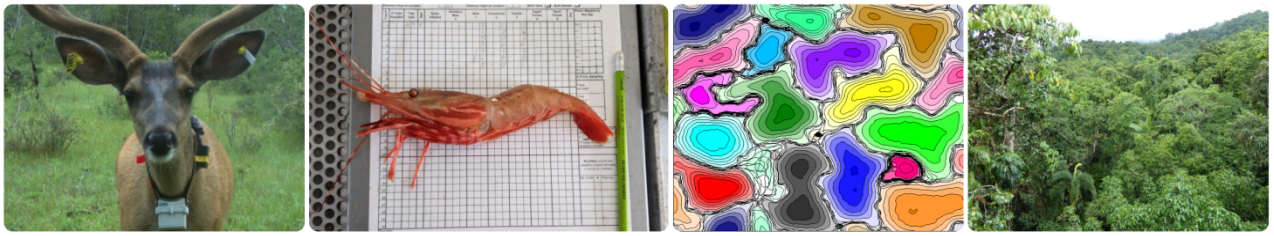
Sheffield Spatial Ecology Workshop: From animal movement processes to spatial distributions



Sheffield

July 11th-14th, 2023

Book of Abstracts

Speaker: Mark Lewis, University of Victoria, Canada

Title: Models and empirical evidence for the use of memory in animal movement pattern

Abstract: Animal movement modelling provides unique insight about how animals perceive their landscape and how this perception influences their space use. This subject has recently been investigated by a variety of theoretical models from the perspective of pattern formation using coupled partial differential equation models. However, most of these models lack a solid empirical foundation. In this talk I focus on empirical evidence for the use of memory by animals while being tracked via radiotelemetry and how the data can be incorporated into a step-selection function that can potentially connect back to partial differential equation models. I focus on patrolling behaviour in wolves (*Canis lupus*) in the foothills of the Rocky Mountains and on foraging behaviour in brown bears (*Ursus arctos*) in the Canadian Arctic.

Tuesday 11th July, 9.30-10.30

Speaker: Ricardo Martinez Garcia, Center for Advanced Systems Understanding (CASUS) - Helmholtz Zentrum Dresden Rossendorf (HZDR), Germany

Title: Absorption statistics of movement models with home-ranging behavior: animal-vehicle collisions as a case study

Abstract: In this presentation, I will first introduce a general framework for probabilistic interactions in stochastic processes, using numerical simulations of the microscopic processes and presenting a continuous approximation to the encounter process based on Fokker-Planck equations. Then, I will discuss how such formalism can be applied to study encounters between a range-resident animal trajectory and a road with varying traffic intensity and how to connect the model's parameters to observational data. The ultimate goal of this project, which is in its first stage, is to develop a data-driven framework to assess the intensity of human-wildlife interactions in populations of range-resident species and support decision-makers and conservation efforts.

Tuesday 11th July, 11.00-11.20

Speaker: Paul Blackwell, University of Sheffield, UK

Title: Stochastic differential equation models linking movement to spatial distribution

Abstract: Standard step-selection models do not scale directly to give the same long-term spatial distributions as resource selection models. Links between the two distributions involved have long been known for some simple processes (Moorcroft & Barnett, 2008; Barnett & Moorcroft, 2008), and Michelot, Blackwell & Matthiopoulos (2019) introduced a much more general approach for constructing models of movement processes consistent with a given spatial distribution, with a consistent parameterization used for both. Here I'll focus on continuous-time models, defined in terms of stochastic differential equations, that again relate short-term selection and long-term distribution, building on the Langevin diffusion applied by Michelot, Gloaguen, Blackwell & Etienne (2019). These models can be extended to incorporate a wide range of biological features, making use of theoretical results of Ma, Fox, Chen & Wu (2019) and giving insight into the wider relationship between process and distribution. Recent joint work with Jason Matthiopoulos shows that such models can also help to address important practical problems of statistical inference and design, for example allowing joint inference from telemetry and survey data. A current open question is how to extend this framework to deal with complexities such as individual differences and interactions between individuals.

Tuesday 11th July, 11.20-11.40

Speaker: Garrett Street, Mississippi State University, USA

Title: A Body In Motion: The Methods and Mechanisms of Movement

Abstract: Analysis of animal movements requires not only extensive data on displacements and behaviors, but also on new technologies capable of collecting such data to enable new analytical directions. Here I will discuss several recent methodological and technological advancements developed by the Quantitative Ecology & Spatial Technologies Laboratory at Mississippi State University; introduce a variety of datasets created using these technologies; and discuss multiple possible research directions integrating fundamental ecological theory, statistical modeling, and mathematical mechanism that are enabled by these data. I will particularly emphasize ongoing questions of how animal behavior and movement influence animal body mass via metabolic ecology, how this can contribute to sustainability in animal production systems (e.g. livestock grazing in managed rangelands), and how movements and emergent space use lead to population viability under multiple competing and potentially interacting ecological hypotheses.

