

ROBERTO A. KRAENKEL

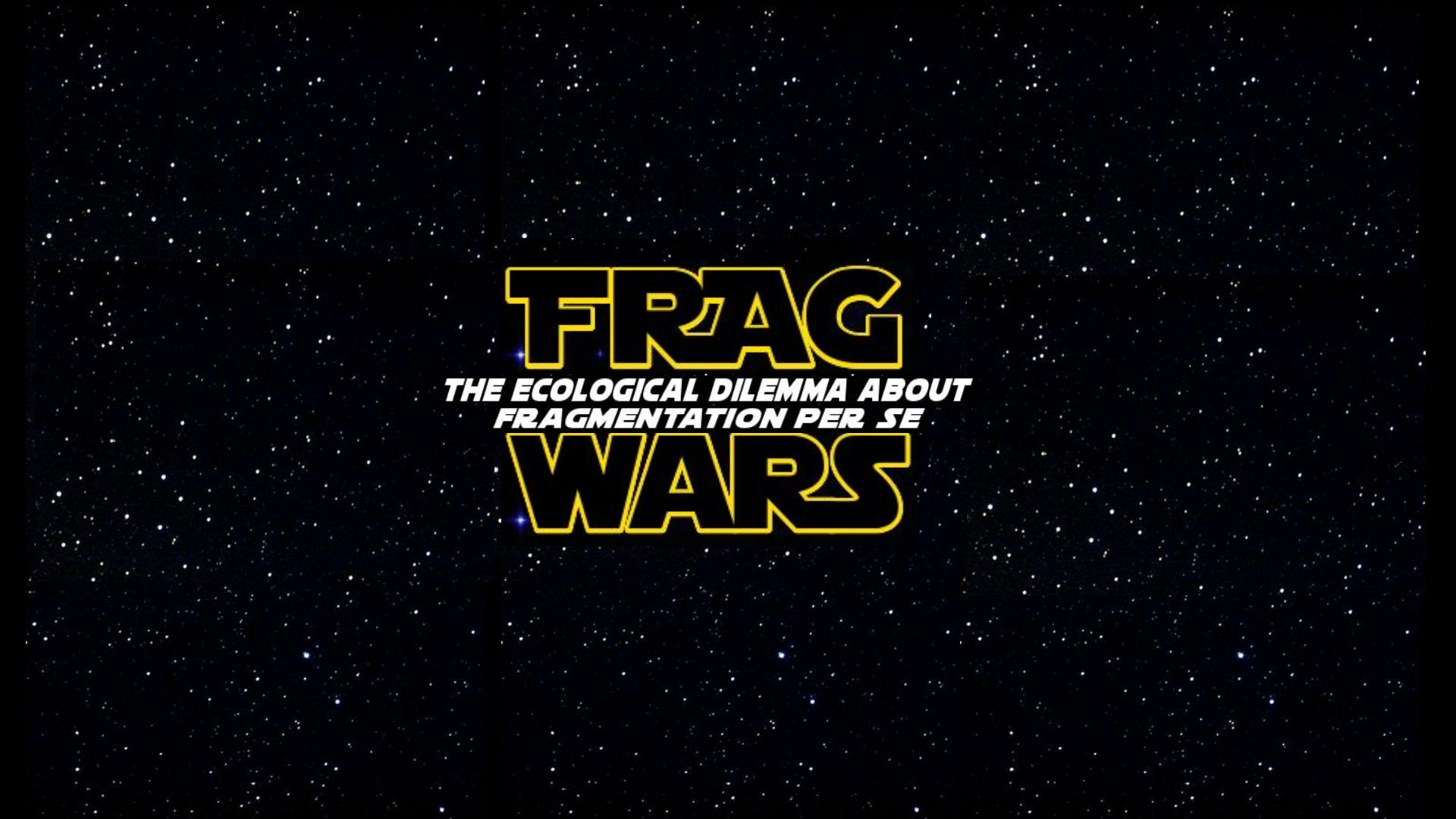
VÍTOR SUDBRACK

RENATO M. COUTINHO

FRAG *INSIGHTS FROM NUMERICAL SIMULATIONS ON THE EFFECTS OF FRAGMENTATION PER SE* WARS

APRIL 15TH, 2020

ORIGINALLY PRESENTED AT EcoENCONTROS (IB-USP)
[LECTURE LINK HERE IN PORTUGUESE](#)



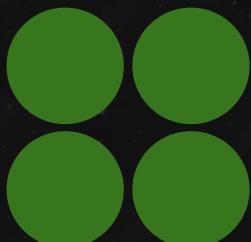
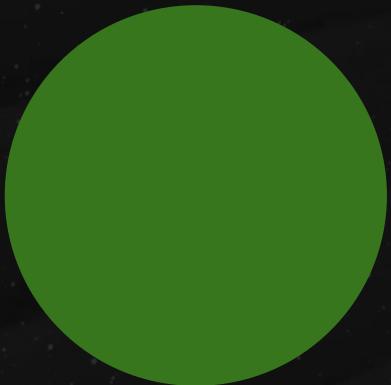
FRAG

**THE ECOLOGICAL DILEMMA ABOUT
FRAGMENTATION PER SE**

WARS

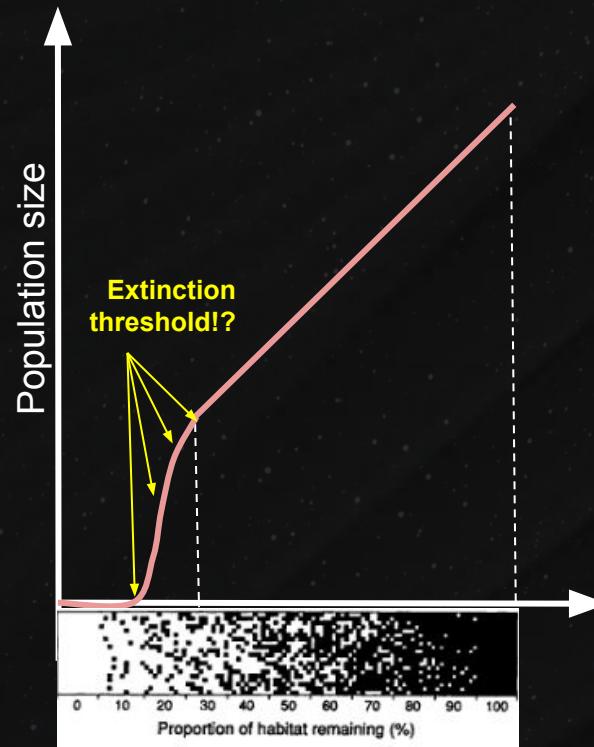
SLOSS (70s, 80s)

Single Large
Or Several
Small ?



Extinction threshold (90s)

Extinction threshold
↓ ??
Percolation threshold
↓
Fragmentation



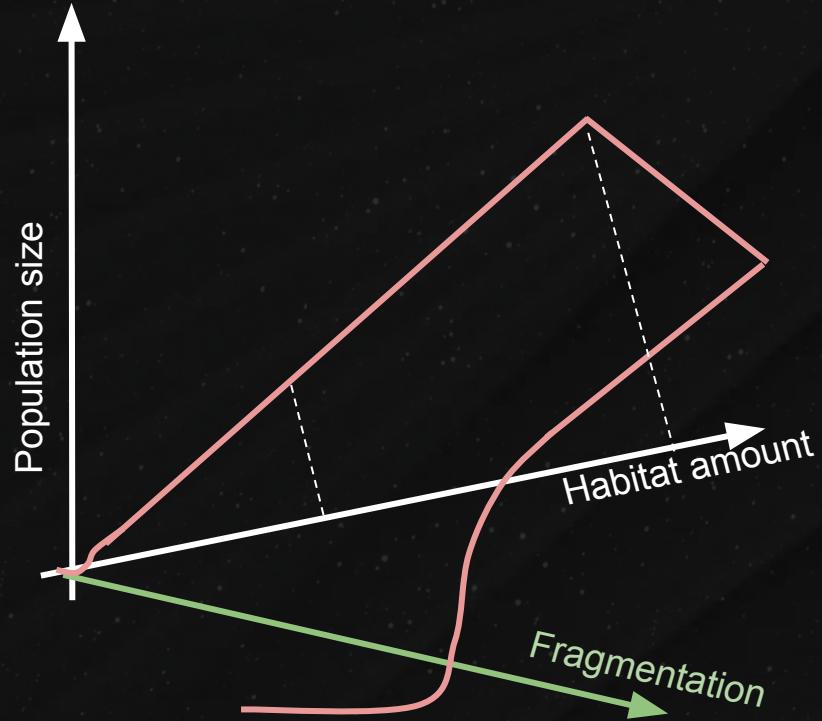
Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review

Fahrig (2002, 2003)

What does
Several Small
mean?



