

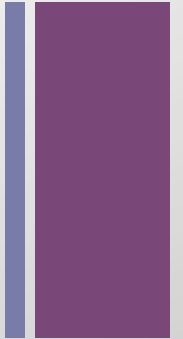


Jean Paul Metzger (USP)

A fragmentação de habitats  
como principal ameaça à  
biodiversidade



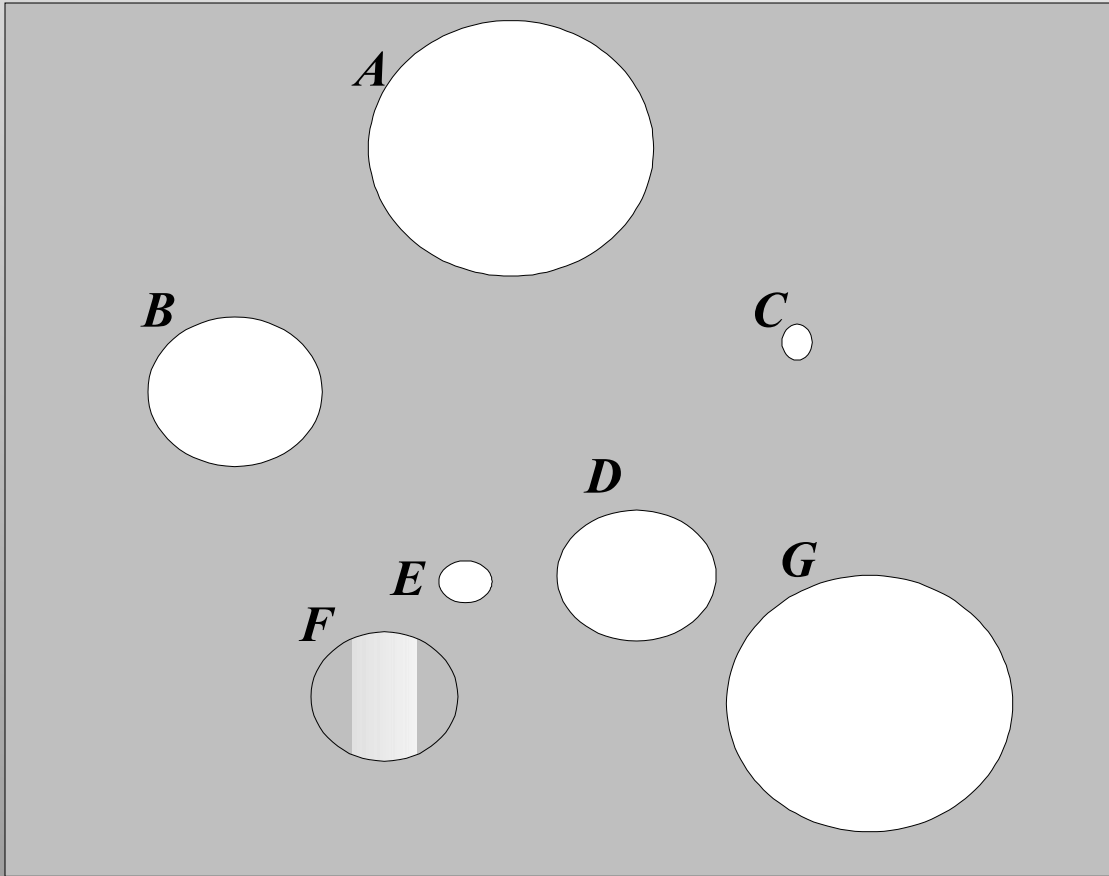
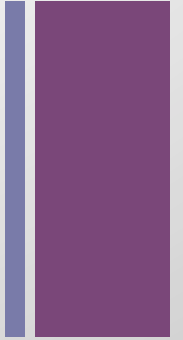
# A fragmentação de habitats como principal ameaça à biodiversidade



- O que é fragmentação?
- Por que devemos nos preocupar com a fragmentação?
- Respostas no tempo
- Implicações para conservação

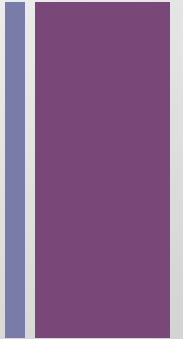


# Onde conservar?





# Onde conservar?

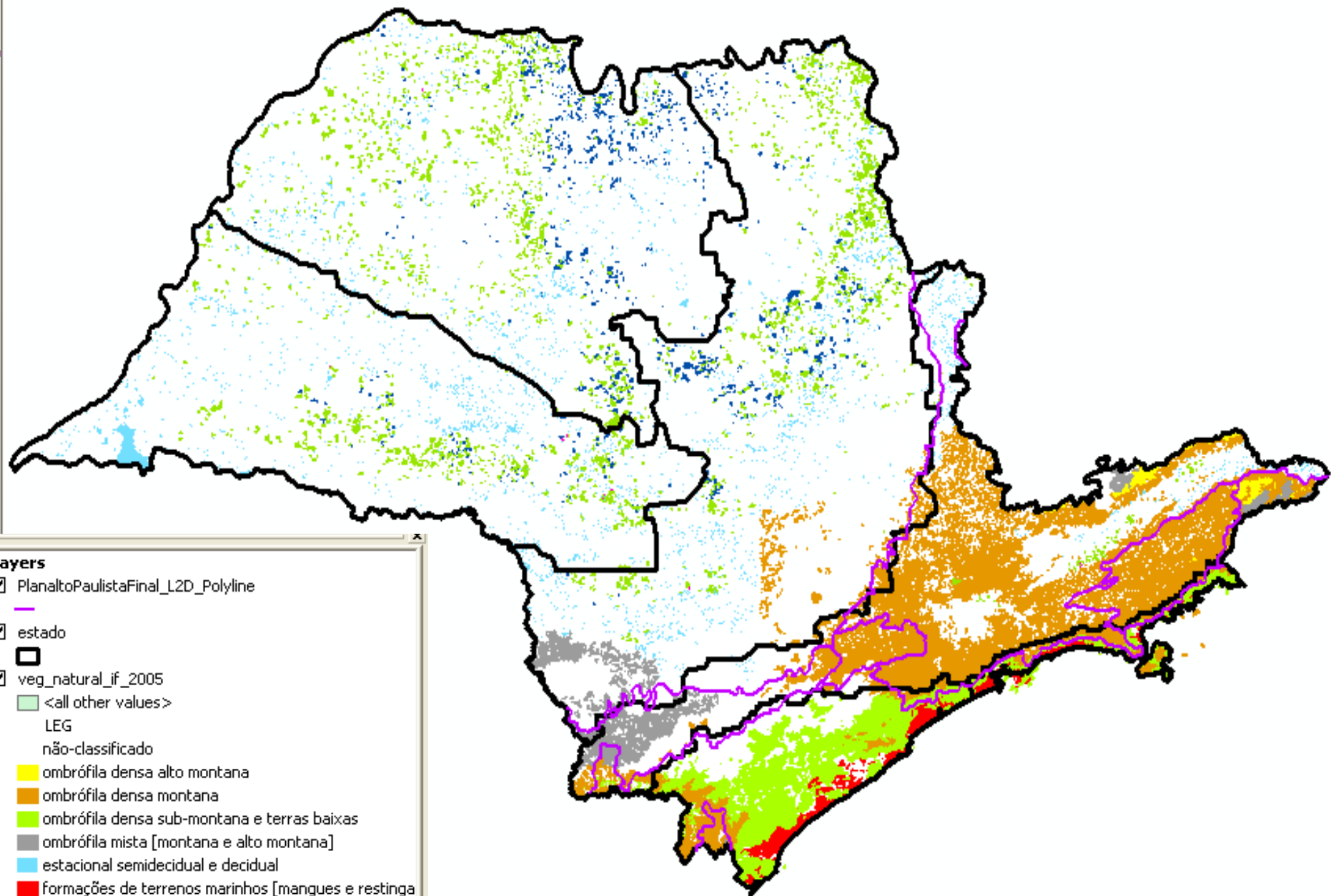


The icons are arranged as follows:

- A:** A circle containing 6 icons: 2 leaves (red, yellow), 2 butterflies (red, yellow), and 2 birds (red, yellow).
- B:** A circle containing 4 icons: 2 butterflies (red, yellow) and 2 birds (red, yellow).
- C:** A white circle containing 1 icon: a red bird.
- D:** A circle containing 4 icons: 2 butterflies (red, yellow) and 2 birds (red, yellow).
- E:** A white circle containing 1 icon: a red bird.
- F:** A circle containing 12 icons: 6 butterflies (black, red, blue, yellow, pink, cyan) and 6 birds (black, red, blue, yellow, pink, cyan).
- G:** A circle containing 9 icons: 3 leaves (red, yellow, cyan), 3 butterflies (red, yellow, cyan), and 3 birds (red, yellow, cyan).

The grid consists of 18 numbered icons arranged in three rows of six:

- Row 1: 1 (black leaf), 2 (red leaf), 3 (blue leaf), 4 (yellow leaf), 5 (pink leaf), 6 (cyan leaf) - icon 6 is circled.
- Row 2: 7 (black butterfly), 8 (red butterfly), 9 (blue butterfly), 10 (yellow butterfly), 11 (pink butterfly), 12 (cyan butterfly) - icon 11 is circled.
- Row 3: 13 (black bird), 14 (red bird), 15 (blue bird), 16 (yellow bird), 17 (pink bird), 18 (cyan bird).



#### Layers

PlanaltoPaulistaFinal\_L2D\_Polyline

estado

veg\_natural\_if\_2005

<all other values>

LEG

não-classificado

ombrófila densa alto montana

ombrófila densa montana

ombrófila densa sub-montana e terras baixas

ombrófila mista [montana e alto montana]

estacional semidecidual e decidual

formações de terrenos marinhos [mangues e restinga]

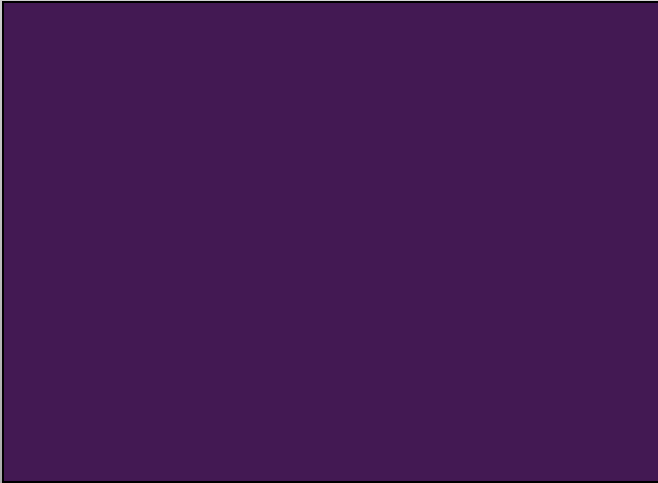
cerrados [savanas florestadas]

savanas arbóreas

savanas [IF]

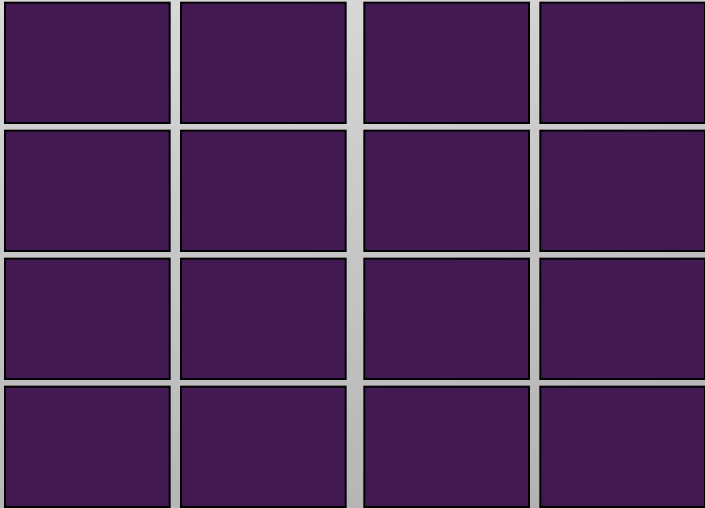


# O debate do SLOSS (“single large or several small”)



single large

or



several small

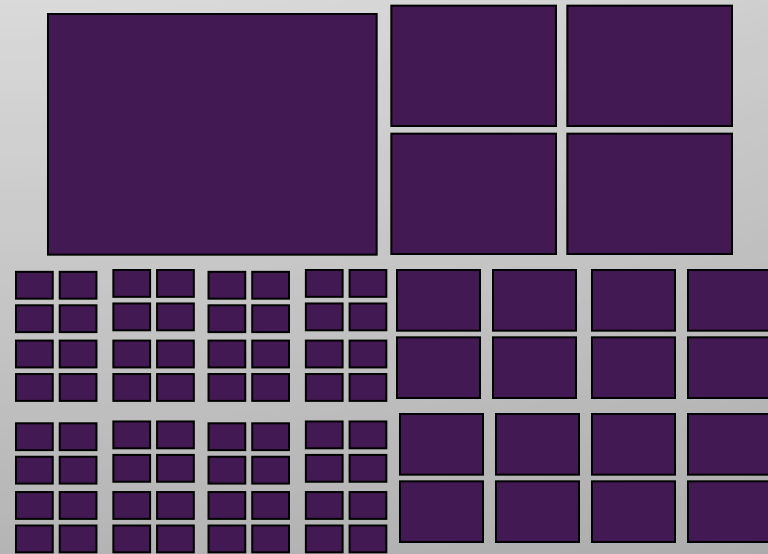


A pergunta do SLOSS não é espacialmente explícita:  
diferentes graus de fragmentação



single large

or

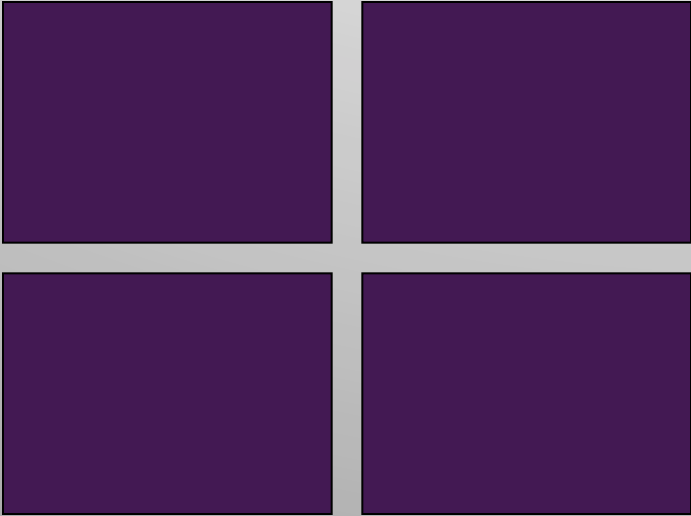


several small

Quantos “several smalls” ?

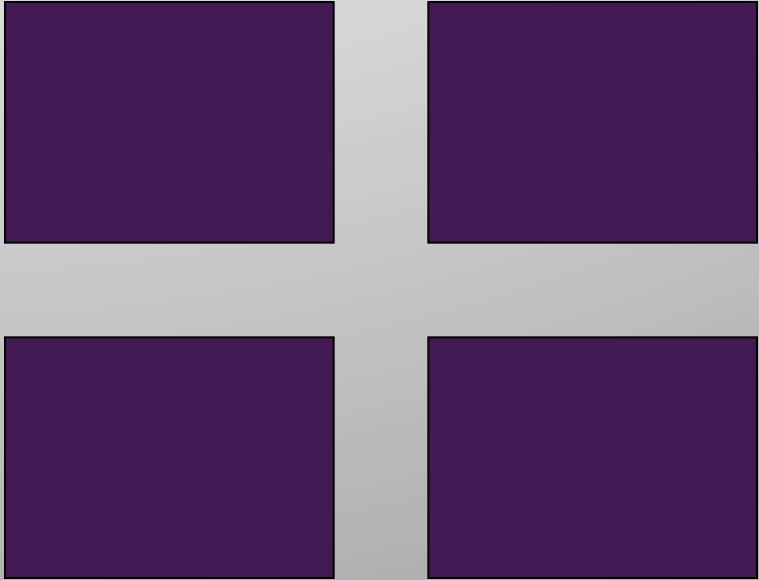


A pergunta do SLOSS não é espacialmente explícita:  
diferentes isolamentos



several small

or



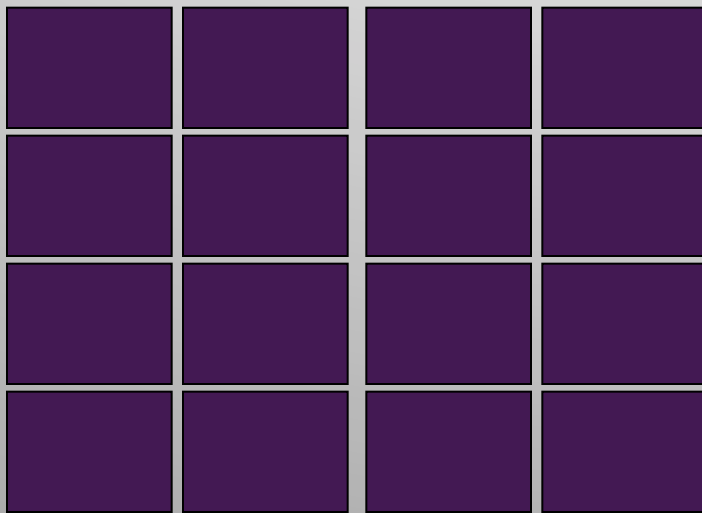
several small

Qual distanciamento ?

