MODELLING DISPERSAL (AND CONNECTIVITY)

Definitions, Options, Opportunities & Challenges

IALE Postgraduate Workshop, Reading 2014

WHAT IS DISPERSAL?

- First, what dispersal is not!
  - Movement (at least not all movement is dispersal)
  - Migration
  - Diffusion
  - Dispersion
  - Foraging
- Biological dispersal is:
  - the movement of individuals from their birth site to their breeding site, as well as the movement from one breeding site to another. [Wikipedia's definition is a good one!]
  - any movement that has the potential to lead to gene flow.

THE FUNDAMENTAL IMPORTANCE OF DISPERSAL

- Spatial population dynamics.
  - The ‘glue’ that sticks together a metapopulation.
  - Dispersal determines the nature of spatial dynamics, influences risk of extinction, influences the position of a range margin, creates source-sink dynamics, etc…
- Coexistence, patterns of diversity.
  - Differences in dispersal between species can promote coexistence.
  - Dispersal influences the richness and diversity of species found at local and regional scales.
- Gene flow and evolutionary processes.
  - Determines rate of spread of alleles across space
  - Impacts rate of adaptation, the accumulation of mutation and migration load, etc.

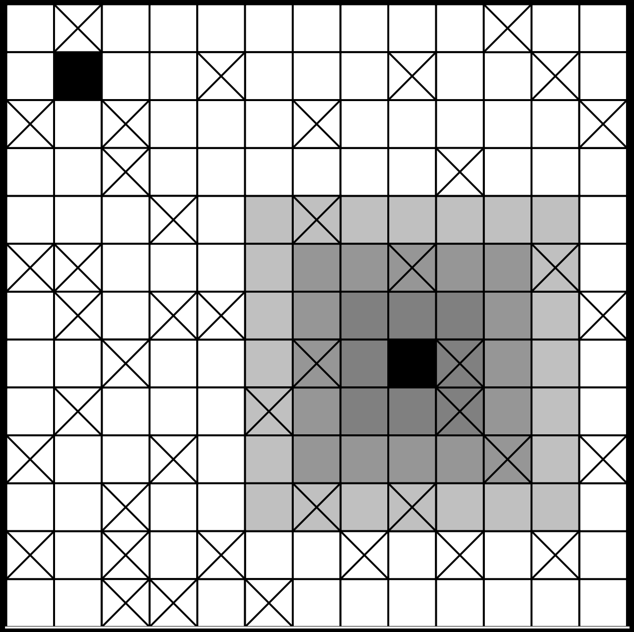
THE APPLIED IMPORTANCE OF DISPERSAL

- Habitat fragmentation
  - Determines probability a population will survive in a fragmented landscape
  - Optimal landscape / conservation management will depend on dispersal
- Invasive species
  - Determines the rate at which an invasive species will spread.
  - Optimal control strategies will be influences by dispersal.
- Climate change
  - Determines the rate of range advance (and retreat?) of species shifting their ranges in response to climate change.
  - Decisions related to landscape management / translocations will depend on dispersal.

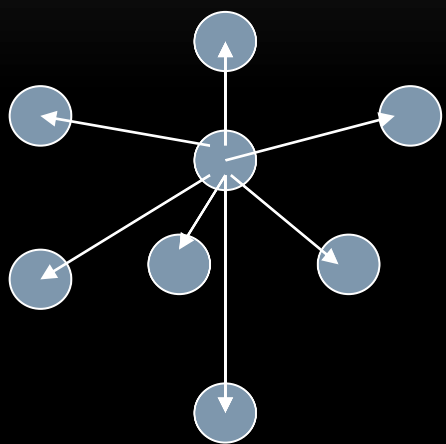
HOW IS DISPERSAL TYPICALLY MODELLED?

- Simplest:
  - As a rate (or probability) of leaving your natal patch and moving, with equal likelihood, to any patch on the landscape. This is often termed global dispersal. It results in a spatial model but the model is *spatially implicit*.
  - As a rate (or probability) of leaving your natal patch and moving, with equal likelihood, to one of the 4 or 8 neighbouring patches. This assumes the landscape is represented as a square grid and is a form of local dispersal. Now the model is *spatially explicit*.
  - All individuals are assumed to have the same dispersal characteristics.