Continuous version
of the problem:
Degree of fragmentation



EFFECTS OF HABITAT FRAGMENTATION ON BIODIVERSITY

Lenore Fahrig

Ottawa-Carleton Institute of Biology, Carleton University, Ottawa, Ontario,
Canada K1S 5B6; email: Lenore.Fahrig@carleton.ca

Fragmentation

How to measure it?



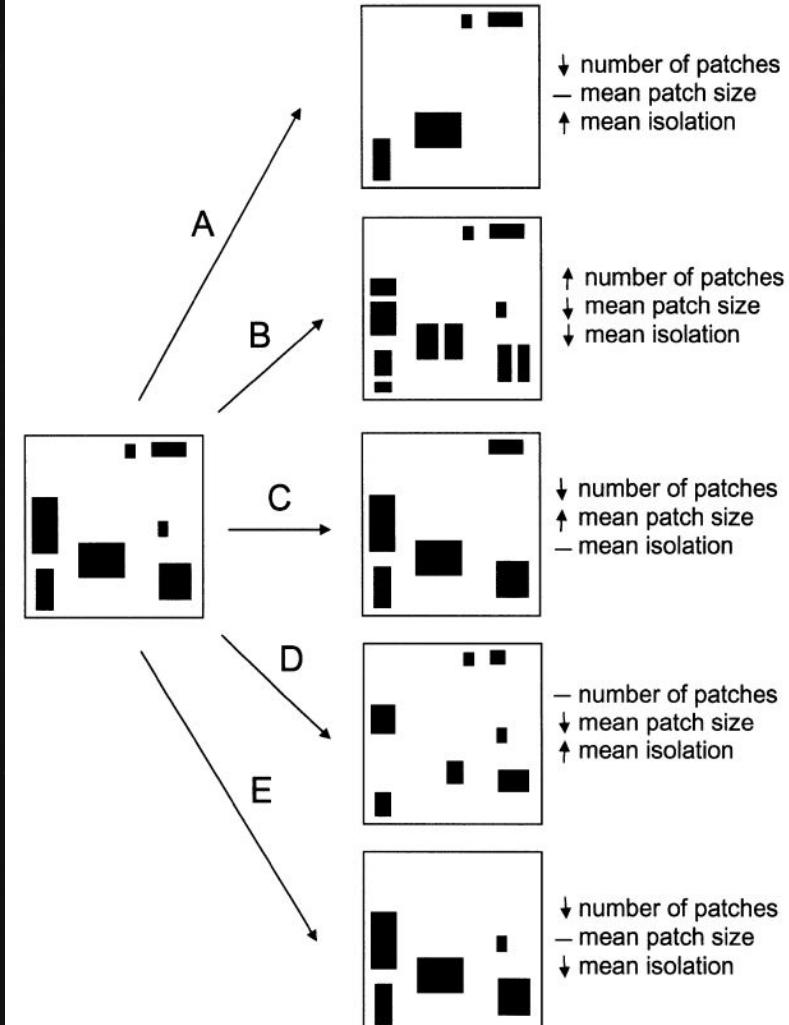
Fragmentation metrics

“Fragmentation” becomes
general term for spatial configuration

EFFECTS OF HABITAT FRAGMENTATION ON
BIODIVERSITY

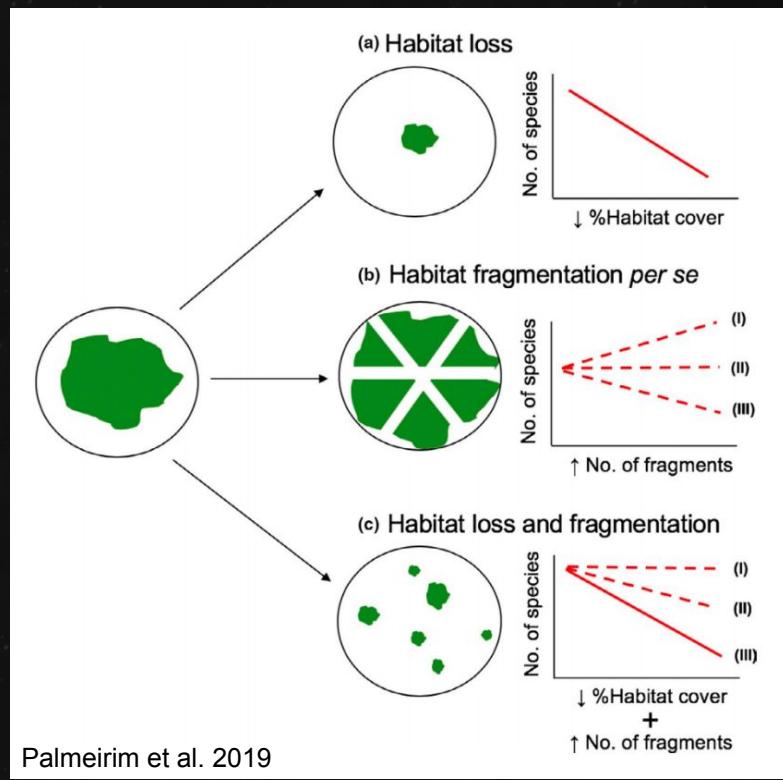
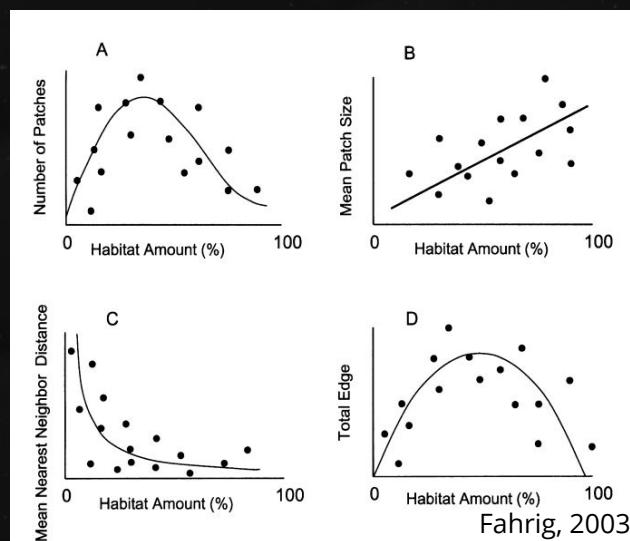
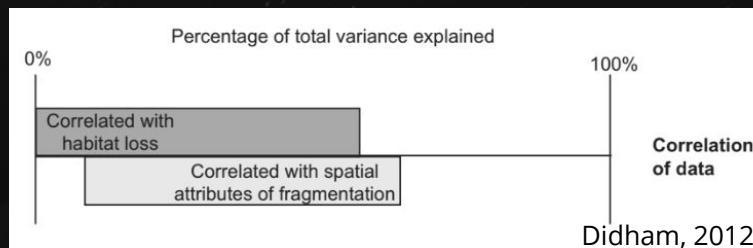
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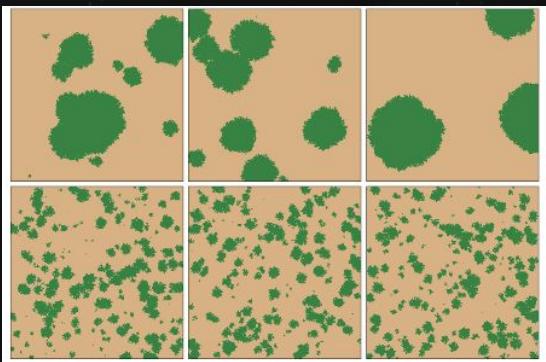
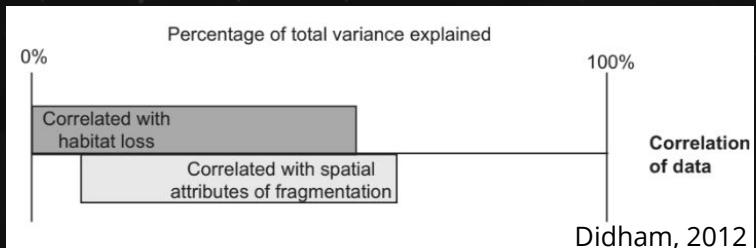
Fragmentation X Fragmentation process