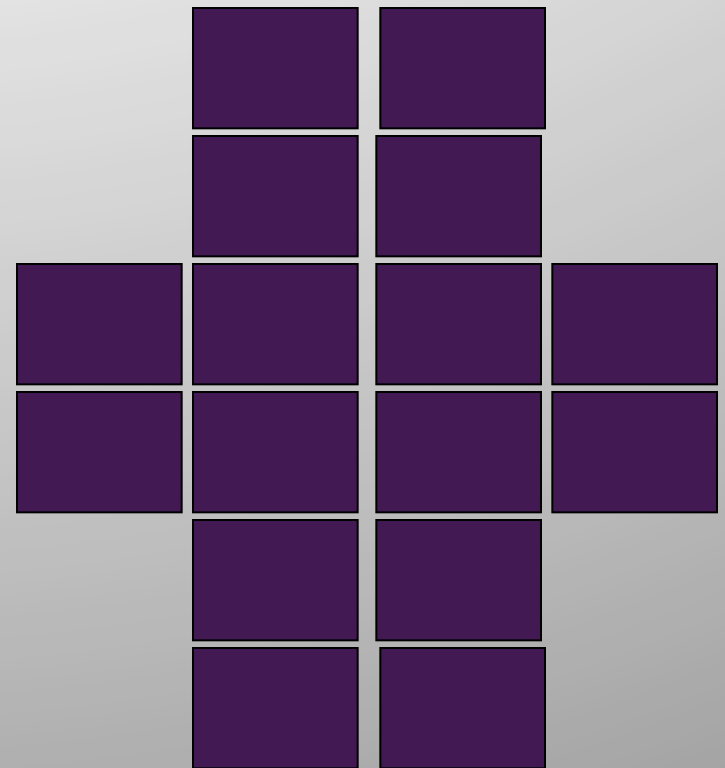


A pergunta do SLOSS não é espacialmente explícita:

diferentes distribuições espaciais



several small



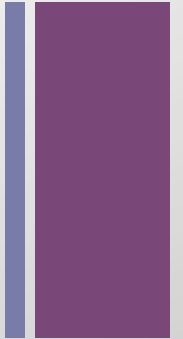
or

several small

Qual disposição?

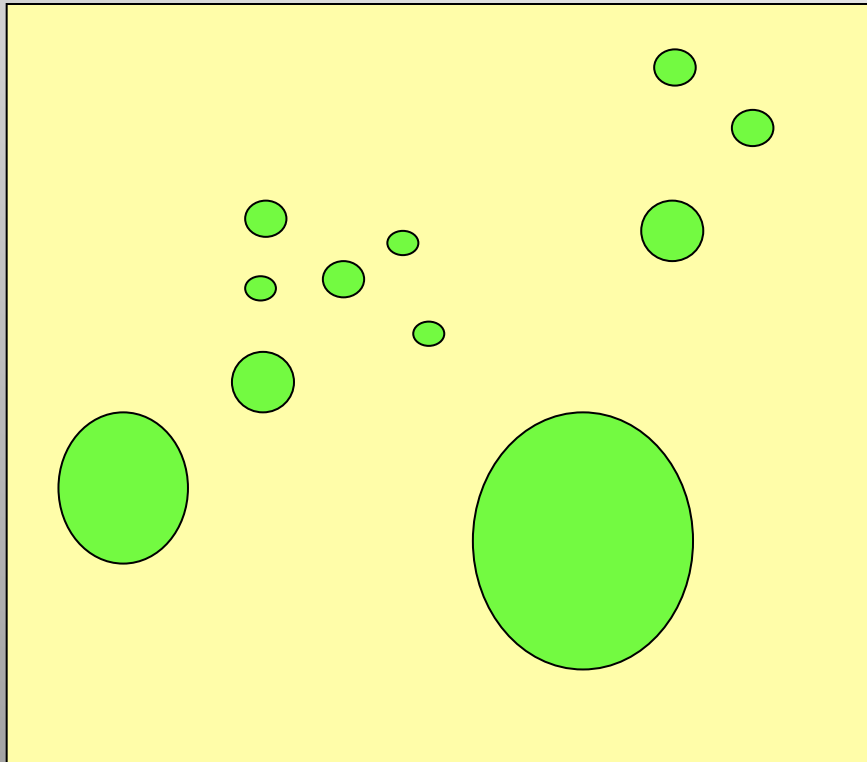








# A fragmentação de habitats como principal ameaça à biodiversidade



- **O que é fragmentação?**
- Por que devemos nos preocupar com a fragmentação?
- Respostas no tempo
- Implicações para conservação

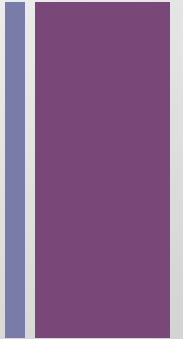
# Dinâmica de paisagens



-  Quantidade de habitat
-  Tamanho dos fragmentos
-  Conectividade dos fragmentos
-  Isolamento entre os fragmentos
-  Número de fragmentos
-  Borda habitat/não-habitat

+

# Qual a porcentagem dos alunos definiram fragmentação



- como um **processo de ruptura da continuidade?**

41% (D)

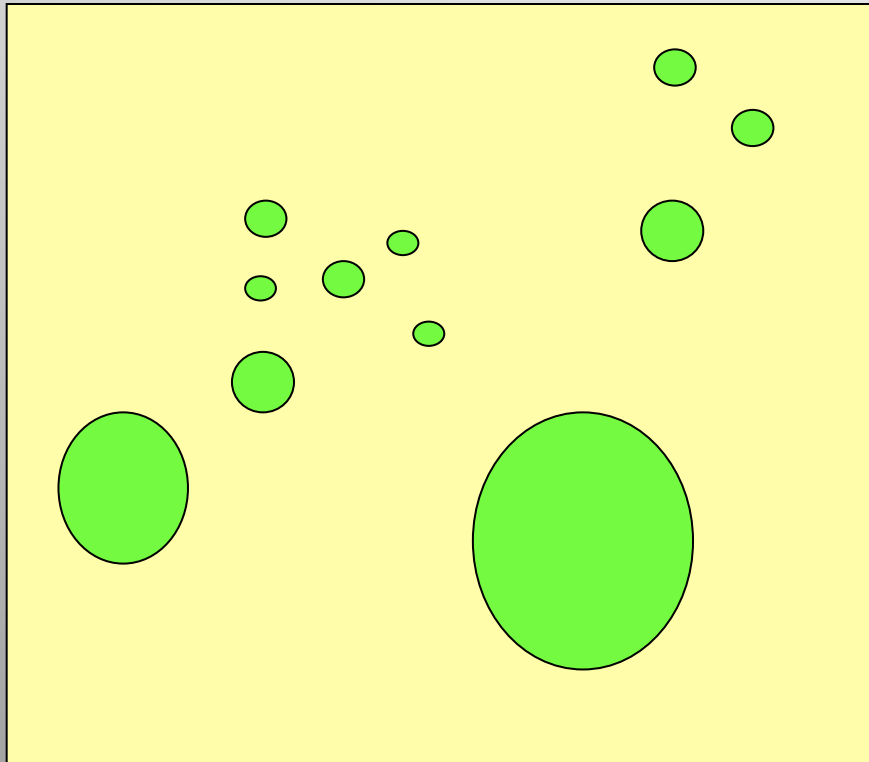
65% (N)

- de uma forma mais ampla, como um **processo de perda de habitat e mudança na disposição espacial deste habitat?**

59% (D)

35% (N)

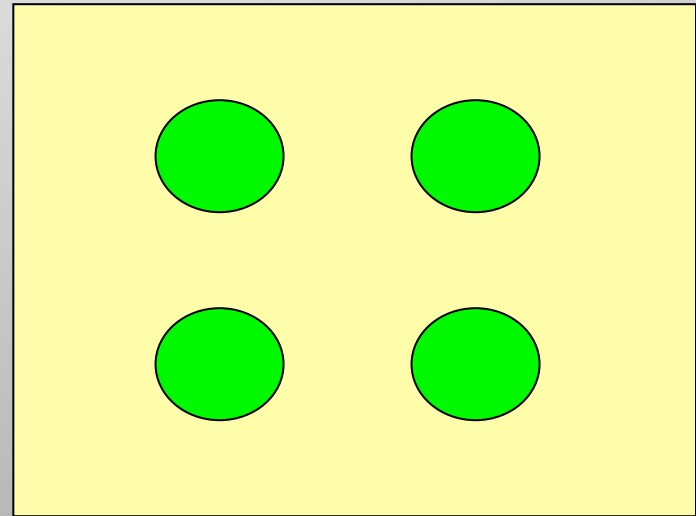
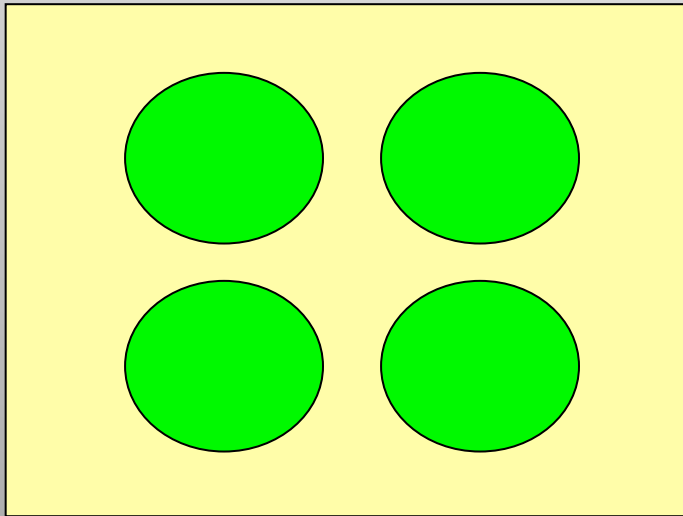
# Perda de habitat e fragmentação



- Quantidade de habitat
- Tamanho dos fragmentos
- Conectividade dos fragmentos
- Isolamento entre os fragmentos
- Número de fragmentos
- Borda habitat/não-habitat



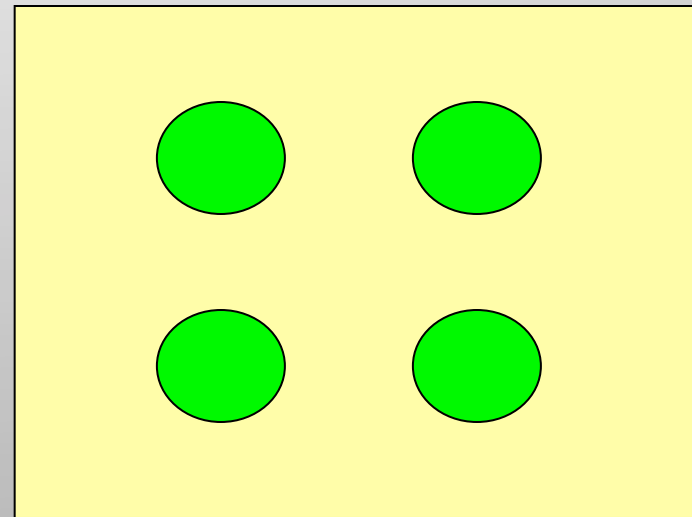
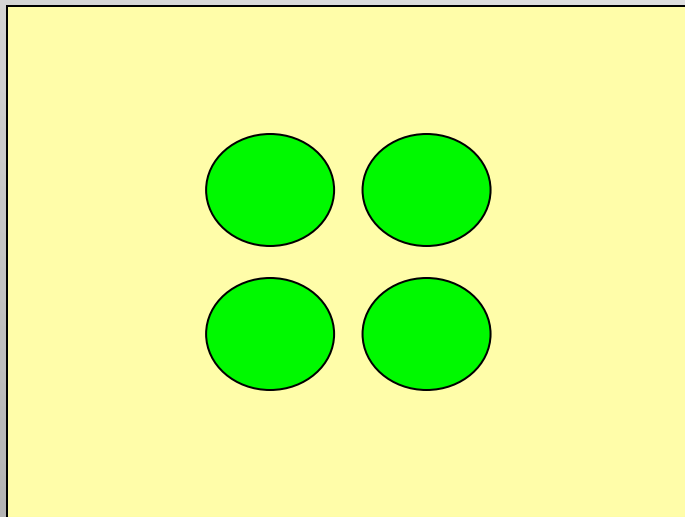
# Fragmentação $\neq$ Redução no tamanho dos fragmentos



Grande

Pequeno

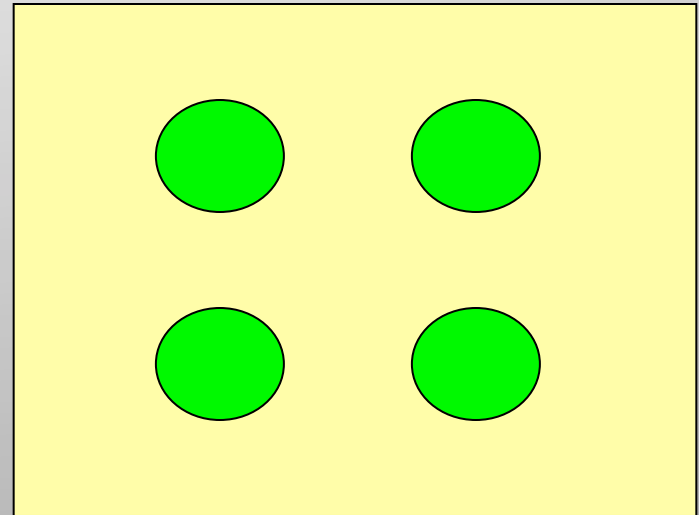
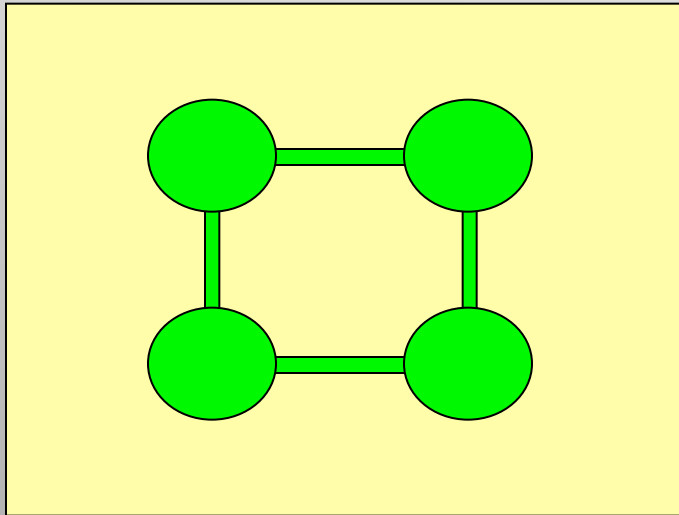
Fragmentação  $\neq$   
Aumento do isolamento



Baixo

Alto

Fragmentação  $\neq$   
Redução da conectividade



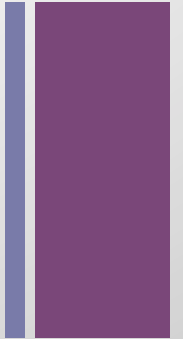
Alta

Baixa





# Qual a porcentagem dos alunos definiram fragmentação



- como um **processo dinâmico** (modificação da paisagem)?

53% (D)

74% (N)

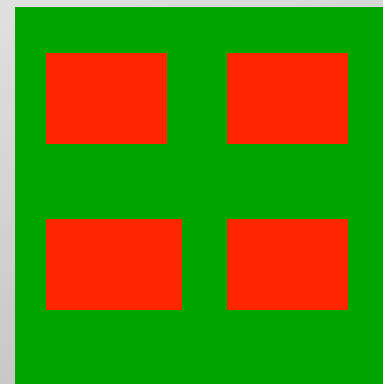
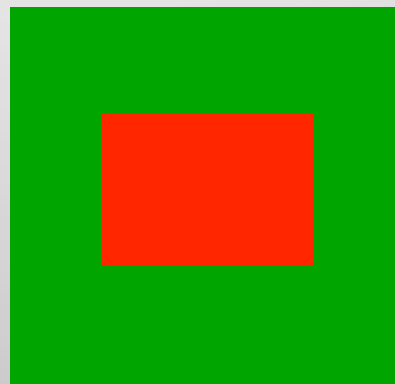
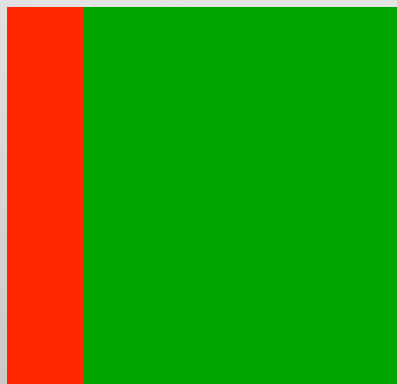
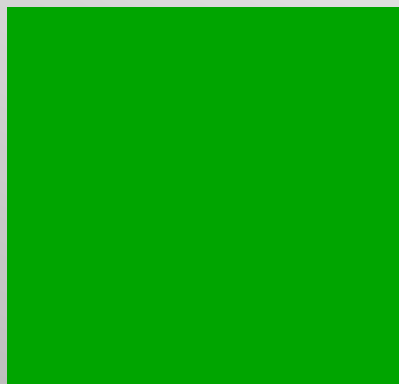
- como um grau de sub-divisão (**padrão espacial estático**)?