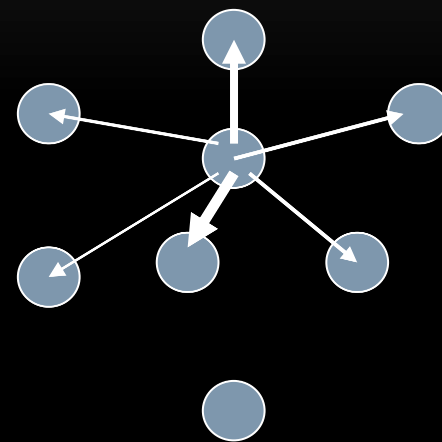
DISPERSAL ON A GRIDDED LANDSCAPE



Spatially implicit



Spatially explicit

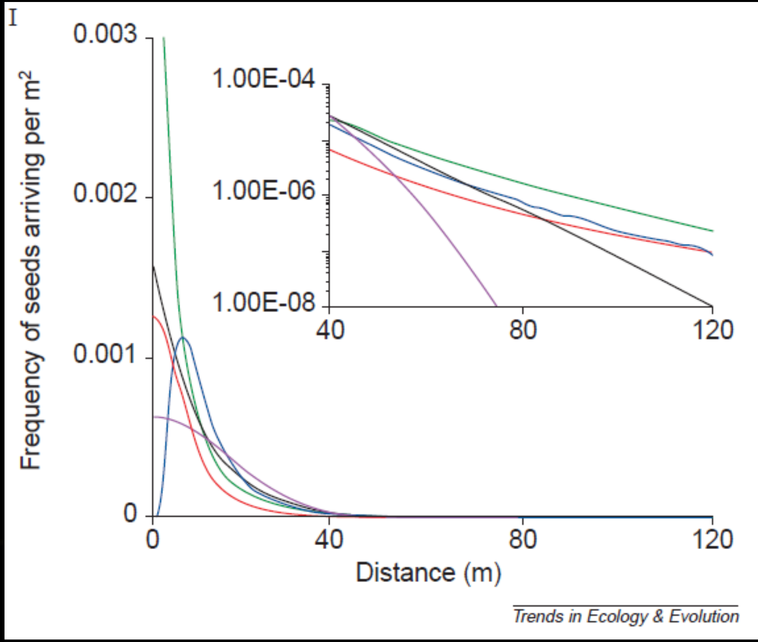


- Population subdivision accounted for.
- but spatial location is not.

- Spatial location matters
- often influences dispersal propensities

MODELLING DISPERSAL DISTANCE

- Phenomenologically
  - Use a statistical distribution to represent the likelihood individuals disperse different distances. This is often termed a dispersal kernel. An organism's dispersal kernel is often described using statistical distributions including negative exponential and inverse power distributions.



Five distributions each with mean dispersal distance = 20m.

From Nathan & Muller-Landau 2000.

HOW IS A DISPERSAL KERNEL APPROACH USED IN POPULATION MODELLING?

- The Metapopulation approach
  - The rates / probabilities of an individual dispersing to potential destination patches are calculated using the distances between natal and destination patches scaled by the dispersal kernel.
- The Individual Based Modelling (IBM) approach
  - Choose the destination of an individual by drawing a distance *z* m at random from the kernel and sampling a random direction, *d*. Then displace the individual *z* m away from its natal location in direction *d*. If the individual lands in unsuitable habitat it may (i) die, (ii) first check if there is suitable habitat nearby and, if so, relocate or (iii) resample direction and distance and displace again from natal site.

Note that the two are equivalent if option (iii) of the IBM is used with unlimited resampling.

ADDRESSING LIMITATIONS 1: ADDING THE MATRIX.

- The dispersal kernel based approach ignores everything between the patches. (Landscape that is not habitat is termed *matrix* by landscape ecologists).
- In reality organisms will disperse differently across matrix of different characteristics.
  - i.e. some matrix types may facilitate movement between habitat patches while some will inhibit it.
  - There is broad recognition that incorporating this detail is vital.
- Least Cost Path (LCP) algorithms have been used as a means to attempt to include this detail.
  - For this approach each type of matrix has a cost (or preference) assigned to it.
  - The LCP algorithm calculates the single least costly route between any two points.
  - Least cost distances between habitat patches can replace Euclidean (i.e. straight line) distances in subsequent population modelling.

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available at www.sciencedirect.com

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journal homepage: www.elsevier.com/locate/ecolmodel

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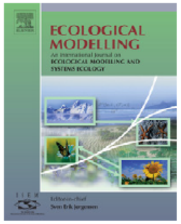
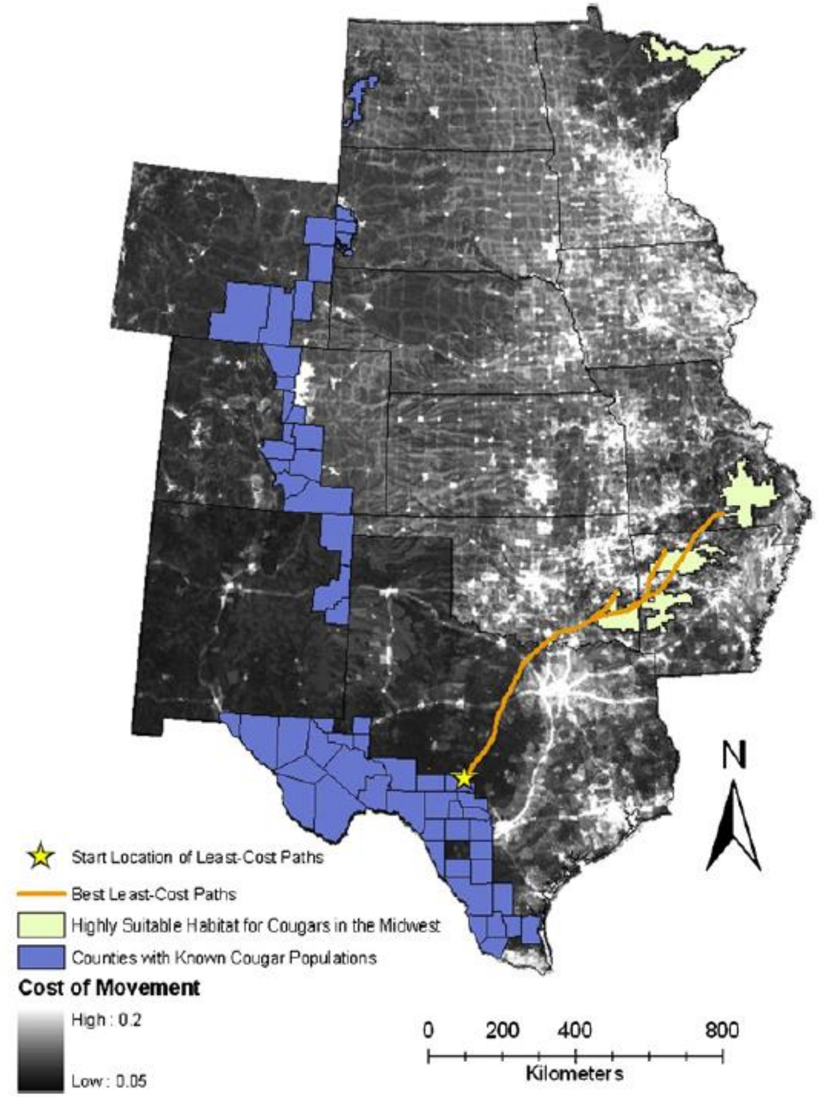


