



@watts\_km @WrENproject

# Woodland Creation & Ecological Networks

WrEN project update – April 2018

Background & introduction

Woodland Creation &  
Ecological Networks



UNIVERSITY of  
**STIRLING**



# Habitat loss & fragmentation – *the problem*

## Science Advances

Home News Journals Topics Careers

Science Science Advances Science Immunology Science Robotics Science Signaling Science Translational Medicine

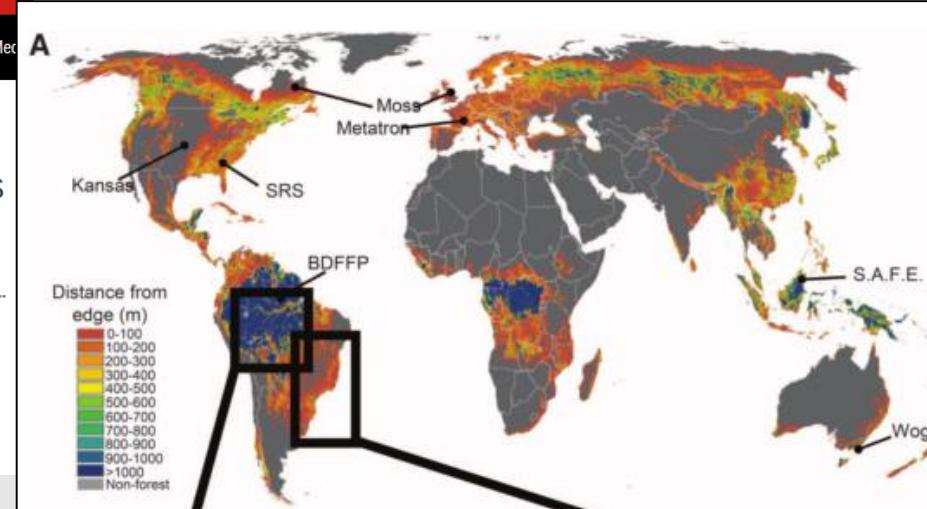
SHARE RESEARCH ARTICLE | APPLIED ECOLOGY

### Habitat fragmentation and its lasting impact on Earth's ecosystems

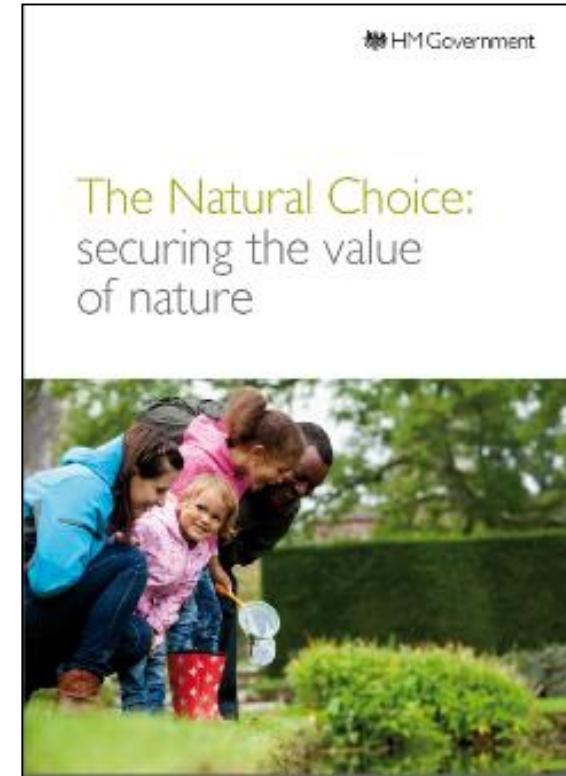
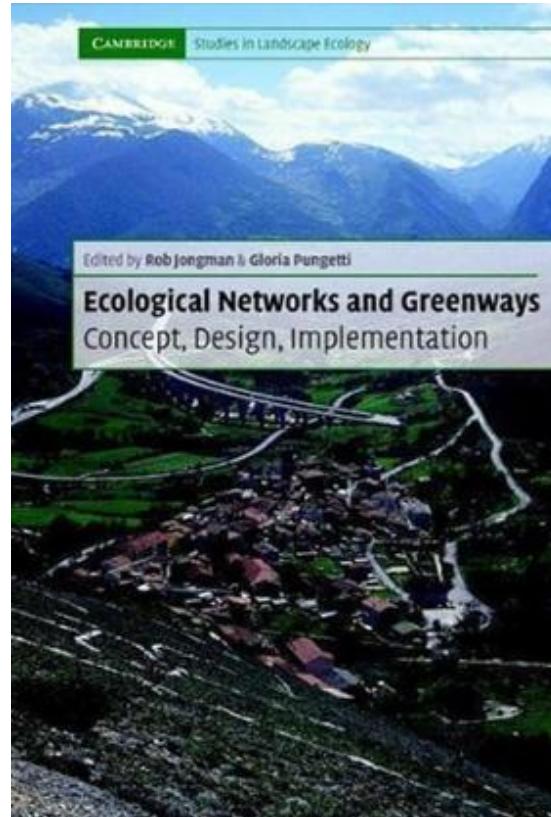
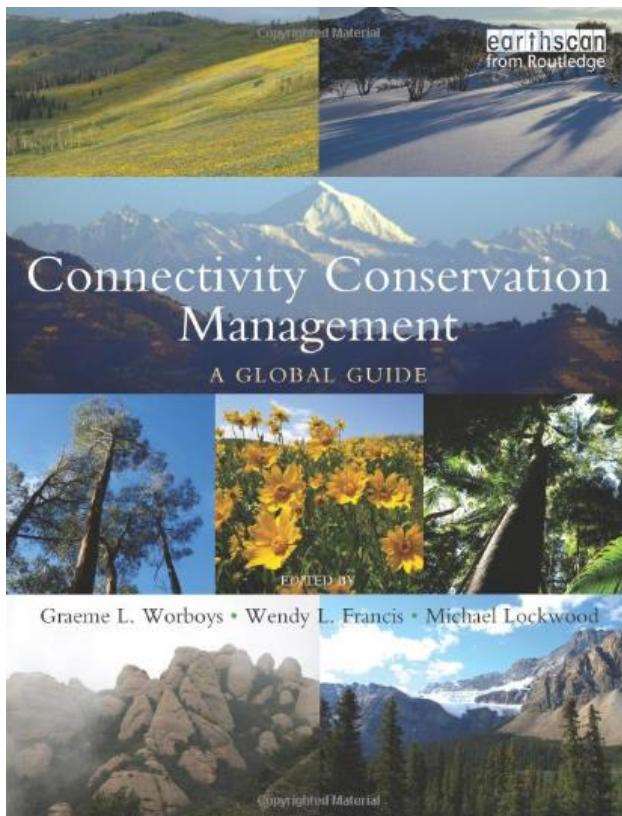
Nick M. Haddad<sup>1,\*</sup>, Lars A. Brudvig<sup>2</sup>, Jean Clobert<sup>3</sup>, Kendi F. Davies<sup>4</sup>, Andrew Gonzalez<sup>5</sup>, Robert D. Holt<sup>6</sup>, Thomas E. Lov...  
\* See all authors and affiliations

### Abstract

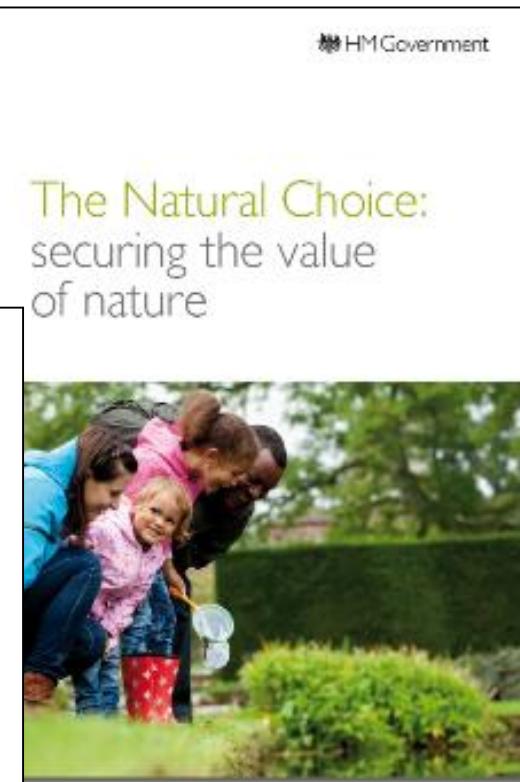
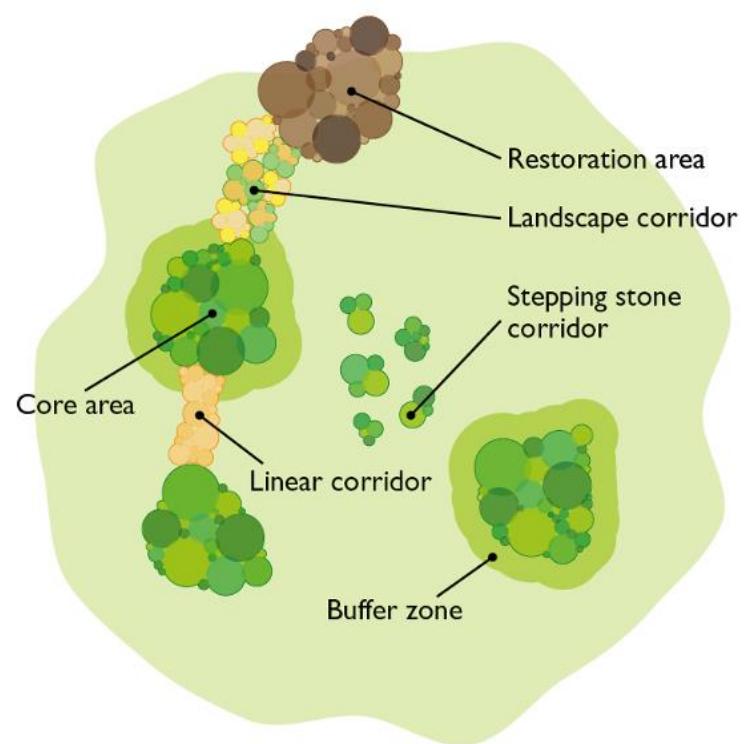
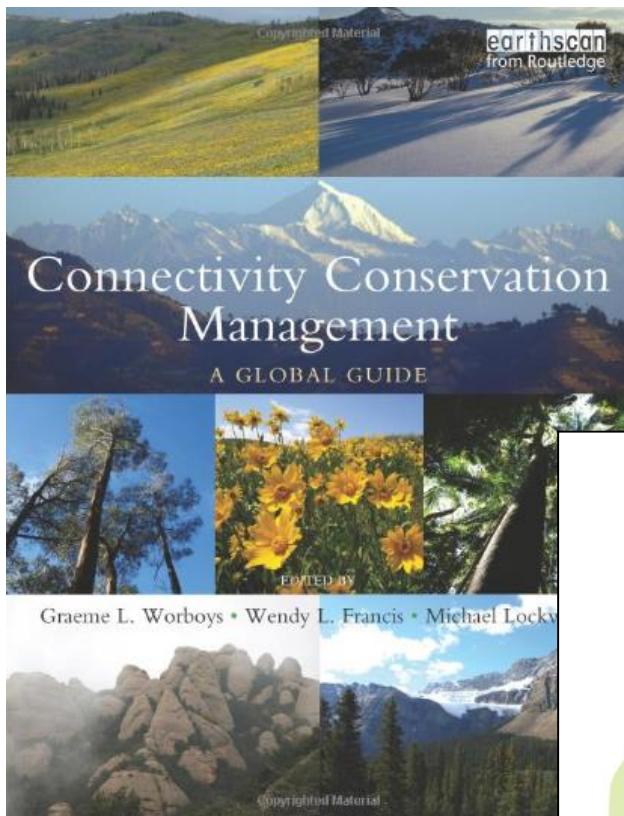
We conducted an analysis of global forest cover to reveal that 70% of remaining forest is within 1 km of the forest's edge, subject to the degrading effects of fragmentation. A synthesis of fragmentation experiments spanning multiple biomes and scales, five continents, and 35 years demonstrates that habitat fragmentation reduces biodiversity by 13 to 75% and impairs key ecosystem functions by decreasing biomass and altering nutrient cycles. Effects are greatest in the smallest and most isolated fragments, and they magnify with the passage of time. These findings indicate an urgent need for conservation and restoration measures to improve landscape connectivity, which will reduce extinction rates and help maintain ecosystem services.