47% (D)

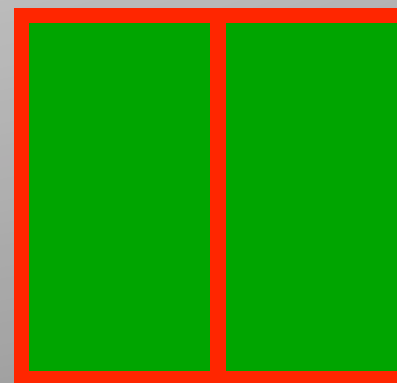
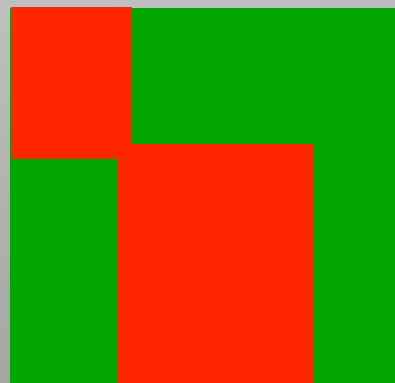
26% (N)

# FRAGMENTAÇÃO : ruptura na continuidade

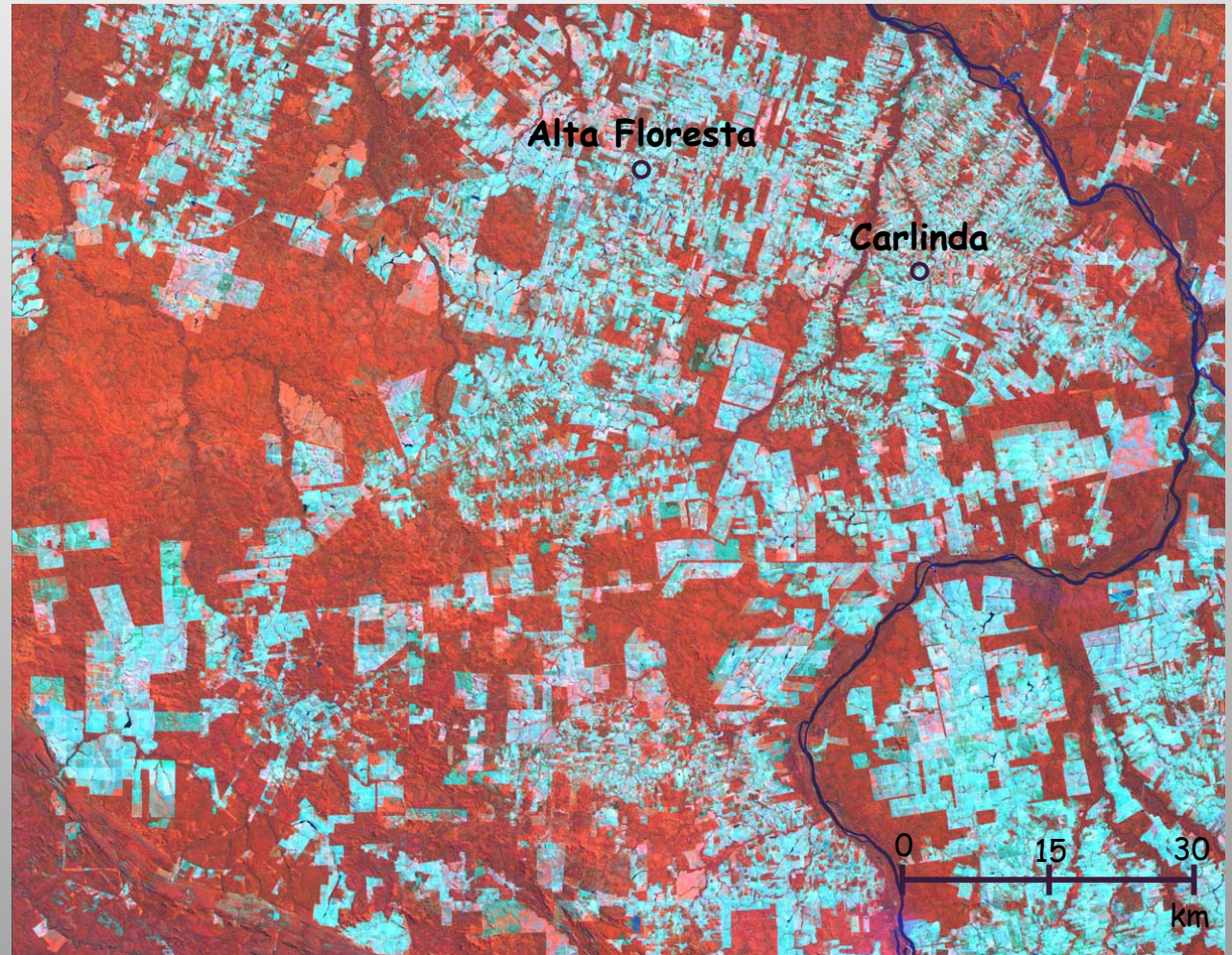
Perda de habitat **SEM** fragmentação



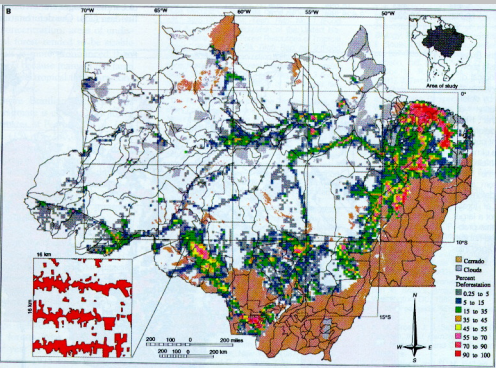
Perda de habitat **COM** fragmentação



# Desmatamento e fragmentação concomitantes...



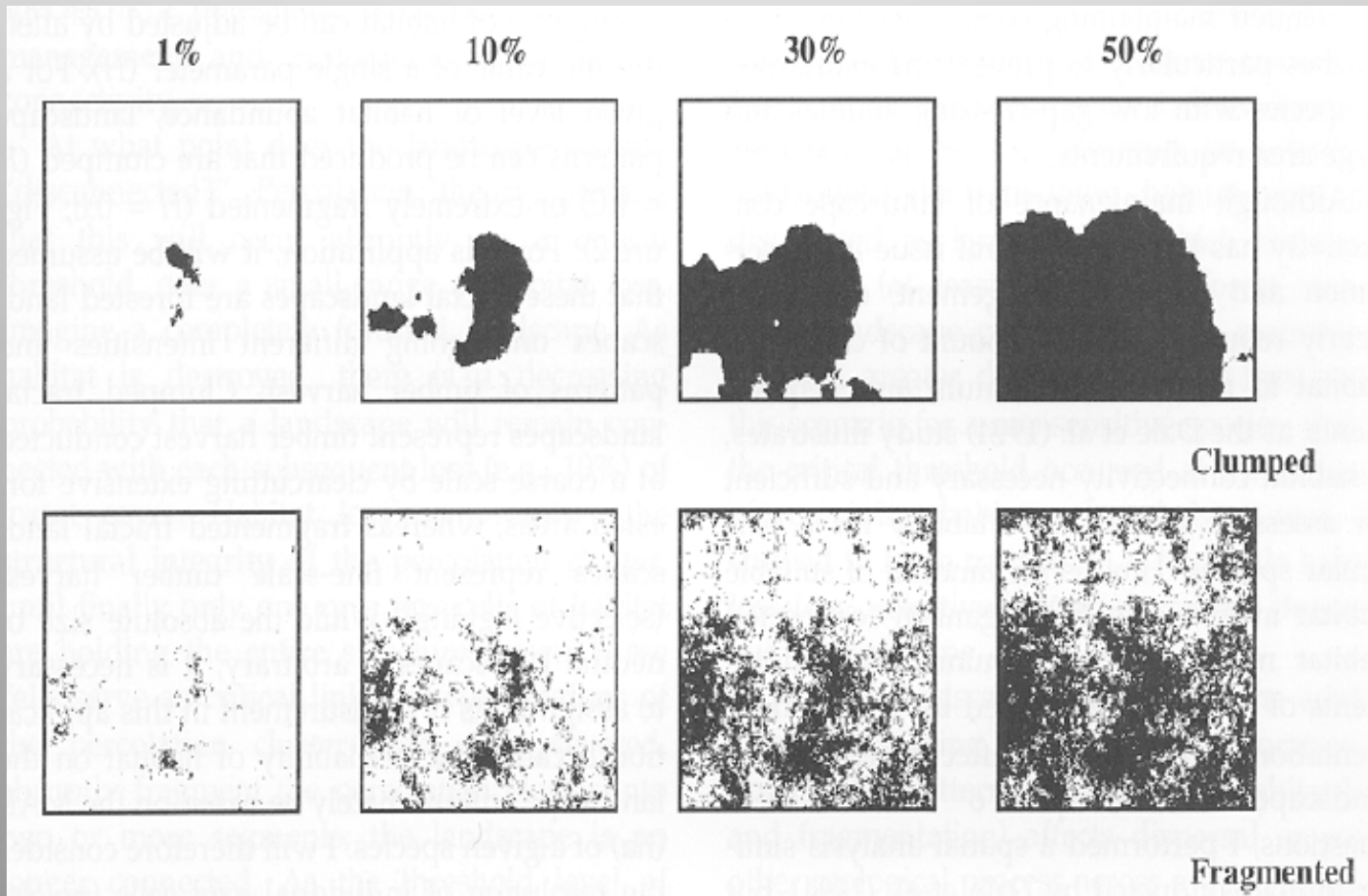
1984 —————> 1998



# Efeito conjunto de perda e fragmentação

Habitat loss

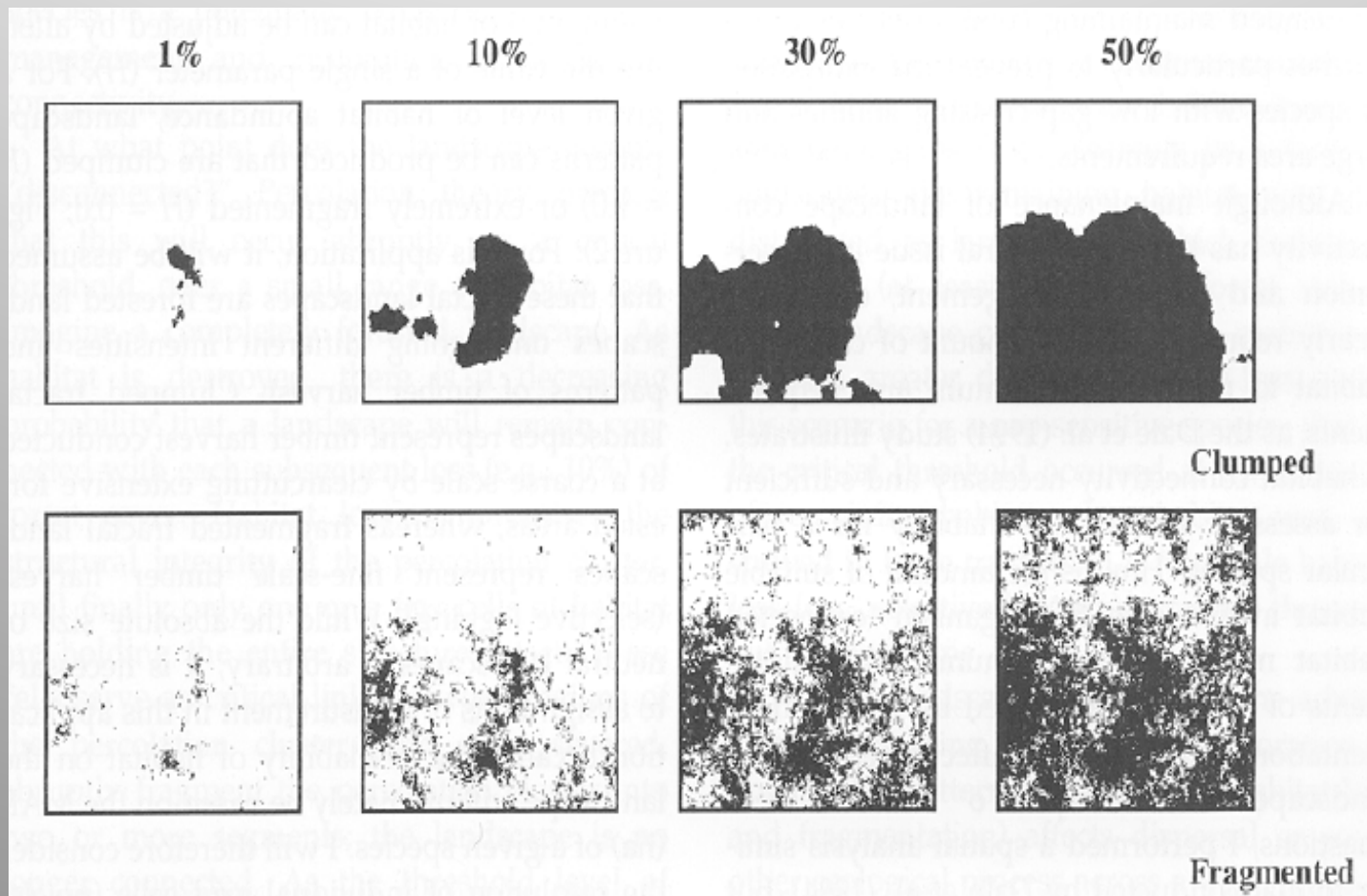
Fragmentation



# Como distinguir os efeitos de perda e fragmentação?

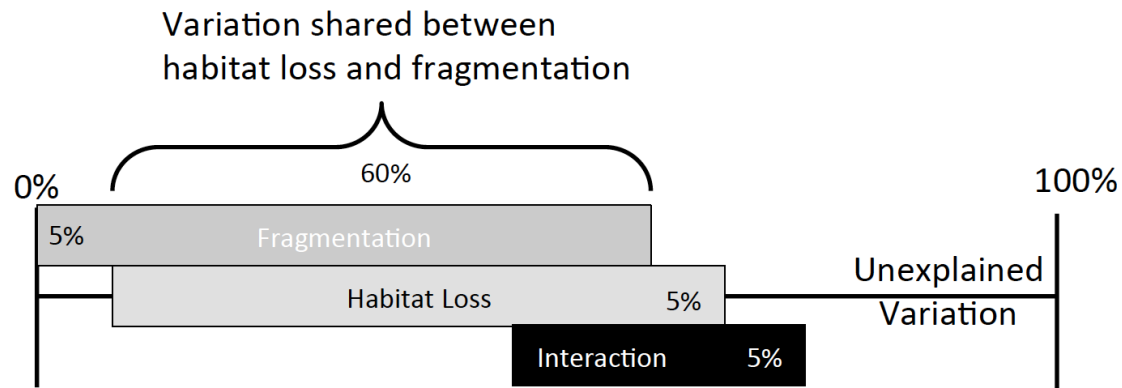
Habitat loss

Fragmentation

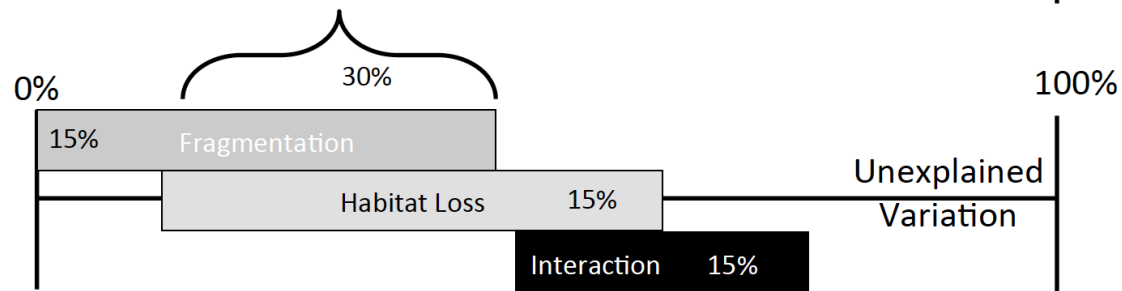


# Como distinguir os efeitos de perda e fragmentação?

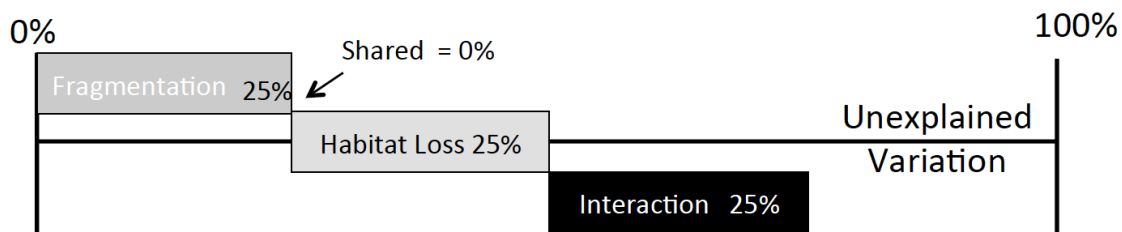
A) Random or poorly designed study

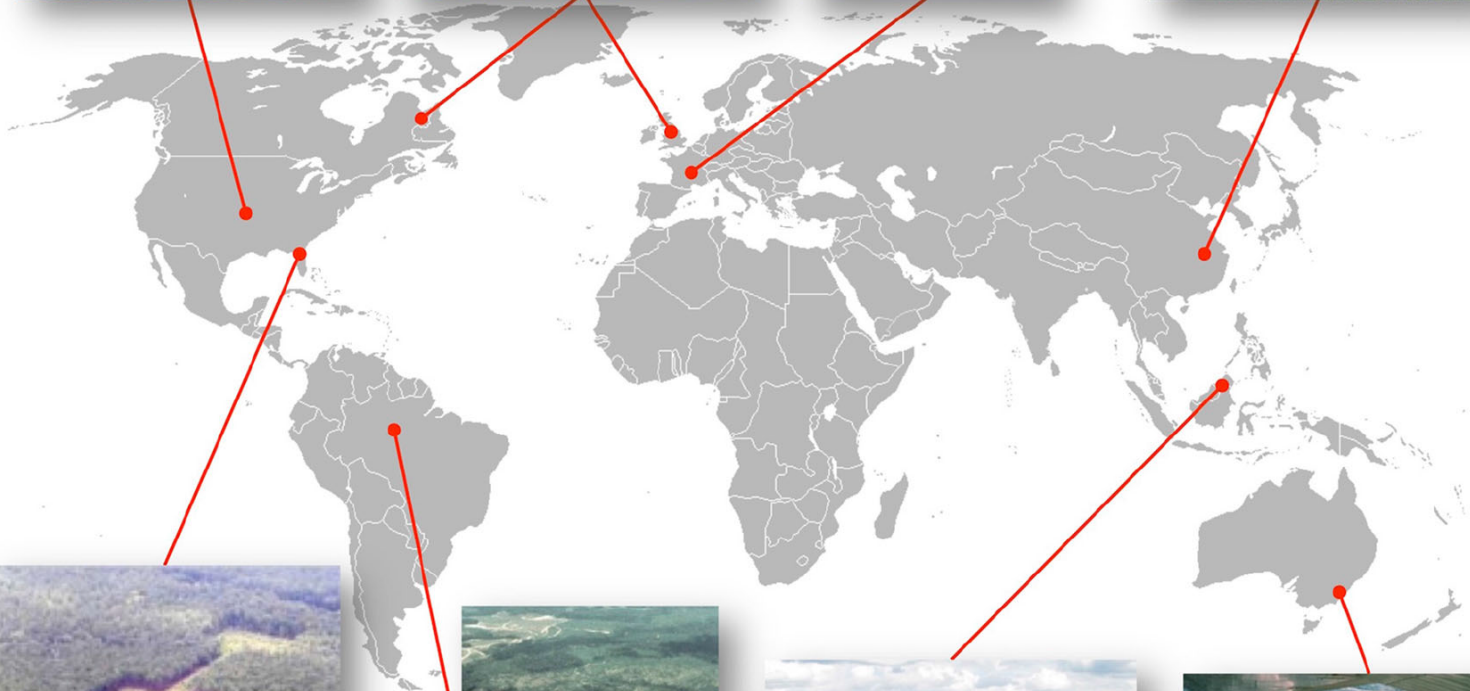


B) Mensurative experiment

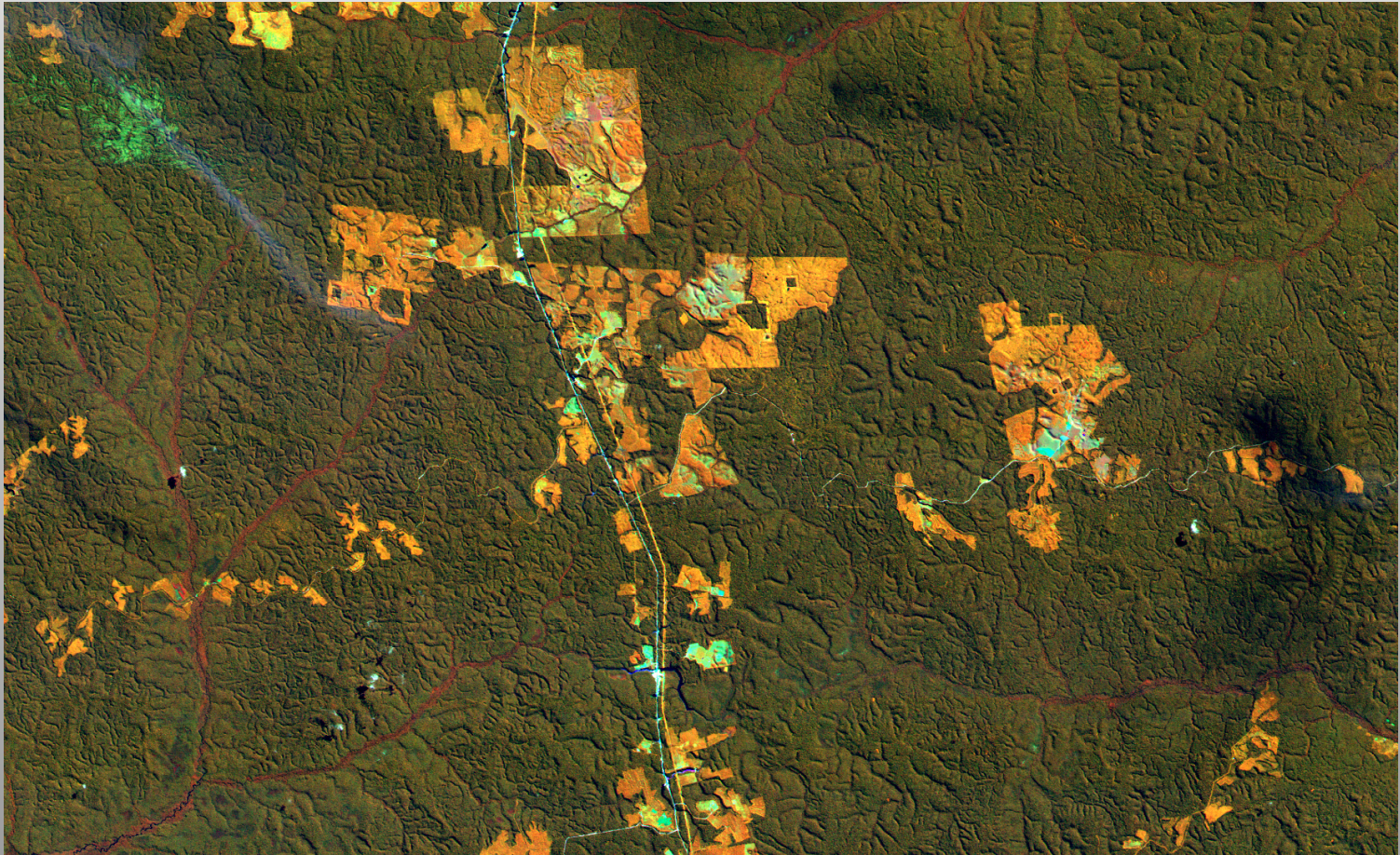


C) Manipulative experiment



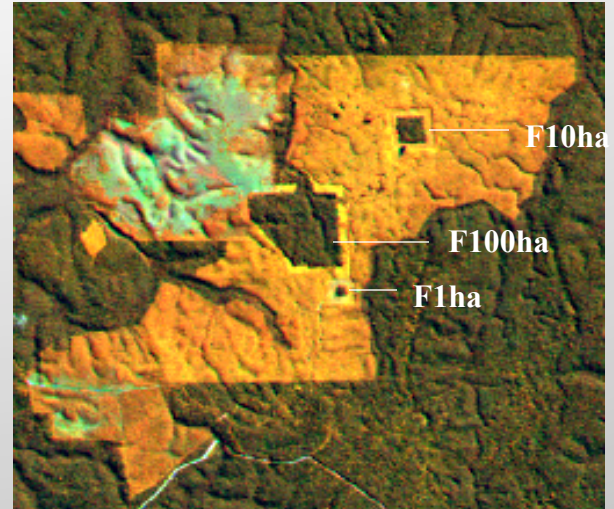


# Projeto Dinâmica Biológica de Fragmentos Florestais (PDBFF)

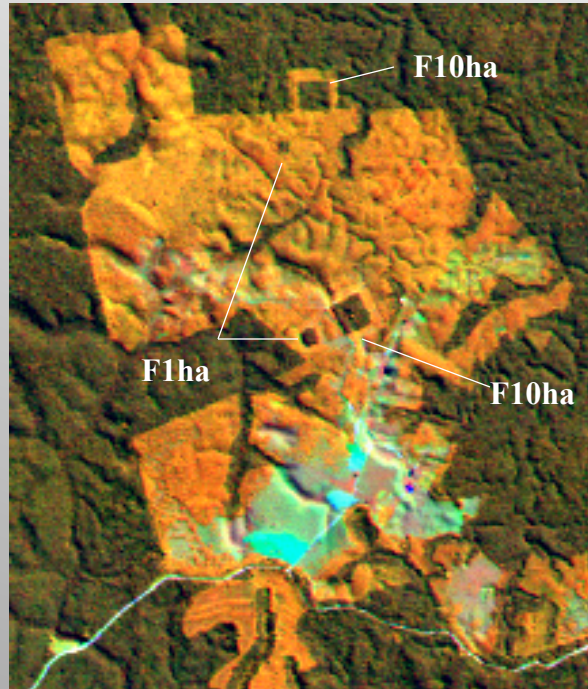




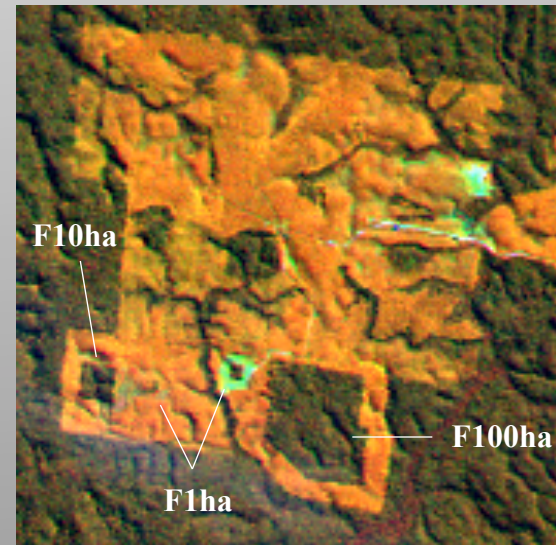
# Fazenda Porto Alegre



# Fazenda Esteio



# Fazenda Dimona



Segundo **Fahrig (2003)** :