Modelling potential dispersal corridors for cougars midwestern North America using least-cost path m

*Michelle A. LaRue, Clayton K. Nielsen**

Cooperative Wildlife Research Laboratory, Southern Illinois University Carbondale, Carbondale, IL, USA



Ecological Modelling 221 (2010) 944–952

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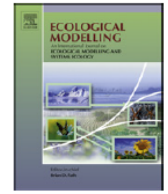
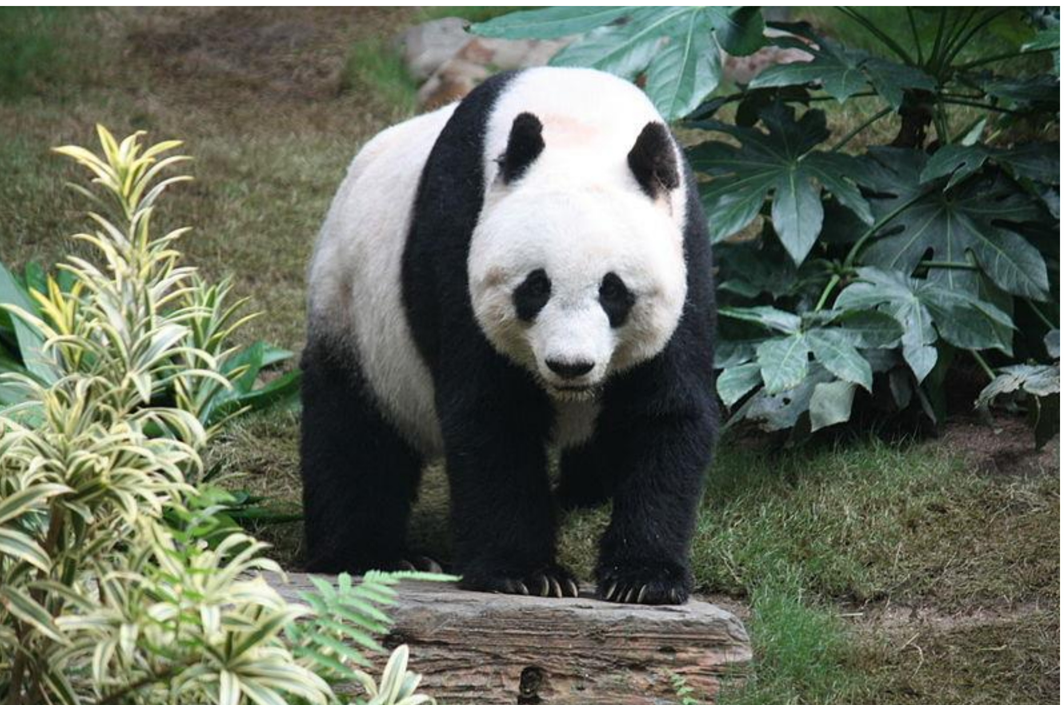
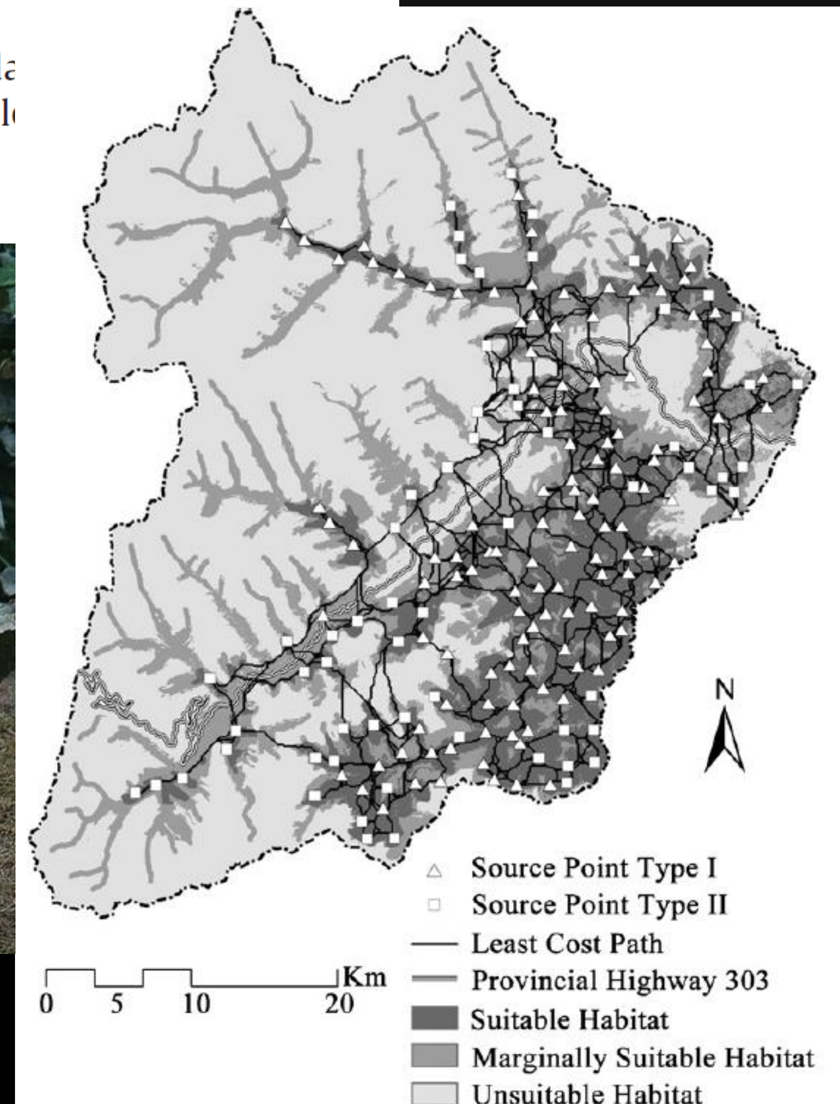


