Impact case study (REF3)

Institution: University of Kent		

Unit of Assessment: 10: Mathematical Sciences		

Title of case study: Transforming Practice: Novel Statistical Models for Biodiversity Monitoring		

Period when the underpinning research was undertaken: 2014-2020		

Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Emily Dennis Eleni Matechou Rachel McCrea Byron Morgan Martin Ridout	Research Associate Senior Lecturer in Statistics Professor of Statistics Emeritus Professor of Statistics Emeritus Professor of Statistics	2015-2016 2014-present 2008-present 1972-2013, Emeritus Leverhulme Fellowship 2017-2019 2000-2019

Period when the claimed impact occurred: 2017-2020		

Is this case study continued from a case study submitted in 2014? No		

1. Summary of the impact (indicative maximum 100 words)

Research undertaken by the Statistical Ecology team at Kent has transformed the way large-scale, long-term monitoring data are collected and analysed, informing Government policy and providing insights into loss of biodiversity and the impact of climate change.

The statistical models developed by the team are routinely used by wildlife and conservation charities, practitioners, Government, and non-governmental organisations to analyse and record biodiversity data in the UK and Europe. Indicators based on the team's work are used in policy and advocacy documents to influence conservation management decisions. In addition, free software and training for researchers and practitioners on the team's methods have had a direct impact on organisations' monitoring practices and data collection, in the UK and abroad.

2. Underpinning research (indicative maximum 500 words)

Biodiversity loss is at an unprecedented level. The Living Planet Report 2020 revealed a global species loss of 68% in less than 50 years: an unprecedentedly catastrophic decline. Conservation decision-makers rely on robust estimates of the state of wildlife populations to understand the drivers of this rapid change in the distribution and dynamics of animal populations. However, monitoring of species is both time-consuming and costly, and can be unsustainable in the longer term. For that reason, charities and non-governmental organisations are relying increasingly on volunteers working within citizen-science schemes (collecting structured and/or opportunistic data), and on new technologies, such as DNA-based surveys and mobile-phone apps, to perform large-scale, long-term surveys. These types of surveys yield large but messy datasets that are prone to observational error.

To analyse such datasets efficiently and reliably, Kent's Statistical Ecology team (SE@K) have developed new statistical models accompanied by free and easy-to-use software, and have provided extensive training so that the models can be used by researchers and practitioners with no statistical experience.

New Statistical Models

Butterfly and Moth Citizen-Science Data: About three-quarters of UK butterfly species have declined over the past four decades. Butterflies respond quickly to habitat changes, so their population status is a valuable indicator for biodiversity change. In 2016, SE@K developed a new generalised abundance index (GAI) model for seasonal abundance data that enables robust population trends to

be estimated **[R1]**. The GAI approach is 90 times faster than previous methods, owing to the implementation of a concentrated likelihood, which separates the step of estimating relative abundance from the estimation of other parameters in the model. This means that annual trends can be reported quickly and that, for the first time, the estimates for UK biodiversity indicators for these species make full use of all available data.

In 2017, the SE@K team demonstrated that meaningful estimates can be obtained from data collected through mass-participation citizen-science schemes **[R2]**, and presented an efficient model for estimating distribution trends from opportunistic observation data **[R3]**. Such data are becoming readily available with the rise in new technologies, such as data entry via mobile phones.

This research has been supported by a Butterfly Conservation grant **[G1]** and a Leverhulme Emeritus Fellowship **[G2]**. The research led to an Honourable Mention for Dennis from the judges of the 2017 Young Biometrician Award, and she was also Highly Commended for the Robert May Prize 2017. Morgan was awarded the 2020 Royal Statistical Society Barnett Award in part for his work at the forefront of developing computationally efficient methods for co-analysis of the UK Butterfly Monitoring Scheme (UKBMS) with citizen-science data sources to give insights into biodiversity in urban versus rural settings **[a]**, while Dennis's work was shortlisted for the SET for Britain 2014 event held in the House of Commons. McCrea was awarded the 2020 Guy Medal in Bronze by the Royal Statistical Society for her 'innovative and novel work in statistical ecology' **[a]**.

Environmental DNA (eDNA) Data: eDNA is an increasingly popular survey tool for assessing the presence of species at surveyed sites. However, although the probabilities of a false positive and false negative observation error are known to be non-negligible in eDNA surveys, so far this has largely been ignored. In 2020, the SE@K team developed the first statistical model for eDNA data that accounts for the probabilities of both types of error in eDNA surveys **[R4]**, yielding reliable estimates of the probability of species presence from eDNA data and, by quantifying the reliability of eDNA data, providing valuable insight into the potential of this recently developed monitoring tool. The team has implemented the new model in an Rshiny app –https://blogs.kent.ac.uk/edna/ – and has been awarded a NERC grant **[G3]** to extend this work.

