"A walk on the wild side – examining the impact of urbanisation on city biodiversity and ecological service production"

Jon Sadler UoB

Robert Pyle writes…

- in his wonderful book "The Thunder Tree (2nd edition)" that:
- "I believe one the greatest causes of the ecological crisis is the state of personal alienation from nature that many people live" (Pyle, 2011,p. 134)
- He dubs this 'the extinction of experience' and describes it simply by saying that the "loss of neighborhood species endangers our experience of nature". (p.134)

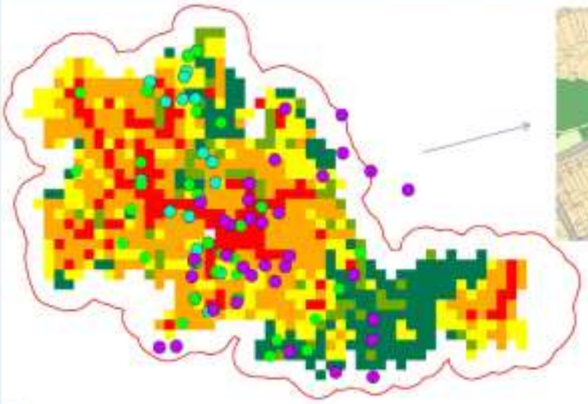
Tim Beatley writes…

- "Part of the great pleasure of living in a city is discovering the many forms of nature in unexpected places. Some of this nature is designed, of course, but much of it is simply extant, and resiliently co-adapting to urban conditions…Over the course of a day there are typically numerous opportunities to be surprised (pleasantly) by the nature around us, as it appears and disappears from view (a bird, a mushroom, a flower), and appears again, depending on season, weather, and on the pathways and routes we choose to travel. Discovery and surprise, the possibility of epiphanous moments of delight, are part of what makes living in a biophilic city so much fun." (Prof. Tim Beatley, 13 October 2014, http://biophiliccities.org)

Outline….

- Brief review of urban form/composition links;
- Focus on connectivity (bham case studies);
- Artificial light at night (ALAN);
- Acoustic variability in the city soundscape (not my research!).