Tuesday 11th July, 11.40-12.00

Speaker: Amal Chantoufi, French National Museum of Natural History (MNHN), France

Title: Bird damage to crops in Switzerland: movement patterns of carrion crows in an agricultural landscape

Abstract: Sunflower and maize are often subject to bird damages at sowing or emergence, causing yield losses and cost increases due to a second sowing in extreme situations. This could even threaten the production of sunflower, as farmers are tempted to give up this crop and choose another one with less risk of failure. The main bird species involved are rooks and crows, but pigeons were also mentioned in some swiss areas. Bird population control through shooting or nest destruction is poorly effective and with the ban of seed coating with repulsive substances, farmers are left without any solution to protect their crops against bird attacks.

The current study focuses on birds' population dynamics using GPS tracking to better understand the impact of agricultural landscape on damage risk for crops.

It aims to improve the understanding of corvid behavior in order to offer durable solutions to prevent damage for a better balance between the economic well-being of farmers and the conservation of bird species.

Tuesday 11th July, 14.00-14.20

Speaker: Valentina Ruco, University of Turin, Italy

Title: Sustainability of human activities in a complex predator-prey system in the Western Alps

Abstract: Our study is based on the fear landscape framework: in a human-dominated landscape, it is hypothesized that roe deer perceive not only wolves, but also humans and LGD as potential predators or sources of disturbance to be avoided. The presence of multiple predators and prey (wild and livestock) can affect the space use and movements of roe deer in different ways and lead to several contrasting hypotheses which take into account the potential impact of humans. Our specific objective is to understand the effect

of human activities on the spatial behaviour of roe deer, given the presence of wolves and red deer. What are the main factors influencing habitat selection by roe deer in an anthropic context? What factors influence the movement of roe deer across a human-dominated landscape? To address our questions, we will evaluate the spatial responses of roe deer movements by applying the Step Selection function. To assess the effect of a specific disturbance (hunting dogs and LGDs) we also compare the movement behaviour of radio-collared roe deer before and after the disturbance. Understanding how movement mechanisms give rise to patterns of space, allows to understand and predict the spatio-temporal distribution of roe deer based on the movement decisions of individuals in response to predation risk. To do this it requires a proper parameterization of the movement processes. Can we identify and quantify the appropriate link between animal movements and the spatio-temporal distributions of individuals? Interdisciplinary collaborations, particularly with statistical ecologists, could be very helpful in finding the best techniques for my analysis.

Tuesday 11th July, 14.20-14.40

Speaker: Lukas Eigentler, Universität Bielefeld, Germany

Title: Competition dynamics in range expansion: the role of initial distributions and spatial heterogeneities

Abstract: The spread of a population into space previously unoccupied by that population is commonly referred to as range expansion. Understanding range expansion is important for the study and successful management of ecosystems, with applications ranging from controlling bacterial biofilm formation in industrial and medical environments to large scale conservation programmes for species undergoing climate-change induced habitat disruption.

In this talk, I present results from an interdisciplinary study in which I investigated the interplay between competition for space and antagonistic interactions during microbial range expansion (biofilm formation). Combining mathematical modelling with experimental assays using the soil-dwelling bacterium Bacillus subtilis, I highlight that traits enhancing competitive fitness during range expansion differ from those guaranteeing competitive success in well-mixed environments. In particular, I reveal that the density of the biofilm inoculum significantly affects competitive dynamics and that competitive outcome can be mapped directly to the spatial distribution within the inoculum. Finally, I highlight the impact the role of spatial environmental heterogeneities on the competition dynamics from a mathematical modelling perspective and will challenge the audience to suggest experimental and/or data-driven approaches to verify modelling hypotheses.

Tuesday 11th July, 16.00-16.20

Speaker: Jonathan Potts, University of Sheffield, UK.

Title: Scaling up from movement decisions to broad-scale space use patterns: an approach via step selection

Abstract: This talk will describe various techniques for deriving broad-scale utilisation distributions from a class of movement kernels that can be parametrised by step selection analysis. We give examples of applying these techniques to empirical data, highlighting how they can be used to assess the goodness of fit between models and data, thus

informing future modelling and data gathering experiments. We also show how this modelling approach can lead the researcher to a class of partial differential equations with rich pattern formation properties and a variety of interesting outstanding mathematical questions: fertile ground for future applied mathematical research with important biological implications.

