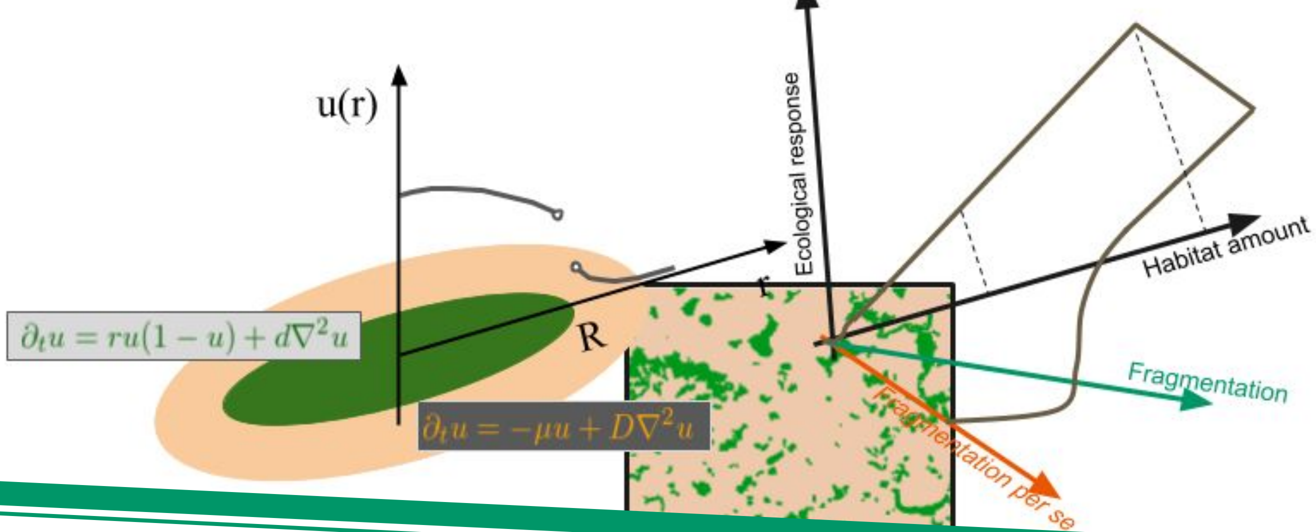

Population dynamics in highly fragmented landscapes

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Outline

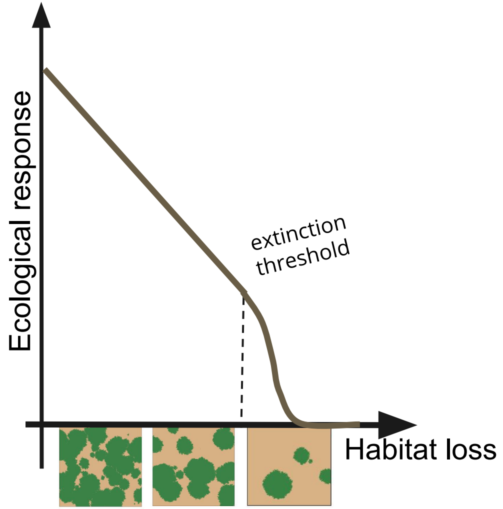
- Introduction to *fragmentation per se*
- Mathematical modelling
- Single large or several small?
- Habitat *core area* vs *total area*
- Statistical modelling
- Analysis of direction of effects
- Effects of fragmentation and *fragmentation per se*
- Final considerations

Introduction

- **Habitat loss** is detrimental to the ecological value of landscapes
  - decrease species abundance
  - decrease biodiversity

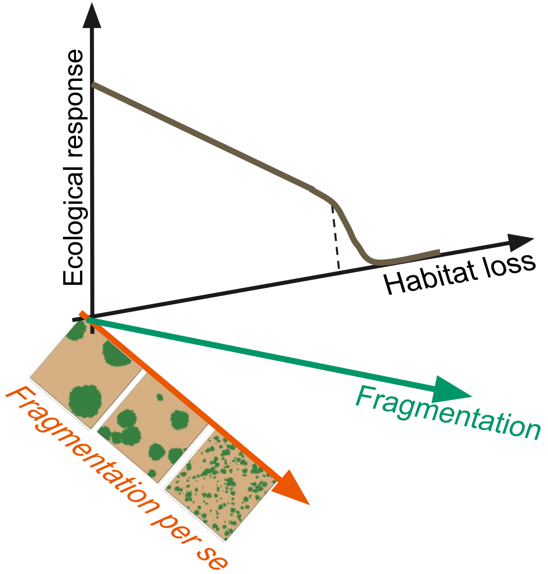
- **Habitat fragmentation** is a general concept for spatial habitat distribution across landscape.

