

Introdução à Modelagem de Nicho Ecológico

WEBINAR NEXT GENERATION



Maurício Vancine

16/07/2020



Webinar

Tópicos

1. Apresentações
2. Introdução aos Modelos de Nicho Ecológico - *Ecological Niche Models* (ENMs)
3. Nicho Ecológico e Distribuição de Espécies
4. Construção dos ENMs passo a passo
5. Dados de entrada: ocorrências e variáveis ambientais
6. Ajuste dos modelos
7. Avaliação dos modelos
8. Predição dos modelos
9. Aplicações e mais informações
10. Prática no R

1. Apresentações

Maurício Vancine

Ecólogo (2015) | Mestre em Zoologia (2018) |
Doutorando em Zoologia (2020-?)



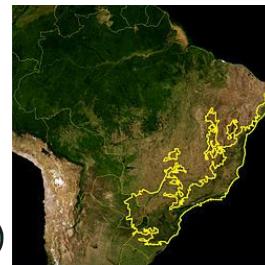
UNIVERSIDADE ESTADUAL PAULISTA
“JÚLIO DE MESQUITA FILHO”

Pesquisa

Ecologia Espacial (Ecologia da Paisagem)

Ecologia Quantitativa (SDM e JSDM)

Ecologia e Conservação de Anfíbios



Especialidades

Modelos de Nicho Ecológico (ENMs)

Análise de Dados Ecológicos e Geoespaciais

Open Source [R, QGIS, GRASS GIS, Linux, Libreoffice, ...]



Prof. Milton Ribeiro Prof. Célio Haddad



Contato e informações

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- @mauriciovancine
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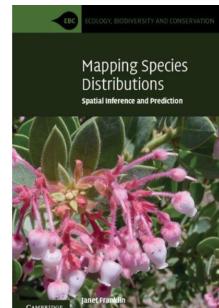
2. Introdução aos Modelos de Nicho Ecológico (ENMs)

Uma abordagem, muitos nomes...

Ecology, 93(7), 2012, pp. 1527–1539
© 2012 by the Ecological Society of America

Uses and misuses of bioclimatic envelope modeling

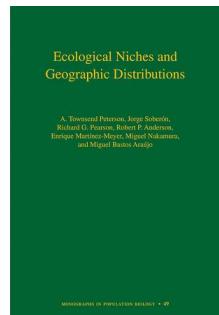
MIGUEL B. ARAÚJO^{1,2,3,5} AND A. TOWNSEND PETERSON⁴



Franklin (2009)

1. Modelos de Envelopes Climáticos (*Bioclimatic Envelope Models*)

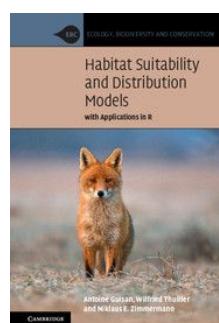
Estimado um espaço multivariado de variáveis climáticas (envelope)



Peterson et al. (2011)

2. Modelos de Nicho Ecológico (*Ecological Niche Models*)

Vincula o envelope à teoria de nicho ecológico (Grinnell e Hutchinson)



Guisan et al. (2017)

3. Modelos de Adequabilidade de Habitat (*Habitat Suitability Models*)

Envelope relacionado ao “habitat”, como espaço físico e recursos

4. Modelos de Nicho Ecológico (*Species Distribution Models*)

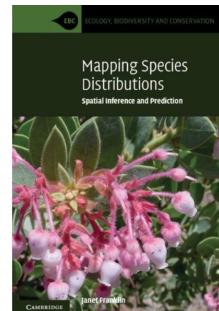
Modelar a distribuição geográfica das espécies

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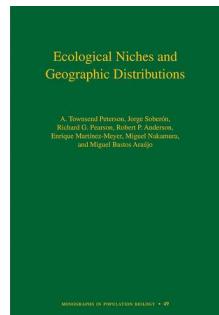
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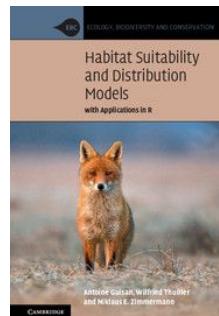
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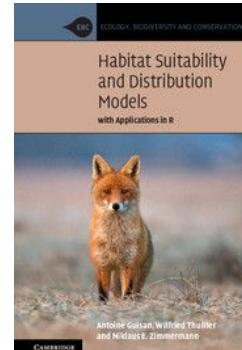
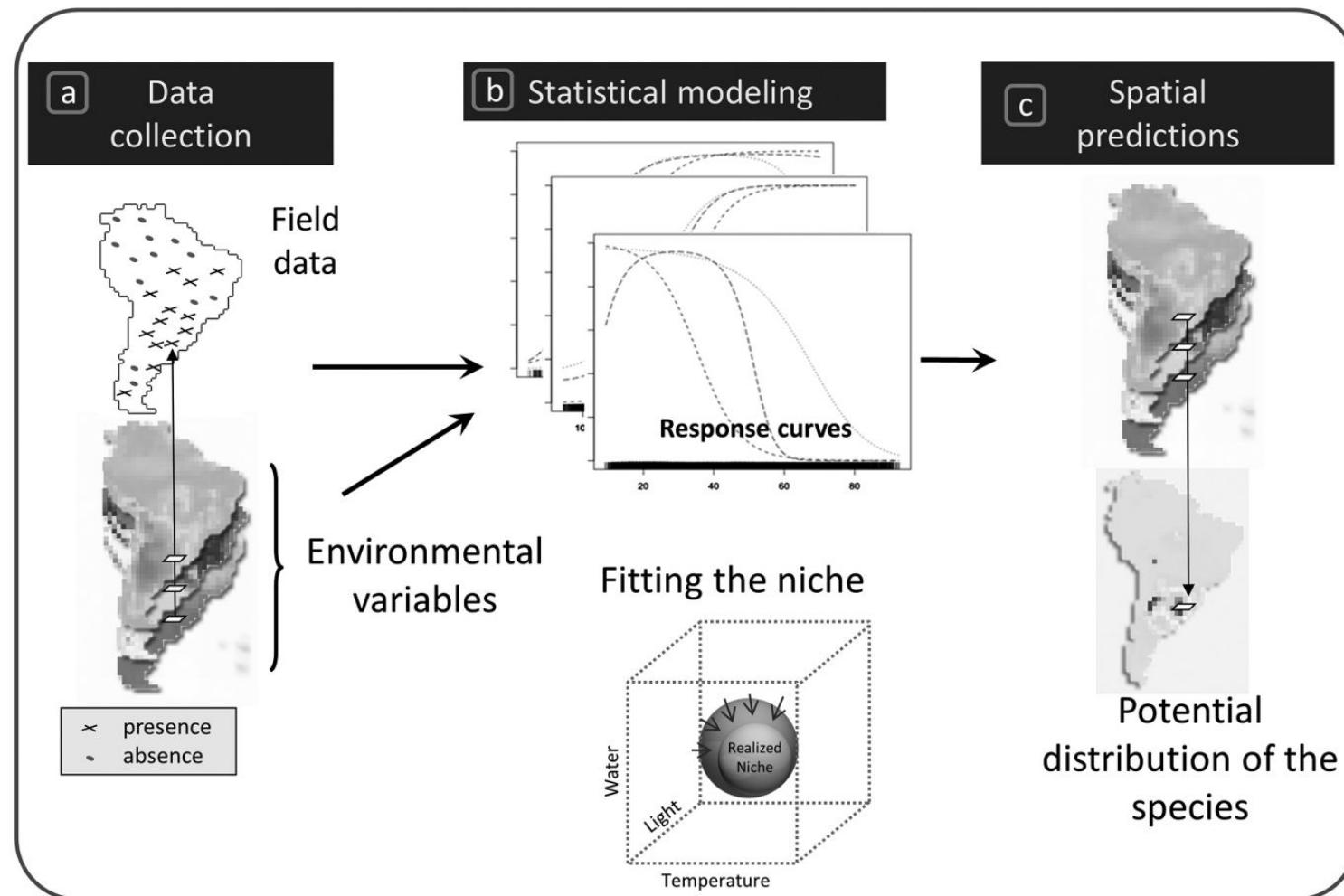
Guisan et al. (2017)

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Modelar a distribuição geográfica das espécies

Modelos de Nicho Ecológico (ENMs)

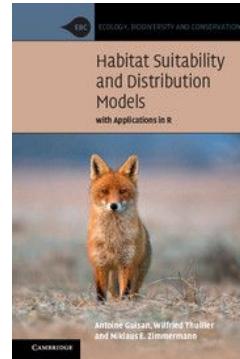
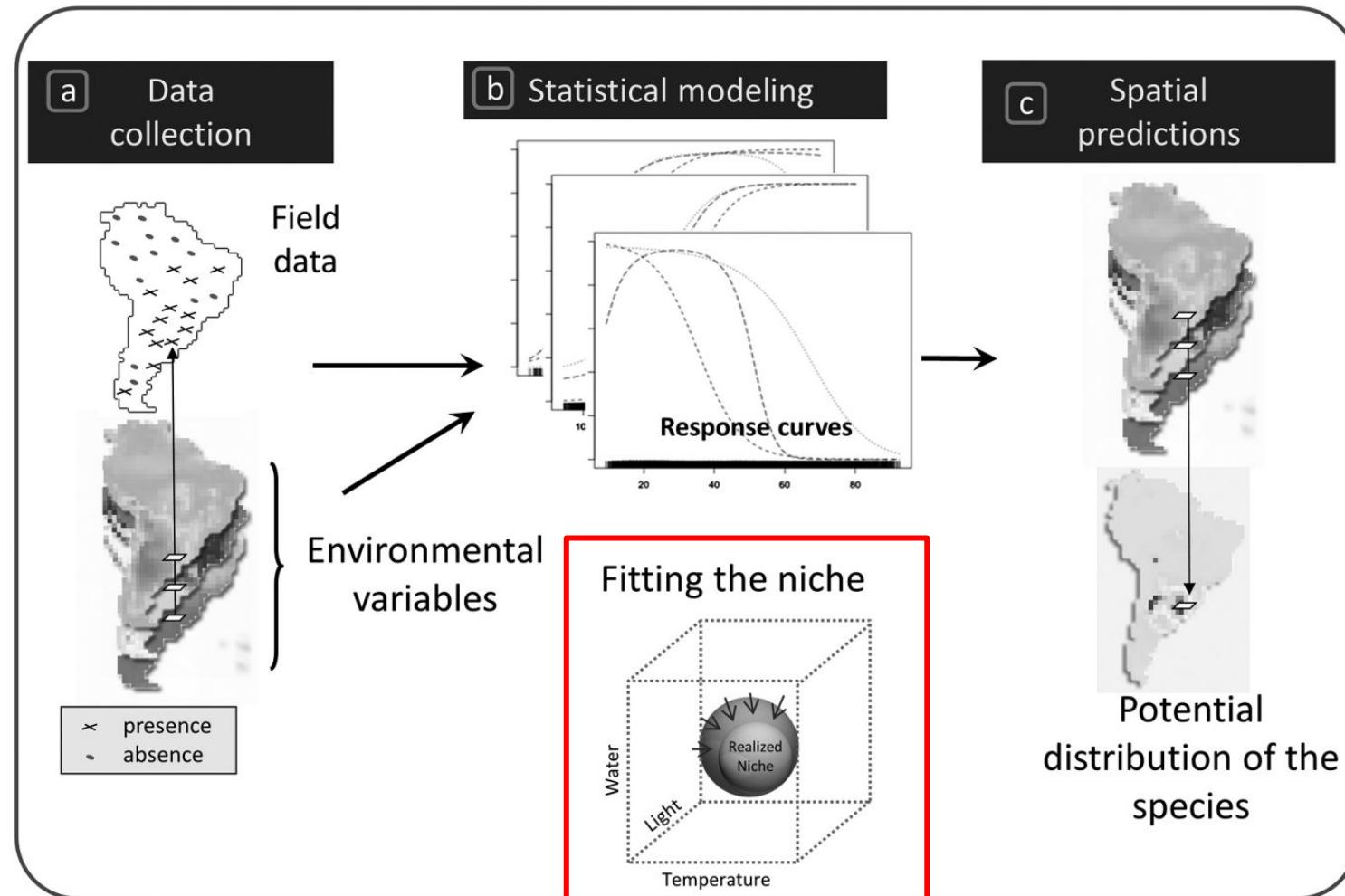
Visão geral



Guisan et al. (2017)

Modelos de Nicho Ecológico (ENMs)

Visão geral



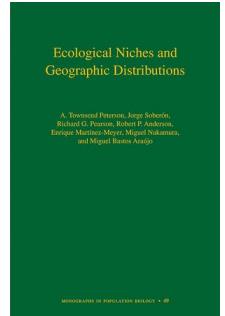
Guisan et al. (2017)

3. Nicho ecológico e distribuição das espécies

O que determina a distribuição de espécies?

Espaço Geográfico (G)

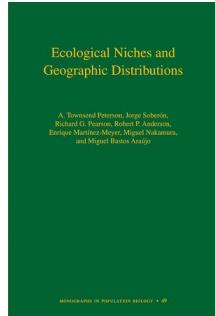
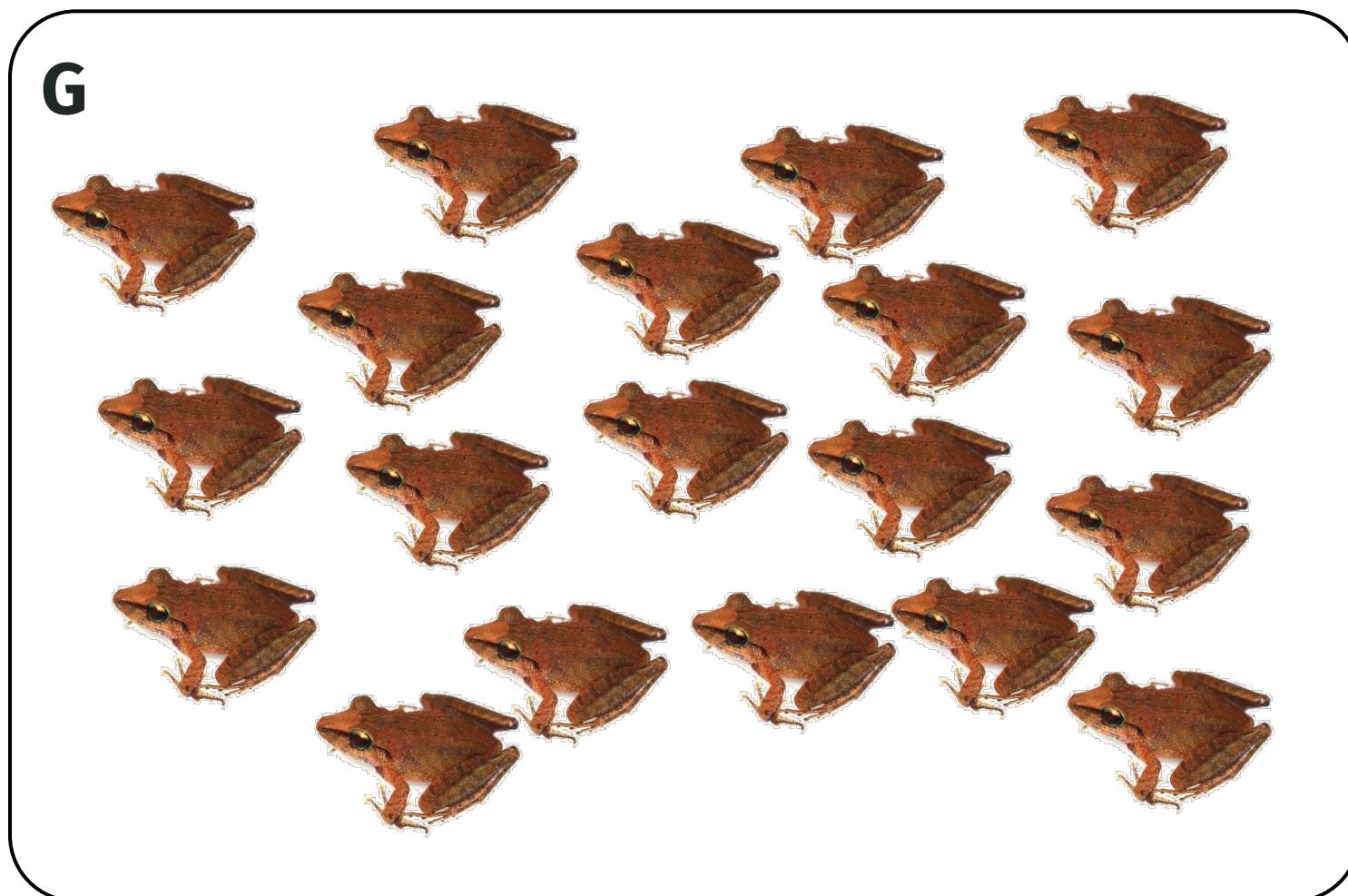
G



Peterson et al. (2011)

O que determina a distribuição de espécies?

