

## **Species distributions in a changing world: statistical tools for dynamic species distribution modelling**

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**Project summary** This project will develop practical statistical and computational tools to enable application of dynamic species distribution models to better predict dynamics of invasive spread and range shifts under climate change.

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**Project background:** Species' distributions and the processes that determine them are dynamic. However, despite the fact that such processes (which unfold over time) are more naturally incorporated into dynamic models, the vast majority of statistical species distributions models (both spatial and non-spatial) are static in nature. This bias reflects both a paucity of suitable temporal and spatio-temporal data and current difficulties in confronting dynamic species distribution models (SDMs) with such data. The need for species distribution modelling to account for the dynamics of demographic processes has repeatedly been acknowledged [1] and dynamic SDMs offer the prospect of e.g. more reliable projections of invasive spread or range shifts under climatic change.

**Key research questions:** This project aims to address such issues by developing appropriate statistical tools for dynamic SDMs that can combine a range of sources of information, including experimental and field data, large-scale observational studies and expert knowledge about the ecology of the species. The ultimate aim is to provide a toolbox to enable the wide application of dynamic models to understand and explain species distributions. This project is likely to include application to models that: allow both colonisation and decolonisation; correct for biases and uncertainty in the observed data e.g. heterogeneity in recording error; account for growth and abundance of local populations; consider interactions with sympatric populations; and account for multiple dispersal mechanisms e.g. along river and along road networks. Recently developed methods [2] that allow different components of dynamic models to be assessed in light of the available data will be employed to test model misspecification. A key question which will be addressed using simulated data is the extent to which dynamics can be inferred from (relatively) stable species distributions. We will also consider application to data on a range of vascular plant species including both invasive aliens and natives e.g. taken from the Atlas of the British and Irish flora (> 9 million records; data available for pre 1970s, 1970s – 1987 and 1987 – 2002; RBGE has extensive network of contact to data recorders to help to establish where data are hampered by recording biases). Furthermore, we will explore the utility of dynamic SDMs for modelling and predicting anthropogenic land conversion (e.g. the conversion of forests to monoculture rubber plantations in continental South East Asia - based on spatio-temporal data on rubber distributions inferred from remotely sensed imagery).

### **Methodology**

This project aims to build on three key strands of work

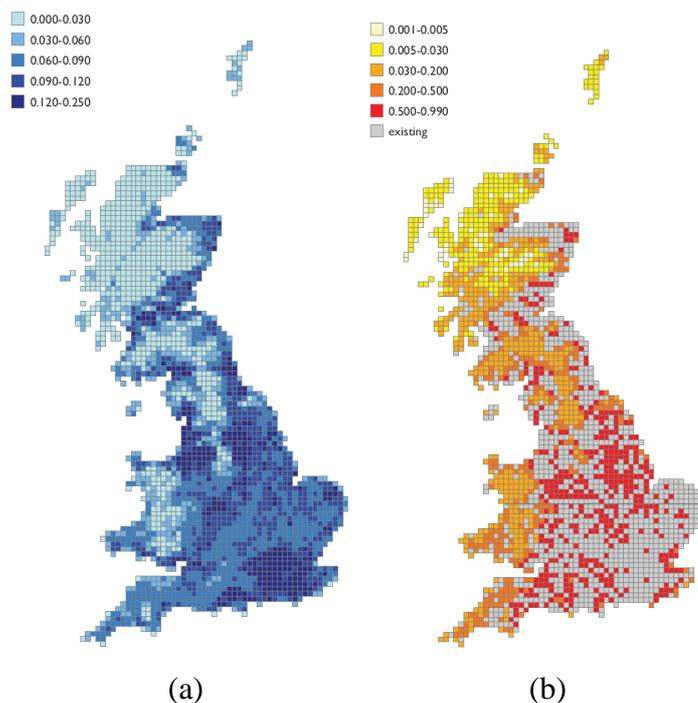
1. A generic statistical framework for inference in dynamic SDMs [3].
2. Implementation of this framework using Markov chain Monte Carlo (MCMC) algorithms for data and models describing the spread of invasive species e.g. giant hogweed (*Heracleum mantegazzianum*) in Britain (see [4] and the figure).
3. Recent developments in efficient algorithms for inference in dynamic models based on particle filtering [5] and novel enhanced MCMC algorithms developed in collaboration between BioSS and the Roslin Institute in the context of disease dynamics [6].

**Timetable:** Develop simulation tools for a range of dynamic SDMs, assess available data sets and identify key scientific questions and associated model requirements, construct suitable simulated data scenarios and assess utility of PMCMC to fit SDMs (*Year 1*); Assess data limitations to/requirements for inference in generic dynamic SDMs, develop and test enhanced MCMC algorithms for such SDMs (*Year 2*); Apply methods to address selected problems and datasets, refine models and inference tools as required (*Year 3 - 3.5*). Write, revise and submit papers for peer review (throughout).

**Training.** There is a pressing need to train the next generation of scientists in the application of modern computational and statistical techniques to problems in ecology and the environmental sciences. This project will provide training in the development, application and analysis of cutting-edge computational statistical and stochastic modelling techniques to an important applied problem. In addition to this on the job training the student will have the opportunity to take courses offered by the Scottish Mathematical Sciences Training Centre see [www.smstc.ac.uk/](http://www.smstc.ac.uk/) and the Academy for PhD Training in Statistics <http://www2.warwick.ac.uk/fac/sci/statistics/apts/>. The breadth of the supervisory team will ensure the student will also develop the ability to communicate complex ideas within and between disciplines. The studentship will therefore develop an individual with a highly sought after and widely applicable set of hard and soft skills.

**Requirements.** This project is an excellent opportunity for a candidate wishing to develop a research career in the field of mathematical biology, and the computational, mathematical and analytical skills developed during the project will be widely transferable. The project requires the ability to program in a language such as C/C++, Java, FORTRAN or equivalent and the ideal candidate would have a quantitative background e.g. in mathematics, statistics or physics with a keen interest in environmental science.

**Further reading or any references referred to in the proposal** [1] Guisan, A. & Thuiller, W. (2005) *Ecol. Lett.*, 8, 993–1009; [2] Lau M.S.Y. *et al.* (2014). *J. R. Soc. Interface* 11, 20131093; [3] Marion, G *et al.*, 2012 *J. Biogeogr.* 39(12), 2225-2239. [4] Catterall S *et al.* 2012. *Ecography* 35, 901-911. [5] Andrieu C *et al.* 2010. *J. R. Stat. Soc. B*72, 269-342. [6] Pooley, *et al.*, 2015. *J. Roy. Soc. Interface* 12, 20150225.



### Application to invasive aliens (giant hogweed).

Advanced statistical methods allow inference of aspects that are not readily observable directly, such as dispersal characteristics and habitat suitability (see plot a). Subsequent simulation based on these inferences enables the probabilistic projection of future species distributions see 2b) [2].