- **More fragmented landscapes** may include:
  - decrease of habitat amount
  - increase of number of patches
  - decrease of patch size
  - increase of patch isolation



Introduction

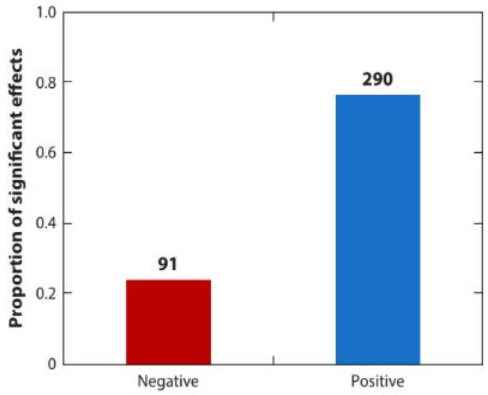
- Habitat fragmentation with a fixed habitat amount (HA) is referred to as ***fragmentation per se***.
- We need to quantify fragmentation via **fragmentation metrics**.
- The **ecological effects** of *fragmentation per se* on landscapes is still a very debated topic.

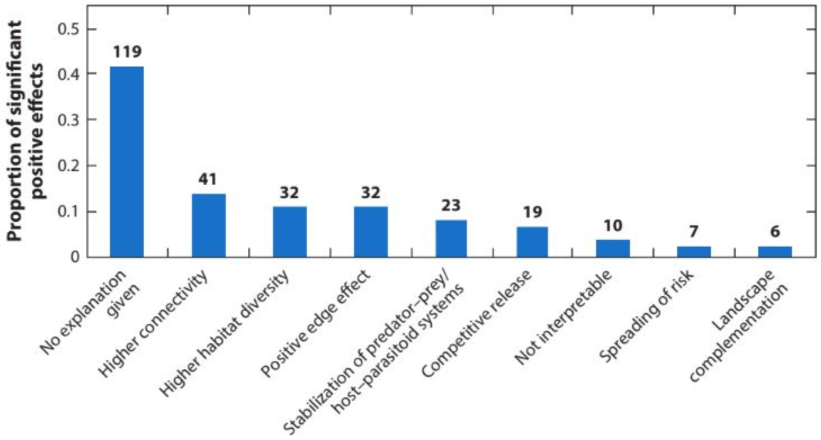


Ecological Responses to Habitat Fragmentation Per Se

Lenore Fahrig

Ecological effects of *fragmentation per se*





Is habitat fragmentation good for biodiversity?

Robert J. Fletcher Jr[a,*], Raphael K. Didham[b,c], Cristina Banks-Leite[d], Jos Barlow[e], Robert M. Ewers[d], James Rosindell[d], Robert D. Holt[f], Andrew Gonzalez[g], Renata Pardini[h], Ellen I. Damschen[i], Felipe P.L. Melo[j], Leslie Ries[k], Jayme A. Prevedello[l], Teja Tscharntke[m], William F. Laurance[n], Thomas Lovejoy[o], Nick M. Haddad[p]

Is habitat fragmentation bad for biodiversity?

Lenore Fahrig, Víctor Arroyo-Rodríguez, Joseph R. Bennett, Véronique Boucher-Lalonde, Eliana Cazetta, David J. Currie, Felix Eigenbrod, Adam T. Ford, Susan P. Harrison, Jochen A.G. Jaeger, Nicola Koper, Amanda E. Martin, Jean-Louis Martin, Jean Paul Metzger, Peter Morrison, Jonathan R. Rhodes, Denis A. Saunders, Dan Simberloff, Adam C. Smith, Lutz Tischendorf, Mark Vellend, James I. Watling

Challenges of empirical studies with ***natural landscapes***:
low variability in fragmentation patterns within regions and *high correlation with HA*

Editorial

How does habitat fragmentation affect biodiversity? A controversial question at the core of conservation biology

Mathematical modelling

- Reaction-diffusion equations

$$\partial_t u = f(u) + \nabla^2 u$$

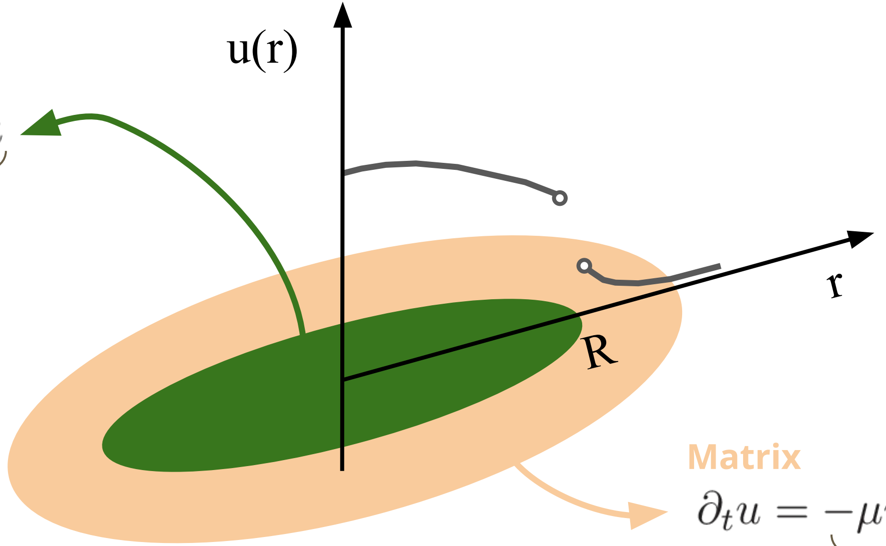
- Local reaction $f(u)$
  - Exponential growth
  - Logistic growth
  - Death rate

