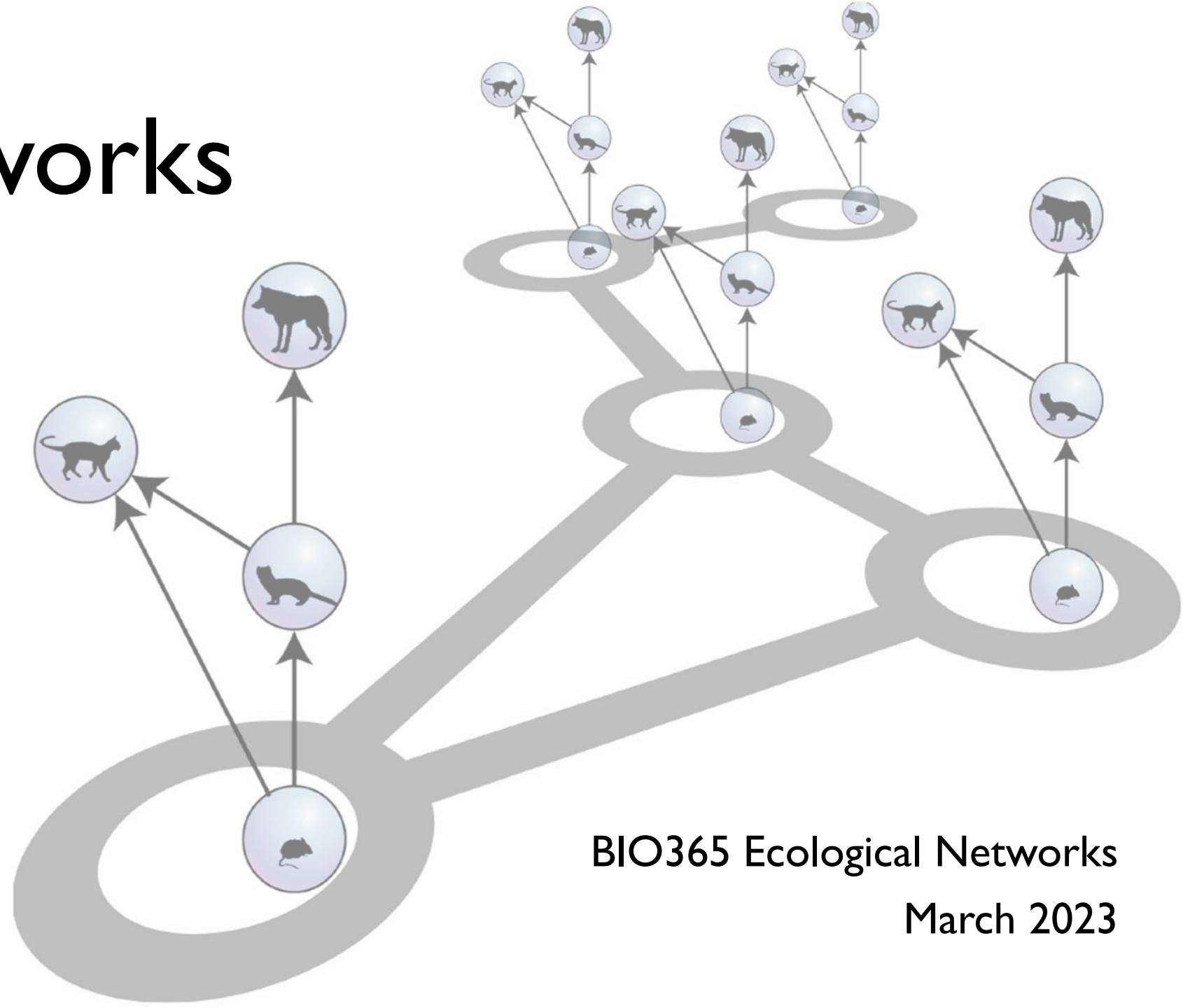


# Spatial Networks

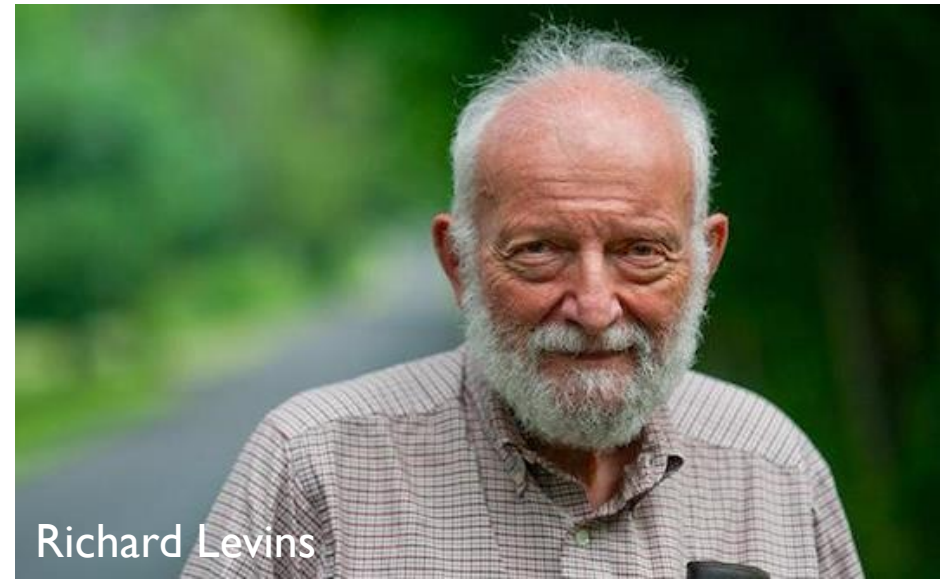
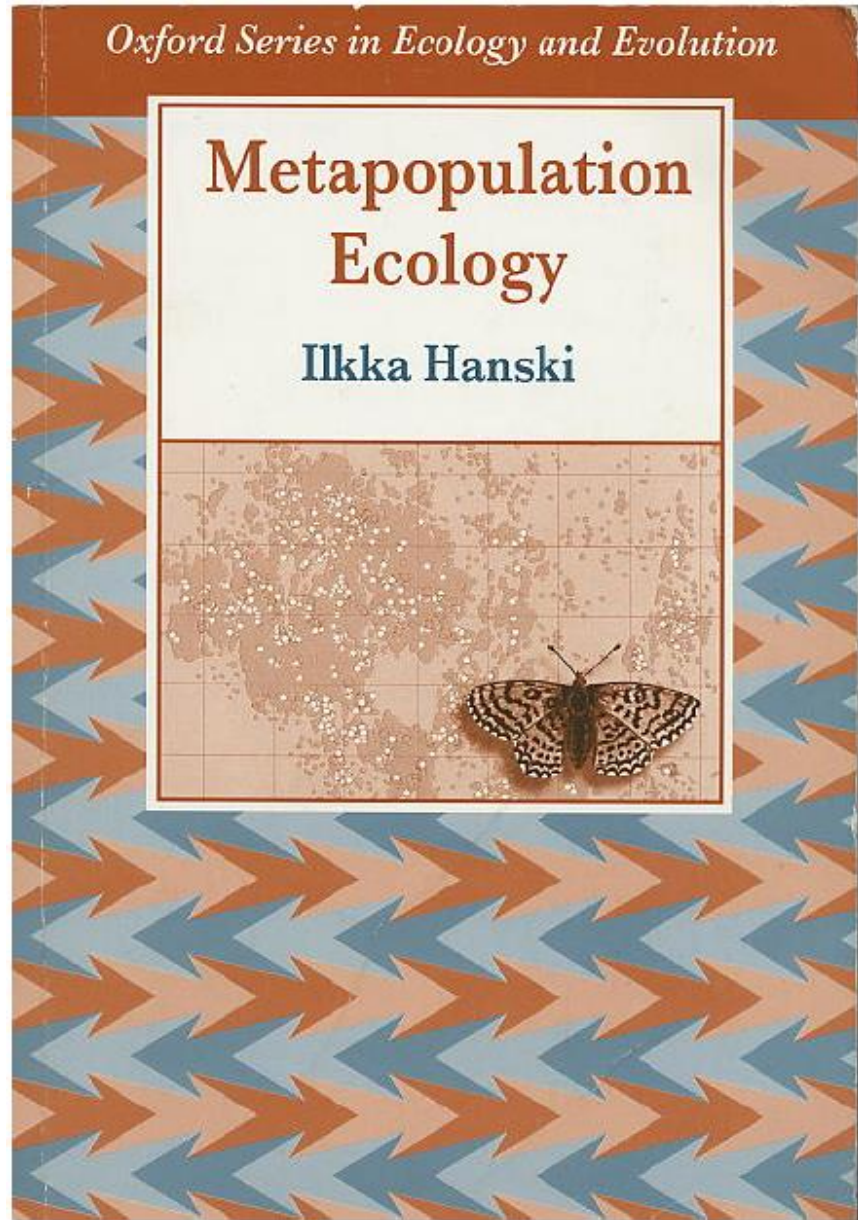


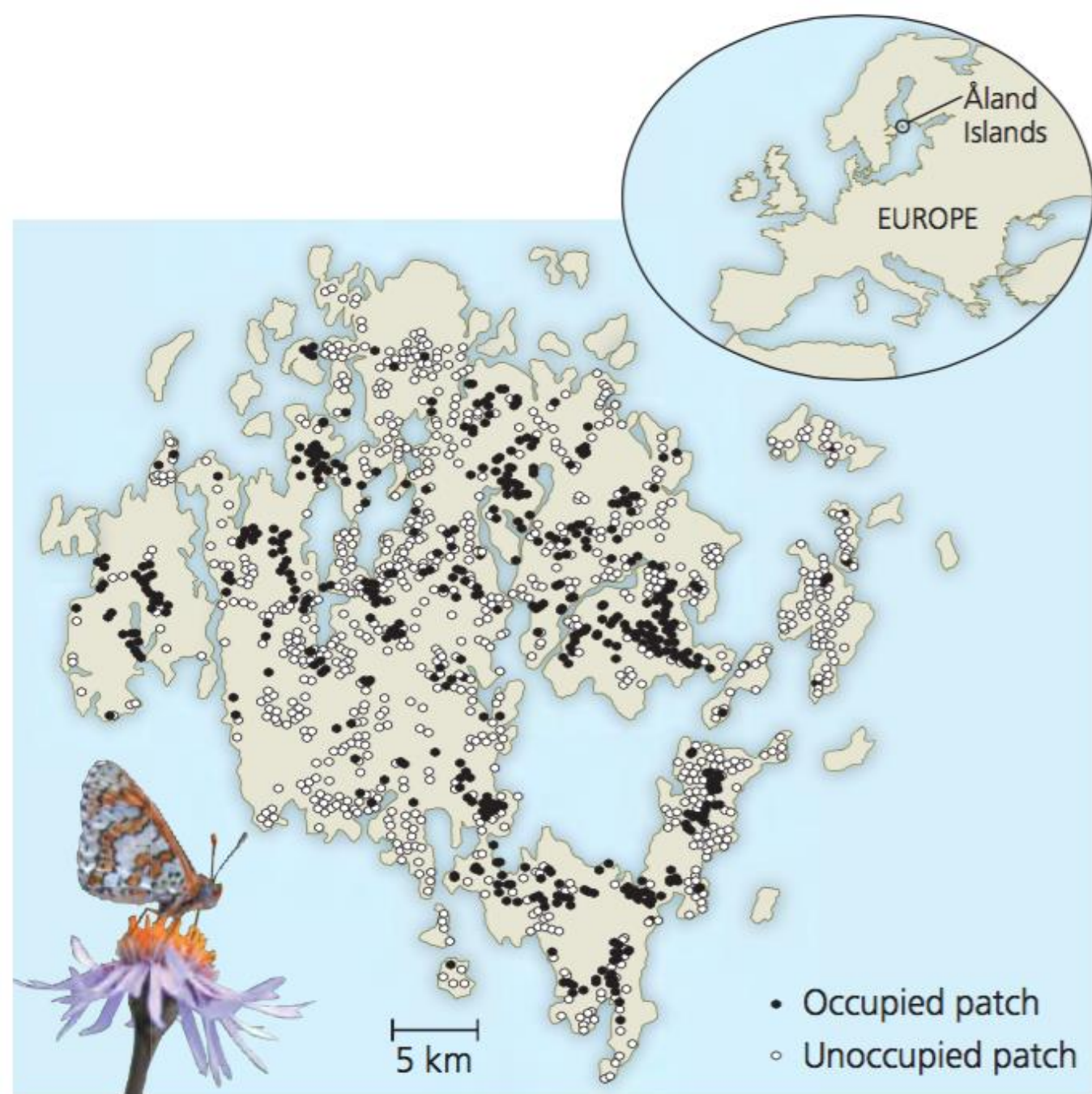
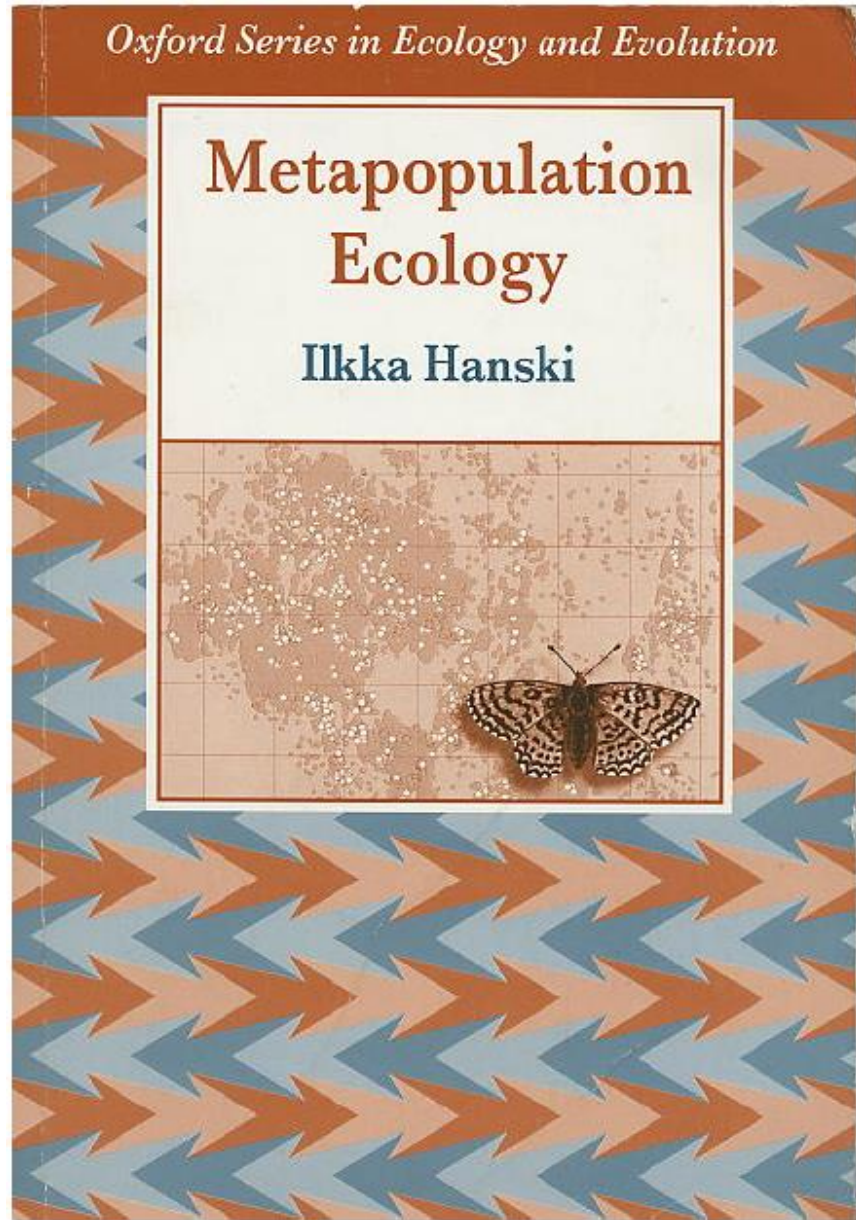
Klementyna Gawecka