Tuesday 11th July, 16.20-16.40

Speaker: Bill Fagan, University of Maryland, USA

Title: Spatial memory and preferred travel routes in mammalian carnivores

Abstract: The growing availability of animal tracking data has prompted rapid growth in the area of cognitive movement ecology. This topic connects with theoretical modeling efforts devoted to such biologically rich topics as memory and learning, and a particular interest deals with how animals navigate following paths that are used repeatedly. Previous work has addressed the importance of reused pathways for movement in a range of biological systems from ants to elephants. Here I report on results from a study that brought together a global database of almost 1300 GPS movement tracks from range-resident mammalian carnivores to test—for free-ranging animals in the wild—predictions from laboratory experiments investigating aspects of animal cognition. Through a series of laboratory studies designed to test the spatial memory capabilities of domestic dogs and cats, researchers found an array of experimental evidence suggesting that dogs have superior spatial memory abilities compared to cats. From these studies, researchers concluded that dogs are more likely than cats to be capable of “cognitive spatial displacement” that, in the wild, could facilitate navigation without relying on a reduced set of heavily favored travel routes. That is, the good spatial displacement skills of dogs should make them better at landmark-based navigation involving path integration and cognitive maps, allowing for more equitable use of space and a more extensive travel network. We tested these predictions concerning the differential importance of favored travel routes using data from 32 wild species, 16 each from the dog family Canidae and the cat family Felidae. These carnivore taxa are modern-day representatives of lineages that diverged ~65 million years ago, a long period that has allowed great opportunities for divergent evolutionary solutions to space use problems. By calculating the location of ‘probability ridges’ within each individual’s home range, we developed a statistical metric that provides a concise summary of internal home range structure, identifying the extent to which travel is concentrated along favored routes. Using these ridges in a comparative analysis, we found strong evidence for a clade-level difference in the carnivores’ reliance on preferred travel routes. On average, home ranges of canids featured ~30% greater ‘ridge density’ than did felids, after fully controlling for effects of body mass, environmental covariates, hunting strategy, home range size, and phylogenetic correlation.

Providing the first large-scale, ‘in the wild’ support for experimental predictions concerning evolutionary differences in the nature of spatial memory among carnivores, we found that felids tended to rely on a reduced set of heavily traveled routes for movement whereas canids employed less spatially intensive movement. These differences, which suggest a greater reliance among canids on navigation via higher-level cognitive processes such as path integration and cognitive maps, have critical implications for how predators use space and interact with mobile resource species.

Wednesday 12th July, 09.30-10.30

Speaker: Dominic Grainger, University of Sheffield, UK.

Title: Improving the efficiency of continuous-time models of individual animal movement within a Bayesian framework

Abstract: The study of animal movement helps to garner a broad ecological understanding of animal species, aiding conservation efforts. However, when modelling spatiotemporal individual animal movement data, it is common to use discrete-time approaches such as Hidden Markov Models (HMMs), which are problematic when faced with irregular (or missing) observations or separate analyses on different timescales. Continuous-time models of animal movement do not have such limitations but are not so widely used due to their computational inefficiency and perceived complexity.

This talk gives an overview of novel research that aims to improve the efficiency and accessibility of continuous-time animal movement models such that their implementation is competitive with models formulated in discrete time. We build on previous work which conceptualises an existing method for exact Bayesian inference in continuous time as a temporally inhomogeneous HMM, improving computation time by reducing the dimensionality of the parameter space that we sample from for MCMC. In doing so, we are developing the Fast Integrated Continuous-time HMM (FInCH).

Wednesday 12th July, 11.00-11.20

Speaker: David Scott, University of Liverpool, UK

Title: Role of spatio-temporal environmental fluctuations in facilitating range expansion under climate change

Abstract: Temperature change can be highly volatile across space and time which may facilitate or hinder a species' response capacity to climate change. A better understanding of this variation, and how spatial and temporal fluctuations interact, is essential to predict which species will be most impacted by current and future climate change and why. I use a single species population dynamics model in discrete time and space to see how spatio-temporal fluctuations impact a theoretical species' ability to track a shifting climate along a latitudinal gradient at its colder range margin.

Wednesday 12th July, 11.20-11.40

Speaker: Natasha Klappstein, Dalhousie University, Canada

Title: Behaviour-dependent habitat selection via state-switching step selection analysis

Abstract: Modelling behaviour-dependent habitat selection can help delineate critical habitats and reduce bias in model parameters. An HMM-SSF (hidden Markov model – step selection function) is a recently developed integrated approach, in which the observation process of an HMM is defined by an SSF. This allows inference into both habitat selection and behavioural dynamics, providing a method to incorporate time-varying dynamics into SSFs and add a spatial component to animal movement HMMs. In recent work, we focused on making this method more efficient and general. By writing the model as a special case of an HMM, well-known inferential methods could be used directly for parameter estimation and state classification. Further, we extended the HMM-SSF to include covariates on the HMM transition probabilities, allowing for inferences into the temporal and individual-specific drivers of state switching. This method can be used to analyse behaviour-specific habitat selection in a wide range of species and systems, and we are currently exploring methodological extensions that will be of utility to ecologists. In particular, we are considering methods to account for inter-individual heterogeneity, coarse-scale temporal dynamics, and measurement error, as well as

assessing the need for model checking techniques and user-friendly software. We also want to consider extending the method to different data types, and develop a better sense of which ecological questions are of the most interest to applied scientists.