- Population diffusion
  - Equivalent to a random-walk in an individual level

Mathematical modelling

Habitat

$$\partial_t u = \underbrace{ru(1-u)}_{\text{logistic growth}} + \underbrace{D_P \nabla^2 u}_{\text{diffusion}}$$



Matrix

$$\partial_t u = \underbrace{-\mu u}_{\text{death}} + \underbrace{D_M \nabla^2 u}_{\text{diffusion}}$$

Mathematical modelling

$$L_P = \sqrt{\frac{D_P}{r}} \qquad L_M = \sqrt{\frac{D_M}{\mu}}$$

$$\kappa = \frac{L_P}{L_M}$$

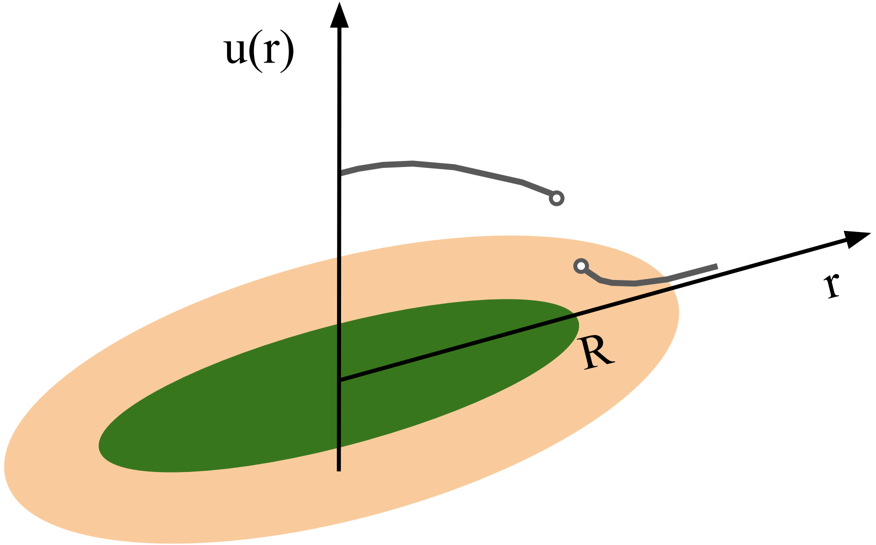
Soft matrix
Inter-patch movement

Hostile matrix
Intra-patch movement

κ

0.01 0.1 1 10 100

The only free parameter in the model for the **stationary solution**.



BIASED MOVEMENT AT A BOUNDARY AND CONDITIONAL OCCUPANCY TIMES FOR DIFFUSION PROCESSES

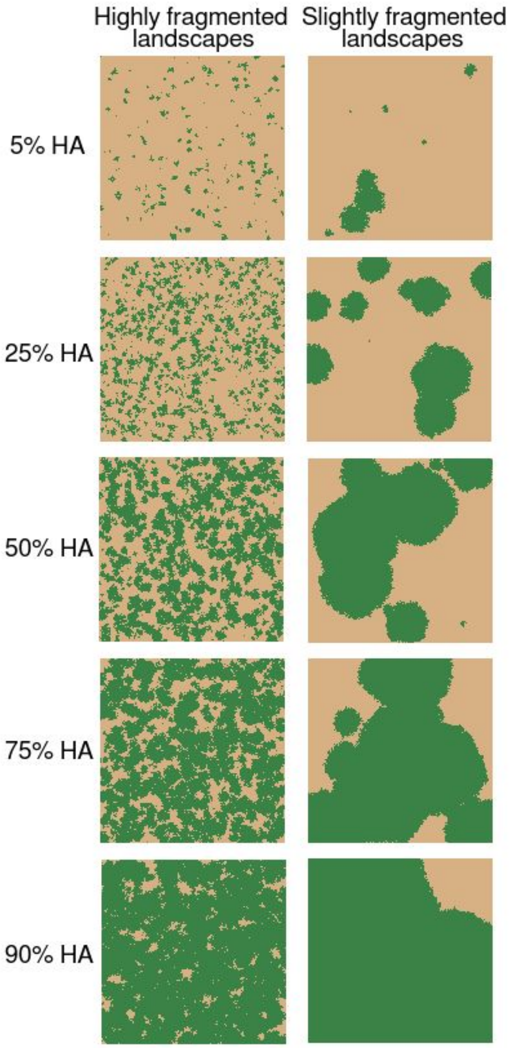
OTSO OVASKAINEN,* *University of Helsinki*
STEPHEN J. CORNELL,** *University of Cambridge*

