How does urbanisation shape biodiversity? Integrating spatial and temporal dimensions (Ref IAP2-18-03)

University of Glasgow, Institute of Biodiversity, Animal Health and Comparative Medicine (IBAHCM)
In partnership with Centre for Ecology and Hydrology

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Key Words
1. Biodiversity
2. Ornithology
3. Urbanisation
4. Spatial-temporal modelling

Overview

Urbanisation is one of the most pervasive forms of habitat change. More than half of the world’s human population now resides in urban areas, and urban land cover is projected to triple between 2000 and 2030 (1). Anthropogenically-driven land conversion from a natural or semi-natural state to intensive agriculture and urban built environment poses a major threat not only to particular species, but also to biodiversity (1).

Anthropogenic land use varies considerably in time and space, making it a key challenge to account for both dimensions in our attempts to understand how biodiversity changes as a result of urbanisation (2). Urban sprawl typically results in habitat fragmentation at the transition zone between urban and rural areas. As this process unfolds, two competing forces are at play: habitat fragmentation makes populations less viable, potentially leading to extinctions that negatively impact biodiversity; conversely, the landscape becomes more diverse, potentially opening up new niches at the fringes of urban development. Later, habitat homogenisation through in-filling of previously spared tracts of land would be expected to decrease biodiversity. All these processes can vary in their speed, spatial extent, and they can even be reversed if urban areas become depopulated (2). As a result, the extinction of existing species and the colonisation of new niches by opportunist species might generate an increasing, decreasing or hump-shaped relationship between biodiversity and urbanisation (Fig. 2c).

Existing research on the relationship between biodiversity and urbanisation is inconclusive. A substantial body of work has suggested that urbanisation leads to biodiversity loss through biotic homogenisation of animal communities (3, 4). Other studies provide evidence for a hump-shaped relationship with urbanisation. More recent work suggests that when green spaces are provided, cities, suburban areas and intensively cultivated rural land can host a considerable proportion of regional biodiversity (5). However, to date, research has focused on rural-urban gradients across space, with little consideration of changes over time (2). This is a critical knowledge gap, potentially leading to biases in the interpretation of previous results, especially if there is a time lag in the response of biodiversity to land-use change. Moreover, previous studies have generally been conducted at small spatial scales, making it difficult to generalise observed relationships (but see (5)).

This project will investigate the response of biodiversity – measured for each site individually (alpha diversity), between sites (beta diversity), and regionally (gamma diversity) (6) – as urbanisation has progressed, at the scale of the UK. The integration of data collected over time at a broad biogeographical scale will help distinguish, for the first time, key factors that modulate the rate and directionality of biodiversity change with urbanisation.
A range of factors might be expected to modulate the relationship between urbanisation and biodiversity. For example, regions of the UK differ in environmental conditions such as climate, altitude, temperature and precipitation, major abiotic drivers of community composition and diversity\(^7\), \(^8\). Areas also differ in their history of land use (e.g. agricultural vs forest land) and such legacies may also affect the future state of biodiversity\(^2\). Finally, communities vary naturally as a result of dispersal and stochastic demographic processes\(^9\). These lead to variation in bird communities and biodiversity, with resultant effects on resistance and/or resilience to land use change that can affect the relationship between urbanisation and biodiversity. Relating to alpha diversity, the effects of habitat loss may be more devastating for a community in which many species carry out the same ecosystem function, than in a community consisting of few species with varied ecosystem functions\(^8\), \(^10\). At larger spatial scales, biotic homogenisation can lead to limited differences between sites (low beta diversity), ultimately impacting regional diversity (gamma diversity)\(^9\), \(^10\).

This project seeks to understand the relationship between biodiversity and urbanisation, using UK-wide long-term biodiversity, land-use and environmental data. Specifically, the project asks:

1) How does the ecological state (climatic, environmental, land use, species richness) affect the relationship between urbanisation and biodiversity?

2) What is the effect of urbanisation on alpha diversity (numbers of species and functional groups), beta diversity (differences in community composition) and gamma diversity (UK-level diversity)?

Answering these questions will fundamentally advance our understanding of how anthropogenic habitat change shapes biodiversity. Moreover, we will gain insights into how specific drivers of loss and gain can affect different aspects of biodiversity which will enable us to make specific recommendations for urban planning to encourage more sustainable and biodiverse cities\(^1\).