klementyna.gawecka@uzh.ch

BIO365 Ecological Networks

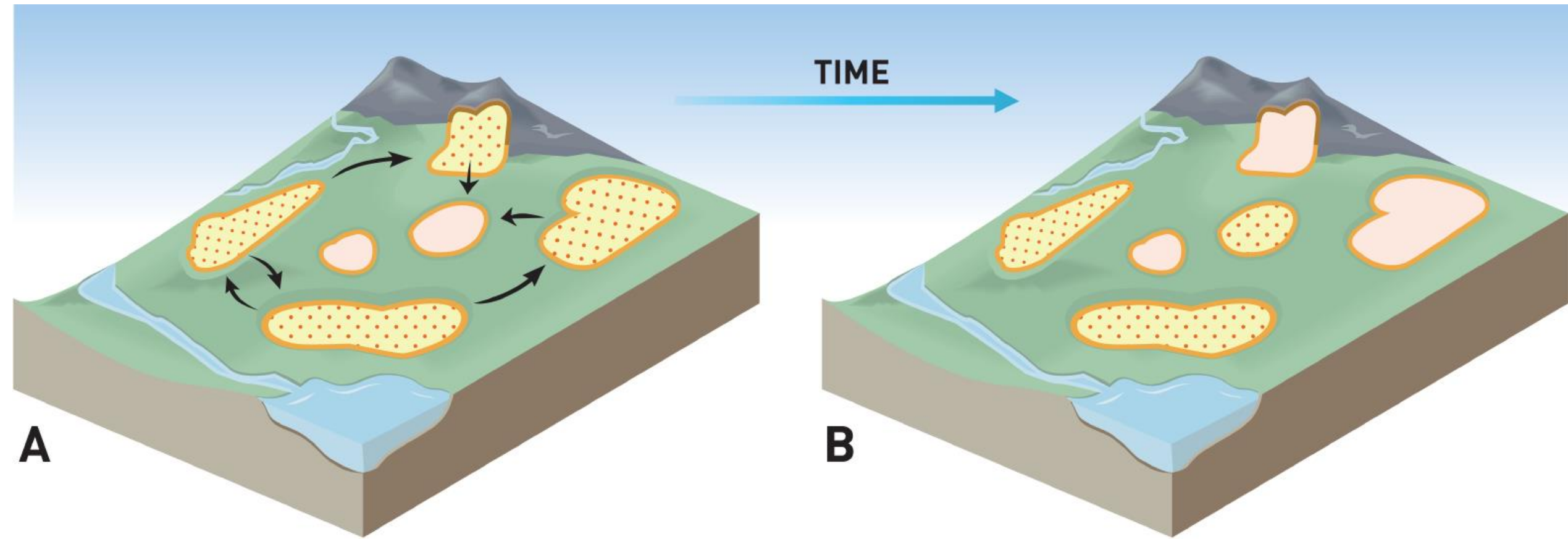
March 2023

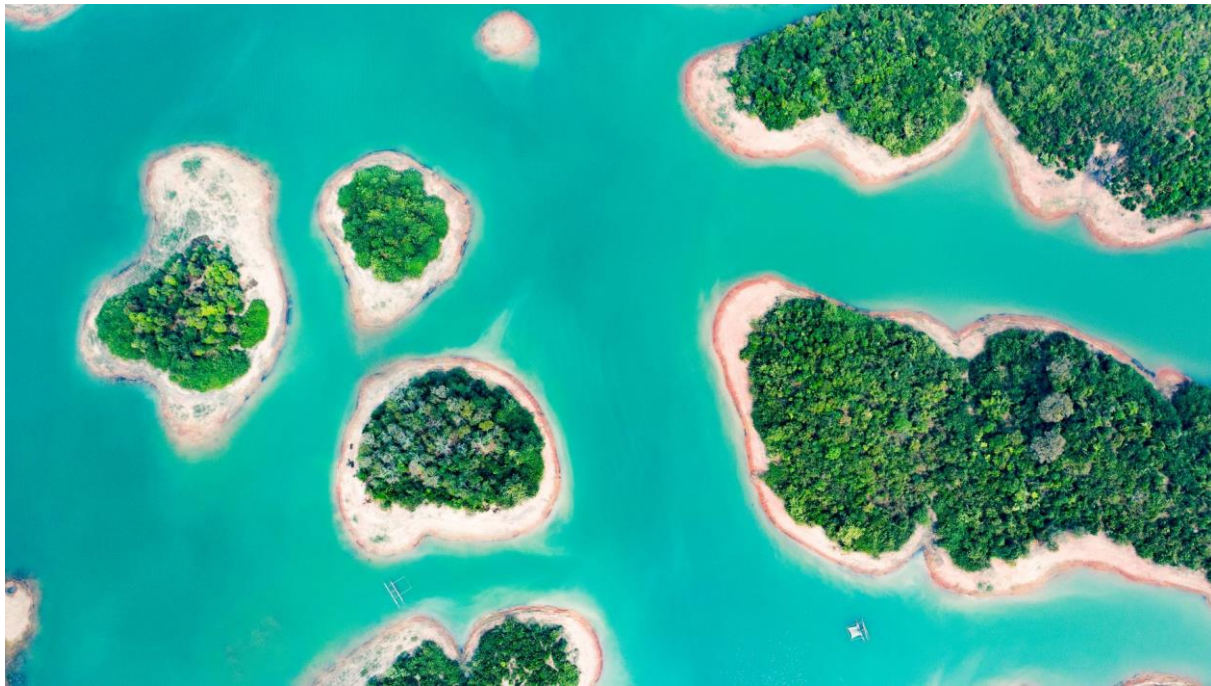




Glanville fritillary butterfly

# Metapopulation dynamics





# Habitat loss and extinction thresholds

Levins' model:

$$\frac{dp}{dt} = cp(1 - D - p) - ep$$

fraction of occupied patches

fraction of destroyed patches

colonisation rate

extinction rate

time

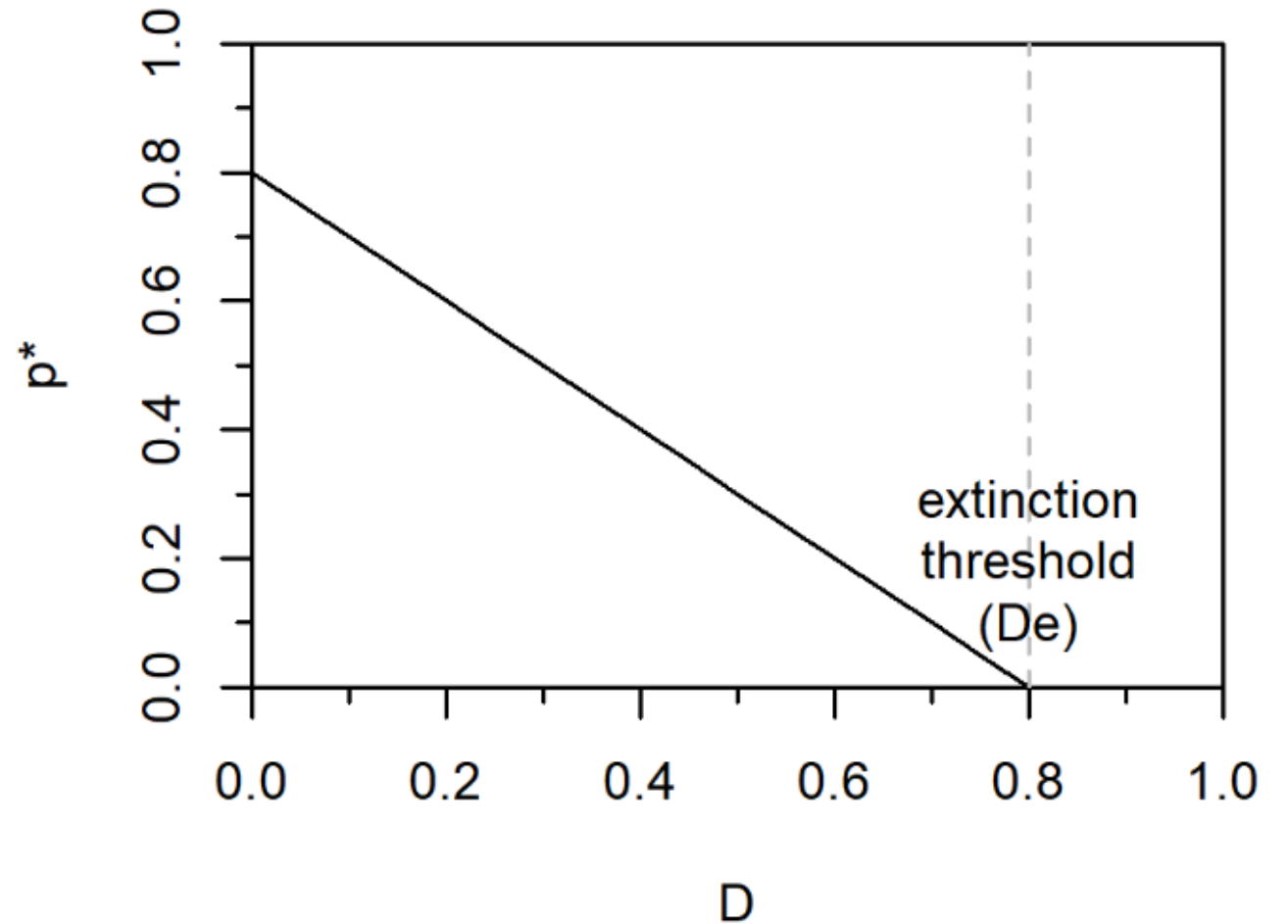
colonisations

extinctions

# Habitat loss and extinction thresholds

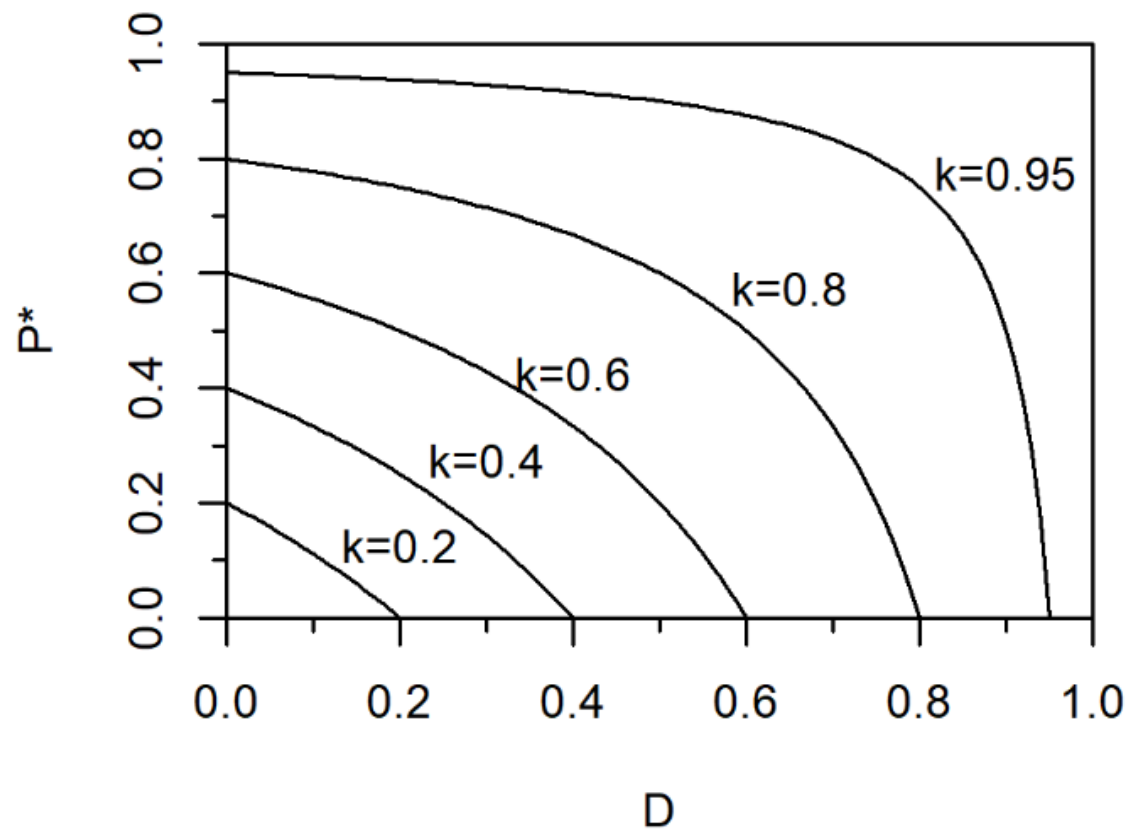
$$p^* = \begin{cases} 1 - D - e/c & \text{if } D < D_e \\ 0 & \text{if } D \geq D_e \end{cases}$$