How Individual Movement Response to Habitat Edges Affects Population Persistence and Spatial Spread

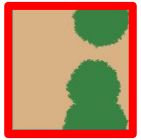
Gabriel Andreguetto Maciel[1] and Frithjof Lutscher[2,*]

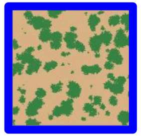
Mathematical modelling

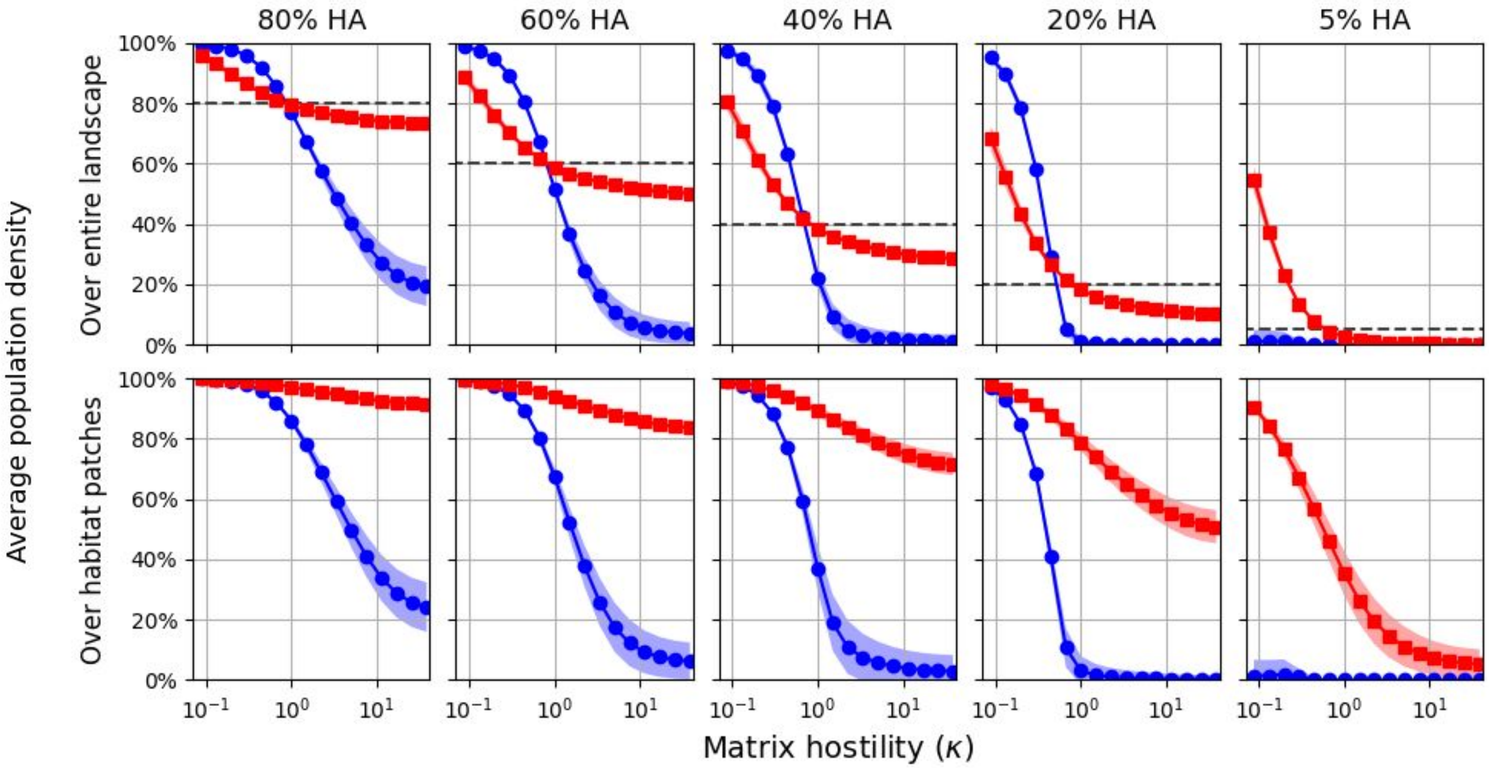
- Generating binary **artificial landscapes**
  - method adapted from *Tischendorf and Fahrig (2000)*
  - controlled total habitat amount (HA):
    5% to 90%
  - controlled degree of fragmentation