Habitat loss → Fragmentation

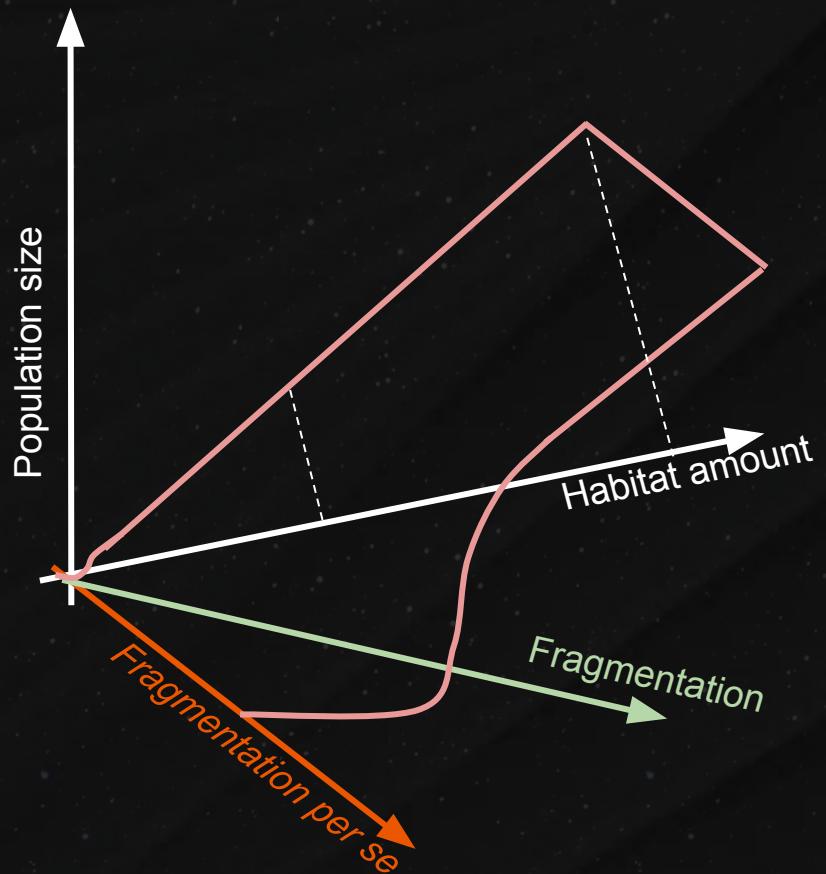


Fragmentation per se

Fragmenting without habitat loss



Didham, 2012



Ecological Responses to Habitat Fragmentation Per Se

Lenore Fahrig

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. Damschenⁱ, Felipe P.L. Melo^j, Leslie Ries^k, Jayme A. Prevedello^l, Teja Tscharntke^m, William F. Lauranceⁿ, 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

Editorial

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

Abraham J. Miller-Rushing^{a,*}, Richard B. Primack^b, Vincent Devictor^c,
Richard T. Corlett^d, Graeme S. Cumming^e, Rafael Loyola^f, Bea Maas^g,
Liba Pejchar^h

Indirect effects of habitat loss via habitat fragmentation: A cross-taxa analysis of forest-dependent species

Thomas Püttker^a  , Renato Crouzeilles^b  , Mauricio Almeida-Gomes^c, Marina Schmoeller^d, Daniel Maurenza^d, Helena Alves-Pinto^{b, e}  , Renata Pardini^f, Marcus V. Vieira^f, Cristina Banks-Leite^g  , Carlos R. Fonseca^h, Jean Paul Metzgerⁱ  , Gustavo M. Accacio^{a, i, l}, Eduardo R. Alexandrino^j  , Camila S. Barros^k, Juliano A. Bogoni^k, Danilo Boscolo^l  , Pedro H.S. Brancalion^j  , Adriana A. Bueno^f   ... Jayme A. Prevedello^{ar}

Support for the habitat amount hypothesis from a global synthesis of species density studies

James I. Watling,^{1*}  Victor Arroyo-Rodríguez,² Marion Pfeifer,³ Lander Baeten,⁴ Cristina Banks-Leite,⁵ Laura M. Cisneros,⁶ Rebecca Fang,⁷ A. Caroli Hamel-Leigue,⁸ Thibault Lachat,^{9,10} Inara

R. Leal,¹¹ Luc Lens,¹² Hugh P. Possingham,¹³ Dinarzarde C. Raheem,¹⁴ Danilo B. Ribeiro,¹⁵ Eleanor M. Slade,¹⁶ J. Nicolas Urbina-Cardona,¹⁷ Eric M. Wood¹⁸ and Lenore Fahrig¹⁹



Ecological effects of *fragmentation per se*

A heated war:
FRAG WARS!

Ecological effects of *fragmentação per se*

Which mechanisms are there and how to unify observational studies?

HAH
Habitat
Amount
Hypothesis

Relation between **species** and **habitat loss**:
Habitat loss harms biodiversity!

Fragmentation effects are secondary order,
and lower habitat amounts increases its significance.

Different mechanisms act in different spatial scales:
Conclusions are not spatially extrapolatable

The whole of matrix (nonhabitat) in persistence and
dispersal mechanisms should be further studied

The ecological responses may change
with respect to the observed time scales

Terminology chaos: different studies/subfields use different
ecological/fragmentation metrics and state different interpretations of results.





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**MATHEMATICAL MODELLING
OF SPATIAL ECOLOGY**

WARS

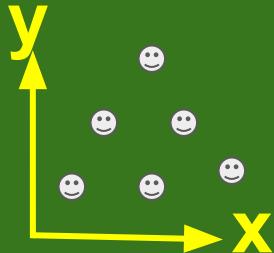
Ecological modeling goals

Writing equations based
on minimal mechanisms:
oversimplification

Solving those
equations on
numerical methods

Search for patterns
observed in nature

Population distribution



$u(t, x, y)$ = population
density in spatial point
(x,y) at instant t

Reaction-diffusion equations

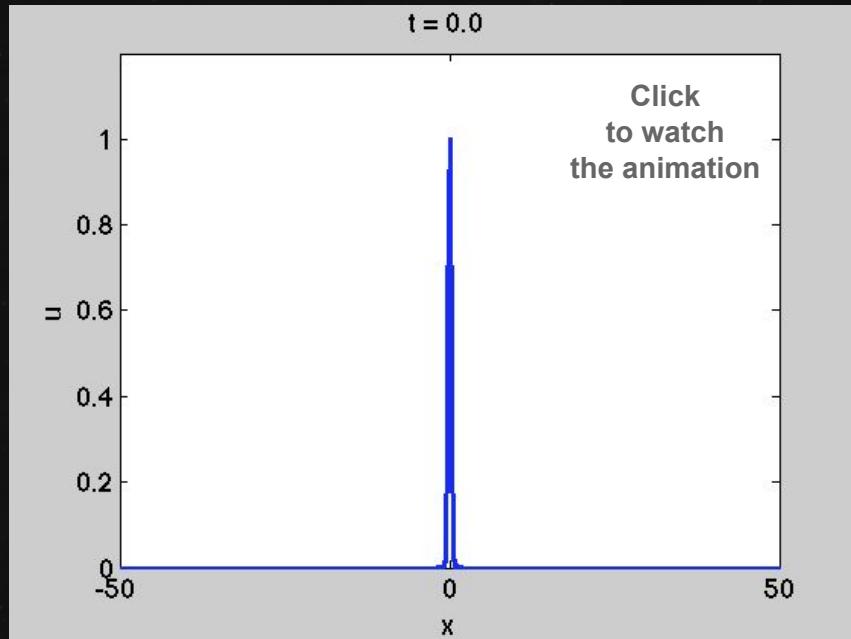
$$\partial_t u = f(u) + D \nabla^2 u$$

↑ ↑
Reaction **Diffusion**

Laplacian:

$$\nabla^2 u = \partial_{xx} u + \partial_{yy} u$$

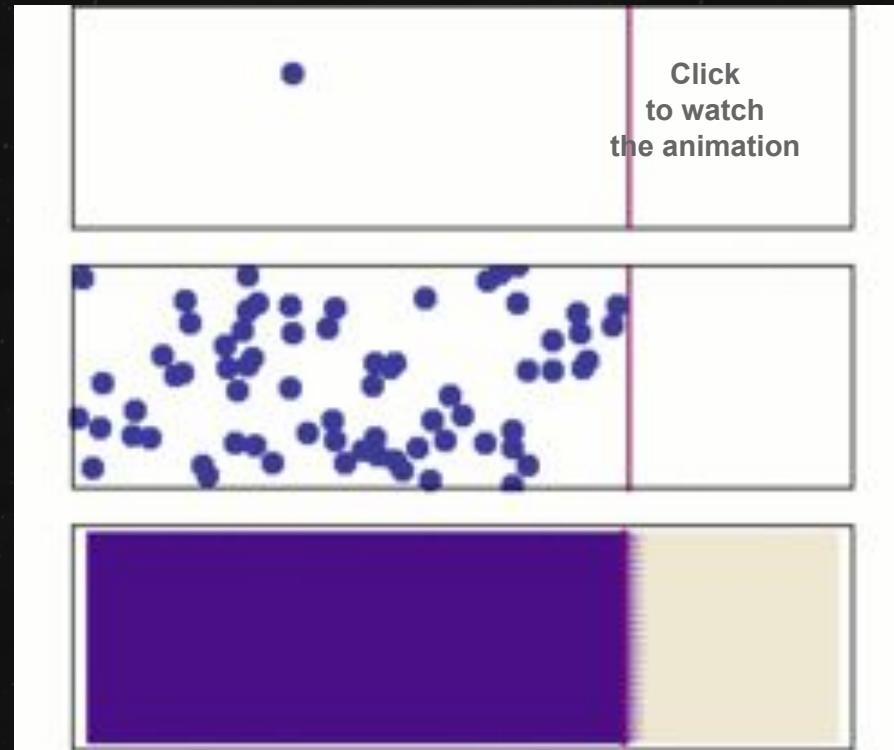
Meaning: pointwise net flux
Effect: spatial homogenization, smoothing and blur



Diffusion movement in population context

**Individually (animal level):
it means a random walk**

**Macroscopically (population level):
Spatial homogenization**

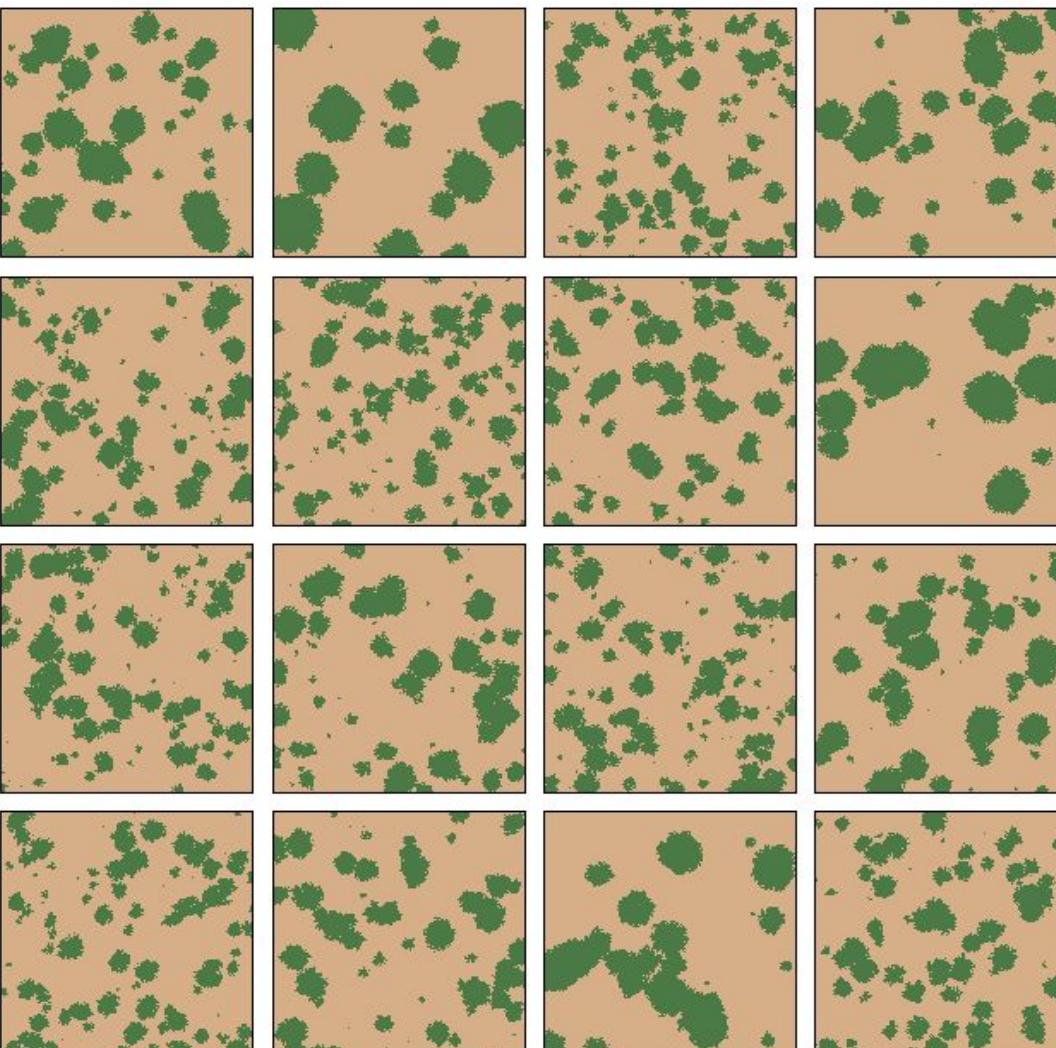




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*NUMERICAL SIMULATIONS ON
FRAGMENTATION PER SE*

WARS



Fragmented landscapes

Binary landscapes: habitat and matrix

Fixed total amount
of habitat (25%)

