Combining animal tracks with remote sensing data about our planet

Program and Abstracts

May 5–8 2014
North Carolina Museum of Natural Sciences
Raleigh, North Carolina

amovee2014.com

Organized with support and cooperation from **NASA**, **Movebank**, the **Max Plank Institute for Ornithology**, **The Ohio State University**, **North Carolina State University**, the **North Carolina Museum of Natural Sciences**, the **Minerva Center for Movement Ecology** and the journal **Movement Ecology**

Legend

- **NC Museum of Natural Sciences**
  - 1 Main Building
  - 2 Nature Research Center
- **Bus Parking**
- **Bus Drop-off**
- **Automobile Parking**
- **Bicentennial Plaza**
- **State Capitol**
- **Legislative Building**

The Museum is located in downtown Raleigh, between the State Capitol and the Legislative Building, at 11 West Jones Street. The main entrance faces the Bicentennial Plaza pedestrian mall linking Jones and Edenton Streets.

For more information visit naturalsciences.org/visitor-info

Getting to and from the airport: The airport bus (Bus 100) costs $2 and runs every 30–60 minutes from 6:00–21:40. More information at www.gotriangle.org/transit/service-to-airport

NORTH CAROLINA
Museum of Natural Sciences
11 West Jones Street • Raleigh, NC 27601
919.707.9800 • 1.877.4NATSCI toll free
naturalsciences.org

Welcome to Raleigh! The symposium will be held on the 4th floor of the Nature Research Center building of the North Carolina Museum of Natural Sciences. Talks will be held in the Environmental Conference Center, divided into two rooms: the Pecan Hickory Room (larger room) and the Red Oak Room (smaller room).

Events

In addition to the presentation and tutorial sessions, there are several other events you won't want to miss.

Monday, May 5

6:00–9:00 PM: Join us for a light dinner and drinks at the **Welcome Reception** on the 1st floor of the Nature Research Center. Also, watch the **Animal Movement Visualization Competition** and vote for your favorite!

Tuesday, May 6

3:00–6:00 PM: The **Poster Session** and **Happy Hour** (5:00–6:00) will take place in the 4th floor lobby.

6:30 PM on: Chat with old and new colleagues and enjoy one of Raleigh's many great restaurants by joining **Dine Around Raleigh**. Sign up at http://bit.ly/1hwcg25.

Thursday, May 8

All day: Join the **Collaborative Working Groups** on comparing movement modeling frameworks (morning) and cross-site comparison of fisher habitat use (afternoon).

Ongoing

Throughout the meeting, explore the rest of the 4th floor to meet with members of the Movebank team, who will be available for questions and one-on-one tutorials at the **Movebank Café**, and to talk with representatives from **North Star Science and Technology** and **Cellular Tracking Technologies**.

Also, admission to the **museum exhibits** is free, so be sure to take some time to explore!

Why a Symposium?

With advances in animal tracking and remote sensing technology, we are quickly entering a new age of discovery about animal movement. A growing range of sensors allow us to collect more data on the movements and experiences of free-ranging animals of more species than ever before, with unparalleled resolution. At the same time, massive datasets describing the ever-changing world are available to quantify the conditions these animals are moving through. Scientists are rapidly developing new statistical methods and analysis tools to facilitate discoveries. The field is now moving into a new era where we are restricted less by the lack of data than by the challenges of fully exploring and discovering the information hidden in these datasets. The goal of this meeting is to help usher in this data-rich, Golden Age of Movement Ecology. Through presentations, tutorials, and working groups, we will learn how scientists are integrating information on animals and the environment to move beyond simply describing movements, to testing hypotheses about movement ecology and the relationship between animals and their changing environment.

Schedule

	Red Oak Room	Pecan Hickory Room	Other
Monday 5 May			
8:15	Opening remarks: Roland Kays		
8:30	Keynote: Martin Wikelski		
9:30	Coffee break		
10:00	Research Talks 1: Physiology & disease	Tutorials 1: Movement models & resource selection functions	
12:00			Lunch on your own
13:00	Research Talks 2: Migration		
14:40	Coffee break	Tutorials 2: Integrative movement models	
15:00	Research Talks 2: Migration (continued)		
18:00			Welcome reception 1st floor, NRC
Tuesday 6 May			
8:30	Keynote: Ran Nathan		
9:30	Coffee break		
10:00	Research Talks 3: Techniques & technology	Tutorials 3: Environmental data	
12:00			Lunch on your own
13:00	Research Talks 5: Ecology of mammals	Research Talks 4: Movement models	
14:40	Coffee break		
15:00	Research Talks 5: Ecology of mammals (continued)	Research Talks 4: Movement models (continued)	Posters and refreshments (Happy Hour 17:00–18:00)
16:20			
18:30			Dine Around Raleigh join a group at http://bit.ly/1hwcg25
Wednesday 7 May			
8:30	Keynote: Josh Millspaugh		
9:30	Research Talks 6: Accelerometry & group dynamics	Tutorials 4: Movement metrics	
12:00			Lunch on your own
13:00	Research Talks 7: Ecology of birds		
14:40	Coffee break	Tutorials 5: Track segmentation & interaction	
15:00	Research Talks 7: Ecology of birds (continued)		
17:00			Dinner on your own
Thursday 8 May			
9:00	Collaborative working group: Comparing movement modeling frameworks		
12:00			Lunch on your own
13:30	Collaborative working group: Cross-site comparison of fisher habitat use		

Program for Monday, 5 May 2014

8:15 Opening remarks: **Roland Kays**

8:30 **Keynote: Martin Wikelski** (Max Planck Institute for Ornithology and the University of Konstanz)
Move it, baby!

9:30 Coffee break

Research Talks 1: Physiology and Disease

Moderated by **David Jachowski**

10:00 **Navinder Singh** Internal state versus external environment: combining eco-physiology and movement ecology of a large herbivore

10:20 **David Jachowski** Linking animal physiology and movement behavior: a case study of the African elephant

10:40 **Subhash Morzaria** Connecting the dots: linking livestock development and value-chains, wildlife habitat use and migration, agro-ecological risk factors and genetic sequences of viruses to understand the emergence, spread, and the potential for zoonotic pandemics

11:00 **Diann J. Prosser** Examining movement ecology of wild birds and their role in disease transmission

11:20 **Scott Newman** Niche mapping, multi-criteria decision analysis and animal movement data for mapping the risk of avian influenza emergence in Asia

11:40 Discussion and brainstorming, led by **Subhash Morzaria** and **Scott Newman**

Tutorials 1: Movement Models and Resource Selection Functions

Moderated by **Marcus Lashley**

10:00 **Oz Garton** Synoptic modeling of animal locations: ask important questions by simultaneously estimating home range and resource selection in an information theoretic framework

11:00 **Christopher Rota** Resource selection functions

Research Talks 2: Migration

Moderated by **Gil Bohrer**

13:00 **Gil Bohrer** Environmental drivers of variability in the movement ecology of four turkey vulture populations in two continents

13:20 **Roi Harel** Age-related variation in soaring-gliding performance of vultures

13:40 **Rachel T. Bolus** Do migrating birds respond to altitudinal variation in winds during long, over-water flights?

14:00 **Pascual López-López** The role of external and internal factors on the movement ecology of long-distance migratory raptors

14:20 **Kasper Thorup** Linking long-distance migration and resources

14:40 Coffee break

15:00 **Bryant Dossman** The probability of departure from stopover in light of ecological context: behavioral adaptations in response to a migratory barrier

15:20 **Shay Rotics** Comparison of juvenile and adult migration in white storks *(Ciconia ciconia)* with implications on survival

15:40 **Lisa Davenport** A tale of four countries: satellite telemetry of the Orinoco Goose *(Neochen jubata)* in Peru, Brazil, Bolivia and Colombia

16:00 **Sarah Supp** Using continental-scale citizen-science data and remote sensing products to identify the drivers of hummingbird migration routes and timing

16:20 **Michael Hallworth** Migratory connectivity of a Neotropical migratory songbird revealed by archival light-level geolocators

Tutorials 2: Integrative Movement Models

Moderated by **Paul Blackwell**

13:00 **Tal Avgar** Inferring sensory and memory capacities based on telemetry and environmental data

14:15 **JF Therrien** Irruptive movements and breeding dispersal of snowy owls: a specialized predator exploiting a pulsed resource

15:30 **Paul G. Blackwell** Bayesian inference for continuous-time modelling of animal movement

Program for Tuesday, 6 May 2014

8:30 **Keynote: Ran Nathan** (Hebrew University of Jerusalem)
Movement ecology keeps moving forward: why, how, when and where are we going

9:30 Coffee break

Research Talks 3: Techniques and Technology

Moderated by **David Douglas**

10:00 **Holger Dettki** Wireless Remote Animal Monitoring (WRAM): a new international database e-infrastructure for management and sharing of telemetry sensor data from fish and wildlife

10:20 **Chi Hin Lam** Where are my tags? Go ask Nagbase

10:40 **Jerry Moxley** Fine-scale movements, nocturnal diving, and evasive maneuvers in a gray seal's unsuccessful attempt to avoid predation by white sharks revealed through mobile-phone telemetry

11:00 **David Douglas** Accuracy assessment of Argos Kalman filter location processing

Tutorials 3: Environmental Data

Moderated by **Johnny Wilson**

10:00 **Somayeh Dodge** Environmental data track annotation with Env-DATA

11:00 **David Brandes** Simulating orographic lift, with examples related to land-based wind energy, golden eagles, and griffon vultures

Research Talks 4: Movement Models

Moderated by **James Sheppard**

13:00 **Debbie Saunders** Small dynamic migrants: the ultimate challenge in tracking migratory movements

13:20 **Justin Calabrese** From fine-scale foraging to home ranges: a semi-variance approach to identifying movement modes across spatiotemporal scales

13:40 **Chris Fleming** Linking statistics of movement to resource dynamics

14:00 **Andrew M. Allen** Scaling up individual movement patterns to population level movements

14:20 **Yun Tao** Transient animal home range: methods and applications

14:40 Coffee break

15:00 **James Sheppard** Movement-based estimation and visualization of space use in 3D for wildlife ecology and conservation

15:20 **Frederic Bartumeus** Multimodal search behaviour in a model organism

15:40 **Paul Holloway** User decisions in step-selection functions: how selection of model parameters influences the relationship between animal movement and the environment

16:00 **Eduardo Martins** Modeling fine-scale fish movements in environments with dynamic water levels and complex flows

Research Talks 5: Ecology of Mammals

Moderated by **Roger A. Powell**

13:00 **Kevin McLean** Modeling movement of three neotropical primates using LiDAR-derived measures of forest structure

13:20 **Nir Sapir** Commuting fruit bats beneficially modulate their flight in relation to wind

13:40 **Hendrik Edelhoff** Detection of potential dispersal behavior in Red Deer *(Cervus elaphus)* movement paths: an application for landscape resistance modeling

14:00 **Aaron Facka** Identification of occupied home ranges using travel distances, changes in speed and final settlement of translocated fishers *(Pekania pennanti)*

14:20 **Roger A. Powell** Dynamic black bears

14:40 Coffee break

15:00 **Claude Fischer** Influence of disturbance regimes and landscape characteristics on wild boar space use patterns in a human dominated landscape

15:20 **Corrie Curtice** Spatially and temporally dynamic humpback feeding areas in Antarctica

15:40 **Jason Riggio** Current status of Tanzania's wildlife corridors

16:00 **Tal Avgar** Analysing caribou space-use as a cognitive movement process

Program for Wednesday, 7 May 2014

8:30 **Keynote: Josh Millspaugh** (University of Missouri)
Animal movements and models for management and conservation

Research Talks 6: Accelerometry and Group Dynamics

Moderated by **John W. Wilson**

9:30 **Ariana Strandburg-Peshkin** Leadership and collective motion in Anubis baboons using high-resolution GPS tracking

9:50 **Damien Farine** Identifying social and non-social affiliations in proximity networks of animal groups on the move

10:10 **William F. Fagan** Information gathering and movement in dynamic landscapes

10:30 **Thomas Mueller** Social learning of migratory performance

10:50 **Andrea Kölzsch** Goose family behaviour decoded by accelerometers and high-frequency GPS

11:10 **John Fryxell** Accelerometry, behavior, and movement ecology of free-ranging woodland caribou

11:30 **John W. Wilson** Cheetahs vary hunting strategies depending on prey species

Tutorials 4: Movement Metrics

Moderated by **Scott LaPoint**

9:30 **Bart Kranstauber** and **Scott LaPoint** The R package move

10:00 **Bart Kranstauber** Dynamic Brownian bridge movement models

10:30 **Zhenhui Li** Mining animal relationships from movement traces

11:00 **Jake Wall** ArcMET: Movement Ecology Tools for ArcGIS

Research Talks 7: Ecology of Birds

Moderated by **Sharon Bewick**

13:00 **Katherine Mertes** Evaluating scale-dependence in species-environment relationships of East African birds

13:20 **Orr Spiegel** Moving beyond curve-fitting: complementary evidence on vultures' long-range forays contradicts Lévy foraging hypothesis

13:40 **Nicolas Lecomte** Home range variation during breeding in an Arctic predator: the case 5 of peregrine falcons in Yamal, Russia

14:00 **Landon Jones** Do toucan movements mitigate clumped patterns of seed dispersal in fragmented tropical forest habitat?

14:20 **Sharon Bewick** Understanding pollinator foraging strategies in terms of dynamic resource landscapes

14:40 Coffee break

15:00 **Ryan Huang** Investigating anthropogenic and environmental impacts on sooty tern survivorship

15:20 **Erik Kleyheeg** Spatiotemporal variation in landscape use by mallards in Dutch wetlands

15:40 **Zoe Crysler** Assessing post-breeding dispersal and autumn migratory movements of the Ipswich sparrow

Tutorials 5: Track Segmentation and Interaction

Moderated by **Somayeh Dodge**

13:00 **Scott LaPoint** Animal-defined movement corridors

14:00 **Joan Garriga** EMbC: an algorithm for behavioral annotation of animal movement

15:00 **Hezi Resheff** Supervised learning of behavior modes from acceleration data

Collaborative working groups

These informal workshops are open to all symposium attendees.

Comparing movement modeling frameworks

This informal group will get together to evaluate the strengths and weaknesses of the rapidly growing suite of movement modeling frameworks that have been published in recent years. The goal will be to identify a collection of good datasets that could be used as benchmarks for assessment, then organize a systematic evaluation of these datasets using the full suite of algorithms to better identify their robustness (led by John Fryxell and Tal Avgar).

Cross-site comparison of fisher habitat use

Fishers *(Pekania pennanti)* are forest dependent species, but their tolerance for habitat fragmentation and land cover heterogeneity has not been investigated across their range. During this group brainstorm, we hope to bring together data owners and modellers to think about the interesting hypotheses that we could explore on this topic and to identify data owners willing to contribute to such an effort.

Abstracts

Abstracts are listed in alphabetical order by presenting author, first for keynotes, then for oral presentations and tutorials, then for poster presentations. Session name and time follow the title and authors. Presenting author is in bold.

Keynotes

Joshua Millspaugh

Animal movements and models for management and conservation

Department of Fisheries and Wildlife Sciences, University of Missouri, Columbia, MO

There are many practical and theoretical motivations to studying animal movements. Because animal movement data offer a unique and integrative perspective about wildlife use of landscapes, such information is important in addressing conservation problems. Mapping the probability of species occurrence, conducting quantitative risk assessments, and providing adequate habitat are all enabled by knowledge of animal movements. Technology has facilitated the recent growth in animal movement research and advances in statistical methodology have closely tracked those advancements. In this talk I will discuss the integration of animal movement data and statistical models to address pressing management problems. In particular, I will demonstrate the application of movement data and statistical models to address issues involving human safety such as bird-aircraft collisions, identifying critical habitats for species of conservation concern and recently restored wildlife populations, and mitigating wildlife impacts from human activities and habitat disturbances. Using a diverse group of wildlife species and locations, my goal is to highlight the important role that animal movement data and statistical models play in addressing many of the most important management and conservation questions of our time. Further, I will highlight how the integration of multiple streams of information, such as movement and vital rate data, can be complementary while providing context for the consequences of or reasons for animal movements we observe. (millspaughj@missouri.edu)

Ran Nathan

Movement ecology keeps moving forward: why, how, when and where are we going?

Department of Ecology, Evolution and Behavior and Minerva Center for Movement Ecology, the Hebrew University of Jerusalem, Jerusalem, Israel

Understanding and predicting the dynamics of complex ecological and evolutionary systems are best accomplished through the synthesis and integration of information, tools and ideas across relevant spatial, temporal and thematic scales. Recent advances in mechanistic modeling, data analysis tools and tracking technology have enriched our capacity to disentangle the key parameters affecting foraging, migration, dispersal and other movement processes and to accurately quantify movement patterns over (and through) land, water or air. In lieu of this favorable background, the field of movement ecology has recently emerged to unify movement research by elucidating the links between the internal state, the motion and the navigation capacities of the individual, the external environmental factors affecting its movement, and the resulting movement pattern. Due to the generality and broad applicability of its basic components, the movement ecology framework provides a unifying template for elucidating the commonalities and differences among species, movement phenomena and environments. As such, movement ecology offers a natural platform for examining the causes, consequences, patterns and mechanisms underlying movement processes, towards the foundation of a generalized theory of organismal movement that can unify different movement types, taxonomic groups and ecosystems. To put this in a broader scientific perspective, Freeman J. Dyson has concluded his appraisal of current research in Physics (Science, 14 Dec 2012) stating that "we are lucky to live in a time when both [tools and ideas] are going strong"; this prognosis utterly describes the current

status of movement ecology as well, but we could and should make both ever stronger, and pursue their integration in particular.

The Symposium on Animal Movement and the Environment (AMoveE) at Raleigh has attracted many researchers to present and discuss their exciting cutting-edge movement ecology studies. The abstracts, the tutorials, and the planned topics jointly depict unmistakable footprints of an exceptionally flourishing scientific enterprise. The time has ripen to challenge major barriers in quantifying, understanding and predicting the movements of organisms, and AMoveE provides a perfect opportunity to discuss why, how, when and where should we go. Towards this end, I will present the basic motivation and principles of the movement ecology approach, and illustrate its application to study different types of movements across species and environments. I will aim to highlight the links among the major movement phenomena, and to propose some possible ways to close the gaps among existing fields of movement research, to stimulate the development and sharing of tools and ideas, and to set the stage for formulating a unified general theory of organismal movements. (rnathan@cc.huji.ac.il)

Martin Wikelski

Move it, baby!

Max Planck Institute for Ornithology, Radolfzell, Germany, and the University of Konstanz, Konstanz, Germany

We all agree that we entered a golden age for studying the movement of animals because we now have the technology, the big data possibilities and the theoretical underpinnings to make rapid advances. I will highlight what I generally see as the biggest deficiencies of the movement ecology field. We generally have very little information about: 1) Selection: Where, when and why an animal dies. Knowing this will answer the ultimate question about selection pressures, and help us advance conservation. 2) Ontogeny: How an individual develops its movements during it's lifetime. Knowing this will give us insights into decision mechanisms and the reaction norms of animal decisions. Although in the biological sciences we generally know more about mechanisms compared to the previous topics, we still have a large knowledge gap about: 3) Mechanisms in the wild: How an individual decides in the wild, based on it's internal physiology and 4) Environmental constraints: What are the external surroundings upon which an individual decides. One of the largest unknowns here are the 5) Social constraints: How does an individual decide based on the decisions of other animals around it and interacting with it.

The movement of animals also has important global ecological as well as societal consequences that our field can uniquely address. We can and should involve the public in interacting and communicating with animals. Where this is done, often in native cultures, animals are already used as indicators and sentinels for biological and earth processes. Modern observational tools now allow us to interact with animals in unforseen ways and change our perception about the connectivity of life on the planet.