PERDA DE HABITAT

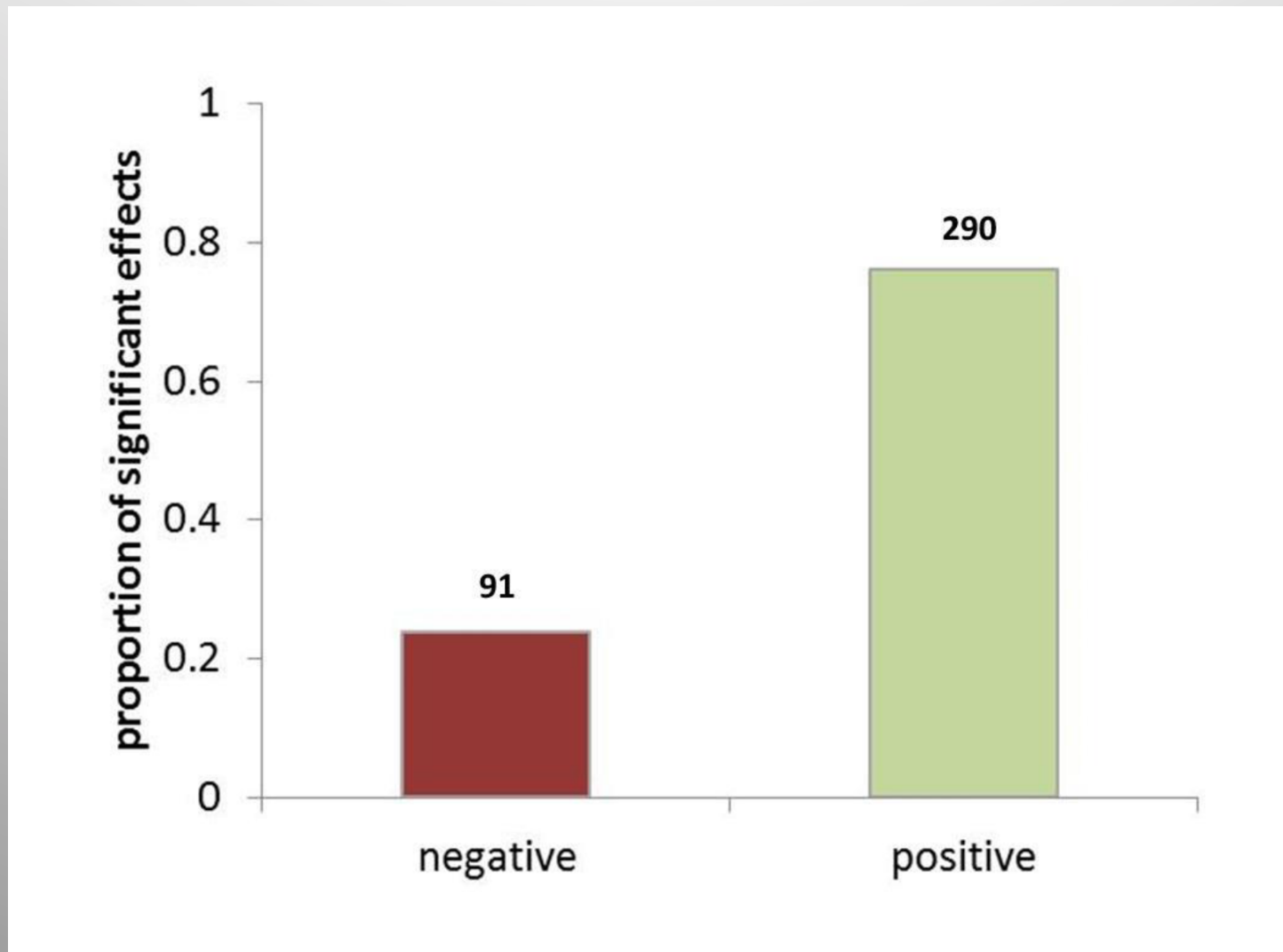


FRAGMENTAÇÃO

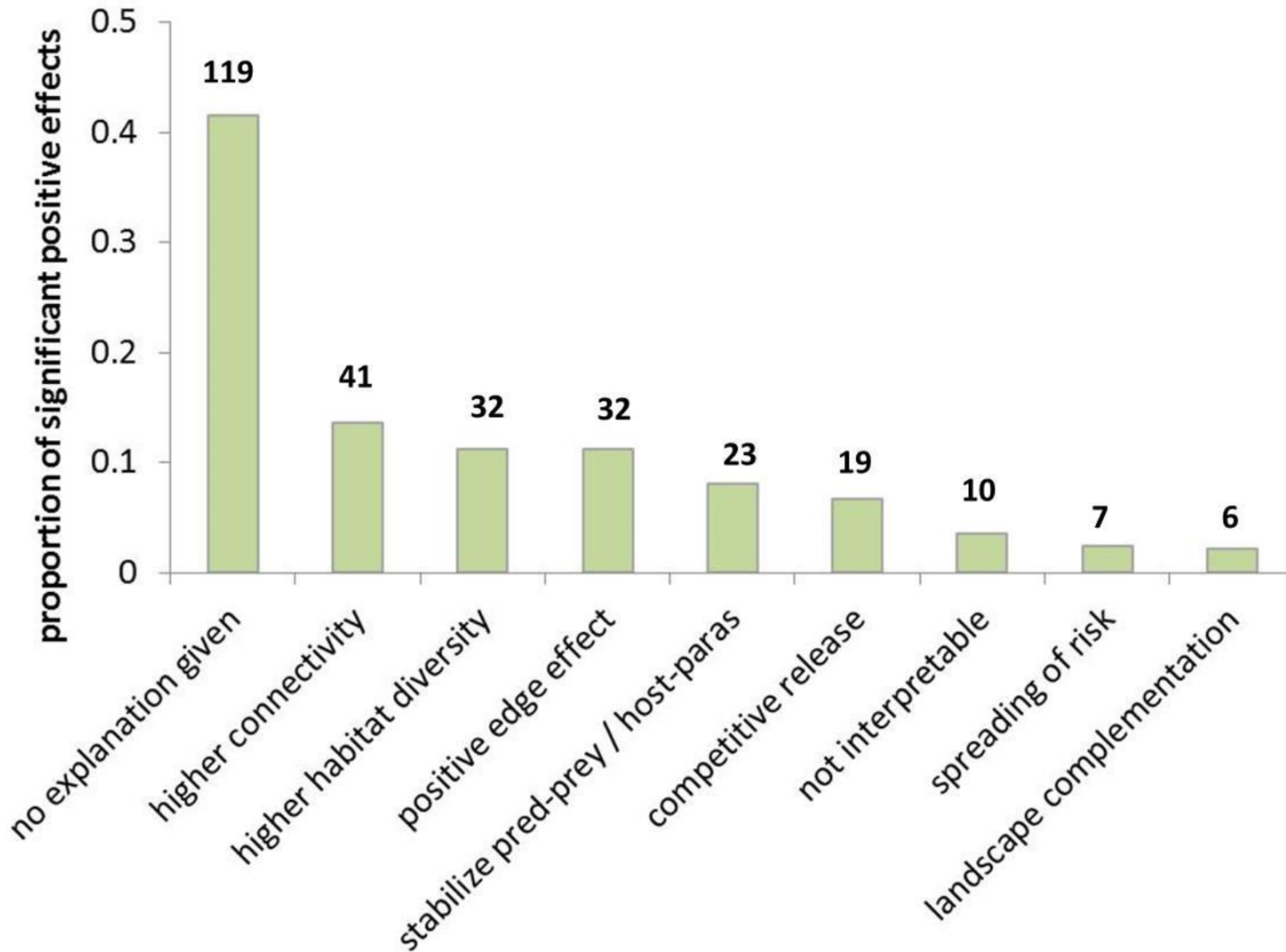
**Lenore Fahrig 2003.** Effects of Habitat Fragmentation on Biodiversity

*Annual Review of Ecology and Systematics*

Segundo **Fahrig (2017)** :

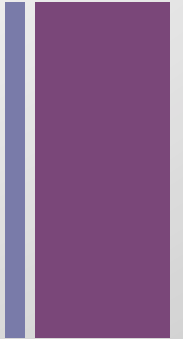


## Segundo **Fahrig (2017)** :





# A fragmentação de habitats como principal ameaça à biodiversidade



- O que é fragmentação?
- **Por que devemos nos preocupar com a fragmentação? (e a perda da habitat)**
- Respostas no tempo
- Implicações para conservação

## 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. Lovejoy,<sup>7</sup> Joseph O. Sexton,<sup>8</sup> Mike P. Austin,<sup>9</sup> Cathy D. Collins,<sup>10</sup> William M. Cook,<sup>11</sup> Ellen I. Damschen,<sup>12</sup> Robert M. Ewers,<sup>13</sup> Bryan L. Foster,<sup>14</sup> Clinton N. Jenkins,<sup>15</sup> Andrew J. King,<sup>9</sup> William F. Laurance,<sup>16</sup> Douglas J. Levey,<sup>17</sup> Chris R. Margules,<sup>18,19</sup> Brett A. Melbourne,<sup>4</sup> A. O. Nicholls,<sup>9,20</sup> John L. Orrock,<sup>12</sup> Dan-Xia Song,<sup>8</sup> John R. Townshend<sup>8</sup>

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.