Wednesday 12th July, 11.40-12.00

Speaker: Yurij Salmaniw, University of Alberta, Canada

Title: Mathematical Analysis of a Scalar Reaction-Diffusion-Advection Equation with Cognitive Map

Abstract: In this talk, I would like to discuss some of the work done by a colleague and myself concerning the mathematical analysis of some equations arising in cognitive movement ecology. In general, these models are multi-species, include non-local terms (through non-local detection or perception), and are nonlinear at higher order. In order to develop the theory, we focus on the effect of the inclusion of a cognitive map in a scalar equation (single species) setting in one spatial dimension. We provide an existence theorem for weak solutions of the problem, and we are able to give a detailed bifurcation analysis with respect to some key parameters. Numerical simulations complement these results, where a pseudo-spectral method is utilized to solve the problem numerically.

Wednesday 12th July, 13.30-13.50

Speaker: Toyo Vignal, Maxwell Institute - Edinburgh, UK

Title: Impact of different destocking strategies on the resilience of dry rangeland

Abstract: Half of the world's livestock live in (semi-)arid regions, where an important proportion of the population relies fully or partially on animal husbandry for survival.

However, overgrazing can lead to land degradation and subsequent socio-economic crises. Sustainable management of dry rangeland requires suitable stocking strategies and has been the subject of intense debate in the last decades.

Our goal is to understand how variations in stocking strategies affect the resilience of a productive dry rangeland. We describe the rangeland dynamics through a simple mathematical model consisting of a system of coupled ordinary differential equations. We assume that the livestock density is limited by forage availability only, which is itself limited by water availability.

We model plant-plant facilitation and land degradation processes typical of dryland as a strong Allee effect, leading to bistability between a vegetated and a degraded state, even in the absence of herbivores. We study analytically the impact of varying the stocking density and the destocking adaptivity on the resilience of a productive system to the effects of drought, modelled as a sudden loss of vegetation.

The tractability of the model enables us to find theoretical insights on the impact of changes along these two axes of variation in management by using dynamical systems theory. Looking at how different measures of resilience are affected by variations in management strategies, we find that:

1) Increasing the stocking density decreases the resilience, giving rise to an expected trade-off between productivity and ecological resilience.

2) There exists a maximal sustainable livestock density above which the system can only be degraded. This animals carrying capacity is common to all strategies, as it depends on biological factors only and not on management choices.

3) Higher adaptivity of the destocking rate to available forage makes the system more resilient: the more adaptive a system is, the bigger the losses of vegetation it can recover from, without affecting the long-term level of productivity.

The first two results emphasize the need for adapted dry rangeland management strategies, in order to prevent irreversible land degradation resulting from the conflict between profitability and sustainability. The third point offers a theoretical suggestion for such a strategy as it shows that increased destocking adaptivity increases the resilience without affecting the long-term stocking density goal.

Outstanding questions that might benefit from new interdisciplinary collaborations: the theoretical work described above does not explicitly take into account the spatial dimension. However, as destocking can correspond to the displacement of animals out of the system, its results suggest that animals mobility can play a key role in increasing the resilience of a system. I am interested in studying how the grazing and mobility behaviour of animals (wild and livestock) adapts itself to changes in the amount of vegetation available.

Wednesday 12th July, 13.50-14.10

Speaker: Eloise Bray, University of Sheffield, UK.

Title: Exploring the effects of anthropogenic environmental change on seabird movement during the breeding season

Abstract: The increased focus on sustainable energy has driven demand for the expansion of offshore renewables along the Scottish coast. In terms of climate change, the net benefit is positive. Yet, there is inevitably an impact on local ecosystems, with seabirds among the affected species.

My work involves modelling the central-place foraging trips of seabirds during the breeding season. These trips are known as out-and-back foraging trips since we assume the bird flies away from its nest towards some area to forage and then returns to its nest once successful. One problem they may encounter is wind farms obstructing their path, known as a barrier effect.

I have been working on simulating these foraging trips using a class of relatively under-used movement models called piecewise-deterministic Markov processes. We want to be able to use this model to explore the effects of wind farms on seabird movement. One advantage of the model is we can easily formulate it in terms of time and spatial covariates, but we need to explore which are more important ecologically. My main statistical challenge lies in how we can produce a fully Bayesian inference method for this class of model.

Wednesday 12th July, 14.10-14.30

Speaker: Lena Lyanna Payne, University of Kent, UK

Title: Social Evolution in a Predator-Prey Model

Abstract: I will be talking through my initial work on showing how a species might develop communal responsibilities/actions like pack hunting, and what I hope to be able to show by the completion of my PhD.

Wednesday 12th July, 15.30-15.50

Speaker: Amal Safar Alnufaie

Title: Modelling Complex Dynamics of Social Protests on Networks

Abstract: Mathematical modelling of riots and protests is now becoming a powerful tool in providing a better understanding of dynamics of social unrests with the eventual goal to ensure a sustainable development of the human society. Currently, however, most of the existing studies in the considered research area are based on either non-spatial or spatially implicit models, whereas in a large number of cases dynamics of social protests clearly exhibit spatial heterogeneity. To bridge the existing gap, here we explore spatial-temporal patterns of social protests using a reaction-diffusion modelling framework. Our model variables are: the number of protesters and the cumulative amount of damage made as an outcome of the protest. The system has been studied analytically as well as by means of extensive numerical simulation in one dimensional and two dimensional space. We show that the proposed model exhibits a variety of dynamical regimes including stationary patterns with round hot spots as well as complex labyrinthine-like structures. The system also predicts the various types propagating waves of protests with regular and irregular fronts as well as a patchy spread, where protests spread in space via irregular motion and interaction of separate patches of high numbers of protestors without formation of any continuous front, the number of protestors between patches being nearly zero. We reveal the structure of the parameter space of the model identifying the range of key parameters for which particular dynamical regimes are possible.