We will address these questions using the Breeding Bird Survey (BBS), a dataset held by the British Trust for Ornithology (BTO), consisting of 25 years of species abundance data for avian communities (Fig. 2a,b). Bird biodiversity is easily observable and has emerged as a reliable index of ecosystem health. Thus birds are an ideal study group for understanding the impact of land-use change on biodiversity. Indeed, birds are a key Biodiversity Indicator for the UK and are included in the international Strategic Plan for Biodiversity 2011-2020.

[Fig. 1. Anthropogenic habitat change occurs at different rates and intensities, and takes a range of forms. This results in a mosaic of land use types that changes through time, exerting pressure on local and regional biodiversity. Source: Roschetzky Photography @ BigStockPhoto.com]

Methodology

This project capitalises on the existence of a high-quality dataset for avian communities in the UK as part of the BTO’s BBS survey. Annual data on species abundance have been collected by experienced ornithologists since 1994 via a systematic, standardised methodology across almost 4000 1x1km grid cells (quadrats) in the UK (Fig. 2a). From species abundance data we will calculate annual indices of alpha biodiversity (species richness and functional diversity) for each quadrant, as well as beta diversity dissimilarity indices based on species composition data between quadrats. This will enable us to create a dataset of changes in biodiversity over time and also to assess biodiversity at the UK (i.e. regional) level (gamma diversity). We will integrate this dataset with data on land-use change (from NERC) as well as...
environmental data during the same time period. The environmental data is available from online databases, and we will focus on temporal changes in temperature, precipitation and normalised difference vegetation index (NDVI) index.

We will begin by examining the shape of the relationship between urbanisation and biodiversity, accounting for explanatory variables, and asking whether this relationship is the same when examining the same quadrant over time, as when we examine the spatial urban gradient. Using this analysis, we will identify an appropriate framework to model both temporal and spatial effects (e.g. GAM or GLM with auto-regressive terms, Bayesian state-space model ([12])). This will allow us to fully characterise the roles of time, space and explanatory variables, permitting biodiversity projections and interpolations to non-censured areas.

**Timeline**

Year 1 – retrieval and data organisation of bird database from BTO and land-use and environmental data from online repositories and published work; writing of review paper on the topic.

Year 2 – building of spatio-temporal models of changes in bird abundance in relation to changes in land use and environmental factors, data analysis, manuscript preparation, regional scientific meeting attendance.

Year 3 – data analysis, manuscript preparation, international scientific meeting attendance.

Year 3.5 – finalisation of manuscripts and thesis submission.

**Training & Skills**

The training provided by this project will cover a broad suite of important formal quantitative and computational approaches and their application, providing the student with an extremely strong basis for pursuing independent research in their field(s) of interest or for a transition to roles in growth areas such as data science.

The scholar will be based within IBAHCM and the award-winning Boyd Orr Centre for Ecosystem and Population Health. The supervisory team will support the student, directly and through specific training, to learn skills in dataset retrieval and management (RM), biodiversity analysis (RM, SS), spatial ecology and GIS (JM), bird ecology (DD) and urbanisation (DD, RM).

As well as selecting from a variety of postgraduate courses for PhD students based on needs, in year 1, the student will receive training on spatial modelling, GIS, diversity indices and management of large datasets by following dedicated courses offered within IBAHCM and through the support of the supervisors. The student will also receive training on using the University of Glasgow compute cluster to enable rapid data processing. In year 2, the student will develop skills in spatio-temporal modelling, integrating different datasets on biodiversity and environmental variables. In year 3, the student will join retreat sessions on scientific writing, organised by the IBAHCM PhD cluster, to help with manuscript preparation. Through participation in Institute seminars and national and international conferences, she/he will also develop presentation and communication skills.

**References & Further Reading**


**Further Information**

This project is in competition with others for funding, and success will depend on the quality of applicants. Funding includes tuition fee waiver for Glasgow University, a competitive stipend, and research support. To express interest please contact Dr Davide Dominoni or Dr Rebecca Mancy by early January 2019, including: 1) a paragraph detailing your reasons for applying and how your experiences fit the project; 2) your CV with marks earned for previous degrees; and 3) contact info for two references. Only the best applicants will be asked to submit a full application by 18th January 2019.