Habitat

Matrix

$$\partial_t u = ru(1 - u) + D_P \nabla^2 u$$

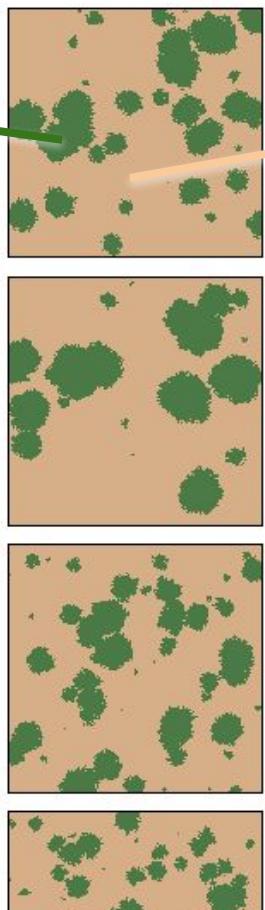
Logistic growth

$$\partial_t u = -\mu u + D_M \nabla^2 u$$

Death process

$$L_P = \sqrt{\frac{D_P}{r}}$$

$$L_M = \sqrt{\frac{D_M}{\mu}}$$



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

Matrix quality parameter

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

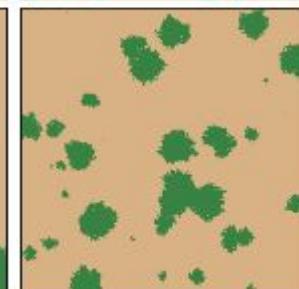
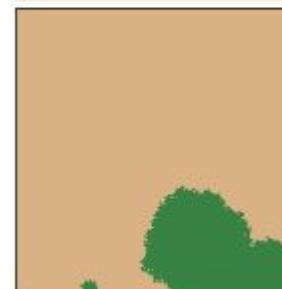
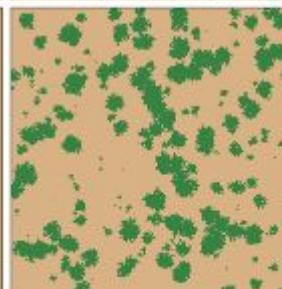
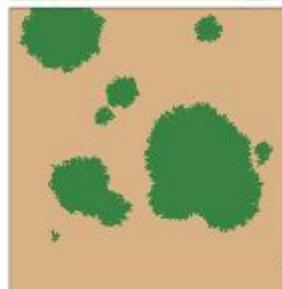
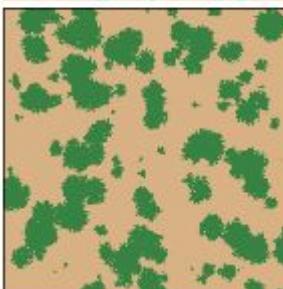
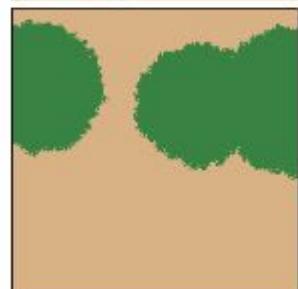
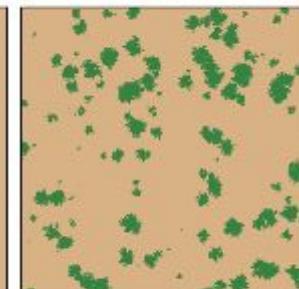
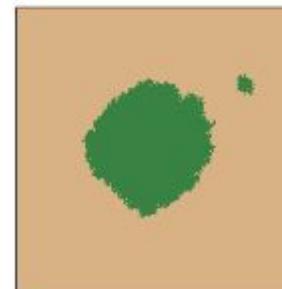
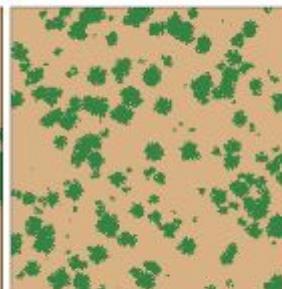
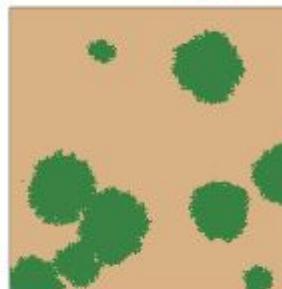
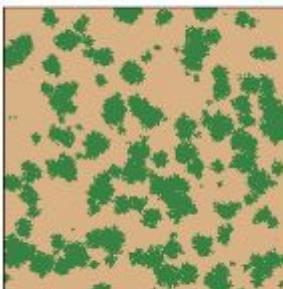
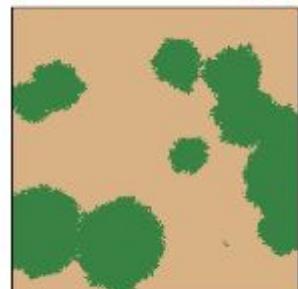
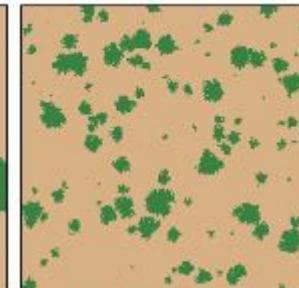
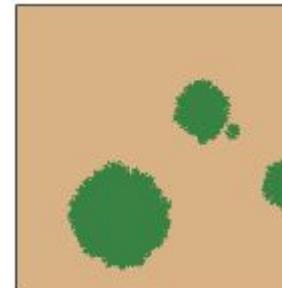
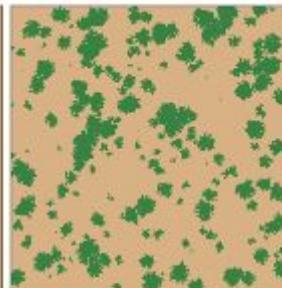
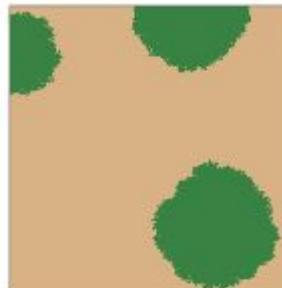
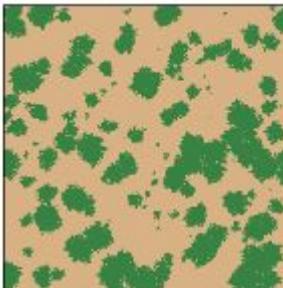
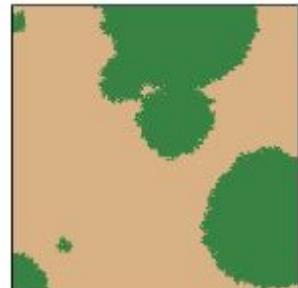


The only parameter that characterize the matrix
(compared to the habitat)

35%

25%

15%

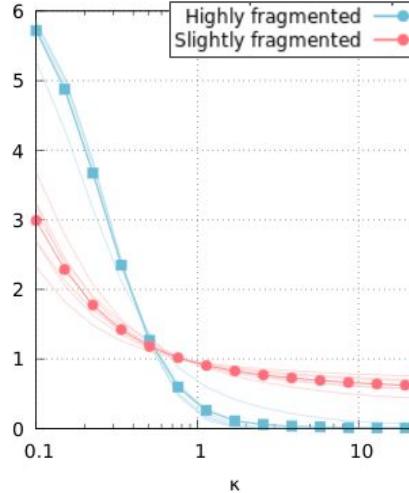
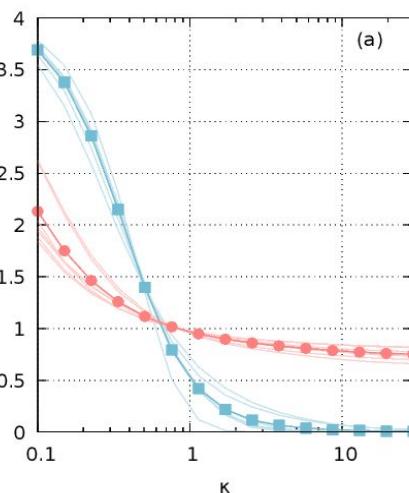
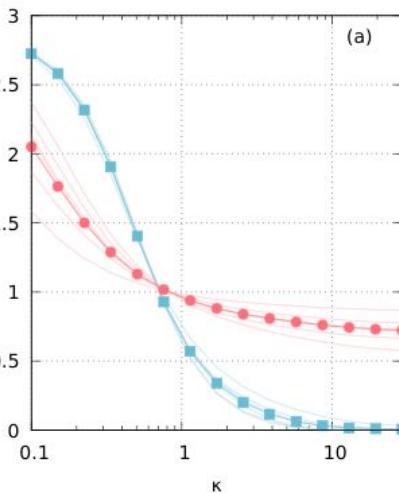


HA = **35%**

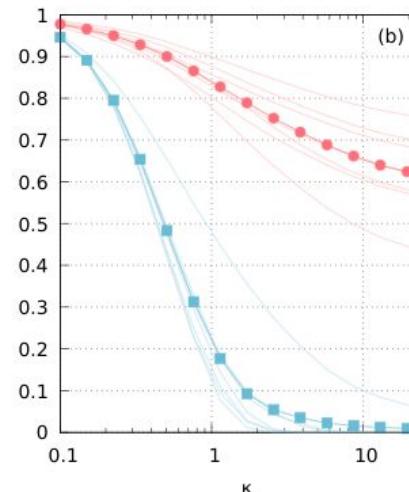
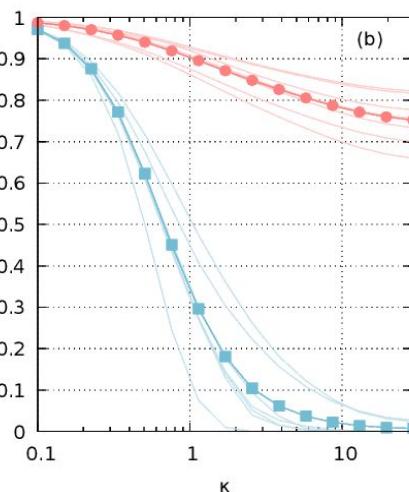
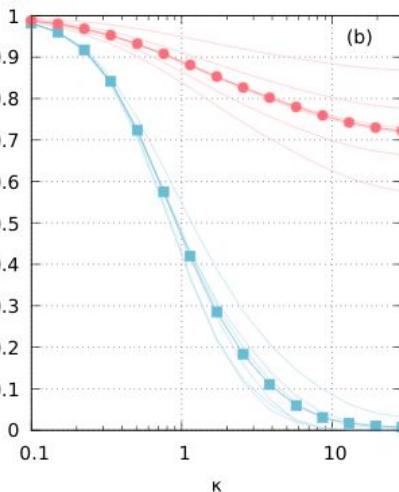
25%

15%

Total pop. in landscape (Norm.)



