Data-driven modelling of pattern formation in ecology and collective behaviour

This is a fully funded PhD opportunity for UK or EU nationals who have or will achieve a Master's degree by the 31st December 2018. The successful applicant will join the Centre for Research in Ecology Evolution and Behaviour of the University of Roehampton (London, UK) and will receive a stipend of £16,777 per year, for three years. The tuition fees of £4,260 per year will be covered by the University. Research funds (£14,000) will also be provided to support the direct research costs of the PhD (research travel costs, computer, consumables etc.)
The start date for this position is the 1st October 2019.

PhD Supervisors: Dr Andrea Perna, Dr Lewis Halsey.

APPLICATION PROCESS:

Expressions of interest, including a CV, should be made to Dr Andrea Perna (andrea.perna@roehampton.ac.uk).

ELIGIBILITY CONDITIONS AND DUTIES:

Graduates in multiple disciplines welcome to apply. We seek candidates with a background in the quantitative sciences (physics, biology, applied mathematics, computer sciences and related scientific areas) and with an interest for pattern formation and self-organisation phenomena in ecology and collective animal behaviour. The successful candidate is expected to join the research group of Dr Andrea Perna and to develop her/his own research project around one (or potentially multiple) of the research topics outlined below.

DETAILS OF POTENTIAL RESEARCH TOPICS:

Individual mechanisms underlying community-level dynamics in microscopic ecological communities

Fig. 2. *Paramecium caudatum swimming and feeding on unicellular algae.*

Ecological interactions, such as herbivory and predation play an important role in determining the relative abundance of species within an ecosystem and ultimately the productivity and stability of the ecosystem itself. Typically, these interactions are described in terms of functional responses. Functional responses provide a synthetic description of the flux of energy across trophic levels and for this reason they constitute an essential building block of realistic food web models. However, functional responses integrate implicitly a number of components, such as prey aggregation and predator chasing behaviour, that typically scale nonlinearly with environmental parameters. One recent line of research in our laboratory is directed at modelling the emergence of ecological-level patterns directly from microscopic-level interactions among organisms. We study this by combining experiments in artificial microcosms with computer-based data analysis and modelling. This project is currently funded by a research grant from the Royal Society to Dr Andrea Perna. The PhD student will be based in the University of Roehampton – London and perform data analysis (e.g. video-tracking, analysis of morphology and trajectories) and modelling (e.g. ecological networks, spatio-temporal pattern formation) on ongoing experiments and then progressively develop their own research direction. Another PhD student in the department (also starting in January 2019) will also work on related projects, focusing mainly on running experimental microcosm experiments. Roehampton University has a thriving research group working in aquatic ecology with expertise in food webs and metabolic scaling (Dr. Daniel Perkins), biodiversity and ecosystem functioning (Dr. Julia Reiss), population dynamics (Prof. Anne Robertson) and other related areas.

References:

Fussmann et al. (2014) Ecological stability in response to warming ***Nature Climate Change*** 4, 206

Woodward et al. (2010) Climate change and freshwater ecosystems: impacts across multiple levels of organization. ***Phyl. Trans. Roy. Soc. B*** 365 2093-2106

Morphogenesis, geometry and function of social insect nests

Nest building by social insects is one of the most classical examples of self-organisation phenomena in living systems, and has contributed to the evolutionary success of ants and termites. Surprisingly, still very little is known about the mechanisms underlying the construction of these structures and about their morphological and functional properties. Our laboratory aims at addressing these questions by using a variety of techniques, from micro-computed tomography imaging, 3D image analysis, mathematical and computational modelling and mechanical experiments on nest fragments.

We are focusing in particular on the characterisation of arboreal nests of nasute termites (fig. 1), which exhibit a range of interesting morphological features and are also phylogenetically important for understanding the evolution of nest building behaviour. This project is currently funded by the Royal Society in the form of a Newton International post-doctoral fellowship to Dr Giulio Facchini and Dr Andrea Perna. The PhD student would mainly be based in the University of Roehampton – London and perform data analysis and modelling of nests, but there is also the possibility (if the student wishes to) to take part in a research expedition to Sydney (Australia) during the first year to visit collaborators working on social insect biology (in particular Prof. Nathan Lo) and to collect nest samples (there is a budget allocated for this).