Biodiversity – landscape studies in Birmingham



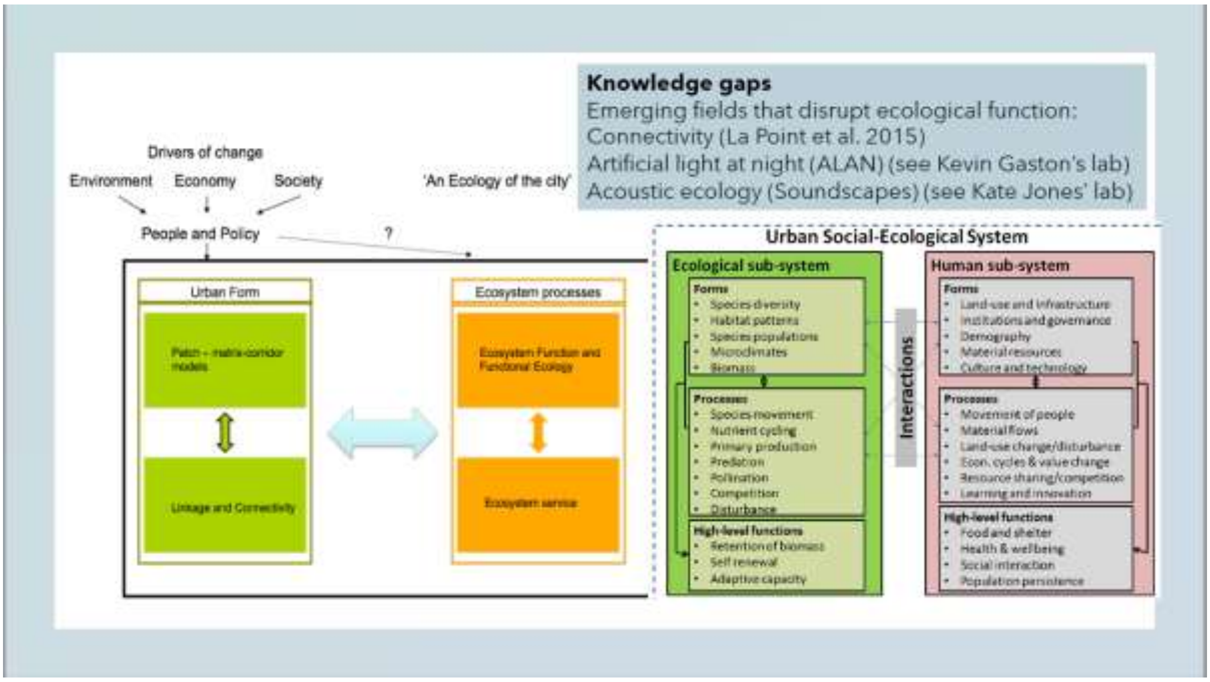
UoB Studies/Researchers

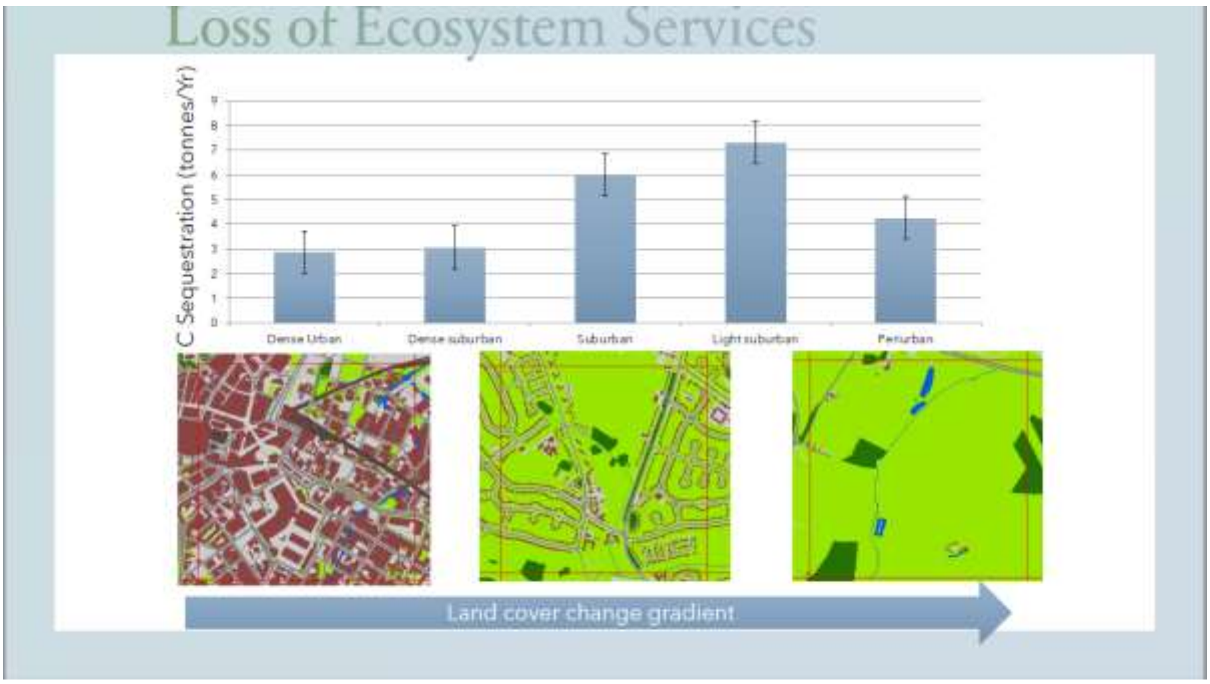
Bates et al. (2011; 2014)
Brunbjerg et al. (2018)
Hale et al. (2012; 2013; 2015)
La Point et al. (2015)
Palma et al. (2016)
Plummer et al. (2018)
Rosenfeld (2012)
Sadler et al. (2006; 2018)

Used multiple taxa, digital data sources from Get Mapping (aerial, photogrammetry, OS data sources, Lidar for landscape and site Survey for field sample locations

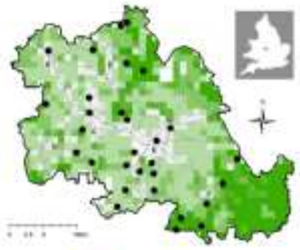
findings…

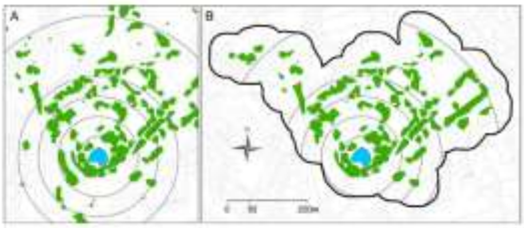
- Confirmed the generalized reduction in species richness among the taxa groups;
- Marked variability in assemblage metrics so evenness changes and dominance of certain species (homogenization of species pools);
- Strong but species-specific gradient patterns exist across the trophic levels with species. Winners are generalists with wide tolerances; losers species with specific habitat associations (e.g woodland species);
- And species with particulars traits (e.g. poor dispersers, large bodied).