# Landscape-scale conservation – *the solution*



# Landscape-scale conservation – *the solution*



**The Natural Choice:**  
securing the value  
of nature

# Nice idea but scientific debate

## Journal of Applied Ecology

*Journal of Applied Ecology* 2009, **46**, 964–969



doi: 10.1111/j.1365-2664.2009.01891

### FORUM

#### Climate change, connectivity and conservation decision making: back to basics

Jenny A. Hodgson<sup>1</sup>, Chris D. Thomas<sup>2</sup>, Brendan A. Wintle<sup>3</sup> and Atte Moilanen<sup>4</sup>

## Journal of Applied Ecology

*Journal of Applied Ecology* 2011, **48**, 143–147



doi: 10.1111/j.1365-2664.2010.01899

### FORUM

#### Connectivity, dispersal behaviour and conservation under climate change: a response to Hodgson et al.

Veronica A. J. Doerr<sup>1,2\*</sup>, Tom Barrett<sup>3</sup> and Erik D. Doerr<sup>1,2</sup>

*Journal of Biogeography (J. Biogeogr.)* (2013) **40**, 1649–1663

### SYNTHESIS

#### Rethinking patch size and isolation effects: the habitat amount hypothesis

Lenore Fahrig

### ECOGRAPHY

PATTERN AND  
PROCESS IN ECOLOGY

[Explore this journal >](#)

Research

#### Experimental evidence does not support the Habitat Amount Hypothesis

Nick M. Haddad, Andrew Gonzalez, Lars A. Brudvig, Melissa A. Burt,  
Douglas J. Levey, Ellen I. Damschen

## Ecological Networks as Conceptual Frameworks or Operational Tools in Conservation

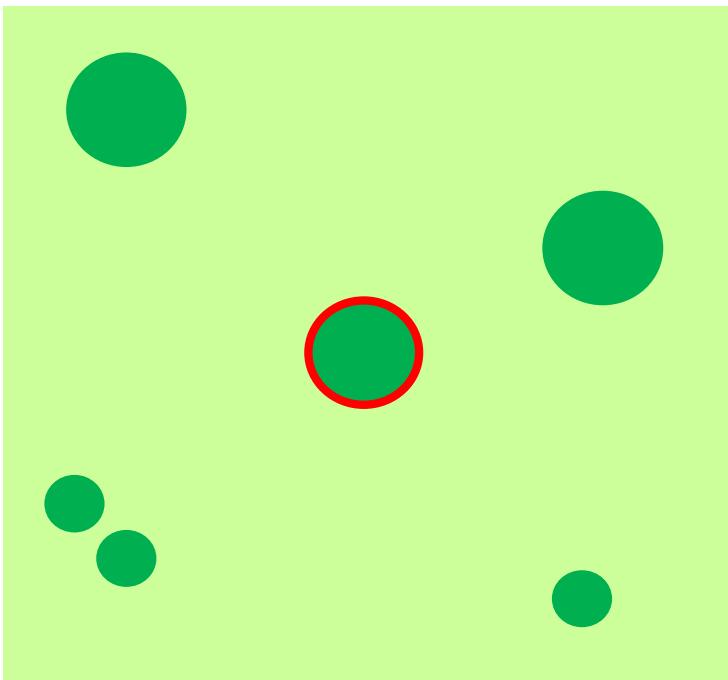
LUIGI BOITANI,\*‡ ALESSANDRA FALCUCCI,\*† LUIGI MAIORANO,\*† AND CARLO RONDININI\*

\*Department of Animal and Human Biology, Sapienza Università di Roma, Viale Università 32, 00185 Roma, Italy

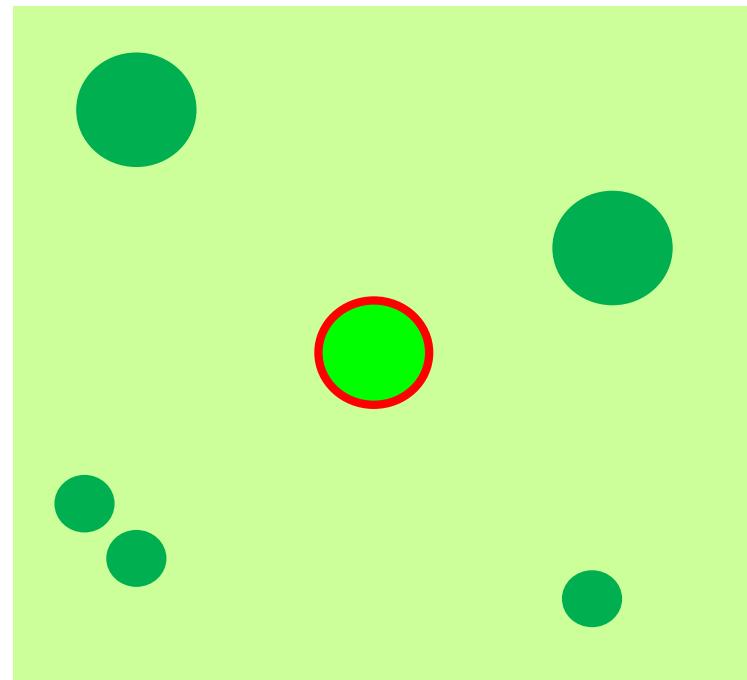
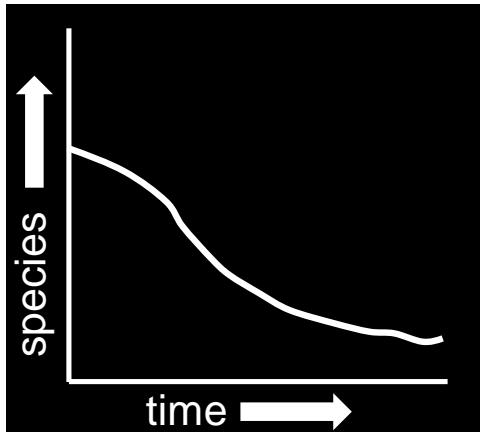
†Department of Fish and Wildlife Resources, University of Idaho, Moscow, ID 83844, U.S.A.

...oversimplifications of complex ecological concepts... offer little for biodiversity conservation beyond a simple conceptual framework... may be misdirecting limited resources

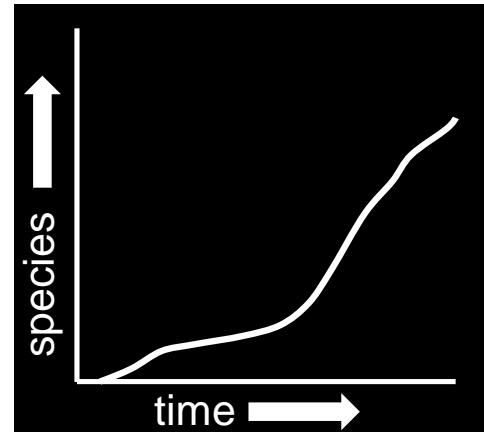
# Fragmentation vs Restoration



extinction debt



colonisation credit



# Fragmentation vs Restoration

Can species reach the patch?

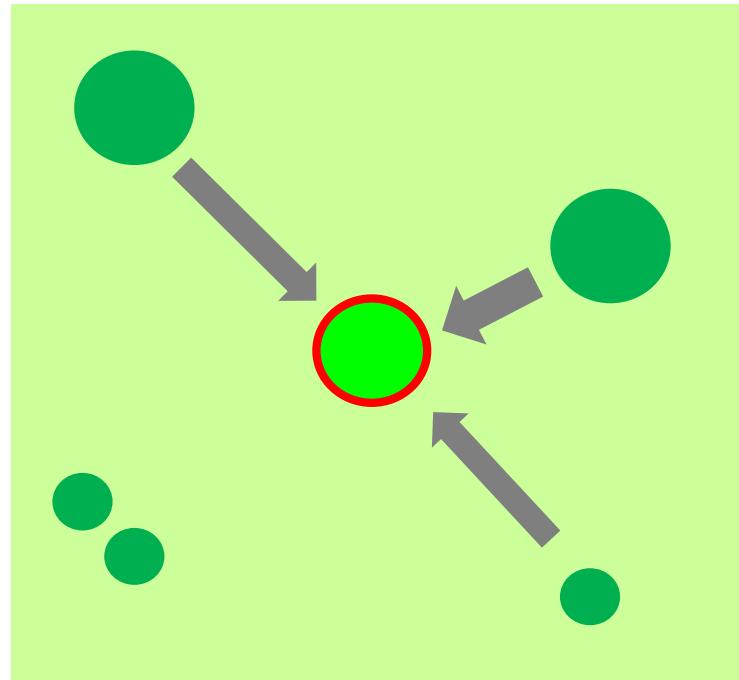
Landscape-scale attributes

1. Surrounding habitat
2. Spatial isolation
3. Surrounding matrix

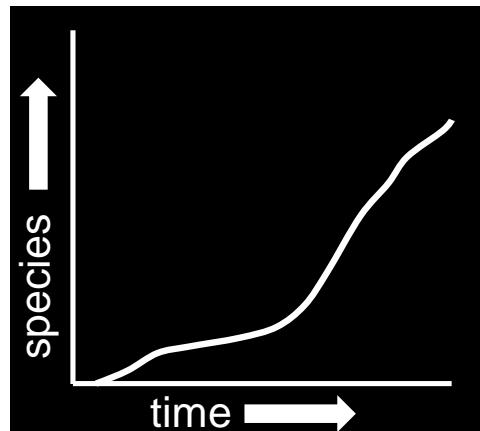
Can species survive in the patch?

Site-scale attributes

4. Area
5. Patch characteristics
6. Age



colonisation credit



# Landscape-scale experiment

---

- Experimentation is fundamental to advance ecology & inform conservation
- However, it remains a rare approach at larger spatial scales where there are a number of challenges:

# Landscape-scale experiment

---

- Experimentation is fundamental to advance ecology & inform conservation
- However, it remains a rare approach at larger spatial scales where there are a number of challenges:

**Spatial scale:**



© Alamy

**Control & replication**

**Ecological realism**

# Landscape-scale experiment

---

- Experimentation is fundamental to advance ecology & inform conservation
- However, it remains a rare approach at larger spatial scales where there are a number of challenges:

**Temporal scale:**

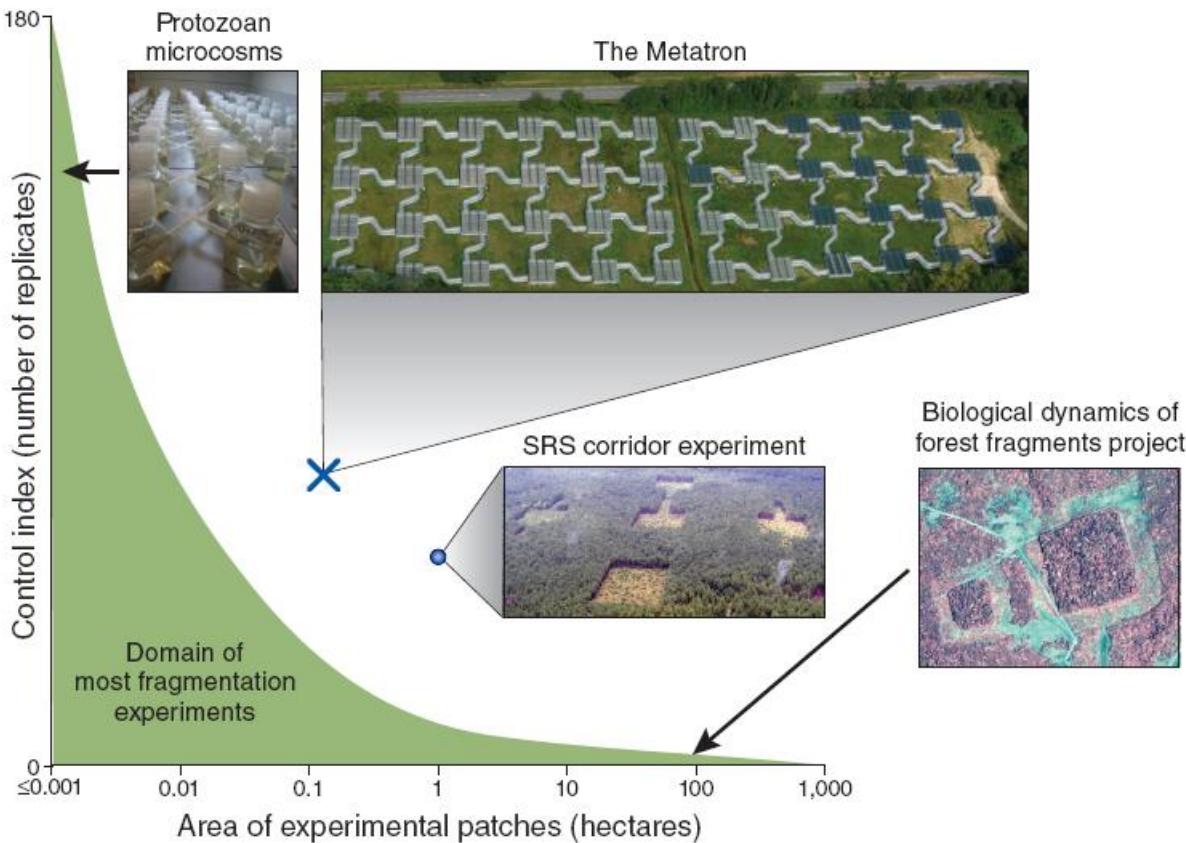


---

→

**Biodiversity response, succession & colonisation**

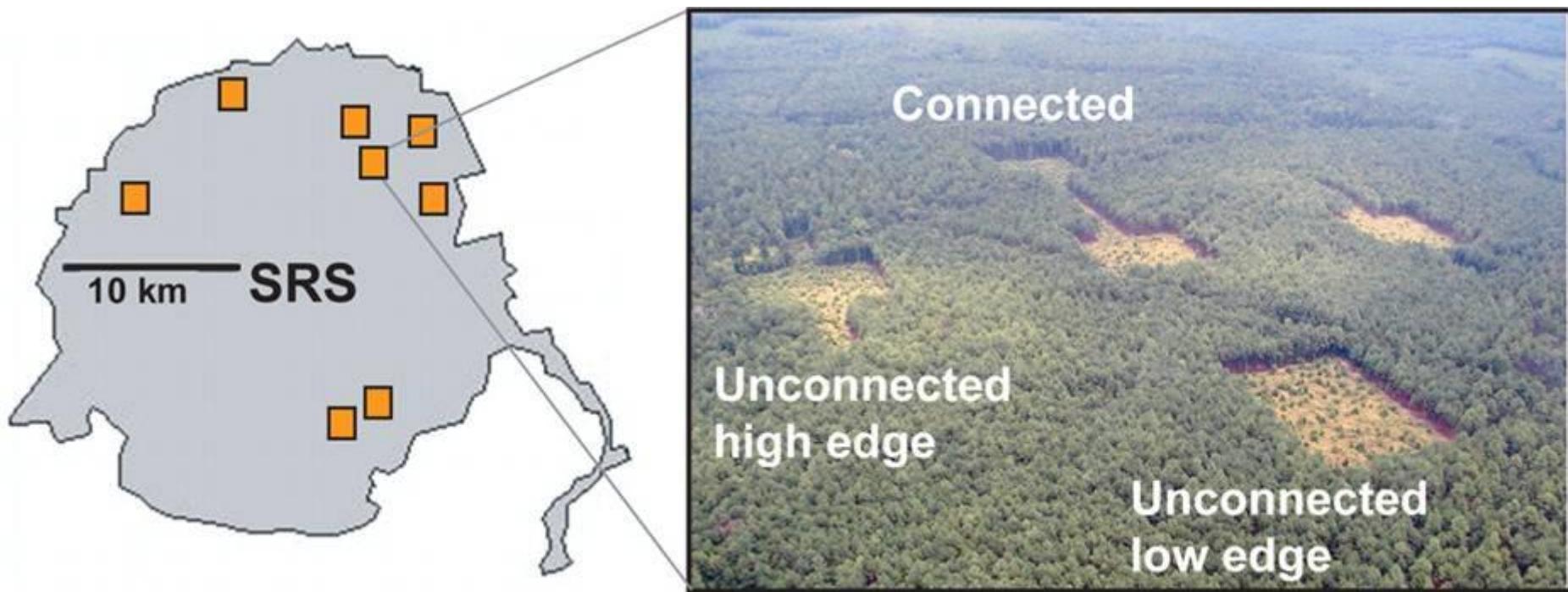
# Landscape-scale experiment



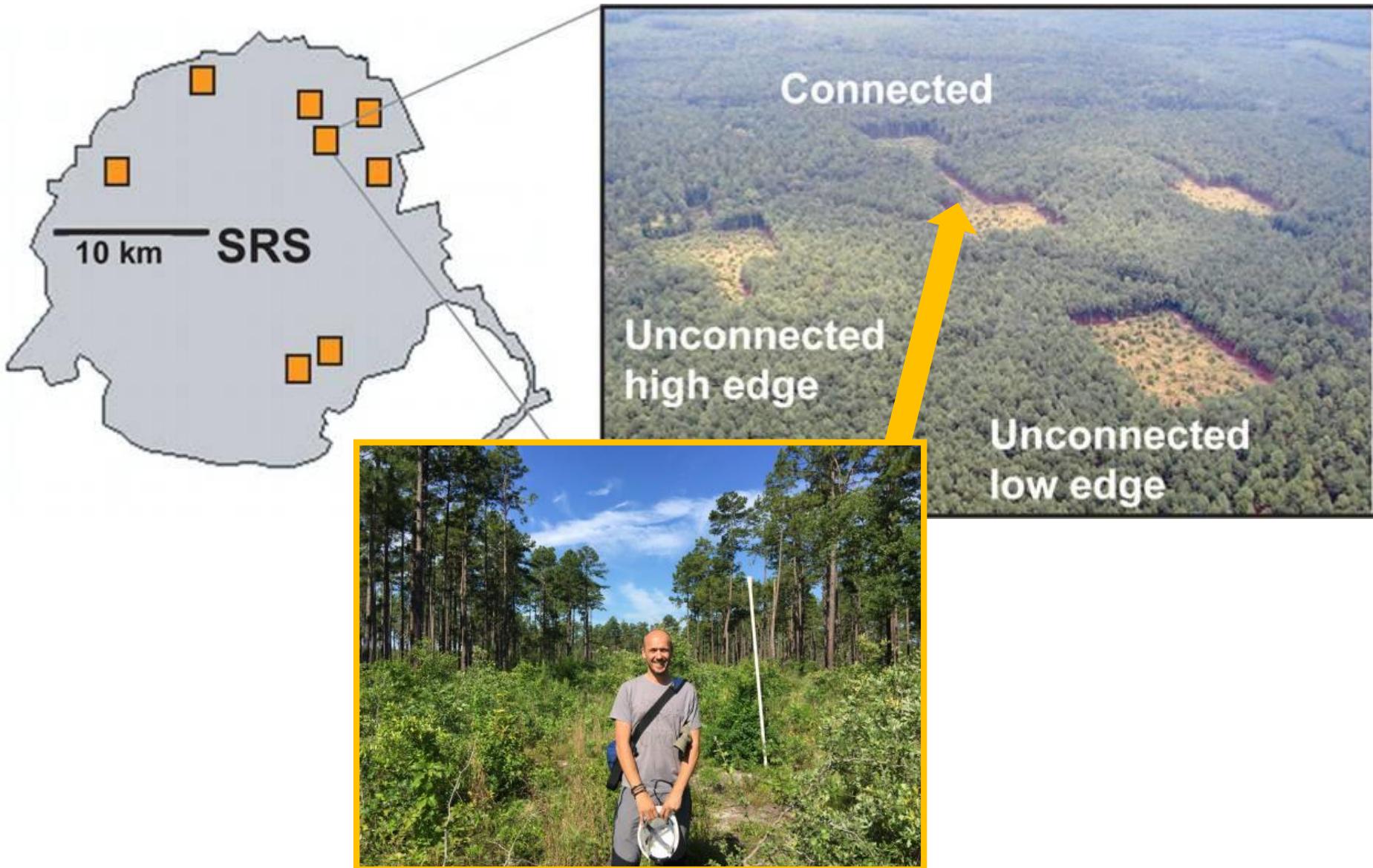
Microcosm, N.M. Haddad; Metatron, Q. Benard; SRS Corridor Experiment, E. Damschen

**Figure 1** | The relationship between the size of study areas and the degree of experimental control in spatial ecology studies. Figure modified from ref. 1. Nearly all experiments from spatial ecology fall within the shaded area. The Metatron is remarkable for its combination of large patches and strict control. SRS, Savannah River Site.

# Landscape-scale experiment



# Landscape-scale experiment



# Time for an experiment...

- 100 years      **Time**      + 100 years

**Now**



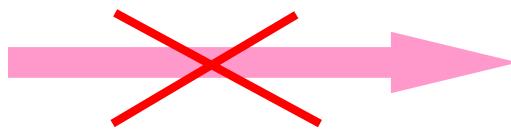
**Experiment 100 + years**



# Time for an experiment...

- 100 years      **Time**      + 100 years

**Now**



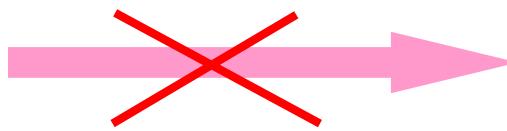
**Experiment 100 + years**



# Time for an experiment...

- 100 years      **Time**      + 100 years

**Now**



**Historical ‘natural’  
experiment**

**Experiment 100 + years**



# The WrEN project

---

Woodland Creation &  
Ecological Networks



Ecology and Evolution

Open Access

**Using historical woodland creation to construct a long-term, large-scale natural experiment: the WrEN project**

# The WrEN project

---

1. Focus on investigating the effects of **habitat restoration and creation**, rather than habitat loss and fragmentation;
2. Study real landscapes at sufficiently **large spatial scales** to ensure ecological realism and the applicability of evidence;
3. Incorporate appropriately **long time scales** to account for lags;
4. Sample a **wide range of explanatory & landscape variables**;
5. Examine a **wide range of species**.

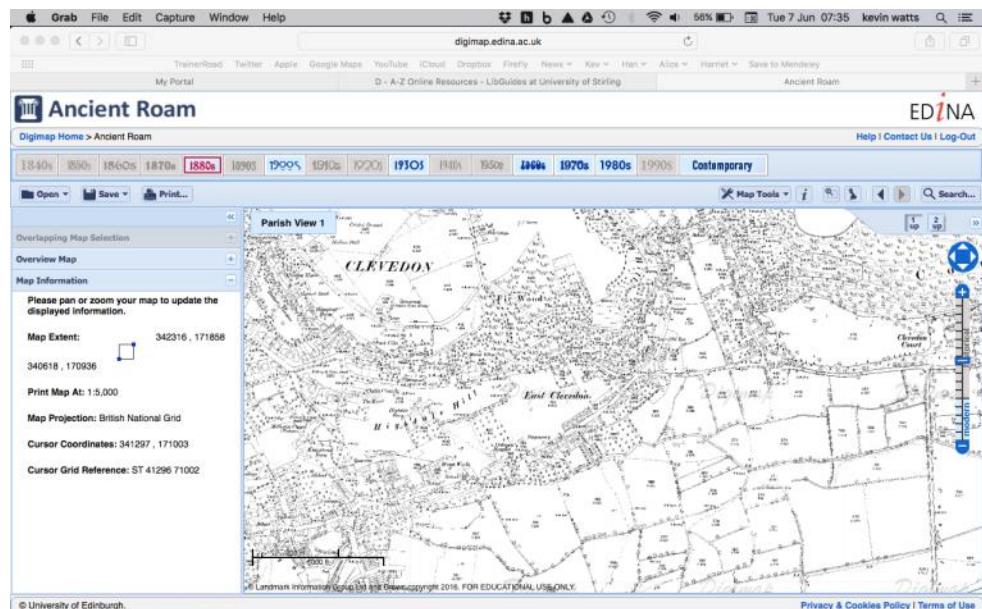
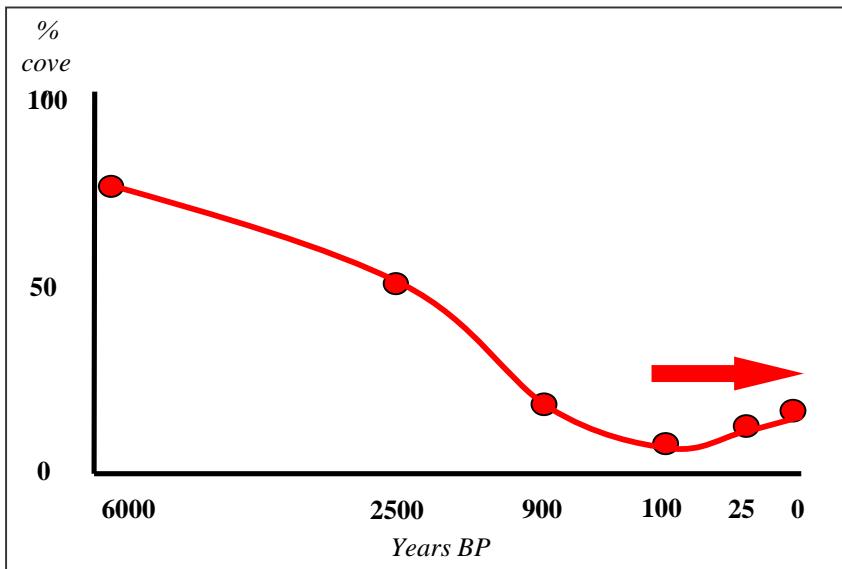
WrEN aims to assess the effects of **past** landscape change on **current** biodiversity to inform **future** conservation actions