$$D_e = 1 - e/c$$



## EXTINCTION THRESHOLDS IN DEMOGRAPHIC MODELS OF TERRITORIAL POPULATIONS

RUSSELL LANDE

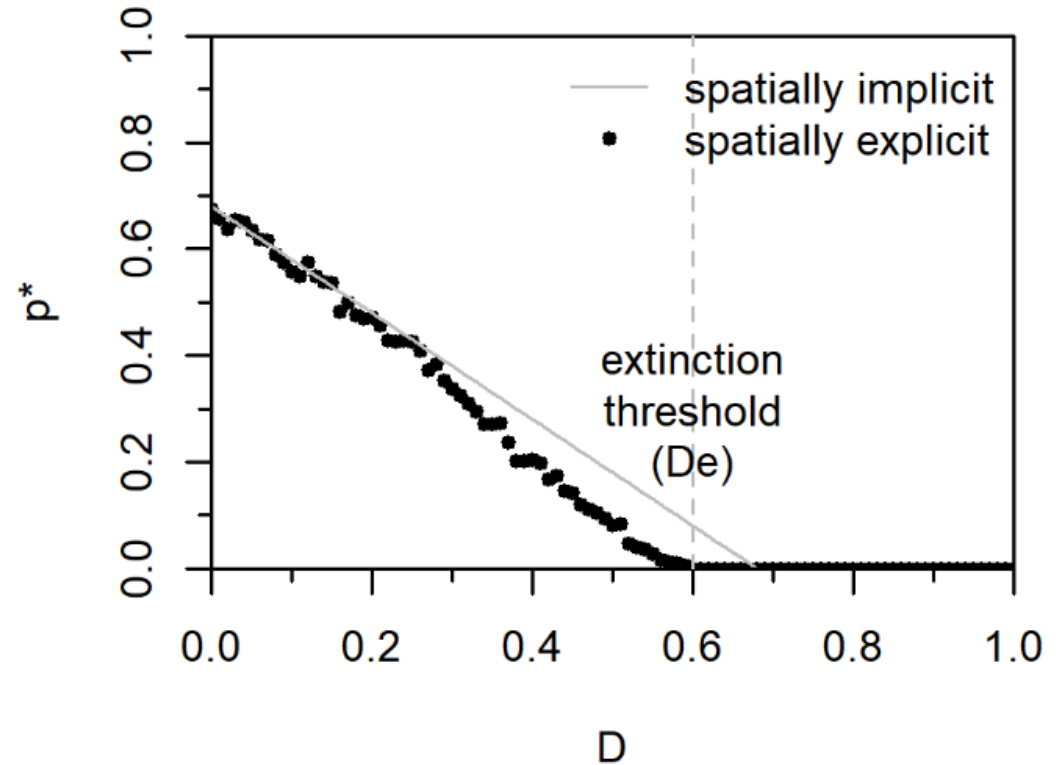
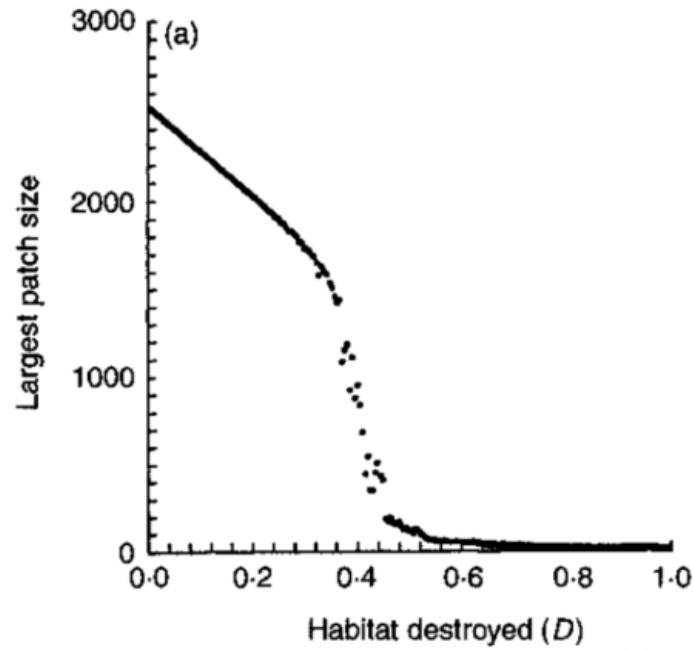
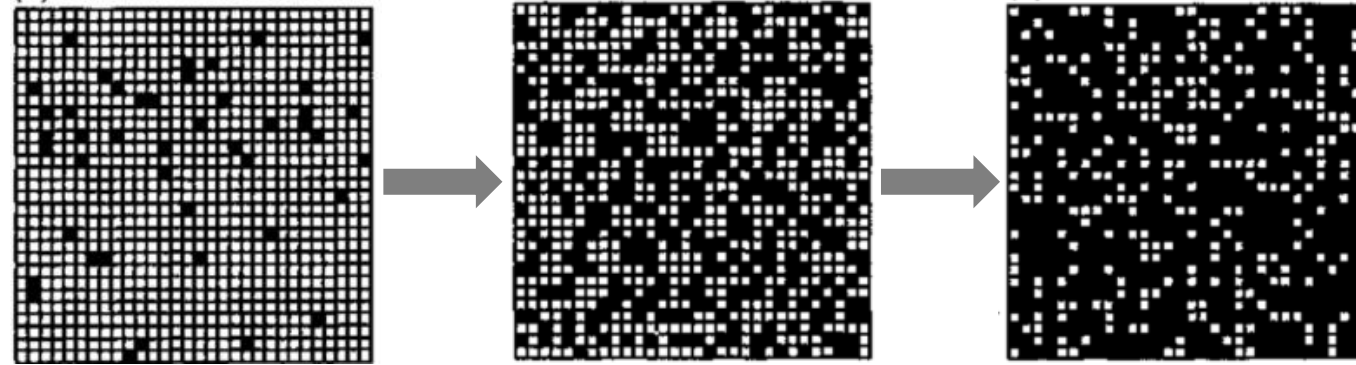


Northern spotted owl



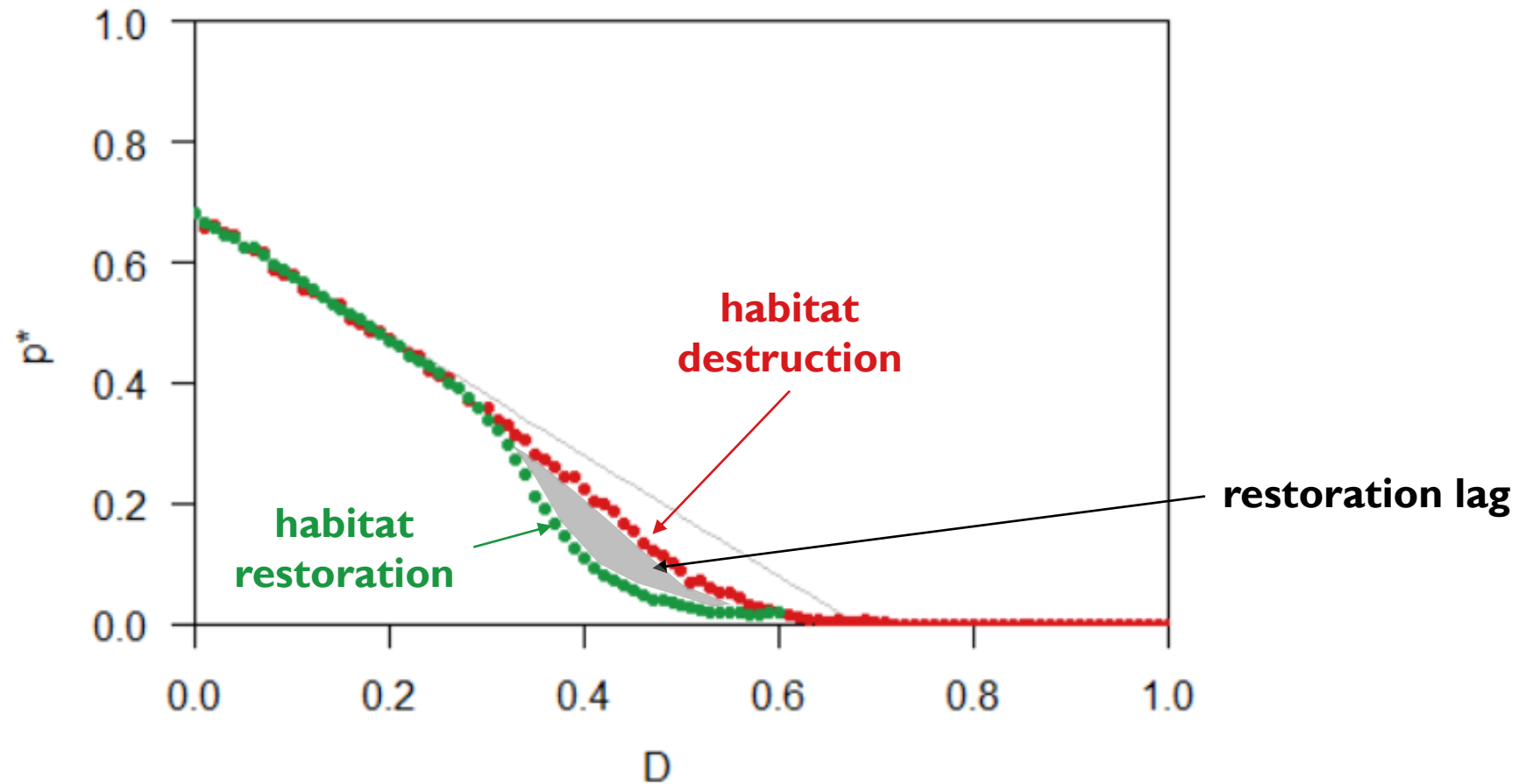
# Habitat fragmentation and extinction thresholds in spatially explicit models