Wednesday 12th July, 15.50-16.10

Speaker: HaDi MaBouDi

Title: Behavioural and neural mechanisms of insect navigation

Abstract: Insects are remarkable creatures known for their advanced abilities in navigating their environment, which is crucial for their survival. They use a combination of sensory cues, such as visual landmarks, the position of the sun, and polarised light patterns, to navigate through a complex neural computation of their current state and past experiences. For instance, some insects, such as bees, can perform incredible feats of navigation, exploring their environment for food and then returning to their hive from distances of several kilometres. The mechanisms behind bee navigation are influenced by what the bee can sense about the environment, her past experiences with space and flower, the context (is a predator nearby?), the state of the bee (does she already carry full load of nectar or pollen?) and the state of her colony. This means the bee navigation is a whole-brain activity that involves sensory system, memory, decision-making, planning and motor systems as well as the bee's subjective state. These elements work together to determine her current position, direction and destination, and then coordinates her movement to reach the goal. Given the impressive abilities of insects in navigation, a deeper understanding of these mechanisms behind insect navigation is important for research in fields such as spatial ecology, cognitive neuroscience and robotic. In this talk, we will provide a comprehensive overview of the behavioural and neural mechanisms of insect navigation, with a focus on species of ants and bees. We will delve into the various strategies these insects use to orient themselves, forage for food, locate mates and to find their way back to their nest.

Wednesday 12th July, 16.10-16.30

Speaker: Raluca Eftimie, University of Franche-Comté, France

Title: Local and global bifurcations in non-local models for ecological aggregations

Abstract: TBA

Thursday 13th July, 09.30-10.30

Speaker: Andrew Morozov, University of Leicester, UK

Title: Modelling the optimal diel vertical migration of zooplankton using novel theoretical and computations frameworks

Abstract: Diel vertical migration (DVM) of marine and freshwater zooplankton in the water column is the largest synchronised movement of biomass on Earth. DVM heavily impacts the biochemical cycles in the ocean, playing a fundamental role in the carbon exchange between the deep and surface waters, the ocean's biological pump and thus, the climate. The typical pattern of DVM consists of the zooplankton organisms ascending to the phytoplankton rich surface waters for feeding at night, then descending to deeper depths and remaining there during the day. Although the phenomenon of DVM has been studied extensively, there are still some crucial gaps in our knowledge. In particular, the relative impacts of visual predators, food and the metabolic costs on patterns of DVM is still poorly understood. In this study, we model DVM of zooplankton across the heterogeneous water column using a novel approach to quantify evolutionary fitness as a result of long-term selection of a large number of competitive strategies. We reveal the optimal trajectories of DVM in the model for different developmental stages of zooplankton depending on the vertical distribution of predators, food, oxygen, temperature, etc. To find the optimal daily trajectory of migration, which is mathematically a function, we develop and apply a new method of bio-inspired stochastic global optimisation in high-dimensional, or even infinite-dimension Hilbert spaces. We call our method the Survival of the Fittest Algorithm (SoFA). We parameterise our model of DVM using 7 years of empirical data on DVM of two dominant zooplankton species in the north Black Sea from 2007-2014. We show that the observed DVM in the Black Sea can be explained as the result of a trade-off between depth-dependent metabolic costs for grazers, anoxia zones, available food, and visual predation.

Thursday 13th July, 11.10-11.30

Speaker: Daniel Bearup, University of Kent, UK

Title: Effects of dispersal on population dynamics in dendritic structures

Abstract: Dendritic structures, e.g. river networks or the surface of a tree, place unique dispersal constraints on the dispersal of individuals that inhabit them. I am currently in the early stages of developing a reaction-diffusion like framework to model habitats of this type on a large scale, i.e. for the habitat as a whole. I will present some initial results around generalisations of the diffusion operator that I have been working on.

It would be useful to talk to ecologists with an interest in population dynamics in these types of habitats. It would also be interesting to talk about alternative modelling approaches for these types of systems.