# The WrEN project

Long-term, large-scale  
woodland creation



Long-term, large-scale  
mapping (to 1850)



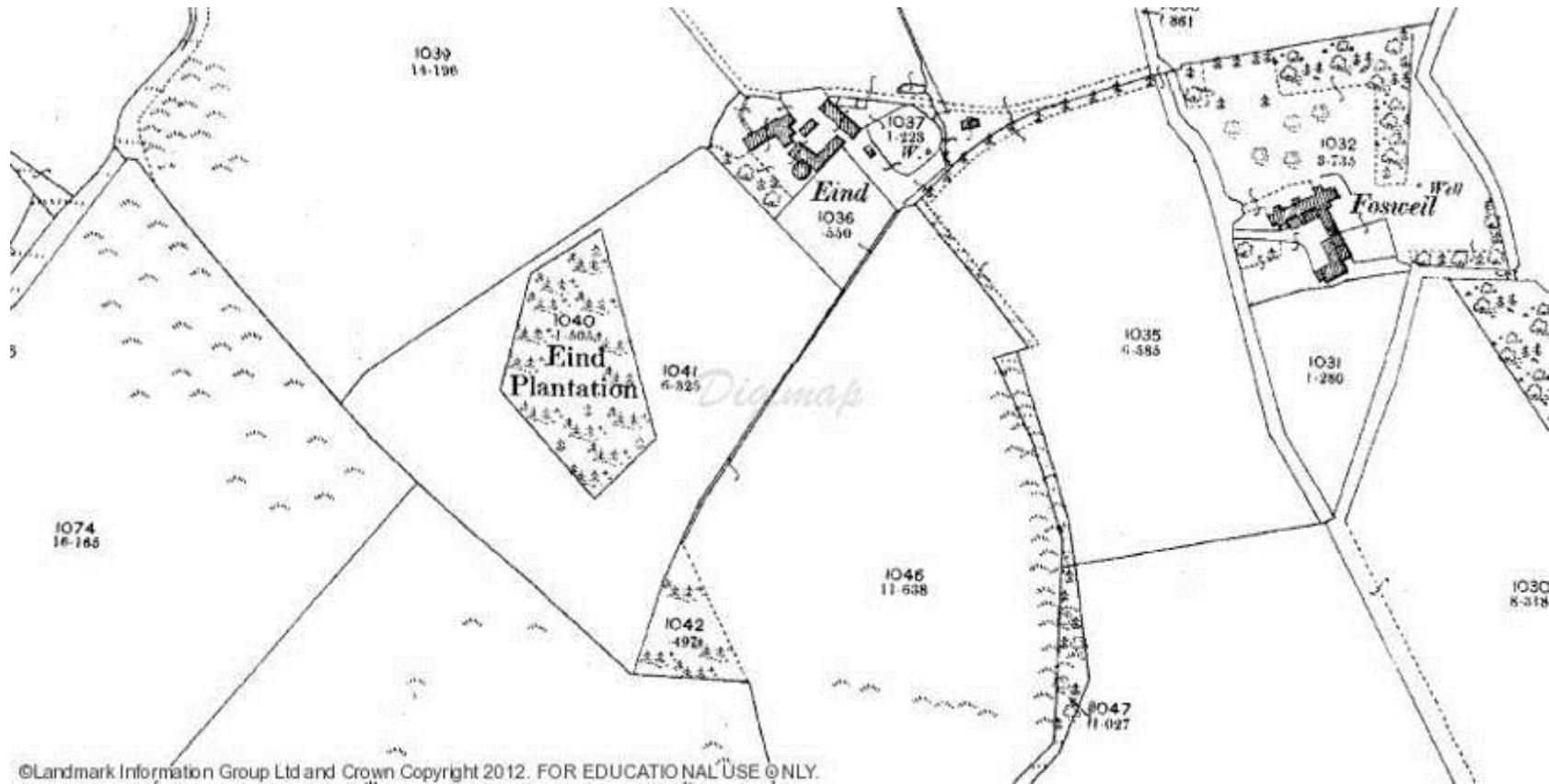
# The WrEN project

---



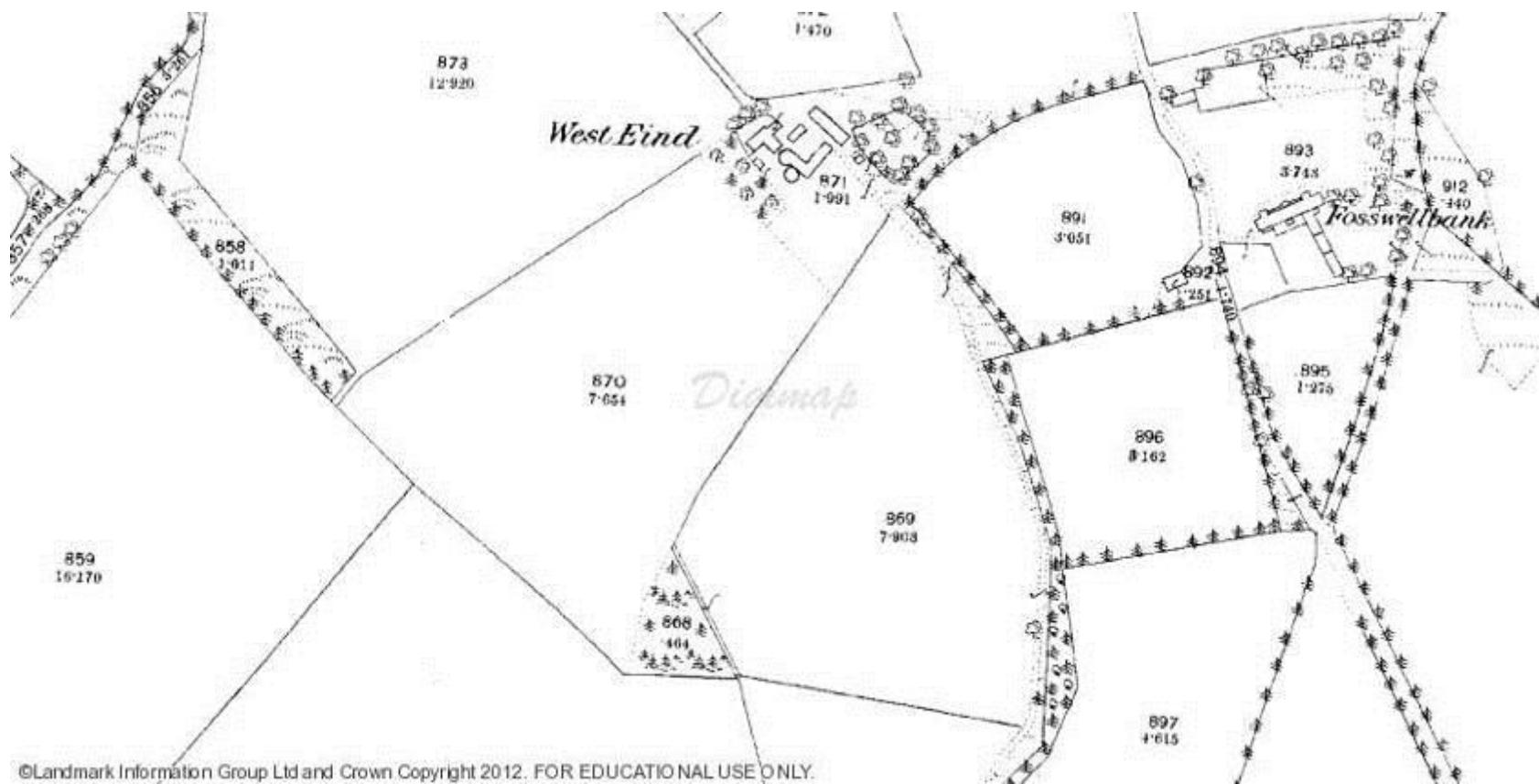
2014

# The WrEN project



**1900 - 2014**

# The WrEN project



1860 - 1900 - 2014

# The WrEN project

---

Can species reach the patch?

## **Landscape-scale attributes**

1. Surrounding habitat
2. Spatial isolation
3. Surrounding matrix

Can species survive in the patch?

## **Site-scale attributes**

4. Area
5. Patch characteristics
6. Age

# The WrEN project

---

Can species reach the patch?

## **Landscape-scale attributes**

- 1. Surrounding habitat**
- 2. Spatial isolation**
3. Surrounding matrix

Can species survive in the patch?