Knowledge gaps
Emerging fields that disrupt ecological function:
Connectivity (La Point et al. 2015)
Artificial light at night (ALAN) (see Kevin Gaston's lab)
Acoustic ecology (Soundscapes) (see Kate Jones' lab)
Drivers of change
Environment
Economy
Society
People and Policy
?
'An Ecology of the city'
Urban Form
Patch – matrix-corridor models
Linkage and Connectivity
Ecosystem processes
Ecosystem Function and Functional Ecology
Ecosystem service
Urban Social-Ecological System
Ecological sub-system
Forms
Species diversity
Habitat patterns
Species populations
Microclimates
Biomass
Processes
Species movement
Nutrient cycling
Primary production
Predation
Pollination
Competition
Disturbance
High-level functions
Retention of biomass
Self renewal
Adaptive capacity
Interactions
Human sub-system
Forms
Land-use and infrastructure
Institutions and governance
Demography
Material resources
Culture and technology
Processes
Movement of people
Material flows
Land-use change/disturbance
Econ. cycles & value change
Resource sharing/competition
Learning and innovation
High-level functions
Food and shelter
Health & wellbeing
Social interaction
Population persistence


Loss of Ecosystem Services
C Sequestration (tonnes/Yr)
0
1
2
3
4
5
6
7
8
9
Dense Urban
Dense suburban
Suburban
Light suburban
Periurban
Land cover change gradient

How does urbanization impact putative connect features?





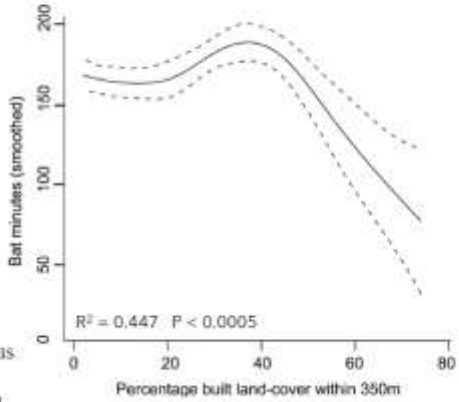
Hale et al. (2012) PLoSONE

- Ponds were surveyed for bat activity fortnightly between May and August 2009 (n= 30).
- We estimated suitable commuting habitats by identifying areas of the landscape where vegetation was greater than 4, 6, 10 or 15 m high, which correspond to the range of typical flight heights for these species.
- In addition, the raster representing vegetation greater than 4 m high was used as connectivity layer representing tree networks separated by gaps of no more than 40 m.
- We used a combination of walking transects and fixed-point detector surveys [33], which allowed multiple microhabitats habitats to be surveyed and activity to be recorded from dusk to dawn.

Empirical studies

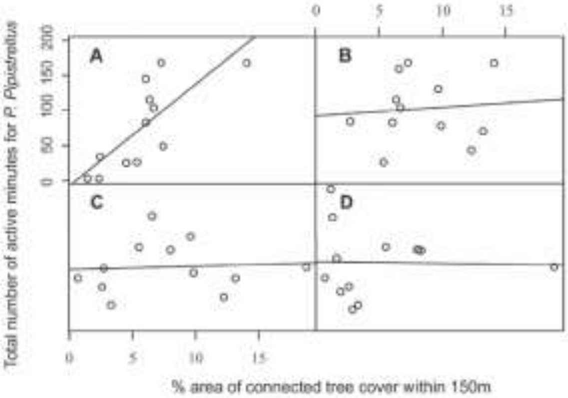
Common pipistrelle © Paul van Hoof

Bat species included:
Pipistrellus pipistrellus (Schreber 1774), Pipistrellus pygmaeus (Leach 1825), Myotis daubentonii (Kuhl, 1817), Eptesicus serotinus (Schreber, 1774), Nyctalus leisleri (Kuhl, 1817) and Nyctalus noctula (Schreber, 1774). T