Thursday 13th July, 11.30-11.50

Speaker: Sébastien Coube-Sisqueille, Basque Center for Applied Mathematics, Spain

Title: Hierarchical Nonstationary Nearest Neighbor Gaussian Process Models

Abstract: Nonstationary spatial modelling is exciting and potentially rewarding, but suffers from several problems : its computational cost, the complexity and lack of interpretability of multi-layered hierarchical models, and the difficulty of model selection.
We tackle those problems by introducing a nonstationary Nearest Neighbor Gaussian Process (NNGP) model.
NNGPs are a good starting point to address the problem of the computational cost because of their accuracy and affordability.
We study the behavior of NNGPs that use a nonstationary covariance function, deriving some algebraic properties and exploring the impact of ordering on the effective covariance induced by NNGPs.
To ease results analysis and model selection, we introduce a readable hierarchical model architecture. In particular, we make parameters interpretation and model selection easier by integrating stationary range, nonstationary range with circular parameters, and nonstationary range with elliptic parameters in a consistent framework.
Given the NNGP approximation and the model architecture, we propose two ad hoc MCMC algorithms based on Metropolis Adjusted Langevin Algorithm and Chromatic Sampling, both being improved using interweaving of parametrizations.
We carry out experiments on synthetic data sets to find empirical practical rules concerning on MCMC algorithm choice, hyperparameter tuning, and model selection. Finally, we use those guidelines to analyze a data set of lead contamination in the United States of America.
The method proposed here allows to model and interpret complex processes relatively easily and hopefully ecologists attending the workshop might find it useful for their own research. A multivariate version is on its way as part of my postdoc contract and applications could be considered as well.
Thursday 13th July, 13.30-13.50

Speaker: Rafael Menezes dos Santos, University of São Paulo, Brazil

Title: Adding realistic movement behavior to spatial models of population growth: The population-level consequences of range-residency

Abstract: Models of population dynamics often assume well-mixed populations and therefore neglect the role of movement and spatial structure in shaping population-level processes. Some exceptions are individual-based models and continuous models based on partial differential equations for population density. These approaches consider how populations distribute in space but rarely incorporate realistic movement behaviors, which often exhibit individual home-ranges smaller than population range and uneven patterns of space utilization. In this presentation, I will introduce a modeling framework to incorporate range-resident movement behavior into spatially explicit logistic models of population growth. Using a combination of stochastic simulations and analytical approximations, I will show how birth, death, competition, and range-resident movement change the spatial distribution of organisms and how this emergent spatial structure determines population sizes at equilibrium. Additionally, by explicitly modeling range-resident movement, our framework can encompass a diverse range of movement behaviors, from sessile organisms with vanishingly small home ranges to roaming organisms with home ranges as large as the environment. In these two limits, our results are consistent with those produced by spatial and well-mixed logistic models. Our modeling framework offers a unifying approach for investigating the interplay between intraspecific competition and

range-resident movement in shaping population dynamics, bridging the gap between models for sessile and Brownian-moving organisms to provide a comprehensive understanding of population growth and spatial distribution.

Thursday 13th July, 13.50-14.10

Speaker: Marianne Damholdt Bergin, Aarhus University, Denmark

Title: Space use requirements in rewilding sites

Abstract: Successful trophic rewilding relies on effects achieved through increased trophic complexity. The degree to which a sites rewilding potential is fulfilled can be calculated by how much introduced animals occupy the available potential habitat (Mata et al., 2021). Knowledge of suitable habitats and potential for animal space-use is therefore key when planning introduction of animals into rewilding sites in order to assess potential effects from animal movement patterns (Menard et al., 2002).

In my study I aim is to identify features in rewilding sites that effects animal movement and in turn effect rewilding success. Multiple sites across the country with cattle or horses in year-round, low-intensity grazing management are included in this study. In order to analyse habitat selection, this project has two components: habitat classification and animal tracking. Based on this multi-site explorations of space-use, this project is expected to result in empirical evidence of habitat selection relevant to rewilding across northern Europe.

A challenge is that I use a range of GPS equipment- ear tags, collars, solar and battery driven. I am interested in how these tags can be used to answer the same questions, even if difference in settings, performance (to be studied) and procession.

Thursday 13th July, 14.10-14.30

Speaker: Julia Emi de Faria Oshima, University of São Paulo, Brazil

Title: From Pantanal to the Caatinga: applying movement ecology for conservation in Brazil

Abstract: Recent advances in global positioning systems (GPS) and data transmission technologies have improved the quality and the quantity of information that we can get from animal tracking, providing new opportunities to explore exciting ecological questions and analytic challenges to work with big data and complex ecological models (Cagnacci et al., 2010; Urbano et al., 2010; Lyons et al., 2013). We have used GPS to track (1) 30 white-lipped peccaries (Tayassu pecari) from 10 different herds in the Cerrado and Pantanal of Brazil, we analyzed the habitat selection using step selection functions to better understand how the landscape structure was influencing the peccaries movement decisions, now we we'd like to use this information to evaluate what are the main corridors that connect suitable habitat for this species in these complex region, which is being rapidly altered by humans, through scaling up our study results to a broader spatial region that interconnects the area used by those monitored herds. In a second study, we monitored (2) native and reintroduced Lear's macaws, an endangered and endemic psittacid, and 4 species of vultures from the Caatinga to understand what the collision risks for those birds with wind power turbine towers are. Wind parks are expanding rapidly in the semiarid region of Brazil, but their impacts for bird species are still poorly investigated. Since these bird species have different flying behavior and habitat selection different models must be developed for each one of them. These are two projects developed in

Brazil that are focused on finding answers to conservation targets, for the peccaries study we would like to focus on providing planning tools for protecting key habitats and restoring potential corridor regions, and for the collision risk analysis we are working with a very specific question that is still unclear but with the expansion of wind energy parks it will be necessary to address the cumulative impacts that these constructions can have in the landscape and in the bird populations in a long term.