To address these questions and tasks we need to observe individual animals throughout their life, ultimately also answering how important dispersal is in animal populations. I will highlight the LifeTrack project where this is attempted on a large scale, observing individual movements from the baby to the gerontological stage, and call for a global open-access data policy in animal observations. (martin@orn.mpg.de)

Andrew M. Allen, Göran Ericcson, Navinder J. Singh

Scaling up individual movement patterns to population level movements

Swedish University of Agricultural Sciences, Umeå, Sweden

R4: Movement Models (Tuesday 14:00)

Little is known about how population level movements emerge from individual movement patterns, as often only a few individuals from a population are tracked in space and time, and their movement strategies are not accounted for. This knowledge is vital for both ecology and management of animal populations since management interventions are usually made at the population level. We analysed the multi-annual space use of 346 moose *(Alces alces)* from seven study areas spread over a 1,500 km latitudinal gradient in order to gain a better understanding of population level movements. Movement data was analysed at annual and seasonal (winter/summer) scales with 551 complete years of movements available for analysis. We identified the movement strategy (migratory, sedentary, nomadic or dispersal) of moose and computed annual and seasonal utilisation distributions (UDs) for all individuals and years. We used multivariate analyses and generalised linear mixed models to identify the relative importance of an individual's life history and the external environment on observed movement patterns. Variation in movement and space use patterns were quantified at multiple scales that include variation between study areas, within study areas and within individuals (i.e. inter-annual variation). Individuals demonstrated variable movement strategies from migration to complete residence, which varied across years and populations. The average UD of migrants was up to seven times larger than that of residents and summer UDs were larger than winter UDs. Males used larger areas than females and older animals had larger ranges than younger individuals. These life history traits explained most variation in the size of UDs, but interacted with external environmental factors that include snow depth, primary productivity and the proportion of important habitats in the landscape. Furthermore, migratory individuals in the north of Sweden showed a clear divide in seasonal space use patterns, using high elevation sparsely vegetated broadleaf-forest landscapes in the summer compared to low elevation coniferous-forest dominated landscapes in the winter. In contrast, resident individuals used coniferous-forest dominated landscapes year round and this pattern was observed in both the north and south of Sweden. Our results indicate the importance of sex ratios, age distribution, movement characteristics and their interaction with external environment on the seasonal and annual home range size in terrestrial animals. The scale of this study provides an important contribution towards understanding intra-specific variation in space use and how population level movements emerge from individual movement patterns, knowledge that is vital for adapting management actions to species ecology.
(andrew.allen@slu.se)

Tal Avgar

Inferring sensory and memory capacities based on telemetry and environmental data

University of Alberta, Edmonton, AB, Canada

T2: Integrative Movement Models (Monday 13:00)

What does a moving animal know about its surroundings at any given point in space and time? The answer to this challenging question may often be critical to our understanding and interpretation of animal movement and resource selection patterns. In this tutorial I will present a modeling framework designed to evaluate the likelihood of alternative processes of movement, perception, memory, and decision making, based on readily available positional data and environmental metrics. The model is based on a flexible cognitive algorithm that provides the framework for an adaptive movement kernel. This enables a straightforward, likelihood-based methodology for estimating key parameters for sensory perception, memory and movement while providing testable predictions of animal resource selection and space use patterns.

Tal Avgar[1], Garrett Street[2], Andrew Kittle[2], John M. Fryxell[2]

Analysing caribou space-use as a cognitive movement process

[1]University of Alberta, Edmonton, AB, Canada; [2]University of Guelph, Guelph, ON, Canada

R5: Ecology of Mammals (Tuesday 16:00)

Animal space-use patterns emerge from complex interactions between the attributes of the traversed landscape and the animal's movement and cognitive capacities. As such, once coupled with ecologically meaningful environmental data, movement patterns offer a rich source of information regarding the behavioral ecology of the animal. This is especially useful for species occupying remote landscapes where direct behavioral observations are limited. Here we present parametrization of an individual-based cognitive movement model based on positional data of woodland caribou *(Rangifer tarandus caribou)*. The model's parameters include individual estimates of locomotion, sensory and memory capacities, as well as resource selection. We use the model to quantify caribou movement response to habitat-based projections of three ecological factors: forage abundance, predator abundance, and apparent competitor habitat. Resulting parameter estimates indicate a consistent, yet weak, attraction to abundant forage and overall strong avoidance of apparent competitor habitat, with little effect of predator abundance. We discuss the sensitivity of these results to model structure and their ecological significance in the context of caribou conservation. Overall, we demonstrate for the first time the utility of a cognitive-movement model in extracting ecological information from movement patterns of free-ranging animals. (avgar@ualberta.ca)

Frederic Bartumeus[1], Mia Panlilio[2], William Ryu[2,3], Joan Garriga[1]

Multimodal search behaviour in a model organism

[1]ICREA-Movement Ecology Laboratory CEAB-CSIC, Blanes, Spain; [2]Department of Physics, University of Toronto, Toronto, ON, Canada; [3]The Donnelly Centre, University of Toronto, Toronto, ON, Canada

R4: Movement Models (Tuesday 15:20)

Movement is a fundamental feature of life. Organisms must search for prey or mates, avoid predators, or explore new habitats. Using novel methods and high-throughput data we seek to elucidate the behavioral strategies governing *C. elegans* searches and their effects on both ecological and evolutionary timescales. Studies of animal movement are often hindered by difficult observations over large spatiotemporal scales, unknown environmental conditions, and complex behavioral descriptions. *C. elegans* is a powerful model system for overcoming such challenges. In this study we capture high-resolution mass centroid positions and images of individual worms crawling through a large isotropic environment. Behavioral reorientation events are automatically flagged. We quantify local and global spatio-temporal searching scales, which over long times are modulated at least in part by the dynamics of distinct types of reorientation behavior. Moreover, since other reorientation types are known to be suppressed under starvation conditions, we propose that this long-term behavioral strategy acts as a compensatory mechanism to prevent both under and oversampling the environment.

We gratefully acknowledge the support of the Human Frontier Science Program and the Ontario Graduate Scholarship (M.P.) (fbartu@ceab.csic.es)

Sharon Bewick[1], Timothy Krotkov[2], Isabela Galarda Varassin[3], William F. Fagan[1]

Understanding pollinator foraging strategies in terms of dynamic resource landscapes

[1]Department of Biology, University of Maryland, Columbia, MD; [2]Department of Electrical and Computer Engineering, University of Maryland, College Park, MD; [3]Department of Botany, Universidade Federal do Paraná, Curitiba, Paraná, Brazil

R7: Ecology of Birds (Wednesday 14:20)

Dynamic resource landscapes can strongly influence how individual movement behaviors give rise to population-level distributions. Here we seek to understand how the foraging behavior of pollinators, which has implications for both plant and pollinator fitness, gives rise to patterns of space use by pollinators. To explore the mechanistic underpinnings of different foraging strategies, we build an individual-based neural network genetic algorithm (ING) model to describe pollinator movement through a 1D field of flowers. Within our formulation, context-specific state

variables representing a pollinator's environment are converted to movement responses using an artificial neural network (ANN). The ANN itself then evolves according to a genetic algorithm. Using our model, we investigate the different types of foraging behaviors that emerge as a function of resource characteristics across the landscape. We consider, for example, flower density, flower patchiness, nectar replenishment rates, flower rewards, variability in nectar replenishment rates and variability in flower rewards. In addition, we consider several pollinator life-history traits, for example competition effects and the capacity for memory. Ultimately, our model allows us to define the types of plant and pollinator characteristics that give rise to different types of pollinator foraging strategies, ranging from restricted foraging that frequents a small number of patches to long-distance trap-lines with and without returns. (sharon_bewick@hotmail.com)

Paul G. Blackwell, Mu Niu

Bayesian inference for continuous-time modelling of animal movement

University of Sheffield, Sheffield, UK

T2: Integrative Movement Models (Monday 15:30)

In this talk I will describe and illustrate some recent progress in continuous-time modelling of movement and in Bayesian inference for such models. The models used will include many of those described in Harris and Blackwell (2013), which incorporate switching between behavioral states and heterogeneity in space and time, with some extensions that allow for more flexibility in the modelling of the environment in which the movement takes place, and also a rich class of models for interactions between multiple animals, building on the work of Langrock et al (2014). The inference uses a Markov chain Monte Carlo approach, exploiting an exact simulation technique to avoid time-discretization error, despite the complex relationship between environment, behaviour and movement. These ideas will be illustrated using real data on individual fishers *(Martes pennanti)*, courtesy of Scott LaPoint (Max Planck Institute for Ornithology, Konstanz) and on a group of simultaneously-tracked reindeer *(Rangifer tarandus)*, courtesy of Anna Skarin (Swedish University of Agricultural Sciences, Uppsala).

References:

Harris, K.J and Blackwell, P.G. (2013) Flexible continuous-time modelling for heterogeneous animal movement. Ecological Modelling, 255:29-37.

Langrock, R., Hopcraft, J.G.C., Blackwell, P.G., Goodall, V., King, R., Niu., M., Patterson, T.A., Pedersen, M.W., Skarin, A., Schick, R.S., (2014) Modelling group dynamic animal movement. Methods in Ecology and Evolution, 5:190-199. (p.blackwell@sheffield.ac.uk)

Gil Bohrer[1], Somayeh Dodge[2], Keith Bildstein[3], Sarah C. Davidson[1,4], Rolf Weinzierl[4], David Barber[3], Roland Kays[5], David Brandes[6], Jiawei Han[7], Martin Wikelski[4,8]

Environmental drivers of variability in the movement ecology of four turkey vulture populations in two continents

[1]The Ohio State University, Columbus, OH; [2]Department of Geography & Environmental Studies, University of Colorado, Colorado Springs, CO; [3]Hawk Mountain Sanctuary, Orwigsburg, PA; [4]Max Planck Institute for Ornithology, Radolfzell, Germany; [5]North Carolina Museum of Natural Sciences, Raleigh, NC; [6]Lafayette College, Easton, PA; [7]University of Illinios Urbana-Champaign, Urbana, IL; [8]The University of Konstanz, Konstanz, Germany

R2: Migration (Monday 13:00)

Variation is key to the adaptability of species and their ability to survive changes to the earth's climate and habitats. Plasticity in movement strategies allows a species to better track spatial dynamics of habitat quality. We describe the mechanisms that shape the movement of a long-distance migrant bird (turkey vulture, *Cathartes aura*) across two continents using satellite tracking coupled with remote-sensing science. Using nearly 10 years of data from 24 satellite-tracked vultures in 4 distinct populations we describe an enormous amount of variation in their movement patterns. We related vulture movement to environmental conditions and found important correlations explaining how far they need to move to find food (indexed by the Normalized Difference Vegetation Index) and how fast they

can move based on the prevalence of thermals and temperature. We conclude that the extensive variability in the movement ecology of turkey vultures, facilitated by their energetically efficient thermal soaring, suggest that this species is likely to do well across periods of modest climate change. The large scale and sample sizes needed for such analysis in a widespread migrant emphasizes the need for integrated and collaborative efforts to obtain tracking data and for policies, tools, and open datasets to encourage such collaborations and data sharing. Our findings, which are based on a large continental-scale and long-term satellite tracking campaign, coupled with the use of remote-sensing databases, provide important insights into the effects of climate and environment on the range of migratory and non-migratory movement behavior occurring in avian migrants, and emphasize the importance of coordinating large sampling efforts with access to the "big-data" resources provided by earth-observing satellites. (bohrer.17@osu.edu)

Rachel T. Bolus[1,2], Gil Bohrer[3], Jill L. Deppe[4], Robert H. Diehl[1], Frank R. Moore[5], Lynn Schofield[4], Michael P. Ward[2], Theodore J. Zenzal, Jr.[5]

Do migrating birds respond to altitudinal variation in winds during long, over-water flights?

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R2: Migration (Monday 13:40)

Each fall in North America, migrating birds accumulate along the northern coast of the Gulf of Mexico. Many of these migrants take advantage of supportive weather conditions to fly the more direct route to their wintering grounds across the Gulf, which shortens their overall migration distance. We hypothesize that birds are able to further optimize their flights by identifying altitudes with the most supportive wind conditions and navigating among these altitudes. By both minimizing migration distance and flight energy, the net energetic benefits of crossing the Gulf should outweigh the risks of these long, non-stop flights. One known over-water route is between coastal Alabama and the Yucatan Peninsula, which has a crossing distance of approximately 950 km. Using automated receiving unit (ARU) towers on the Alabama and Yucatan coasts, we monitored radio-tagged migrants and identified departure times, departure directions, arrival times, and over-water flight durations. We used these data and modeled environmental data provided by the Env-DATA system (movebank.org) from the NCEP North American Regional Reanalysis (NARR) to develop individual based models that test different hypotheses for migratory birds' responses to altitudinal differences in favorable winds. Using the actual departure and arrival data of migrating individuals to constrain the model results in a more precise, more biologically likely solution space. Simulated tracks that match both flight duration and arrival location reveal to what extent birds are able to respond optimally to favorable winds over water. The decisions Trans-Gulf migrants make en route likely impact their energy expenditure, which has carryover effects on overwinter survival probability and reproductive success. (rbolus@usgs.gov)

David Brandes

Simulating orographic lift, with examples related to land-based wind energy, golden eagles, and griffon vultures

Department of Civil and Environmental Engineering, Lafayette College, Easton, PA

T3: Environmental Data (Tuesday 11:00)

Orographic lift generated by upward deflection of surface winds provides an important source of energy for soaring birds, supporting local to continental scale movements (Bohrer et al 2012). Orographic lift results from the interaction between topography and wind, generating structured patterns of vertical wind velocity (Wo) near the ground surface that can be used to predict flight paths. In the case of large raptors, soaring flight using low-altitude orographic lift has been shown to be correlated with elevated collision risk at wind farms; thus, the ability to simulate Wo is valuable in understanding and predicting collision risk, as well as in micro-siting the turbines. A

simplified model for Wo (Brandes and Ombalski, 2004; Bohrer et al 2012) that uses a digital elevation model and archived interpolated wind data has been incorporated into the ENV-DATA system. In this workshop the model will be described and applied to migration tracks of golden eagles *(Aquila chrysaetos)* and spatial patterns of raptor collisions at two wind farms. (brandesd@lafayette.edu)

Justin Calabrese[1], Chris H. Fleming[1], Thomas Mueller[2], Kirk A. Olson[1], Peter Leimgruber[1], William F. Fagan[2]

From fine-scale foraging to home ranges: a semi-variance approach to identifying movement modes across spatiotemporal scales

[1]Smithsonian Conservation Biology Institute, Front Royal, VA; [2]University of Maryland, College Park, MD

R4: Movement Models (Tuesday 13:20)

Understanding animal movement is a key challenge in ecology and conservation biology. Relocation data often represent a complex mixture of different movement behaviors, and reliably decomposing this mix into its component parts is an unresolved problem in movement ecology. Traditional approaches, such as composite random walk models, require that the time scales characterizing the movement are all similar to the usually arbitrary data-sampling rate. Movement behaviors such as long-distance searching and fine-scale foraging, however, are often intermixed but operate on vastly different spatial and temporal scales. An approach that integrates the full sweep of movement behaviors across scales is currently lacking. Here, we show how the semi-variance function (SVF) of a stochastic movement process can both identify multiple movement modes and solve the sampling rate problem. We express a broad range of continuous-space, continuous-time stochastic movement models in terms of their SVFs, connect them to relocation data via variogram regression, and compare them using standard model selection techniques. We illustrate our approach using Mongolian gazelle relocation data, and show that gazelle movement is characterized by ballistic foraging movements on a six-hour time scale, fast, diffusive searching with a ten-week time scale, and asymptotic diffusion over longer time periods that leads to a per-individual annual range size of 91,000 km^2. (CalabreseJ@si.edu)

Zoe Crysler[1], Phil Taylor[1,2]

Assessing post-breeding dispersal and autumn migratory movements of the Ipswich sparrow

[1]Biology Department, Acadia University, Wolfville, NS, Canada; [2]Bird Studies Canada, Port Rowan, ON, Canada

R7: Ecology of Birds (Wednesday 15:40)

Post-breeding dispersal and migration are difficult periods to study for many small passerines because individuals can be cryptic, and can move over broad temporal and spatial scales. Island breeding birds are ideal candidates for studies of the post-breeding and initial migratory movements because their populations are clearly demarcated, their movements are restricted, and individuals typically depart for migration from the same location. The Ipswich Sparrow *(Paserculus sandwichensis princeps)* is a subspecies of the Savannah Sparrow that breeds exclusively on Sable Island, Nova Scotia and winters along the Atlantic coast of North America. Twice annually, Ipswich sparrows navigate a minimum overwater distance of 120 km between Sable Island and the mainland. The general migratory patterns of the species are known, but the timing and choices of routes used to depart Sable Island are unknown. We used a network of 50 automated VHF telemetry receivers to track adult and juvenile IPSP equipped with VHF radio tags from immediately post-breeding through the first half of their migratory journey. Compared to adults, juveniles undertake extensive post-breeding movements, leave the island earlier, have more variation in their initial migratory flight, and use a migratory route with shorter ocean crossings. (zcrysler@gmail.com)

Corrie Curtice[1], Ari Friedlaender[2], David Johnston[1], Patrick N. Halpin[1], Nick Gales[3], Hugh Ducklow[4]

Spatially and temporally dynamic humpback feeding areas in Antarctica

[1]Duke University, Beaufort, NC; [2]Marine Mammal Institute, Oregon State University, Newport, OR; [3]Australian Antarctic Division, Australian Department of the Environment, Kingston, Tasmania, Australia; [4]The Earth Institute, Columbia University, New York, NY

R5: Ecology of Mammals (Tuesday 15:20)

Humpback whales *(Megatptera novaeangliae)* are the most abundant baleen whale found in the nearshore waters around the Antarctic Peninsula. As a migratory animal, they must acquire enough energy during the summer months in the resource-rich feeding grounds around Antarctica to fuel their migrations to breeding and calving grounds in tropical waters in winter, where resource are limited.

Previous work has shown that the distribution and abundance of humpback whales is best predicted by that of Antarctic krill, the primary component of humpback whale diets in Antarctic waters. Since humpback whales are mobile predators with high energetic demands, it stands to reason that humpback whales will seek out areas with increased prey abundance, changing their distribution to reflect krill distribution changes throughout the feeding season. During summer months, krill are distributed broadly from nearshore to beyond the continental shelf. In autumn, krill are thought to move inshore and toward deep coastal waters in sheltered bays where they coalesce into large aggregations that will be covered by sea ice formation, minimizing predation risk from diving predators, including humpback whales. Given the known distribution of whales in summer months and the ultimate distribution of both whales and krill later in the feeding season, we hypothesized that the movement patterns and home ranges of humpback whales reflect concurrent changes in the distribution of Antarctic krill: home ranges of humpback whales will decrease in size during the austral summer and fall, and the overall distribution of humpback whales will move significantly closer to shore over this time period.

To evaluate these hypotheses, six whales were instrumented with Platform Transmitting Terminals (PTTs) during January of 2012. We applied a new product kernel method over the full date range of location data (162 days). On every fifth day, we calculated the Utilization Density (UD) for each whale whose track existed on that date. The 95% isopleth was used as the extent for the home range. To explore the hypotheses that humpback whale home range area and distance to mainland both decrease during the summer and fall months we used linear mixed effects models to assess humpback home range area and distance from land. Both Julian date and month were used as predictors, and the PTT was used as a random effect to examine individual variation between whales. Home ranges were created for 75 specific days, with between one to five whales having tracks on each day used for the model.