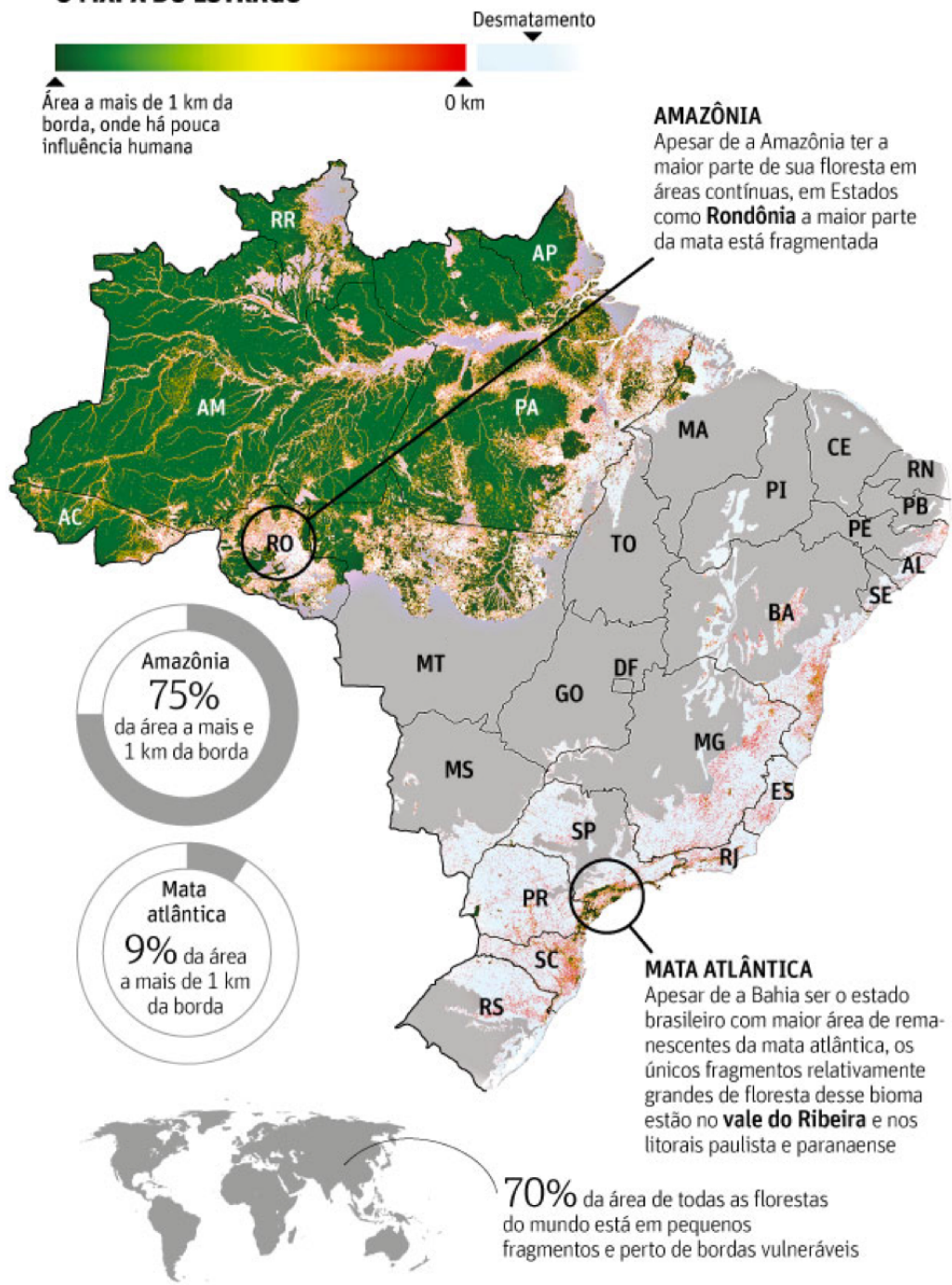
2015 © The Authors, some rights reserved; exclusive licensee American Association for the Advancement of Science. Distributed under a Creative Commons Attribution License 4.0 (CC BY).  
10.1126/sciadv.1500052

## Fragmentação deixa 70% das florestas sob ameaça, aponta estudo

RAFAEL GARCIA  
DE SÃO PAULO

23/03/2015 © 01h55

### O MAPA DO ESTRAGO



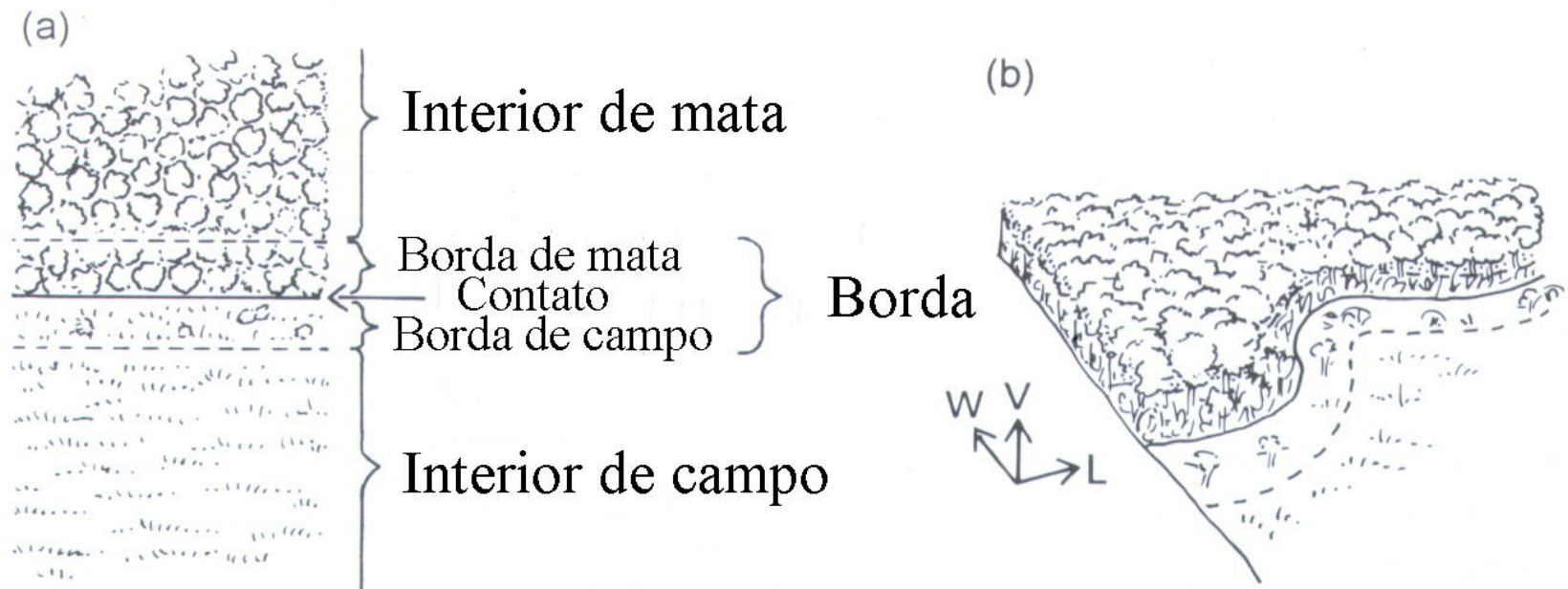
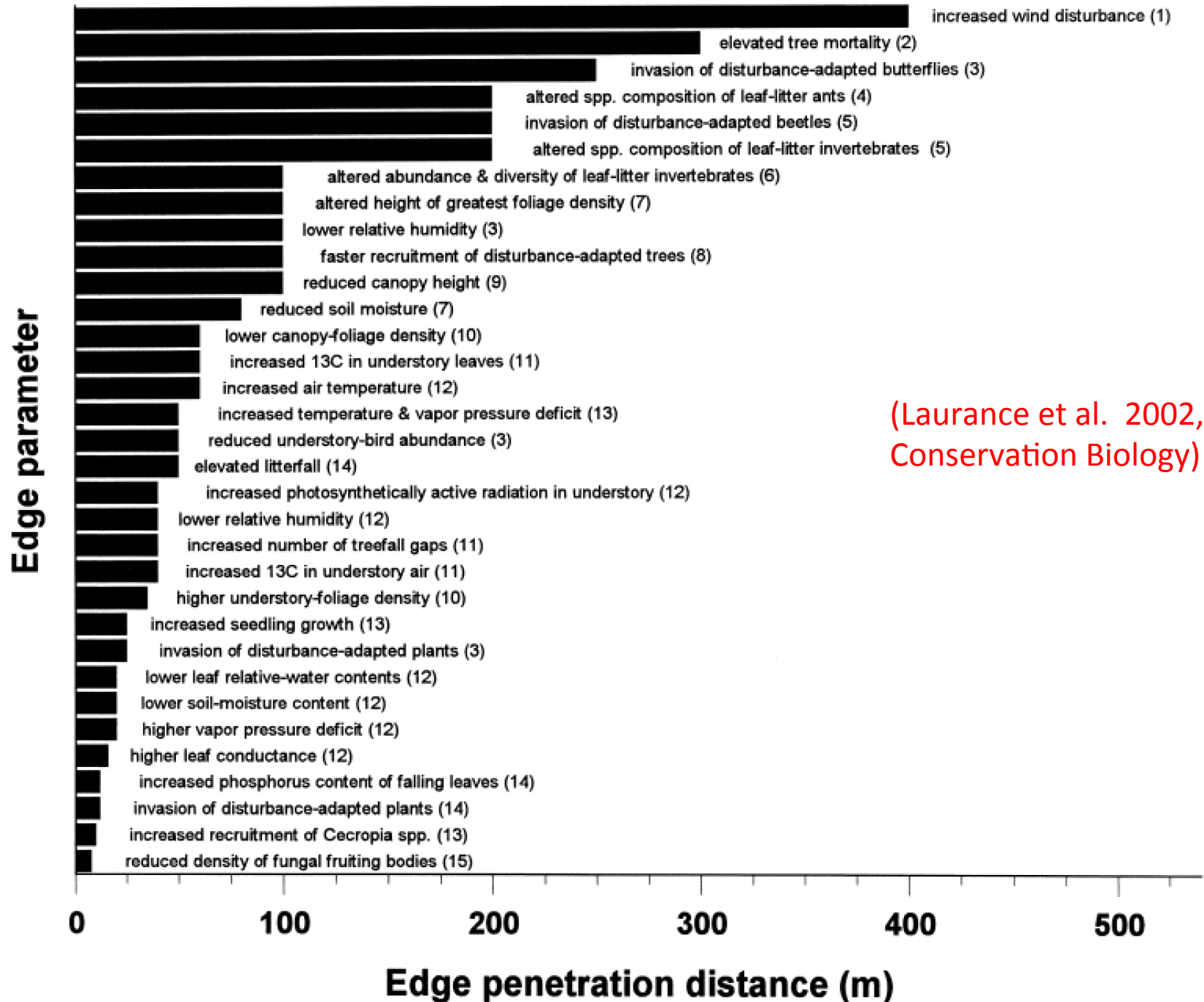


Fig. 3.4. Spatial relationships of boundary, border, and edges. Adapted from Forman & Moore (1992). W = width dimension of edge; V = vertical; L = length.



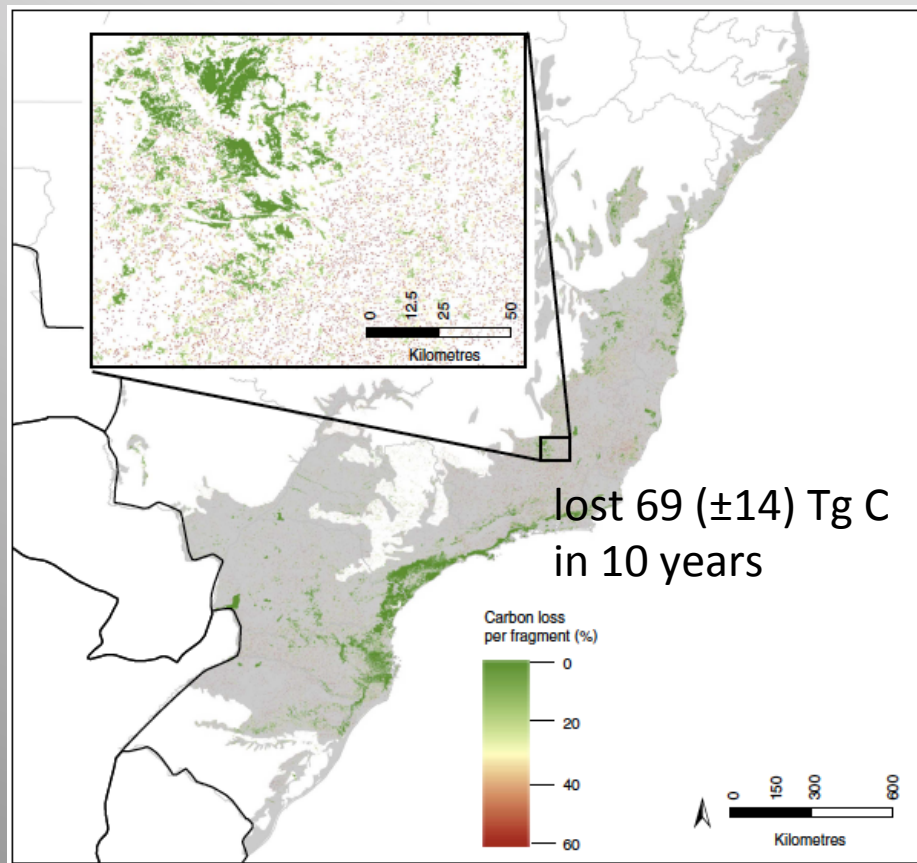


(Laurance et al. 2002,  
Conservation Biology)

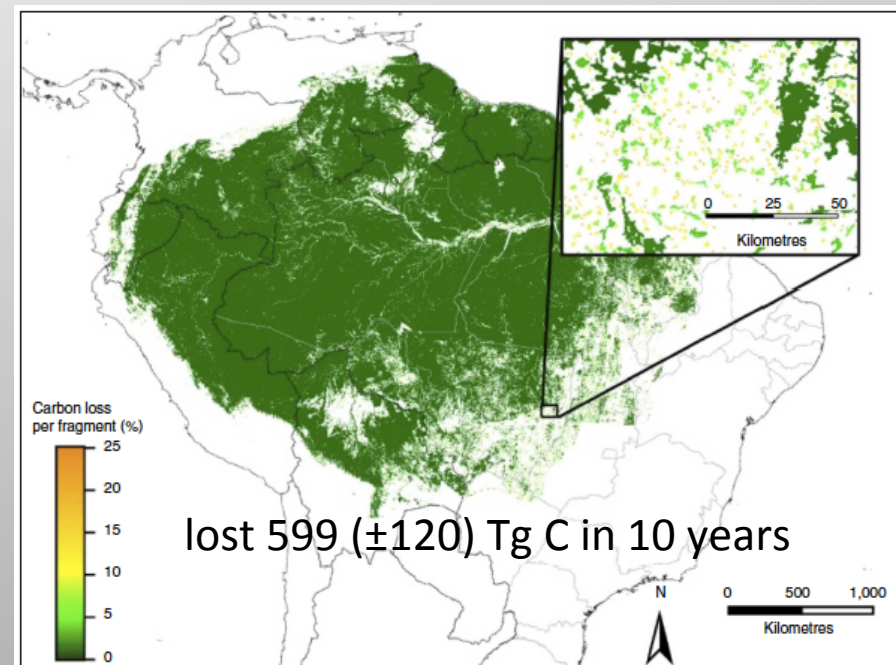
# Long-term carbon loss in fragmented Neotropical forests

Sandro Pütz<sup>1,2,3</sup>, Jürgen Groeneveld<sup>1,4</sup>, Klaus Henle<sup>3</sup>, Christoph Knogge<sup>3</sup>, Alexandre Camargo Martensen<sup>5</sup>, Markus Metz<sup>6</sup>, Jean Paul Metzger<sup>7</sup>, Milton Cezar Ribeiro<sup>7,8</sup>, Mateus Dantas de Paula<sup>1</sup> & Andreas Huth<sup>1,9,10</sup>

## Atlantic Forest



## Amazonian Forest



For all tropical forests, we estimate emissions up to 0.2 Pg Cy<sup>-1</sup> or **9 to 24% of the annual global C loss due to deforestation**



# Year

1980

1990

2000

2010



Biological Dynamics of Forest Fragments (Brazil)



Kansas Fragmentation Experiment (USA)



Wog Wog Fragmentation Experiment (Australia)

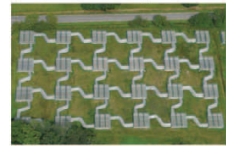


SRS Corridor Experiment (USA)



Moss Fragmentation (UK, Canada)

Metatron (France)



S.A.F.E. Project (Borneo)



## Legend:



Evergreen broadleaf tree



Evergreen coniferous tree



Shrub/palm/small tree



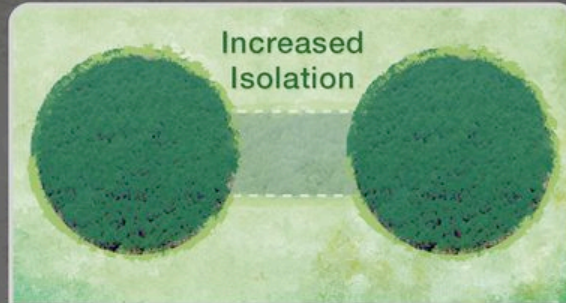
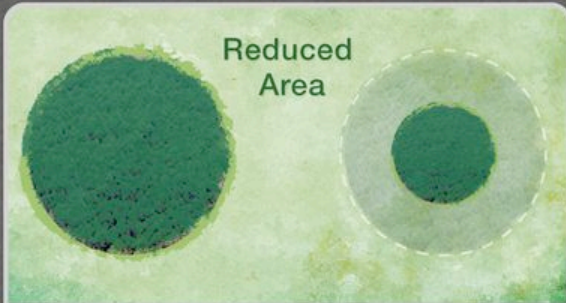
Grassland or moss



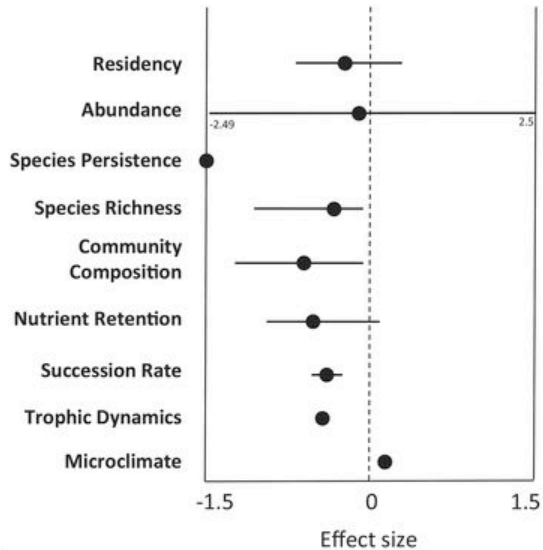
Successional

Variable			Area (ha)	Fragment	Matrix
Area	Isolation	Edge			
✓		✓	100		
✓	✓	✓	0.5		
✓	✓	✓	3.1		
	✓	✓	1.4		
✓	✓	✓	$2 \times 10^{-7}$		
	✓		0.01		
✓	✓	✓	100		

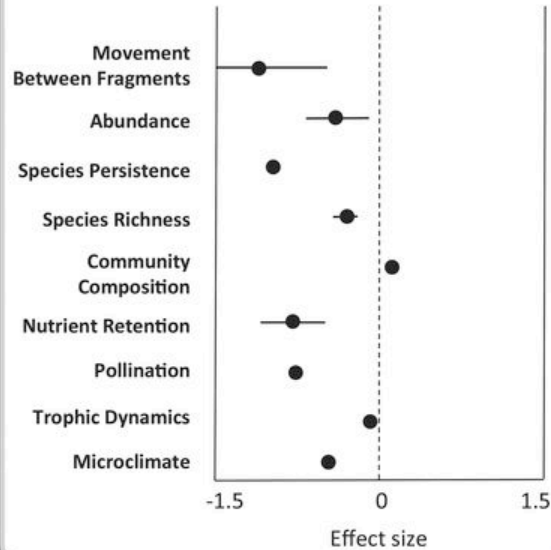
(Haddad et al. 2015)