Thursday 13th July, 15.30-15.50

Speaker: Érika Garcez da Rocha, Federal University of Mato Grosso do Sul / Swansea University.

Title: Predicting animal responses to the loss of thermal shelters by deforestation: scaling up step selection functions

Abstract: The giant anteater, *Myrmecophaga tridactyla*, is a large mammal which uses the forest as a thermal shelter, as it has a low capacity for internal thermoregulation. However, forest loss is an increasing threat to biodiversity mainly due to human-induced deforestation. In this study, we aim to investigate how to reduce the impacts of the loss of thermal shelters due to deforestation on giant anteaters. We GPS-tracked 14 giant anteaters in Brazil and performed an integrated step selection analysis (iSSA) to estimate habitat selection parameters for the forest, environmental temperature and time of the day. Firstly, we developed five individual-based models(IBMs) to simulate the space use of these individuals by combining different covariates from habitat selection. The IBMs were parameterized with the coefficients extracted from the integrated step selection analysis (iSSA). Then, we produced predicted spatial occurrence distribution (OD) for each individual and compared it with the observed data. As this is an ongoing study, we have performed some tests on the parameters and settings of the IBMs to evaluate the efficiency of the models to predict space use, which will be the preliminary results to be presented in this talk. The next steps include simulating different scenarios of deforestation and performing simulations to evaluate how the loss of forest might affect space use of these animals. In addition to that, we aim to expand this study to other mammals in Brazil.

Thursday 13th July, 15.50-16.10

Speaker: Lucie Thompson

Title: Simulating the effects of dispersal barriers across food webs with metacommunity models

Abstract: TBC

Thursday 13th July, 16.10-16.30

Speaker: Luca Börger

Title: Disentangling individual behaviour and ecological and evolutionary processes driving organismal movements under global change

Abstract: The combined actions of human caused land use and climate change are increasingly affecting the distribution, movements and survival of organisms across earth, but understanding and predicting how organisms will respond is not well achieved currently in movement ecology. A difficulty is that the movements and spatial ecology of organisms are affected by variation in individual behaviour, interacting with ecological and

evolutionary processes across different temporal scales, and disentangling their roles is challenging. Here, I provide examples on these three topics from our recent research. Firstly, I focus on experimental evolution of dispersal, discussing how adopting an integrative framework of theory, experimental evolution and natural systems allows to overcome practical constraints and improve our understanding of dispersal evolution under more complex and realistic biological scenarios. Second, I show how including traits allows a better understanding of biogeographic dispersal across evolutionary timescales, using recent work on chameleons and a broad analysis across tetrapods. Third, I show how high-frequency multi-sensor biologgers allow now to jointly investigate animal movements and behaviour, greatly enhancing our understanding of animal responses to changed conditions. Specifically, I show our recent work on the ecology of sleep in free-living wild species, a topic which until now was entirely precluded from scientific studies, but for example allows now to understand how wild boar react to sudden pulses of human visitors to parks, caused by the Covid-19 lockdown policies. Combining these three strands of research, I briefly discuss future avenues of study.

Friday 14th July, 09.30-10.30

Speaker: Annalisa Iuorio, University of Vienna, Austria

Title: The Impact Of Autotoxicity On Vegetation Dynamics: A Mathematical And Ecological Overview

Abstract: Understanding vegetation dynamics, particularly the mechanisms leading to the emergence of several types of vegetation patterns in different environments, is a crucial goal of our time. Such structures, in fact, are not simply interesting from the theoretical viewpoint, but also play a major role in preserving ecosystems' resilience by being important ecological indicators of their "fitness". In recent years, increasing attention has been devoted to the influence of so-called autotoxicity on the dynamics of living organisms - including vegetation. This has opened the door for new, biologically feasible explanations of experimental observations known to theoretical and applied ecologists which were hard to justify by means of "standard" models focusing only on the interplay between biomass and water dynamics.

Together with several researchers both from the mathematical and the ecological field, we have explored how autotoxicity affects the formation of several types of patterns, including fairy circles and Janzen-Connell distribution. To this aim, we have constructed and analysed mathematical models based on partial differential equations including reaction, diffusion, and advection mechanisms (the latter to account for the case of sloped terrains).

In this talk, I will introduce the concept of autotoxicity from the biological viewpoint and then provide an overview of several models we constructed in recent years including this factor. The aim of my talk is to show the impact of autotoxicity on vegetation and its ability to lead to novel features in the emerging patterns, both in mathematical and ecological terms. From an analytical perspective, in fact, autotoxicity leads to more complicated stationary/travelling patterns, which can be investigated by extending tools in the area of Geometric Singular Perturbation Theory. Ecologically, the inclusion of autotoxicity provides a potential justification of observed patterns also in environments where water is not a limited resource.