JORDI BASCOMPTE\*‡ and RICARD V. SOLÉ†



# Habitat restoration in spatially explicit metacommunity models

Klementyna A. Gawecka  | Jordi Bascompte 



# Spatial networks

## path

sequence of nodes such that nodes are visited only once

## spanning tree

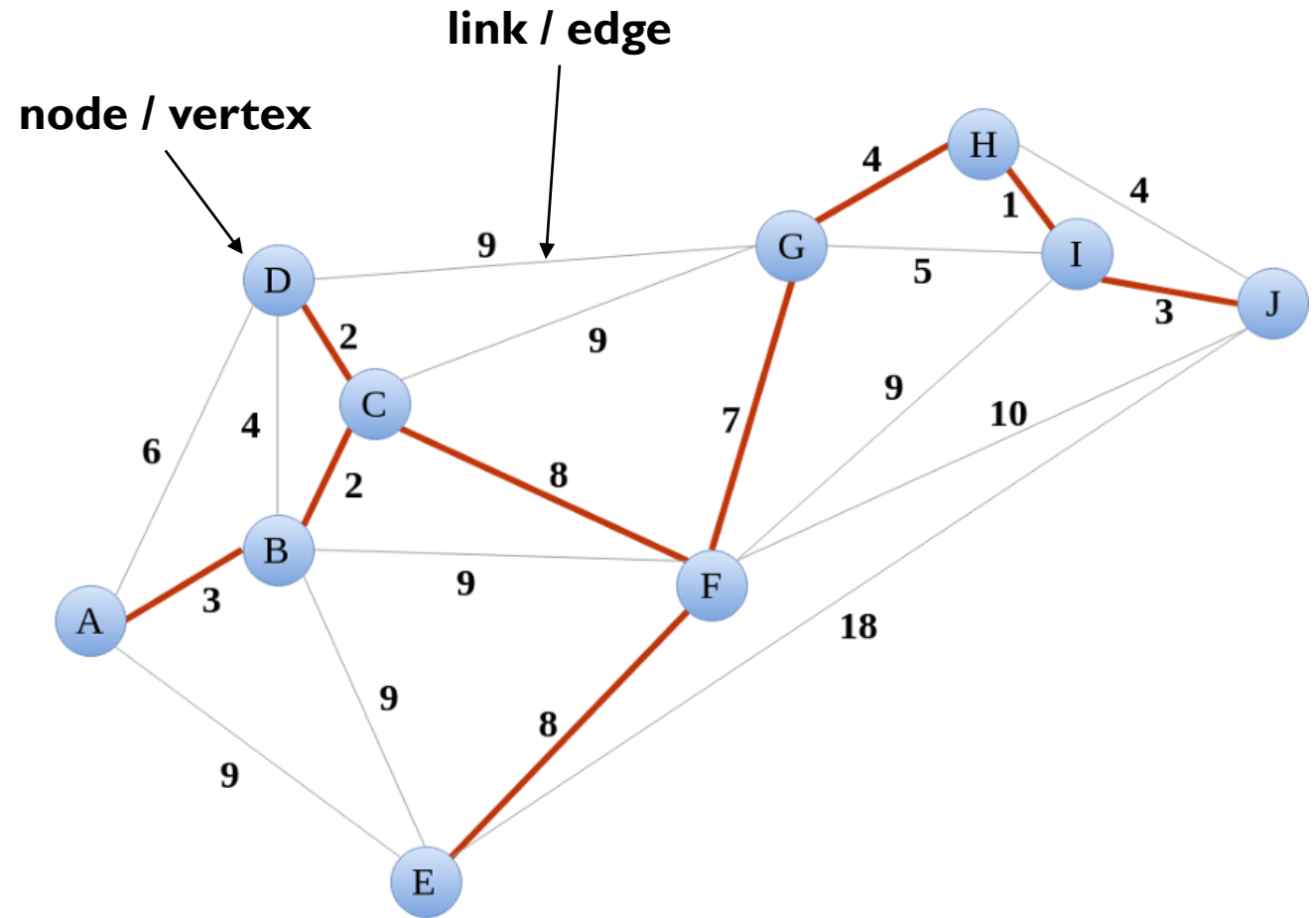
path that includes every node only once

## minimum spanning tree

spanning tree with the shortest length

## connected graph

graph where a path between each pair of nodes exists



# Spatial networks

## I. Identifying nodes

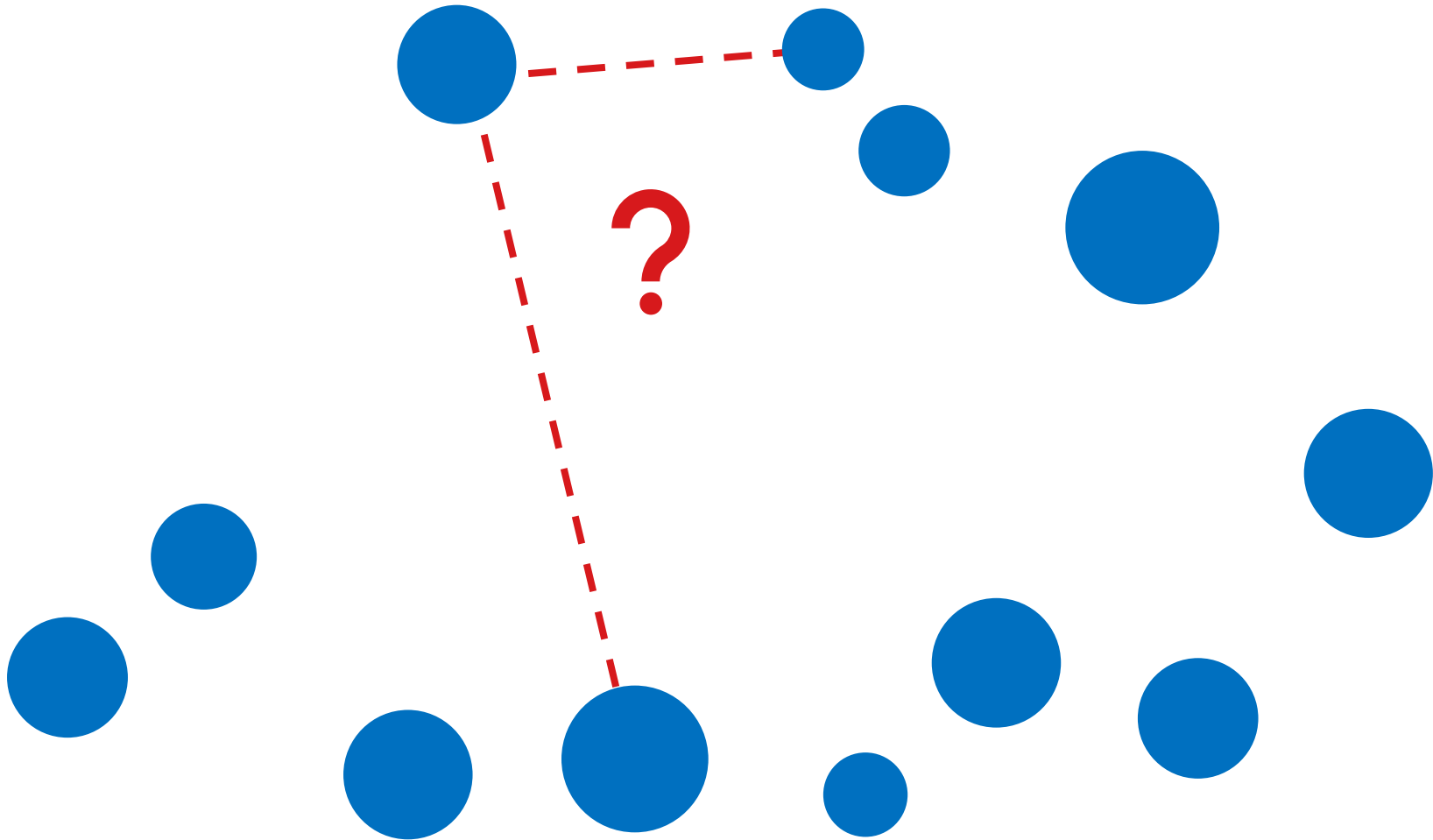


# Spatial networks

## 2. Connecting nodes

- Nearest neighbours
- Minimum spanning tree
- Connected graph
- ...

- Threshold distance
- Dispersal probabilities
- Least-cost paths
- ...



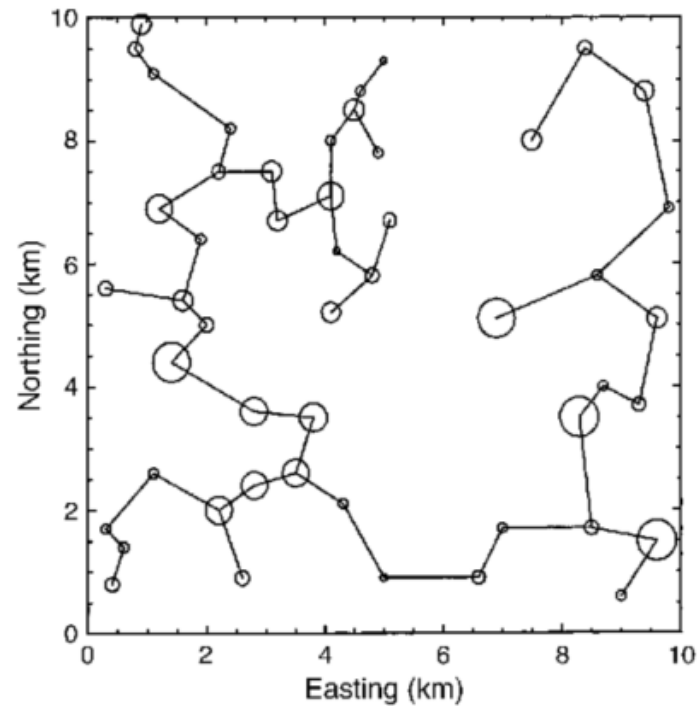
# Spatial networks

## 2. Connecting nodes

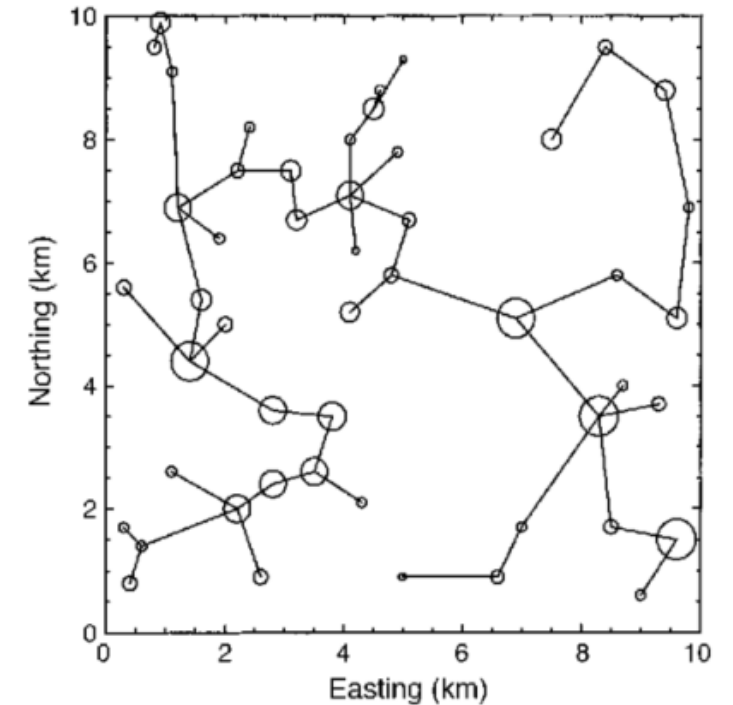
- Nearest neighbours
- Minimum spanning tree
- Connected graph
- ...

- Threshold distance
- Dispersal probabilities
- Least-cost paths
- ...

minimum spanning  
tree



area-weighted  
dispersal probabilities



## LANDSCAPE CONNECTIVITY: A GRAPH-THEORETIC PERSPECTIVE

DEAN URBAN<sup>1,3</sup> AND TIMOTHY KEITT<sup>2,4</sup>

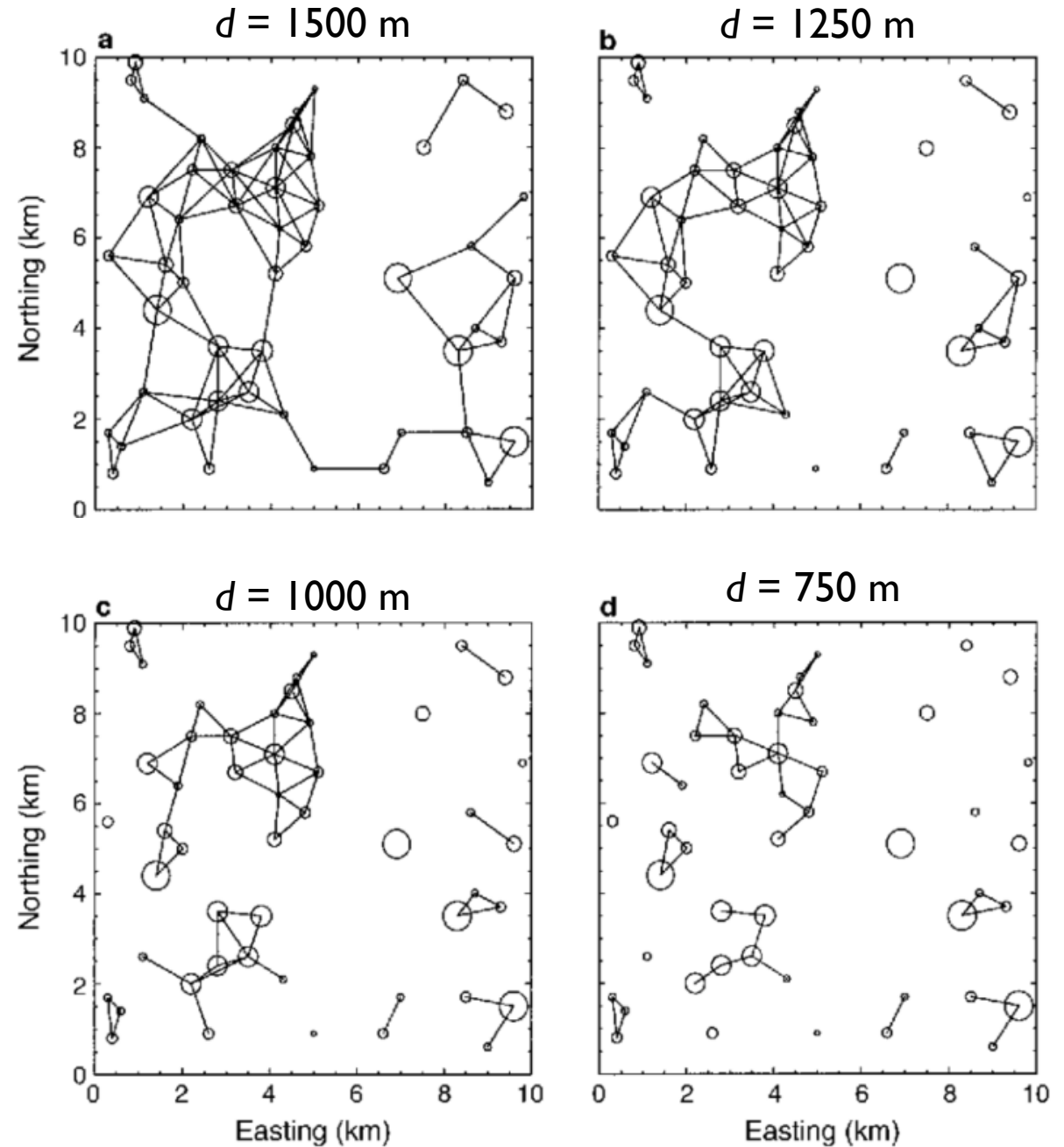
### link removal

Is there a systematic relationship between the connectivity of a graph and the number of links removed?

How should corridors be preserved to maintain overall connectivity of the habitat mosaic?

At what threshold distance ( $d$ ) does the graph become unconnected?

How does this distance compare to dispersal capabilities of species of concern?



## LANDSCAPE CONNECTIVITY: A GRAPH-THEORETIC PERSPECTIVE

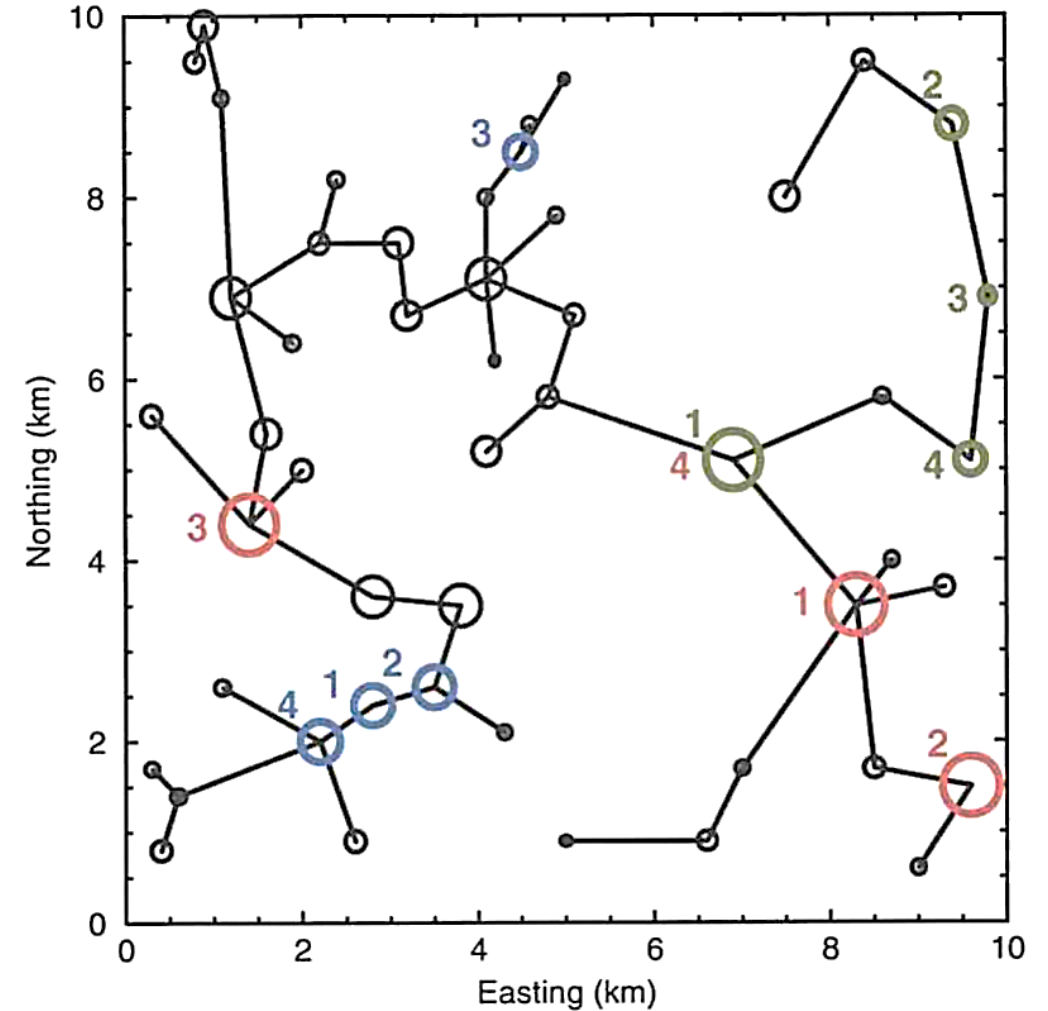
DEAN URBAN<sup>1,3</sup> AND TIMOTHY KEITT<sup>2,4</sup>

### node removal

Which nodes are most important for preserving the graph's structure?

Which habitat patches have most influence on metapopulation processes within the landscape?

Which patches should be prioritised for monitoring / protection / restoration?