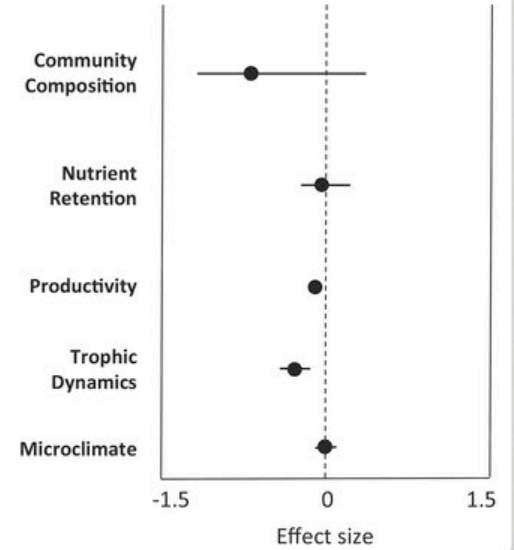
**A Reduced Area**



**B Increased Isolation**

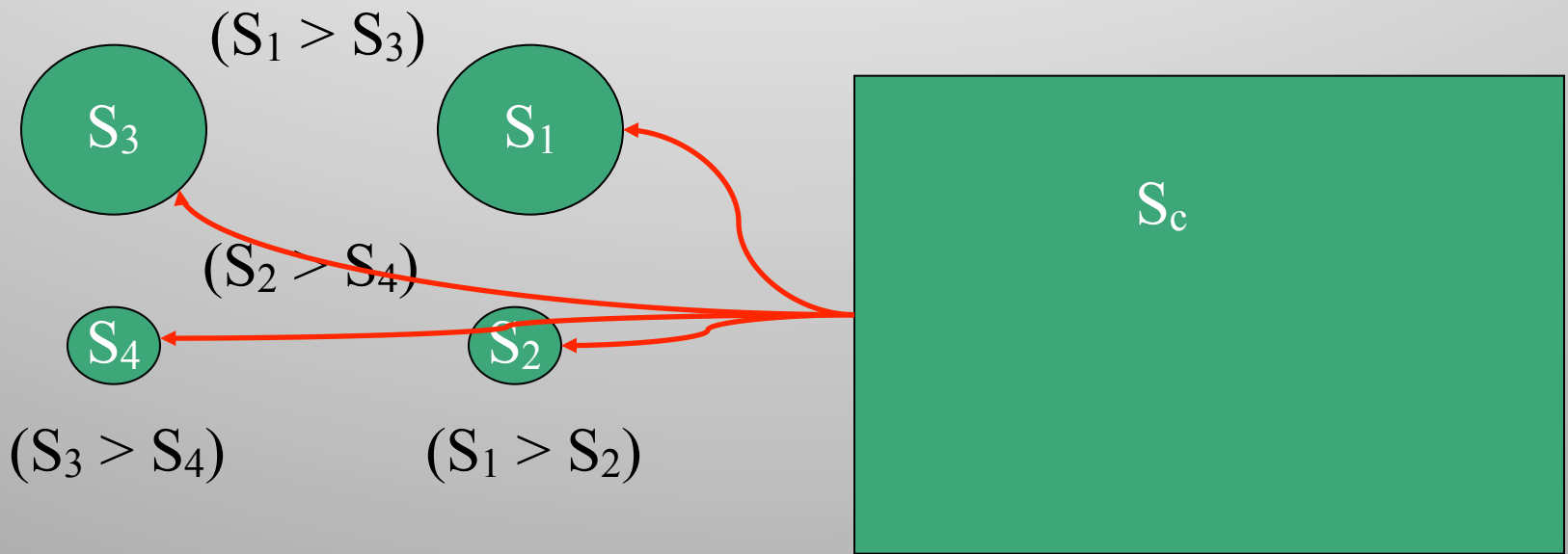


**C Increased Edge**



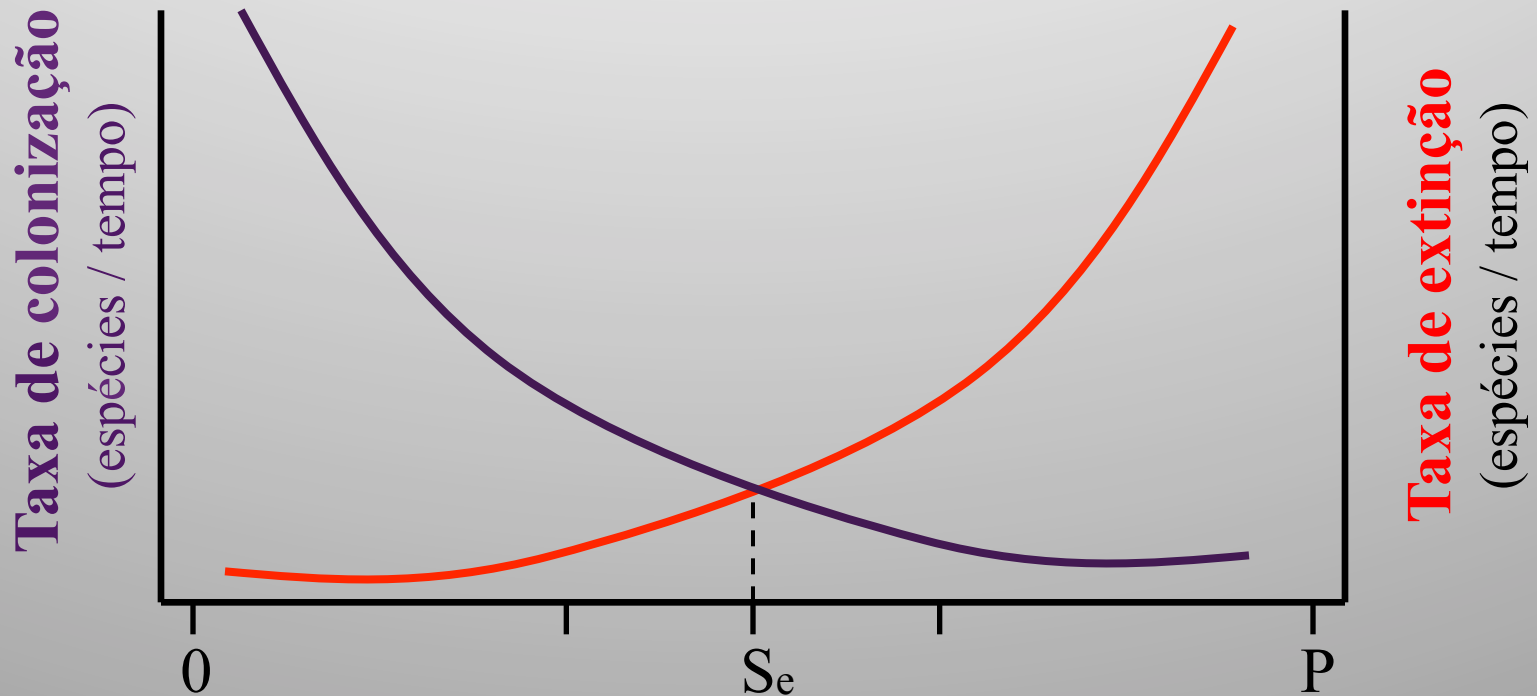
(Haddad et al. 2015)

# A teoria da biogeografia das ilhas



(MacArthur & Wilson 1967)

➔ Existe um **equilíbrio dinâmico** entre extinção e imigração

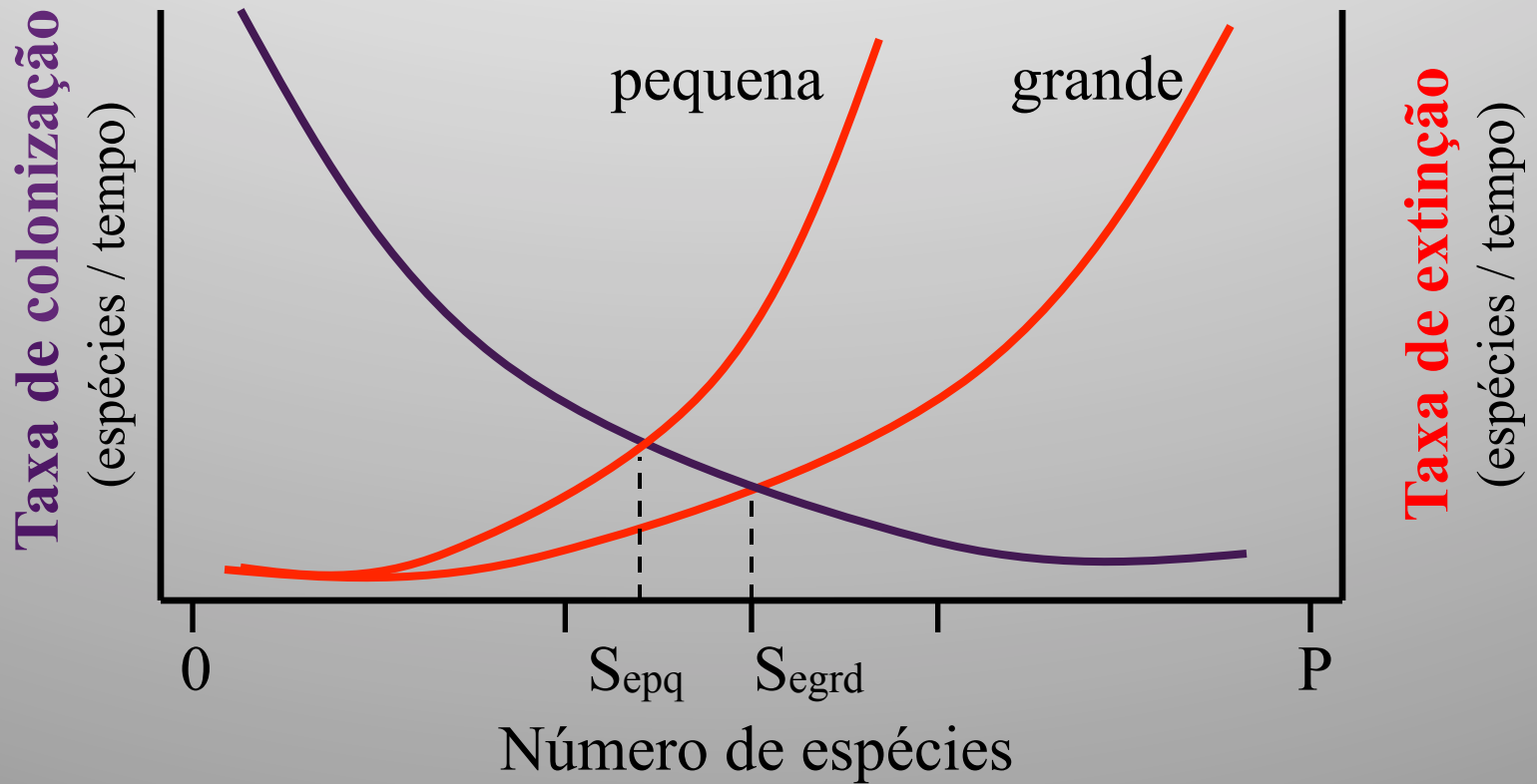


Espécies com maior capacidade de locomoção chegam mais rapidamente

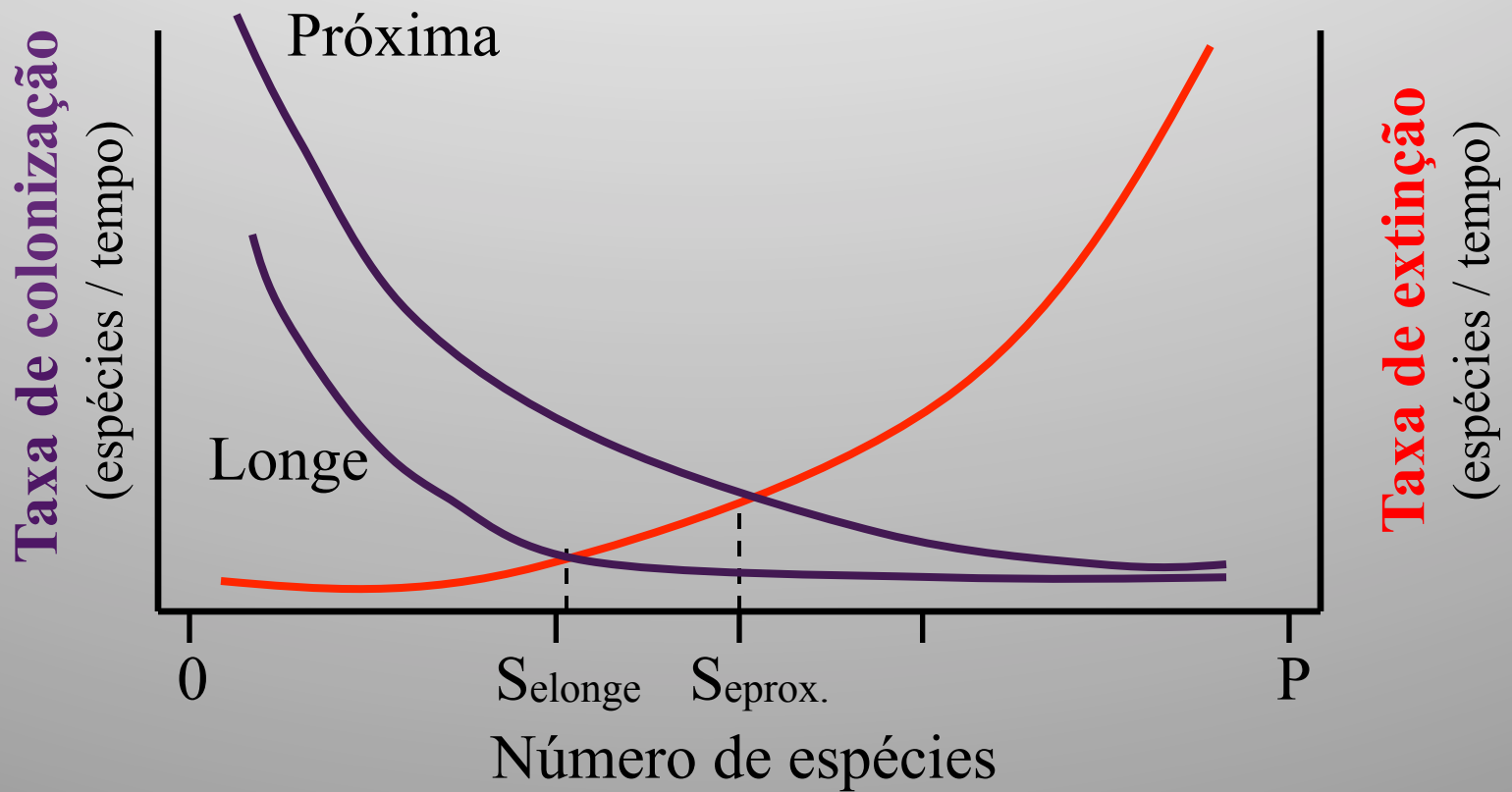
Número de espécies

Predação e competição aumentam o risco de extinção

➔ Este **equilíbrio dinâmico** depende da área da ilha.



➔ Este **equilíbrio dinâmico** depende do isolamento da ilha.





# Fragmentação



**ESTRUTURAL**

**FUNCIONAL**

Redução na  
área do  
fragmento



**> Extinção local**

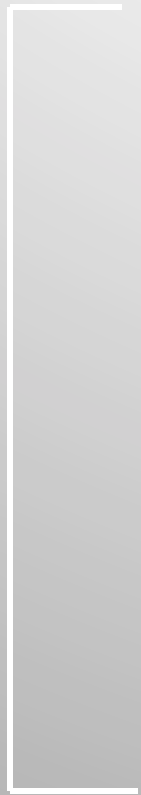


**EXTINÇÃO**

Isolamento

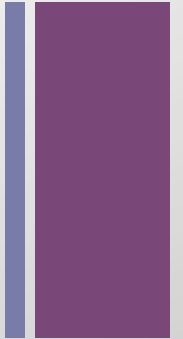


**< recolonização**





# A fragmentação de habitats como principal ameaça à biodiversidade



- O que é fragmentação?
- Por que devemos nos preocupar com a fragmentação?
- **Respostas no tempo**
- Implicações para conservação

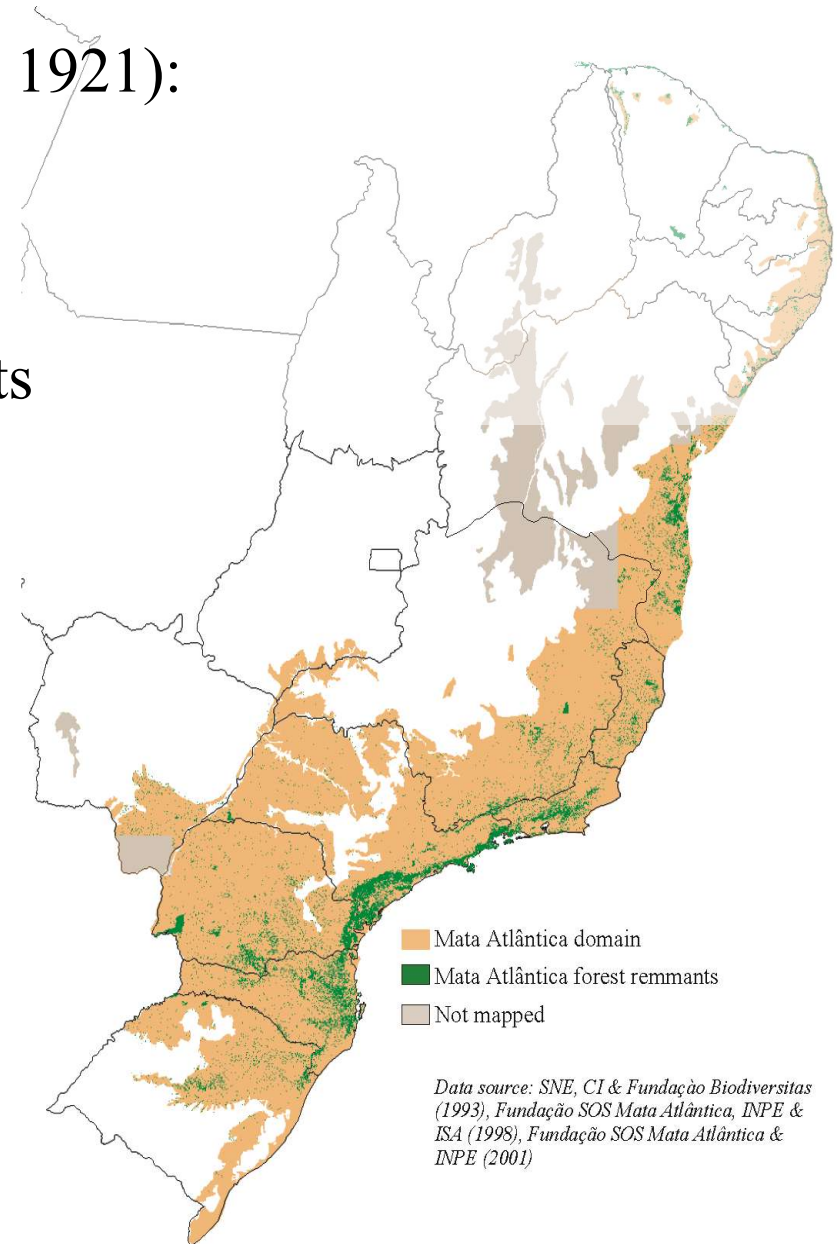
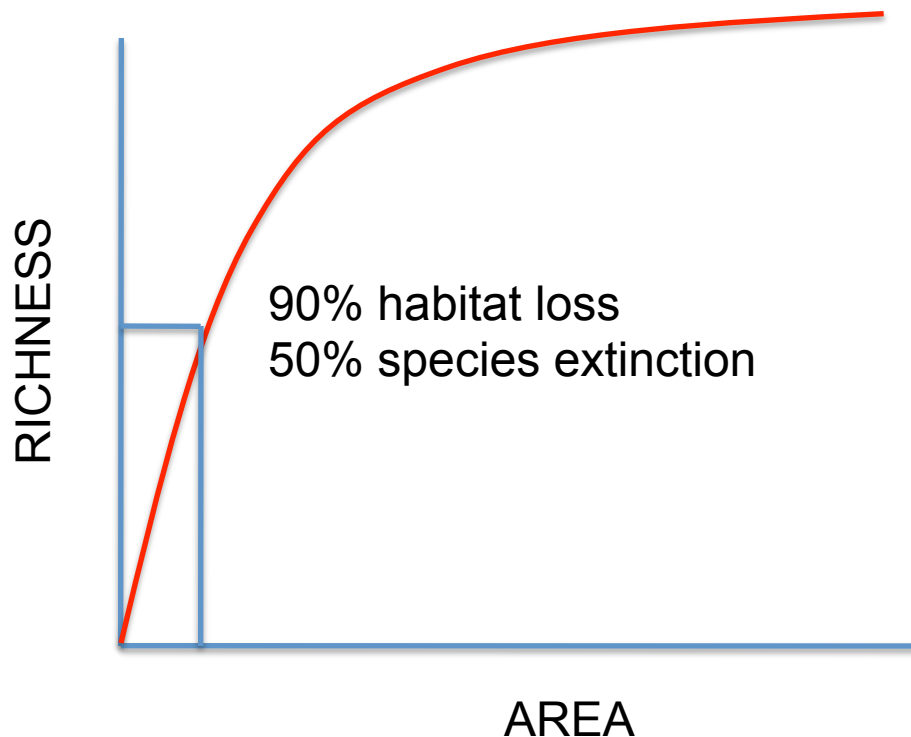
# Species-Area Relationship (Arrhenius 1921):