## **Site-scale attributes**

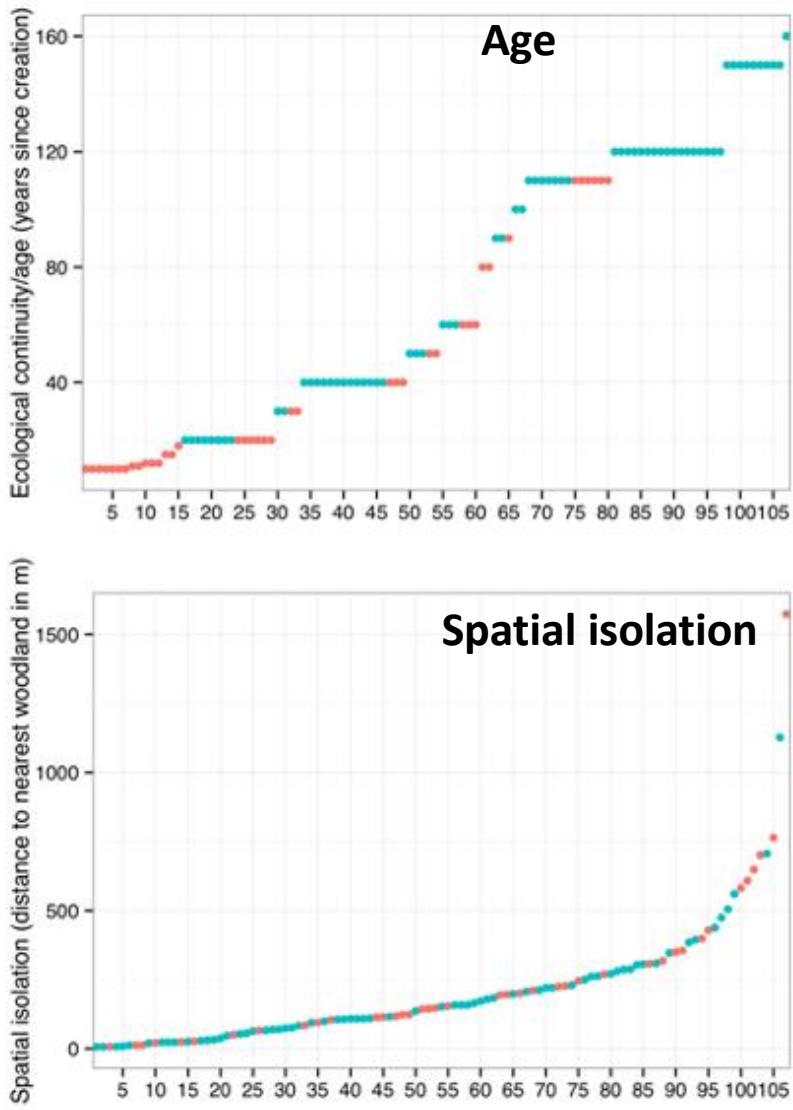
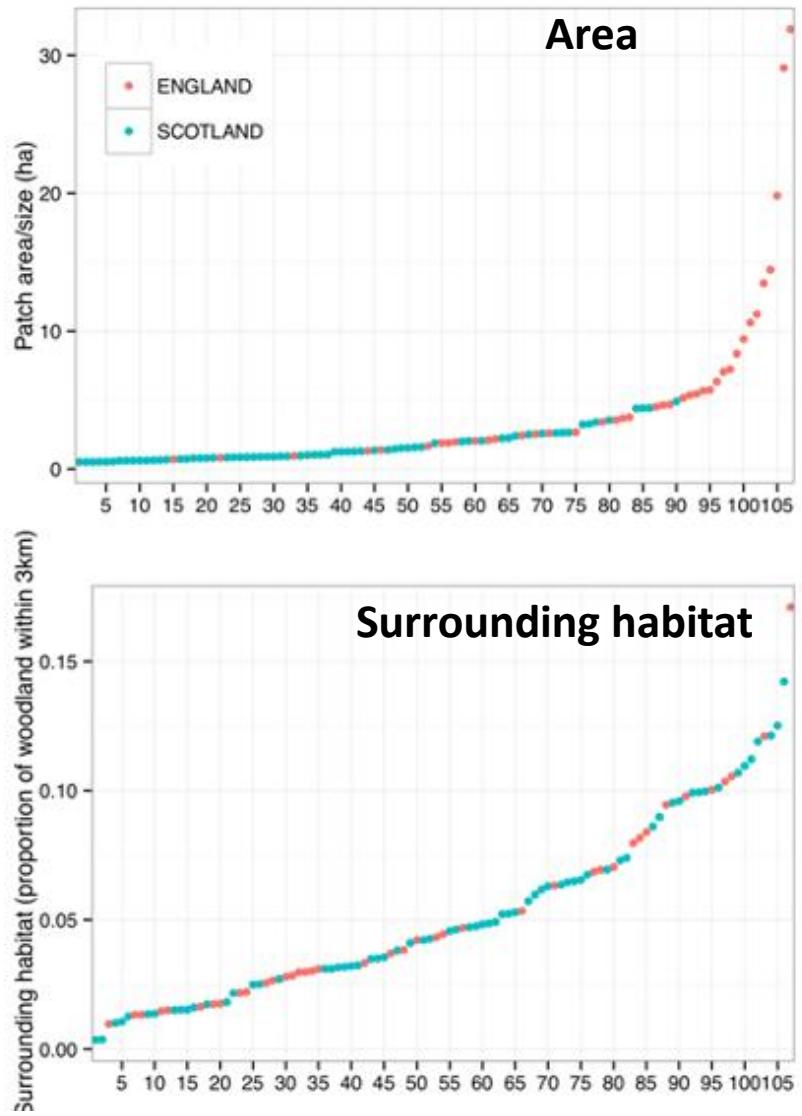
- 4. Area**
5. Patch characteristics
- 6. Age**

# The WrEN project

67 sites in Scotland



# The WrEN project





@EFuenMont @WrENproject

# Woodland Creation & Ecological Networks

WrEN project update – April 2018

Summary of results



Woodland Creation &  
Ecological Networks



# Local & landscape attributes:

- Field surveys to obtain information on vegetation structure.
- Digital maps for patch geometry.



*grazing*

*understorey cover*



*canopy cover*



*tree diameter*

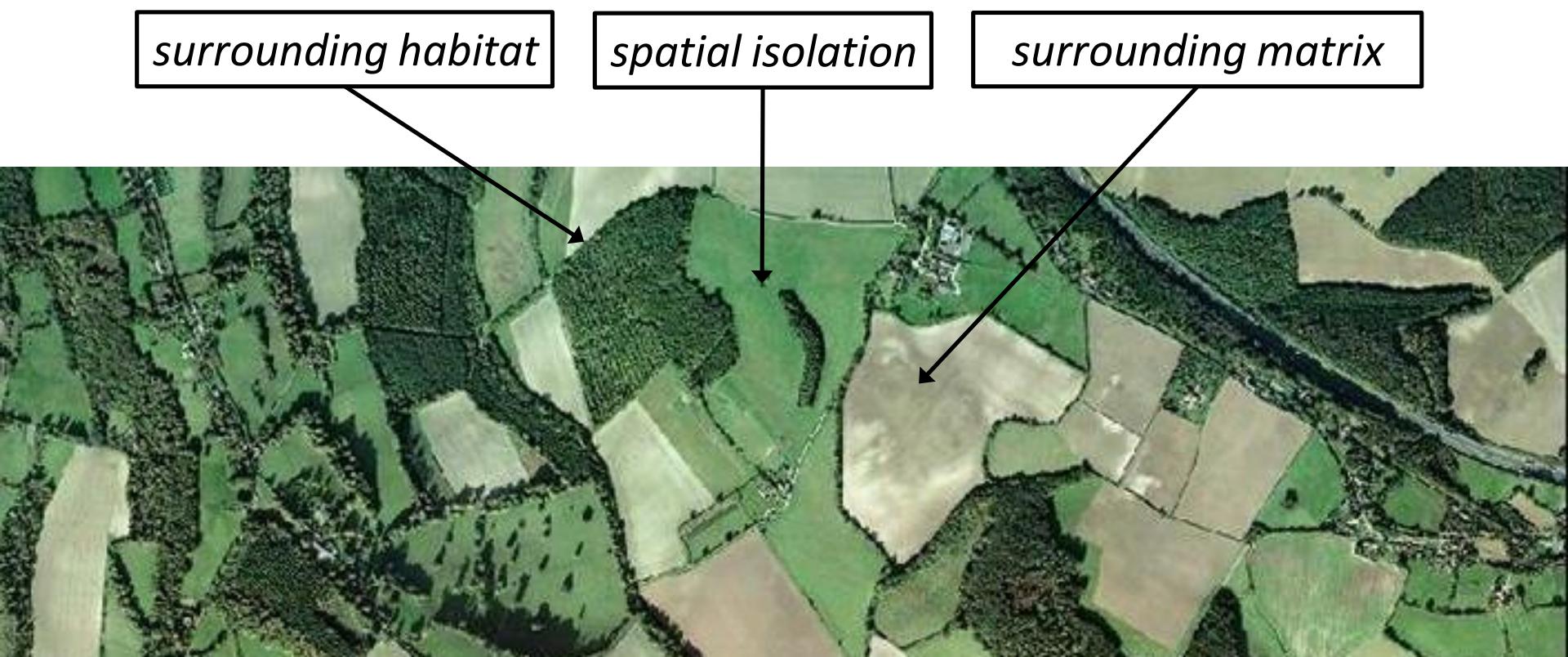
*patch size & shape*



# Local & landscape attributes:

---

- Field surveys to obtain information on vegetation structure.
- Digital maps for patch geometry & landscape attributes.



# Species selection:

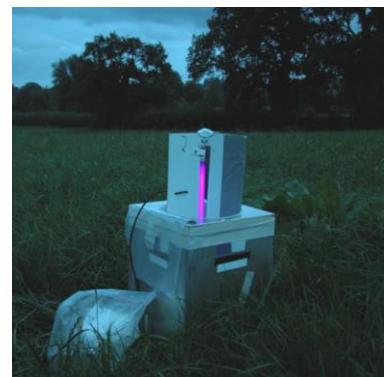
- Range of woodland-dependent species likely to respond to woodland local structure, spatial configuration and landscape context:

- Lower plants (lichens and bryophytes)
- Vascular plants
- Invertebrates (ground-dwelling & flying)
- Small mammals
- Bats
- Birds

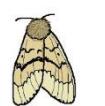
**1,100+ species!**



# Surveying methods:



# Data collected:

										
	Small mammals	Bats	Ground inverts	Diptera	Moths	Trees	Ground flora	Lichens	Bryophytes	Birds
Scotland 2013-16	67	66	39	45	64	67	65	54	30	64
England 2014-15	38	36	21	33	-	39	39	39	-	37
Total	105	102	60	78	64	106	104	93	30	101

# Summary results:

## Bryophytes:

- 77 species (in Scotland only).
- Range per site: 4 – 22 species.
- Mean per site  $\pm$  SE:  $13 \pm 1$  species.

[Species id completed, some analysis conducted](#)



*Lejeunea cavifolia*

## Lichens:

- 172 species (156 in Scotland, 82 in England).
- Range per site: 10 – 53 species.
- Mean per site  $\pm$  SE:  $28 \pm 1$  species.

[Species id completed, some analysis conducted](#)



*Buellia griseovirens*

## Vascular plants:

- 223 species (168 in Scotland, 114 in England).
- Range per site: 6 – 47 species.
- Mean per site  $\pm$  SE:  $22 \pm 1$  species.

[Species id completed, analysis underway](#)



*Geranium robertianum*

# Summary results:

Beetles: Species id completed, some analysis conducted

- 2,660 samples.
- Mostly Carabidae & Staphylinidae; also Elateridae & Curculionidae.
- 18% of species classed as ‘tree-associated’.

	Beetle (all) abundance	Carabidae abundance	Beetle (all) species rich	Carabidae species rich
Total (%):	29,400	13,700 (47%)	130	52 (40%)
Range per site:	30 – 2,809	7 – 1047	6 – 39	4 – 22
Mean per site ± SE:	490 ± 65	228 ± 35	20 ± 1	10 ± 0.5



*Pterostichus melanarius*

# Summary results:

Spiders: Species id completed, some analysis conducted

- 2,660 samples.
- Mostly Linyphiidae.
- 24% of species classed as ‘tree-associated’.

	Spider abundance	Spider species rich
Total:	4,050	103
Range per site:	18 – 171	6 – 25
Mean per site ± SE:	$68 \pm 4$	$14 \pm 1$



# Summary results:

Flying inverts:      Species id completed, analysis conducted, paper published

- 312 samples.

	Hoverfly	Cranefly
Abundance	1,298 (10% wood spp)	4,607 (60% wood spp)
Species richness	65 (38% wood spp)	107 (63% wood spp)
Range abu per site:	0 - 22	2 – 29
Mean abu per site ± SE:	5.0 ± 0.5	12 ± 0.7



*Episyrphus balteatus*



*Tipula paludosa*

# Summary results:

Moths: Species id completed, some analysis conducted

- 282 night-traps.
- Mostly Noctuidae, Geometridae, Tortricidae and Crambidae.

	Moth abundance	Moth species richness
Total:	8,678 (16% wood spp)	253 (30% wood spp)
Range per site:	0 – 267	0 – 37
Mean per site ± SE:	31 ± 2	12 ± 0.5



# Summary results:

## Birds:

- 174 hours of surveying.
- 59 species (51 in England, 46 in Scotland).
- Range 5 – 26.

Wren



Willow warbler

Species id completed, analysis conducted, paper published

# Summary results:

Small mammals: Species id completed, analysis conducted, paper in prep.

- 15,120 night-traps, 1,676 individuals, 4 species:



1 Yellow-necked mouse  
(*Apodemus flavicollis*)



Bank vole  
(*Myodes glareolus*)



Wood mouse  
(*Apodemus sylvaticus*)



Field vole  
(*Microtus agrestis*)

Sites present:	80	72	33
Total animals (%):	1006 (60%)	571 (34%)	98 (6%)
Range per site:	0 – 67	0 – 54	0 – 14
Mean per site ± SE:	9.6 ± 1.2	5.4 ± 0.8	0.9 ± 0.2

Data on body condition, sex-ratio, age, reproductive status...

# Summary results:

## Bats:

- 840 hours of ultrasonic recordings.
- 56,500 bat passes, 6 species/genera.



	Soprano pipistrelle	Common pipistrelle	<i>Myotis</i> bats	<i>Nyctalus</i> bats	Brown long-eared	Barbastelle
Sites present:	95	92	70	31	26	3
Total passes (%):	27,183 (48%)	23,014 (41%)	1,171 (2%)	582 (1%)	95 (0.2%)	9 (0.0%)
Range per site:	0 – 4,323	0 – 3,950	0 – 230	0 – 142	0 – 22	0 – 6
Mean per site ± SE:	267 ± 60	226 ± 55	12 ± 3	6 ± 2	0.9 ± 0.3	0.3 ± 0.2

Species id completed, analysis conducted, paper published

# Woodland Creation & Ecological Networks

WrEN project update – April 2018

## Analyses



Woodland Creation &  
Ecological Networks



# Taxa analysed so far...

---



coming soon...