We found that distance to mainland was significant, indicating that with each increase in month there was a corresponding decrease of 41.43 km in the distance to mainland. Home range area was not significantly different over time. This suggests while the distribution of whales changes seasonally with respect to proximity to shore, the lack of a change in home range may indicate that krill is still broadly distributed over a greater area than we thought. (corrie.curtice@duke.edu)

Lisa Davenport[1], Whaldener Endo[2], Natalia Ocampo-Peñuela[3], Carlos Peres[4], Ines Nole Bazán[5], Bennett Hennessey[6]

A tale of four countries: satellite telemetry of the Orinoco Goose *(Neochen jubata)* in Peru, Brazil, Bolivia and Colombia

[1]Duke University Center for Tropical Conservation, Durham, NC; [2]Centro Nacional de Pesquisa e Conservação de Mamiferos Carnívoros, Brazil; [3]Duke University Nicholas School of the Environment, Durham, NC; [4]School of Environmental Sciences, University of East Anglia, Norwich, UK; [5]Universidad Autónoma de Madrid, Madrid, Spain; [6]Asociación Armonía, Santa Cruz, Bolivia

R2: Migration (Monday 15:40)

The Orinoco Goose *(Neochen jubata)*, is described as the "only true forest goose," and is rare and declining (CR in Peru and NT elsewhere). It is a long-distance intra-Amazonian migrant, tracked via satellite telemetry between breeding populations in both Peru and Brazil to the Llanos de Moxos, Bolivia (Davenport, Nole and Carlos 2012). Birds tracked showed high site fidelity to both breeding grounds and wet-season feeding grounds (Davenport, Endo and Peres, unpub results). We report on the movements of 7 birds tagged between 2010 and 2013, including 3 tagged in Peru, 2 tagged in Brazil and 2 tagged in Colombia. Timing of wet-season migrations should be related to the schedule and extent of flooding of the beaches and lake habitats where they feed and raise young each dry season. Flooding events are relatively stable in the lowland Rio Jurua (Brazil) fieldsite compared to the Rio Manu (Peru) headwaters fieldsite; however, timing of the onset of migration for our tagged individuals was highly divergent from both sites. We report on observations that suggest that the timing and duration of migration is more dependent on survivorship of young-of-the-year than on flooding schedule. High predation of juveniles, a constraint faced by many tropical bird species, appears to be an important determinant of the Orinoco Goose's unusual reproductive behavior (including cavity nesting), partial migration patterns, and social structure. Movements of Colombian birds tagged in December 2013 are forthcoming and will be compared to work from Peru and Brazil. (lisa.davenport@duke.edu)

Holger Dettki[1], Michel Brode[2], Ivan Clegg[2], Timothy Giles[2], Jerry Halllgren[2]

Wireless Remote Animal Monitoring (WRAM): a new international database e-infrastructure for management and sharing of telemetry sensor data from fish and wildlife

[1]Department of Wildlife, Fish, and Environmental Studies, Swedish University of Agricultural Sciences, Umeå Center for Wireless Remote Animal Monitoring (UC-WRAM), Umeå, Västerbotten, Sweden; [2]IT Department, Swedish University of Agricultural Sciences, Uppsala, Sweden

R3: Techniques & Technology (Tuesday 10:00)

New tracking technologies have become available to ecologists, allowing remote real-time data capture from an increasing number of taxa, species and animals. To realize the potential of the data, researchers must be able to share data and collaborate with the global research community. The Wireless Remote Animal Monitoring (WRAM) database system, started in 2003, contains 92.0 million positions and other sensor data and is used to date by 31 user groups from 8 countries, tracking 15 species und 2071 individual animals. The infrastructure represents the Swedish national data node and data sharing portal for real-time telemetry sensor data from fish and wildlife. WRAM will be part of Swedish LifeWatch and is cooperating with several other international database initiatives. The infrastructure consists of 2 main parts: 1) The WRAM Data Warehouse (WDW) is a high performance data warehouse for real-time "big data" such as position, acceleration, or heartbeat data from fish and wildlife, hosted by the High Performance Computing Center North in Umeå, Sweden. 2) The WRAM Data Broker (WDB) is the single-sign-on web interface federating the WDW with other similar database systems around the world as MoveBank, EuroDeer or CAnMove to enable seamless querying across systems and easy data sharing between data owners, while honoring local authentication and authorization settings. Query results are also accessible through ODBC in a temporary database, enabling users to use local analysis tools for further analyses. Here, we give an overview over the different parts of the e-infrastructure, including automated data capture tools, database models, data sharing approaches, and web-based visualization tools. (holger.dettki@slu.se)

Somayeh Dodge[1], Gil Bohrer[2], Sarah C. Davidson[2,3], Rolf Weinzierl[3]

Environmental data track annotation with Env-DATA

[1]Department of Geography & Environmental Studies, University of Colorado, Colorado Springs, CO; [2]Department of Civil, Environmental & Geodetic Engineering, The Ohio State University, Columbus, OH; [3]Max Planck Institute for Ornithology, Radolfzell, Germany

T3: Environmental Data (Tuesday 10:00)

The Env-DATA System is a set of free web-based tools at Movebank (www.movebank.org) for linking animal movements with estimates of environmental conditions such as weather, land cover, topography, sea surface temperature and productivity that are available from a wide range of global environmental data products. The Env-DATA Track Annotation Service allows anyone to annotate tracking data on Movebank, providing estimates of hundreds of environmental variables for each time-location record in the tracking dataset. By automatically acquiring, transforming, and interpolating data, this service dramatically reduces the time and technical skill needed to annotate spatiotemporal data and address questions about the relationship between animals and their changing environmental context. By providing a consistent methodology for estimating environmental conditions experienced by individual animals anywhere in the world, the Env-DATA System and Movebank support the collaboration and meta-analysis that will be required to address many questions about animals' behavioral responses to changing environments and robustly test hypotheses about movement ecology.

In this tutorial we provide an overview of products available from the Env-DATA Track Annotation Service, describe how the system works, and show how to submit a request and understand the results. Any Movebank user can submit an annotation request for data that they have permission to download, and can use a growing number of publicly available datasets to try out the system before adding her own data. An easy-to-use interface allows users to browse available environmental products, select variables for annotation, submit a request, and receive an email when the annotated data are ready for download. Documentation on Movebank and in the readme file delivered with the results helps users to find relevant datasets, choose appropriate variables and understand the data they receive, such as the resolution of the original dataset, units and terms of use. During and after the tutorial we will collect feedback to help us plan future development of the Env-DATA System. (sdodge3@uccs.edu)

Bryant Dossman[1], Greg W. Mitchell[2], Stephen N. Matthews[1], Paul G. Rodewald[3]

The probability of departure from stopover in light of ecological context: behavioral adaptations in response to a migratory barrier

[1]School of Environment and Natural Resources, The Ohio State University, Columbus, OH; [2]Department of Biology, University of Western Ontario, London, ON; [3]Cornell Lab of Ornithology, Ithaca, NY

R2: Migration (Monday 15:00)

Migratory barriers have long been implicated on their role in influencing decisions and behaviors during migration. However, no study has compared how decisions relating to departure from stopover differ across a migratory barrier. Using two automated radio telemetry systems—on the south and north coast of Lake Erie—we sought to identify 1) the primary factors that influence the probability of departure during spring migration and 2) the extent to which Lake Erie serves as a barrier to migration. We found that fuel reserves upon capture and favorable tail wind conditions were correlated with a greater probability of departure for both American redstarts *Setophaga ruticilla* and Yellow-rumped (Myrtle) warblers *Setophaga coronata coronata*. It was also determined that these relationships did not differ between species with arguably differing migratory tactics suggesting that there may be underlying generalist rules for departure. Furthermore, we found that post-crossing birds were in significantly poorer condition upon capture than pre-crossing. Interestingly, despite the strong effect of fat upon capture on the probability of departure, stopover duration did not differ between sites suggesting that in terms of duration, it does not appear that Lake Erie serves as an appreciable barrier to migration. It can further be hypothesized that birds employ two potential strategies during stopover that enable individuals to compensate for any delays imposed by reduced condition post-crossing. Individuals can either 1) simply depart with lower fuel reserves than pre-crossing birds, or 2)

individuals may be increasing foraging intensity and refueling more quickly. This study is the first to compare the extent to which migratory barriers influence the relationship between endogenous and exogenous factors on the probability of departure from a stopover site. By understanding how migratory barriers influence both the duration of stopover and potential behaviors, we are better able to predict the importance of stopover habitat (extent and quality) in relationship to ecological context. (dossman.2@osu.edu)

David Douglas

Accuracy assessment of Argos Kalman filter location processing

U.S. Geological Survey, Alaska Science Center, Juneau, AK

R3: Techniques & Technology (Tuesday 11:00)

In 2011, CLS (Service Argos) introduced a new method for estimating locations of Doppler-type satellite transmitters. Compared to the legacy least-squares (LS) processing method, the new method applies a Kalman filter (KF) and a user-defined maximum transmitter speed to constrain location errors and to provide location estimates from single-message satellite overpasses. Unless users specifically instruct CLS otherwise, KF processing is applied to new tracking applications with default transmitter speeds of 10 m/s, 16 m/s, and 16 m/s for marine animal, terrestrial animal, and bird tracking, respectively. We used tracking data (Doppler and GPS) obtained from 12 polar bears and 9 bald eagles to compare the number and accuracy of locations derived with LS and KF processing. Accuracy of the LS and KF locations were judged using coincident (+/- 30 min) GPS locations. Compared to LS, KF processing produced 59% and 11% more bear and eagle locations respectively. While KF processing generated modest increases in the number of standard quality (LC 3, 2, or 1) locations, the majority (90% and 70%, respectively) of additional bear and eagle locations produced by KF were those derived from 1-message overpasses. The polar bear transmitters were predisposed to disproportionately benefit from KF processing owing to atypically large transmission pulse rates (130-200 seconds). Among all animals, accuracy (defined as the 67th percentile of the pooled error distribution) of standard quality locations in the raw KF data was somewhat poorer (10% larger error) compared to raw LS data, but accuracy among auxiliary classes (LC 0, A, B) in the KF data was substantially improved (40% smaller error). Although raw KF auxiliary location classes have markedly improved accuracy, applying a filtering strategy to constrain the upper error distribution remains advisable and effective. We present comparative results of filtering LS and KF location data using 3 approaches: the Douglas Argos-filter algorithm, a Bayesian state-space model, and a continuous-time correlated random walk model. (ddouglas@usgs.gov)

Hendrik Edelhoff, Niko Balkenhol

Detection of potential dispersal behavior in Red Deer *(Cervus elaphus)* movement paths: an application for landscape resistance modeling

Department of Wildlife Sciences, Georg-August University Göttingen, Göttingen, Germany

R5: Ecology of Mammals (Tuesday 13:40)

Telemetry data is increasingly used to quantify the influences of animal movement behavior on habitat selection, because habitat preferences may vary between different behavioral states (e.g. foraging versus dispersal). Therefore, analyzing and segmenting individual movement paths with regard to changes in movement modes can be a valuable tool for understanding behavior-specific habitat selection. Several methods have been proposed for determining behavioral states from movement data. Considering behavior-specific habitat preferences may also help to improve management and conservation guidelines derived from telemetry studies. For example, path segments of exploratory and potential dispersal movements can be used to model functional landscape connectivity and for delineating dispersal corridors. In our study, we analyzed GPS telemetry data of 23 Red Deer *(Cervus elaphus)* individuals from Northern Germany to quantify specific dispersal habitat preferences. We implemented a Behavioral Change Point Analysis on the persistence velocity time series to determine changes in movement behavior within the individual movement paths. Only change points determined for at least two times were considered for the path segmentation. For all resulting segments, total path length, number of steps included,

path sinuosity and mean persistence velocity were recorded. In the next step, K-Means clustering of the segment characteristics was used to detect similar structures within the path segments. The cluster with the highest medians regarding total path length, path sinuosity, and persistence velocity was defined as potential dispersal behavior. Similarly, the cluster with the lowest medians was considered foraging movement.

We next applied a Brownian bridge movement model to link resource utilization along the dispersal path segments with habitat variables. The resulting habitat model was than employed to develop a landscape-resistance model, which can be used for determining potential movement corridors. The results underline the effectiveness of path analyses to determine potential dispersal movements and their application for quantifying behavior-specific habitat preferences. Furthermore, the approach provides new insights in species-specific functional connectivity. Therefore, it can also improve management measures to maintain dispersal corridors and gene flow in fragmented landscapes. (hendrik.edelhoff@gmail.com)

Aaron Facka, Roger A. Powell

Identification of occupied home ranges using travel distances, changes in speed and final settlement of translocated fishers *(Pekania pennanti)*

Department of Applied Ecology, North Carolina State University, Raleigh, NC

R5: Ecology of Mammals (Tuesday 14:00)

Animals establish and maintain home ranges to ensure access to important resources such as food, shelter, or mates. Experience and information pertaining to resources should be advantageous to the occupier of a home range compared to conspecifics that frequent other areas. Since interlopers into a home range are less competitive at exploiting limited resources it benefits them to spend limited time and energy in areas that are already occupied. Thus, animals that are dispersing or that have no established home range (e.g., translocated animals) should move quickly and as efficiently as possible when they encounter the home ranges of existing animals. Further, when and where individuals exhibit such behaviors could be used to identify the home ranges of animals that we have no knowledge of. We tested these ideas by studying fishers *(Pekania pennanti)* that were translocated into the Northern Sierra Nevada of California in 2009-2010, and 2010-2011, and 2011-2012. Using satellite transmitters (Argos) and land-based (VHF) telemetry we made daily observation of fisher locations and movements immediately after release and through the development of their home ranges. Fisher released in the first year averaged maximum movements from their release point of 10 km (SD = 6.2) for females and 33 km (SD = 19.3) for males. The centers of their home ranges averaged 3.5 km (SD = 1.54) females and 32.8 km (SD = 19) for males. Comparison of females fisher released in the second year moved an averaged maximum movements from their release of 13.5 km (SD = 4) for females and 22.2 km (SD = 19) for males. In the third year we placed 4 individuals in locations away and 3 within the established home ranges of the known home ranges of earlier released animals to compare their movements to animals from earlier years. Individuals moved quickly through the home ranges of animals released during all years. We identified fishers moving through 4 home ranges of fisher that were lost from telemetry contact, but suspected to be alive. Fisher released during year 2 and 3, and within already established home ranges, moved faster and further than did animals released in year 1 or those released outside of known home ranges. Trapping and detection by baited camera station revealed that at least 2 of those home range continued to be occupied. Generally, newly released animals responded very quickly to the presence of already established home ranges and the speed of their movements is a promising index of whether areas are occupied by existing animals. (anfacka@ncsu.edu)

William F. Fagan, Sharon Bewick, Steven Cantrell, Chris Cosner
Information gathering and movement in dynamic landscapes
University of Maryland, College Park, MD

R6: Accelerometry & Group Dynamics (Wednesday 10:10)

Real landscapes are dynamic in space and time, and the scale over which such variation occurs can determine the success of different strategies of population growth and movement. Real species rely on a variety of individual-level behaviors to move in and navigate through their landscapes. One such behavior is 'oriented movement' in which animals move in response to cues that occur within their perceptual range.

Inputs from many different sensory modalities determine the extent of perceptual ranges, which represent the spatial extent of the region from which animals can acquire information about their surroundings. From behavioral studies, we know that such information, which might include such sources as vocalizations from conspecifics or visual detection of resources, can have a strong influence on movement.

Here I will present original results from investigations of a spatially explicit mathematical model in which we use integrodifferential equations to represent non-local information gathering. In this set-up, the balance between population growth and decay hinges upon the degree of match (or mismatch) between an animal's perceptual range and the critical spatial scales of its landscape. Such integrodifferential models are intriguing in this context because they provide a reasonable approximation to the underlying biology but represent a substantial departure from the assumptions and structure of the kinds of mathematical models most commonly used to study animal movement. (bfagan@umd.edu)

Damien R. Farine[1,2,3], Ariana Strandburg-Peshkin[4], Meg C. Crofoot[1]
Identifying social and non-social affiliations in proximity networks of animal groups on the move
[1]Department of Anthropology, University of California Davis, Davis, CA; [2]Smithsonian Tropical Research Institute, Panama; [3]University of Oxford, Oxford, UK; [4]Princeton University, Princeton, NJ

R6: Accelerometry & Group Dynamics (Wednesday 9:50)

How group movements are influenced by social relationships between participants is a central question in collective animal behaviour. Spatial associations are often assumed to reflect affiliative relationships, and proximity networks are increasingly being integrated into collective movement models as modulators of influence (i.e. behaviour is thought to be more strongly impacted by nearby group-mates than those that are far away). However, spatial proximity may be driven by multiple factors, both social and non-social. We use high-resolution GPS tracking of a troop of Anubis baboons in order to isolate the social components of proximity networks from effects arising due to preferred individual positioning. This spatial assortment can lead to non-random edges in a proximity network, such as between two dominant males consistently found in safer central positions, that are independent of affiliative relationships. By identifying how individual traits—sex, age and dominance—influence positioning in baboons on the move, we construct a framework for partitioning edges in a dynamic proximity network. By identifying social dyads, this framework gives us a deeper insight into the component of individual movement decisions that are driven by affiliative relationships, and subsequently how within-group social structure impacts movement at the troop level. (damien.farine@zoo.ox.ac.uk)

Claude Fischer[1], Julien Fattebert[2], Rob Slotow[2]

Influence of disturbance regimes and landscape characteristics on wild boar space use patterns in a human dominated landscape

[1]University of Applied Sciences of Western Switzerland, Jussy, Geneva, Switzerland; [2]School of Life Sciences, University of Kwazulu-Natal, Durban, South Africa

R5: Ecology of Mammals (Tuesday 15:00)

Home-range size, placement and use reflect the distribution of limiting resources that animals access to meet ecological requirements, while simultaneously interacting with conspecifics to increase individual fitness. Space-use patterns are influenced by habitat productivity and food availability, body mass and related size-specific metabolic rates, and mating system. Harvest regimes can also affect space-use patterns in creating a contrasting landscape of fear. We used 6 years of VHF telemetry data collected in three distinct areas of the Basin of Geneva, 2003–2008 to test the effect of various disturbance regimes on wild boar space use patterns. We used a GLM framework to explore the influence of sex, season, disturbance regime and study area on the size of total seasonal home-ranges, and diurnal (resting sites) and nocturnal (foraging period) home-ranges. Preliminary results show that 90% MCP seasonal home-range size of wild boar differed between sexes and among populations. Male home-ranges (mean ± SE : 3.6 ± 0.4 km2, n= 73) were significantly larger than female home-ranges (1.7 ± 0.1 km2, n= 246). Among subpopulations, home-ranges in the Geneva countryside were marginally smaller (1.8 ± 0.3 km2, n= 105, $p<0.1$) than in the other two subpopulation in France (2.2 ± 0.2 km2, n= 159) and in the Versoix region (2.6 ± 0.4 km2, n= 55). Sex only affected the size of diurnal or nocturnal home-ranges. Male diurnal seasonal home-ranges (3.3 ± 0.5 km2, n= 32) were significantly larger that females' (1.4 ± 0.1 km2, n= 133). Male nocturnal seasonal home-ranges (3.0 ± 0.5 km2, n= 44) were significantly larger that females' (1.6 ± 0.1, n= 146). Wild boar home-ranges in the Basin of Geneva were among the smallest recorded for the species in Europe, consistent with high density found in the study area. The mild climate, absence of natural predator and abundance of food resources throughout the year, including diverse crops, most likely contribute to these space use patterns, despite a high anthropogenic pressure and low forest proportion. Further detailed analyses are needed to understand the influence of more fine scaled environmental variables such as land-use and anthropogenic structures in the habitat selection patterns and the movement patterns of wild boar in these three subpopulations. (claude.fischer@hesge.ch)