ELSEVIER

Application of least-cost path model to identify a giant pand
network after the Wenchuan earthquake—Case study of Wol
in China

Hailong Li[a], Dihua Li[a,*], Ting Li[a], Qing Qiao[a], Jian Yang[b], Hemin Zhang[b]





IS LCP A GOOD MODEL FOR DISPERSAL?

- Positives
  - It recognises that dispersal is not blind
  - It includes the matrix through different costs/preferences
  - It is simple and straightforward to implement
- Negatives
  - Implicitly assumes an organism knows everything about the landscape
  - Also assumes an individual knows where it wants to get to when it departs
  - It is straightforward to implement (Discuss!)

ALTERNATIVE MODELS TO LCP

- Least cost corridors
- Stochastic models of individual movement (e.g. Stochastic Movement Simulator, Mechanistic models of seed dispersal by wind).
- You will hear more about SMS later….

ARE LCP, SMS *ETC.* FULL DISPERSAL MODELS?

- Think about the process of dispersal?
  - Recall the earlier models where emigration rate/probability was being modelled.
  - Imagine a group of juvenile sparrows, hedgehogs, toads currently in their natal patches. What processes need to be modelled in order to establish where these individuals attempt to breed?

- So, what should a full dispersal model include?

BIOLOGICAL REVIEWS

Cambridge Philosophical Society

Biol. Rev. (2011), pp. 000–000.
doi: 10.1111/j.1469-185X.2011.00201.x

Costs of dispersal

Dries Bonte[1,*], Hans Van Dyck[2], James M. Bullock[3], Aurélie Coulon[4], Maria Delgado[5] Melanie Gibbs[3], Valerie Lehouck[1], Erik Matthysen[6], Karin Mustin[7], Marjo Saastamoinen[5], Nicolas Schtickzelle[2], Virginie M. Stevens[8], Sofie Vandewoestijne[2], Michel Baguette[9], Kamil Barton[10], Tim G. Benton[11], Audrey Chaput-Bardy[4], Jean Clobert[12], Calvin Dytham[13], Thomas Hovestadt[10], Christoph M. Meier[14], Steve C. F. Palmer[7], Camille Turlure[2] and Justin M. J. Travis[7]