Espaço Geográfico (G)



Peterson et al. (2011)

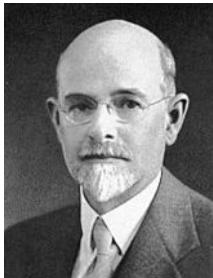
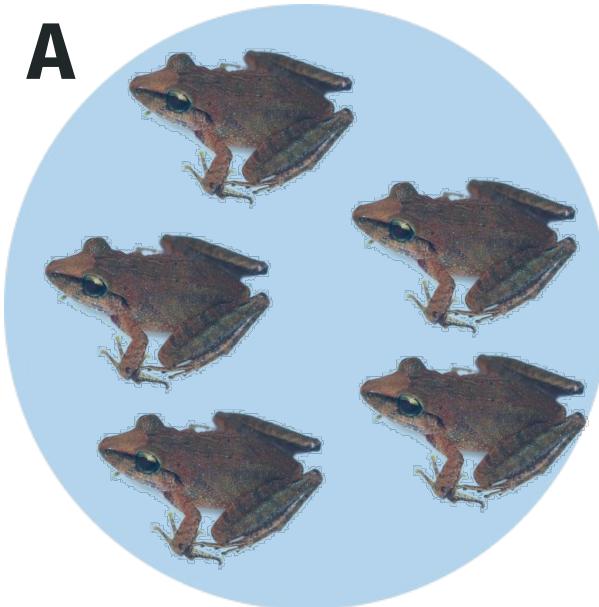
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Condições Abióticas (A)

G

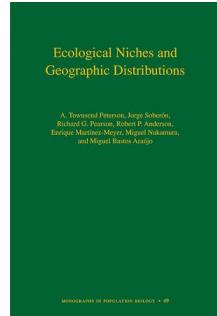


A



Joseph Grinnell (1917)

Requerimentos ambientais “condições climáticas”

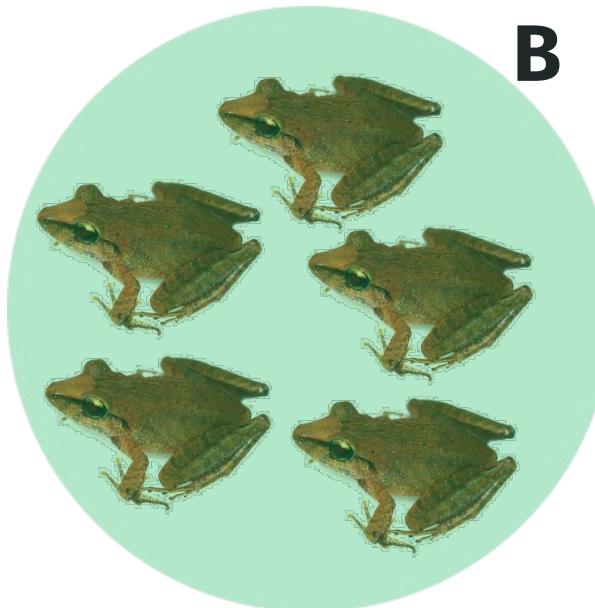


Peterson et al. (2011)

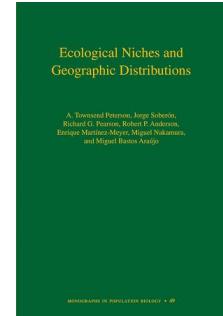
O que determina a distribuição de espécies?

Condições Bióticas (B)

G



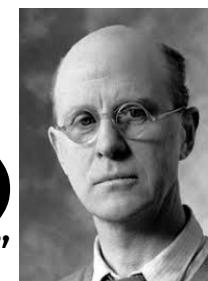
B



Peterson et al. (2011)

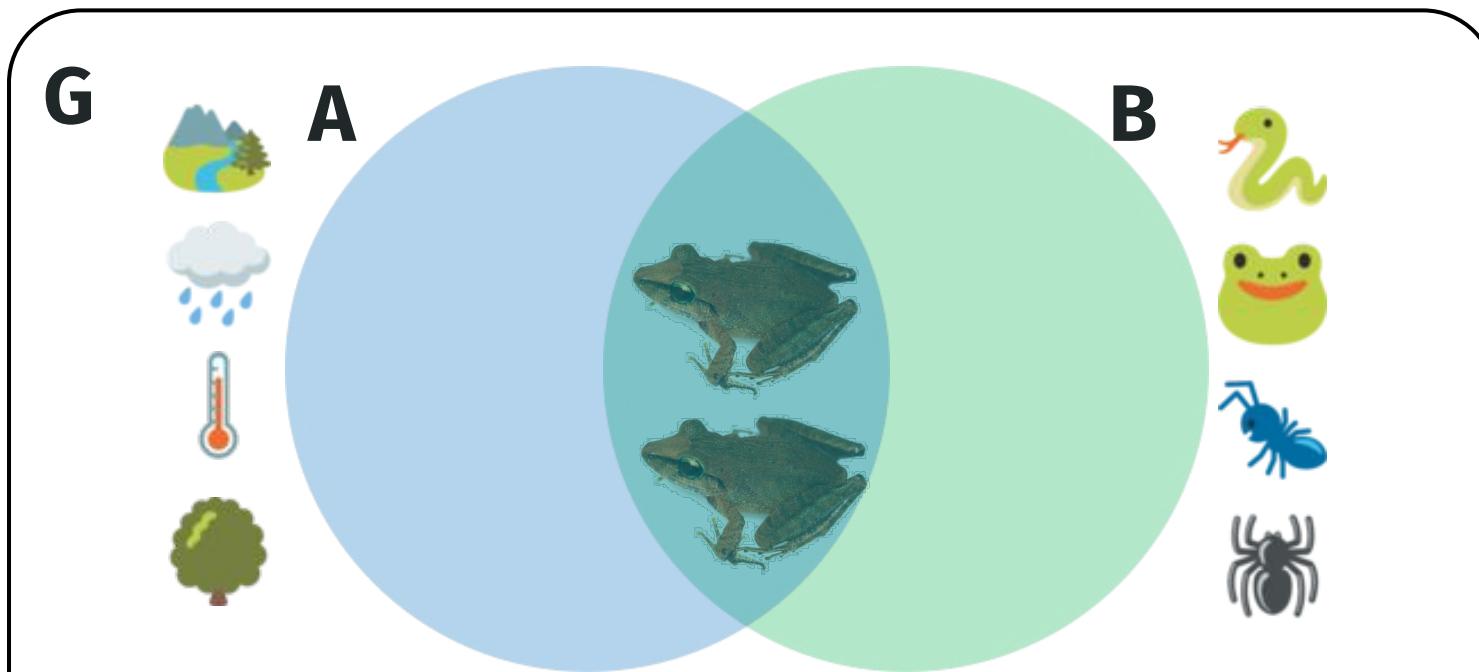
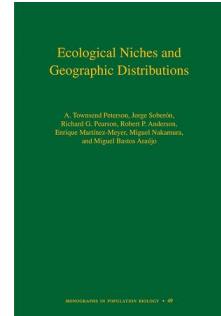
Charles Elton (1927)

Papel funcional dos organismos “impacto”



O que determina a distribuição de espécies?

Relação entre condições abióticas e bióticas



Peterson et al. (2011)



George E. Hutchinson (1957)

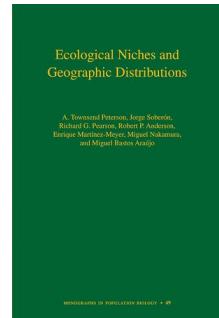
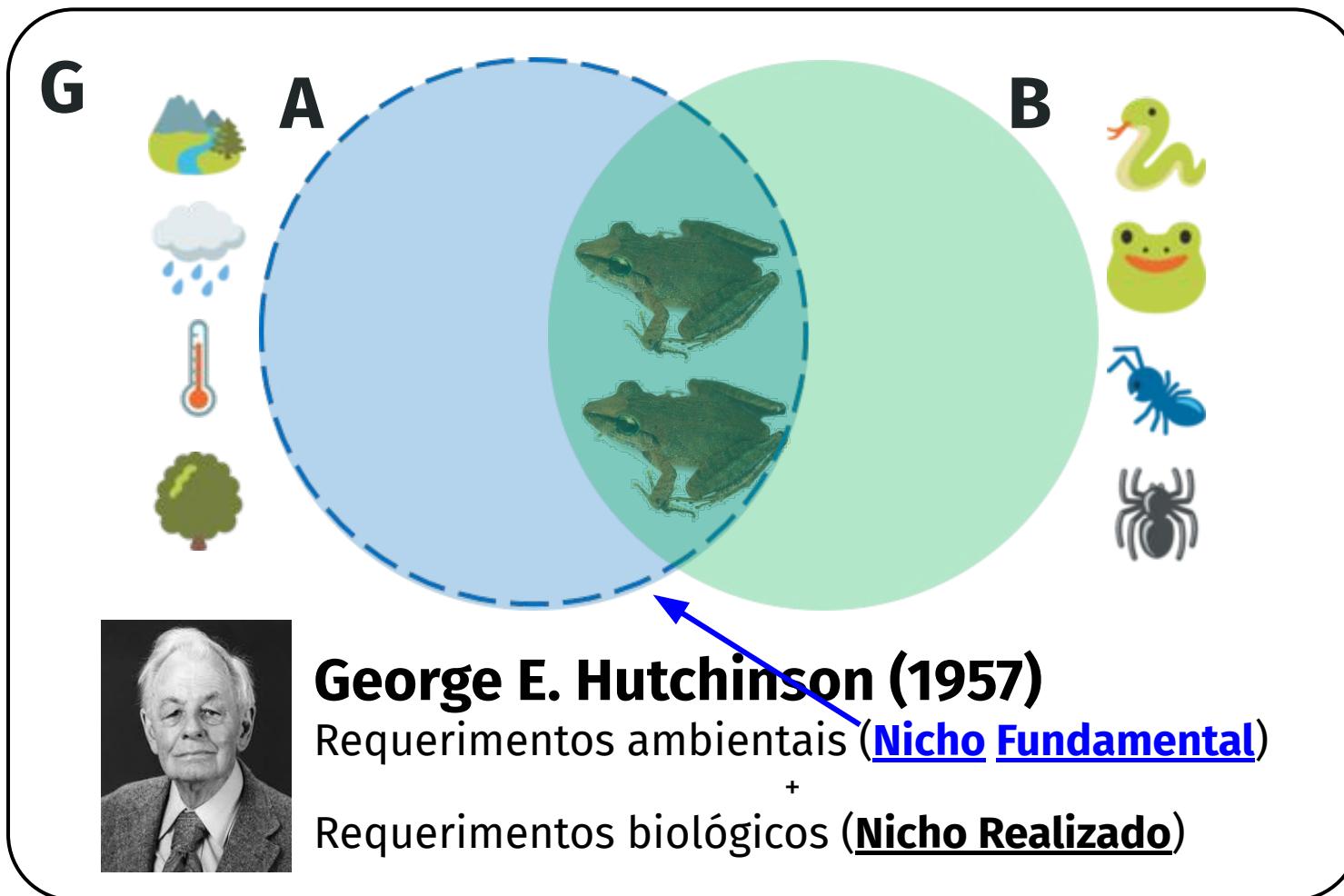
Requerimentos ambientais (Nicho Fundamental)

+

Requerimentos biológicos (Nicho Realizado)

O que determina a distribuição de espécies?