$$S = c A^z$$

where:  $S$ : richness

$A$ : area

$c$  and  $z$  constants

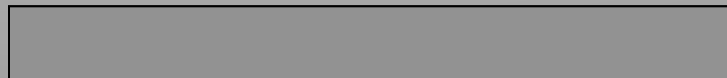


## Atlantic Forest Extinction

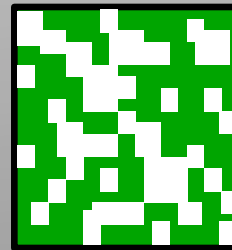
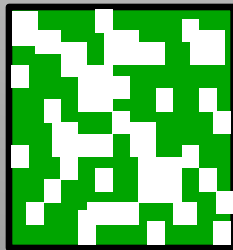
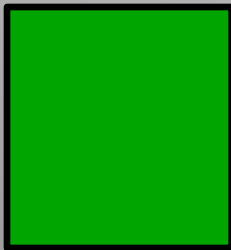
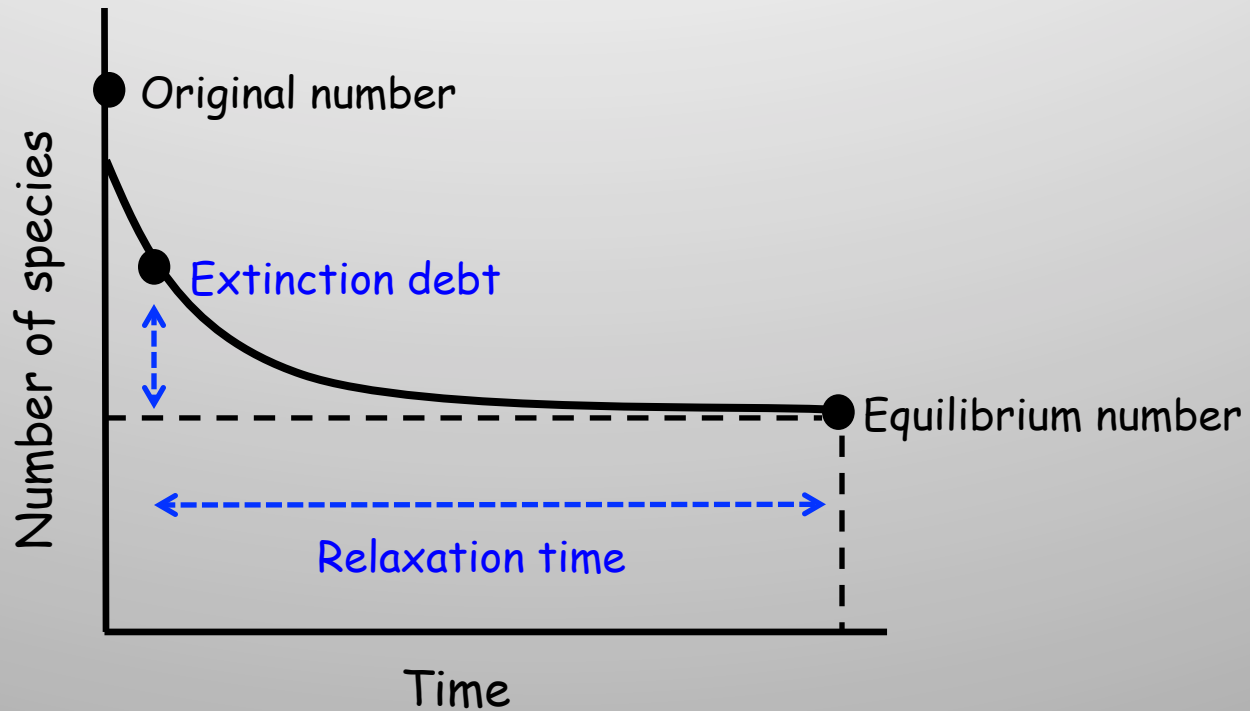
(Brooks & Balmford 1996, Nature)

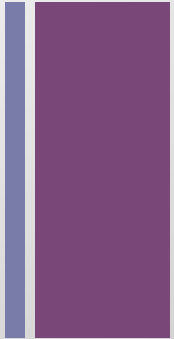
Name of area	EBA code	Proportion of forest remaining ( $A_n/A_o$ )	Endemic bird species ( $S_o$ )	Extinctions predicted from forest losses ( $S_e$ )	Currently threatened species ( $S_t$ )
Alagoan Atlantic slope	B47	0.02	11	7	9
Bahian deciduous forest	B48	0.06	2	1	2
Brazilian lowlands	B51/52	0.12	57	24	27
Araucaria forest	B54	0.20	4	1	2
<b>Whole region</b>		<b>0.12</b>	<b>214 (= 74+140)</b>	<b>88</b>	<b>60 (= 40+20)</b>

# Fragmentation and species extinction

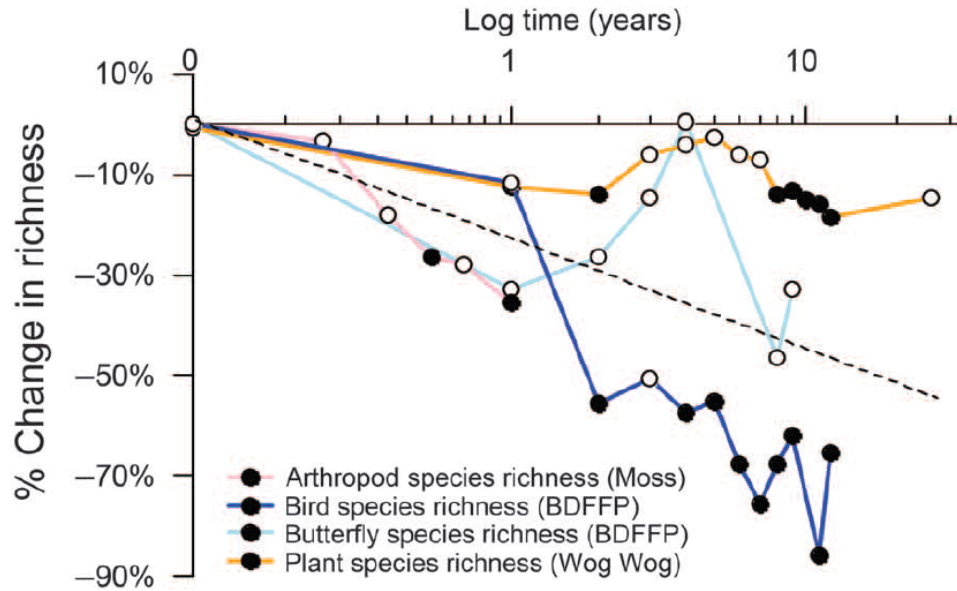


# Débito de extinção

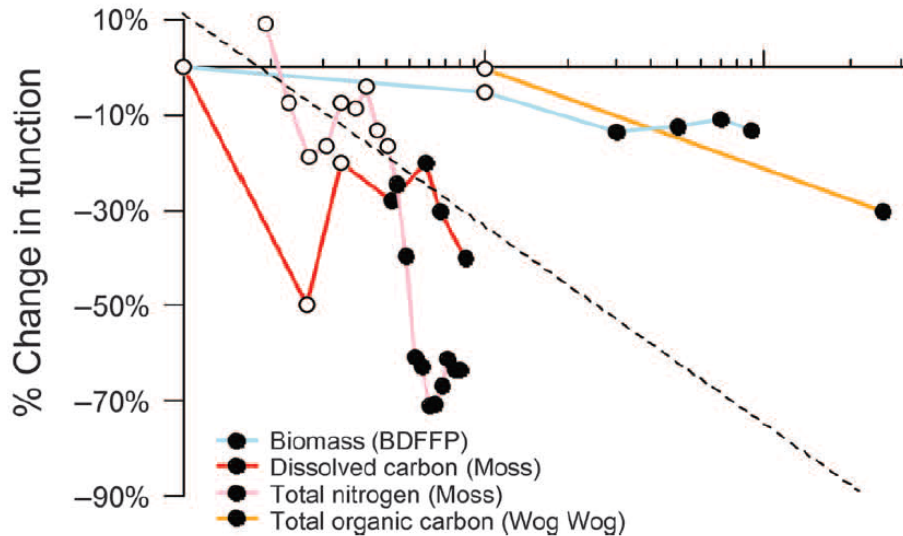




### A Extinction debt



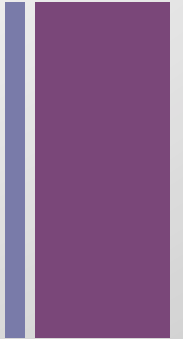
### C Ecosystem function debt



(Haddad et al. 2015)



# A fragmentação de habitats como principal ameaça à biodiversidade



- O que é fragmentação?
- Por que devemos nos preocupar com a fragmentação?
- Respostas no tempo
- **Implicações para conservação**



# CONECTIVIDADE DA PAISAGEM

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“Capacidade da paisagem de facilitar fluxos biológicos entre fragmentos de habitat”

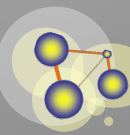
(Taylor et al. 1993)

Isolamento

Corredores

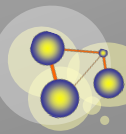
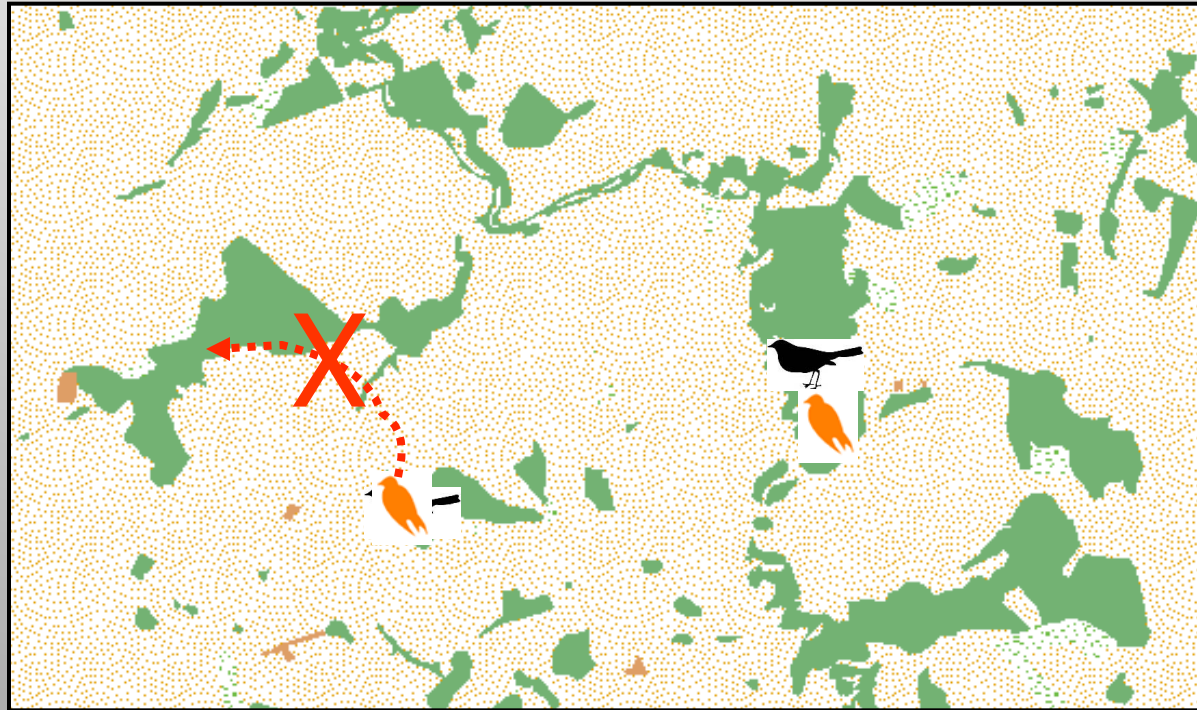
Stepping stones

Permeabilidade da matriz



# CONECTIVIDADE DA PAISAGEM

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# CONECTIVIDADE DA PAISAGEM

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“Capacidade da paisagem de facilitar os fluxos biológicos entre fragmentos de habitat”

(Taylor et al. 1993)