Chris Fleming[1,2], Thomas Mueller[1,2], Kirk A. Olson[1], Peter Leimgruber[1], Bill F. Fagan[2], Justin M. Calabrese[1]

Linking statistics of movement to resource dynamics

[1]Smithsonian Conservation Biology Institute, Front Royal, VA; [2]University of Maryland, College Park, MD

R4: Movement Models (Tuesday 13:40)

Both animal movement and resource dynamics can be modeled in a sampling-independent or "scale-free" way as continuous-time, continuous-space stochastic processes and parametrized in terms of the biologically relevant spatio-temporal scales that characterize their behavior. We previously modeled the movement of Mongolian gazelle with a short ballistic scale and long ranging scale. Here we analyze the NDVI data contained within the gazelles' individual ranging areas and quantify the characteristic time and length scales for which the vegetation is autocorrelated. The characteristic scales of movement and resource dynamics are then compared at the individual level to test for possible movement mechanisms without having to assume any particular model by which resources drive movement. Results of this comparison reveal that NDVI drives the long ranged movement of the gazelles. (chris.h.fleming@gmail.com)

John Fryxell[1], Anna Mosser[2], Tal Avgar[3], Ian Thompson[4], Glen Brown[5], Jen Shuter[5], Art Rodgers[5]
Accelerometry, behavior, and movement ecology of free-ranging woodland caribou
[1]University of Guelph, Guelph, ON, Canada; [2]University of Minnesota, Twin Cities, St. Paul, MN; [3]University of Alberta, Edmonton, AB, Canada; [4]Natural Resources Canada; [5]Ontario Ministry of Natural Resources, ON, Canada

R6: Accelerometry & Group Dynamics (Wednesday 11:10)

Energetic balance is thought to be a key determinant of demographic rates, yet estimating energetic costs in free-ranging animals presents significant challenges. Animal-borne activity monitors (using accelerometer technology) combined with behavioral assessment (using on-board video cameras) present a promising method for meeting this challenge. We monitored accelerometry, behavior, and movement on 34 free-ranging caribou in northern Ontario as well as corroborating these relationships on captive animals. Accelerometry was capable of predicting with reasonably high precision coarse categories of behavior (lying down, feeding, standing, running) that differ in energetic costs. Both captive and free-ranging studies revealed positive relationships between activity level based on accelerometry and energy expenditure. Activity patterns based on accelerometry scores were then measured over thirteen months for 131 free-ranging woodland caribou *(R. t. caribou)* spanning 450,000 km2 in northern Ontario. Individual displacement was strongly related to integrated accelerometer scores. After accounting for displacement, activity was significantly influenced by vegetation abundance (presumably due to foraging), snow depth (presumably associated with digging for winter forage), and temperature (suggestive of behavioural thermoregulation by caribou). (jfryxell@uoguelph.ca)

Joan Garriga, Frederic Bartumeus
EMbC: an algorithm for behavioral annotation of animal movement
ICREA-Movement Ecology Lab (CEAB-CSIC), Blanes, Girona, Spain

T5: Track Segmentation & Interaction (Wednesday 14:00)

The growing capacity to process and store animal tracks has spurred the development of new methods to segment animal trajectories into their elementary units of movement: behavioural modes. Key challenges for movement trajectory segmentation are to (i) minimize the need for supervision, (ii) limit analytical complexity (number of parameters and prior assumptions), (iii) avoid sensitivity to prior assumptions and/or initial values, and (iv) capture sufficiently general and biologically meaningfully semantics.

We present the EMbC algorithm (Expectation-Maximization binary Clustering) for behavioural annotation. This algorithm is a variant of the Gaussian Mixture Model maximum likelihood estimation algorithm, also known as Expectation-Maximization Clustering.

The EMbC algorithm fills a gap in movement trajectory segmentation procedures by reaching a good compromise between meaningful and easily interpretable behavioural segmentation and sound (and robust) statistical performance. As an unsupervised and non-intensive computing method, the EMbC algorithm is particularly suited for big data and large scale analyses where comparisons across species, sampling schemes, tracking technologies, and ecological contexts are looked for. (jgarriga@ceab.csic.es)

Oz Garton, Jon Horne, Adam Wells, Janet Rachlow, Harry Jageman
Synoptic modeling of animal locations: ask important questions by simultaneously estimating home range and resource selection in an information theoretic framework
Department of Fish and Wildlife, University of Idaho, Moscow, ID

T1: Movement Models & Resource Selection Functions (Monday 10:00)

A new approach to analysis of animal location data combines animal movements, home range and resource selection analyses into a synoptic model of space use which can be used to ask important questions about ecology and management of animals. This approach entails 11 steps to develop a synoptic model which begin with classic steps of the scientific method including defining research question(s) and animal populations to sample, identifying

potentially important strata (e.g., age-sex-behavior classes, temporal seasons). Next it is critical to list interesting and important ideas (hypotheses) about ecological factors, processes or drivers determining patterns of space use prior to selecting a null model for space use. The ideas (hypotheses) must be stated in the form of multiple parametric (synoptic) models in which parameters express effects of key ecological factors or processes that can be estimated with maximum likelihood methods, and use information theoretic methods to evaluate competing models. Assembling potentially predictive covariate maps makes it feasible to fit and evaluate the multiple competing synoptic models. We illustrate development of synoptic models for Barren ground caribou in Central Alaska USA, white rhino males in Matobo National Park, Zimbabwe, mountain goats in Cascade Mountains, Washington, USA and Northern Pygmy Owls in managed forests of Northern Idaho, USA. (ogarton@uidaho.edu)

Michael Hallworth[1], T. Scott Sillett[1], Steven L. VanWilgenburg[2], Keith A. Hobson[2], Peter P. Marra[1]
Migratory connectivity of a Neotropical migratory songbird revealed by archival light-level geolocators
[1]Migratory Bird Center, Smithsonian Conservation Biology Institute, National Zoological Park, Washington, D.C.; [2]Environment Canada

R2: Migration (Monday 16:20)

Understanding the linkage between breeding and non-breeding locations is critical for effective conservation strategies of migratory species. We evaluated the migratory connectivity of Ovenbirds *(Seiurus aurocapilla)* by combining data from archival light-level geolocators recovered during breeding and non-breeding seasons and USGS bird band recoveries. Our results suggest a complete separation of eastern and western populations throughout the annual cycle. Breeding Ovenbirds from western Canada spent the non-breeding season throughout Central America and migrated through the North American central flyway. Birds breeding in northeastern United States were distributed in the Greater Antilles and migrated through the Eastern flyway. Incorporating Ovenbird abundance as prior information in a Bayesian framework improved area of origin estimates compared to geolocator estimates alone. Ovenbirds exhibited strong connectivity at broad spatial scales but weaker patterns within sub-populations, which has important implications for various aspects of ecology and conservation for this species. (mhallwor@masonlive.gmu.edu)

Roi Harel, Ran Nathan
Age-related variation in soaring-gliding performance of vultures
Department of Ecology, Evolution and Behavior, Alexander Silberman Institute of Life Sciences, The Hebrew University of Jerusalem, Jerusalem, Israel

R2: Migration (Monday 13:20)

Individual animals generally gather experience and improve performance with age, most pronouncedly at early stages of life, by establishing skills and refining decisions. Low performance in basic functional tasks might have detrimental consequences for the individual, and could explain the relatively high mortality rates of juveniles observed in nature. Soaring-gliding birds utilize energy from the environment by using rising air columns (thermals) and orographic lifts. Based on ample evidence from glider pilots, the capacity to optimally exploit such resources varies with experience, and differences in thermalling performance are known to have substantial direct movement costs. Assessing thermalling performance in birds requires recording movement paths in high spatiotemporal resolution, a rather challenging task, hence intraspecific differences in soaring-gliding performance of birds remain largely under-investigated.

In this study, we examined how soaring-gliding performance—both within thermals and over daily foraging journeys—varies with age in an avid soaring bird, the griffon vulture *(Gyps fulvus)*. GPS/ACC/GSM solar transmitters were deployed on 17 individuals, 9 juveniles and 8 adults, recording their movement paths in high temporal sampling frequency (1 Hz) for 12±2 (mean±SE) days. We found that individuals in the first months of their life climbed thermals in a lower rate, spent more time thermalling and expended more energy per unit time (as inferred from their higher Overall Dynamic Body Acceleration) during flight, compared to adult birds in the same site.

Therefore, juvenile vultures have lower performance and higher costs, presumably due to their lower flight experience, and their soaring-gliding flight is much less cost-effective than adults. The fitness consequences of this handicap are probably further enhanced if juveniles are preceded by adults in terms of finding and/or arriving to a new carcass and in feeding hierarchy. (roi.harel@mail.huji.ac.il)

Paul Holloway, Jennifer A. Miller

User decisions in step-selection functions: how selection of model parameters influences the relationship between animal movement and the environment

University of Texas at Austin, Austin, Texas

R4: Movement Models (Tuesday 15:40)

A step-selection function (SSF) is a powerful method which quantifies the environmental influences of animal movement and is an important tool in identifying for developing conservation strategies associated with landscape connectivity. An SSF is calculated using conditional logistic regression to differentiate between environmental factors associated with a step actually taken by an individual compared to a set of potential random steps. This method is increasingly being applied to address biogeographical questions, but there has been little research on how parameters specified in the model building phase affect the results. This research quantitatively assesses how user decisions influence the coefficients of the subsequent regression models for oilbirds and brown hyenas. Systematically altering the method of generating available steps, the number of steps used, the number of individuals in the model, the method of conditional logistic regression (population versus individual), we found that user decisions strongly influence the results of step-selection functions and any subsequent inferences about animal movement and environmental interactions. The largest significant differences occurred between as a result of conducting a population level regression model and compared to an individual level model, highlighting the importance idiosyncratic preferences of the individuals used in the model and the importance of the user to acknowledge such. Differences were found between categories for every variable used in analysis and will inform SSF practitioner's with further information with which to develop SSF research and reduce uncertainty when discussing results. (paul_holloway@utexas.edu)

Ryan Huang[1], Stuart L. Pimm[1], Oron L. Bass, Jr.[2]

Investigating anthropogenic and environmental impacts on sooty tern survivorship

[1]Duke University, Durham, NC; [2]Everglades National Park, FL

R7: Ecology of Birds (Wednesday 15:00)

Seabirds often make for useful sentinel species of ocean health due to their abundance and expansive ranges. This makes determining sources of mortality and locations of migratory and feeding routes crucial. The sooty tern *(Onychoprion fuscatus)* is a common seabird that breeds at the Dry Tortugas National Park and has the typical characteristics of a sentinel species. Here I will present animal tracking data of the sooty tern using two types of data, data loggers that measure daylight in addition to satellite transmitters. In order to determine survivorship requires me to understand hurricane induced mortality by incorporating climate data in addition to tracking seabird movement. This data will help answer the questions of how anthropogenic disturbances and fisheries impact seabird populations while accounting for background mortality rates caused by the natural disturbances of the ecosystem. (ryan.huang@duke.edu)

David Jachowski[1], Rob Slotow[2], Joshua J. Millspaugh[3]

Linking animal physiology and movement behavior: a case study of the African elephant

[1]Virginia Tech, Blacksburg, VA; [2]Amarula Elephant Research Programme, School of Life Sciences, University of KwaZulu-Natal, Durban, South Africa; [3]Department of Fisheries and Wildlife Sciences, University of Missouri, Columbia, MO

R1: Physiology and Disease (Monday 10:20)

Animal movement is known to be a complex association of factors, including navigation and motion capacity, external conditions, and internal state. Of these factors, internal state is perhaps the most difficult to monitor and

often overlooked component of animal movement ecology. To date, most attempts to incorporate internal state into movement ecology have been indirect, such as the inference of internal state based on movement path characteristics. However, modern, non-invasive physiological assay techniques allow for the simultaneous collection physiological data in conjunction with animal movement data. This type of simultaneous monitoring not only identifies movement patterns when animals are in differing internal states, but potential mechanisms behind observed movement behaviors. As a case study, we present results from long-term simultaneous monitoring of wild African elephant physiology and movement in South Africa. We found that elephant family groups in elevated physiological states exhibited distinct movement patterns indicative of refuge behavior. Further, family groups in elevated physiological states were more likely to make quick, streaking movements along corridors among refugia during nighttime than elephant family groups in basal physiological states. Given elephants in elevated physiological states can be more prone to aggression towards humans, knowledge of when elephants are likely in differing internal, physiological states based on elephant movement behaviors can be used to help mitigate human-elephant conflict. For example, by combining real-time GPS tracking data with computer-based monitoring, managers can create virtual fences that provide alerts when elephants enter refugia, corridors, or leave protected area boundaries—allowing for reactive management that limits human-elephant conflict and enhances long-term African elephant conservation. (djachowski@gmail.com)

Landon Jones[1], Derek M. Johnson[2]

Do toucan movements mitigate clumped patterns of seed dispersal in fragmented tropical forest habitat?

[1]University of Louisiana Lafayette, Lafayette, LA; [2]Virginia Commonwealth University, Richmond, VA

R7: Ecology of Birds (Wednesday 14:00)

The movements of animal dispersers create the spatial template upon which plant demography is based, especially in the tropics, where over 80% of tree species rely upon animals to disperse their seeds. Previous research and mathematical simulations indicate that fragmentation of tropical forest habitat for human use can increase clumped patterns of animal-mediated seed dispersal compared to continuous forest. We tested the hypothesis that large animals are able to mitigate the effects of clumping on seed dispersal in fragmented tropical forest by moving long distances before dispersing seeds, producing patterns comparable to those found in continuous forest. We radio-tracked 23 individuals of two species of toucans, the Collared Aracari *(Pteroglossus torquatus)* and Keel-billed Toucan *(Ramphastos sulfuratus)*, in a fragmented mosaic of agricultural habitats and secondary rainforest in Turrialba, Costa Rica from January 2011 to May 2012. We estimated seed dispersal by toucans in mathematical simulations parameterized from these movement data and seed retention times from an additional study with captive individuals. Simulations indicated that toucan movements created even patterns of seed dispersal in fragmented habitats, comparable to those in continuous forest habitat based primarily on the use of four key structures in agricultural habitats: forest edge, agricultural plantations with trees, live fences, and remnant trees. (lrj1327@louisiana.edu)

Erik Kleyheeg[1], Merel B. Soons[1], Bart Nolet[2], Jacintha van Dijk[2]

Spatiotemporal variation in landscape use by mallards in Dutch wetlands

[1]Utrecht University, Utrecht, the Netherlands; [2]Netherlands Institute of Ecology, Wageningen, the Netherlands

R7: Ecology of Birds (Wednesday 15:20)

Waterbirds are increasingly recognized as major players in wetland ecosystem functioning, for example contributing to dispersal of plants and invertebrates, spread of viruses and wetland eutrophication. This role is, however, dependent on the spatial scale of their landscape use. In the context of seed dispersal we analyzed the spatiotemporal variability of movement patterns in mallards *(Anas platyrhynchos)* in the Netherlands during the non-breeding season. We collected GPS data from 102 male mallards between august 2012 and February 2013 in four landscape types varying in wetland connectivity. We tested the effect of landscape configuration, seasonality, weather parameters and body condition on several movement parameters, including flight frequencies and distances, site fidelity and time budgets. Overall we found a strong diurnal movement pattern, highly dependent on

seasonal variation in day length. Most mallards leave their day roost shortly after sunset for nocturnal foraging in nearby, semi-natural, wet habitats, returning to the same day roost before sunrise. There was high fidelity to both roost and foraging sites, especially in landscapes with presumably high resource availability. Local movements were short, ranging from <100 meters up to several kilometers, resulting in small home range sizes. However, the spatial scale of these movements was highly negatively correlated with the availability of suitable habitat, meaning that mallards fly longer distances in drier landscapes, rather than staying at a combined roost and foraging site. This implies that habitat loss will on one hand result in higher energetic costs for mallards as they have to fly longer distances, but on the other hand enhance the impact of mallards as dispersal agents, forming a biotic connection between remnant plant and invertebrate populations in isolated habitat patches. Natural infection with avian influenza virus did not affect the local scale movements of mallards, although infected birds had a slightly lower body condition. We could also not identify an effect of temperature, rain or wind on movement parameters, although fleeing to larger, open water was observed during a cold spell. In summary we conclude that Dutch mallards show a very predictable, repetitive movement pattern in the non-breeding season. Our next aim is to simulate mallard movements in a spatially explicit model in order to quantify the relative importance of different landscape features and to quantify their role in dispersal of plant seeds. This could allow extrapolation of our results to other landscapes and leads to better understanding of the role of mallards in ecosystem functioning. (E.Kleyheeg@uu.nl)

Andrea Kölzsch[1], Gerhard J.D.M. Müskens[2], Helmut Kruckenberg[3], Martin Wikelski[1]

Goose family behaviour decoded by accelerometers and high-frequency GPS

[1]Max Planck Institute for Ornithology, Radolfzell, Germany; [2]Alterra Wageningen-UR, Wageningen, the Netherlands; [3]Institute for Wetlands and Waterfowl Research e.V., Germany

R6: Accelerometry & Group Dynamics (Wednesday 10:50)

Most species of migratory geese fly between their breeding and wintering grounds in family groups. Some families even stay together all winter and during the first spring migration. So, from observation studies it has been concluded that the juveniles learn migration timing, the route and about foraging opportunities from their parents. However, how exactly this knowledge is passed on is still unknown. What is the role of each of the parents and do the young stay close to them at all times? To pursue those questions we have tagged 14 adult and 6 young greater white-fronted geese *(Anser a. albifrons)* in family groups in their Russian breeding sites using GPS transmitters with 3D accelerometers. Additionally, in the wintering grounds 3 complete families (each with 2 adults and 2 young) were caught and equipped with such a tag. High resolution positions and accelerometer measurements that were downloaded during the winter provide insights in the foraging and social behaviour of those geese in the breeding sites, during migration and in the winter. First results from the breeding sites indicate that compared to the parents the young geese move much more, but usually stay very close to their parents. However, the young also seem to take small detours, during which they seem to stay together with their siblings. We expect to see similar dynamics during migration and wintering as families aggregate into larger flocks. From GPS tracks of adult white-fronted geese of the same population that were collected in 2006–2010 we know that they migrate in a narrow front from the Russian Tundra to their Central European wintering sites, stopping at sites along the sea or on large lakes to refuel. There was high variation in timing of autumn migration between years and individuals indicating that it is important for young geese to learn about the correct cues and suitable stopover sites. Such knowledge will influence their future survival and reproductive success, giving us baseline insight into the beginning of complete life time tracks of individual animals. (akoelzsch@orn.mpg.de)

Bart Kranstauber

Dynamic Brownian bridge movement models

Max Planck Institute for Ornithology, Radolfzell, Germany

T4: Movement Metrics (Wednesday 10:00)

The recently developed Brownian bridge movement model has advantages over traditional methods because it quantifies the utilization distribution (UD) of an animal based on its movement path rather than individual points and accounts for temporal autocorrelation and high data volumes. Based on this model, the recently developed dynamic Brownian bridge movement model (dBBMM; Kranstauber et al. 2012) allows the user to estimate the UD of animals with heterogeneous behavior. This new method provides a more accurate utilization distribution that better describes the space use of realistic, behaviorally heterogeneous tracks.

In this tutorial, I will show how a UD is calculated using the brownian.bridge.dyn function and use it for data visualizations using the R package move. Attendees must have the most recent versions of program R and the move package installed on their machines. For those unfamiliar with the move package there is an introduction tutorial beforehand. This hands-on tutorial will use a provided movement data set and also provide attendees with an opportunity to explore their own data sets afterwards.