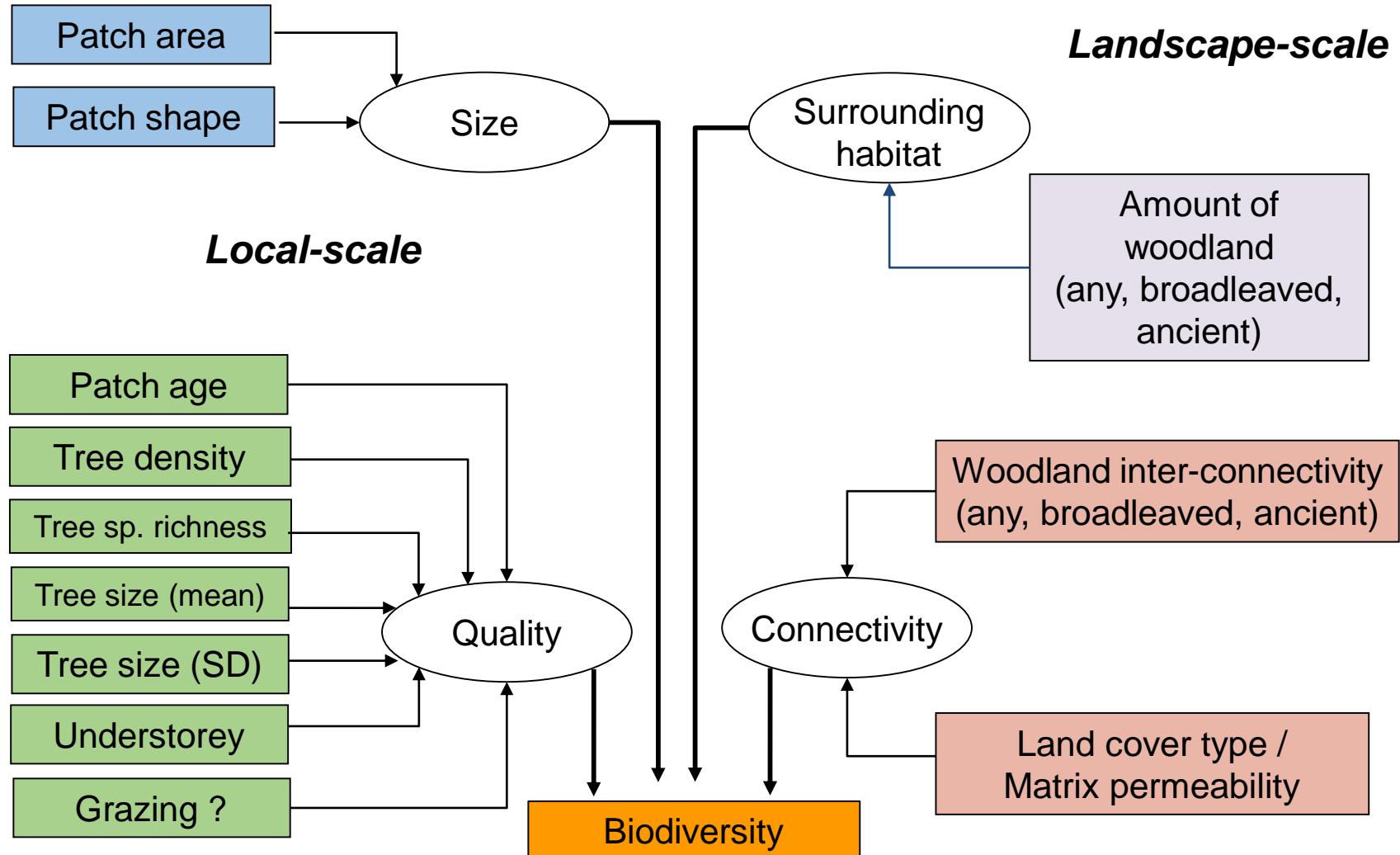
## Publications:

Bats: Fuentes-Montemayor et al. (2017). Ecological Applications 27: 1541-1554.

Birds: Whytock et al. (2017). Conservation Biology 32: 345-354 

Diptera: Fuller et al. (2018). Journal of Applied Ecology 55:1173-1184 

# Conceptual model:



# What is the relative importance of local vs. landscape according to mobility of bat species?

---



Local-scale attributes: vegetation structure → reduced using PCA

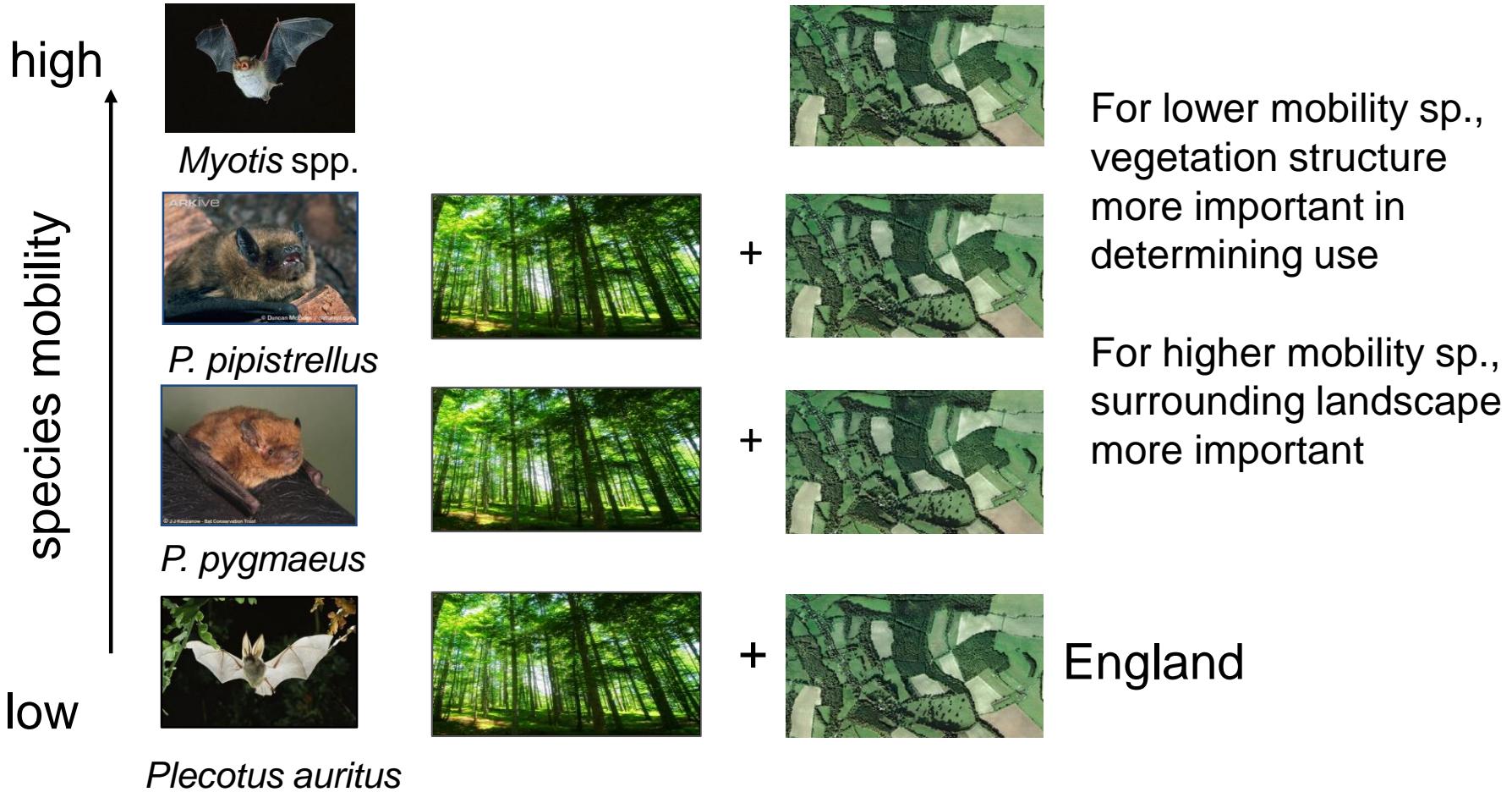


Landscape-scale attributes:  
amount & connectivity  
→ reduced using PCA



Mobility (500 m – 6 km)

# What is the relative importance of local vs. landscape according to mobility of bat species?



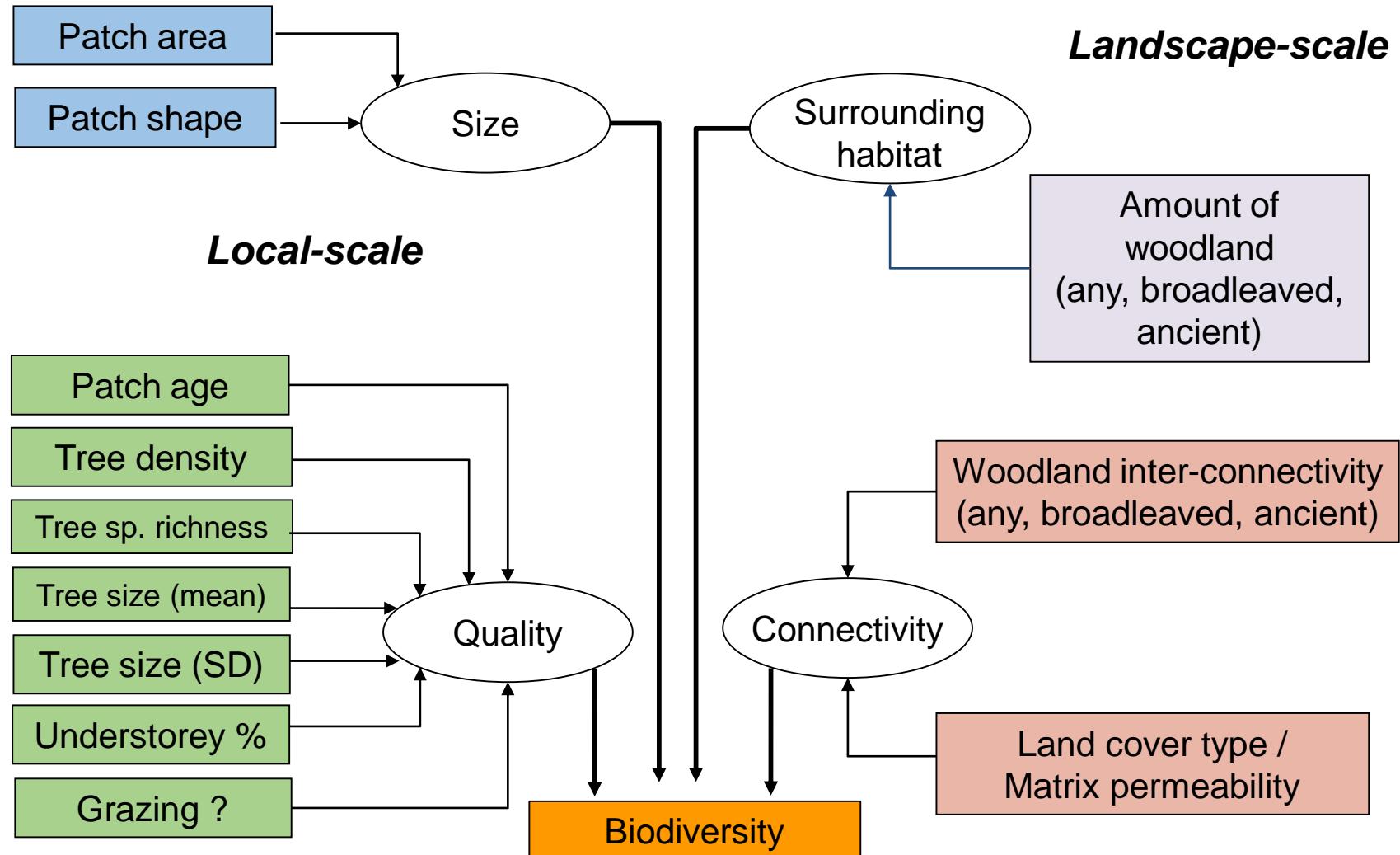
# What is the relative importance of local vs. landscape according to mobility of bat species?