Estrutural

Isolamento

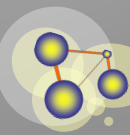
Corredores

Stepping stones

Matriz

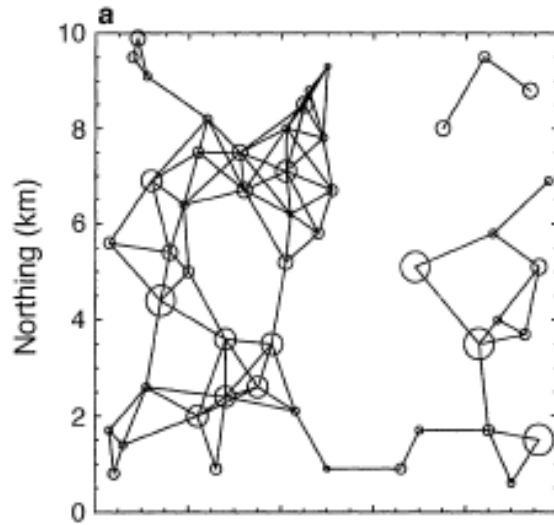
Funcional

Movimento das espécies

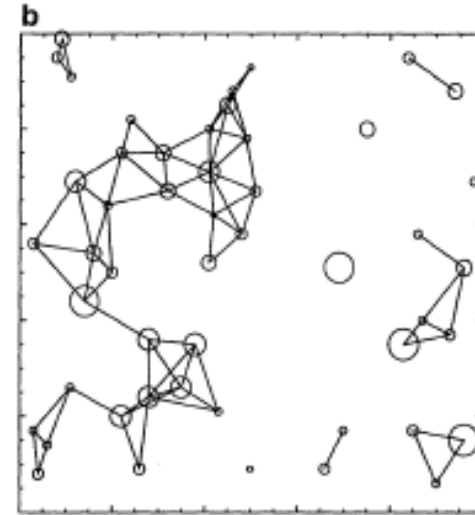


# Conectividade funcional segundo a teoria dos grafos

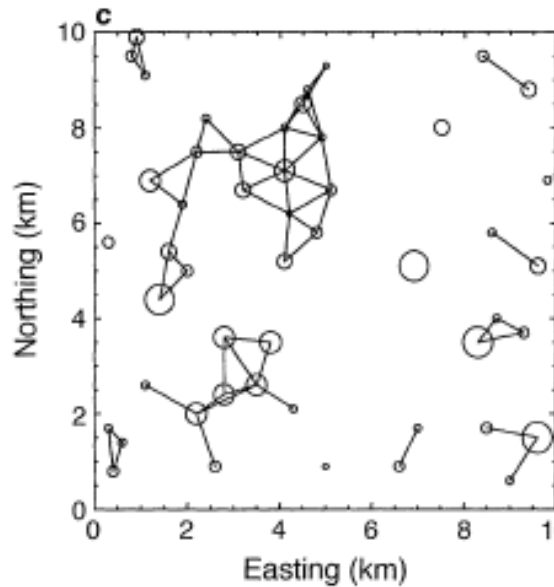
1500 m



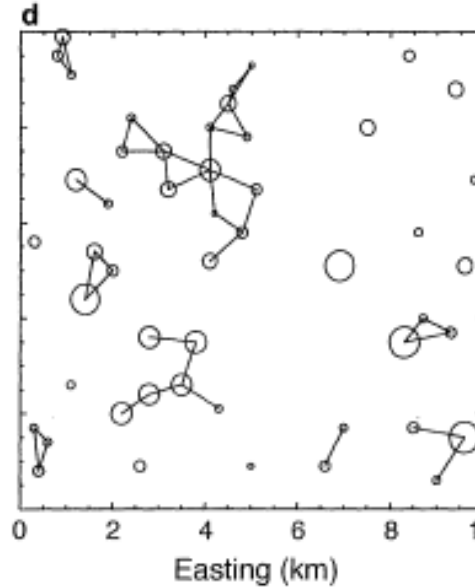
1250 m

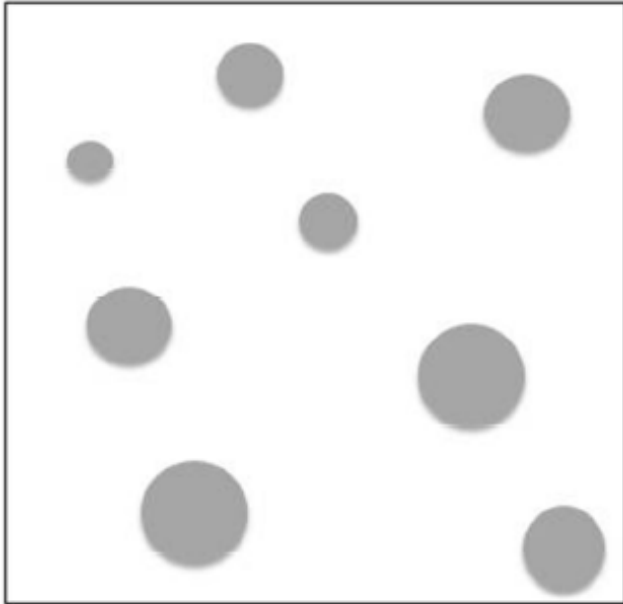
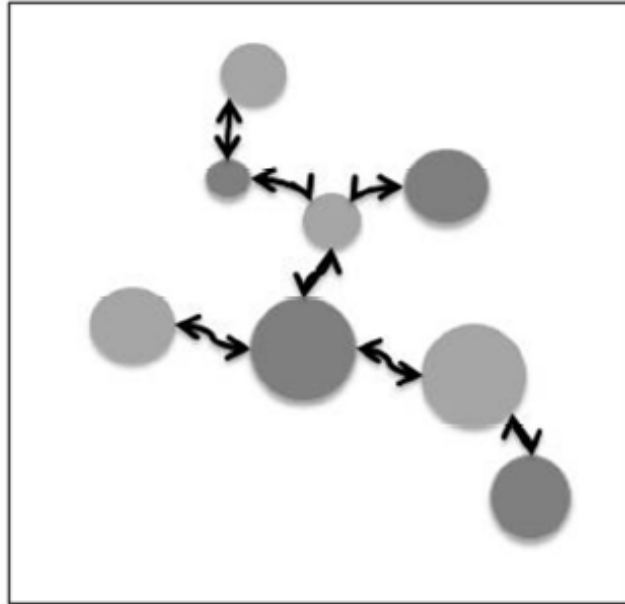
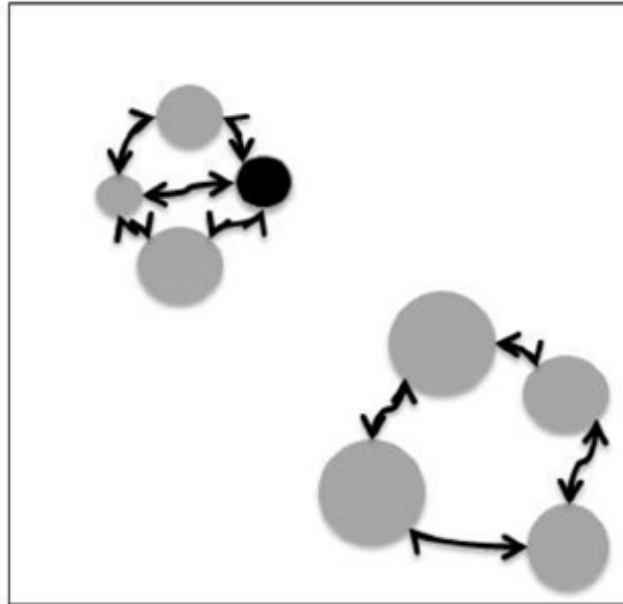
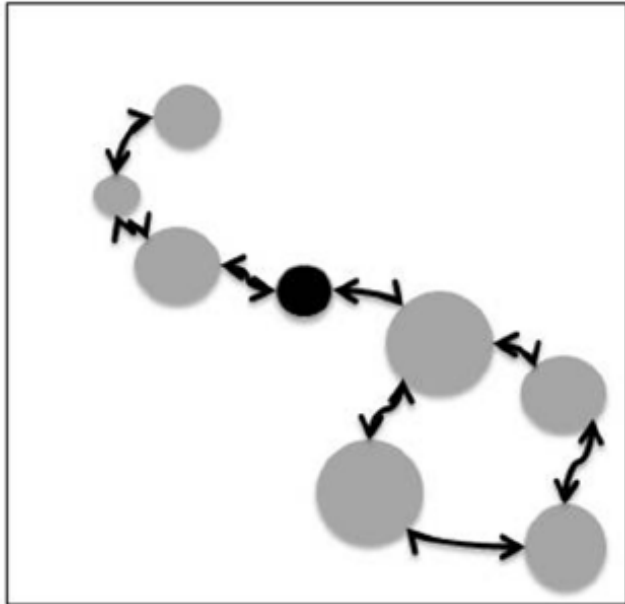


1000 m



750 m

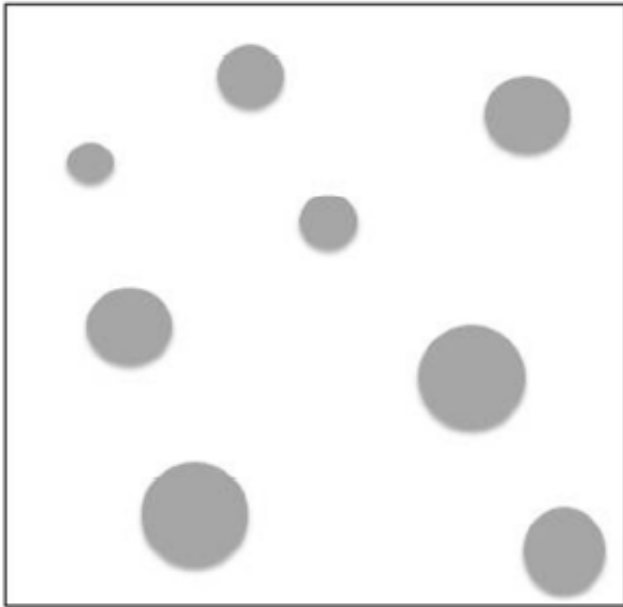


**A****B****C****D**

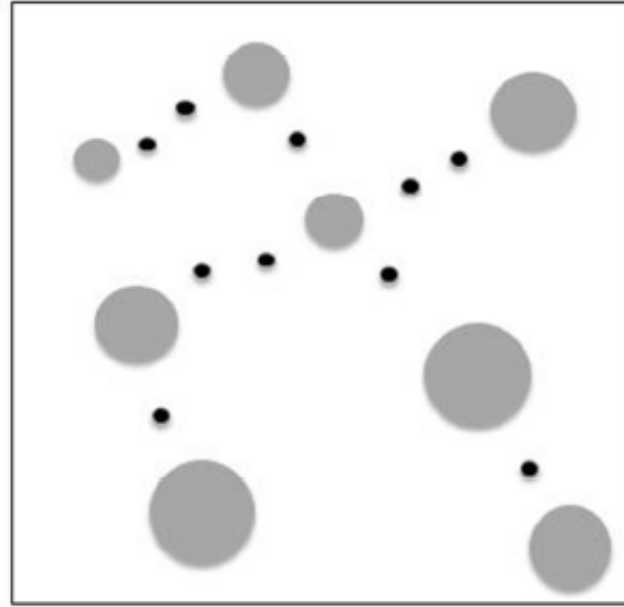
(Villard & Metzger 2014)



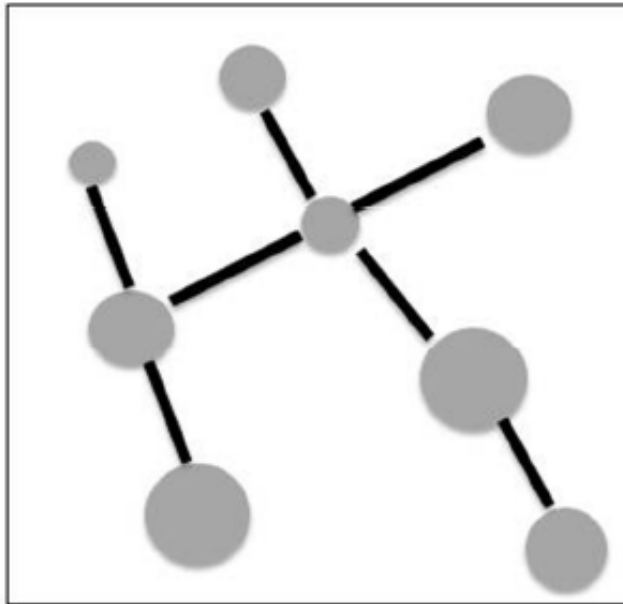
A



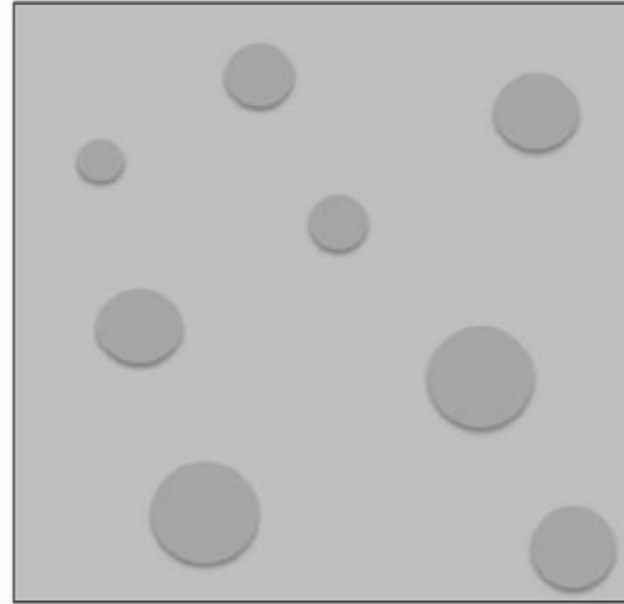
B



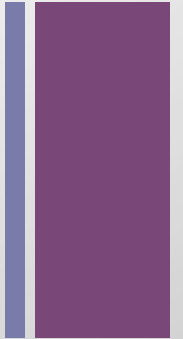
C



D



(Villard & Metzger 2014)



# Demanda de restauração para a Floresta Atlântica



**PACTO**  
PELA RESTAURAÇÃO DA  
MATA ATLÂNTICA

MAPA DE ÁREAS  
POTENCIAIS PARA  
RESTAURAÇÃO  
FLORESTAL

1ª EDIÇÃO ATUALIZADA - JANEIRO DE 2011

O Pacto pela Restauração da Mata Atlântica é um movimento da sociedade brasileira, aberto a todas as instituições dispostas a apoiar ou a participar de esforços de restauração florestal.

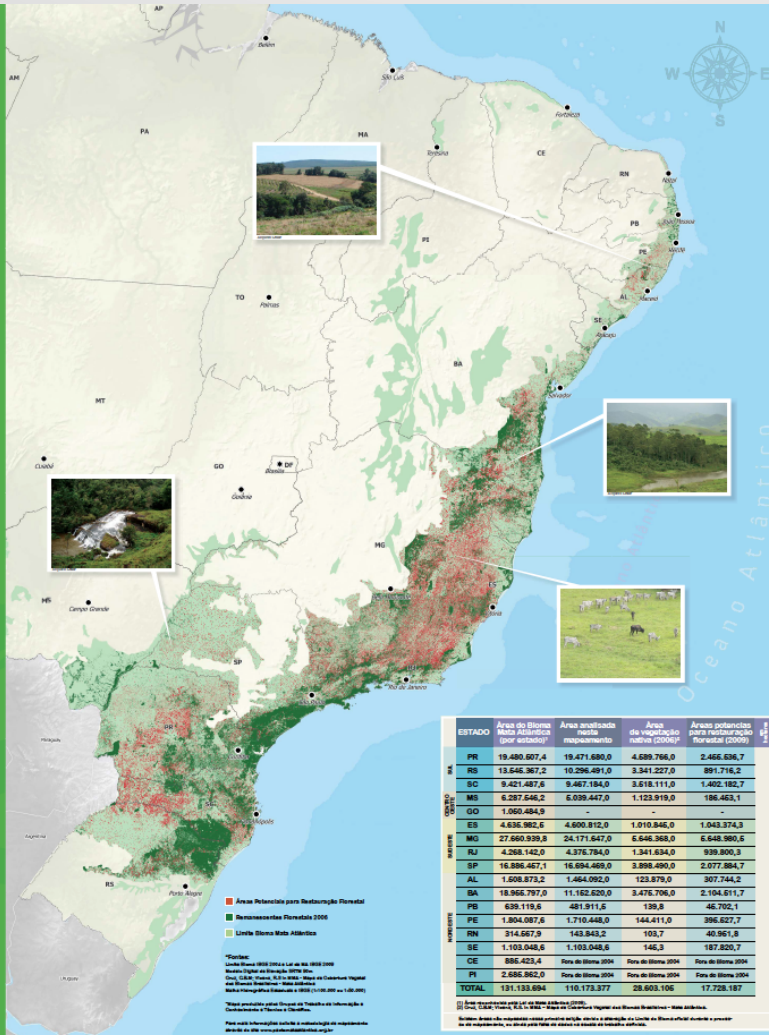
O objetivo do Pacto é articular instituições públicas e privadas, governos, empresas e proprietários de terras para integrar seus esforços e recursos na geração de resultados em restauração e conservação da biodiversidade.

A meta do Pacto é viabilizar a restauração florestal de 15 milhões de hectares até o ano de 2050.

**PARTICIPE EM CAMPO!**  
Qualquer pessoa ou instituição pode apoiar as ações do Pacto pela Restauração da Mata Atlântica.

Para identificar precisamente as áreas potenciais para restauração mais próximas da sua cidade ou da sua área de atuação, visite a versão digital do mapeamento, disponível no website do Pacto.

[www.pactomataatlantica.org.br](http://www.pactomataatlantica.org.br)



Adequação ao novo  
Código Florestal:  
**3-6 milhões ha**

Pacto de restauração:  
**15 milhões ha** até  
2050

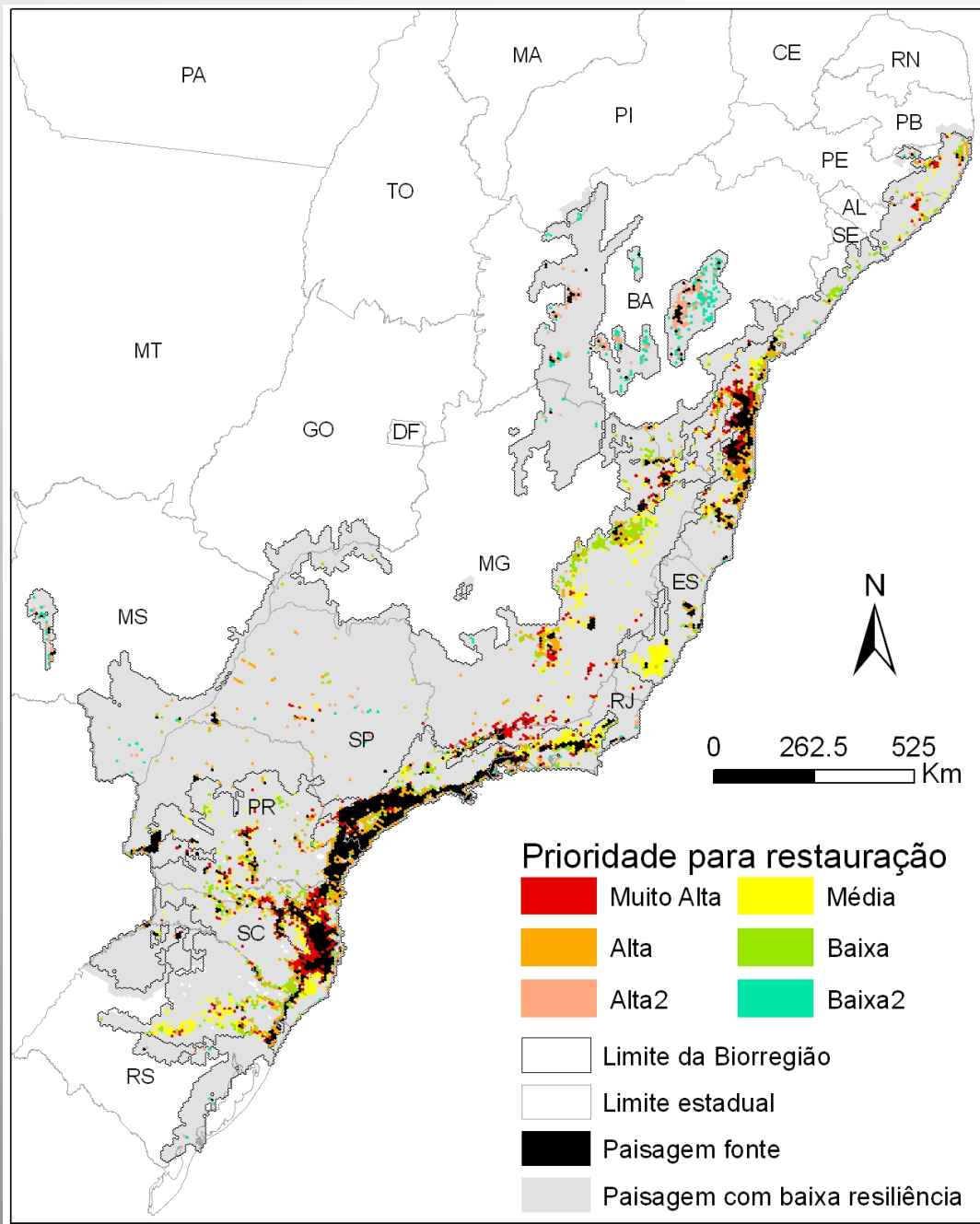
Cobertura atual:  
**16 milhões ha**

# Mapeamentos para a conservação e recuperação da biodiversidade na **Mata Atlântica**: em busca de uma estratégia espacial integradora para orientar ações aplicadas



## Projeto Proteção da Mata Atlântica II

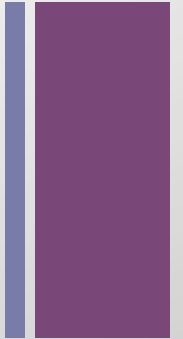




(Tambosi et al. 2014,  
Restoration Ecology)



# A fragmentação de habitats como principal ameaça à biodiversidade



- Fragmentação – sub-divisão do habitat
- É uma das principais ameaças à biodiversidade
- É necessário considerar a escala temporal
- A noção de conectividade permite integrar aspectos estruturais e funcionais da fragmentação
- A pesquisa recente vem fomentando importantes subsídios para políticas de conservação



**Obrigado!**

Dept. de Ecologia— Universidade de São Paulo

**[jpm@ib.usp.br](mailto:jpm@ib.usp.br)**

**<http://eco.ib.usp.br/lepac>**