Reference: Kranstauber, B., Kays, R., LaPoint, S., Wikelski, M. and Safi, K. (2012), A dynamic Brownian bridge movement model to estimate utilization distributions for heterogeneous animal movement. Journal of Animal Ecology, 81: 738–746. (kranstauber@orn.mpg.de)

Bart Kranstauber, Scott LaPoint

The R package move

Max Planck Institute for Ornithology, Radolfzell, Germany

T4: Movement Metrics (Wednesday 9:30)

The move package facilitates the easy handling and analysis of animal movement data stored at www.movebank.org. The package provides functions to import, visualize and analyze animal movement related data in an object-oriented way. The introduced classes allow users to store data that are related to an individual in one object, such as coordinates, timestamps, animal id, species, age, sex, study id, etc. This makes working with multiple animals, tags, and studies much easier. In addition to facilitating online data importation, the move package also contains several unique analyses functions, including utilization estimates (e.g., brownian.bridge.dyn) and the corridor function. See subsequent tutorials.

We will provide an introduction into data import and exploration using the move package. Attendees must have the most recent version of program R and the move package installed on their machines. Attendees will learn how to import animal location data from www.movebank.org, including how to handle multiple individuals and tags as a moveStack. We will demonstrate how to query www.movebank.org for study details, species, and users. We will also calculate summary statistics, (e.g., mean speed and turning angle), and visualize the data with the plot() function. The move package also allows users to subset their data sets into bursts by the temporal, spatial, and behavioral properties of the data set (e.g., day versus night, or migration versus breeding).
(kranstauber@orn.mpg.de)

Chi Hin Lam, Benjamin Galuardi

Where are my tags? Go ask Nagbase

Large Pelagics Research Center, University of Massachusetts Amherst, Gloucester, MA

R3: Techniques & Technology (Tuesday 10:20)

In this age of smartphones and tablets, gadgets are often misplaced and lost—at an estimated global cost of $7 million per day (www.backgroundcheck.org/world-of-lost-smartphones). Tagging programs that grow in scope,

continue across years and utilize ever changing technology often lack a unified inventory system which complicates the seemingly simple question: "Where are my tags?" A classic, simple inventory control database in Microsoft Access (nicknamed Nagbase) built to track electronic tags used by the Large Pelagic Research Center (www.tunalab.org) is presented. A lifetime approach is taken to follow the history of a tag from its order and delivery, storage, testing, field operations, deployment to recovery. Emphases are placed to ensure tags were not lost in transit among collaborators or returning unused from the field. Event logs allow identification of hardware and software issues, tag condition, and most importantly, the fate of a tag that is reused or refurbished. Deployment metadata, including environmental conditions and biological information, is stored for easy reference. Cost savings from identifying unused Argos PTT as well as understanding tag performance issues are just a few of the additional benefits. While MoveBank (www.movebank.org) provides useful Argos support, a local database like Nagbase allows customizations for group level notifications and connectivity to downstream data management and processing. We will demonstrate a workflow linking free or low-cost software and web services, like Gmail and Google Maps, in generating email alerts and routine reports for all your tags. (tagtuna@gmail.com)

Scott LaPoint

Animal-defined movement corridors

Max Planck Institute for Ornithology, Radolfzell, Germany

T5: Track Segmentation & Interaction (Wednesday 13:00)

Landscape connectivity is integral for preserving ecosystem function. Models that identify landscape features that promote connectivity (e.g., corridors) are powerful and increasingly employed, yet require assumptions on animal movement that may unnecessarily generalize animal behavior. We developed a simple model of "corridor behavior" based on the speed and turning angles from GPS- tracking collars deployed on free-ranging individuals. We compared our model corridor identifications with those predicted by two popular resistance-based models (i.e., least-cost path analysis and circuit theory) using detection rates of camera traps. The cost-based models poorly predicted the location of the observed corridors. We believe this is due not to the models themselves, but because the information used to build the resistance layers ignores the distinction between corridor use and habitat selection.

The purpose of this tutorial is to introduce attendees to the animal-defined corridor model with the program R function corridor of the move package. Attendees must come with the most recent versions of program R and the move package installed on their own machines. For those unfamiliar with the move package there is an introduction tutorial beforehand. I will provide an overview of the animal-defined model and show attendees how to import animal location data from www.movebank.org via the move package. Then, we will work through the steps of the corridor function with data and step descriptions. We will end with questions, comments, and opportunities for attendees to explore the corridor function with their own data.

Reference: LaPoint S.D., Gallery P., Wikelski M., Kays R. (2013) Animal behavior, cost-based corridors, and real corridors. Landscape Ecology, 28: 1615–1630. (sdlapoint@gmail.com)

Marcus Lashley, M. Colter Chitwood, Roland Kays, Craig A. Harper, Cristopher S. DePerno, Christopher E. Moorman

White-tailed deer burn unit selection and site fidelity following prescribed fire

North Carolina State University, Raleigh, NC

Frequent growing-season fires are used to restore and maintain the longleaf pine *(Pinus palustris)* ecosystem. However, little is known about fire effects on wildlife species that may be sensitive to fire timing and season. Because the lactation period in white-tailed deer *(Odocoileus virginianus)* co-occurs with the targeted burn season (May–June) in contemporary fire regimes, adult female deer may be positively (increased forage quality) or negatively (decreased cover and/or forage density) affected by burning during this period. In June–August 2011 and 2012, we used GPS data from 16 adult female deer to assess the effects of fire season and time-since-fire on

burn unit selection, space use (i.e., 95% home range and 50% core area sizes), and core area site fidelity (i.e., area of overlap in core area between years). Using a compositional analysis, we determined deer selected unburned drainages and burn units ≥1yr-since-fire, essentially avoiding burn units burned in the same growing or dormant season. With increasing percentage of home range burned, the size of the core area increased, while the size of the home range was unaffected. Furthermore, site fidelity decreased as the percentage of the 2011 core area burned in 2012 increased, and as a greater percentage of the 2012 core area was burned, site fidelity increased. Because fire decoupled forage quality and cover, we were able to determine cover and/or forage availability was the more important resource to white-tailed deer even when nutritional stress was high. Deer avoided recently burned burn units in lieu of increased forage quality, likely because they needed cover to mitigate predation risk. Furthermore, it appears home range establishment was dictated by intraspecific competition and social structure, whereas core area size was strongly linked to the availability of cover within the home range. (marcus_lashley@ncsu.edu)

Nicolas Lecomte[1], Vasiliy Sokolov[2], Aleksandr Sokolov[2], Md. Lutfor Rahman[3], Andrew Dixon[3]

Home range variation during breeding in an Arctic predator: the case 5 of peregrine falcons in Yamal, Russia

[1]Université de Moncton, Moncton, NB, Canada; [2]Russian Academy of Sciences, Moscow, Russia; [3]International Wildlife Consultants, Carmarthen, Wales, UK

R7: Ecology of Birds (Wednesday 13:40)

Many different ecological factors affecting the size, use, and spatial configuration of home ranges have been investigated yet the chronology of the breeding cycle has been relatively under represented. Here we studied peregrine falcons *(Falco peregrinus)* to portray variation in home range during three consecutive years in the Yamal peninsula, a region of the Russian Arctic with a high breeding density of peregrines. We used satellite telemetry to investigate variation in home range at different stages of the breeding cycle during three breeding seasons (2009-2011). We fitted Argos satellite transmitters to 10 breeding peregrines (9 females and 1 male) and 2 male fledglings. All breeding females showed fidelity to the breeding region, but at a finer spatial scale, they were not necessarily faithful to their specific breeding ranges. The population of peregrines in our study area was relatively synchronous in their breeding phenology, with all clutches initiated within 7 days despite the birds arriving on their breeding ranges ca. 3 weeks earlier. The average home range size for breeding peregrines on the Yamal Peninsula was 104 km2 (95% Maximum Convex Polygon). Over the breeding season, the home range area utilized by females more than quadrupled after the early nestling period and then doubled again after the chicks fledged. Expansion of the home range coincided with changes in behaviour associated with parental care, resulting in greater activity and more time spent away from the nest area when the female began hunting to provision nestlings and fledglings. (nicolas.lecomte@umoncton.ca)

Zhenhui Li

Mining animal relationships from movement traces

College of Information Sciences and Technology, Penn State University, University Park, PA

T4: Movement Metrics (Wednesday 10:30)

In this talk, we will present our newly developed data mining methods to understand the relationships among animals based on their movement traces. Two types of relationships will be discussed: (1) attraction and avoidance relationship; and (2) following relationship.

In an attraction relationship, the presence of one individual causes the other to approach (i.e., reduce the distance between them). On the other hand, in an avoidance relationship, the presence of one individual causes the other to move away. Finally, with a neutral relationship, individuals do not alter their movement patterns based on the presence (or the absence) of the other individual. We propose to look at the backgrounds of the movement history and compare "what happened" vs. "what is expected to happen". The permutation test is designed detect the significant attraction and avoidance relationships. We will also discuss the experimental results on capuchin monkeys *(Cebus capucinus)* data.

In the following (or leading) relationship, we study how to automatically detect the time intervals in which the following relationship occurs. Generally speaking, to mine the following relationship, it suffices to identify time intervals in which an object (the follower) has similar trajectories as another object (the leader), but always arrives at a location with some time lag. We propose a novel mining algorithm to tackle the challenges that the following time lag is unknown and varying and the following intervals are short and subtle. We will show our findings on African baboon data.

We have also implemented these methods into public software tools and linked with Movebank databases. We will demonstrate how to use our tools to explore the animal movement data and analyze their relationships.

References:
Zhenhui Li, Bolin Ding, Fei Wu, Tobias Kin Hou Lei, Roland Kays, and Margaret Crofoot, Attraction and Avoidance Detection from Movements, Proc. 2014 Int. Conf. on Very Large Data Bases (VLDB'14/PVLDB), Hangzhou, China, Sept. 2014.

Zhenhui Li, Fei Wu, and Margaret Crofoot, Mining Following Relationships in Movement Data, Proc. 2013 IEEE Int. Conf.on Data Mining (ICDM'13), Dallas, TX, Dec. 2013. (JessieLi@ist.psu.edu)

Pascual López-López

The role of external and internal factors on the movement ecology of long-distance migratory raptors

University of Alicante, San Vicente del Raspeig, Alicante, Spain

R2: Migration (Monday 14:00)

Understanding space use of free-living animals is key to gain insight into spatial ecology and to inform management decisions for conservation planning. Internal factors such as experience and sex, and external ones such as environmental conditions (e.g. meteorology, landscape characteristics) and food availability can promote differences in animals' behavior. Using satellite telemetry we investigated whether such differences occur and which factors promote them among long-distance migratory raptors. Here I will present our latest results of our investigations about the Egyptian vulture and the Eleonora's falcon, two raptor species that breed in Europe and winter in the Sahel region of Africa and Madagascar, respectively. Using resource utilization functions we found that food availability and especially, food predictability, determines ranging behavior of the Egyptian vulture in Europe. This result emphasizes the importance of anthropogenic predictable sources of food (mainly vulture restaurants) in shaping the space use of scavengers, which is particularly important in the present context of limiting carrion dumping in the field due to sanitary regulations according to European legislation. In the case of Eleonora's falcons, our results showed that they integrate spatially seasonal changing resources on a continental scale throughout their annual cycle, changing their movement patterns in response to age and external factors such as habitat, trophic resources and meteorological conditions experienced en route. This resulted in a loop migration pattern, which is widespread among other trans-continental migratory species. In conclusion, our results show that the environment plays a key role in the movement ecology of long-distance migratory raptors, although the effects of external factors vary in relation with internal factors such as sex and experience. (lopez.pascual@gmail.com)

Eduardo Martins[1], Lee F. G. Gutowsky[1], Philip M. Harrison[2], Mat Langford[3], Joanna E. Mills Flemming[4], Ian D. Jonsen[4], David Z. Zhu[3], Alf Leake[5], David A. Patterson[6], Michael Power[2], Steven J. Cooke[1]

Modeling fine-scale fish movements in environments with dynamic water levels and complex flows

[1]Carleton University, New Westminster, BC, Canada; [2]University of Waterloo, Waterloo, ON, Canada; [3]University of Alberta, Edmonton, AB, Canada; [4]Dalhousie University, Halifax, NS, Canada; [5]BC Hydro, BC, Canada; [6]Fisheries and Oceans Canada

R4: Movement Models (Tuesday 16:00)

Animal movements result from complex interactions between abiotic and biotic factors and their study is further complicated when using data obtained from error prone positioning systems. The application of state-space models (SSM) for estimating true animal locations and hidden behaviours from data observed with error has

revolutionized the field of movement ecology. SSMs have been applied to movement data from a variety of marine and terrestrial animals tracked with geolocation devices and used to investigate their horizontal movement in relatively large temporal (hours to days) and spatial (kilometres) scales. Here, we will present SSMs that were developed to analyze fine-scale (60 secs) three-dimensional movement data of bull trout *(Salvelinus confluentus)* obtained with acoustic telemetry in the vicinity (within 500 m) of the generating station of a hydropower reservoir in British Columbia, Canada. The model extends the first-difference correlated random walk with switch between behavioural states (DCRWS) developed by Jonsen et al. (2005, Ecology 86:2874_2880). The DCRWS model was extended with the incorporation of an autoregressive model of order 1 (AR1) to estimate true fish depth from pressure sensor data. Integrating the DCRWS and AR1 models with bathymetry and water elevation data from the reservoir enabled us to develop a dynamic three-dimensional land mask that informed the SSMs of locations to where bull trout could not move. Outputs from the SSMs are being integrated with the outputs of a computational fluid dynamics model developed for the study site. This integration will help us understand how bull trout respond to intake-induced flows and become vulnerable to entrainment. The model developed in our study should be useful to researchers using acoustic telemetry to investigate fine-scale three-dimensional animal movements in environments with dynamic water levels, such as reservoirs, floodplains, and coastal habitats.
(egmartins@gmail.com)

Kevin McLean[1], Patrick A. Jansen[2,3], Greg P. Asner[4,5], Margaret C. Crofoot[6], Christina J. Campbell[7], Mariah E. Hopkins[8]

Modeling movement of three neotropical primates using LiDAR-derived measures of forest structure

[1]Greeley Memorial Laboratory, Yale University, New Haven, CT; [2]Smithsonian Tropical Research Institute, Panama; [3]Wageningen University, Wageningen, the Netherlands; [4]Stanford University, Stanford, CA; [5]Carnegie Institution for Science, Stanford, CA; [6]University of California, Davis, Davis, CA; [7]California State University, Northridge, Northridge, CA; [8]University of Texas at Austin, Austin, TX

R5: Ecology of Mammals (Tuesday 13:00)

Forest structure has long been acknowledged as an important factor in how primates select arboreal pathways that are repeatedly used. Studies that include forest structure often rely on observers measuring percent cover by height while following animals, which may feasible at the scale of a daily trajectory or home range, but not at the landscape or regional scale at which habitat suitability is assessed. High-resolution airborne Light Detection and Ranging (LiDAR) has the potential to solve this scaling issue by measuring detailed three-dimensional forest structure relevant to individual movement decisions at the landscape scale. I applied step selection functions to assess the role of forest structure in the movement behavior of three neotropical primate species. Similar LiDAR-derived variables, including canopy height, crown density or thickness, and distance to gaps were often significant across species. Integrating behavioral ecology with high-resolution information about the habitat in which behavior occurs may provide a useful approach from which subsequent research and management decisions can be made.
(kevin.mclean@yale.edu)

Katherine Mertes, Walter Jetz

Evaluating scale-dependence in species-environment relationships of East African birds

Osborne Memorial Laboratories, Yale University, New Haven, CT

R7: Ecology of Birds (Wednesday 13:00)

Previous investigations into hierarchy theory, hierarchical habitat selection, and perceptual capacities suggest that vertebrate species respond to environmental conditions differently across spatial grains. Wiens (1989) introduced the concept "domains of scale" to describe regions along a theoretical axis of spatial grain where species responses to environmental conditions are relatively similar, separated by transition zones where species responses may abruptly take different forms. A key challenge in ecology is to develop reliable methods to identify scale domains and thresholds for species or broader groups, in order to select grains and extents of analysis that enable accurate inferences on ecological relationships and distribution predictions. Here, we describe scale-dependence in

species-environment relationships for select East African bird species. We use remotely sensed data at six relatively fine spatial grains (10–1000m) to represent biologically meaningful environmental conditions, and fuse observational and movement data to capture potential changes in habitat preferences with behavioral state. (katherine.mertes@yale.edu)

Subhash Morzaria, Jan Hinrichs, Wantanee Kalpravidh, David Castellan, Elizabeth Parker, Juan Lubroth
Connecting the dots: Linking livestock development and value-chains, wildlife habitat use and migration, agro-ecological risk factors and genetic sequences of viruses to understand the emergence, spread, and the potential for zoonotic pandemics
Food and Agriculture Organization of the United Nations (FAO) Emergency Center for Transboundary Animal Diseases (ECTAD) Viet Nam & Regional Office for Asia and the Pacific, and Animal Health and Production—FAO Headquarters, Hanoi, Vietnam

R1: Physiology and Disease (Monday 10:40)

By 2020, the demand for animal based protein will increase fifty percent, primarily in developing countries requiring more than 30 billion livestock animals during the same timeframe. Conservatively, a 2009 FAO estimate suggests there are more than 11 billion poultry in production in Asia and the Pacific based and countries in the region have a range of intensive production systems to low biosecure back-yard farms with consumers most often accessing poultry via live bird markets. As livestock production expands and intensifies to meet consumer demands, we will inadvertently promote pathogen adaptation to; a) intensive farming production systems, and b) human modified natural landscapes. This, along with encroachment into natural habitats to expand farming systems coupled with regional and international value chains driven by commodity prices will inevitably lead to increased contact rates and transmission between people, livestock and wildlife. The likelihood and risks for pathogens to jump among livestock, people and wildlife will increase, and hence, the public health sector will be further challenged to manage high impact zoonotic diseases. Defining critical risk points where interfaces exist and contacts will take place will enhance prevention, improve targeting of surveillance and increase timely response capacity in order to address critical risk points and minimize impacts of emerging zoonoses. (Scott.Newman@fao.org)

Jerry Moxley, Patrick N. Halpin, David W. Johnston
Fine-scale movements, nocturnal diving, and evasive maneuvers in a gray seal's unsuccessful attempt to avoid predation by white sharks revealed through mobile-phone telemetry
Duke University, Beaufort, NC

R3: Techniques & Technology (Tuesday 10:40)

Following extirpation in the 20th century, gray seals *(Halichoerus grypus)* in the Northwest Atlantic recolonized the US coast and grew in abundance quickly, particularly on Cape Cod. Abundant pinniped populations along popular beaches on Cape Cod have prompted concerns over their role as prey and an attractor to predatory white sharks *(Carcharodon carcharias)*. Given that the Southern New England region is one of few areas of range overlap in these two species, regional gray seals are expected to modify their behavior in the presence of predators. Using mobile phone telemetry technology, the movement, diving, and behavior of gray seals are tracked through seasons of varying predator presence. During summer months when regional white shark activity is heightened, gray seals remain coastal (<10 km to shore), transit in large groups, and forage at night almost exclusively. Nocturnal diving is comparatively infrequent in other well-studied gray seal populations that experience less predatory pressure. After the confirmed predation of a tagged seal by a white shark, a conclusive analysis of the fine-scale behavior and evasive maneuvers of gray seals in response to a predator's presence and pursuit illuminate predator-driven behavioral modifications. Movement, ranging, and behavior of the predated animal are compared to other tagged animals at the time of the shark kill as well as other seasons when animals experience less predatory pressure. The bandwidth, resolution, and richness of data offloaded economically via GSM networks presents a rich behavioral context for understanding how seals respond to the presence of predators in ways that are unobserved through traditional satellite tags. Furthermore, high-resolution dive data retrieved from archival memory following tag

recovery depict the animal's unsuccessful evasive maneuvers and anti-predator behavior of pinnipeds at an unprecedented temporal resolution. (jhm15@duke.edu)