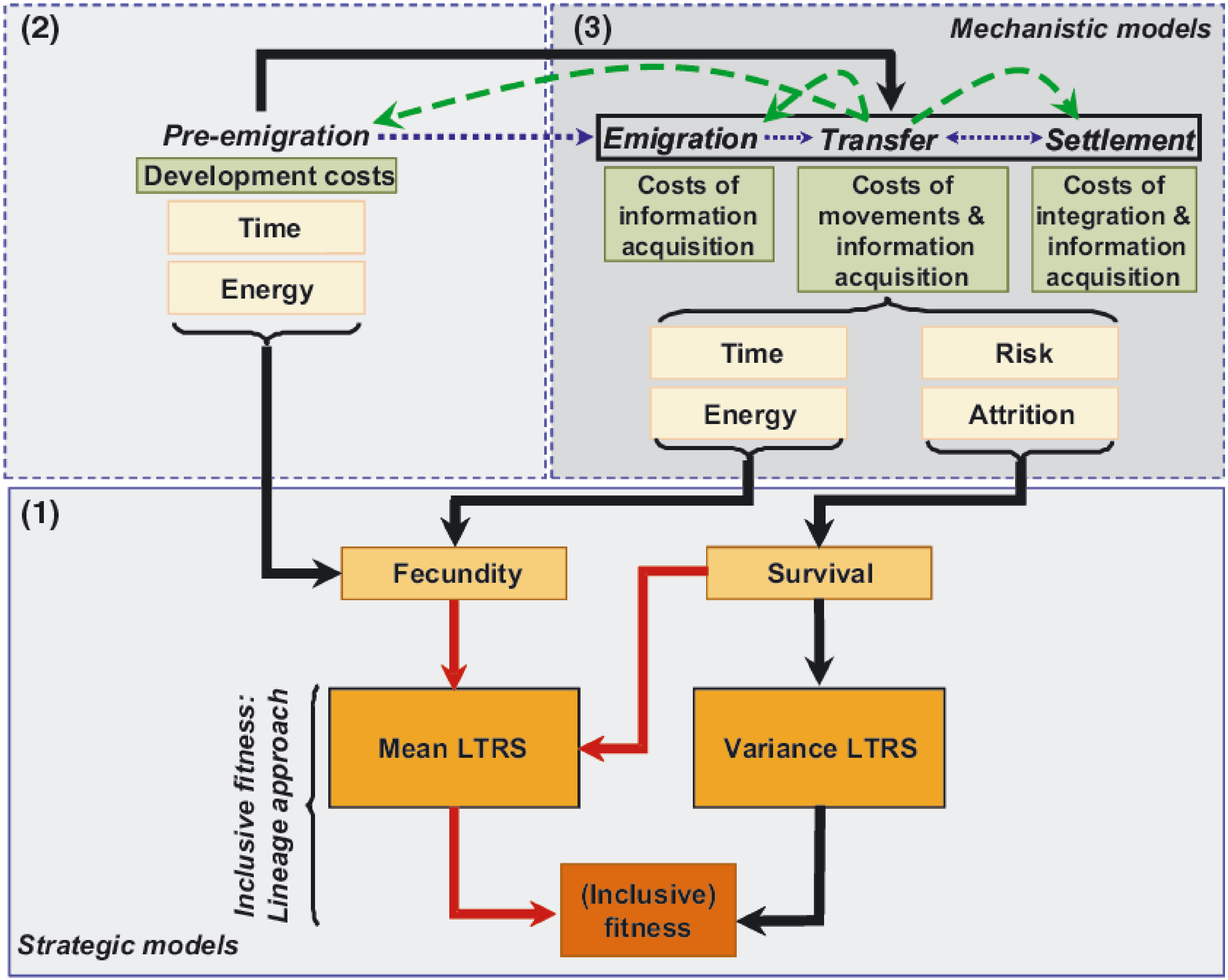
Methods in Ecology and Evolution

British Ecological Society

Methods in Ecology and Evolution 2012, **3**, 628–641 doi: 10.1111/j.2041-210X.2012.00193.x

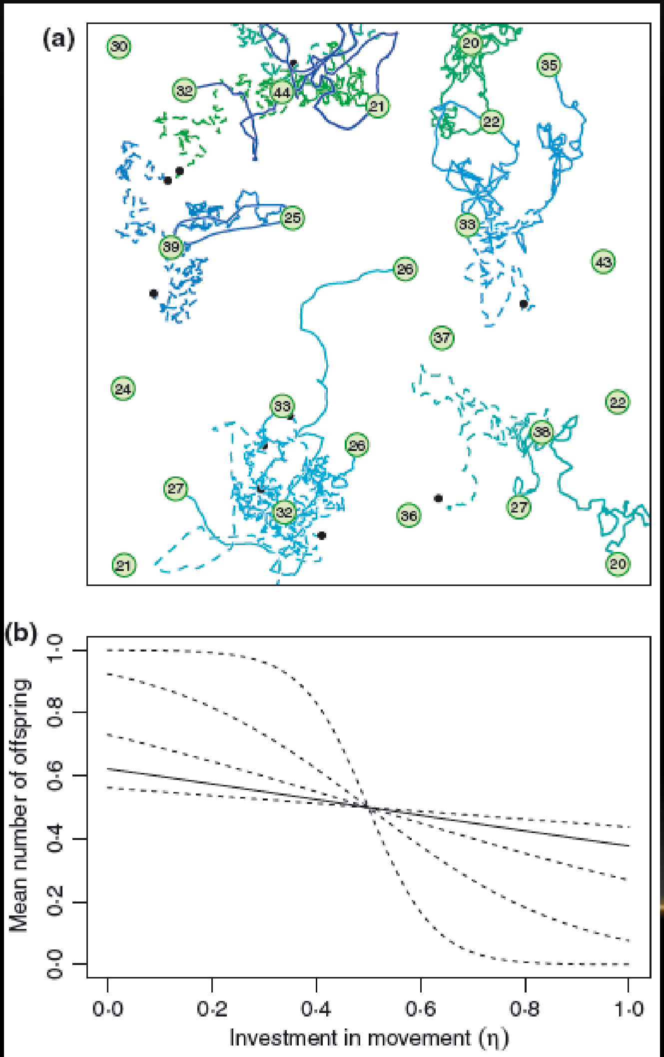
Modelling dispersal: an eco-evolutionary framework incorporating emigration, movement, settlement behaviour and the multiple costs involved