Pipistrelle activity

Pattern is variable down the gradient



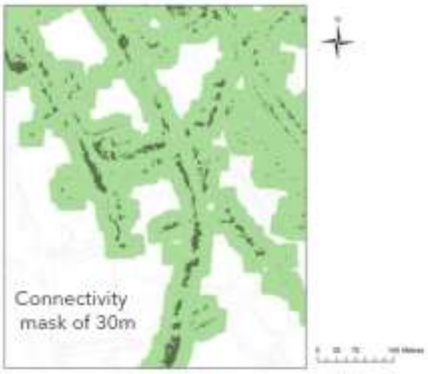
(A) sites within Dense Urban and Dense Suburban (B) Dense Suburban and Suburban (C) Suburban and Light Suburban, (D) Suburban and Rural land classes.

Follow the thing…?

- Study of passerine bird movement using ringing data from two types of greenspace in Birmingham (n=27);
- Birds captured with mist nets and ringed with BTO metal and colour rings;
- A total of 223 visits were carried out at the 27 sites during 2008, 2009, 2010 and 2011 equating to ~12000 hrs of effort with volunteer ringing teams working simultaneously at various sites;
- There were 1,087 re-trap records of which 837 paired records were used in the analysis. A total of 249 movements were identified across the four-year study period.

Bird movement in Birmingham

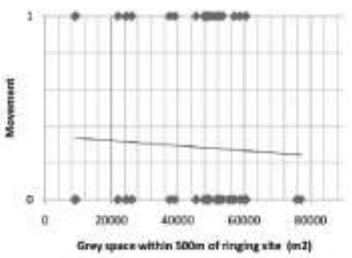
Species	Distance (m)	
	Maximum	Mean (± 1 SE)
Common Blackbird	3970	1552.05 ± 314.3
Eurasian Blue Tit	14667	1819.66 ± 405.0
Eurasian Bullfinch	5161	1842.93 ± 747.7
Coal Tit	10466	1634.49 ± 992.3
Dunnock	14091	4161.34 ± 1555.1
Great Tit	13530	1955.35 ± 372.0
Long-tailed Tit	13503	1297.95 ± 397.6
Eurasian Nuthatch	1300	1041.54 ± 111.0
European Robin	13503	1703.85 ± 710.6
Eurasian Wren	14091	3402.62 ± 710.6



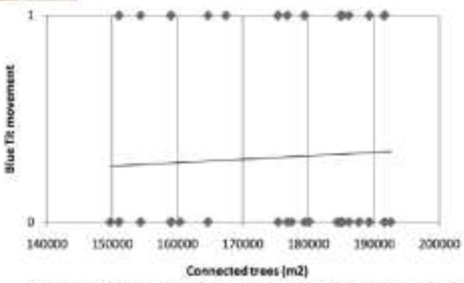
The largest total number of movements were recorded for Great Tits and Eurasian Blue Tits, followed by Long-tailed Tits and European Robins

Blue tit movements

The best-fit model demonstrates that the amount of connected habitat is highly significant ($p = 0.001$), especially for adult birds ($p < 0.05$)



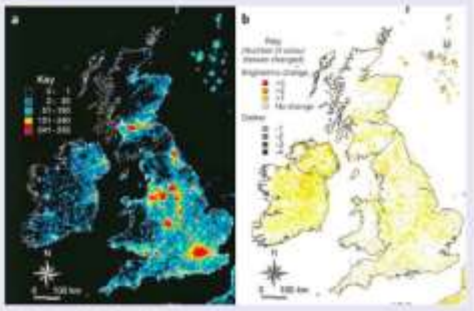
Increased P of movements for birds first captured in heavily built-up sites



Increased P they more to more connected sites

Ecological impacts of artificial light

FIGURE 2-1
Light at night



RCEP (2009)

What do we now know about ALAN impacts?