Bumblebee Citizen-Science Data: In 2018, the SE@K team developed a novel modelling framework for structured citizen-science data on UK bumblebee species **[R5]**. This new dynamic mixture model provides the first ever estimates of species-specific UK bumblebee population trends, as well as estimates of nest productivity and of caste-specific patterns of emergence in the wild. This provides invaluable information regarding these pollinators, which are suffering from severe and ongoing contractions in range and abundance in the UK.

3. References to the research (indicative maximum of six references)

[R1] Dennis, E., **Morgan, B**., Freeman, S., Brereton, T., and Roy, D. (2016).' A generalised abundance index for seasonal invertebrates'. *Biometrics* 72: 1305-1314. doi: https://doi.org/10.1111/biom.12506

[R2] Dennis, E., **Morgan, B.**, Brereton, T., Roy, D., and Fox, R. (2017). 'Using citizen science butterfly counts to predict species population trends'. *Conservation Biology* 31: 1350-1361. doi: https://doi.org/10.1111/cobi.12956

[R3] Dennis, E., **Morgan, B.**, Freeman, S., **Ridout, M.**, Brereton, T., Fox, R., Powney, G., and Roy, D. (2017). 'Efficient occupancy model-fitting for extensive citizen-science data'. *PLoS ONE*. doi: https://doi.org/10.1371/journal.pone.0174433

[R4] Griffin, J. E., **Matechou, E.**, Buxton, A. S., Bormpoudakis, D., and Griffiths, R. A. (2020). 'Modelling environmental DNA data; Bayesian variable selection accounting for false positive and false negative errors'. J*ournal of the Royal Statistical Society: Series C (Applied Statistics)* 69: 377-392. https://kar.kent.ac.uk/78219/1/edna.pdf

[R5] Matechou, E., Freeman, S. N., and Comont, R. (2018). 'Caste-specific demography and phenology in bumblebees: modelling BeeWalk data'. *Journal of Agricultural, Biological and Environmental Statistics* 23: 427-445. doi: https://doi.org/10.1007/s13253-018-0332-y

The research referenced in Section 2 was funded by the following external grants:

[G1] Butterfly Conservation (2015). *New methods for the analysis of National Butterfly and Moth Data*. PI: **Morgan**. Value: £50,000.

[G2] EM-2017-061 Leverhulme Emeritus Fellowship (2017). *Environmental modelling for moths and butterflies.* PI: **Morgan**. Value: £15,920.

[G3] NE/T010045/1 NERC grant (2020). *Integrating new statistical frameworks into eDNA survey and analysis at the landscape scale.* PI: **Matechou**. Value: £303,199.

The training courses referenced in Section 4 were funded by the following external grants:

[G4] NE/P020356/1 NERC Advanced training short course (2017-18). *Statistical models for wildlife population assessment and conservation*. PI: **McCrea**. Value: £53,584.

[G5] NE/N018346/1 NERC Advanced training short course (2016). *Statistical models for wildlife population assessment and conservation.* PI: **McCrea**. Value: £28,795.

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4. Details of the impact (indicative maximum 750 words)

The new statistical models developed by SE@K have led to: (1) new approaches to biodiversity surveys, assessments and indicators; (2) better-informed conservation policies in the UK (Office for National Statistics / Department for Food, Environment and Rural Affairs indicators) and Europe (EEA indicators); (3) better prioritisation of species in need of protection; and (4) changes in professional practice through expert training.

Butterfly and moth transect data: new ways to assess insect populations in the UK and Europe

The Head of the Biological Records Centre, UK Centre for Ecology and Hydrology, has described how the generalised abundance index (GAI) developed by the Kent team **[R1]** has 'revolutionised how the status of insect populations is assessed' **[b]**. The GAI is 'now routinely used to produce UKBMS trends that underpin statistics published each year by the Office for National Statistics and a UK Biodiversity Indicator published by Defra on "Insects on the wider countryside"' **[b]**.

In addition to informing national biodiversity data in the UK, the GAI method has also been used internationally; for example: 'to produce EU butterfly indicators, published by the European Environment Agency each year' **[b],** and is 'foundational for the Assessing Butterflies in Europe (ABLE) project which involves the development of a suite of indicators for butterflies in Europe' **[c]**.

Alongside these applications, the new indicators are (according to Professor Tom Brereton, Butterfly Conservation) of 'wide value to policy and environmental impact' **[d]**. The indicators are used in the production of advocacy reports presenting long-term trends and conservation case studies in an accessible way, and are widely distributed to politicians and policy-makers. For example, Butterfly Conservation is a member of an umbrella organisation, Wildlife and Countryside, which uses these evidence-based statistics to lobby Government directly and respond to Government enquiries **[e]**.

Environmental DNA data: new approaches to biodiversity surveys

The new model developed in **R4** and associated RShiny app are used by Natural England to guide their future strategies of the use of eDNA. The Director of Specialist Services and Programmes at Natural England has described how 'the recent research by Dr Eleni Matechou and her colleagues at the University of Kent has been instrumental in formulating our thinking', and that 'It has led not only to a step-change in our approach to biodiversity surveys, but also to significant gains for biodiversity (and habitat)' **[f]**. For example, Natural England is currently using the research to guide their 'monitoring and evaluation of the environmental outcomes of district level licensing for great crested newts' **[f]**.