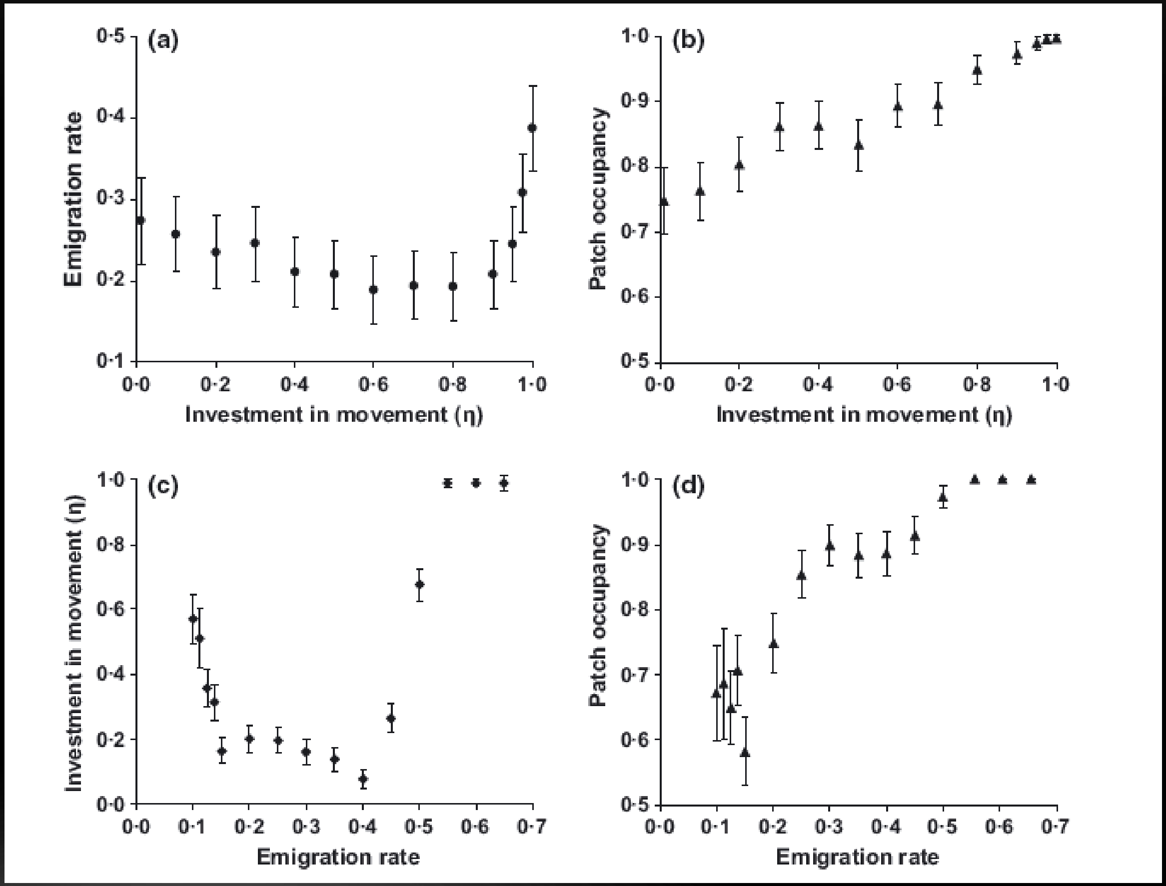
Justin M. J. Travis[1*], Karen Mustin[1], Kamil A. Bartoń[2], Tim G. Benton[3], Jean Clobert[4], Maria M. Delgado[5,6], Calvin Dytham[7], Thomas Hovestadt[2,8], Stephen C. F. Palmer[1], Hans Van Dyck[9] and Dries Bonte[10]



(2)
(3)
Mechanistic models
Pre-emigration
Development costs
Time
Energy
Emigration
Transfer
Settlement
Costs of information acquisition
Costs of movements & information acquisition
Costs of integration & information acquisition
Time
Energy
Risk
Attrition
(1)
Fecundity
Survival
Mean LTRS
Variance LTRS
Inclusive fitness: Lineage approach
(Inclusive) fitness
Strategic models

AN EXAMPLE MODEL:





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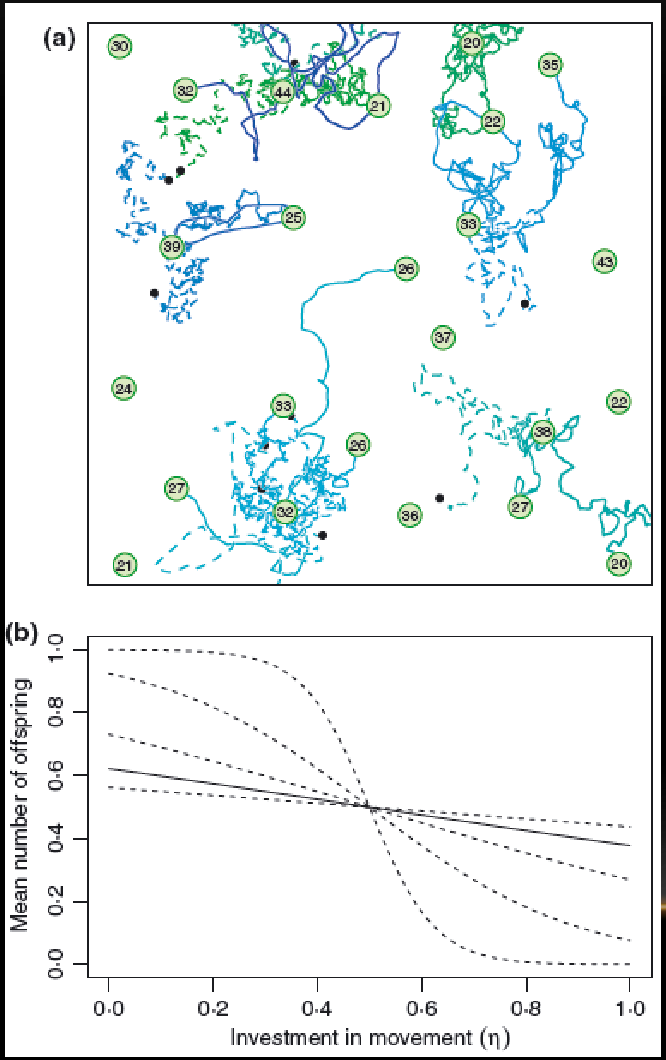
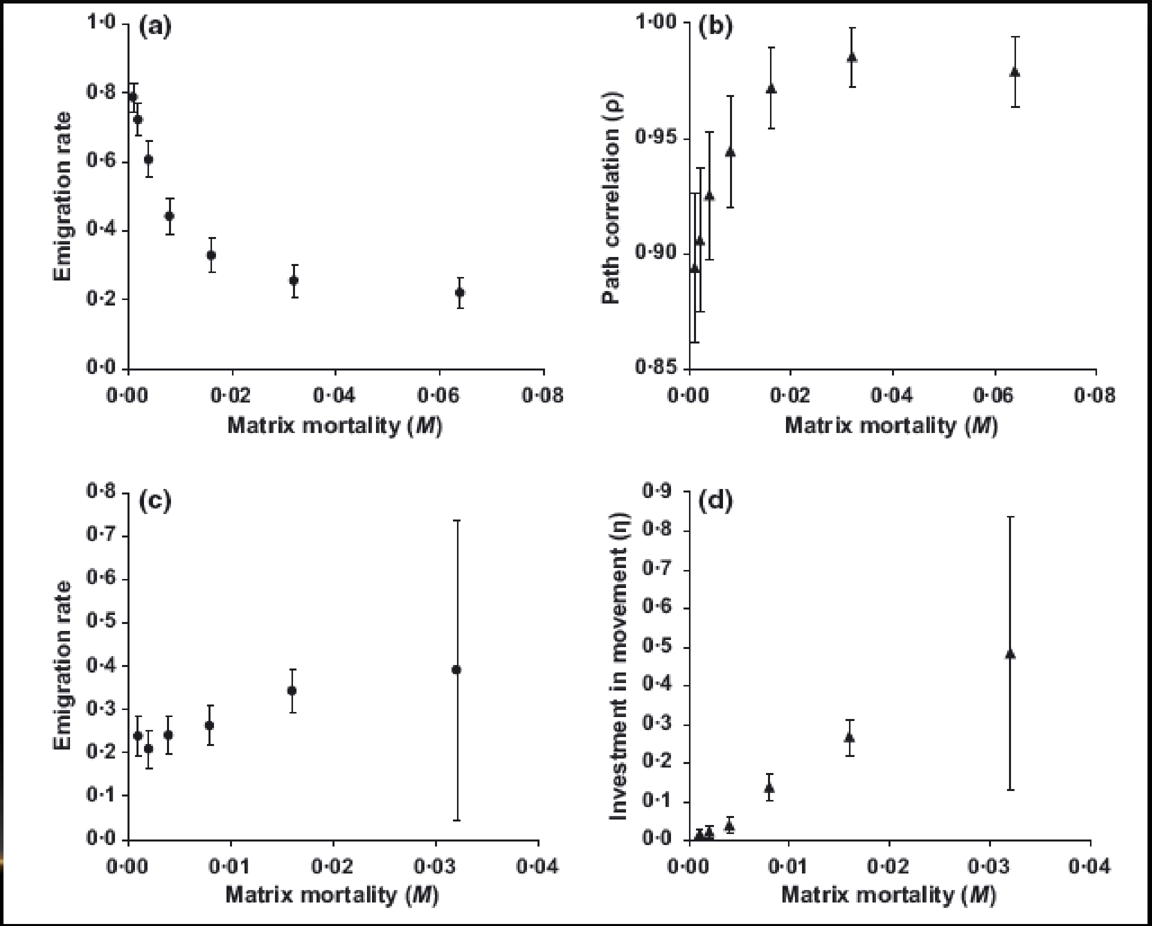




RANGESHIFTER AND DISPERSAL

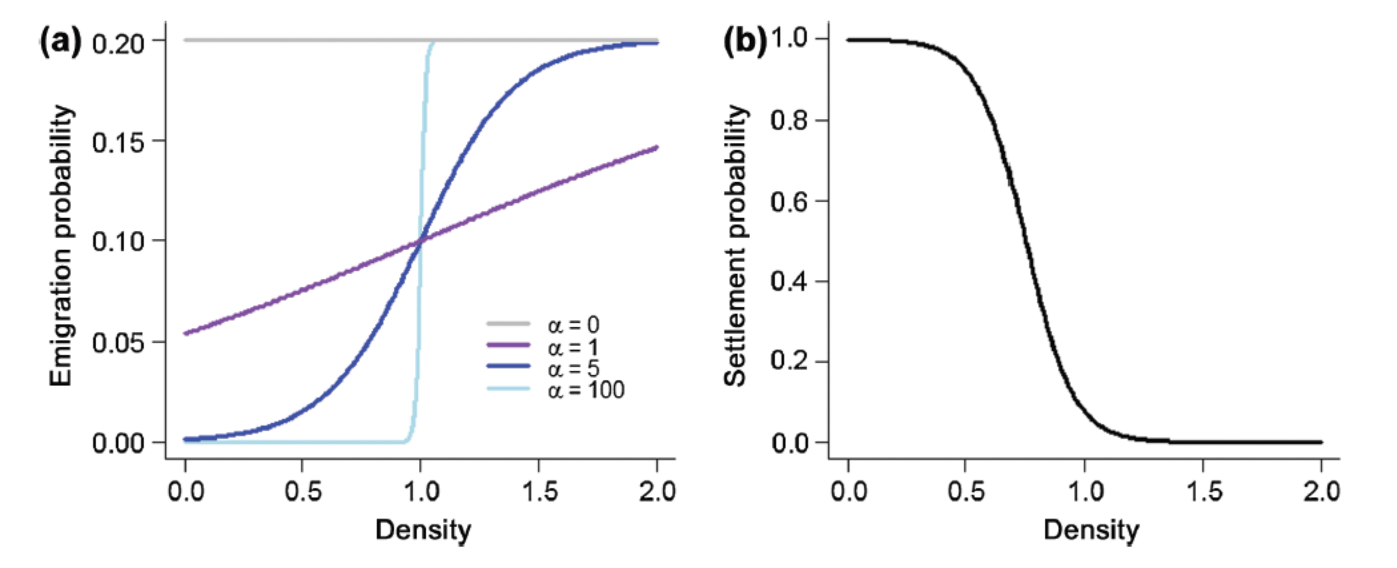
- RangeShifter includes the three phases of dispersal
- Two sexes can be modelled with different dispersal rules.
- Different stages (e.g. juveniles and adults) can be modelled with different dispersal rules.
- Context dependency can be included
  - Emigration can be density dependent
  - Settlement can be density / sex / mate dependent
- Movement phases can be modelled using SMS or correlated random walk
- Dispersal morality can be an emergent property of the movement of individuals through complex landscapes with different risks in different matrix types.
- **Provides opportunity for much greater realism in modelling dispersal across realistic landscapes.**