4 most important patches for:

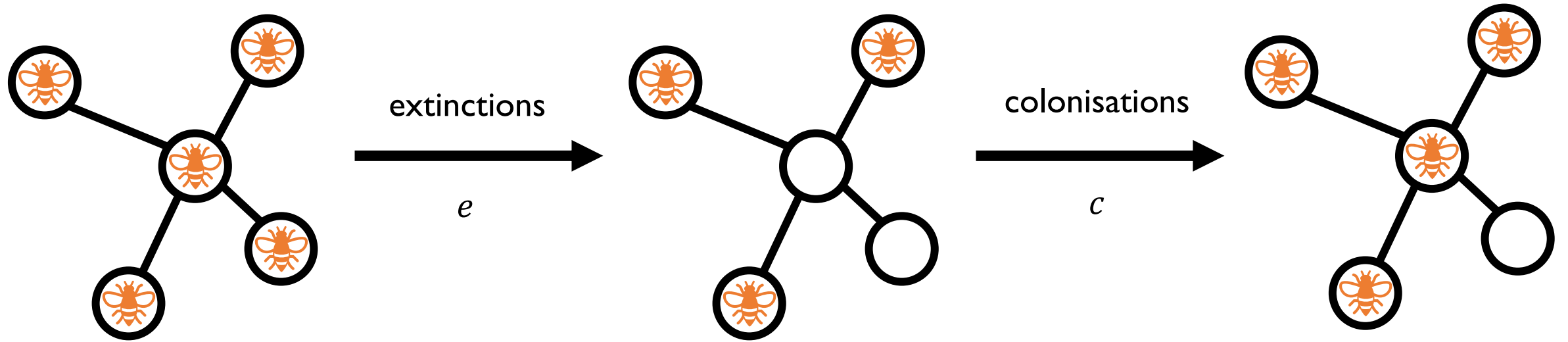
recruitment potential

dispersal flux

traversability

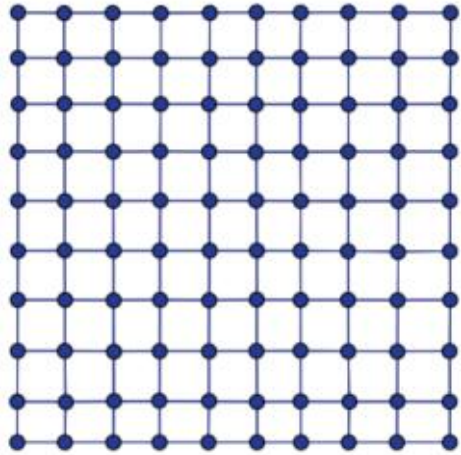


# Spatial networks and metapopulations

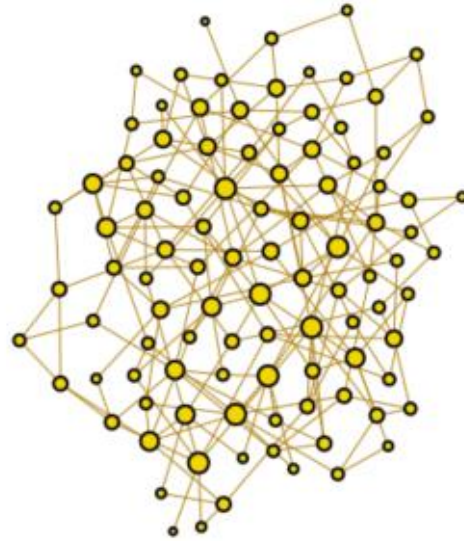


# Spatial network structure and metapopulation persistence

Luis J. Gilarranz\*, Jordi Bascompte



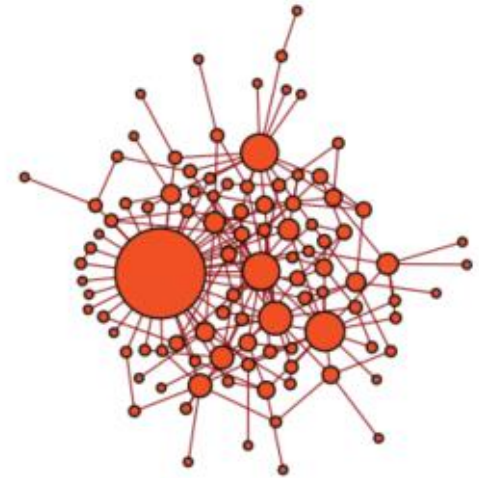
regular



random



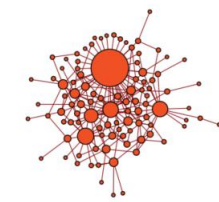
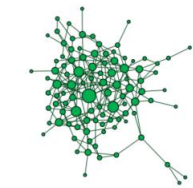
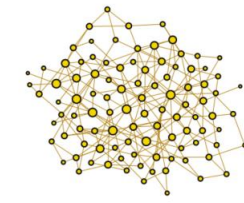
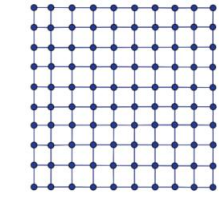
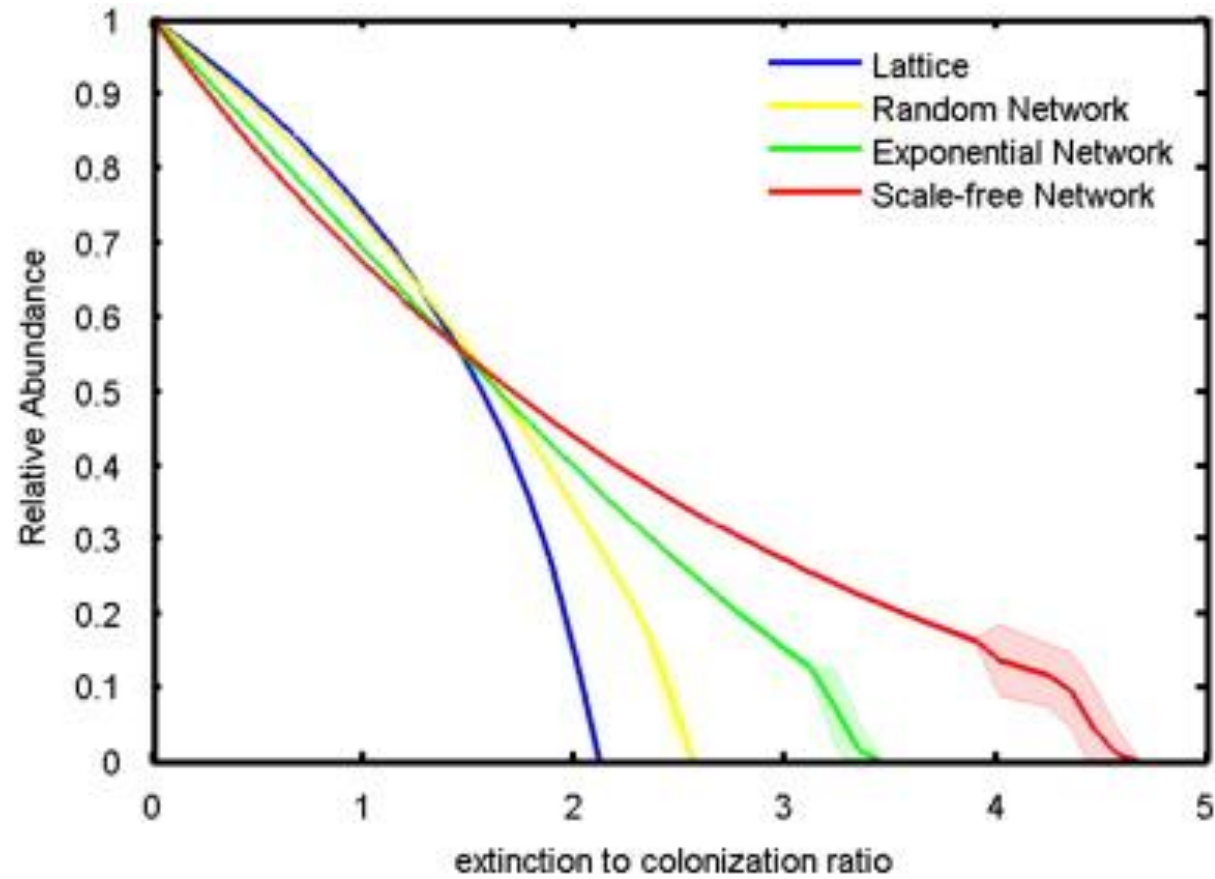
exponential

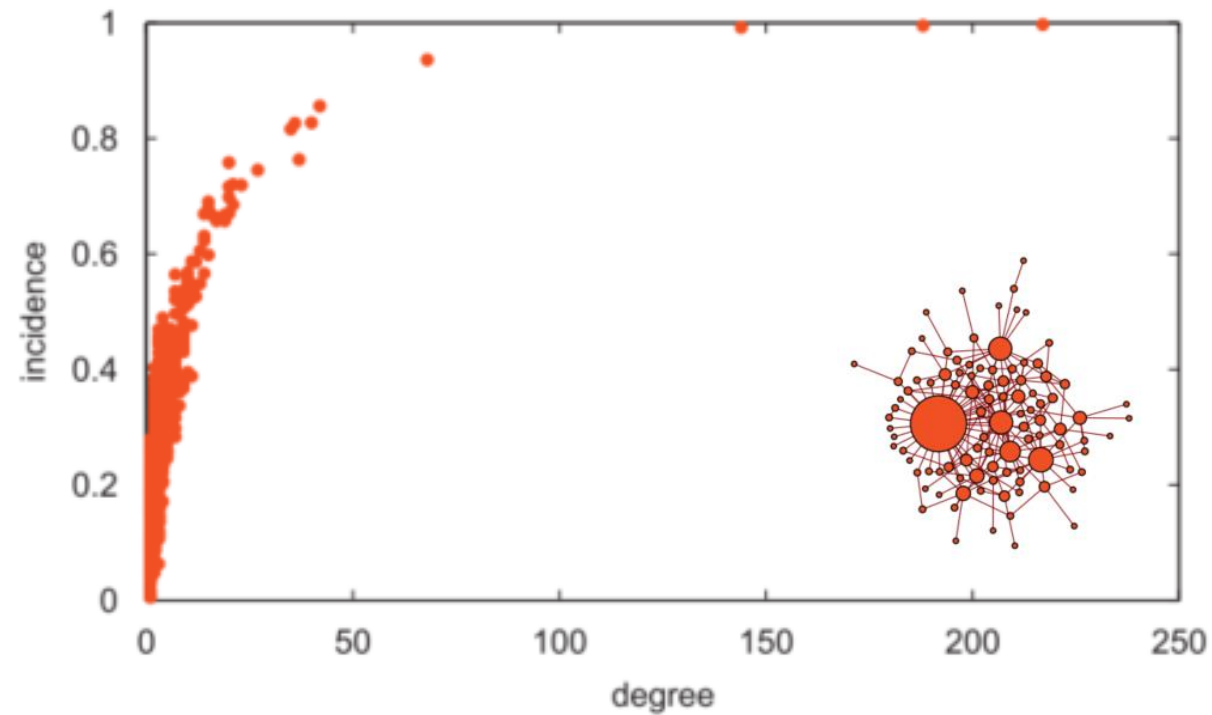
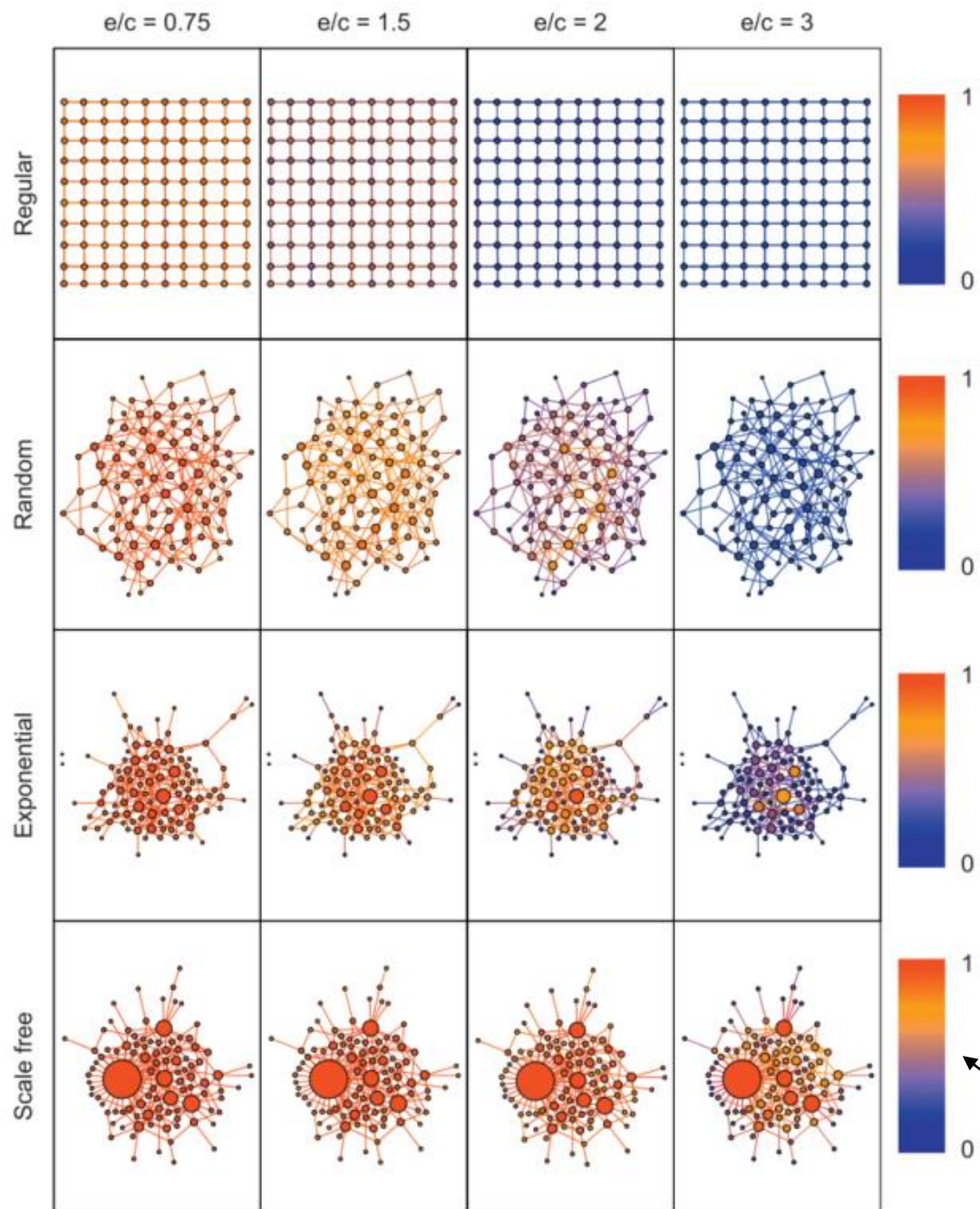