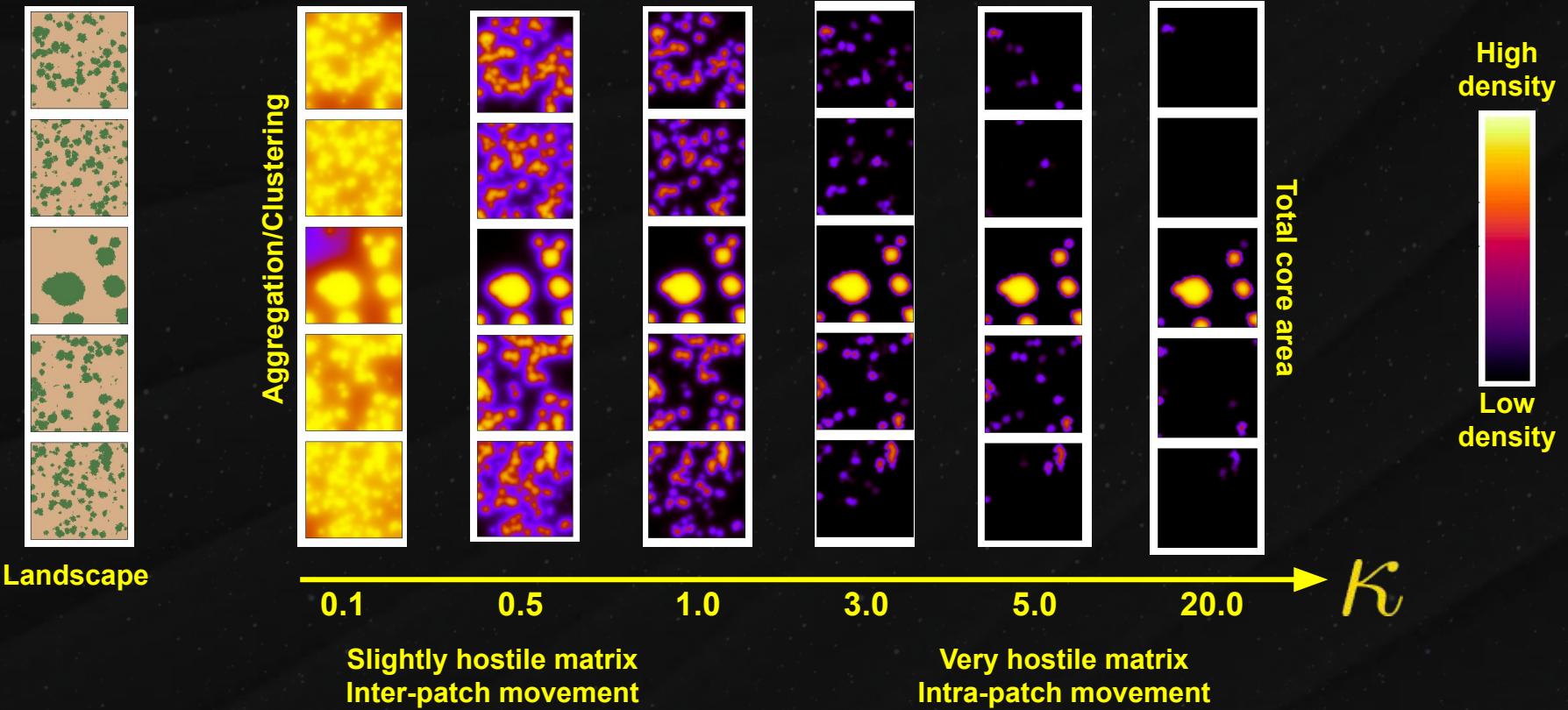
Total pop. in patch (Norm.)



- Effects of fragmentation may have different directions (good or bad) and different magnitudes;
- Highly fragmented landscapes lead to extinction in hostile enough matrices;
- Lower HA have wider extinction ranges wrt matrix quality;
- Fragmentation effects are more significant with lower HA;
- Non-linear decrease in total population from 25%H to 15%HA (normalization vanish linear effects).

Test-run results, to be confirmed

Which landscape features matter the most to ecology?



Effective carrying capacity

$$K = kA + c(A, \kappa)F(\kappa)$$

Many correlated metrics

Why we still use Pearson correlation if we do not expect linear relations?

PCA techniques may “combine” different metrics, losing their meaning...

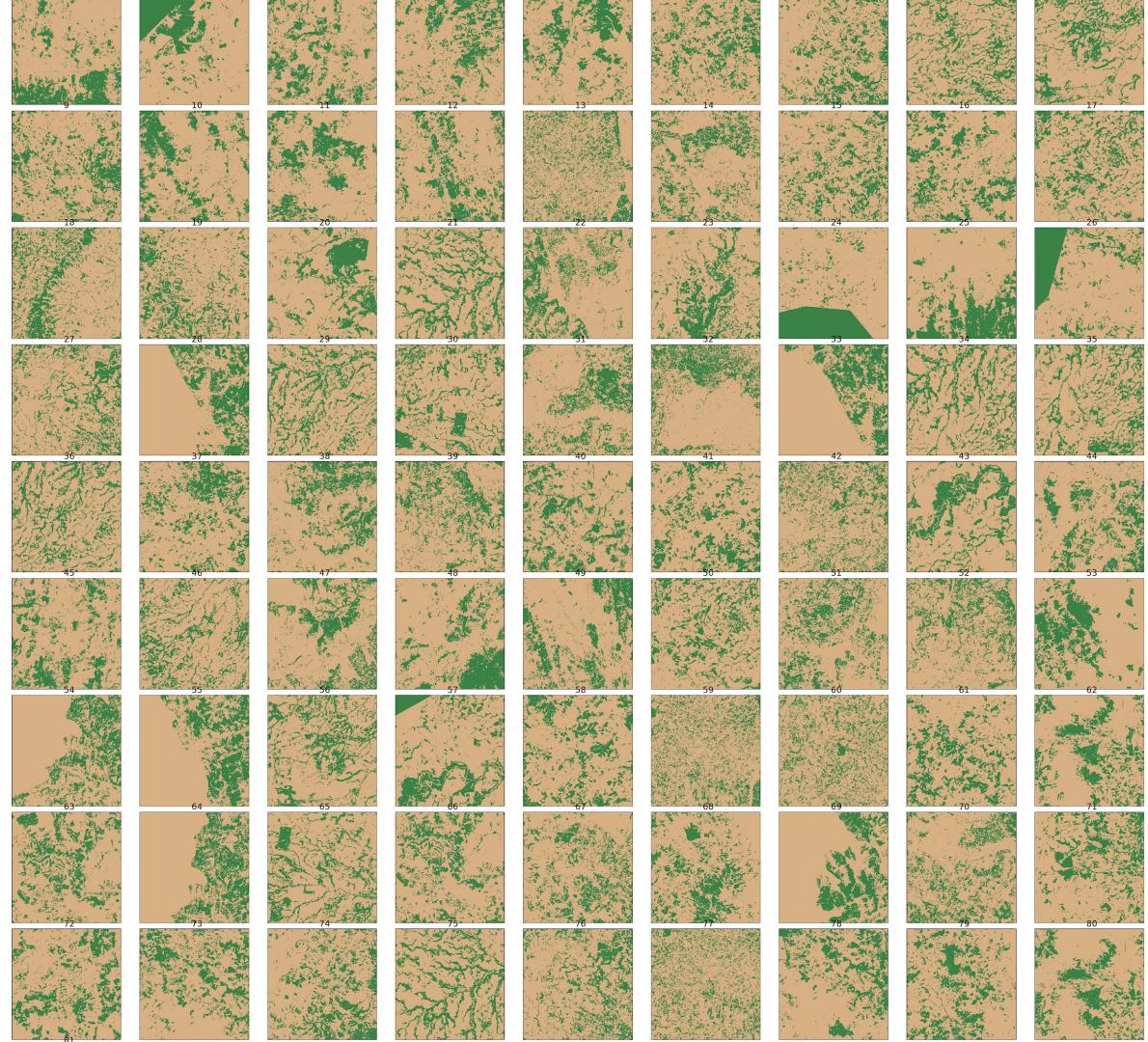
The method we use to generate artificial landscapes changes their correlations