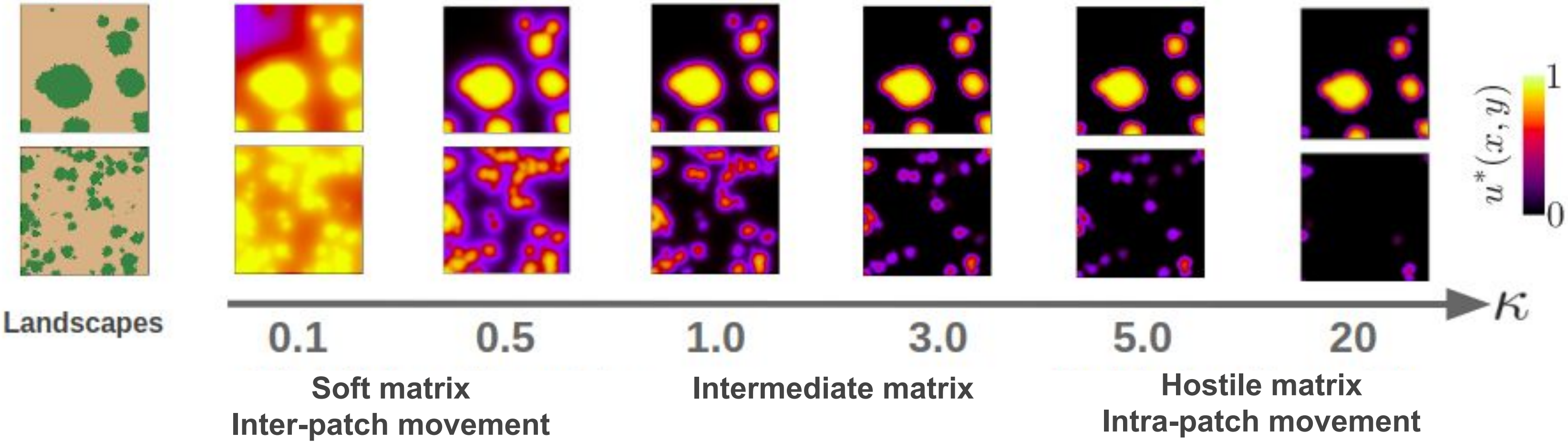
Single large or several small?