Thomas Mueller[1], Sarah Converse[2], Bob O'Hara[1], Richard Urbanek[3], William Fagan[4]

Social learning of migratory performance

[1]Biodiversity and Climate Research Center, Frankfurt, Germany; [2]U.S. Geological Survey, Patuxent Wildlife Research Center, Beltsville, MD; [3]U.S. Fish and Wildlife Service, Necedah National Wildlife Refuge, WI; [4]University of Maryland, College Park, MD

R6: Accelerometry & Group Dynamics (Wednesday 10:30)

Successful bird migration can depend on individual learning, social learning, and innate navigation programs. Using 8 years of data on migrating whooping cranes, we were able to partition genetic and socially learned aspects of migration. Specifically, we analyzed data from the Eastern Migratory Population wherein all birds were captive bred and artificially trained by ultralight aircraft on their first lifetime migration. For subsequent migrations, in which birds fly individually or in groups but without ultralight escort we used deviations from a straight-line path between summer and winter ranges on the migratory route of individual birds as a proxy for migratory performance. We built a hierarchical linear mixed model to examine how much of those deviations at each observed location on the migratory route could be explained by individual age, age of the oldest individual(s) in a migratory social group, group size, and genetic relatedness on both individual and group levels. The age of the oldest individual(s) in a group improved migratory performance by ~5.5% per year of age, decreasing the average deviation from a straight-line path by ~4.2 km per year of age for each relocation event [posterior mode: -4.2 km, 95% highest posterior density interval (HPDI): -1.1 to -7.2 km]. We found no significant effects of individual migratory age, group size, or mean group genetic variance. Our results show that social learning enhances group navigation performance for long-distance migrants and that the benefits of experience accrue over many years. (muellert@gmail.com)

Marius Gilbert[1], Tim Robinson[2], Xiangming Xiao[3], Diann Prosser[4], John Takekawa[5], Scott Newman[6]

Niche mapping, multi-criteria decision analysis and animal movement data for mapping the risk of avian influenza emergence in Asia

[1]Université Libre de Bruxelles, Brussels, Belgium; [2]International Livestock Research Institute, Nairobi, Kenya; [3]University of Oklahoma, Norman, OK; [4]U.S. Geological Survey Patuxent Wildlife Research Center, Beltsville, MD; [5]U.S. Geological Survey Western Ecological Research Center, Vallejo, CA; [6]Food and Agriculture Organization of the United Nations, Hanoi, Vietnam

R1: Physiology and Disease (Monday 11:20)

Over the last decade, several avian influenza viruses belonging to different sub-types (H5N1, H7N9 and to a lesser extent H10N8) have emerged in Asia and caused infections in domestic poultry and humans. Understanding the socio-ecological conditions favoring these emergence is key to the prevention of future events. A set of key spatial factors important for the emergence of avian influenza in poultry was assembled an integrated into a spatial database, including environmental (wild waterfowl migration patterns and habitats), agricultural (irrigated cropland, chicken density, duck density, poultry production systems), demographic (human population density) and socio-economic (GDP per capita) factors. The set of factors was combined in two different ways. First, a cluster map was produced to highlight the distribution of areas, or agro-ecological niches, sharing the same socio-ecological characteristic. Second, a multi-criteria decision analysis was carried out to weight the different factors according to their respective importance for the introduction and evolution of new avian influenza viruses and translate expert's knowledge into a combined risk maps. Outputs from those two approaches, combined with data on major waterfowl migration pathways and habitat use, allow delineating areas where local conditions may favour the emergence of new avian influenza viruses. (Scott.Newman@fao.org)

Roger A. Powell
Dynamic black bears
Department of Applied Ecology, North Carolina State University, Raleigh, NC

R5: Ecology of Mammals (Tuesday 14:20)

Female black bears *(Ursus americanus)* studied in the Southern Appalachians in 1981–2002 did not always move as predicted. During their active period from May to November, female bears should move predominantly to forage. Foraging effort for adult females in the fall was predicted to vary inversely with the annual productivity of hard mast. This makes sense: bears travel only as far as needed to find sufficient food. Contrary to predictions, foraging effort of females varied positively with annual production of squaw root *(Conopholis americana)*, an important food in early summer. Female bears did not respond to the large variation in the summer berry crops. My coworkers and I suggested 2 hypotheses for the responses of adult, female bears to variation in the annual productivity of squaw root: 1) Female bears use extra food in early summer to fuel movements during the breeding season, and 2) Female bears behave as do tits *(Parus sp.)*, whose optimal behavior is to forage at low effort on winter mornings (for bears, in the spring) when food is scarce but to hoard food energetically (for bears, put on fat) when food is abundant. A dynamic model for optimal foraging behavior for bears agreed with field results that foraging effort should vary inversely with the fall mast crop. The model predicted a positive relationship between foraging effort and squaw root production only when bears have a negative energy budget for low squaw root production and a positive energy budget when squaw root production is high. If squaw root production always leads to a negative energy budget, bears should always minimize effort. If production always leads to a positive energy budget, no matter how small, bears should always forage energetically. Actual range of production of squaw root appears to span the energy budget threshold for female bears. (newf@ncsu.edu)

Diann J. Prosser[1], John Y. Takekawa[2], Xiangming Xiao[3], Scott H. Newman[4]
Examining movement ecology of wild birds and their role in disease transmission
[1]U.S. Geological Survey Patuxent Wildlife Research Center, Beltsville, Maryland
[2]U.S. Geological Survey Western Ecological Research Center, Vallejo, CA; [3]University of Oklahoma, Norman, OK; [4]Food and Agriculture Organization of the United Nations, Hanoi, Vietnam

R1: Physiology and Disease (Monday 11:00)

Over the past decade, the role of wild birds in the transmission of diseases that affect poultry and humans has been highly debated. Little information has been available on their movement ecology in Asia where diseases such as highly pathogenic avian influenza (HPAI) have emerged. In response to the threat of HPAI, the United Nations Food and Agriculture Organization, U.S. Geological Survey, and University of Oklahoma developed a research partnership to mark wild birds, assess their movements and association with poultry, and apply models to evaluate their potential for disease spread. The partnership deployed more than 550 satellite transmitters on 26 waterfowl species across 12 countries from Africa to Asia. Focal areas included two areas of China—Qinghai Lake in the Central Asian Flyway, site of the first large scale outbreak of H5N1 in wild birds, and Poyang Lake, an integrated landscape of people, rice agriculture, and wild birds in the East Asian Flyway. Here, we summarize our efforts to integrate wild bird movement data in Brownian Bridge Movement Models, 3-D Utilization Distributions, and other approaches with ecological risk factors to model their potential role in disease transmission. (dprosser@usgs.gov)

Hezi Resheff, Ran Nathan
Supervised learning of behavior modes from acceleration data
The Hebrew University of Jerusalem, Jerusalem, Israel

T5: Track Segmentation & Interaction (Wednesday 15:00)

Part 1. Supervised learning of behavior modes from acceleration data has been used in many recent studies for behavioral annotation of animal tracks. In order to make the process simple and accessible, we have developed a web application for selecting and calculating models. The talk will outline the general steps necessary for

supervised learning of behavior modes, and describe how to use the web app. This talk will be followed by a hands-on experience with the app.

Part 2. This hands-on workshop session will be given following a lecture describing the web app, but will be as self-contained as possible. The purpose of this workshop is to allow users to get acquainted with the software, try the app out on their data, or alternatively use data files that we will provide. During this workshop we will answer any questions you might have about using the software and learning behavior modes from acceleration data in general. (yehezkel.resheff@mail.huji.ac.il)

Jason Riggio[1], Andrew Jacobson[2], Andrew Stanish[3], Jessie Godfrey[1]

Current status of Tanzania's wildlife corridors

[1]University of California, Davis, Davis, CA; [2]Institute of Zoology, Zoological Society of London, London, UK; [3]Freelance web developer

R5: Ecology of Mammals (Tuesday 15:40)

Tanzania contains one of the most diverse and intact large mammal assemblages on Earth, yet land conversion and habitat degradation have resulted in many local extirpations of mammal populations, and species are increasingly restricted to reserves that are isolated from each other by agriculture and urbanization. Nowadays, many view connectivity between protected areas as essential to large mammal population viability because such wildlife corridors (a) allow mammals to disperse between reserves, (b) maintain genetic variability within populations, (c) can rescue populations from local extinction, and (d) provide for species' range shifts due to global climate change. Tanzania is one of the few countries globally that has compiled a summary of current knowledge concerning their wildlife corridors. In that 2009 report, Jones and colleagues identified a total of 31 corridors, with the majority assessed to be in "critical condition"—estimated to have less than five years remaining before they disappear. While some of these corridors were documented via known animal movements, the majority are unconfirmed and based on historical or suspected animal movement, the shortest distance between protected areas, and/or the potential for continuous or semi-continuous natural vegetation linking reserves. We developed a novel remote sensing land cover classification technique using high-resolution satellite imagery freely available on Google Earth. Using this software, we confirmed the presence of these connections, determined which have been severed by land conversion, and identified any currently unknown corridors. The results of this research will establish a stronger foundation from which to direct future conservation efforts aimed at preserving connections between protected areas. (jsriggo@ucdavis.edu)

Christopher Rota, Joshua Millspaugh

Resource selection functions

University of Missouri, Columbia, MO

T1: Movement Models & Resource Selection Functions (Monday 11:00)

The study of resource selection by animals is of great interest to ecologists. Technological and analytical developments have advanced the ability to collect data and model resource selection over large areas. This tutorial will provide an overview of several common statistical techniques and software used to estimate resource selection functions (RSF) and resource selection probability functions (RSPF). We will introduce resource selection models in the context of use / availability (presence-only) and paired use / availability data and discuss statistical techniques and software used to estimate RSFs and RSPFs from such data. One of the most commonly used sampling schemes involves a collection of sample units known to be used by a species and a second collection of sample units considered available for use. These use-availability data permit use of logistic regression, case-control logistic regression, or maximum entropy to estimate the relative probability a sample unit is used and, with auxiliary data, the absolute probability a sample unit is used. Paired use-availability data arises if sample units considered available for use are explicitly paired with used sample units. Such a sampling scheme permits use of discrete choice models

to estimate the relative probability of use. We will provide examples of how to fit resource selection models in program R. Additionally, we will discuss assumptions and interpretation of fitted models. (rotact@missouri.edu)

Shay Rotics[1], Michael Kaatz[2], Yehezkel Resheff[1], Martin Wikelski[3], Ran Nathan[1]

Comparison of juvenile and adult migration in white storks *(Ciconia ciconia)* with implications on survival

[1]Department of Ecology, Evolution and Behavior, The Hebrew University of Jerusalem, Jerusalem, Israel; [2]Vogelschutzwarte Storchenhof Loburg e.V., Loburg, Germany; [3]Max Planck Institute for Ornithology, Radolfzell, Germany

R2: Migration (Monday 15:20)

Mortality of juveniles during their early life period is a common phenomenon in nature. High rates of juvenile mortality during the first year of life were documented in avian migratory species, where the migration time is considered a critical phase. In white storks, the annual survival rates of adults are about four times higher than those of juveniles. The objectives of this work were to compare the fall migration of juvenile storks migrating for the first time of their lives with experienced adult migrants in order to elucidate the effect of age on the migration patterns and to conclude about the causes of the lower survival rates of juveniles.

The study took place in the state of Sachsen-Anhult, Germany from 2011–2013. Sixty-two adults and 64 juvenile storks were fitted with solar GPS transmitters (E-OBS GMBH, Munich, Germany). The transmitter acquires high resolution GPS and body acceleration data in 5 minutes intervals. The body acceleration data was reliably translated to behavioral categories using field observations as a calibration and a machine learning algorithm (support vector machine). Body acceleration was also used as a measure of energy expenditure by calculating overall dynamic body acceleration (ODBA).

We examined the eastern flyway of the fall migration of the storks from Europe to Africa and found that juvenile storks had higher rates of ODBA during flight than adults. This pattern resulted from a more frequent use of flapping flight by the juveniles as compared to the adults, which showed that juveniles fly less efficiently. On the ground, ODBA values or the extent of foraging behavior didn't differ between the age classes. We suggest that the juvenile storks experience a more negative energy balance during the migration as they expend more energy in flight and do not compensate for this by increased foraging on the ground. We compared "weak" juveniles (who died or stopped during the migration) versus "normal" juveniles (who successfully completed the migration) and found that the weak ones spent more energy during flight. This finding illustrates a significant relation between the flight efficiency and survival. As the progress south along the migration, the average flight effort of the storks is decreasing, probably due to enhanced climatic conditions with higher thermal kinetic energy (TKE). However this decrease is stronger for the juvenile storks and it can imply learning and improvement of flight skills throughout the migration. For soaring, gliding birds, like white storks, learning to fly efficiently by utilizing atmospheric assistance is most likely crucial for saving energy during long distance migration. Juveniles fly less efficiently, probably because of less flight experience, and we suggest that this is one of the causes for their lower survival.
(shay.rotics@mail.huji.ac.il)

Nir Sapir[1], Nir Horvitz[1], Dina K. N. Dechmann[2], Jakob Fahr[2], Martin Wikelski[2,3]

Commuting fruit bats beneficially modulate their flight in relation to wind

[1]The Hebrew University of Jerusalem, Jerusalem, Israel; [2]Max Planck Institute for Ornithology, Radolfzell, Germany; [3]University of Konstanz, Konstanz, Germany

R5: Ecology of Mammals (Tuesday 13:20)

When animals move, their tracks may be strongly influenced by the motion of air or water, and this may affect the speed, energetics and prospects of the journey. Flying organisms, like bats, may thus benefit from modifying their flight in response to the wind vector. Yet, practical difficulties have so far limited the understanding of this response for free-ranging bats. We tracked nine straw-coloured fruit-bats *(Eidolon helvum)* that flew 42.5 ± 17.5 km (mean ± S.D.) to and from their roost near Accra, Ghana. Following detailed atmospheric simulations, we found that bats compensated for wind drift, as predicted under constant winds, and decreased their airspeed in response to

tailwind assistance such that their groundspeed remained nearly constant. In addition, bats increased their airspeed with increasing crosswind speed. Overall, bats modulated their airspeed in relation to wind speed at different wind directions in a manner predicted by a two-dimensional optimal movement model. We conclude that sophisticated behavioural mechanisms to minimize the cost of transport under various wind conditions have evolved in bats. The bats' response to the wind is similar to that reported for migratory birds and insects, suggesting convergent evolution of flight behaviours in volant organisms. (nir.sapir@mail.huji.ac.il)

Debbie Saunders[1], Robert Heinsohn[1], Robert Fitch[2], Salah Sukkarieh[2]

Small dynamic migrants: the ultimate challenge in tracking migratory movements

[1]Fenner School of Environment and Society, Australian National University, Canberra, ACT, Australia; [2]Australian Centre for Field Robotics, University of Sydney, NSW, Australia

R4: Movement Models (Tuesday 13:00)

With significant technological advances for tracking individual animals, we now have a much greater understanding of biological phenomenon such as animal migration. The ability to track migratory movements of individuals that return to the same sites each year has shed light on many aspects of migration that were not previously possible. However the movement strategies of many small animals that undertake spatio-temporally dynamic movements in response to variable environmental conditions have largely remained a mystery. This knowledge gap is predominantly due to the very difficult task of repeatedly locating and/or capturing the same individuals at different locations each year depending on variable seasonal conditions. However, with growing recognition of the inherent diversity and variation in movement strategies, and anticipated technological advances in aerial VHF tracking systems, including unmanned aerial vehicles at the local scale and a low orbiting international space station at the global scale, there is great scope for unravelling the mysteries of some of the world's most complex animal movements. (debbie.saunders@anu.edu.au)

James Sheppard[1], Jeff A. Tracey[2], Jun Zhu[3], Robert N. Fisher[2], Ron Swaisgood[4], Wei Fuwen[5], Robert Sinkovits[6], Glenn Lockwood[6], Amit Chourasia[6]

Movement-based estimation and visualization of space use in 3D for wildlife ecology and conservation

[1]San Diego Zoo Institute for Conservation Research, Escondido, CA; [2]San Diego Field Station, U.S. Geological Survey Western Ecological Research Center, San Diego, CA; [3]Department of Statistics and Department of Entomology, University of Wisconsin—Madison, Madison, WI; [4]Institute for Conservation Research, San Diego Zoological Global, Escondido, CA; [5]Key Laboratory of Animal Ecology and Conservation Biology, Institute of Zoology, Chinese Academy of Science, Beijing, Peoples Republic of China; [6]San Diego Supercomputer Center, La Jolla, CA

R4: Movement Models (Tuesday 15:00)

The increasing sophistication and miniaturization of digital biotelemetry devices are enabling the collection of larger, more accurate and longer term datasets on the spatial behaviors of free-ranging wildlife that are normally prohibitively difficult to observe directly in the wild. Animal space-use is three-dimensional and can be characterized within two x and y planar spatial dimensions, as well as a z dimension representing altitude (for flying or arboreal species), elevation (for terrestrial species), or depth (for aquatic or subterranean species). Modern GPS biologgers record this vertical z dimension in addition to an animal's x and y planar dimension. Yet, there is no robust and comprehensive modeling technique that explicitly integrates the 3rd spatial dimension into quantitative characterizations of animal spatial behaviors and habitat use. Nor is there a 3D home range estimator. Disregarding the z dimension greatly limits our understanding of the vertical component of animal ranging patterns and our ability to discern how animal spatial patterns and environmental heterogeneity interact across multidimensional scales to modify animal habitat selection, resource use and niche separation. We report on a novel movement-based 3D home range estimator that successfully integrates the vertical dimension into estimates of animal space-use. We use case studies of 3D home ranges generated from California condor, giant panda and dugong biotelemetry data to demonstrate the ecological insights and conservation management benefits provided by a 3D modeling approach. (jsheppard@sandiegozoo.org)

Navinder Singh[1], Jon M. Arnemo[1,2], Alina Evans[2], Fredrik Stenbacka[1], Göran Ericsson[1]

Internal state versus external environment: combining eco-physiology and movement ecology of a large herbivore

[1]Department of Wildlife, Fish and Environmental Studies, Faculty of Forest Sciences, Swedish University of Agricultural Sciences, Umeå, Sweden; [2]Faculty of Applied, Ecology and Agricultural Sciences, Hedmark University College, Evenstad, Norway

R1: Physiology and Disease (Monday 10:00)

How will animals respond to changing climate is a fundamental question in ecology and evolution. Large animals in northern latitudes are especially vulnerable as they are heat sensitive and may require a variety of adaptations (internal and external) to cope with the warming north. Such studies require novel methods of monitoring animals. We tracked moose *(Alces alces)* equipped with GPS collars and novel abdominal temperature loggers for a two-year period to understand their movement patterns and simultaneous changes in body temperatures. These patterns were then related to external environmental variables to study the changes in internal state in response to external environment, using generalized additive mixed models (GAMMs). The mean daily body temperature of individuals ranged from 37.09°C to 39.92°C. The lowest body temperatures were recorded in March and April and highest during July, when ambient temperatures were also highest. The body temperatures started rising around mid April and increased till late June and started to drop at the end of July and continued to drop until end of September. There were no significant differences in body temperatures between migratory and resident moose, however across areas; the body temperature was on an average slightly higher in the area at a higher elevation. In this first study measuring the internal state of a northern herbivore, we discuss our results in context of movement and habitat use of moose at multiple scales and relate them to changes in ambient temperature, snow regimes, habitat composition and individual fitness. (navinder.singh@slu.se)