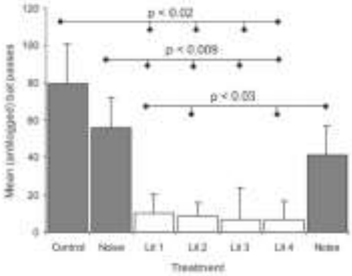
- It has influenced time budgets of diurnal, nocturnal and crepuscular species;
- 'Flight to light' responses can impact foraging, movement patterns (leading to mortality in some groups);
- There are functional impacts in terms of services such as pollination;
- There are likely ecological network and food web issues

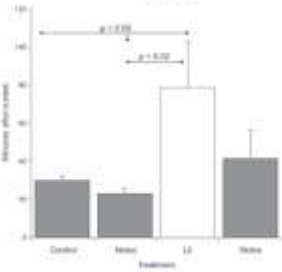
What about movement and links to foraging?

Table 1. Experimental Treatment Regime

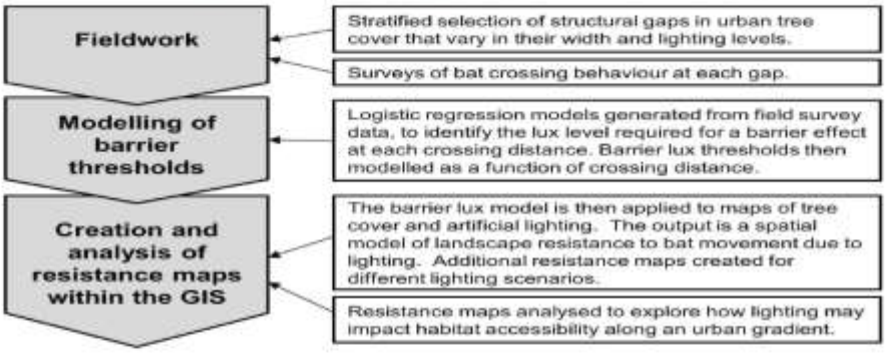
Night	Treatment	Description
1	Control	Detectors installed at hedge, no lighting treatment or generator
2	Noise	Detectors installed at hedge, lighting units installed but switched off, generator running all night
3	Lit 1	Detectors installed at hedge, lighting units installed and switched on, generator running all night
4	Lit 2	As Lit 1
5	Lit 3	As Lit 1
6	Lit 4	As Lit 1
7	Noise	Repeat of noise treatment as in night 2

Stone *et al.* (2009) Current Biology 19, 1123-1127



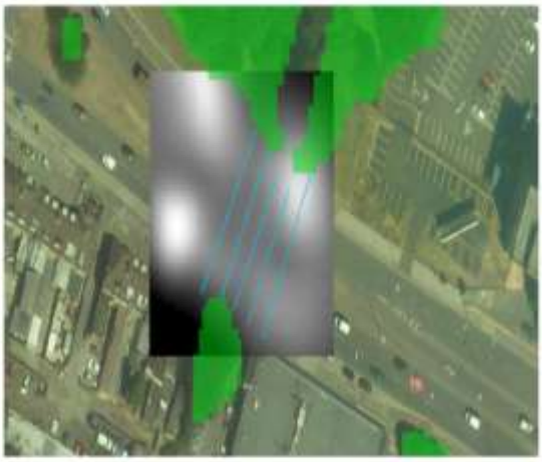


Bats / light and gap crossing

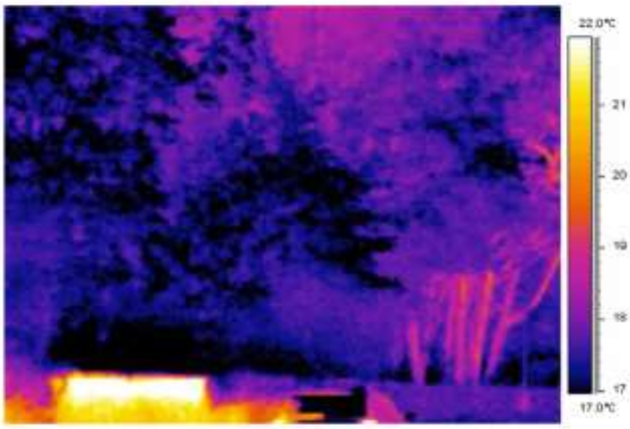


Hale et al. 2015– Global Change Biology

Study design…..