Measuring habitat fragmentation: An evaluation of landscape pattern metrics

Xianli Wang^{1*}, F. Guillaume Blanchet^{1,2,3} and Nicola Koper⁴

Example of Spearman correlation:

Cohesion	1.00	0.56	-0.80	0.80	-0.71	-0.76	0.22	0.79	-0.60	0.73	-0.68	0.76
ENN	0.56	1.00	-0.72	0.72	-0.55	-0.71	0.28	0.44	-0.45	0.57	-0.67	0.71
NP	-0.80	-0.72	1.00	-1.00	0.86	0.99	-0.29	-0.67	0.69	-0.89	0.92	-0.99
MapP	0.80	0.72	-1.00	1.00	-0.86	-0.99	0.29	0.67	-0.69	0.89	-0.92	0.99
CAI	-0.71	-0.55	0.86	-0.86	1.00	0.91	0.09	-0.56	0.68	-0.94	0.72	-0.91
ED	-0.76	-0.71	0.99	-0.99	0.91	1.00	-0.18	-0.65	0.71	-0.93	0.92	-1.00
Gyrate	0.22	0.28	-0.29	0.29	0.09	-0.18	1.00	0.22	0.08	-0.02	-0.35	0.18
LPI	0.79	0.44	-0.67	0.67	-0.56	-0.65	0.22	1.00	-0.53	0.60	-0.67	0.65
Circums.Circle	-0.60	-0.45	0.69	-0.69	0.68	0.71	0.08	-0.53	1.00	-0.82	0.71	-0.71
PA ratio	0.73	0.57	-0.89	0.89	-0.94	-0.93	-0.02	0.60	-0.82	1.00	-0.81	0.93
PA fractal dim.	-0.68	-0.67	0.92	-0.92	0.72	0.92	-0.35	-0.67	0.71	-0.81	1.00	-0.92
Mutual Information	0.76	0.71	-0.99	0.99	-0.91	-1.00	0.18	0.65	-0.71	0.93	-0.92	1.00



**What about
natural landscapes?**

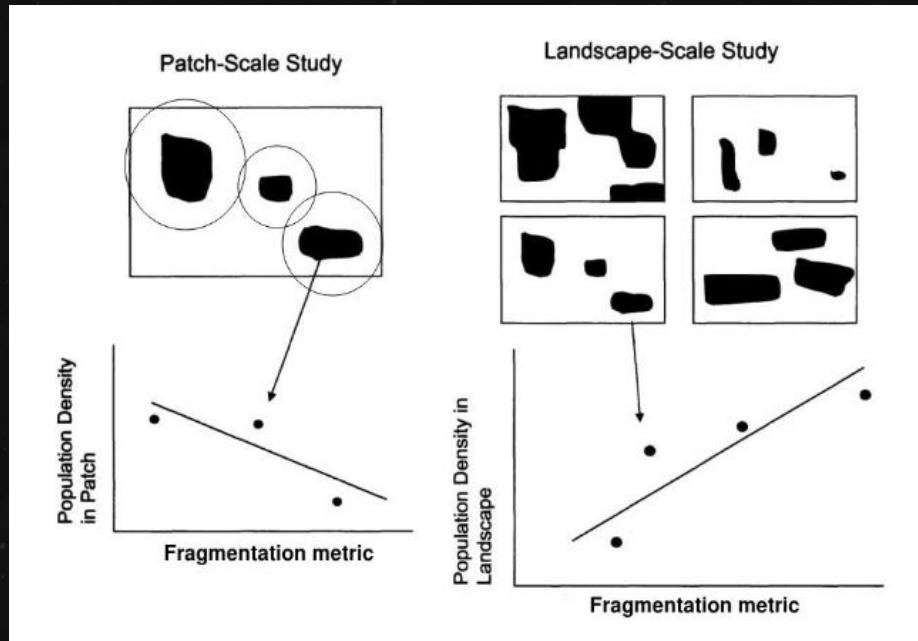
**Different
fragmentation patterns**

SSLOT?
Several small or lots of tiny?

**Heterogeneous
fragmentation**

**Brazilian forests
with 25% of HA**

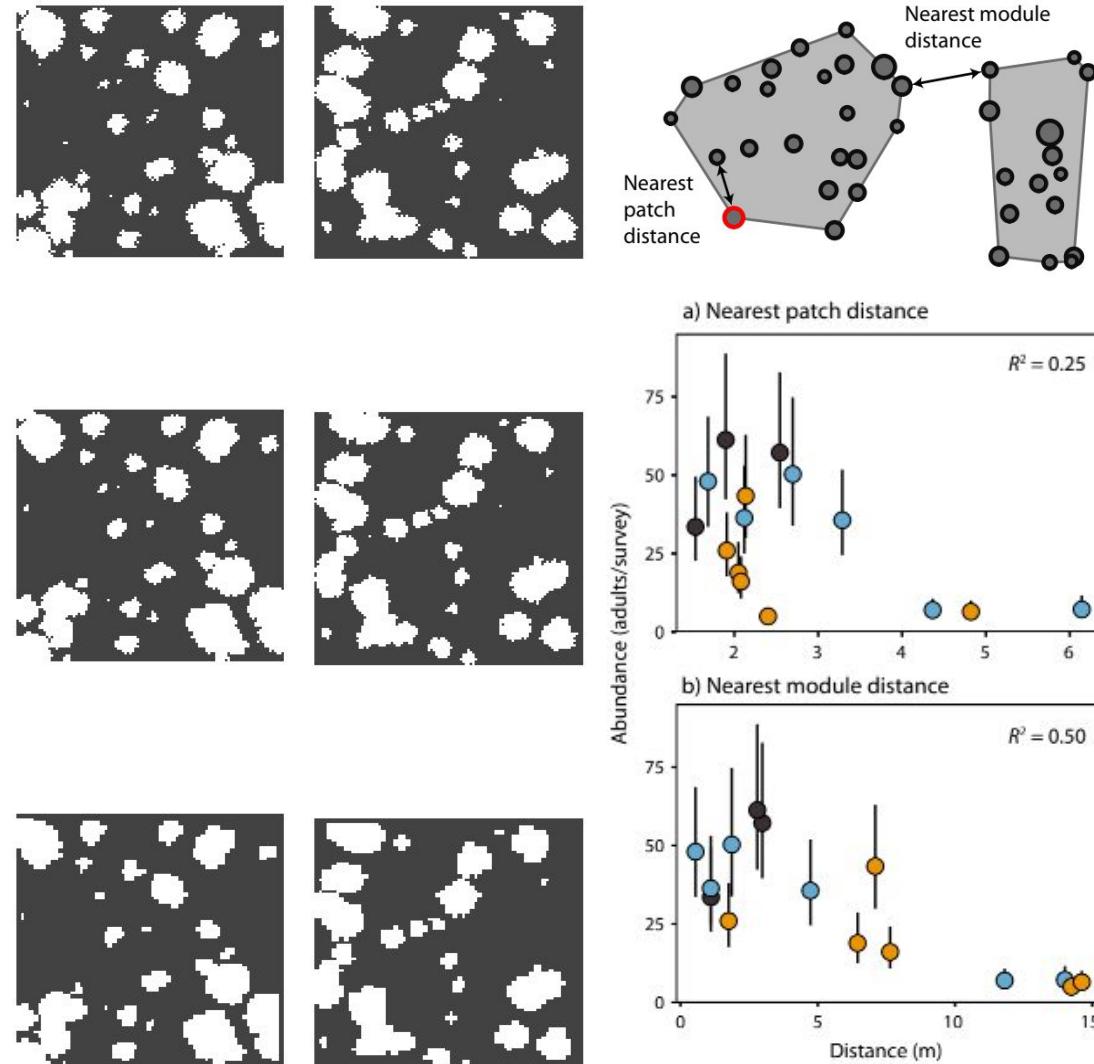
A patch-scale observation is representative of landscape-scale observations?