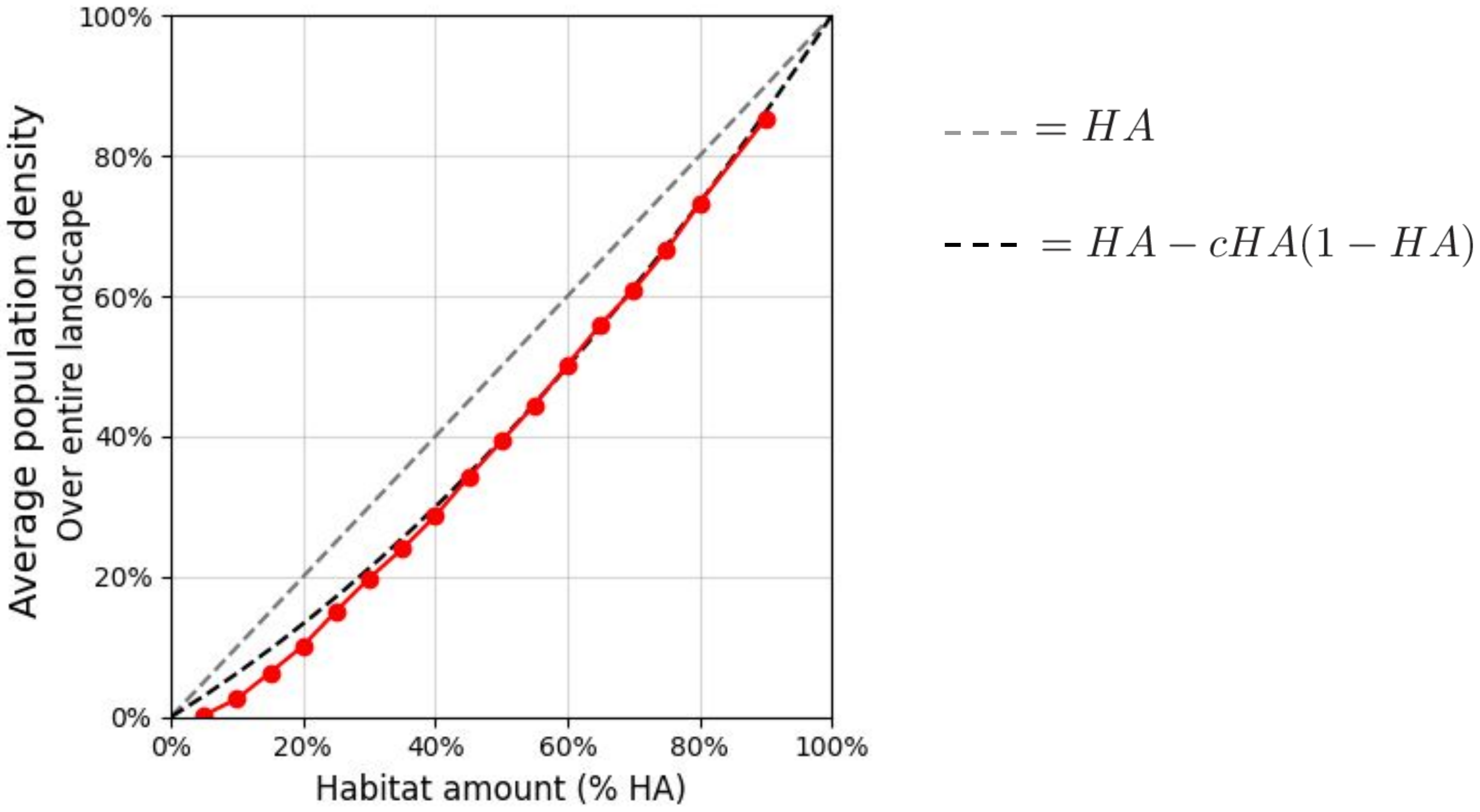


What features of landscape matter?



Effects are dependent on matrix hostility.
Future analysis will consider **soft, intermediate** and **hostile matrices**.

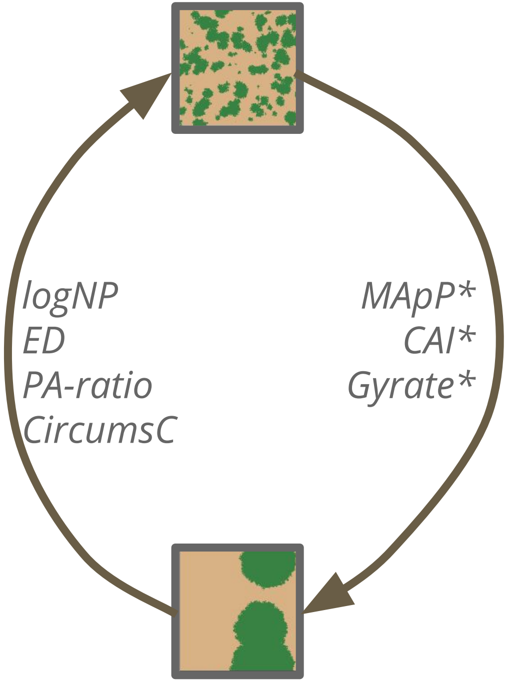
Habitat total area vs core area, in hostile matrices



Fragmentation metrics

Measurements of different aspects of spatial habitat distribution:

- Aggregation metrics
    - log of number of patches (logNP)
- Area and edge metrics
    - mean area per patch (MApP*)
    - edge density (ED)
- Core area metrics
    - % of core area (CAI*)
- Shape metrics
    - perimeter-area ratio (PAratio)
    - mean circumscribe radii of patches (CircumsC)
    - deformation from ‘optimal shape’ (Gyrate*)



All metrics were scaled and normalized.

Statistical description

Linking function: Logit

Geographical information → **Ecological information**

MODEL 1

$$a_0 + a_1 \cdot HA$$

The ecological value **depends exclusively on the HA** of the landscape.

MODEL 2

$$a_0 + a_1 \cdot HA + a_2 \cdot F_j$$

Independent effects of habitat amount and habitat fragmentation

MODEL 3

$$a_0 + a_1 \cdot HA + (a_2 + a_3 \cdot HA) \cdot F_j$$

Interdependent effects of the fragmentation and habitat amount

$\{a_i\}$ are adjusted by Maximum Likelihood Estimator (*MLE*).

MODEL 1
$$a_0 + a_1 \cdot HA$$

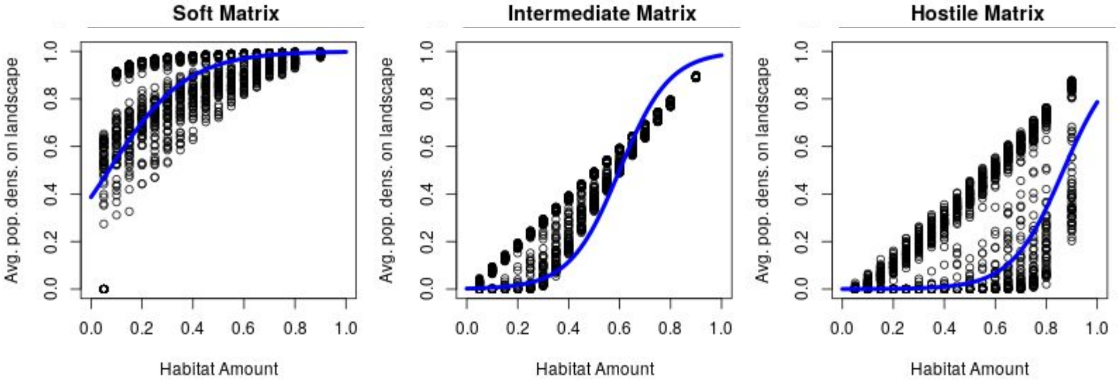
MODEL 2
$$a_0 + a_1 \cdot HA + a_2 \cdot F_j$$