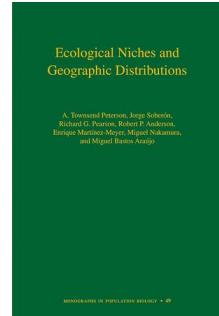
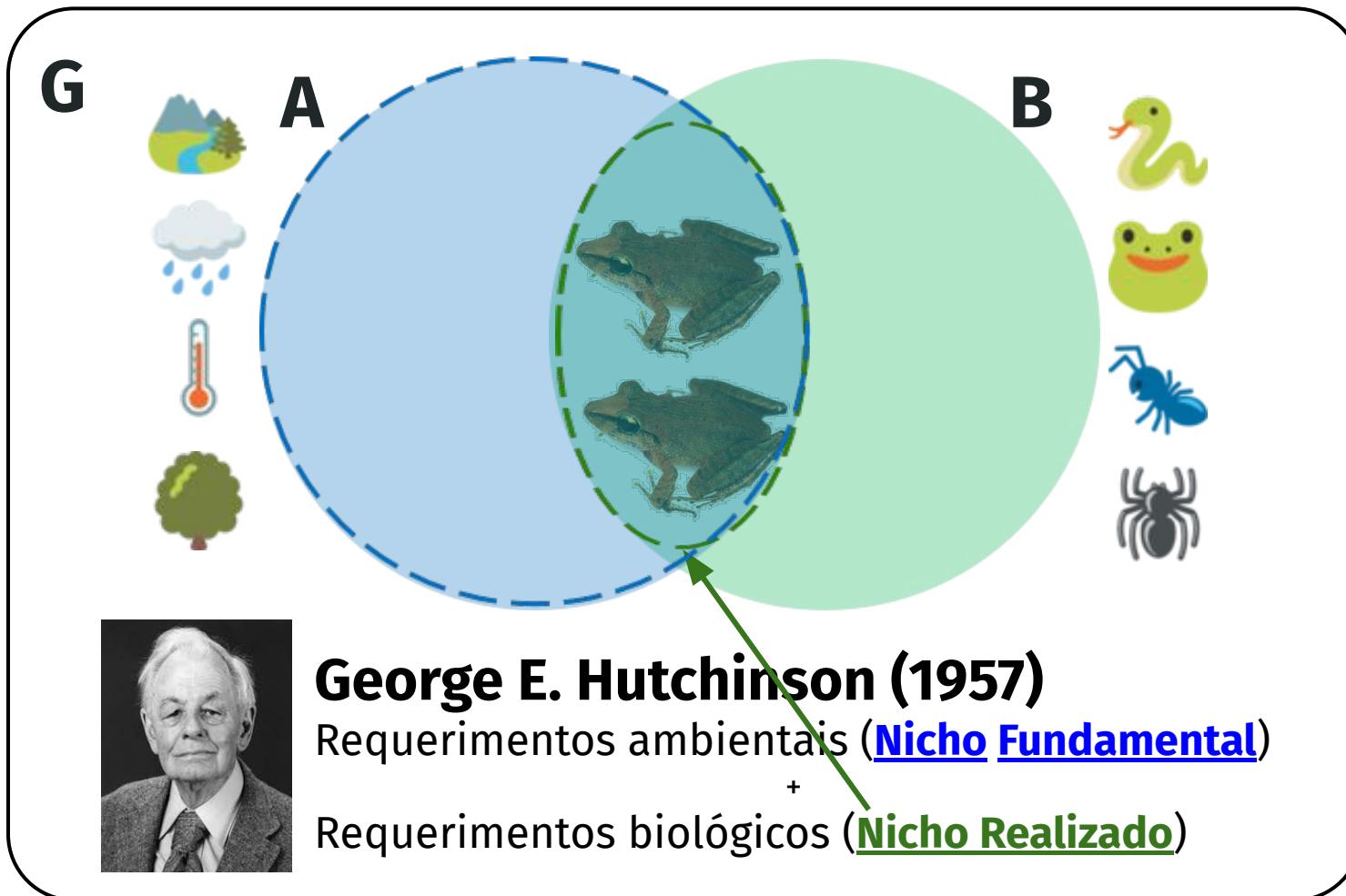
Nicho Fundamental



Peterson et al. (2011)

O que determina a distribuição de espécies?

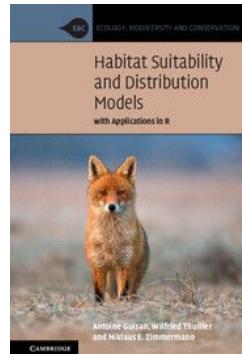
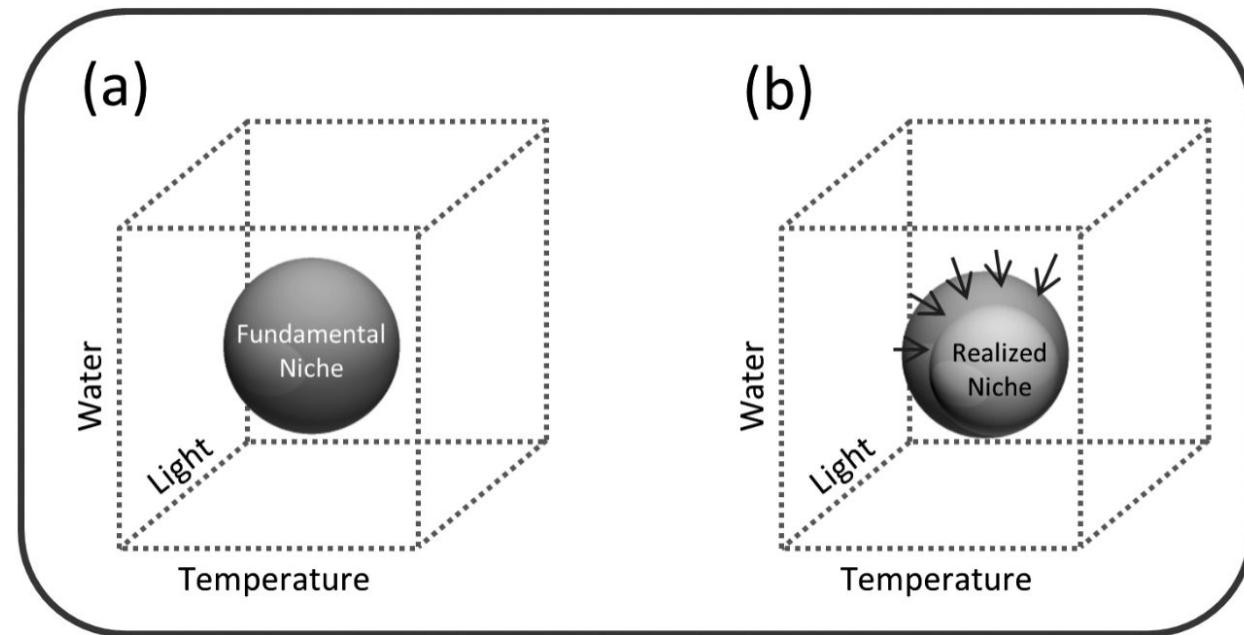
Nicho Realizado



Peterson et al. (2011)

O que determina a distribuição de espécies?

Hipervolume n-dimensional



Guisan et al. (2017)

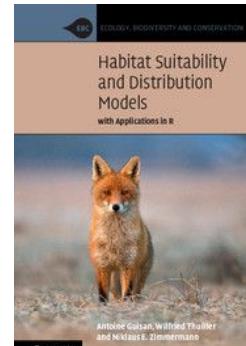
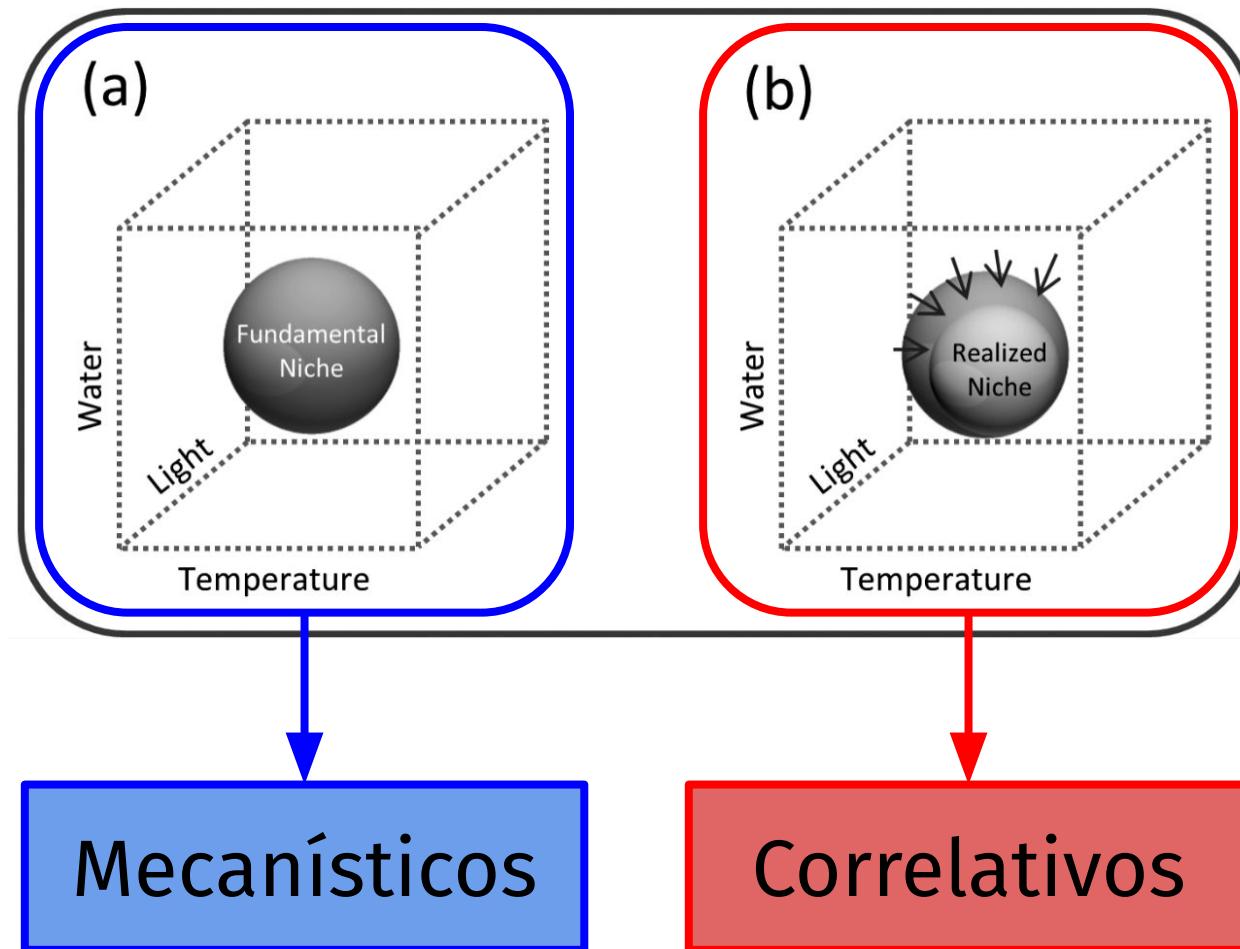


George E. Hutchinson (1957)
Requerimentos ambientais (Nicho Fundamental)
+
Requerimentos biológicos (Nicho Realizado)

Os ENMs estimam o nicho
fundamental ou **realizado**?

Nicho fundamental e realizado

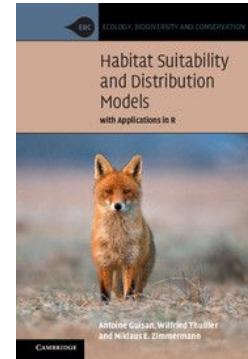
Modelos mecanísticos e correlativos



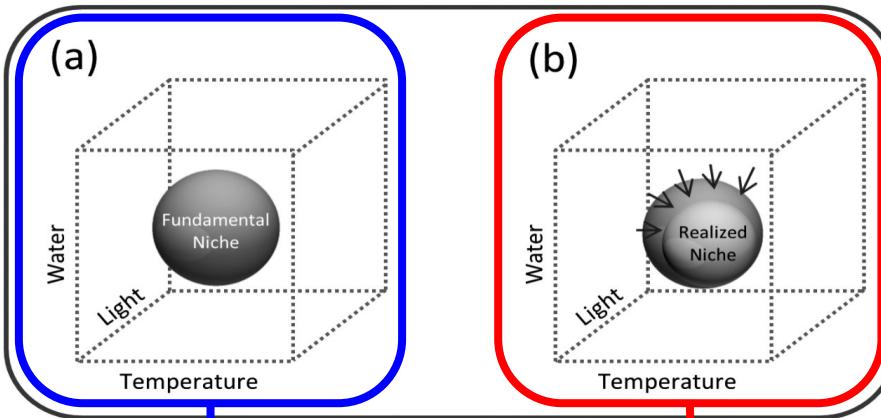
Guisan et al. (2017)

Nicho fundamental e realizado

Modelos mecanísticos e correlativos

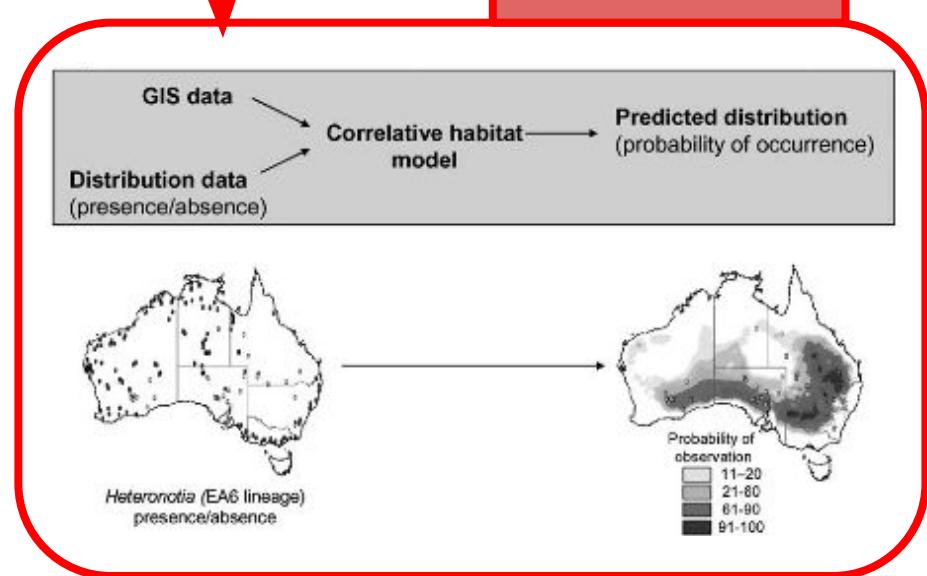
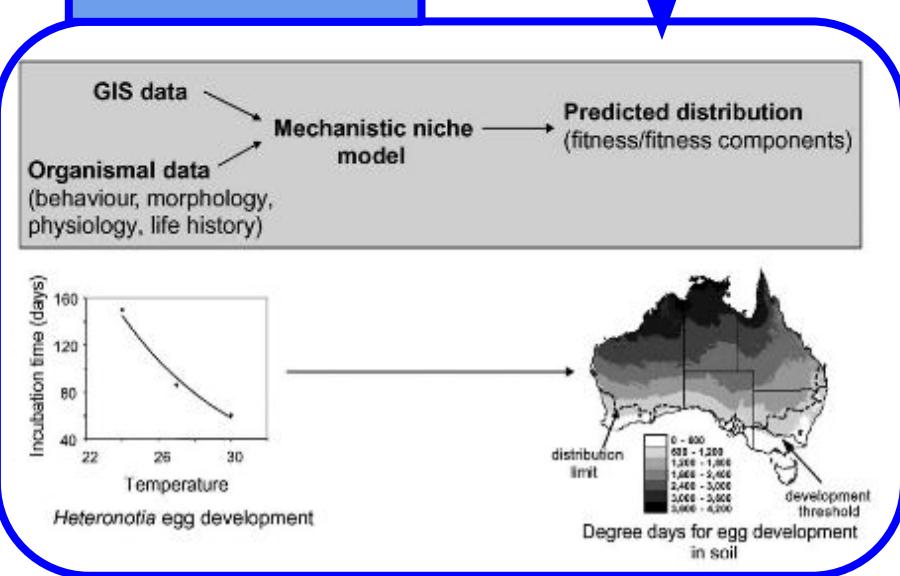


Guisan et al. (2017)