How correlated is the ecological response in the largest patches
and the ecological response in the whole landscape?

Is this correlation uniform in the habitat and fragmentation gradients?

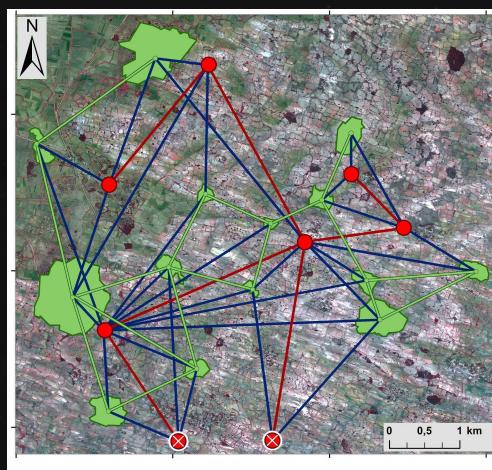
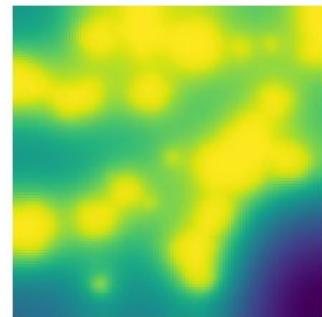
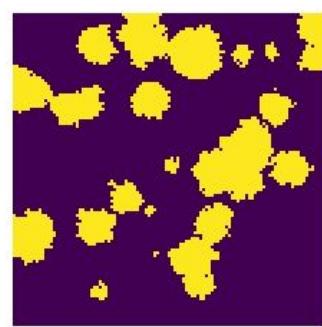
What is the correct spatial scale to measure fragmentation?



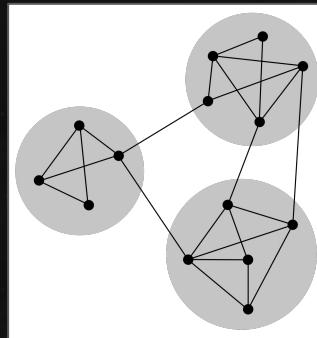
How metrics depend on the granularity of landscapes and observed scales?

The negative effects of habitat fragmentation operate at the scale of dispersal

Functional patches



Functional
patches network

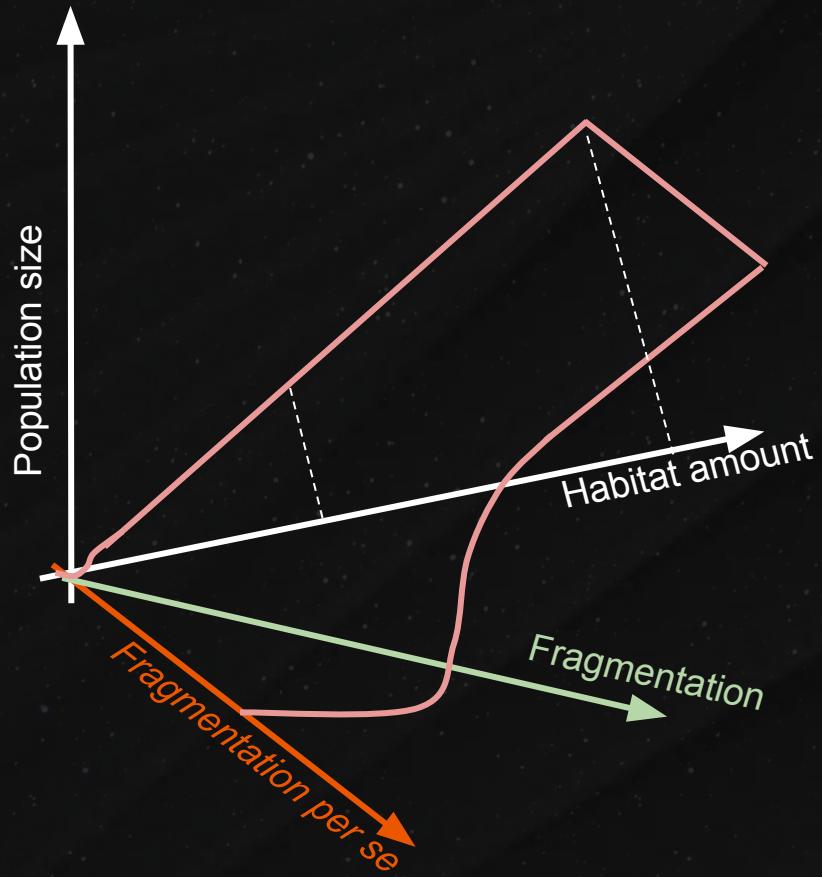


Patch betweenness
and clustering
algorithms

$$w_{ij} \propto e^{-\kappa d_{ij}}$$

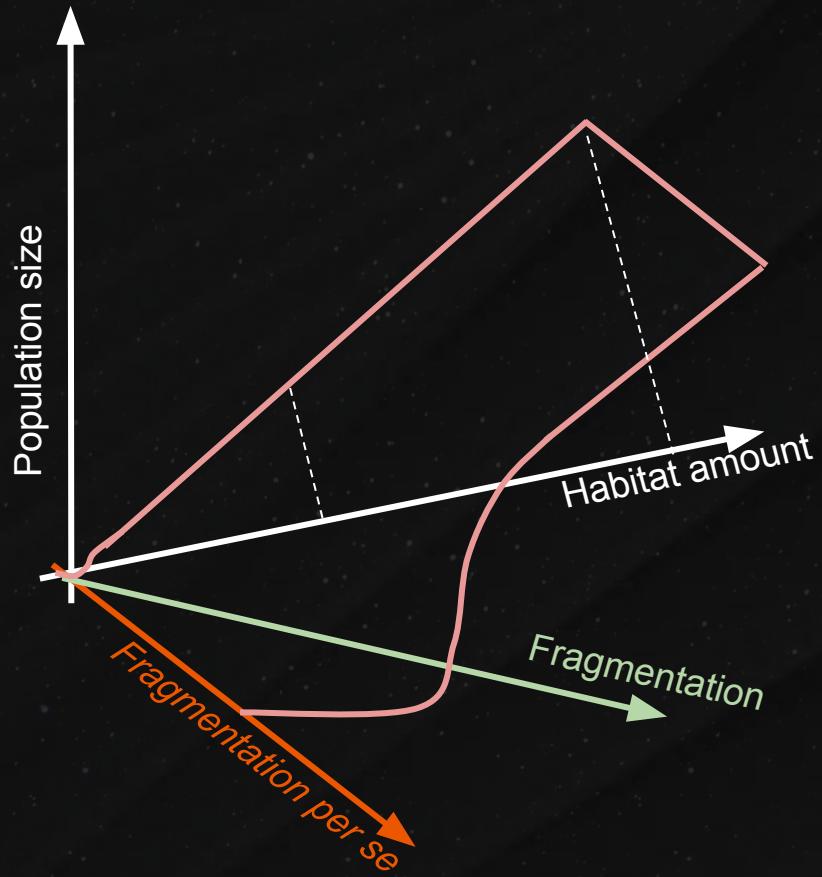
Conclusions

- Computer simulations is a powerful tool to **test, isolate and hypothesize minimal mechanisms** necessary to explain the observed patterns in nature
- We need to verify our methods with **test-run statistical analysis on controlled artificial data** before applying it to observational data
- We should stop binary thoughts or expectations about the effect of fragmentation per se
 - Under which **conditions and characteristics** will the effect be positive or negative?



Conclusions

- **Fragmentation metrics** to measure its effects depend on the quality of matrix and the natural spatial scale of the population
 - Which metrics better relate the geographical information to the ecological information?
- There are many things to **(re-)define, quantify e explain** in the fields of habitat fragmentation, fragmentation metrics, natural landscapes,...





Thank you!

I specially thank to
EcoEncontros and my colleagues from
Professor Kraenkel's lab

Vítor Sudbrack

IFT - Unesp



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