Orr Spiegel[1,2], Roi Harel[1], Alejandro Centeno-Cuadros[1], Ohad Hatzofe[3], Wayne M. Getz[4,5], Ran Nathan[1]

Moving beyond curve-fitting: complementary evidence on vultures' long-range forays contradicts Lévy foraging hypothesis

[1]Department of Ecology, Evolution and Behavior, Alexander Silberman Institute of Life Sciences, The Hebrew University of Jerusalem, Jerusalem, Israel; [2]Department of Environmental Science & Policy, University of California at Davis, Davis, CA; [3]Science Division, Israel Nature and Parks Authority, Jerusalem, Israel; [4]Department of Environmental Science, Policy and Management, University of California at Berkeley, Berkeley, CA; [5]School of Mathematical Sciences, University of KwaZulu-Natal, Durban, South Africa

R7: Ecology of Birds (Wednesday 13:20)

Animal movements exhibit an almost universal pattern of fat-tailed step-size distributions. The Lévy flight foraging hypothesis asserts that this pattern reflects an optimal search strategy for unpredictable sparse resources, combining many short steps of local search with rare and much longer steps of inter-patch movements. Despite empirical and theoretical support, this hypothesis remains controversial and alternative explanations have rarely been tested with complementary data. To confront alternative explanations for observed fat-tailed distributions, we tracked three vulture species (*Gyps fulvus, G. africanus* and *Torgos tracheliotus*) in two very different ecosystems in Africa and the Middle East using high-resolution GPS/accelerometer tags accompanied by behavioral, genetic and morphological data for *G. fulvus*. Maximum-likelihood estimation of alternative probability density functions revealed fat-tailed step-size distributions with three distinct superimposed movement modes for all species. These modes, with characteristic scales of reorientation every 46–83m, 2–4km and 12–31km, respectively corresponded to (i) local moves and stops, (ii) foraging flights within core parts of the home range, and (iii) long-range movements outside the core area. The latter include long-range forays (LRFs)—short-term, large-scale circular journeys exceeding beyond the typical foraging range—that contributed to the observed fat-tailed pattern. Nevertheless, analysis of the complementary behavioral and energy expenditure data reveal that vultures' LRFs entail high energy costs and low food intake, thus contrasting the most basic expectations of the Lévy foraging hypothesis. Analyses of additional morphological, meteorological and genetic datasets, refuted alternative LRF explanations based on

preferred weather conditions or population genetic structure. In contrast, female biased sex ratios, distinct seasonality (pre-breeding period) and behavior (frequent roost alternation at the LRFs wandering phase) jointly suggest that LRFs in these species might represent failed breeding dispersal attempts to find mates at remote colonies. We conclude that inference about the mechanisms underlying commonly observed movement patterns should always be confronted with data other than just spatial locations and call for investigating the hypothesis invoking superposition of distinct behavioral movement modes as a general explanation for animals fat-tailed step-size distributions. (orr.spiegel@mail.huji.ac.il)

Ariana Strandburg-Peshkin[1], Damien R. Farine[2], Iain D. Couzin[1], Margaret C. Crofoot[2]

Leadership and collective motion in Anubis baboons using high-resolution GPS tracking

[1]Princeton University, Princeton, NJ; [2]University of California Davis, Davis, CA

R6: Accelerometry & Group Dynamics (Wednesday 9:30)

The central question of how groups of animals coordinate their motion has been studied in a wide range of systems, including bird flocks, fish schools, honeybee colonies, and primate groups. Experimental studies of collective animal behavior have mainly focused on group motion under homogeneous or highly controlled laboratory conditions, limiting their applicability to natural environments. On the other hand, field studies have often been limited by the restricted visibility to human observers imposed by some environments, and the difficulty inherent in observing multiple individuals simultaneously. In recent years, technological advances have allowed for the simultaneous remote tracking of multiple individuals as they move in more complex, natural environments. In this study, we obtained simultaneous GPS trajectories for all adult members of a troop of Anubis baboons (twenty-six individuals), at a resolution of one location estimate per second, over the course of four weeks. These data allow us to use trajectory-based methods to address how leadership regarding movement decisions is distributed in this primate group. In contrast to many other animal groups, baboon troops are characterized by relatively low apparent coordination between individuals (despite groups maintaining cohesion), a relatively high heterogeneity of individual traits, and a complex social organization—all embedded within a heterogeneous environment that may influence or constrain movement decisions. We employ a novel method based on individuals' tendencies to move toward the positions previously occupied by their group-mates to uncover dynamical leader-follower relationships between pairs of baboons. We then investigate the structure of the leader-follower networks determined by these relationships to test hypotheses about the process of decision-making at the group level. (arianasp@gmail.com)

Sarah Supp[1], Tina Cormier[2], Frank A. La Sorte[3], Gil Bohrer[4], Scott Goetz[2], Don Powers[5], Susan Wethington[6], Catherine H. Graham[1]

Using continental-scale citizen-science data and remote sensing products to identify the drivers of hummingbird migration routes and timing

[1]Stony Brook University, Stony Brook, NY; [2]Woods Hole Research Center, Falmouth, MA; [3]Cornell Lab of Ornithology, Ithaca, NY; [4]The Ohio State University, Columbus, OH; [5]George Fox University, Newberg, OR; [6]Hummingbird Monitoring Network, Patagonia, AZ

R2: Migration (Monday 16:00)

Understanding the drivers of long-distance movement is critical to predicting how climate change will impact migratory species. These species depend on their ability to reach suitable habitat and resources along migratory routes. Identifying the cues to start migration, and what cues influence speed and direction of migration, will help describe where migratory species occur, identify target areas for conservation and management, and predict which species will be most at risk under climate change scenarios. Hummingbirds are ideal avian species for evaluating the impacts of climate change on long-distance migration, since they inhabit a broad range of ecosystems, respond quickly to environmental shifts, and are directly tied to changes in environment through their mutualistic relationship with flowering plants. Since hummingbirds are very small, it has not been possible to track individual long-distance movement, as has been done for other species. We present results from 10 years (2004–2013) of citizen-science observations reported to eBird for 9 North American hummingbird species, evaluating the temporal

and environmental drivers of migration timing, speed, and geographic location. We used the number of checklists submitted to eBird and daily observation location to define the dates for begin and end of spring and fall migration in each year 2004–2013. We used a generalized-additive model (GAM) to estimate the spring and fall migratory routes for each species in each year, and to estimate daily rate of migration in each season. We annotated the raw location data from submitted checklists, with environmental and weather data (day length, elevation, temperature, precipitation, wind, EVI, NPP) using Movebank. We used a correlative approach to determine which variables are associated with hummingbird species along their spring versus fall migratory routes. We compare the results among seasons (spring vs. fall) and among years to test for temporal variation in migration timing and location, and to test for differences among species. We predict that species responding primarily to static drivers (e.g. day length) will have more difficulty maintaining stable populations under climate change scenarios than species responding primarily to dynamic factors (e.g., daily weather, resource availability). Rapid climate change or an increase in the frequency of extreme weather events, however, may pose an unsurmountable challenge even for species with very flexible movement responses. (sarah@weecology.org)

Yun Tao, Alan Hastings

Transient animal home range: methods and applications

University of California, Davis, Davis, CA

R4: Movement Models (Tuesday 14:20)

The field of movement ecology has undergone a veritable transformation in recent years, encompassing an increasing number of interdisciplinary offshoots. Transient analyses represent one of the most ground-breaking developments to date, and incorporation of such techniques seem poised to jumpstart a paradigm shift for the entire field. The basis of transient approaches lies in biologically relevant timescales as opposed to older models that generally ignore them due to technical limitations (e.g., data resolution, numerics), many of which have rapidly diminished in the past few years. This advanced approach has profound implications in ecosystem management where predictions need to be far more reliable on short-terms to accommodate environments that are subject to frequent perturbations. Using a newly designed computational platform built on finite volume method, we are able to explore animal home range dynamics free from the traditional restriction of sampling frequency, and consequently, indicate potential underestimation of animal space use in natural reserves. By solving movement models over a time continuum, this simulation framework presents new opportunities for enhanced association between theory and data in the near future. (yuntao@ucdavis.edu)

JF Therrien[1], Gilles Gauthier[2], David Pinaud[3], Joel Bety[4]

Irruptive movements and breeding dispersal of snowy owls: a specialized predator exploiting a pulsed resource

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T2: Integrative Movement Models (Monday 14:15)

Mobility and irruptive movements have been proposed as mechanisms that could allow some diet specialists to inhabit and breed in environments with highly unpredictable resources, like the arctic tundra. The snowy owl, one of the main avian predators of the tundra, is known to specialize on lemmings during the breeding season. These small mammals are also well known for their tremendous spatial and temporal variations in abundance. We examined the spring (pre-breeding, from March to June) movements of snowy owls by tracking 9 breeding females in the Canadian Arctic for up to 3 years with satellite transmitters. We used state-space modeling to assess searching behavior and measure breeding dispersal distances. We also ascertain lemming abundance at some of the sites used by the marked owls. Tracked owls displayed searching movements for extended periods (up to 108 days) and traveled over large distances (up to 4093 km) each spring. The distance between furthest apart searching areas in a given year averaged 828 km (range 220 to 2433 km). Settlement date, distance between searching areas, traveled distance and the duration of prospecting movements were longer in the year where density of lemmings

recorded in the eastern High-Arctic (Bylot Island) was lowest. Nonetheless, snowy owls settled in areas where local lemming abundance was relatively high. Individual breeding dispersal distance between consecutive years averaged 725 km (range 18 to 2224). Overall, the high mobility of female snowy owls allowed those diet specialists to behave as irruptive migrants and to sustain their reproductive activities during consecutive years even under highly fluctuating resources. (therrien@hawkmtn.org)

Kasper Thorup

Linking long-distance migration and resources

Center for Macroecology, Evolution and Climate, University of Copenhagen, Copenhagen, Denmark

R2: Migration (Monday 14:20)

Recent developments in tracking technology have allowed mapping individual inter-continental migrations of several songbird species. Accurate spatio-temporal location data potentially allow an evaluation of how seasonal vegetation changes ultimately drive the current migration schedules. We correlate the migration three smaller land bird species, common cuckoo, red-backed shrike and thrush nightingale migrating between the Palearctic and Southern Africa with changes in seasonal vegetation greenness as estimated by the Normalised Difference Vegetation Index. The tracks were related to the observed changes though we found species-specific differences as to whether migration schedules optimised vegetation greenness or were related to resource peaks. (kthorup@snm.ku.dk)

Jake Wall

ArcMET: Movement Ecology Tools for ArcGIS

University of British Columbia, Vancouver, BC, Canada

T4: Movement Metrics (Wednesday 11:00)

The study of animal movement using remote tracking devices is advancing rapidly. Sensor and battery technologies are improving and getting smaller while the number of species being tracked globally is continually on the rise. With these advances come challenges for efficient data work-flows given the increase in size and complexity of modern tracking datasets. Four principles underscore any analysis involving movement data: 1) data storage 2) data retrieval 3) data processing & analysis 4) data visualization.

To address these principles, I present a new software package called "ArcMET: Movement Ecology Tools for ArcGIS" for the analysis of animal movement data. ArcMET is freely available at www.movementecologytools.net and is installed as an extension to the popular ArcGIS Desktop Geographic Information System (GIS) software. Integration with ArcGIS allows for powerful visualizations and cartographic outputs. Development of ArcMET is based on the Microsoft .Net framework using the C# language. Where possible ArcMET tools have taken advantage of multi-threaded concurrency operations which lead to significantly reduced calculation times on multi-core computers.

The growing suite of tools within ArcMET provide functionality such as data filtering and the generation of movement trajectories from sampled positions, as well as advanced animal home-range calculations including Localized Convex Hull (LoCoH), Brownian Bridge Movement Model (BBMM) and Time-Density models. Among others, ArcMET also provides a novel "vector-grid" tool for summarizing movement vector attributes across landscapes and a temporal moving-window tool that provides a framework for performing calculations on temporal subsets of data and advancing calculations within a window of time either iteratively or continuously along an animal's movement trajectory. (walljcg@gmail.com)

John W. Wilson[1], Rory P. Wilson[2], Gus Mills[3], Michael Scantlebury[4]

Cheetahs vary hunting strategies depending on prey species

[1]Department of Biological Sciences, North Carolina State University, Raleigh, NC; [2]Swansea Laboratory for Animal Movement, College of Science, Biosciences, Swansea University, Singleton Park, Swansea, UK; [3]The Lewis Foundation, Craighall, South Africa; [4]School of Biological Sciences, Queen's University Belfast, Belfast, Northern Ireland, UK

R6: Accelerometry & Group Dynamics (Wednesday 11:30)

Predator-prey interactions are fundamental in the evolution and structure of ecological communities. Even so, we have limited knowledge of the dynamics involved in prey acquisition, including the cost of hunting, and strategies used during pursuit of prey. Here we report on the hunting dynamics of the world's fastest land animal, the cheetah, *Acinonyx jubatus*. Using miniaturized data loggers, we recorded fine-scale movement, speed and acceleration of 14 free-ranging cheetahs to measure how hunting dynamics relate to chasing different prey. Cheetahs attained hunting speeds of up to 18.9 m/s and accelerated up to 7.5 m/s2. However, rather than a simple maximum speed chase, cheetahs first accelerate to decrease the distance to their prey before reducing speed to facilitate rapid turns to match species-specific escape tactics. The interplay between forward and lateral acceleration during a chase showed that the total forces involved in changing speed and turning angles were approximately constant over time but varied with prey type. Predator and prey thus strike a fine balance of speed against maneuvering capability in a race for survival. (johnnybirder@gmail.com)

Mirka Zapletal[1], Batdorj Sodnompil[2], Jonathan L. Atwood[1], James D. Murdoch[3], Richard P. Reading[4]

Daurian hedgehog habitat selection at multiple scales in the Gobi Steppe

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The Daurian hedgehog *(Mesechinus dauuricus)* is a relatively little-studied insectivore found throughout the arid steppe regions of Mongolia and northern Asia. Previous research on this species in Mongolia suggested that they use larger home ranges than other hedgehog species in Europe and Asia. However, little information exists on their basic spatial requirements or patterns of habitat selection. We examined home range characteristics and habitat selection of 4 Daurian hedgehogs (2 males and 2 females) at multiple scales in Ikh Nart Nature Reserve, Mongolia from June through August 2011. We fitted hedgehogs with VHF transmitters for radio-tracking and continuously tracked each animal during 10 nights to estimate home ranges for Early Summer (June 11–July 17) and Late Summer (July 21–August 31). We used relative ranking and compositional analysis to determine habitat selection by broad vegetation type at the home range- and foraging path-level. To evaluate fine-scale habitat selection, we used radio-tracking data from actual hedgehog paths to develop random alternative paths, and then compared local habitat data from 5 actual paths and 5 randomly-generated alternatives per animal. Hedgehogs exhibited differing habitat selection patterns at broad- and finer-scale levels of investigation, suggesting that selection pressures may vary with scale. Relative preference for rocky outcrop and low-density shrub areas at the home range level may be tied to shelter and food resources, or connected to predator avoidance. Habitat selection within home ranges also changed between Early and Late Summer, shifting to greater use of low-density shrub areas and decreased use of forb-dominated short grass. Hedgehogs demonstrated relative preference for low-density shrub and tall vegetation areas when we analyzed foraging-path data across broad vegetation types. At the fine-scale level, hedgehogs foraged around wild apricot *(Amygdalus pedunculata)* shrubs, probably because they support higher densities of insects that are important to hedgehog diets, and used flatter areas, perhaps to reduce the energetic costs of foraging. Our results provide evidence of non-random habitat use by Daurian hedgehogs, improving our understanding of habitat preferences by the species, and suggest that habitat management for the species should consider multiple scales. (mxz7236@louisiana.ed)

Evan Buechley[1], Çağan H. Şekercioğlu[1,2], Emrah Çoban[2], Lale Aktay[2], Kayahan Ağırkaya[2]

Movement and conservation of the Egyptian Vulture *(Neophron percnopterus)* in the Middle East and Horn of Africa

[1]Department of Biology, University of Utah, Salt Lake City, UT; [2]KuzeyDoğa Society, Kars, Turkey

The Egyptian Vulture *(Neophron percnopterus)* is globally endangered and declining throughout its range in Europe, South Asia, and Africa. There have been extensive efforts to conserve Egyptian Vultures in Europe, but very little is know about the ecology, status, or threats to the species in other regions of the world. We summarize data from the first satellite telemetry study on a breeding population of Egyptian Vultures in the Middle East. In the summers of 2012 and 2013 we trapped 6 Egyptian Vultures and fitted them with either PTT or GSM/GPS transmitters in Iğdır Province in Eastern Turkey, the location of one of the largest documented breeding populations of the species in the world. To date, we have collected over 83,000 locations on these six individuals. This data has provided an unprecedented look at the movement ecology of Egyptian Vultures in the Middle East and the Horn of Africa, revealing a previously undocumented migratory route for the species over the Arabian Peninsula and crossing the Straight of Bab-el-Mandeb into Africa. Along their way, they have visited Turkey, Azerbaijan, Iran, Iraq, Syria, Jordan, Saudi Arabia, Yemen, Djibouti, Ethiopia, and Somalia. They migrated, on average, over 4,000 km in 20 days from Eastern Turkey to their wintering territories in Yemen, Ethiopia, and Somalia and we have documented them traveling as fast as 109 km per hour in sustained flight, covering as many as 424 km in a single day, reaching a maximum elevation of 7,970 m, and traveling well over 20,000 km in a year, providing further details on the impressive migrations and flight capabilities of this species. Using ArcGIS and the package AdeHabitat in R, we evaluate kernel home ranges for summer and winter territories and highlight migration corridors and potential geographic bottlenecks. Importantly, this information, coupled with surveys on the ground in Turkey and Ethiopia, has led to the identification of communal feeding areas and nest sites. Understanding how these birds use their environment is an important step in targeting conservation actions for this endangered species, the ultimate goal of this project. (ebuechley@gmail.com)

Kaycee Coleman[1], Thomas Grothues[2], Kenneth W. Able[2]

Monitoring cross-continental shelf movement of winter flounder *(Pseudopleuronectes americanus)*

[1]Rutgers University, New Brunswick, NJ; [2]Rutgers University Marine Field Station, Institute of Marine and Coastal Sciences, New Brunswick, NJ

The objectives of this study are to understand the cross-continental shelf movements of winter flounder, *Pseudopleuronectes americanus*, off of New Jersey via several tagging methods to explore the possibility of a non-migratory contingent cryptic to assessment. We tagged 222 winter flounder with 150 marker tags, 60 archival tags and 12 acoustic tags in September 2012 at the "Mud Hole," a depositional feature at the head of the Hudson Shelf Valley. Acoustic signals telemetered by a roving boat and an autonomous underwater vehicle (AUV), were geolocated using Sound Pressure Level Weighted Center of Activity. These fish were tracked within a few kilometers of the release location as late as December. To evaluate the archival tag data, which records temperature, salinity, pressure, and a time stamp every 24 minutes, we developed a Monte Carlo Markov Chain and an Adaptive Kernel Density algorithm to obtain the most likely position of the fish as constrained by fit to environmental model data from Rutgers University's Regional Ocean Modeling System (ROMS). Since the majority of archival tags are still at large but expected to increase with the reopening of the commercial fishery, we validated the model by attempting to recover simulated (known) fish tracks with this algorithm. (kaycee.coleman@gmail.com)

Tina Cormier[1], Sarah R. Supp[2], Frank A. La Sorte[3], Gil Bohrer[4], Rolf Weinzierl[5], Susan Wethington[6], Donald Powers[7], Catherine H. Graham[2], Scott Goetz[1]

A framework for modeling population-level hummingbird migration using citizen science observations and Env-DATA annotation

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Long-distance migratory movement is influenced by resource availability, weather conditions, and land use along migration routes. Advances in remote sensing technology allow tracking of environmental changes through both space and time across scales. Linking population-level animal movements with various remotely-sensed environmental observations provides insights into the mechanisms influencing the route and timing of migration for a given species. There are, however, technical challenges associated with developing such linkages, including data acquisition, preparation, and interpolation. Using the Rufous Hummingbird *(Selasphorus rufus)* as a case study, we present a novel application of the Environmental-Data Automated Track Annotation (Env-DATA) service that was recently added to Movebank, an open portal of animal tracking data. We use 10 years (2004–2013) of *S. rufus* observation data collected by citizen scientists, as part of the eBird online checklist program, to provide occurrence information. Because of their small body size, high metabolic rates, and dependence on nectar resources, hummingbirds often operate at the edge of their energetic budgets and thus make rapid movement decisions based on available resources and current environmental conditions. For these reasons, hummingbirds are appropriate for testing the utility of the Env-DATA annotation service for range-wide species distribution modeling. Though Env-DATA was developed with the goal of annotating individual animal tracks, we demonstrate its utility in modeling seasonal migration at the population level over large geographic areas and through time. We focus here on the technical methods of annotating eBird observation data with remote sensing proxies for hummingbird resources (vegetation indices), physiological demand (temperature), and migration opportunity (wind conditions) using Movebank. With these data, we build habitat suitability models that describe S. rufus' daily spatial range limits based on changing environmental variables.