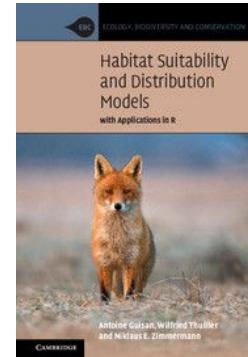
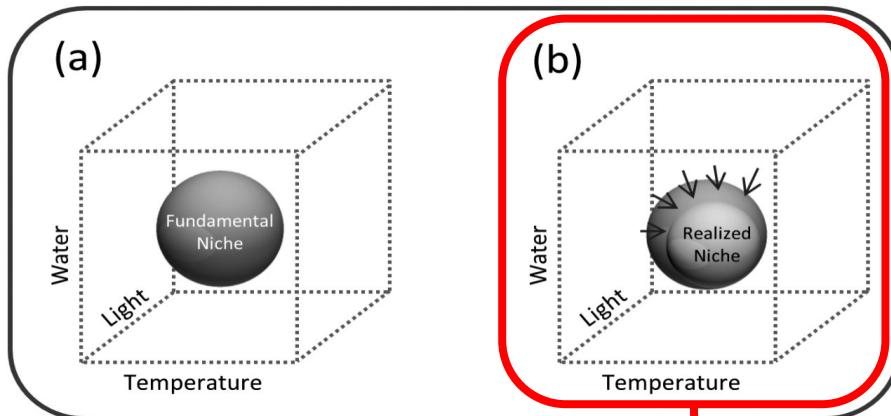
Mecanísticos

Correlativos



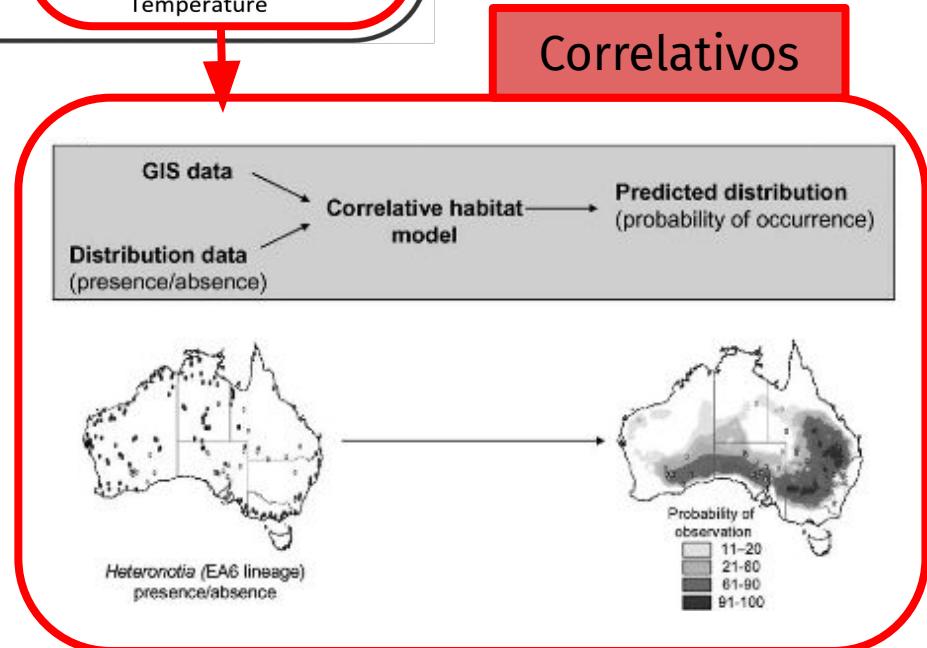
Nicho realizado

Modelos correlativos



Guisan et al. (2017)

Correlativos



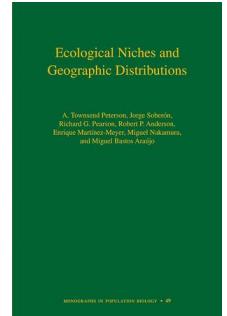
Modelos correlativos

Ocorrências

Espaço geográfico (G)



Jackson & Overpack (2000)

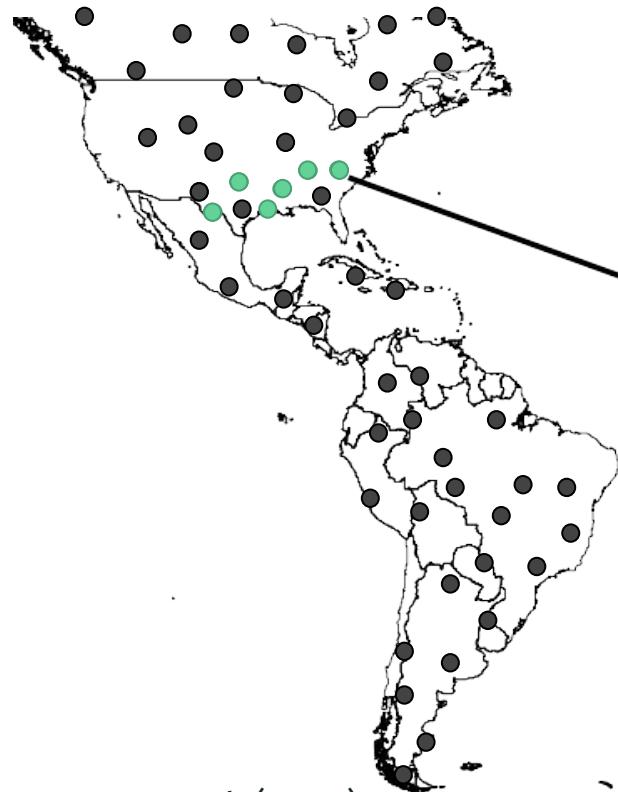


Peterson et al. (2011)

Modelos correlativos

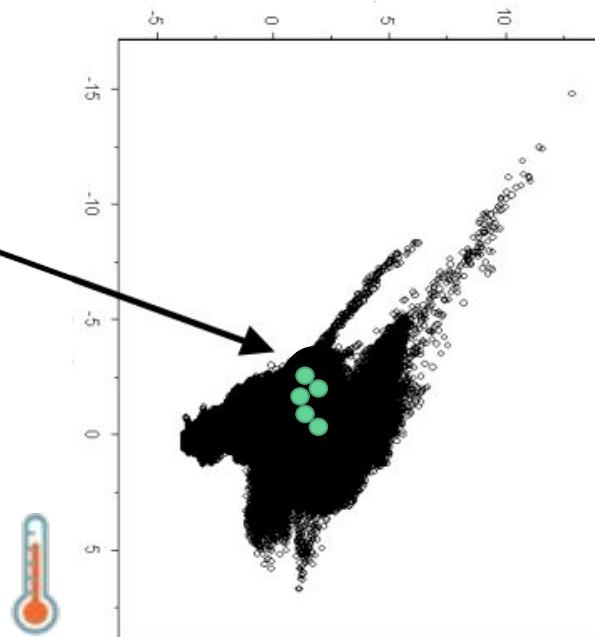
Condições ambientais

Espaço geográfico (G)

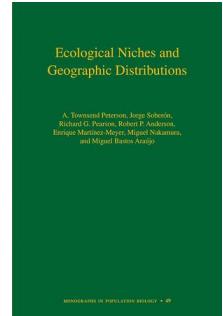


Jackson & Overpack (2000)

Espaço ambiental (E)



Peterson et al. (2011)

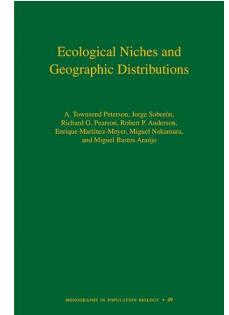


Ecological Niches and
Geographic Distributions

A. Townsend Peterson, Jorge Soberón,
Richard G. Pearson, Robert P. Anderson,
Enrique Muñoz-Meyer, Miguel Nakamura,
and Miguel Jerez Avango

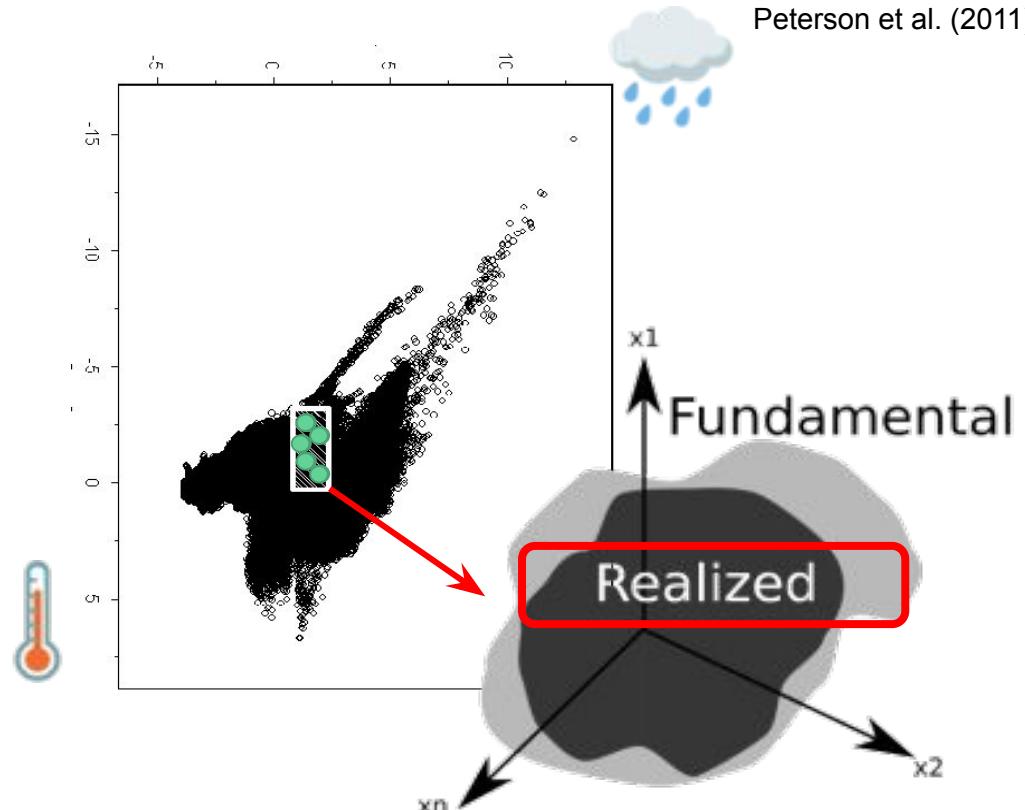
Modelos correlativos

Estimativa do nicho realizado



Peterson et al. (2011)

Espaço ambiental (E)

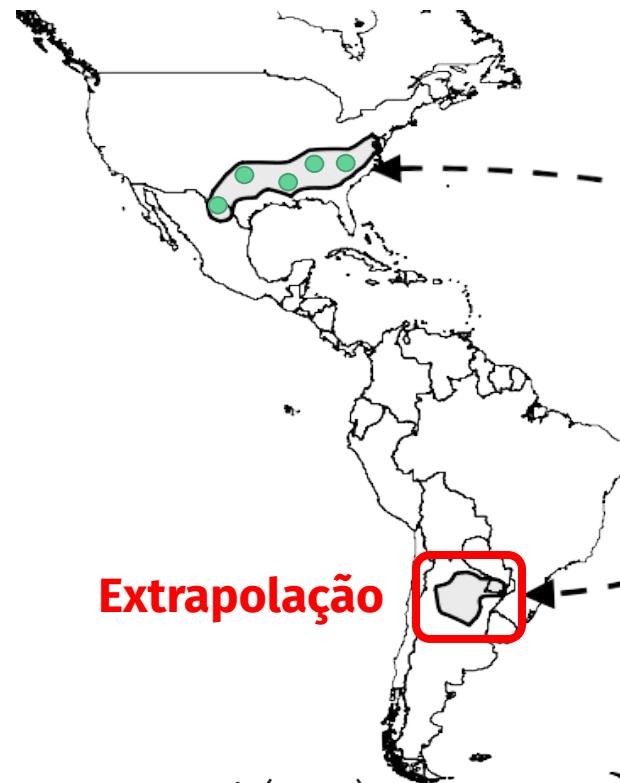


Jackson & Overpack (2000)

Modelos correlativos

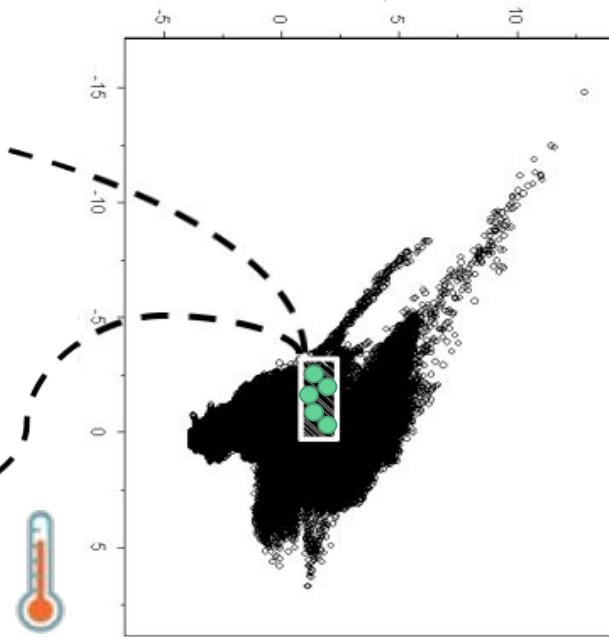
Predição do nicho realizado estimado

Espaço geográfico (G)

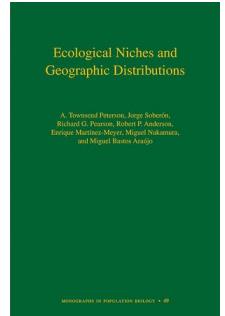


Jackson & Overpack (2000)

Espaço ambiental (E)