---

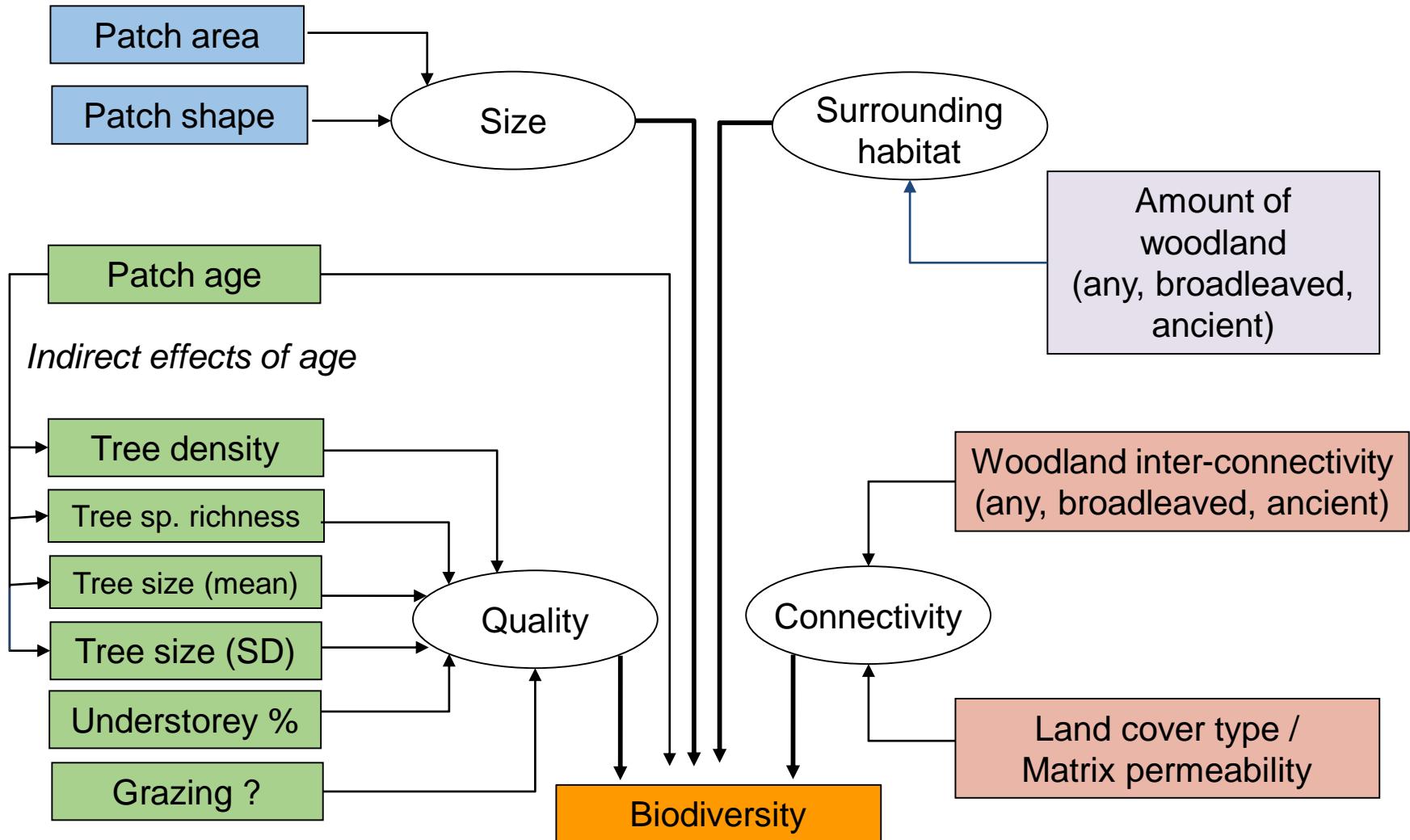
- Species mobility influential in determining relative importance of local vs. landscape-level attributes
- Landscape-level attributes more important in more homogeneous/intensive landscapes
  - Higher activity in older woodlands with larger trees / variation in tree size
  - Species-specific responses to tree density, understorey



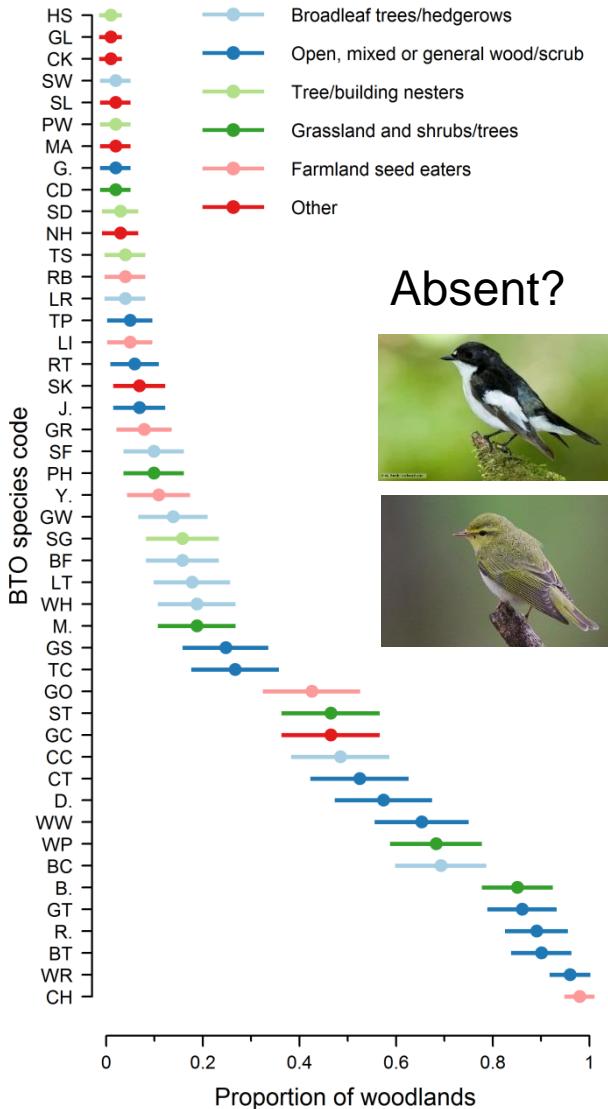
# Structural Equation Model:



# Structural Equation Model:

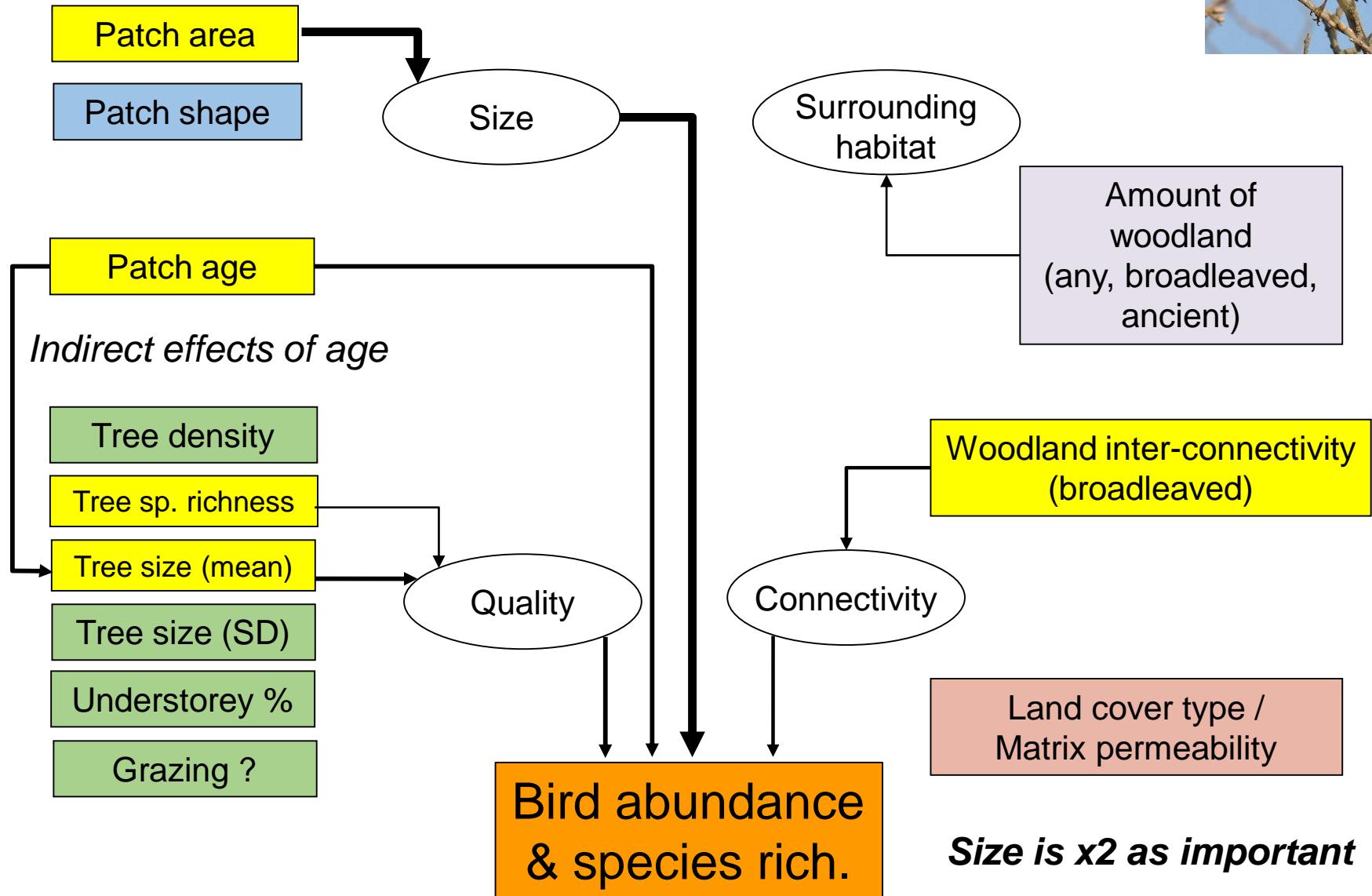


# Responses of bird communities to habitat creation:



- Functional groups described using feeding, breeding, resting habitats (French & Picozzi 2002)
- Those in woodland related groups most commonly recorded
- Some notable absences (species known to breed in the region)

# Structural Equation Model: birds



# Responses of bird communities to habitat creation:

---



- Lack of “continuity/age” effect on woodland functional groups
- Generalist species in *open/mixed* and *general wood/scrub* groups colonise quickly (< 10 yrs)
- Species in *broadleaf trees* group relatively scarce (2/9 in > 20%)
  - Most woodlands still too young?
  - Post-agri woodlands unsuitable (size/management)?