scale-free

# Spatial network structure and metapopulation persistence

Luis J. Gilarranz\*, Jordi Bascompte



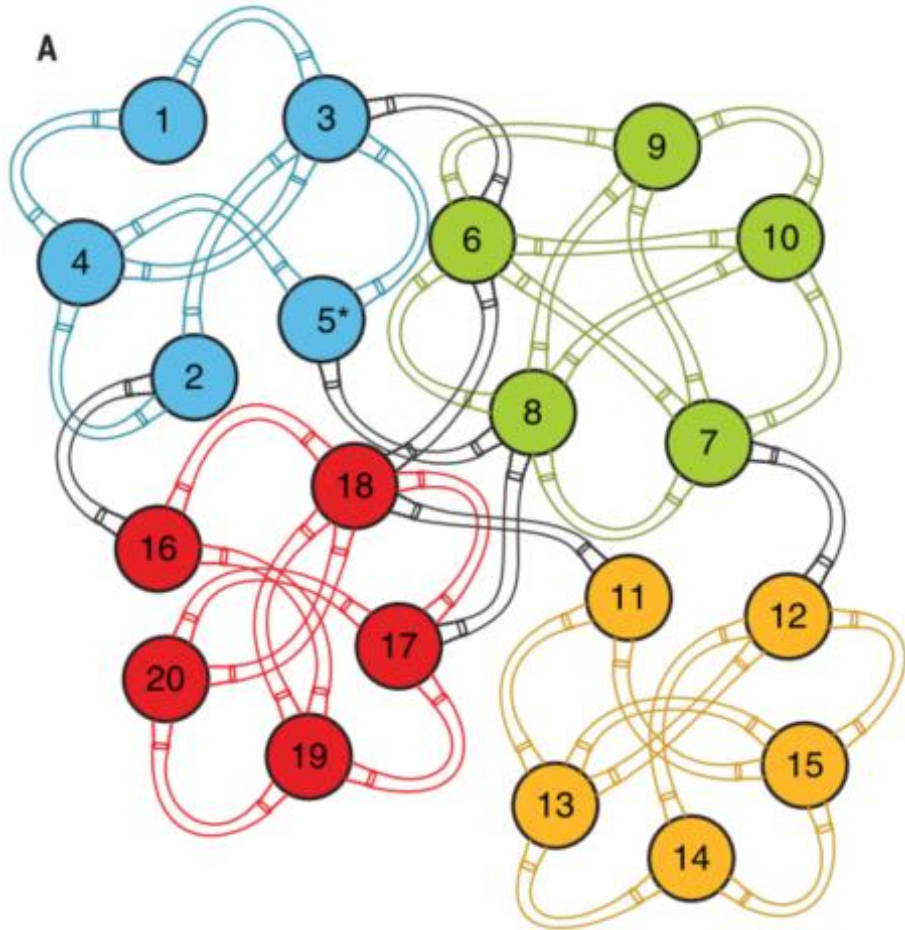


incidence – proportion of time steps a node is occupied

# Effects of network modularity on the spread of perturbation impact in experimental metapopulations

Luis J. Gilarranz,<sup>1,2</sup> Bronwyn Rayfield,<sup>3</sup> Gustavo Liñán-Cembrano,<sup>4</sup>  
Jordi Bascompte,<sup>1,2</sup> Andrew Gonzalez<sup>3\*</sup>

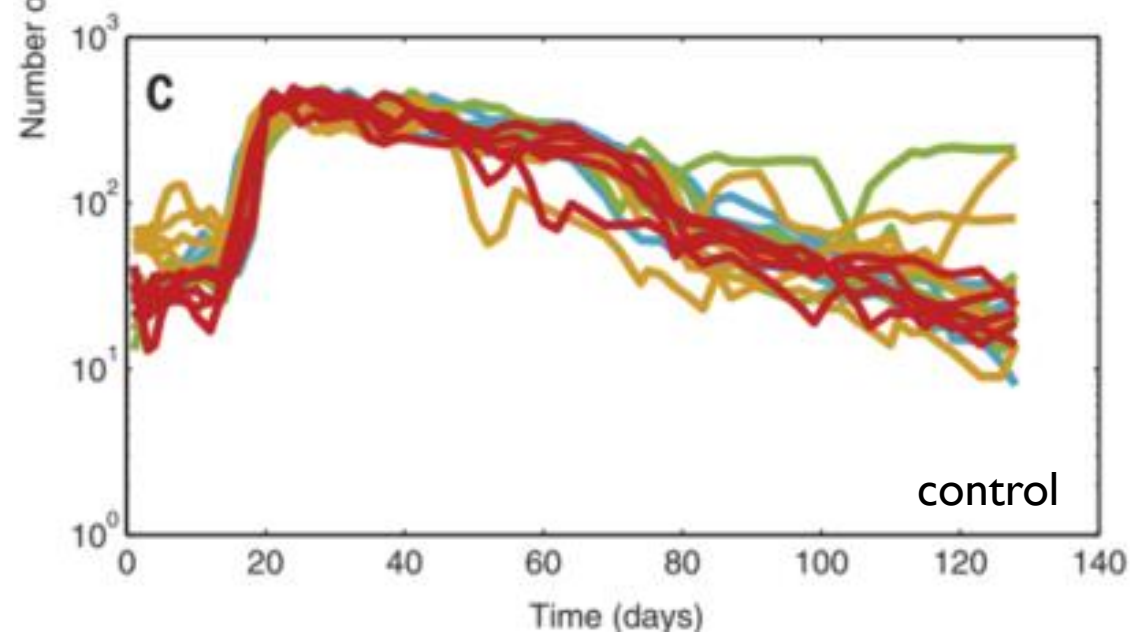
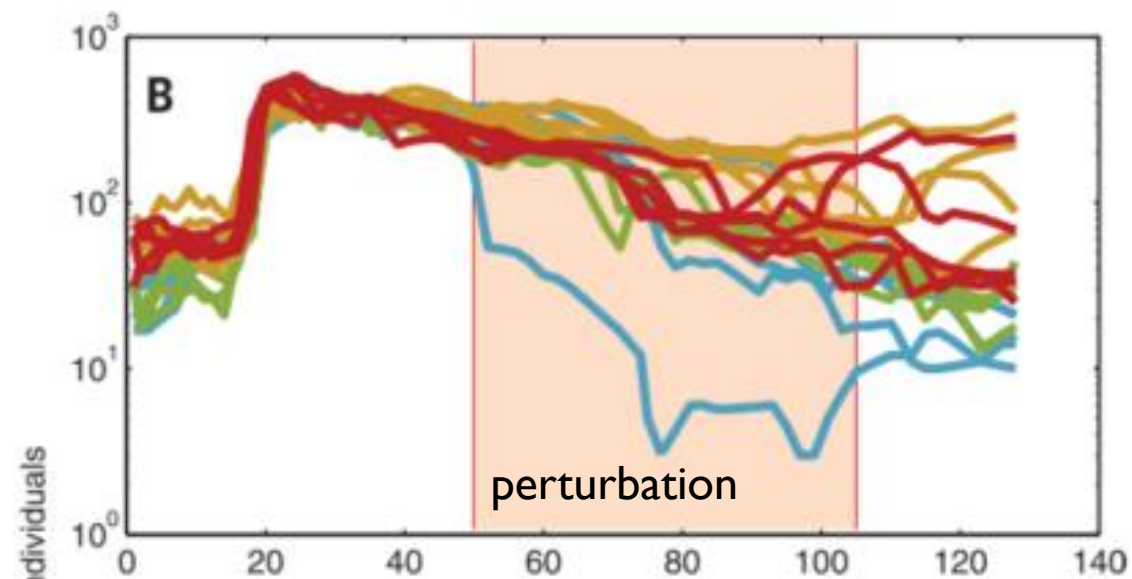
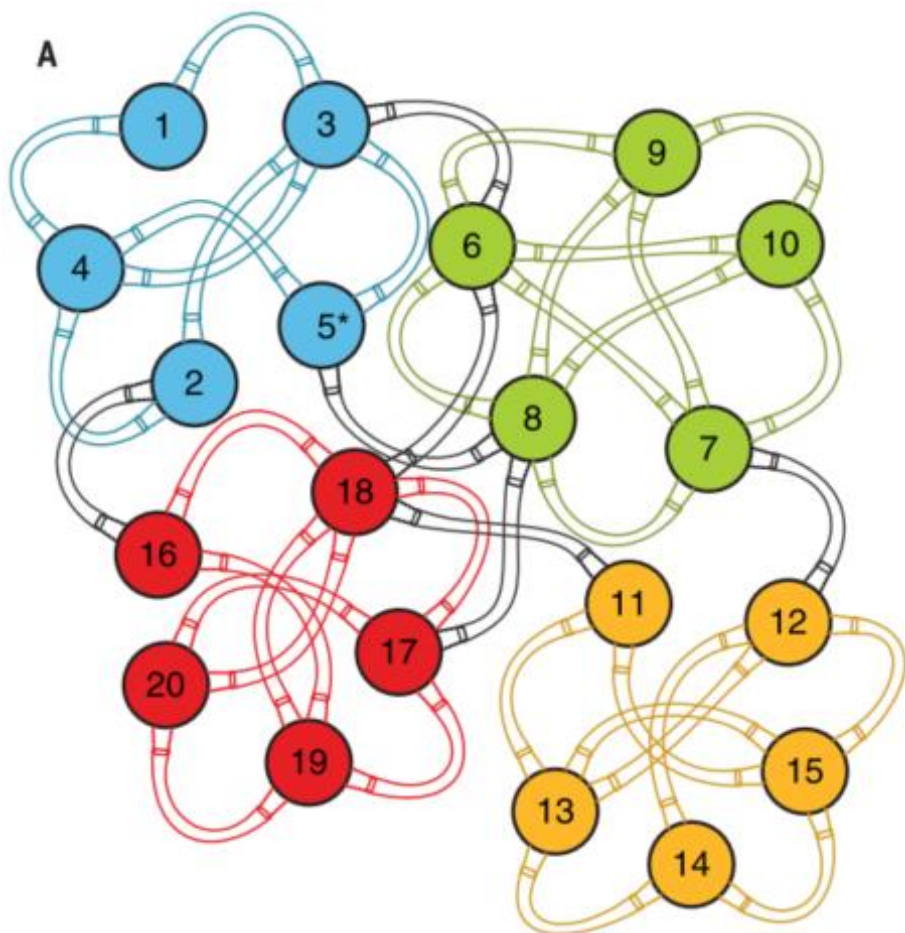
*Science* 357, 199–201 (2017)



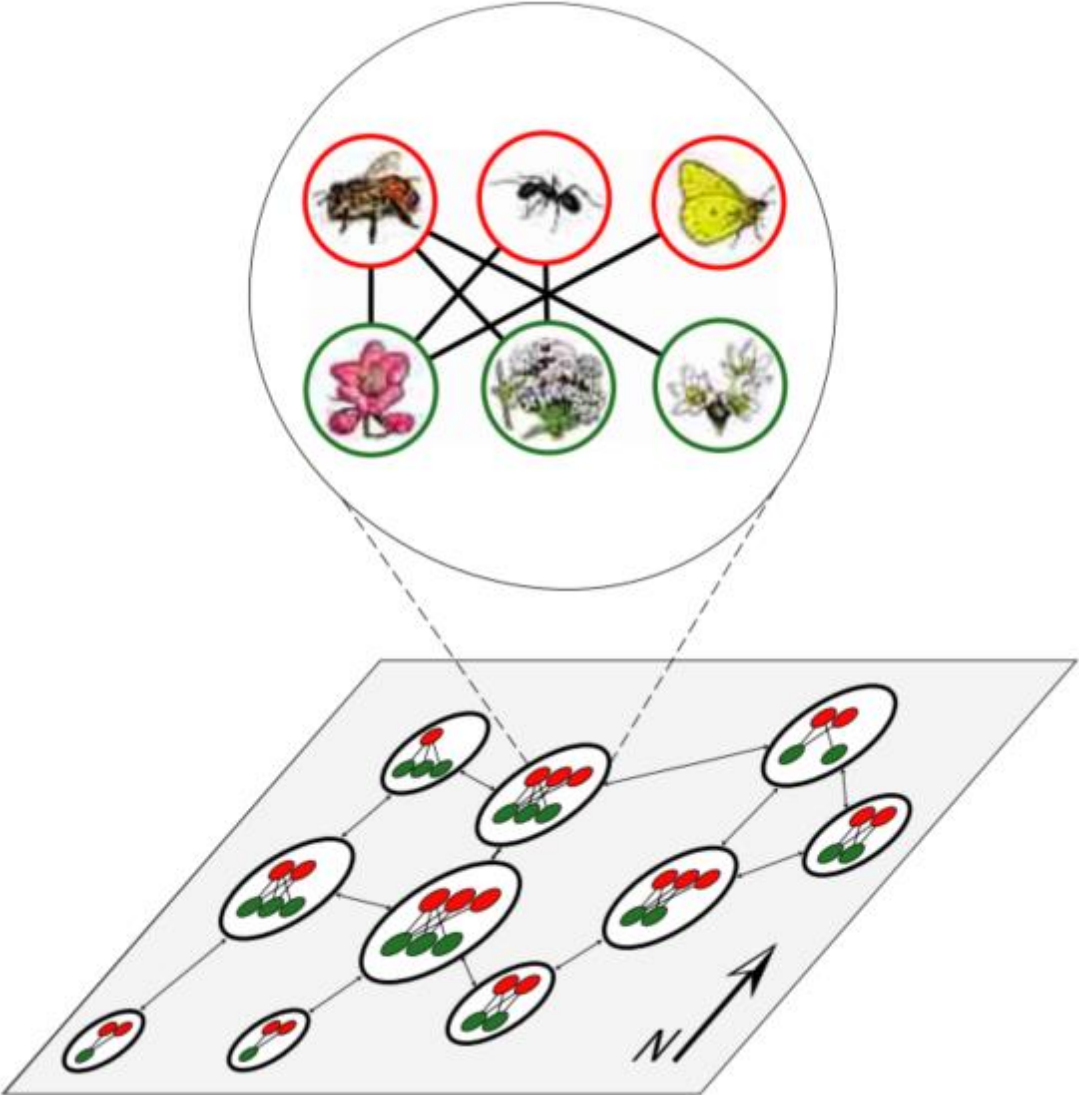
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*Science* 357, 199–201 (2017)