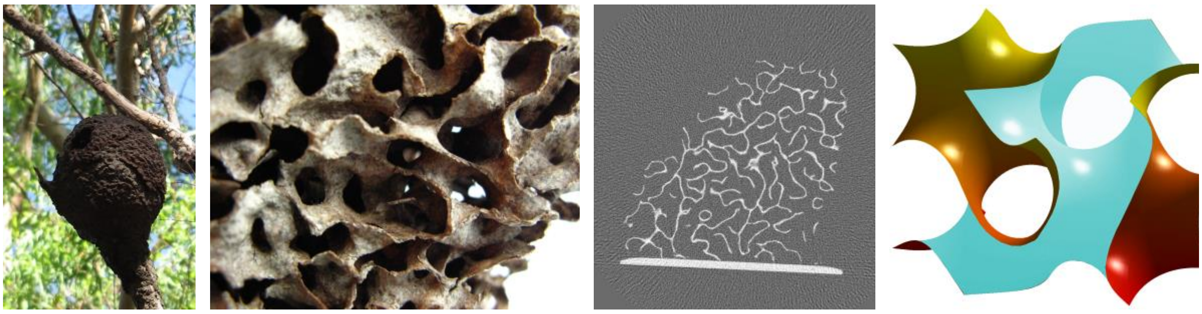

Fig. 1. *From the left: Intact Nasutitermes walkeri (image Neil Ross) nest on a tree, close up on arboreal nest; CT-scan slice image of a nest; representation of a gyroid.*

References:

Perna and Theraulaz (2017) When social behaviour is moulded in clay: on growth and form of social insect nests. ***Journal of Experimental Biology***. 220, 83-91.

Arab et al. (2017) Parallel evolution of mound building and grass feeding in Australian nasute termites. ***Biology letters*** 13, 20160665

Khuong et al. (2016) Stigmergic construction and topochemical information shape ant nest architecture. ***PNAS*** 113, 1303-1308

Perna et al. (2008) Topological efficiency in three-dimensional gallery network of termite nests. ***Physica A*** 387, 6235-6244

Hunting on the wing: investigating the manoeuvrability of preying raptors

Hawks and falcons are pursuit predators that actively chase their prey at high speed and high *g*-forces. However, in the wild, many of the attacks of these predators end in failure because the evasion capabilities of their prey almost equal the raptor's predatory capabilities. This arms race has resulted in birds of prey being able to exhibit extreme aerial manoeuvrability, yet, to date, their flight capability has barely been quantified.

As part of a collaboration with the Hawk Conservancy Trust in Andover we aim at characterising the flight behaviour and the manoeuvrability of raptors. Data collection includes video-recordings with a high-speed camera and bio-logging with a miniature accelerometer attached to the bird's back.

Coordination of individual and collective motion in animal groups

Animals moving in group, such as shoaling fish and flocking birds can move together in synchrony, and can very rapidly negotiate a new direction of movement without splitting the group. Our laboratory is specialised in developing techniques to characterise the interaction rules underlying the coordination of collective motion from empirical data. In our ongoing and planned research, we focus on linking the mechanisms of individual and collective motion to biological function (adaptation, energy acquisition / expenditure etc.)

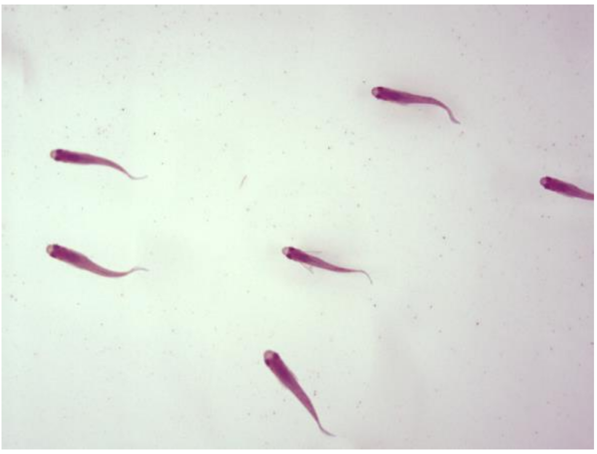

Fig. 3. *Shoaling fish (in this image mosquitofish; image James Herbert-Read)*

References:

Jiang et al. (2017) Identifying influential neighbours in animal flocking. ***Plos Computational Biology***, 13 e1005822

Perna et al. (2014) On the duality between interaction responses and mutual positions in flocking and schooling. ***Movement Ecology*** 2, 22

Pettit et al. (2013) Interaction rules underlying group decisions in homing pigeons ***J. Royal Society Interface*** 10, 20130529

Mann et al. (2013) Multi-scale inference of interaction rules in animal groups using Bayesian model selection ***Plos Computational Biology***, 9, e1002961

Sumpter et al. (2012) The modelling cycle for collective animal behavior. ***J. Royal Society Interface – Interface Focus***, 11, 12

Herbert-Read et al. (2011) Inferring the rules of interaction of shoaling fish. ***PNAS*** 108,18726-18731