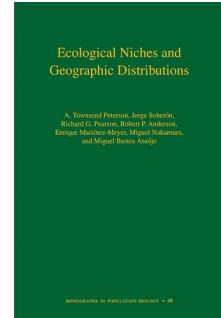
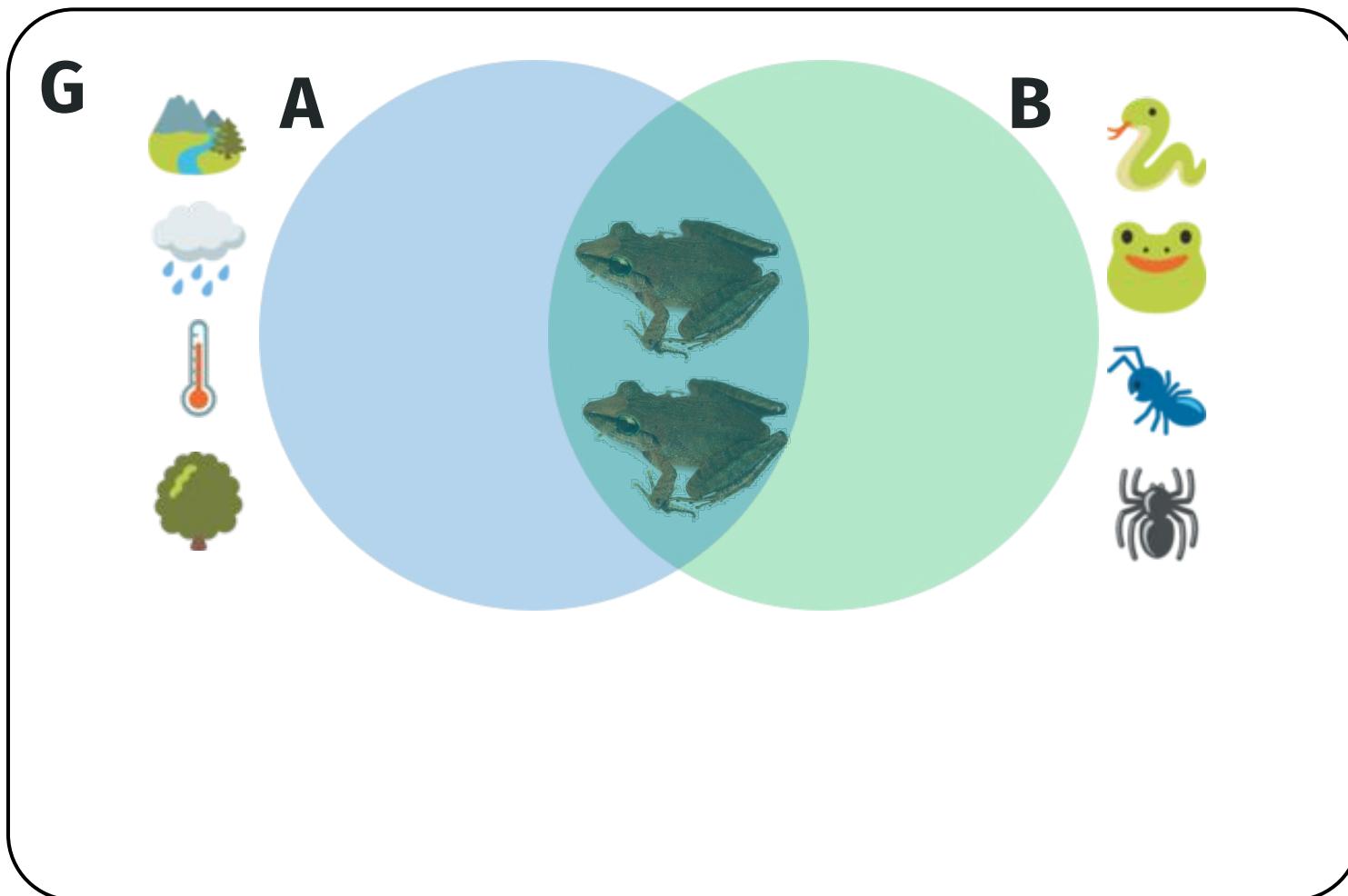
Peterson et al. (2011)



E como contornar essa
extrapolação?

O que determina a distribuição de espécies?

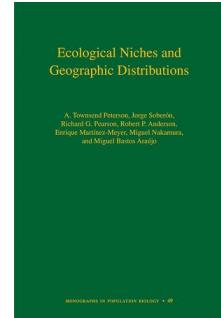
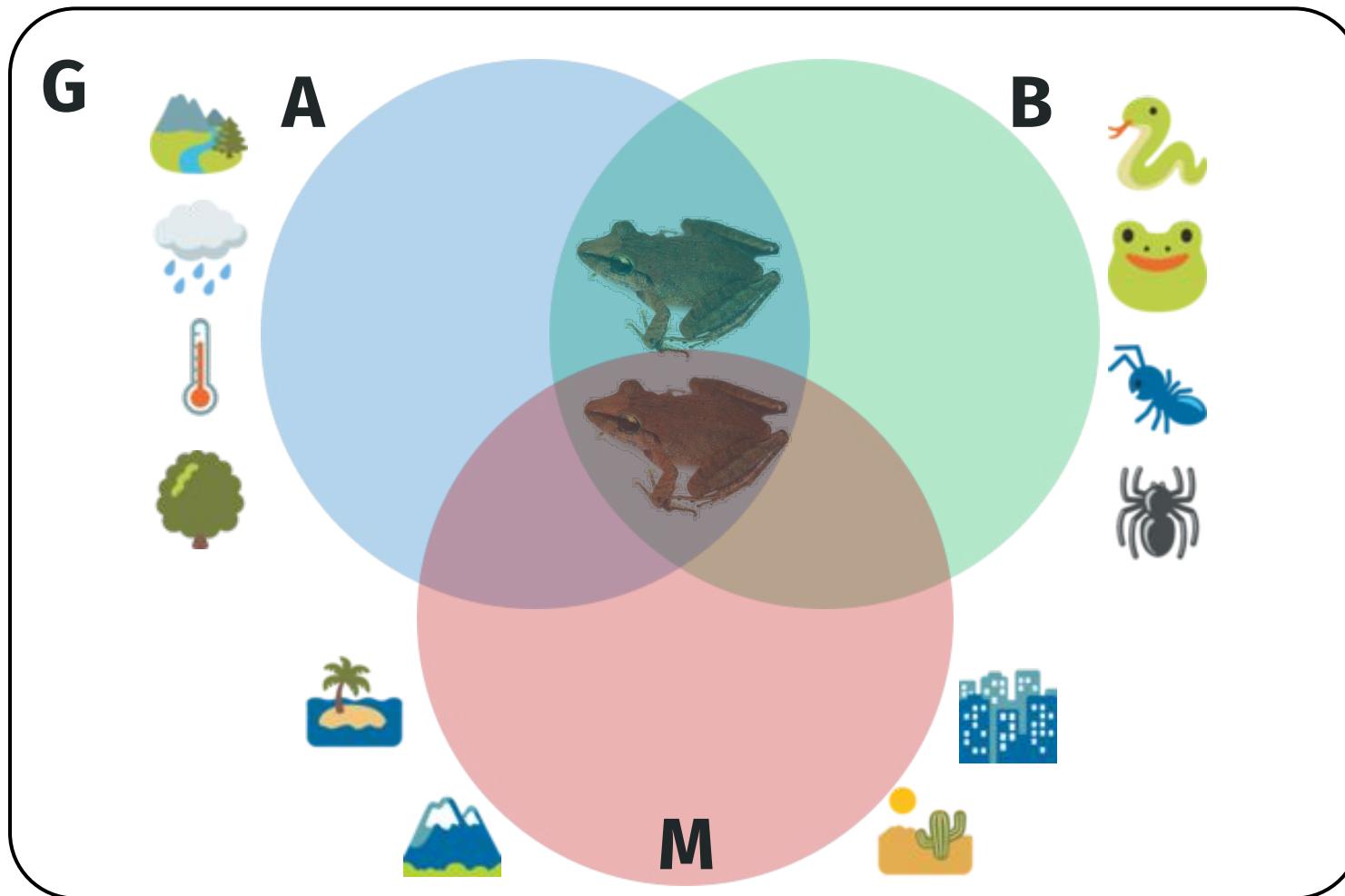
Nicho Ecológico



Peterson et al. (2011)

O que determina a distribuição de espécies?

Nicho Ecológico limitado pelo movimento



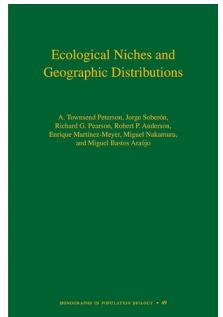
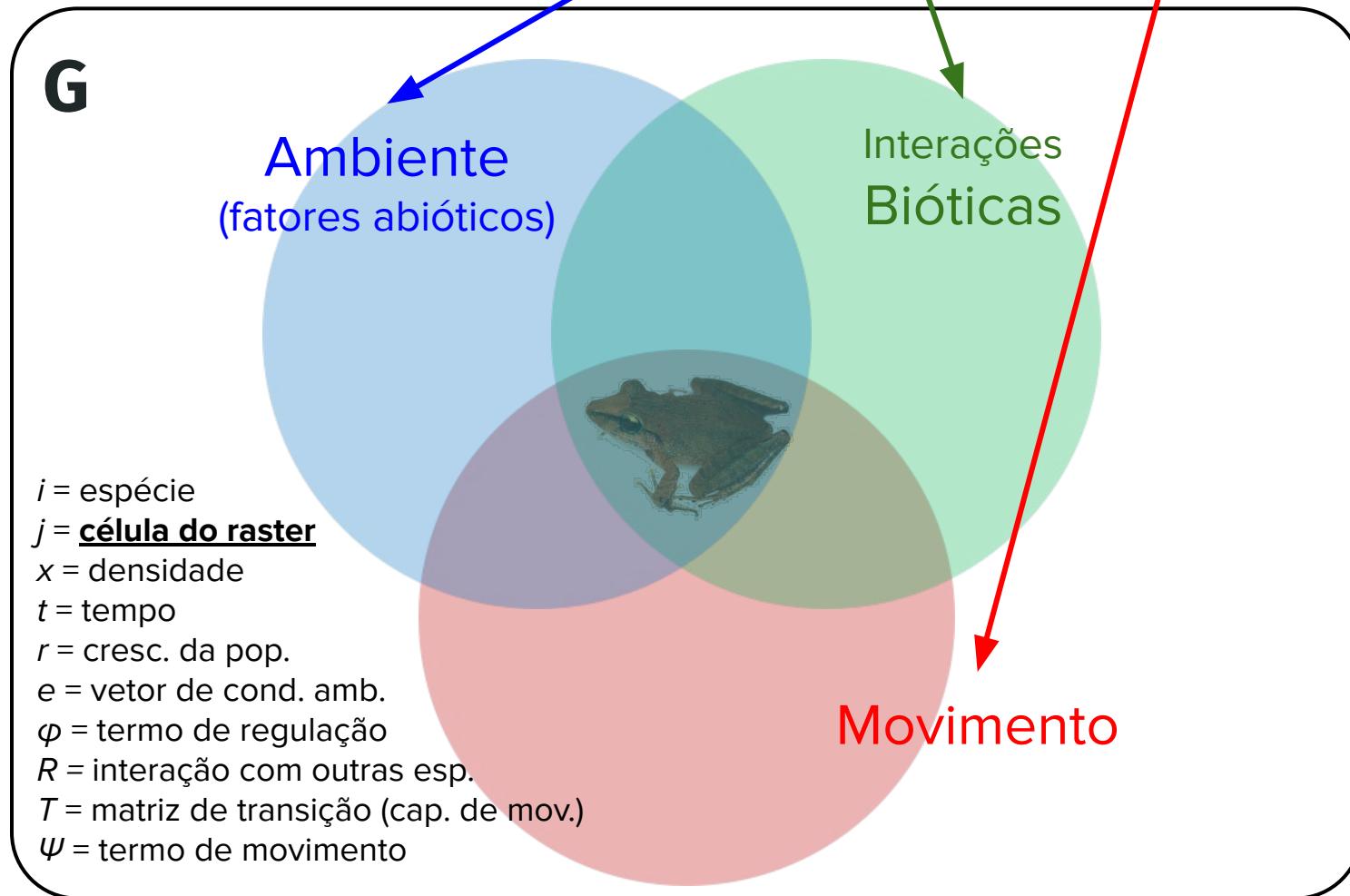
Peterson et al. (2011)

A teoria dos modelos...

O que determina a distribuição das espécies?

Teoria

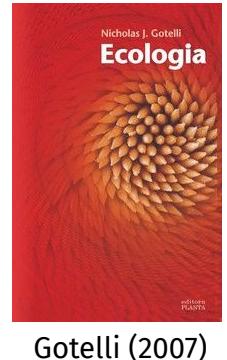
$$\frac{1}{x_i^j} \frac{dx_i^j}{dt} = r_i(\vec{e}^j) - \varphi_i^j(\vec{x}^j; \vec{R}_i^j) + \psi^j(\vec{x}; \mathbf{T})$$



Peterson et al. (2011)

O que determina a distribuição das espécies?

Ecologia de Populações



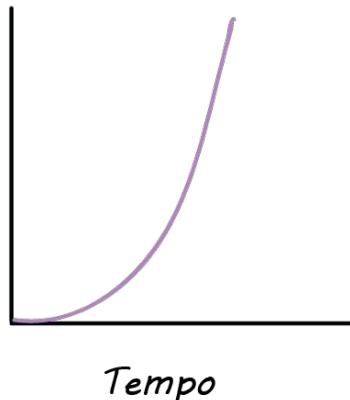
Crescimento exponencial

$$\frac{dN}{dt} = r N$$

A taxa de crescimento per capita (r) não muda, mesmo se a população aumentar muito.

$$\frac{dN}{dt} = r_{\max} N$$

Tamanho da população (N)

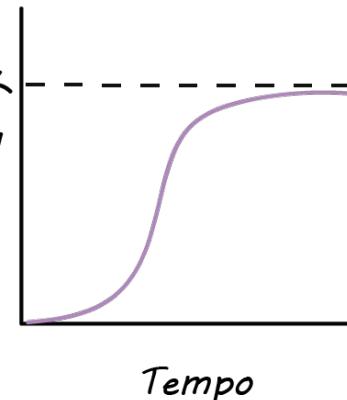


Crescimento logístico

A taxa de crescimento per capita (r) diminui à medida que a população se aproxima de seu tamanho máximo.