# Spatial networks and metacommunities



# Hot spots of mutualistic networks

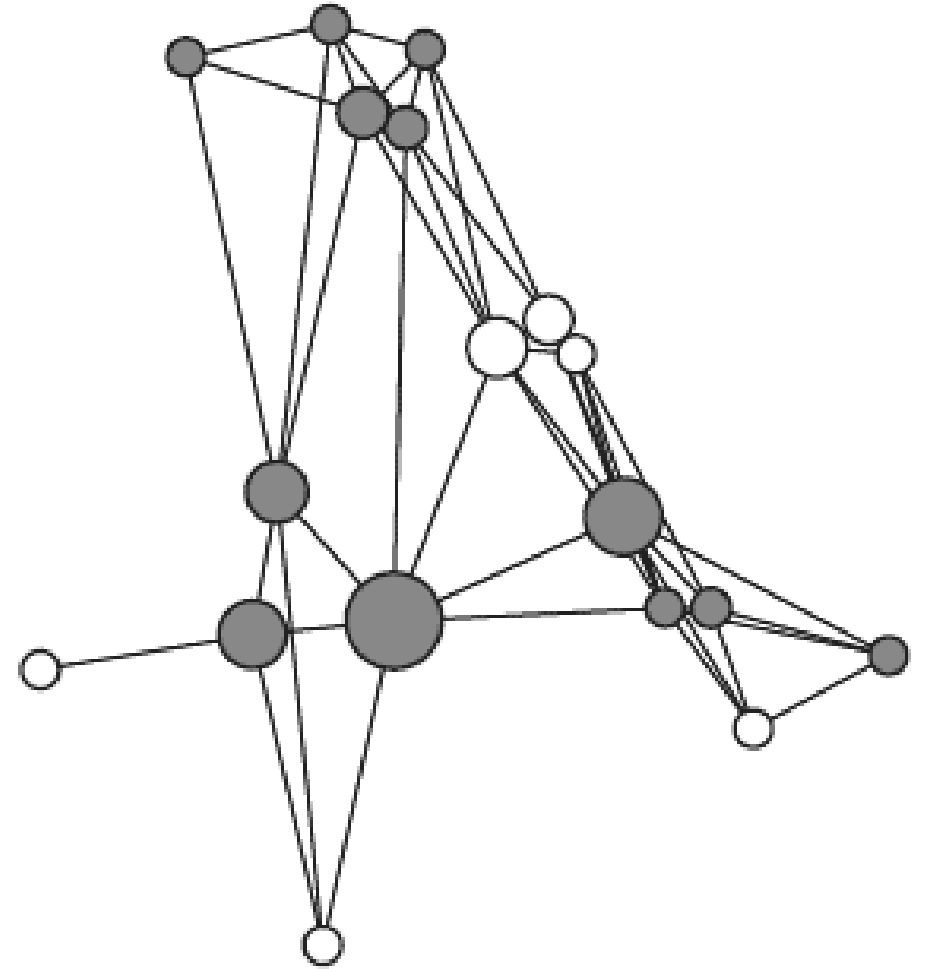
Luis J. Gilarranz<sup>1,\*</sup>, Malena Sabatino<sup>2,3</sup>, Marcelo A. Aizen<sup>2</sup> and Jordi Bascompte<sup>1</sup>



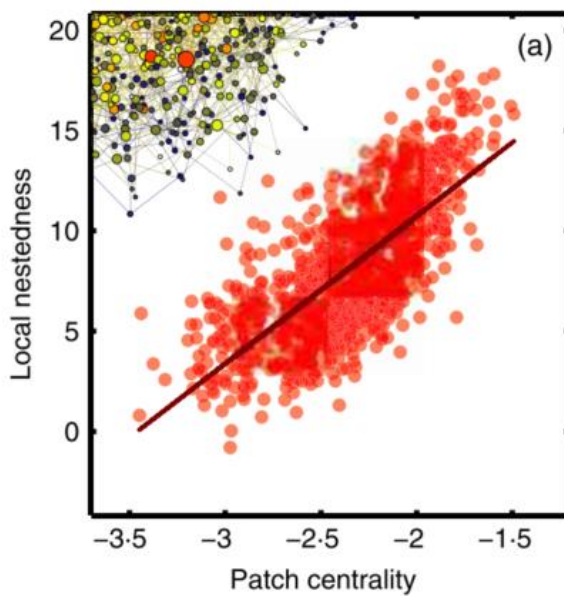
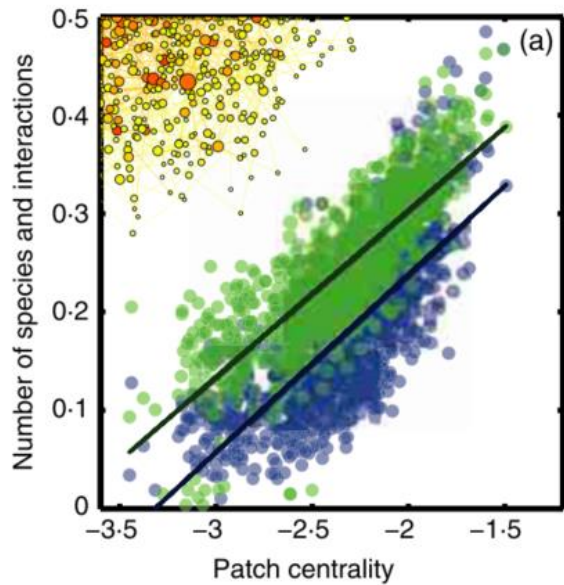


# Hot spots of mutualistic networks

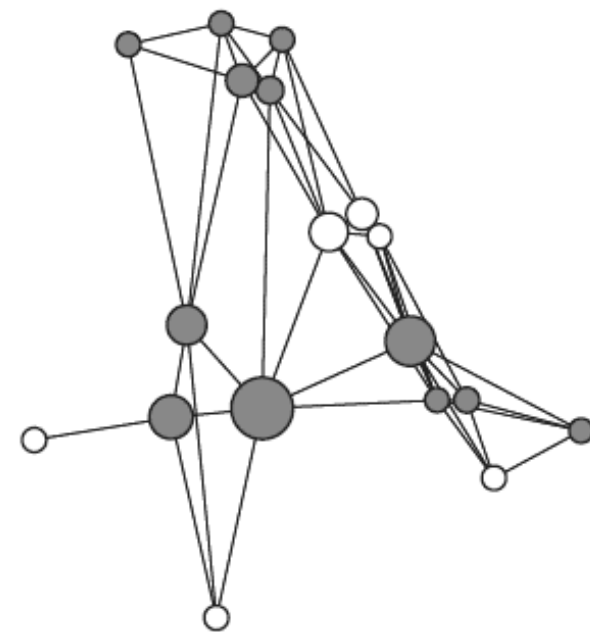
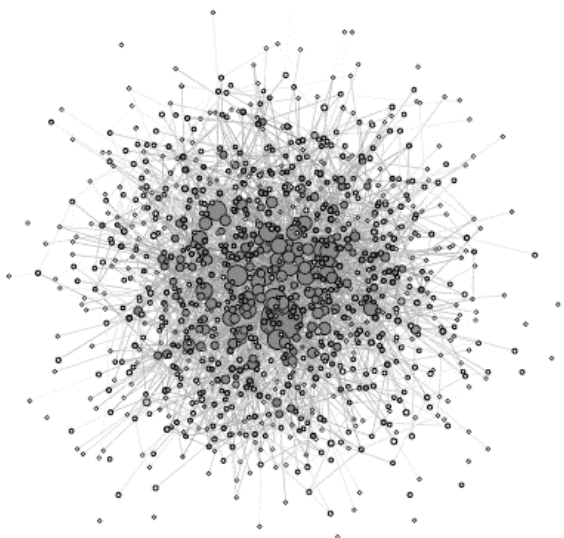
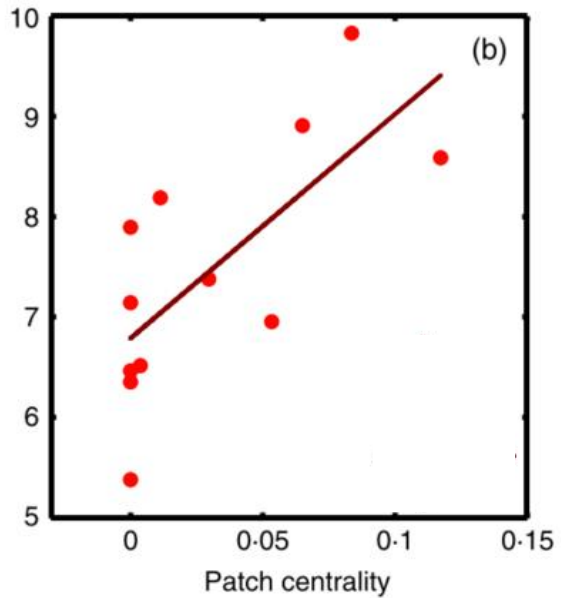
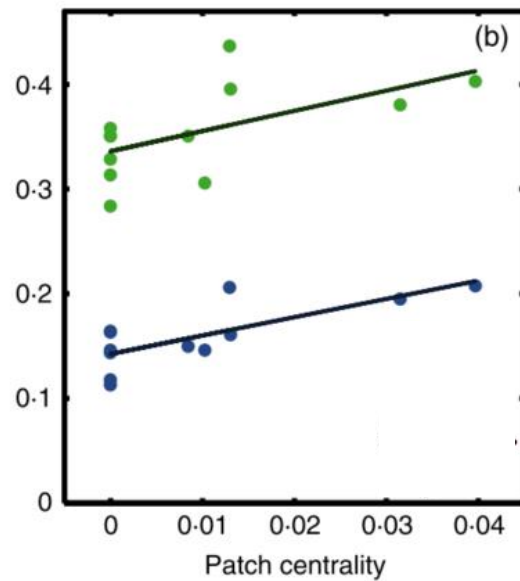
Luis J. Gilarranz<sup>1,\*</sup>, Malena Sabatino<sup>2,3</sup>, Marcelo A. Aizen<sup>2</sup> and Jordi Bascompte<sup>1</sup>



# THEORY



# FIELD DATA

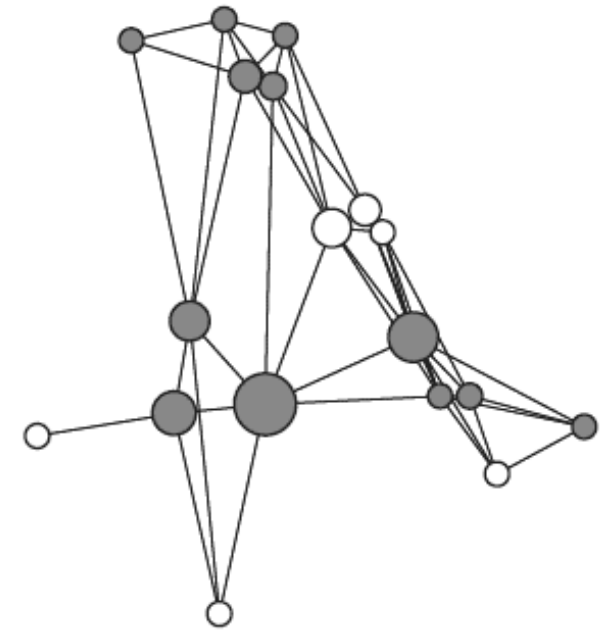


## Hot spots of mutualistic networks

Luis J. Gilarranz<sup>1,\*</sup>, Malena Sabatino<sup>2,3</sup>, Marcelo A. Aizen<sup>2</sup> and Jordi Bascompte<sup>1</sup>

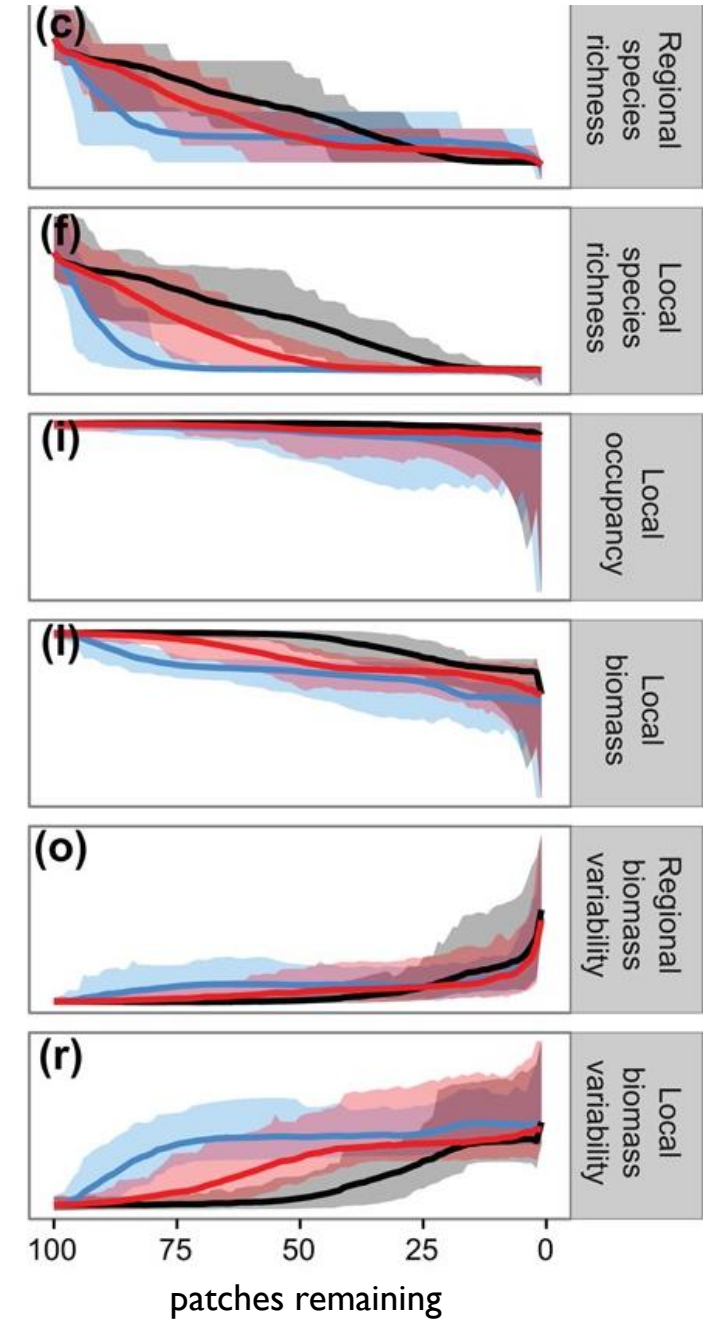
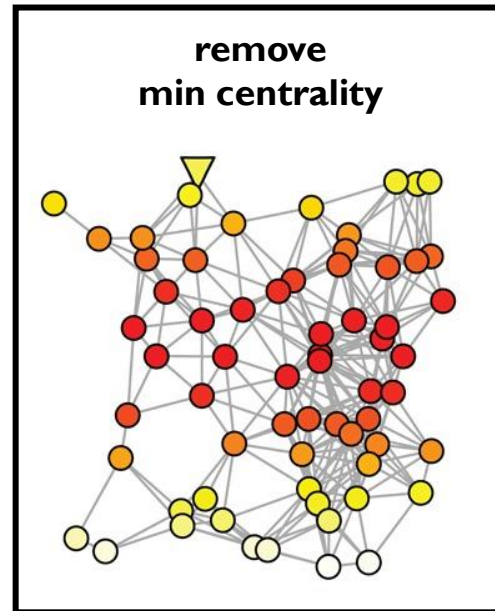
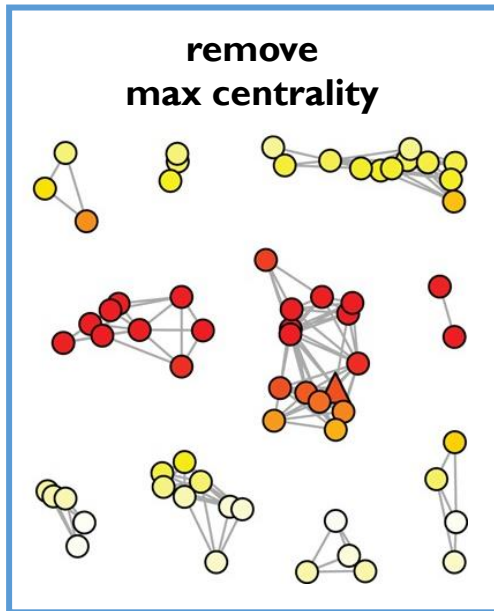
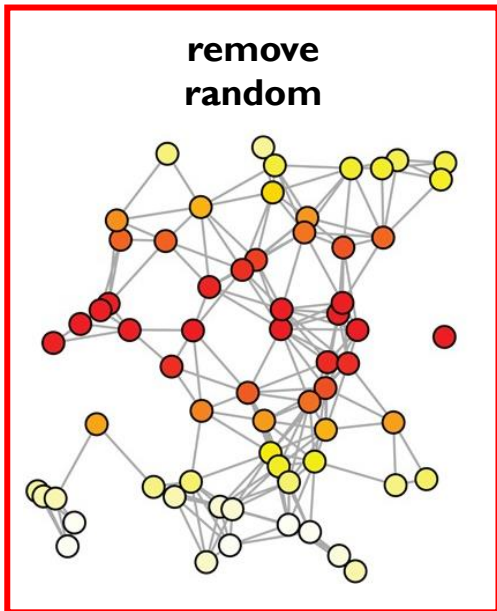
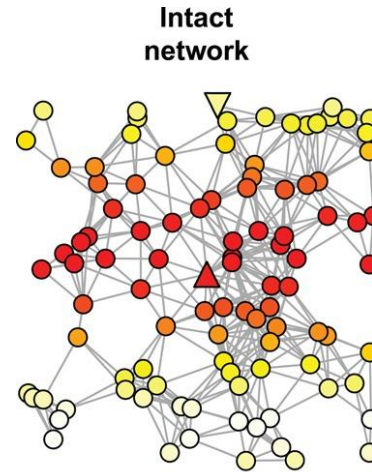
	number of species	number of interactions	nestedness
patch centrality	0.66	0.67	0.75
patch area	0.37	0.12	0.09