Ecography 37: 001–014, 2014
doi: 10.1111/ecog.01041

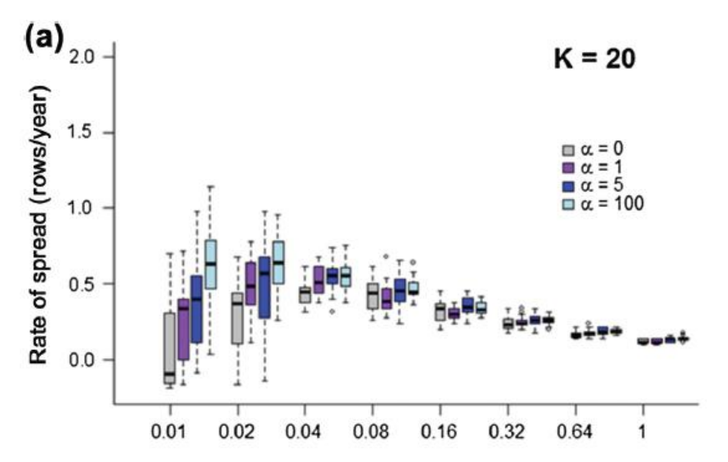
Subject Editor: Heike Lische. Accepted 20 May 2014

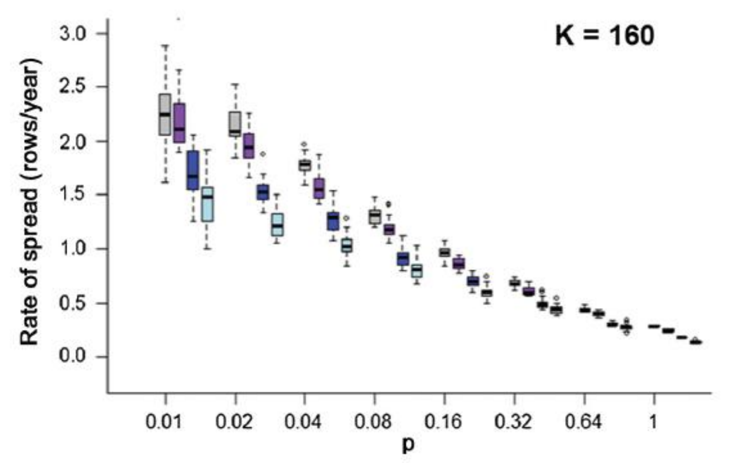
Mechanistic modelling of animal dispersal offers new insights into range expansion dynamics across fragmented landscapes

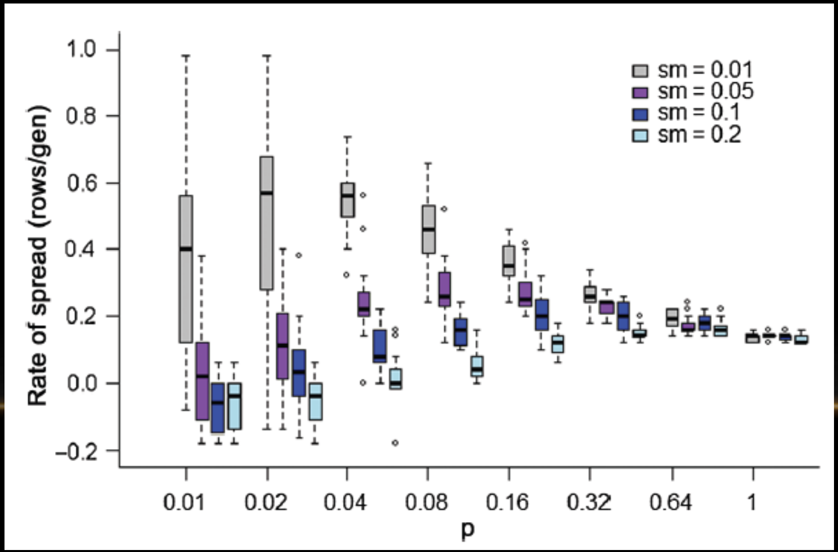
Greta Bocedi, Damaris Zurell, Björn Reineking and Justin M. J. Travis



HOW DOES SPREAD RATE DEPEND ON HABITAT AVAILABILITY?







WHAT IS ECOLOGICAL CONNECTIVITY?

HOW DOES ECOLOGICAL CONNECTIVITY RELATE TO LANDSCAPE CONNECTIVITY?

HOW DOES ECOLOGICAL CONNECTIVITY RELATE TO DISPERSAL?