# Responses of woodland Diptera to habitat creation:

---

- Hoverflies & crane flies, two dipteran groups, differing in mobility



N = 78 sites  
4 x 1 week samples

# Responses of woodland Diptera to habitat creation:

---



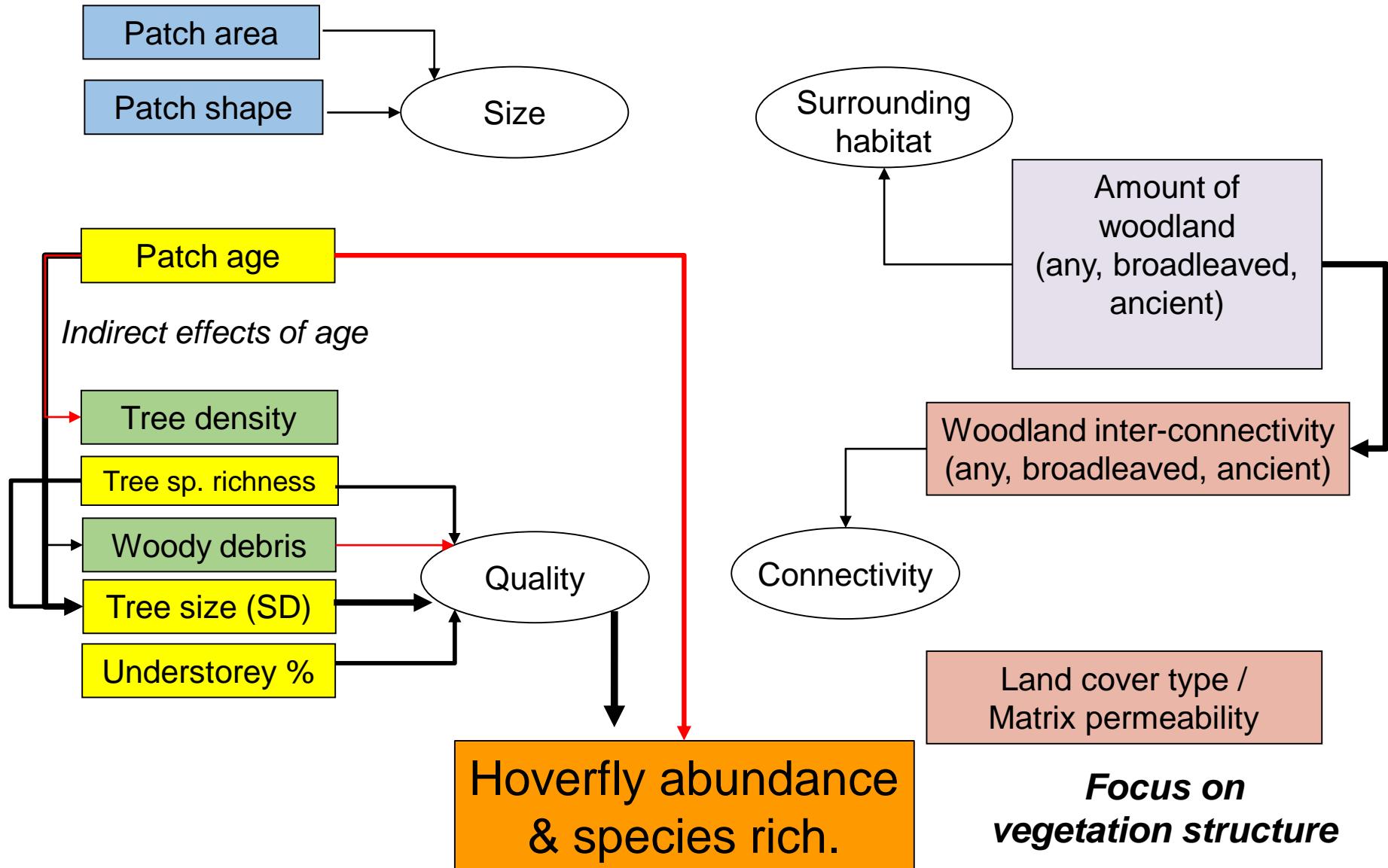
Species richness:

- 25 woodland-associated hoverfly sp.  
(27% of UK sp.)
- 67 woodland-associated crane fly sp.  
(43% of UK sp.)

% of catch that were woodland-associated:

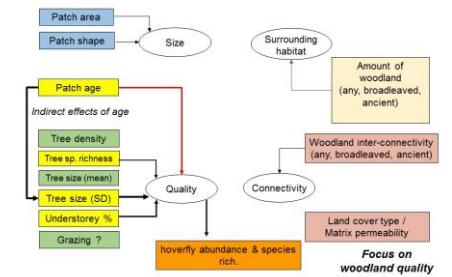
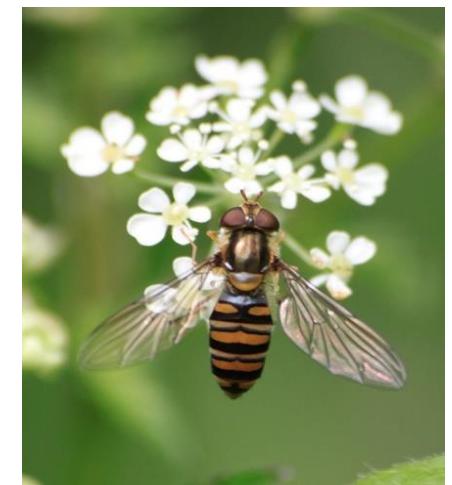
- c. 40% hoverfly species  
(only 10% individuals)
- 63 – 80% crane flies (57 – 79% individuals)

# Structural Equation Model: hoverflies



# Responses of woodland Diptera to habitat creation:

- Secondary woodlands providing habitat for hoverflies & craneflies - despite size & fragmentation
- Low abundance of woodland-associated hoverflies
- Local >> Landscape
- Value of SEMs to examine indirect effects



# Implications for woodland creation so far:

---



- The relative importance of site and landscape characteristics differs between taxa and species mobility
- Manage woodlands to increase tree size and structural heterogeneity
- Remove or reduce grazing pressure
- Importance of woodland size for some taxa (e.g. birds)

# Woodland Creation & Ecological Networks

WrEN project update – April 2018

Comparative results from ancient vs. secondary woodlands



Woodland Creation &  
Ecological Networks



# Introduction:

---

- Woodland age likely to influence the occurrence/abundance of woodland-dependent species.
  - Ecological continuity
  - Old-growth habitat structure
- Ancient semi-natural woodlands:
  - “...rich, complex, and irreplaceable ecosystems”
  - High quality habitat for many taxa
  - Reference sites



# Objectives:

---

- Assess the value of secondary woodlands for biodiversity by using ancient semi-natural woodlands as reference sites.
- Specific questions:  
*Influence habitat quality...*
  - How similar is the habitat structure (e.g. clutter, tree density) of secondary woodlands to that of ancient woodlands?
  - How does the biodiversity (e.g. bat foraging activity) of secondary woodlands compare to that of ancient woodlands?

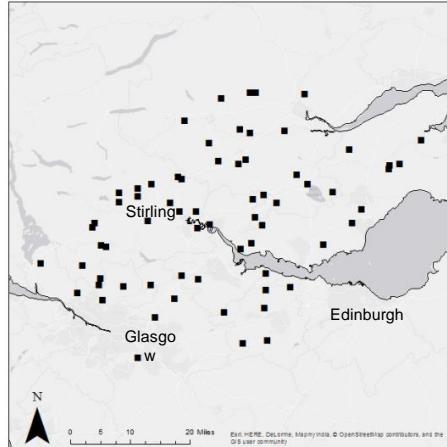


**vs.**



# Sites surveyed:

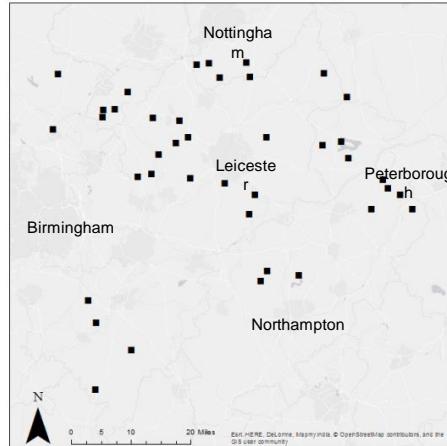
67 sites in Scotland



ancient woodlands



39 sites in England



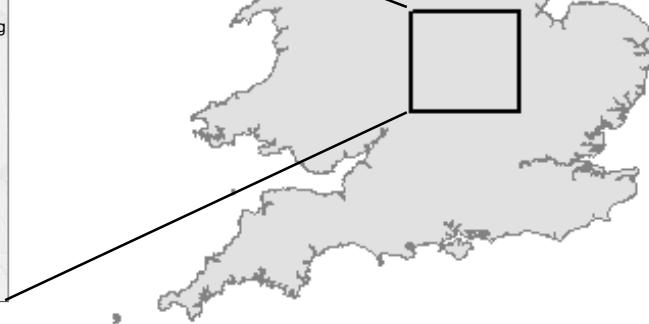
secondary woodlands  
10 – 160 yrs



15 sites in  
Scotland

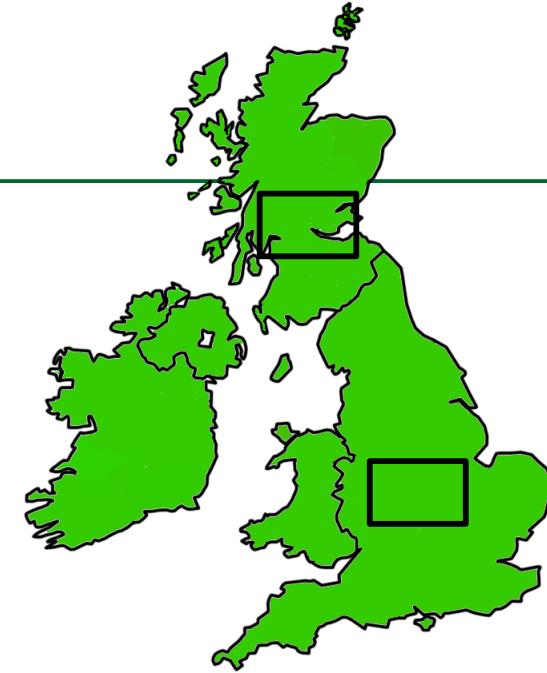


12 sites in  
England



# Sites surveyed:

- 27 ancient woodlands (250+ years): from AWI digital spatial database.
- 27 secondary woodlands (30–120 years): from historic maps.
- Similar sizes (1–13 ha), landscapes (agricultural) and location.



	Small mammals	Bats	Ground inverts	Diptera	Moths	Trees	Ground flora	Lichens	Bryophytes	Birds
Ancient 2016	-	27	26	14	15	27	27	-	-	26
Secondary 2016	-	27	26	14	15	27	27	-	-	26
Total	-	54	52	28	30	54	54	-	-	52

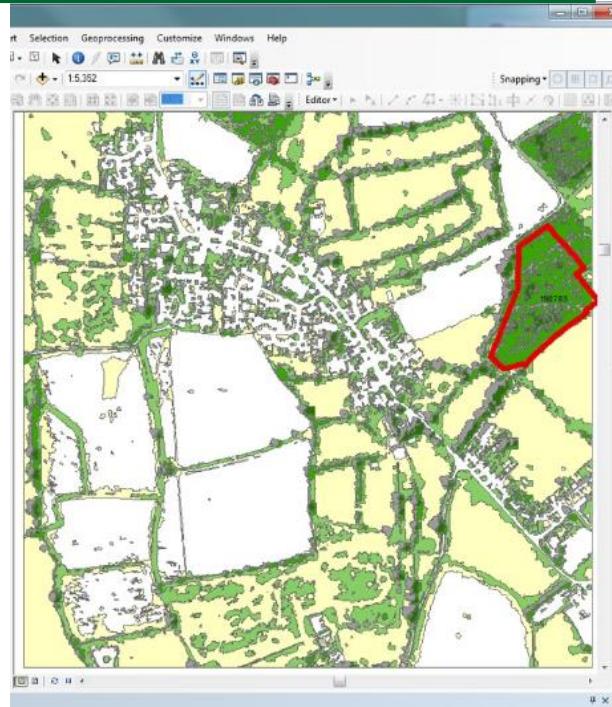
# Progress to date:

---

- Habitat structure: *some analysis done.* 
- Ground flora: *species id completed, analysis underway.* 
- Ground inverts: *beetle carabids id to species, analysis to do; spiders separated but not yet id.*  
- Diptera: *hoverflies id to species, analysis to do; craneflies separated but not yet id.*  
- Moths: *species id completed, some analysis done.* 
- Bats: *analysis completed, paper in prep.* 
- Birds: *point count data still to be digitised, analysis to do.* 
- Soil development and biodiversity: *analysis underway.* 

# Ongoing and future work:

- Data analyses & publications
- Additional surveys for missing taxa (e.g. larger mammals, grazers)
- Role of hedgerows and trees outside woods
- Synthesis / analyses across taxa to identify areas of concordance and conflict
- Developing guidance for practitioners
- Quantify relative effects of restoration on ecosystem functioning
- Manipulative experiments



# Acknowledgements:

## Co-authors/collaborators:

Simon Duffield  
Mark Ferryman  
Elisa Fuentes-Montemayor  
Lauren Fuller  
Jonathan Humphrey  
Bill Kunin  
Nick Macgregor  
Kirsty Park  
Kevin Watts  
Robbie Whytock

## Land owners for access.

Woodland Creation &  
Ecological Networks



## Field assistance & advice:

Roy Allen, Tom Armitage, Katy Baird,  
Katja Bitenc, Stephen Brennan, Pete  
Carey, Ruth Coxon, Paul French,  
Lloyd Garvey, Natasha Hambly, Ian  
Hayward, Joe Hope, Jamie Irvine,  
Holly Langridge, Ed Lewis, Zeltia  
Lopez, Suzie May-Graham, Ron  
Rotbarth, Rory Whytock, Mariko  
Whyte, Scott Wilson, + many staff at  
Forestry Commission, Forest  
Research & Natural England



Sustainable Forestry



# For more information:

---

Website: [www.wren-project.com](http://www.wren-project.com)

Twitter: @WrENproject



*The WrEN team on retreat  
Fort William, Oct 2016*