**centrality is a better predictor than area**

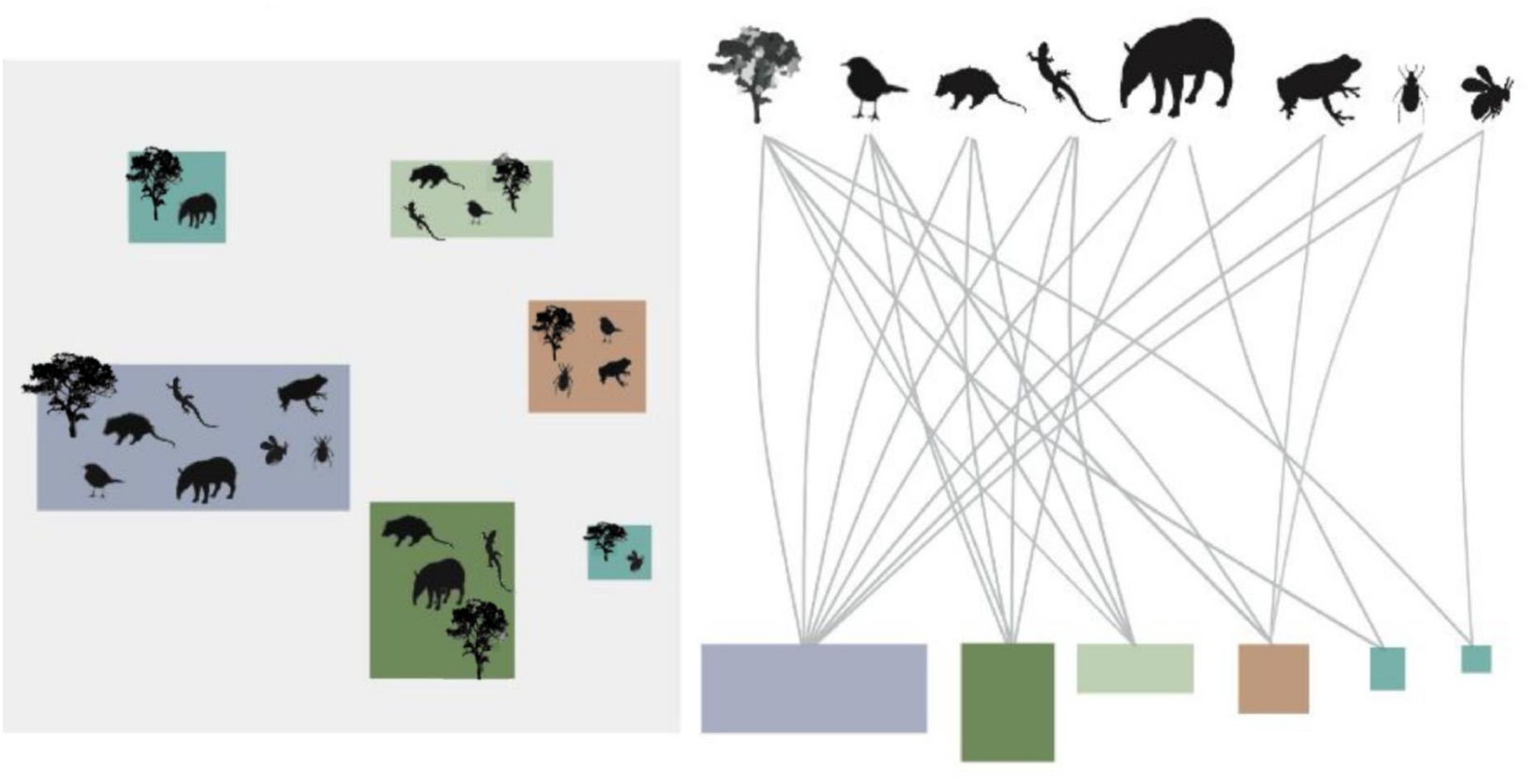


# Loss of habitat and connectivity erodes species diversity, ecosystem functioning, and stability in metacommunity networks

Patrick L. Thompson, Bronwyn Rayfield and Andrew Gonzalez

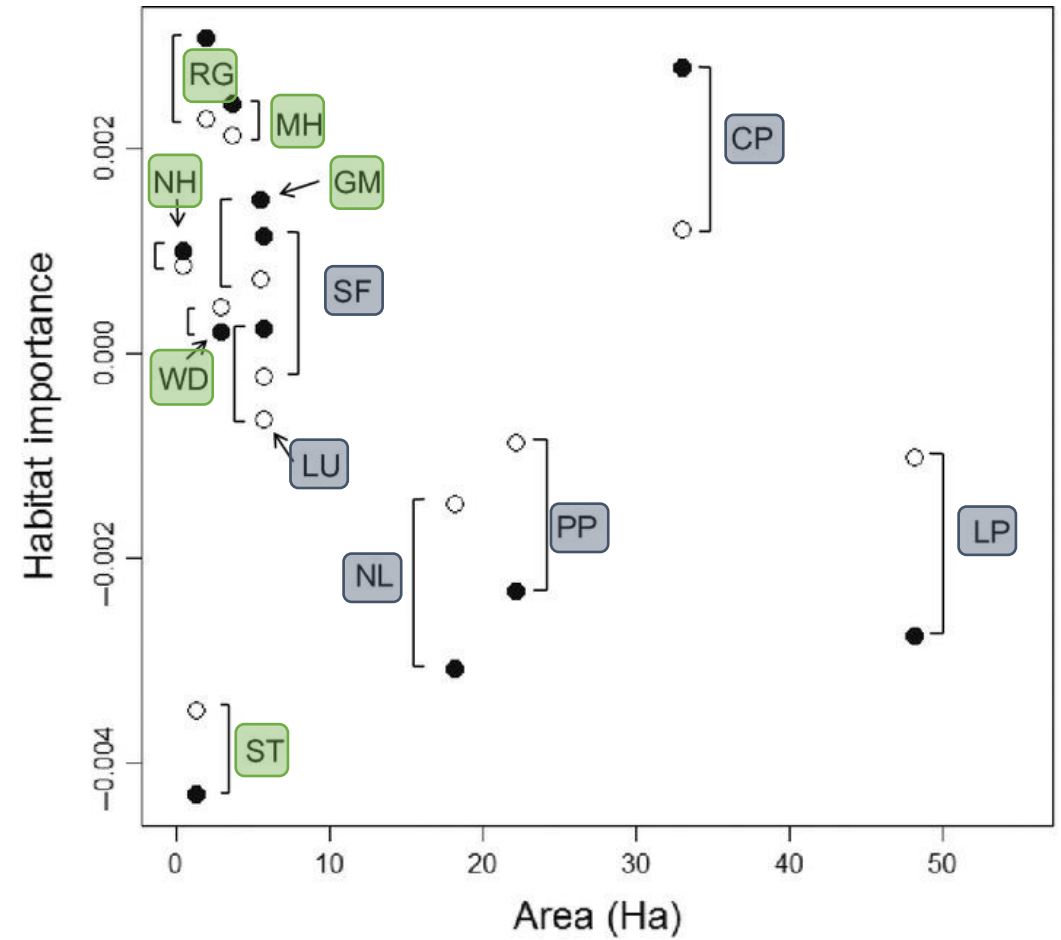
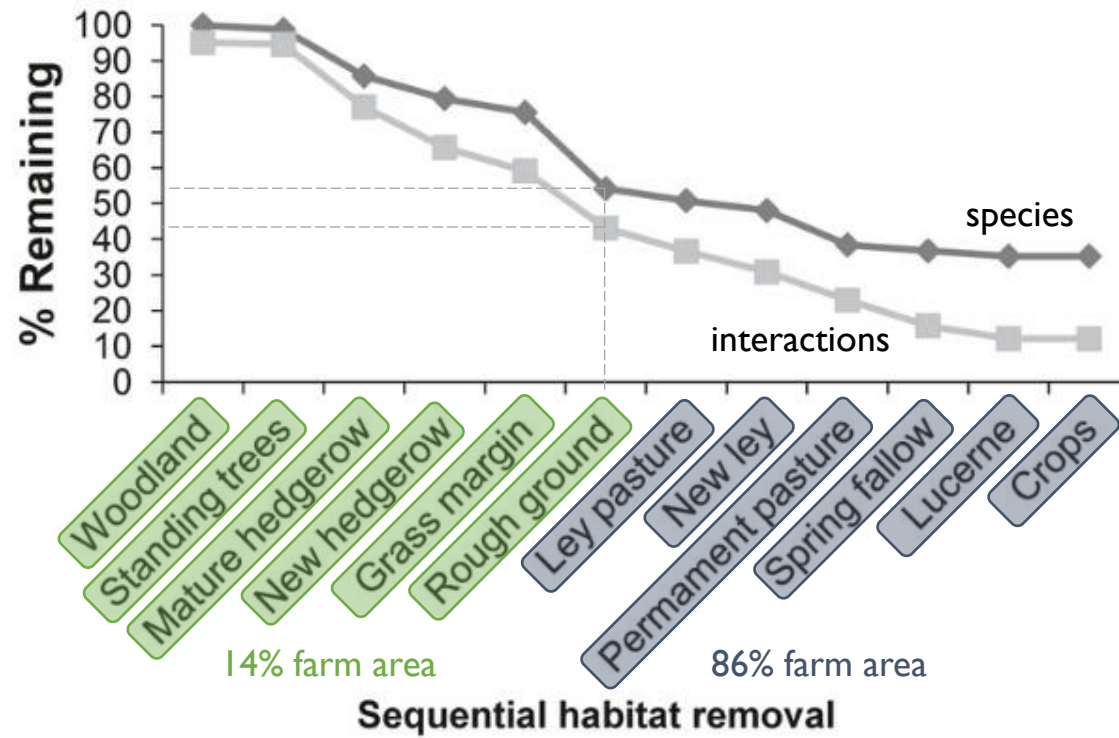


# Species-habitat networks



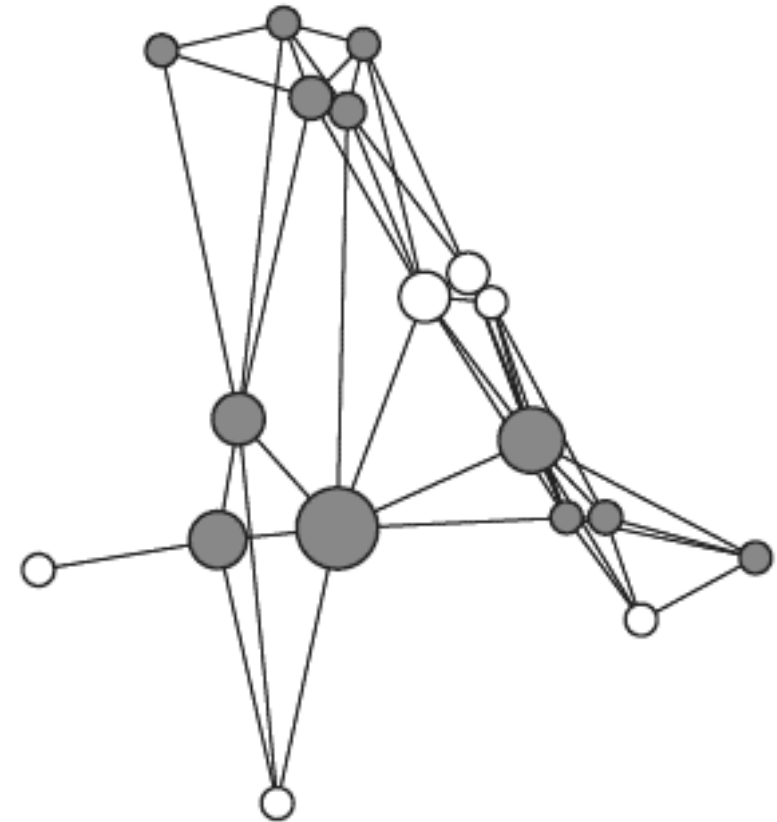
# The robustness of a network of ecological networks to habitat loss

Darren M. Evans,<sup>1,2\*</sup> Michael J. O. Pocock<sup>1,3</sup> and Jane Memmott<sup>1</sup>



# Afternoon

## Comparing Networks in Space



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BIO365 Ecological Networks

March 2023