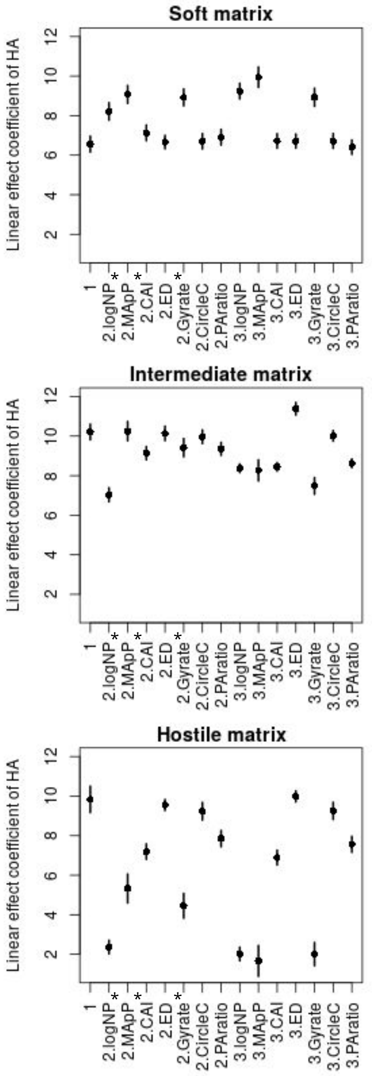
MODEL 3
$$a_0 + a_1 \cdot HA + (a_2 + a_3 \cdot HA) \cdot F_j$$

Negative effects of habitat loss

All models presented negative ecological effects of habitat loss at all matrices.

Model 1





MODEL 1

$$a_0 + a_1 \cdot HA$$

MODEL 2

$$a_0 + a_1 \cdot HA + a_2 \cdot F_j$$

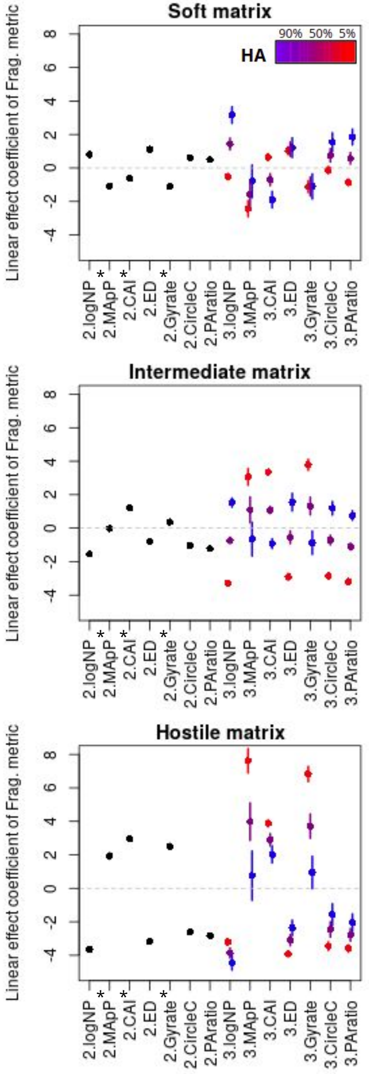
MODEL 3

$$a_0 + a_1 \cdot HA + (a_2 + a_3 \cdot HA) \cdot F_j$$

Effects of habitat fragmentation

Statistical modelling presented **non-negligible effects of fragmentation** and confirmed the visual inspections of previous analysis.

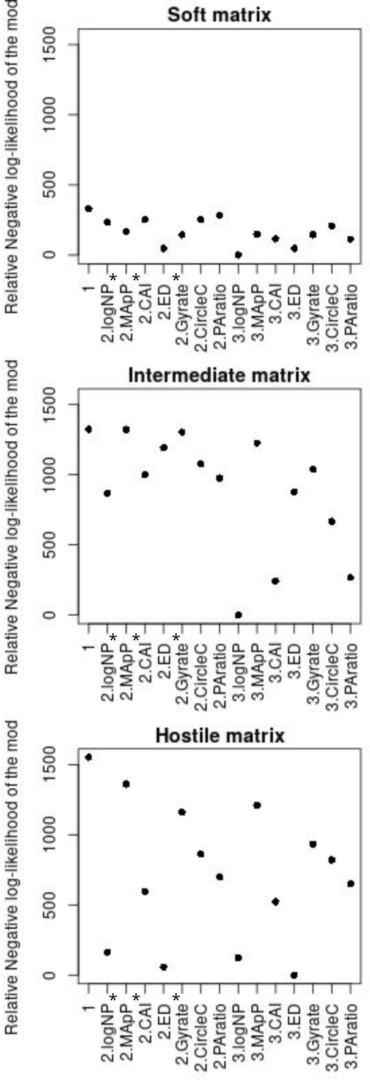
- **Soft matrices:** fragmentation is good.
- **Intermediate matrices:** fragmentation is slightly bad.
    - Inversion of direction of effects across the HA gradient in Model 3.
- **Hostile matrices:** fragmentation is bad.