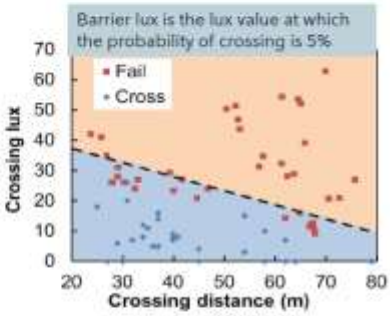


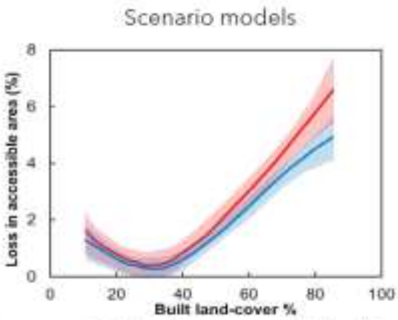
- Located gaps in treelines (in Birmingham, n=27)
- Varied gap width 10-80m
- Different levels with variable light intensity levels
- To record crossing behaviour of P. pipistrellus, surveys were undertaken at each gap for a 1.5-h period following. Surveyors were positioned at either end of the gap. Thermal cameras used to validate crosses
- Probabilities of crossing were generated.
- The data were used to model scenarios, dark and light sky (max 20 lux) using a GIS



Bat gap crossing

Results…





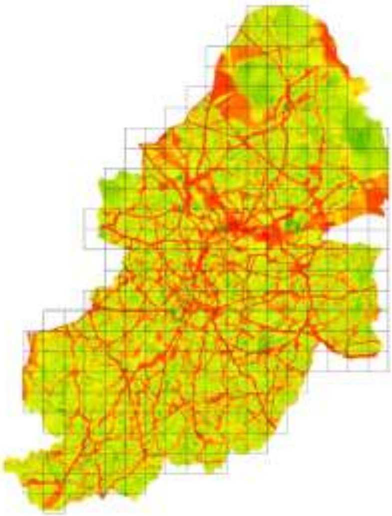
- When modelled using 2009 lighting data, accessible land cover was highest in areas where built surfaces account for <25% of the landscape, but dropped markedly when built land cover was >65%.
- Compared to a Dark City baseline model, lighting levels in 2009 further reduce the percentage of accessible land cover surrounding ponds by up to 5% in heavily built areas, and by up to 7% under a Bright City scenario
- Bats generally took the darkest route across the gap

Bioacoustics and noise pollution

What are the likely impacts on species lifecycles?

- Emphasis on singing and mating behaviour;
- Impacts on predator vigilance v foraging time;
- Much less on foraging success and prey capture;
- Nest location and territory creation;

Is it an issue in urban areas?



Sound map of Birmingham……

Great tit singing – a behavioural response

- 20 populations studied in different cities
- Background noise recorded and great tit song
- Playback crossed and individual male responses captured

Table 1. The range and mean noise measurements taken on rural and urban sites.

site	minimum (dB)	maximum (dB)	mean (dB)
rural (recording)	37	49	43
urban (recording)	48	68	57
rural (playback)	37	49	43
urban (playback)	46	68	57

Mockford & Marshall (2009) Proc. R. Soc. B 276, 2979-2985

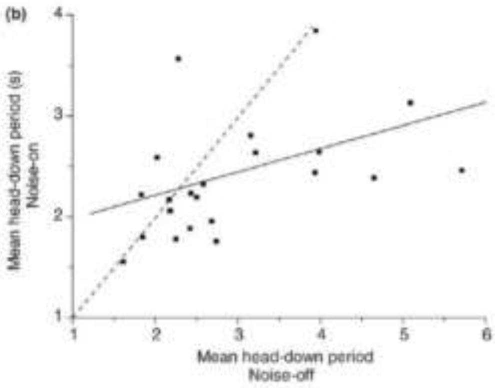
Results…

- There is a difference in spectral aspects of rural and urban song in a common passerine, the great tit *Parus major*.
- Found also that induced differences in song influence the response of male territory holders. Males from quiet territories exhibited a significantly stronger response when hearing song from another territory holder with low background noise than from those with high background noise.

		correlation with background noise		paired *t*-test between rural and urban populations	
type of measure	variable	*r*	adjusted *p*	*t*	adjusted *p*
temporal	average duration of note	−0.358	0.138	1.478	0.936
	average interval between notes	−0.283	0.462	1.231	1.000
spectral	average minimum frequency	0.508	0.006*	−7.395	<0.002*
	average maximum frequency	0.150	1.000	−1.084	1.000
	average peak frequency	0.187	1.000	−2.847	0.060
	average bandwidth	0.111	1.000	0.600	1.000