SE@K's findings on the probabilities of observation error, and hence the reliability of eDNA as a monitoring tool, have resulted in an invitation from the Department for Food, Environment and Rural Affairs (Defra) to Dr Matechou to produce a Think Piece on the potential of DNA-based surveys as a large-scale monitoring method in the UK **[g]**.

Bumblebee citizen-science data: enabling better prioritisation of species in need of protection in the UK

Since 2018, the Bumblebee Conservation Trust (BBCT) has used the model developed by SE@K **[R5]** to analyse data from the only UK-based citizen-science scheme specifically targeting bumblebees, the *BeeWalk,* which involves more than 800 volunteers. According to the BBCT, the research has been 'pivotal to increasing [the BBCT's] understanding of British bumblebee populations' **[h]**. This has resulted in BBCT being able to 'better prioritise the species in need of protection', and has influenced the 'establishment of several conservation projects' and the 'enshrinement of these priorities in [the Trust's] 2019-2024 strategic plan' **[h]**. SE@K's work also forms the basis of policy engagement between the BBCT and Natural England, Naturescot, and Natural Resources Wales **[h]**.

Fundamental to the BBCT has been the translation of the new methods into the provision of the app (and training of staff), which enables them independently to assess bumblebee population dynamics. The Trust confirms that 'The work of the team at Kent – invention of the methods, coding and provision of the app itself, and free training of BBCT staff in its use – have permitted the Trust to assess bumblebee population dynamics using more years of data, more species, and for the first time we have been able to compare regions to ensure our regional projects are as targeted as possible' **[h]**.

Training courses and workshops: changing professional conservation practice in the UK and beyond

The SE@K team have provided expert training courses to equip researchers and practitioners with statistical modelling skills to carry out reliable population assessments. Attendees at NERC-funded training courses **[G4, G5]** learned about the statistical methodology developed by the Kent team, and this training has impacted on their practical approaches in the workplace and conservation careers. The impact of this training has been far-reaching, with over 100 attendees over the three courses.

A number of organisations have changed their approaches to monitoring and data analysis as a direct result of the training. For example, a letter to McCrea from the Durrell Wildlife Conservation Trust and Mauritian Wildlife Foundation states that 'The expert statistical training you and your colleagues at the University of Kent provided, and subsequent ongoing research collaboration, has enabled us to reshape our methodologies for monitoring threatened species in Mauritius. This has improved our ability to monitor species abundance, permitting us to adapt our management approaches and ensure long-term survival of threatened species' **[i]**.

Similarly, Amphibian and Reptile Conservation (ARC) has redesigned its monitoring programme in Jersey to ensure improved species detectability alongside sufficient survey replicates, as a consequence of the training it has had from SE@K **[j]**. The 'increased capacity to use' the cutting-edge statistical methods has meant that ARC is 'better placed to assess conservation status of the species' and is 'more effective in identifying conservation actions and policy measures to improve the status of those species' **[j]**.

More recently, the new statistical model in **R4**, and the corresponding Rshiny app, were presented to over 100 participants in workshops organised at the University of Kent and at the Herpetofauna Workers' Meeting in 2020.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[a] Royal Statistical Society Awards 2020, confirming that Morgan was awarded the 2020 Royal Statistical Society Barnett Award and that McCrea was awarded the Guy Medal in Bronze.

[b] Letter from the Centre for Ecology and Hydrology, providing evidence that the GAI changed the way in which the status of insect populations is assessed.

[c] Letter from De Vlinderstichting, providing evidence that GAI paper is being used in annual reporting and that it was foundational for the 'Assessing Butterflies in Europe Project'.

[d] KMTV documentary *Counting Butterflies*. This 12-minute documentary provides an insight into the underpinning research for a general audience.
https://youtube.com/watch?v=a6wIxvWvpPI

[e] Letter from Butterfly Conservation, confirming that the new models are being used to produce improved annual indicators of biodiversity change, which are reported to Government.

[f] Letter from Natural England, confirming that Natural England changed its approach to biodiversity surveys as a result of the Kent team's research.

[g] Contract with the Department for Food, Environment and Rural Affairs (Defra) for invited Think Piece by Dr Matechou on the potential of DNA-based surveys.

[h] Letter from the Bumblebee Conservation Trust, confirming that, as a result of the Kent team's research, the Trust is benefiting from improved monitoring options and able to better target regional projects.

[i] Letter from the Mauritian Wildlife Foundation/Durrell Wildlife Conservation Trust, confirming that the collaboration with, and training provided by, the Kent team enabled the Trust to alter monitoring methodologies in Mauritius.

[j] Letter from Amphibian and Reptile Conservation, confirming that, as a result of the Kent team's activities, the organisation gained an increased awareness of methods and tools available for monitoring as well as increased capacity to use them.