Friday 14th July, 11.00-11.20

Speaker: Sara Bernardi, Polytechnic University of Turin, Italy

Title: What mechanisms allow leaders to steer a swarm?

Abstract: Collective migration of cells and animals often relies on a specialised set of “leaders”, whose role is to steer a population of naive followers towards some target. We investigate the dynamics and structure of such groups using a continuous approach where a population is subdivided into follower and leader types with non-local interactions and different orientation responses influencing the turning rates of group members. Within this modeling framework, we incorporate leader influence via three mechanisms: a bias in the orientation of leaders towards the destination (orientation-bias), a faster movement of leaders when moving towards the target (speed-bias), and leaders making themselves more clear to followers when moving towards the target (conspicuousness-bias). Analysis and numerical computation are used to illustrate the various patterns displayed by the models, thus assessing the extent to which the swarm is successfully shepherded towards the destination.

📍 *Friday 14th July, 11.20-11.40*

Speaker: Bradly Deeley, University of Birmingham, UK

Title: The Propagation Of Invasive Plant Species In The Heterogeneous Landscape

Abstract: Biological invasion is identified as one of the most serious environmental problems currently facing society. Invasive plant species cause damage to both the ecosystem and the economy at an increasing rate. We have developed a mathematical model that incorporates landscape heterogeneity (e.g., a road) in the spatial domain. While our previous work [1] has been focused on various regimes of propagation of invasive species in the heterogeneous landscape, we now investigate how the propagation speed depends on the presence of a road in a 1-D spatial domain. The propagation speed is a widely studied property of invasive species, and understanding how it varies in different landscape conditions is necessary to accurately predict the spatio-temporal distribution of the invasive species. It will be argued in the talk, both analytically and computationally, that the propagation speed is different when we compare it to the ‘no road’ case of uniform landscape. We then argue that at the short-time scale, the propagation speed behaves non-monotonically with the detection sensitivity leading to uncertainty in predicting how an invasive species will spread in the spatial domain.

[1] Deeley, B., Petrovskaya, N. (2022) Propagation of invasive plant species in the presence of a road. Journal of Theoretical Biology, 548, 111196.

📍 *Friday 14th July, 11.40-12.00*

Speaker: Valeria Giunta, University of Sheffield, UK

Title: Multi-stability in non-local advection-diffusion models

Abstract: Understanding the mechanisms behind the spontaneous emergence of aggregation patterns in the distribution of individuals is one of the greatest challenges in the life sciences. Aggregation phenomena are usually driven by interactions between individuals and their environment. In nature any organism, be it a cell or an animal, interacts non-locally, meaning that it inspects a portion of its environment before making decisions. The analysis of non-local interactions is a cutting-edge topic, and in recent years mathematical models incorporating non-local terms have been receiving increasing

attention, due to their ability to accurately describe how interactions between individuals and their environment can affect their movement, reproduction rate, and well-being.

In this talk, I will present a study of a class of non-local advection-diffusion equations modelling population movements generated by inter- and intra-species non-local interactions. Using a combination of analytical and numerical tools, I will show the existence of a large variety of spatio-temporal patterns, which are able to reproduce segregation, aggregation and periodic in time behaviours. Under appropriate conditions, the stationary patterns appear as local minimisers of an energy functional and I will show the use of a novel technique for making conjectures about the number and qualitative structure of minimum energy solutions. This technique is able to reveal parameter regions with multiple stable steady states in the form of strongly modulated patterns and hysteresis phenomena. I will then present a multi-scale asymptotic analysis to recover the existence and stability of solutions bifurcating from a homogeneous steady state. I will show that, depending on the parameters, bifurcations can be subcritical (always unstable), stable supercritical, or unstable supercritical. I will also show that, when small amplitude patterns are unstable, the system can exhibit bistability and hysteresis, even in supercritical regimes. Finally, by combining different analyses and approaches, I will show the existence of parameter regions in which stable small amplitude patterns coexist with strongly modulated solutions.

Friday 14th July, 14.00-14.20

Speaker: Edward Codling, University of Essex, UK

Title: Movement ecology of farm and zoo animals

Abstract: Movement ecology has typically involved the study of wild animals in their natural environment. However, movement ecology techniques are increasingly being applied to managed animals kept in captivity in farms or zoos. Analysis of movement and space-use behaviour of managed animals can give insights into their health, welfare, production, and reproductive status. In parallel, the controlled and well understood environment in farms and zoos and the detailed individual data available means that managed animals are ideal case studies to test the Movement Ecology paradigm. I will explore these themes using example data sets from dairy cows, farm dogs, and elephants.

Friday 14th July, 14.20-14.40

Speaker: Thomas Hillen, University of Alberta, Canada

Title: How the Tulips get their Stripes

Abstract: Tulips have captivated human interest for centuries, with their vibrant colors and unique shapes. Particularly striped tulips have been highly popular, leading to the “tulip-mania” in the Dutch Golden Age. But how do the tulips get their stripes? Maybe Turing can help?

Friday 14th July, 14.40-15.00