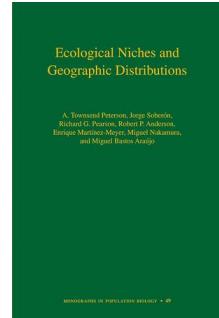
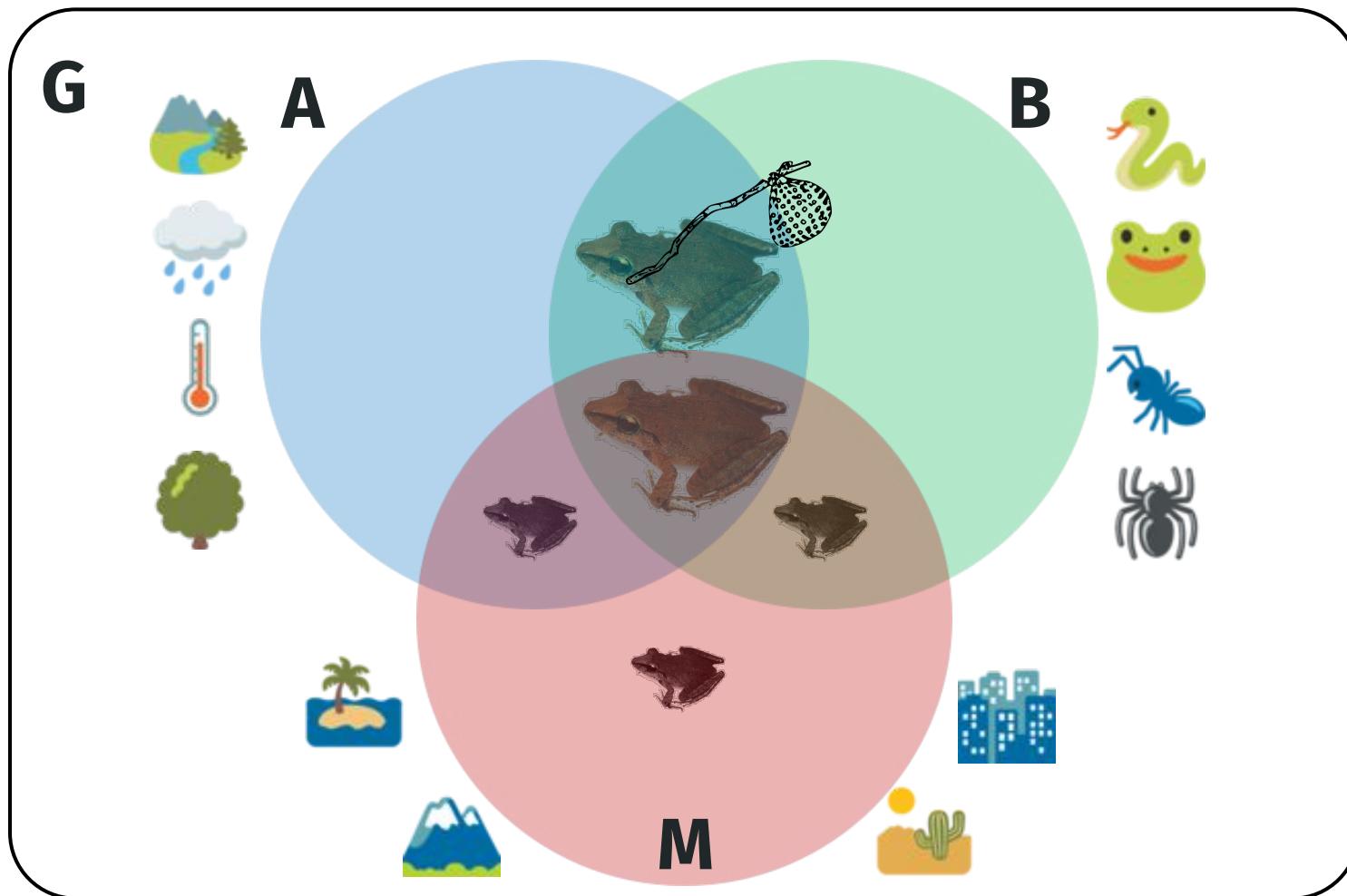
$$\frac{dN}{dt} = r_{\max} \left(\frac{K - N}{K} \right) N$$

Tamanho da população (N)



O que determina a distribuição de espécies?

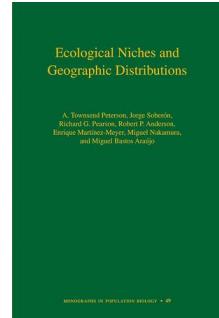
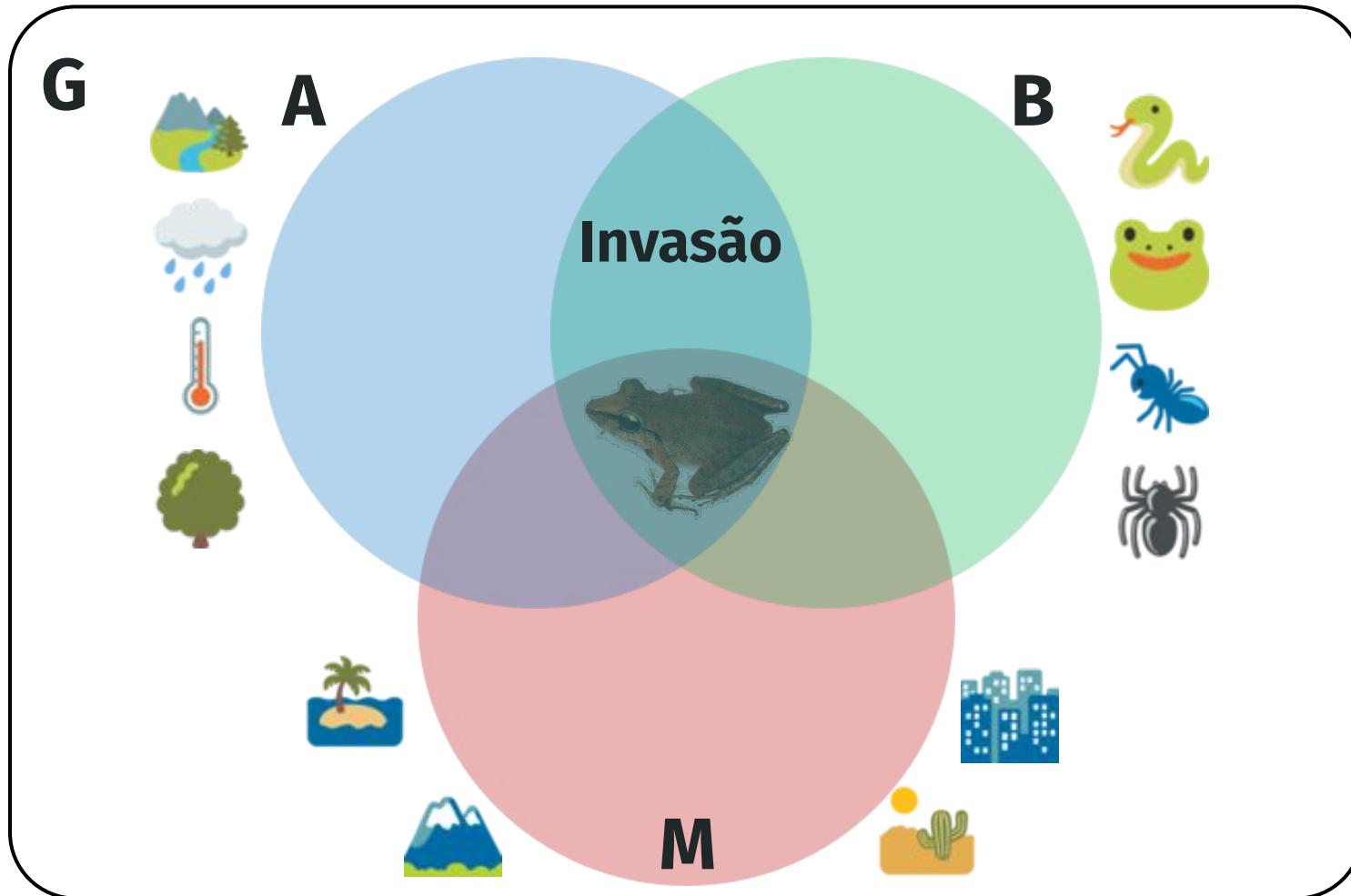
Populações fonte e ralo (source-sink)



Peterson et al. (2011)

O que determina a distribuição de espécies?

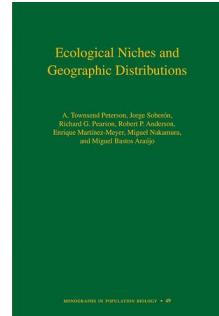
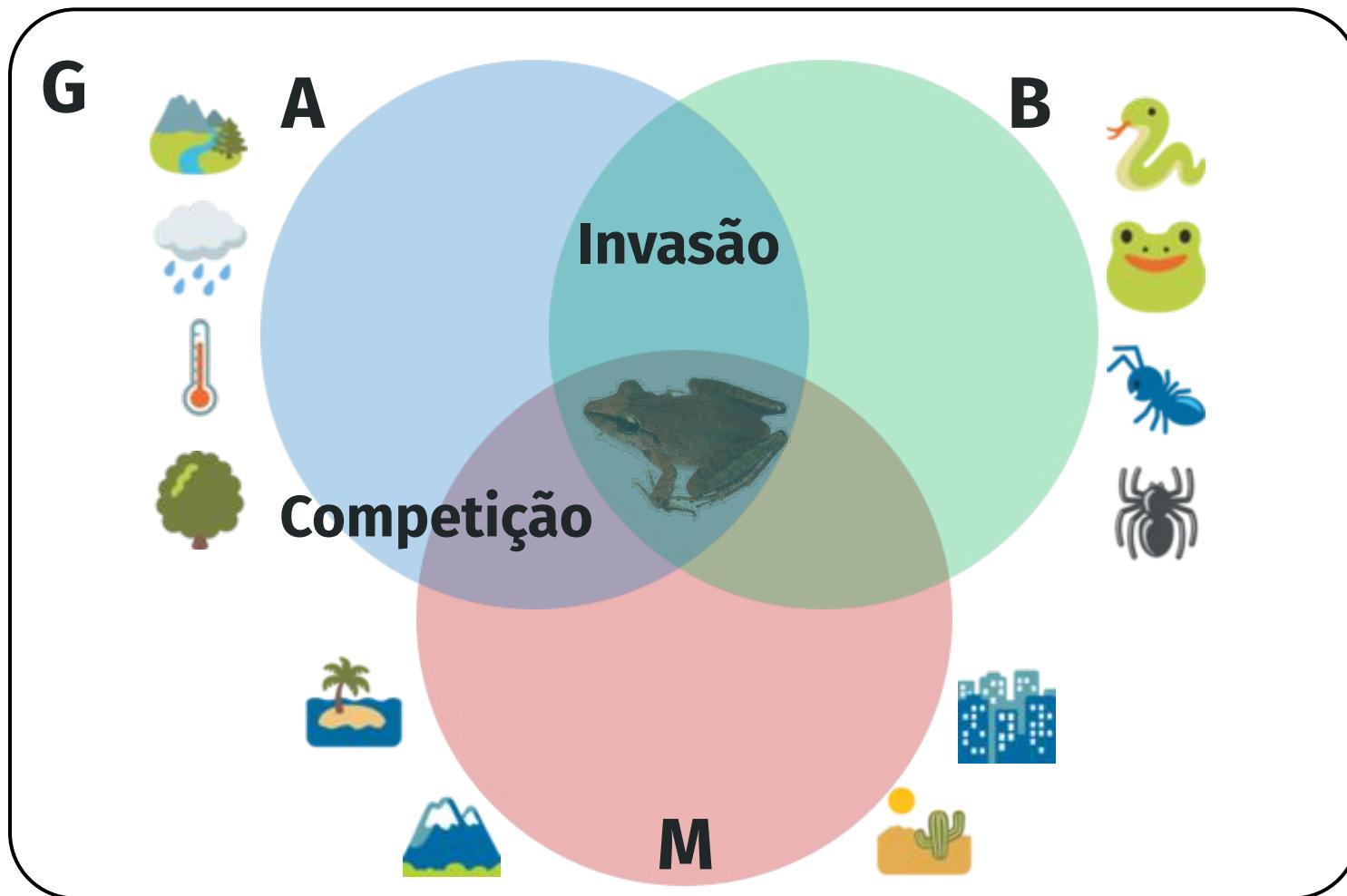
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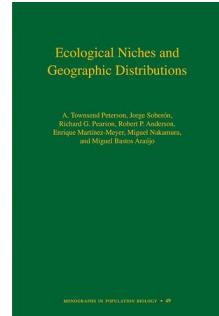
Populações fonte e ralo (source-sink)



Peterson et al. (2011)

O que determina a distribuição de espécies?

Populações fonte e ralo (source-sink)



Peterson et al. (2011)

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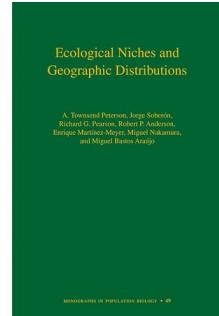
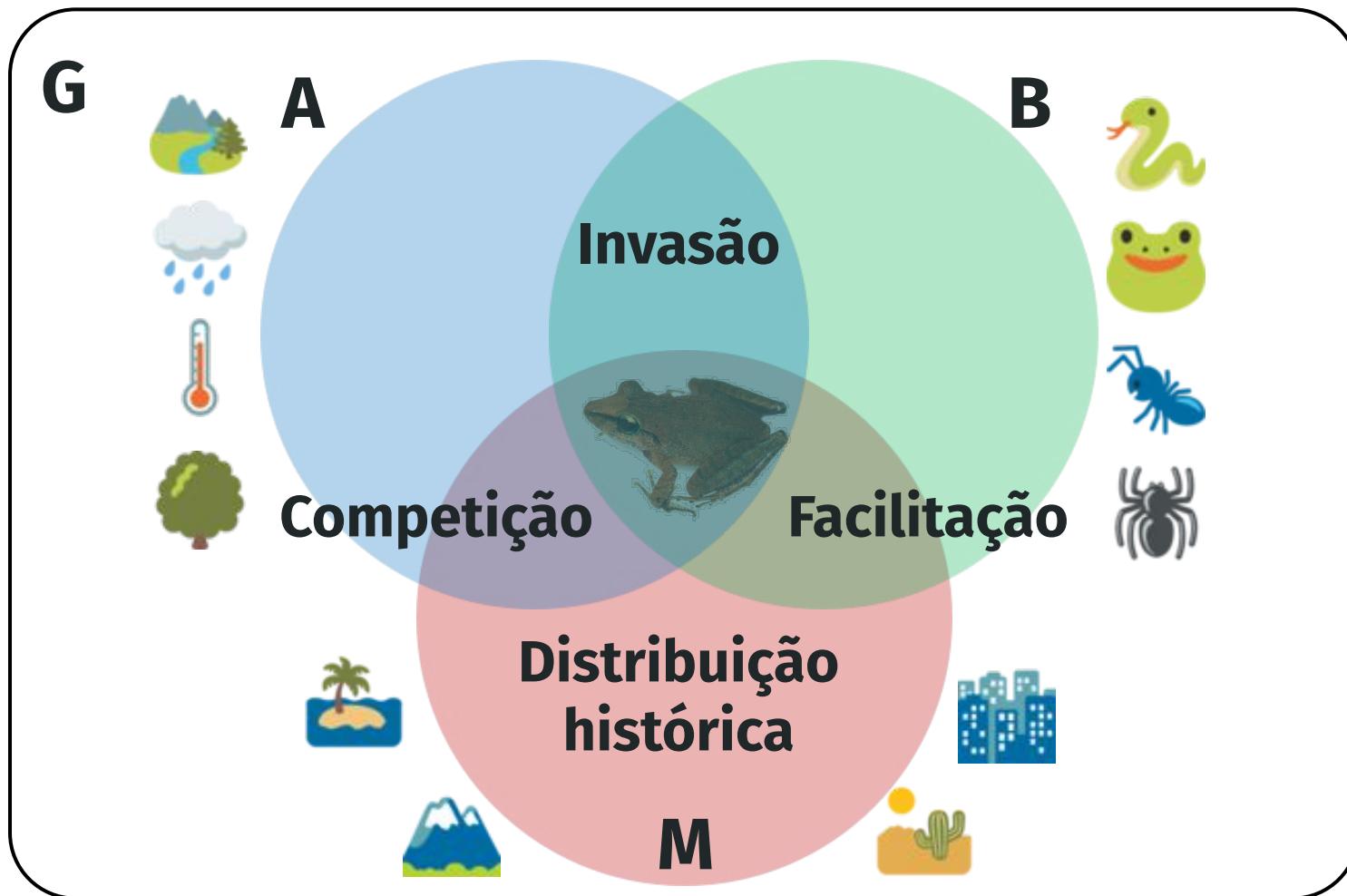
Populações fonte e ralo (source-sink)

The diagram illustrates several ecological concepts:

- Source-sink populations:** A population source (G) is shown with icons of a landscape, rain, temperature, and a tree. A population sink (B) is shown with icons of a snake, frog, ant, and spider.
- Invasão (Invasion):** Represented by a frog in the center of overlapping circles labeled A and B.
- Competição (Competition):** Represented by a circle labeled A.
- Facilitação (Facilitation):** Represented by a circle labeled B.
- Niche Theory:** Two diagrams show niche components:
 - (i) Realized niche (solid green circle), Fundamental niche (dashed green circle), Competition, Predation, Recruitment limitation, Disease and parasitism.
 - (ii) Realized niche (solid green circle), Fundamental niche (dashed green circle), Resource enhancement, Predation refuge, Recruitment enhancement, Habitat amelioration.
- Opinion Article:** A box from *TRENDS in Ecology and Evolution*, Vol. 18 No. 3 March 2003, by John F. Bruno¹, John J. Stachowicz² and Mark D. Bertness³. The title is "Inclusion of facilitation into ecological theory".