Ecological impacts of noise

Head down feeding in chaffinches



Quinn, J.L. et al. (2006) J. Avian Biol. 37, 601–608

- Background white noise was played 2 m from the experimental cage for two to four periods of 30 s interspersed with 30 s periods of silence until the chaffinch had fed during a period.
- For each individual foraging data was collected from one noise on and one noise-off period (i.e. a total of 60 s)
- The solid line indicates the regression relationship between the two treatments for the same individual and the dashed line the expected 1:1 relationship if there was no effect of noise on duration of the head-down period.
- Most points lie below the line indicating that head-down periods were longer in the absence of loud white noise).

Bats and foraging

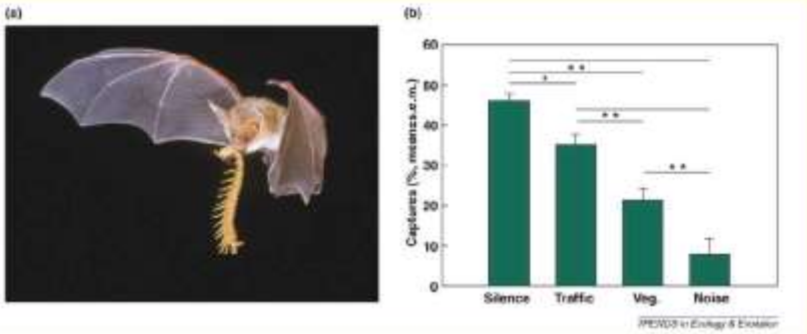
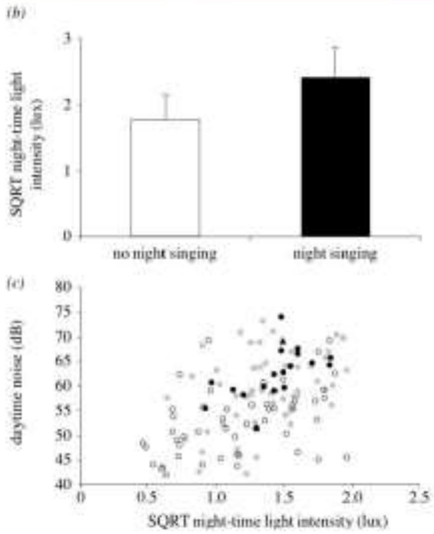


Figure I. Gleaning bats avoid hunting in noise. The pallid bat, *Antrozous pallidus* **(a)**, relies upon prey generated movement sounds to localize its terrestrial prey. Recent work demonstrates that another gleaning bat, the greater mouse-eared bat, *Myotis myotis*, avoids foraging in noise [74]. **(b)** A laboratory two-compartment choice experiment showed that this bat preferred to forage in the compartment with played-back silence versus the compartment with played-back traffic, wind-blown vegetation or white noise. This pattern held true whether the percentage of flight time, compartment entering events, the first 25 captures per session or overall capture percentage were compared across silent and noise playback compartments. Asterisks indicate the results of post repeated-measure ANOVA, paired t-tests (**P<0.01, *P<0.05, N=7 bats). The differences between noise types (traffic, vegetation and white noise) probably reflect increased spectral overlap between prey generated movement sounds and the spectral profile of the noise. Reproduced with permission from Scott Altenbach (a) and Ref. [74] (b).

Schaub, A. et al. (2008) Foraging bats avoid noise. J. Exp. Biol. 211, 3174–3180

As always in urbans systems there are marked interactions that we need to be mindful of…



Robin

Fuller et al. 2007

- But note there is a conflicting stressors here. Nocturnal robin song is also well predicted by day time noise.

To recap….

- LULC patterns clearly impact urban biodiversity;
- Importantly they also interact to influence ecological functions (e.g. connectivity / pollination) and hence service provision;
- Urban infrastructure patterns add additional elements into the mix with ALAN and sound pollution influencing individuals and community/assemblage responses.

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- Volunteers: Birmingham Bird Ringing group (lead Dr Stefan Bodnar), Garden Moth Scheme, OPAL national survey respondents, Birmingham and Black Country Bat group.

Readings I

1.Bates, A. J. *et al.* Changing Bee and Hoverfly Pollinator Assemblages along an Urban-Rural Gradient. *PLoS ONE* **6**, e23459 (2011).
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