Model selection

All criteria employed - *Relative Log-likelihood*, *AIC* or *model variance* - pointed towards the same metrics:

- **Soft matrices:** Model *3.logNP*, followed by *3.ED*.
- **Intermediate matrices:** Model *3.logNP*.
- **Hostile matrices:** Model *3.ED*, followed by *2.ED*.



Statistical description

MODEL 3

$$a_0 + a_1 \cdot HA + (a_2 + a_3 \cdot HA) \cdot F_j$$

Interdependent effects of the fragmentation, linearly constrained to habitat amount

MODEL 4

$$a_0^{(k)} + a_1^{(k)} \cdot F_j$$

Effects of *fragmentation per se*, unconstrained to habitat amount

$k = 90\%, 85\%, 80\%, ...of HA$

MODEL 3

$$a_0 + a_1 \cdot HA + (a_2 + a_3 \cdot HA) \cdot F_j$$

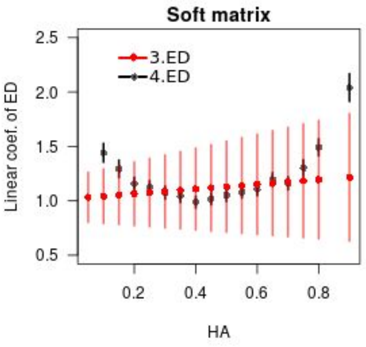
MODEL 4

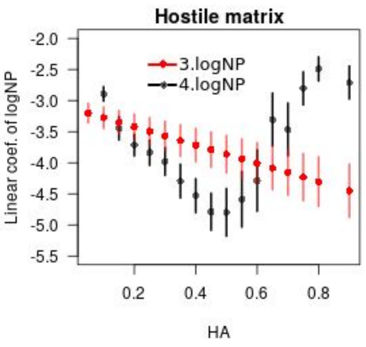
$$a_0^{(k)} + a_1^{(k)} \cdot F_j$$

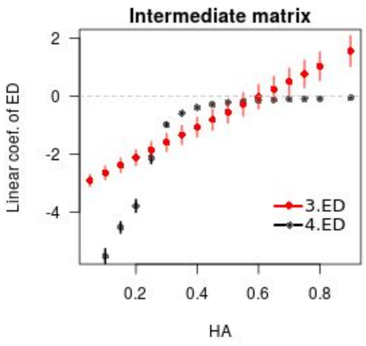
Effects of *fragmentation per se*

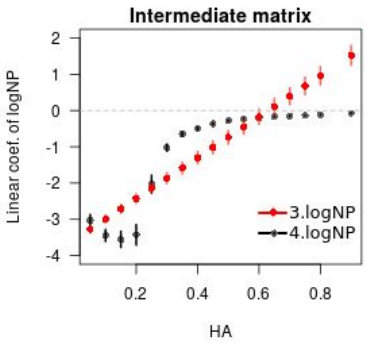
Two non-linear patterns of effects of *fragmentation per se* along the HA gradient:

- **Parabolic**, stronger effects at mid HA;
- **Significant at low HA**, especially in intermediate matrices.







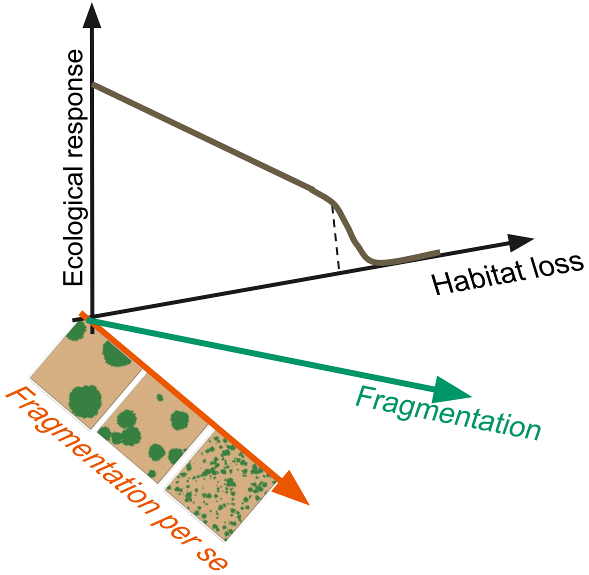


Final considerations

- The model presented in this work had **emerging effects of habitat loss and habitat fragmentation**.

- The model could explain **diverging results** in the literature considering **different matrix hostilities**.
    - The direction of effects of habitat fragmentation (as well as *fragmentation per se*) depend on the matrix hostility.

- Hence, the empirical studies could consider **quantifying matrix hostilities** in their statistical studies.



Acknowledgements

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Thank you!