Our workflow parallels that of others who describe habitat use and animal movement using Movebank-annotated observations; however, once we have determined the variables limiting distribution, we predict population movement through time and geographic space using a set of gridded environmental conditions over the entire spatiotemporal range for years not included in model development. These types of analyses have the potential to lead to enhanced modeling of predicted changes in migration patterns and distributions in response to environmental change. The ability to not only quickly annotate observation points but also entire range grids with hundreds of relevant environmental variables is a significant advance in spatiotemporal distribution modeling, as it saves time in acquisition, pre-processing, and interpolation of many heterogeneous remote sensing datasets, often among the most time consuming, tedious, and error-prone parts of a project. (tcormier@whrc.org)

Don H. Crockett

Visualizing daylight and telemetry data to better understand the movements of diurnal/nocturnal animals

Great Blue Virtual Tours

Animal Tracker 1.0 is a Google Maps Javascript App that help users explore telemetry data collected from animals. Animal Tracker 1.0 displays arrows between GPS locations that are color coded to represent the daylight (day, night, twilight) at the time the GPS reading was recorded. The resulting visualizations facilitate interpreting an animal's diurnal, nocturnal and crepuscular movement and potentially its underlying behavior. The use of the Google Maps satellite layer and controls enables in-depth exploration of specific GPS locations and creates a very interactive and engaging experience for explorers of all ages. (doncrockett63@gmail.com)

Angela Darnell[1], Jan A. Graf[2], Michael J. Somers[3], Rob Slotow[2], Micaela Szykman Gunther[4,5]

Space use of African wild dogs in relation to other large carnivores in South Africa

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Interaction among species through competition is a principle process structuring ecological communities, affecting behavior, distribution, and ultimately the population dynamics of species. High competition among large African carnivores, associated with extensive diet overlap, manifests in interactions between subordinate African wild dogs *(Lycaon pictus*) and dominant lions *(Panthera leo)* and spotted hyenas *(Crocuta crocuta).* Using telemetry locations of large carnivores in Hluhluwe-iMfolozi Park, South Africa, we found different responses from wild dogs to their two main competitors. Wild dogs avoided lions, particularly during denning, through a combination of spatial and temporal avoidance. However, wild dogs did not exhibit spatial or temporal avoidance of spotted hyenas, likely because wild dog pack sizes were large enough to adequately defend their kills. Understanding that larger carnivores affect the movements and space use of other carnivores is important for managing current small and fragmented carnivore populations, especially as reintroductions and translocations are essential tools used for the survival of endangered species, as with African wild dogs. (ange.darnell@gmail.com)

Andrea Flack, Wolfgang Fielder, Martin Wikelski

Social aspects of white stork migration

Max Planck Institute for Ornithology, Radolfzell, Germany

Group movements and collective navigation are widespread among social animals and can take place on a variety of different spatial and temporal scales. Many migrants rely on social cues during their long-distance trips, but the specific mechanisms as well as the ecological and energetic consequences of sociality during migration remain unclear. In social migrants, the migratory direction is presumably much influenced by the accompanying flock members. Theoretical work has shown that collectively migrating groups can consist of a small group of actively navigating individuals while the greater part of the group adopts socially facilitated movement behaviour. The few empirical studies on wild birds suggest that social learning is essential for young birds to successfully migrate to their wintering grounds. Yet, disentangling the relative contributions of genes and culture remains a fundamental challenge in understanding the complex phenomenon of animal migration. Here we use the White Stork (Ciconia ciconia), a most suitable model, to study further the impact of sociality on costs, pattern and success of long-distance journeys. We ask how the migratory pattern of siblings relates to that of nonrelated individuals. Using a combination of high-resolution GPS data and analytic techniques common in statistical physics, we not only expose the relationship among individual, but also elucidate the organisation of decision-making in small family groups, focusing on the nature and weight of the input that each individual is able to provide into the overall behaviour of the group. A better understanding of how social factors influence movement and dispersal of migratory species is of highest importance for developing effective conservation strategies. (aflack@orn.mpg.de)

Amanda E. Holland[1,2], Michael E. Byrne[1,2], A. Larry Bryan[2], Travis L. DeVault[3], Olin E. Rhodes, Jr.[2,4], James C. Beasley[1,2]

Efficacy of solar-powered Groupe Spécial Mobile/Global Positioning System (GSM/GPS) transmitters in a range of weather conditions

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Solar-powered Groupe Spécial Mobile/Global Positioning System (GSM/GPS) transmitters are a relatively new technology available for tracking animal movements at fine spatial and temporal scales. The benefit of solar-powered tracking devices can be substantial when tracking animal movements that occur primarily in the daytime and in areas with relatively consistent sunlight. However, limitations may exist if tracking animals in areas with reduced solar availability such as high latitudes, conditions with abundant precipitation/cloud-cover, or for

organisms with considerable nocturnal movements. We used fine-scale GPS data from 7 black vultures *(Coragyps atratus)* and 7 turkey vultures *(Cathartes aura)* equipped with solar-powered GSM/GPS transmitters to examine the influence of variation in weather conditions on the frequency of data collection over an 8 month period. Specifically, we investigated the influence of common environmental (e.g., cloud-cover, precipitation), behavioral (e.g., roosting vs. soaring), and temporal (e.g., time of day, season) covariates on the number of accurate locational fixes recorded per hour. Our study is the first to quantify data collection capabilities for solar-powered GSM/GPS transmitters under a range of environmental and behavioral conditions. This information will be useful for wildlife researchers and managers considering the use of solar-powered GSM/GPS transmitters for future animal movement studies. (aeholland@srel.uga.edu)

Edward Hurme[1], Noam Cvikel[2], Noga Kronfeld[2], Yossi Yovel[2], Eran Levin[3]

Bats fat on ants: estimating the energy expenditure and storage of *Rhinopoma microphyllum* bats

[1]University of Maryland, College Park, MD; [2]Tel Aviv University, Tel Aviv, Israel; [3]University of Arizona, Tucson, AZ

How do animals store energy needed for seasonal migration or hibernation? It is well known that migratory birds quickly store fat by substantially increasing their food intake, known as hyperfagia, however little is known about the physiological and behavioral mechanisms utilized by bats. We examined wild, insectivorous bats, *Rhinopoma microphyllum*, as they explored their environment for ant alates in late fall. Through the use of onboard GPS tracking and ultrasonic audio monitoring devices, we recorded multiple individuals over several nights in Northern Israel. Our methodology allowed for unique insights into the ecology of this cryptic species by providing data such as the time spent foraging, the distances covered, flight speed, and estimates of the number of insects attacked per night. Integrating this data with measurements of caloric intake per ant, resting and torpor metabolic rates of *R. microphyllum* at different ambient temperatures, roosting cave temperatures and estimates of metabolic rates during flight, we calculated the nightly net caloric gain in the weeks leading up to migration. Understanding the total energetic investment made before winter may provide clues into the environmental and evolutionary constraints of bat migration and hibernation. (ehurme@umd.edu)

Elizabeth Kalies[1,2], Tavis Forrester[3], William McShea[3], Roland Kays[2], Robert Costello[4], Megan Baker[3], Arielle Parsons[2]

eMammal: broad-scale long-term mammal research through citizen science

[1]University of Missouri, Columbia, MO; [2]North Carolina Museum of Natural Sciences, Raleigh, NC; [3]Smithsonian Conservation Biology Institute, National Zoological Park, Washington, D.C.; [4]National Museum of Natural History, Smithsonian Institution, Washington, D.C.

eMammal recruits citizen scientists to survey mammals with camera traps to increase the spatial and temporal scale of wildlife survey data. Our workflow includes remote photo upload, expert review of species ID, and storage of photos and data in a Smithsonian repository. In our 1st year, over 200 volunteers deployed cameras to 2360 sites in 29 parks across 6 states, recording >115,000 human and animal detections. Preliminary occupancy analysis indicate that deer, black bear, and red fox were more common in unhunted areas while coyotes and turkeys were more common in hunted areas. Deer and gray squirrels avoided hiking trails, while most predators were detected at higher rates on trails. Volunteers identified most species at >90% accuracy. eMammal shows the potential for camera traps and citizen science to monitor mammals at large scales to provide important data for conservation and establish stronger personal connections between people and animals. (kaliese@missouri.edu)

Aimee Kessler[1], Tseveenmyadag Natsagdorj[2], Nyambayar Batbayar[3], Dashnyam Batsuur'[4], Andrew T. Smith[1]

High-resolution satellite imagery allows more complete understanding of animal interactions with dynamic agricultural mosaics

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Low-intensity agricultural mosaics are unique in terms of the complex, rapid and profound changes they undergo. Within the course of a single year, active fields are plowed, seeded, crops mature and are harvested. Fallow fields

are cycled through a series of plowings and wild growth that occurs asynchronously to that on nearby pasture. From year to year, individual fields change in status as they are brought into or out of production. These dynamic ecosystems present a challenge to interpretation of animal tracking data. Use of traditional, moderate-resolution satellite imagery in combination with animal location data allows researchers to determine only whether individuals are within or outside of the agricultural mosaic. Instead, we use high-spatial and temporal resolution imagery to capture habitat preferences within the changing mosaic. We use high-spectral resolution imagery (GeoEye & IKONOS) to define field edges and concomitantly use mid-spectral imagery at higher temporal resolution (LandSat) to determine crop phenology. This precise determination of the type of agricultural habitat preferred by a species offers unique insights into the threats posed by agricultural intensification and allows us to make recommendations to ensure maintenance of appropriate habitat and reduce disturbance or mortality by agricultural machinery. As a case study, we apply this approach to threatened populations of Great Bustard, a large, ground-nesting bird, in Mongolia. (aekessle@asu.edu)

Laura Mendenhall[1], David Douglas[2], Joseph Brandt[1]

Automated GPS data analysis alerts California condor field biologists of near-real-time clustering events

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We seek to underscore the operational relevance of using hourly daytime GPS location data to further objectives in the recovery of an endangered species: the California condor *(Gymnogyps californianus)*. The leading cause of condor mortality is lead poisoning from the ingestion of spent lead ammunition found in non-proffered carrion across the landscape. The California Condor Recovery Program has deployed GPS transmitters on a subset of condors to, among other reasons, identify non-proffered feeding events and possible lead sources. Biologists must stay abreast of feeding events in order to intervene in a timely manner when carrion is thought to contain lead fragments. Given the social nature of the species, daytime clustering of multiple individuals can often indicate a feeding event. We have developed an automated algorithm that identifies potential feeding events based on spatio-temporal pairwise proximities among GPS location data from all tagged condors. The location, size (number of condors), and persistence (number of consecutive days) of detected events are monitored by the algorithm and distributed by email in tabular and KML formats to field biologists on a daily basis to facilitate prompt response and intervention where necessary. Using 31 known non-proffered feeding locations and GPS location data from 30 individuals in 2012, we tuned the algorithm to minimize errors of omission, thus providing a more inclusive overview of possible feeding events. (laura_mendenhall@fws.gov)

Renee Obringer[1], Gil Bohrer[1], Sarah C. Davidson[1,2], Rolf Weinzierl[2], Mike Ward[3], Frank Moore[4], Rachel Bolus[5], Robert Diehl[5], Jill Deppe[6]

Correlations between thrush migrations and weather variables

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A Swainson Thrush *(Catharus ustulatus)* is a small songbird that migrates from the northeastern United States and Canada to Mexico and Central America in the winter. This annual migration involves a 1000-kilometer trip across the Gulf of Mexico from Alabama to the Yucatan Peninsula in Mexico. There is still very little known about the details surrounding the flight and the decisions made by the birds during flight, such as the timing of the Gulf crossing and the flight speed, that ultimately affect the survival of this difficult hurdle. In a National Science Foundation (NSF) funded experiment, thrushes are tracked by a radio transmitter which allows us to record a timestamp of when they leave Alabama, and when they arrive in the Yucatan. The Environmental-Data Automated Track Annotation (Env-DATA) system—a new data exploration system developed through Movebank (www.movebank.org) and The Ohio State University allows us to link the movement track with data from global and regional weather reanalysis models and remote sensing. I tested for correlations between the flight timing, gulf-crossing flight time, and the weather data between the departure and arrival points. These correlations allow us to

formulate hypotheses on the various decision-making strategies the birds use during their migration over the Gulf of Mexico. These hypotheses will later serve as the building blocks for the creation of migration models and will allow us to gain insight into the migration of thrushes. A strong understanding of aerial migrant decision-making, as well as a model that will show what happens under specific conditions will be important to predicting the effects of climate change on the migratory animal populations. Climate change may likely cause changes to the environmental variables that directly affect the flight, which in turn may affect the migratory habits, times, routes, and survival rates of many migratory birds, such as the thrushes. (obringer.21@osu.edu)

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The behavioral response of Gunnison Sage Grouse to seasonal motorized use

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Loss, alteration and fragmentation of sage-steppe habitat, due to many factors, has been identified as a primary reason for declines in Gunnison Sage-grouse *(Centrocercus minimus)* (GUSG) populations. The GUSG is a species of special concern for all federal and state natural resource management agencies throughout its range. One of the remaining 7 populations, the Crawford population, exists in Gunnison Gorge National Conservation Area and the Black Canyon of the Gunnison National Park in Colorado. One of the potential major challenges for GUSG is the effects of spatial and temporal habitat fragmentation created by roads and their use. Our study area, located in Western Colorado, is approximately 26,272 ha in size, contains 1,232 km of roads and is managed by multiple federal land management agencies and private land owners. A major objective of this project has been to evaluate the effects of motorized use and the physical existence of roads on GUSG. To assess this relationship we instrumented 12 female and 2 male GUSG with Global Positioning System backpacks and developed a 10-vehicle monitoring network. To date we have collected over 40,000 GUSG locations and over 23,000 vehicle counts. We are also developing innovative techniques for dynamic presentation and analysis of simultaneously collected GUSG movement data and motorized use data. This analysis will inform wildlife management agencies and hopefully provide information to develop effective strategies for increasing populations of this species of special concern. (ourend@usgs.gov)

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Breeding season space use dynamics of female lesser prairie-chickens in Kansas and Colorado

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Knowledge of lesser prairie-chicken *(Tympanuchus pallidicinctus)* movements, space use, and habitat use during the breeding season is lacking in its northern range and yet is a necessary prerequisite to conservation planning and management. The goal of this study was to estimate space use and characterize habitat utilization of female lesser prairie-chickens during the 2013 breeding season across the northern range of the species. Habitat use, space use, and movements were measured using radio-marked females captured during the lekking season. Home-ranges were estimated using Kernel Density Estimators and creating a 50% isopleth for core areas and 95% isopleth for home-range size. My results indicate that amount of movement varies regionally with birds in NW Kansas moving greater amounts than SC Kansas. Home-range sizes varied temporally throughout the breeding season but were relatively consistent in size between regions. Analysis of resource utilization in forthcoming. It is difficult to develop meaningful management and conservation strategies for species of concern if we lack the basic knowledge of their spatial needs. Understanding relationships between lesser prairie-chicken space use and habitat characteristics could improve the process of prioritizing and defining the appropriate scale of conservation decisions and management actions for lesser prairie-chickens. (rtplumb@ksu.edu)

Andrew Ricketts, Brett K. Sandercock

Resource utilization by a top predator in an experimental landscape

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Top-down forces play an important role in the structuring of aquatic and terrestrial ecosystems. Distinguishing between top-down and bottom-up effects can be difficult, because many species can be involved and networks of trophic interactions can be complex. Coyotes are an important predator of small mammals and ground nesting birds in prairie ecosystems. Coyotes may play a role in structuring small mammal communities by selectively preying on certain species. To assess the strength of bottom up forces on resource use, and the possibility of trophic cascades caused by coyotes, we monitored coyote movements at Konza Prairie Biological Station using GPS telemetry. Resource utilization functions were used to determine the role of disturbance (fire and grazing), elevation, habitat characteristics, and small mammal abundance in resource use by coyotes. Preliminary results indicate that coyotes are selecting areas of low cover and high elevation within their territories. Hispid cotton rats and prairie voles are the primary small mammal prey reported in coyote diet studies, and these species occur in low densities in areas with little vegetative cover. Coyotes may be limiting hispid cotton rat and prairie vole abundance in recently burned and grazed prairie, allowing deer mice to be the dominant small mammal species in such habitats. (arickett@ksu.edu)

Cody Schank, Jennifer A. Miller

Building SDMs from temporally explicit environmental data: a test case using eBird and MODIS

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Species distribution models (SDMs) are often used in conservation planning as a tool to predict habitat suitability for species of conservation concern in order to aid the decision-making process of reserve network design. However, SDMs frequently use long-term climate averages as environmental predictors, essentially giving a coarse temporal view of habitat suitability. Incorporating the temporal information from species observations, and linking this information with environmental conditions at the time of observation, can provide a better understanding of how species might track a changing environment. Building on the methods of Reside et al (2010), I test whether SDMs that use temporally explicit environmental variables perform better than models that use long-term climate averages. Instead of building "weather" variables from long-term climate datasets, I use remotely sensed data, as it can provide environmental information at more frequent time scales (every 2 days for MODIS vs the 3-month "weather" data used by Reside et al). The analysis utilizes data from eBird, as this dataset provides frequent observations, and includes many species that are good dispersers. (codyschank@gmail.com)

Mikkel Willemoes, Kasper Thorup

Using environmental data to explain the evolution of migration routes

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Migrating animals, birds in particular, often show species and even population specific migration routes and non-breeding distributions. Assuming that these differences are caused by natural selection and that existing routes are reflecting optimal solutions in relation to the underlying environment, we intent to test the potential role of different environmental parameters in shaping the movement patterns observed. Using satellite tracks for the common cuckoo *Cuculus canorus* and environmental factors as habitat suitability, wind and geomorphology we can find the least cost path between the known breeding and wintering locations. To create a movement cost layer, assumptions are required on the relation between the environmental parameters in question and the actual movement cost. Currently models are incorporating static parameters, but creating a design that incorporates dynamic parameters is more complex and needs further work. Eventually we hope to be able to predict not only which environmental parameters have had the strongest evolutionary influence on the current migration system, but also to predict individual migration decisions in real time. (mwkristensen@snm.ku.dk)

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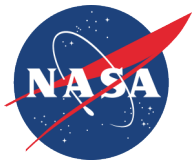

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