, the study of movement experienced a technological boom, which provided massive quantities of tracking data of both animal and human movement globally and at ever finer spatio-temporal resolutions. In this work, we provide a quantitative assessment of the state of research within the MEF, focusing on animal movement, including humans and invertebrates, and excluding movement of plants and microorganisms. Using a text mining approach, we digitally scanned the contents of > 8000 papers from 2009 to 2018 available online, identified tools and methods used, and assessed linkages between all components of the MEF. Over the past decade, the publication rate has increased considerably, along with major technological changes, such as an increased use of GPS devices and accelerometers and a majority of studies now using the R software environment for statistical computing. However, animal movement research still largely focuses on the effect of environmental factors on movement, with motion and navigation continuing to receive little attention. A search of topics based on words featured in abstracts revealed a clustering of papers among marine and terrestrial realms, as well as applications and methods across taxa. We discuss the potential for technological and methodological advances in the field to lead to more integrated and interdisciplinary research and an increased exploration of key movement processes such as navigation, as well as the evolutionary, physiological, and life-history consequences of movement.

Keywords: Biologging, Movement ecology framework, Tracking technology, Text mining, Interdisciplinarity

Paper discussion: Monday Nov 7

Wright *et al. Movement Ecology* (2017) 5:3
DOI 10.1186/s40462-017-0094-0

Movement Ecology

RESEARCH Open Access

Fine-scale foraging movements by fish-eating killer whales (*Orcinus orca*) relate to the vertical distributions and escape responses of salmonid prey (*Oncorhynchus* spp.)

Brianna M. Wright[1,2,3*], John K. B. Ford[2,3], Graeme M. Ellis[3], Volker B. Deecke[4], Ari Daniel Shapiro[5], Brian C. Battaile[1,2] and Andrew W. Trites[1,2]

Abstract

Background: We sought to quantitatively describe the fine-scale foraging behavior of northern resident killer whales (*Orcinus orca*), a population of fish-eating killer whales that feeds almost exclusively on Pacific salmon (*Oncorhynchus* spp.). To reconstruct the underwater movements of these specialist predators, we deployed 34 biologging Dtags on 32 individuals and collected high-resolution, three-dimensional accelerometry and acoustic data. We used the resulting dive paths to compare killer whale foraging behavior to the distributions of different