O que determina a distribuição de espécies?

Populações fonte e ralo (source-sink)

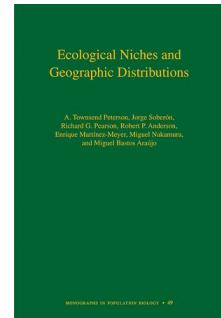
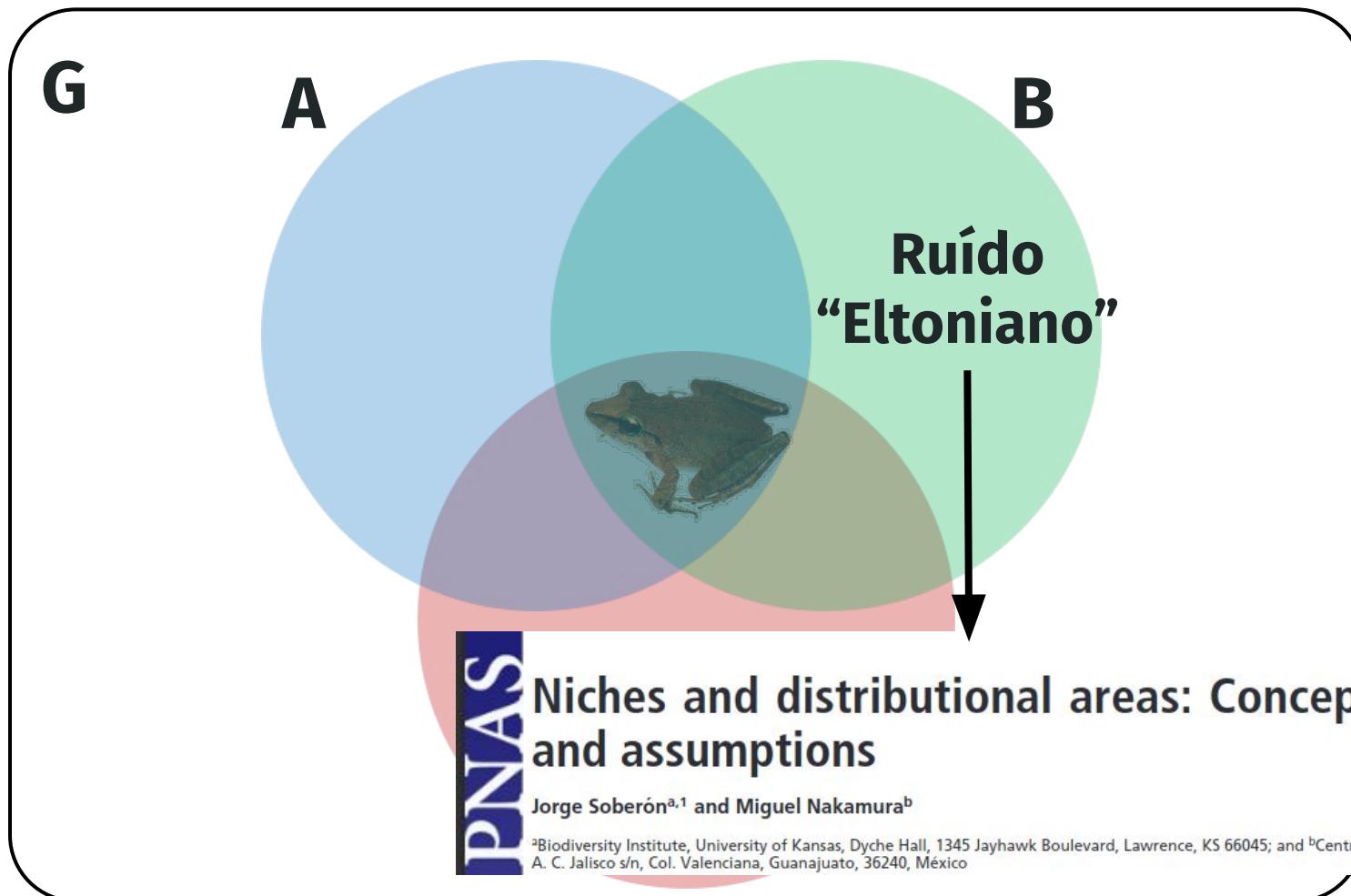


Peterson et al. (2011)

E as interações bióticas?

O que determina a distribuição de espécies?

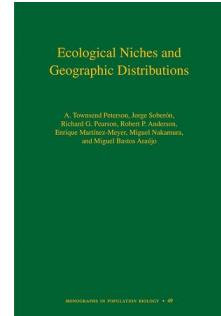
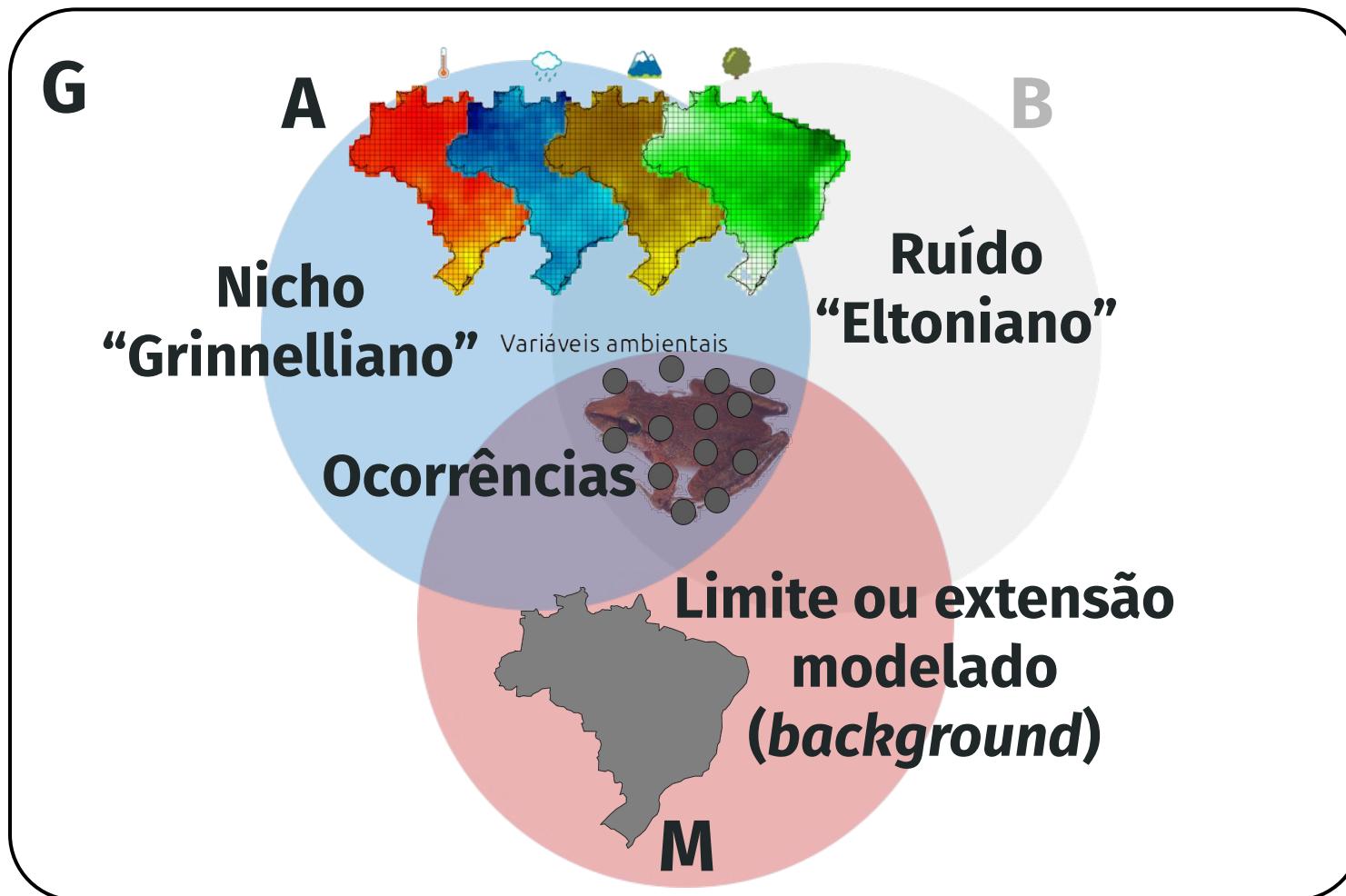
Interações bióticas “ignoradas”



Peterson et al. (2011)

O que determina a distribuição de espécies?

Estimativa do nicho Grinnelliano realizado



Peterson et al. (2011)

Área em desenvolvimento

Como inserir as interações bióticas nos ENMs?

RESEARCH PAPER

WILEY Journal of Biogeography

Using biotic interactions in broad-scale estimates of species' distributions

Iulian Gherghel^{1,2,3}  | François Brischoux⁴ | Monica Papes⁵

BIOLOGICAL REVIEWS

Cambridge Philosophical Society

 Open Access

The role of biotic interactions in shaping distributions and realised assemblages of species: implications for species distribution modelling

Mary Susanne Wisz , Julien Pottier, W. Daniel Kissling, Loïc Pellissier, Jonathan Lenoir, Christian F. Damgaard, Carsten F. Dormann, Mads C. Forchhammer, John-Arvid Grytnes ... See all authors 

Journal of Biogeography



Original Article  Full Access

The importance of biotic interactions in species distribution models: a test of the Eltonian noise hypothesis using parrots

Carlos B. de Araújo , Luiz Octavio Marcondes-Machado, Gabriel C. Costa

Ecology and Evolution

Open Access

ORIGINAL RESEARCH   

Effects of biotic interactions on modeled species' distribution can be masked by environmental gradients

William Godsoe , Janet Franklin, F. Guillaume Blanchet

RESEARCH REVIEWS

WILEY Global Ecology and Biogeography

A Journal of
Macroecology

Biotic interactions in species distribution modelling: 10 questions to guide interpretation and avoid false conclusions

Carsten F. Dormann¹  | Maria Bobrowski² | D. Matthias Dehling³ | David J. Harris⁴ | Florian Hartig^{1,5} | Heike Lischke⁶ | Marco D. Moretti⁷  | Jörn Pagel⁸ | Stefan Pinkert⁹  | Matthias Schleuning¹⁰ | Susanne I. Schmidt¹¹  | Christine S. Sheppard⁸  | Manuel J. Steinbauer^{12,13}  | Dirk Zeuss¹⁴  | Casper Kraan^{15,16} 

Biotic interactions and climate in species distribution modelling

Daniel P. Bebber,  Sarah J. Gurr

doi: <https://doi.org/10.1101/520320>

4. SDM passo a passo

SDM passo a passo

Estrutura dos ENMs

ECOGRAPHY

Review and synthesis

A standard protocol for reporting species distribution models

Damaris Zurell, Janet Franklin, Christian König, Phil J. Bouchet, Carsten F. Dormann, Jane Elith, Guillermo Fandos, Xiao Feng, Gurutzeta Guillera-Arroita, Antoine Guisan, José J. Lahoz-Monfort, Pedro J. Leitão, Daniel S. Park, A. Townsend Peterson, Giovanni Rapacciulo, Dirk R. Schmatz, Boris Schröder, Josep M. Serra-Díaz, Wilfried Thuiller, Katherine L. Yates, Niklaus E. Zimmermann and Cory Merow

Ecography

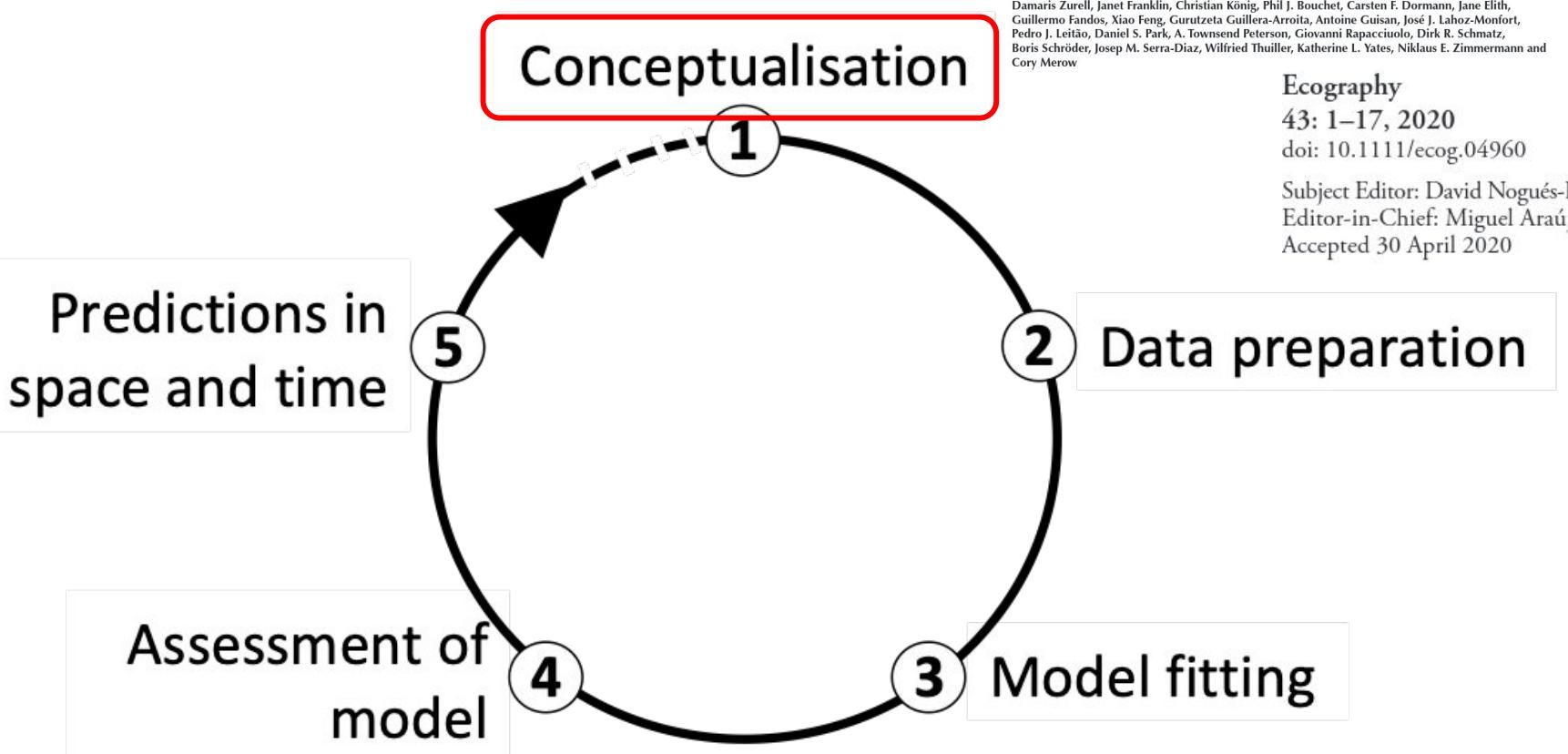
43: 1–17, 2020

doi: 10.1111/ecog.04960

Subject Editor: David Nogués-Bravo

Editor-in-Chief: Miguel Araújo

Accepted 30 April 2020



Conceitualização

Perguntas associadas à distribuição das espécies

Teoria -> Perguntas -> Hipóteses ->
Estatística (modelos) -> Respostas

Conceitualização

Perguntas associadas à distribuição das espécies

Teoria -> Perguntas -> Hipóteses ->
Estatística (modelos) -> Respostas

- 1. Padrões de diversidade
- 2. Mudanças climáticas (futuro)
- 3. Mudanças climáticas (passado)
- 4. Invasão de espécies
- 5. Transmissão de doenças
- 6. Interações entre espécies
- 7. Processos de diversificação
- 8. Dispersão de espécies
- 9. Processos de extinção
- 10. Conservação-evolução do nicho
- 11. Testar hipóteses filogeográficas
- 12. Estabelecer refúgios climáticos
- 13. Estabelecer hotspots
- 14. Estabelecer áreas protegidas
- 15. Eficiência das áreas protegidas

