Guest editors' introduction to the special issue on "Ecological Statistics"

Roland Langrock¹ · David L. Borchers²

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This special issue is a product of discussions between us and the journal editors after observing that only relatively few statisticians in Germany work on ecological data, in contrast (i) to other countries such as the UK, the US or Australia, where there are several large interdisciplinary research groups working almost exclusively on statistical ecology, and (ii) to other disciplines such as economics and medicine.

In response to technological and general scientific developments—e.g. in the areas of remote sensing, satellite imaging, camera trapping and genotyping—the discipline of ecology is experiencing a small revolution driven by the new types of data generated by the technology. Many of these new data types, e.g. animal location data collected using global positioning systems (GPS), clearly contain important information on ecological processes and their drivers. Moreover, technology now enables biologists to study species such as marine mammals at much higher spatial and temporal resolution than was possible using more conventional data collection methods.

These new kinds of data often generate new challenges for statisticians, such as dealing with complex dependence structures in space and time, missing data and measurement error, to name but a few. As a consequence, there is a rapidly growing demand within the field of ecology for statistical expertise and innovation. Here we argue, perhaps somewhat provocatively, that this demand is not currently being met within Germany and call for a greater exchange of ideas between ecologists and statisticians.

✉ Roland Langrock
roland.langrock@uni-bielefeld.de

David L. Borchers
dlb@st-andrews.ac.uk

¹ Department of Business Administration and Economics, Bielefeld University, Bielefeld, Germany

² School of Mathematics and Statistics, University of St Andrews, St Andrews, UK

With this special issue, we showcase several current research areas in statistical ecology, hoping to therefore increase awareness of the interesting statistical content of modern ecological data and to attract more statisticians to this exciting and fast-developing area. The broad scope of problems in statistical ecology provides a host of opportunities for novel development and application of regression analysis, spatial statistics, time series analysis and general stochastic processes, survival analysis, stochastic differential equations and many other statistical methods. The variety of new problems and statistical challenges makes this a very rewarding area for those interested in innovative statistical method development grounded in actual applied problems.

For this special issue, we invited authors to contribute on the topics of genetics, occupancy modelling, animal movement, population dynamics, distance sampling/spatial capture–recapture, diversity and spatial modelling. We briefly summarise the contributions below.

[Fewster \(2017\)](#) provides an introduction to statistical analysis of genetic data in ecology, at a level appropriate for statisticians with no previous knowledge of genetics. Statistical analysis of genetic data is too large a subject to be covered in a single paper; this paper restricts attention to multilocus genotype data from microsatellite loci, considering how they are used to address two particular problems: (a) investigating population structure by genetic assignment and related techniques, and (b) using genotype data in capture–recapture studies for estimating population size and demographic parameters. Capture–recapture methods are also considered by [Borchers and Marques \(2017\)](#) in this issue, although that paper focuses on the spatial aspects of capture–recapture, treating capture histories as known, whereas [Fewster \(2017\)](#) covers a range of capture–recapture methods and deals specifically with the issue of uncertain individual identification from genetic data.

[Guillera-Aroita and Lahoz-Monfort \(2017\)](#) consider species occupancy, i.e. the proportion of sites occupied by a species, and investigate whether in corresponding surveys it is beneficial to continue to survey at a site after a species has been detected. The rationale for doing so is to improve the precision of estimates of species detectability, essentially a nuisance parameter, which, however, turns out to be a crucial model component especially for species that are hard to detect. Addressing uncertainty in species detectability is a common theme in many ecological contexts (see, for example, [Borchers and Marques 2017](#); [Besbeas and Morgan 2017](#)) and is often addressed within a state–space modelling framework.

[Patterson et al. \(2017\)](#) provide a review of statistical models of individual animal movement, including approaches based on hidden Markov models, state–space models and diffusion models. Unlike previous review papers in this area which were targeted primarily at ecologists, this paper focuses specifically on statistical aspects of modelling animal movement. A comprehensive discussion of practical challenges aims at helping to bridge the gap between the sophisticated statistical methods commonly applied and the actual biological problems that are being addressed using movement data.

[Besbeas and Morgan \(2017\)](#) discuss the use of state–space models for integrated population analyses. Such analyses comprise multiple data sets related to population dynamics, the models for which have some parameters in common (e.g. survival prob-

ability). In those instances it is usually beneficial to combine all existing data within a joint model, so as to increase precision of all estimators. In this issue, Besbeas and Morgan discuss inference for such joint models, specifically regarding the estimation of the variance of error components within the associated state–space models.

Buckland et al. (2017) consider measures of biodiversity, which are highly relevant, also politically, as indicators to assess biodiversity loss. Buckland et al. focus specifically on temporal trends and hence on potential changes in biodiversity. Their paper gives a comprehensive review of existing measures and provides guidance on selecting a suitable measure for any given study aim.

Borchers and Marques (2017) review distance sampling and spatial capture–recapture models and demonstrate how they are related to one another. They demonstrate how spatial models are a central component of both, and to this extent this paper ties in with that of Illian and Burslem (2017) in this issue, which deals with the utility of spatial point process models in ecology. In a broader statistical context, Borchers and Marques (2017) show that distance sampling and spatial capture–recapture models can be viewed as particular kinds of hierarchical binary regression, Poisson regression, survival or time-to-event models, with individuals' locations as latent variables and a spatial model acting as the latent variable distribution.

Illian and Burslem (2017) give an overview of the kinds of ecological problems and issues that can be usefully addressed using spatial point process methods, arguing for greater engagement between spatial statisticians and ecologists. They discuss the benefits of spatial point process modelling in ecology and issues that arise when fitting these models, such as confounding of a spatially structured random field with covariate coefficients. They suggest that the recent development of software that facilitates spatial point process model fitting will facilitate greater uptake of these method in ecology and outline areas in which further methodological developments are required.

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