SDM passo a passo

Estrutura dos ENMs

ECOGRAPHY

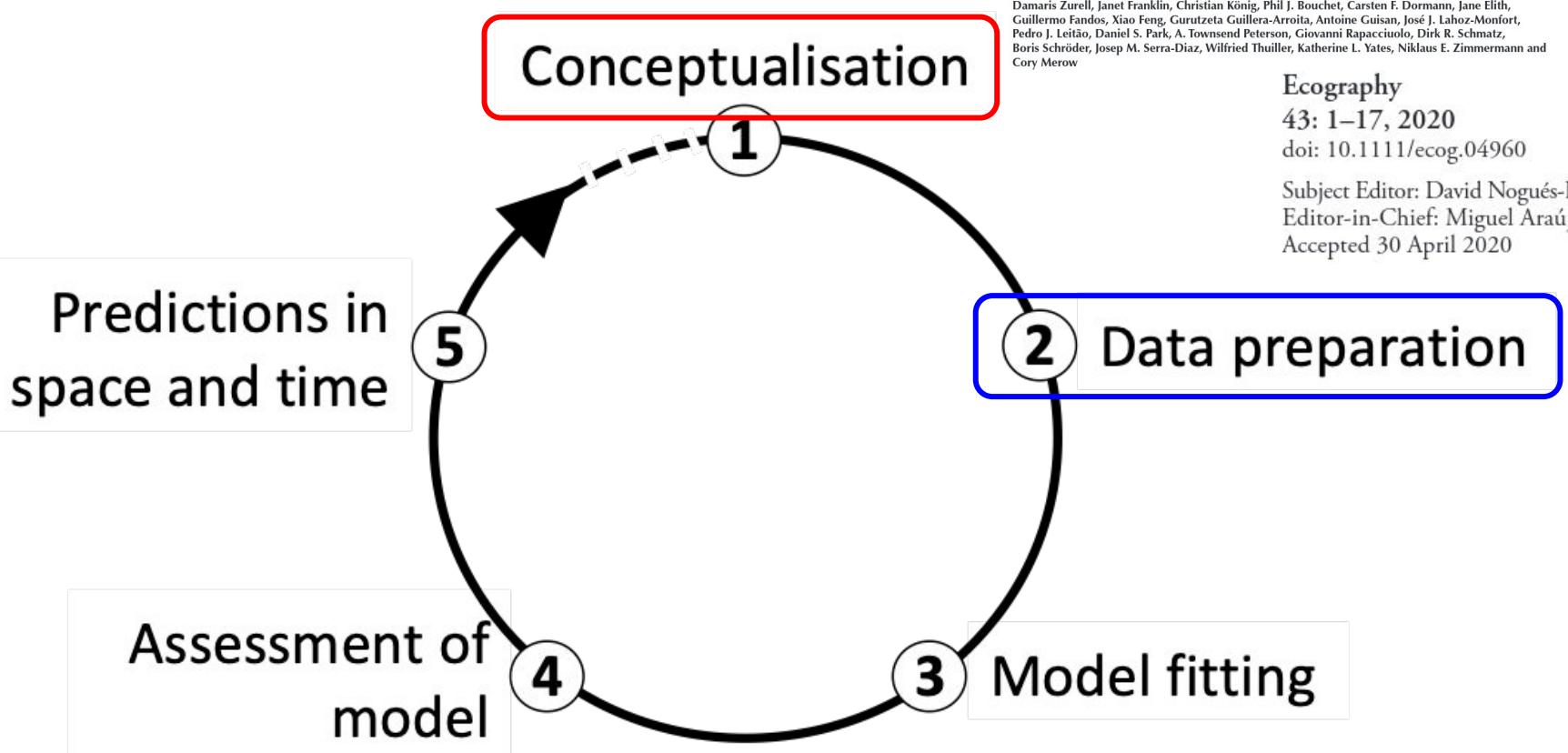
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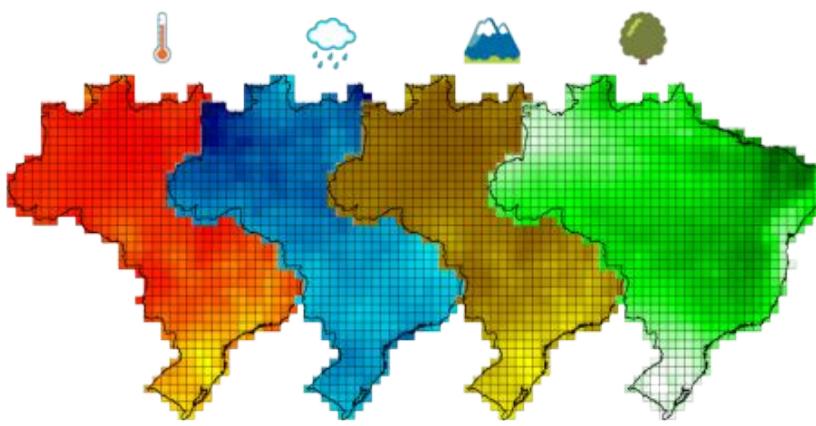


Modelos de Nicho Ecológico (ENMs)

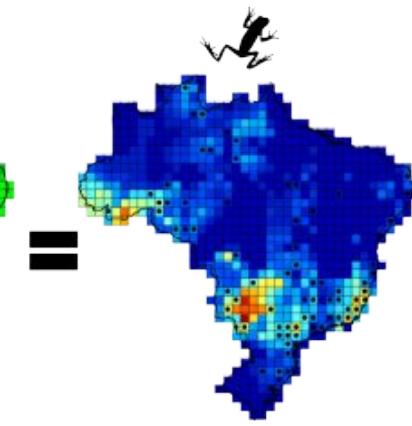
Preparação dos dados



"Ocorrências"



Variáveis ambientais



Adequabilidade

species	lon	lat
sp1	-40.2	-23.4
sp1	-38.8	-20.3
sp1	-43.3	-19.9

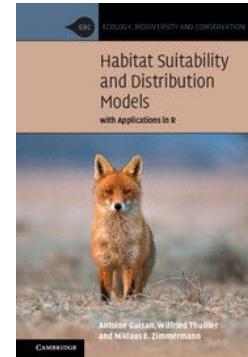
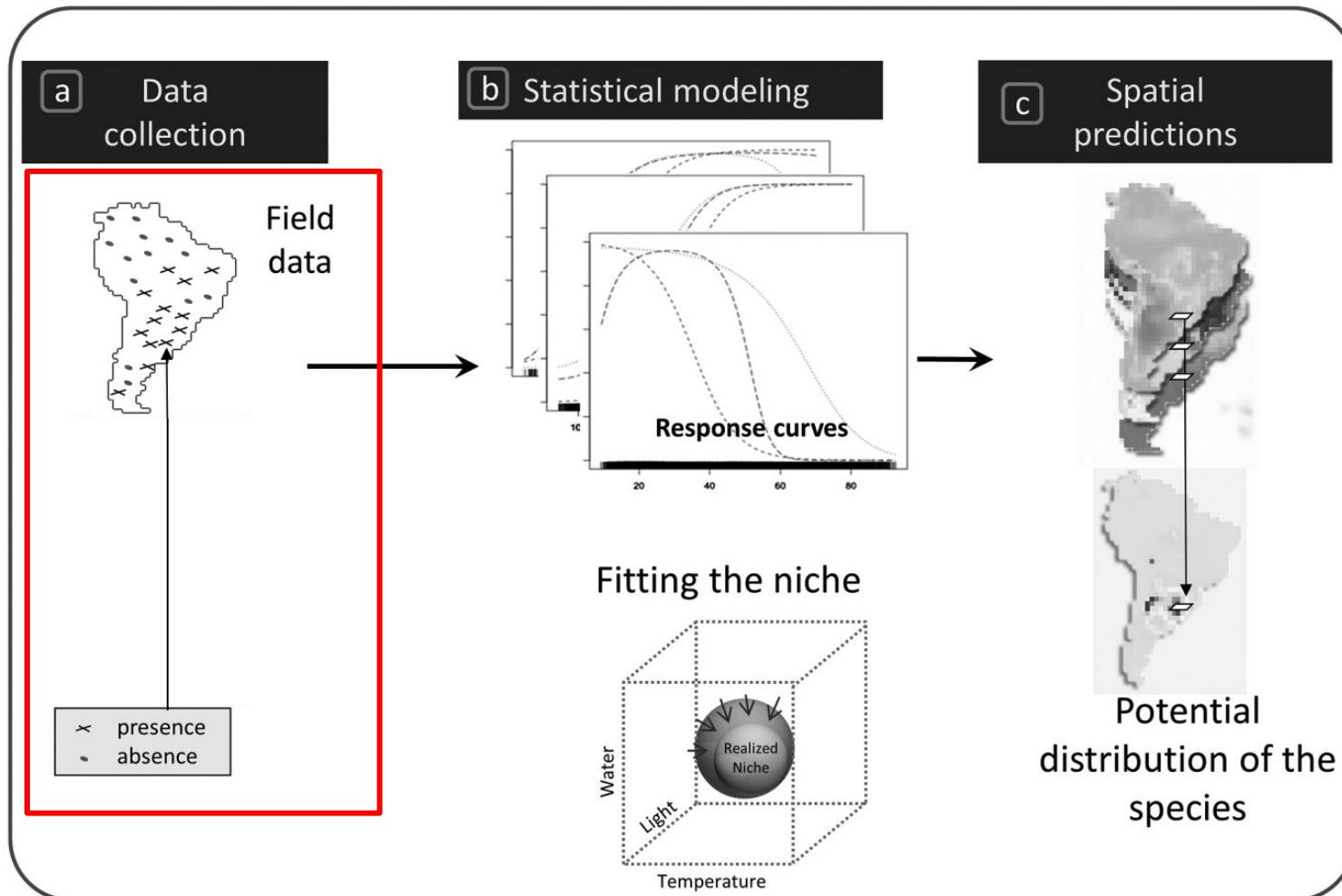
variaveis
temperatura
precipitação
relevo

valores
0
até
1

5. Dados de entrada: ocorrências e variáveis

Ocorrências

Visão geral



Guisan et al. (2017)

Ocorrências

Fontes

1. Coletas em campo



Ocorrências

Fontes

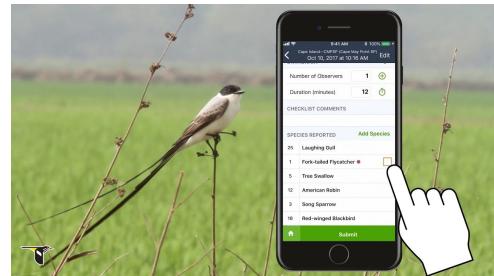
1. Coletas em campo
2. Literatura (artigos, data papers, ...)



Ocorrências

Fontes

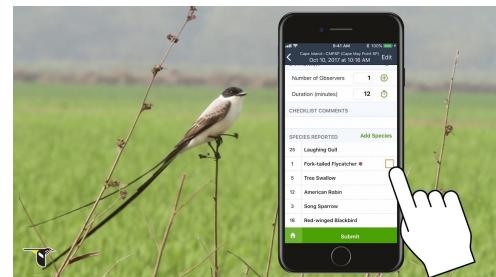
1. Coletas em campo
2. Literatura (artigos, data papers, ...)
3. Naturalistas e ciência cidadã (e-Bird, iNaturalist, ...)



Ocorrências

Fontes

1. Coletas em campo
2. Literatura (artigos, data papers, ...)
3. Naturalistas e ciência cidadã (e-Bird, iNaturalist, ...)
4. Coleções científicas e museus (Museu Nacional, MZUSP, CFHB, ...)

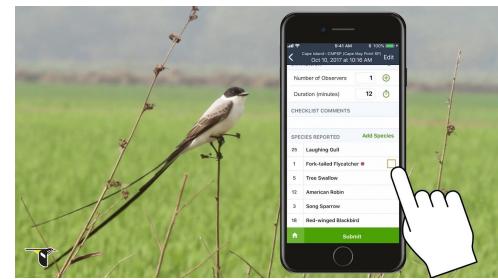
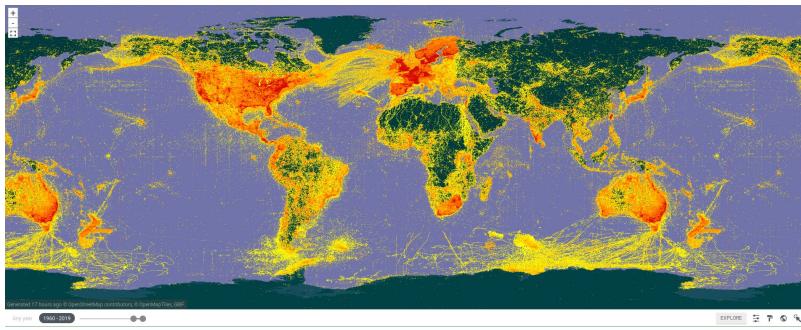


Ocorrências

Fontes

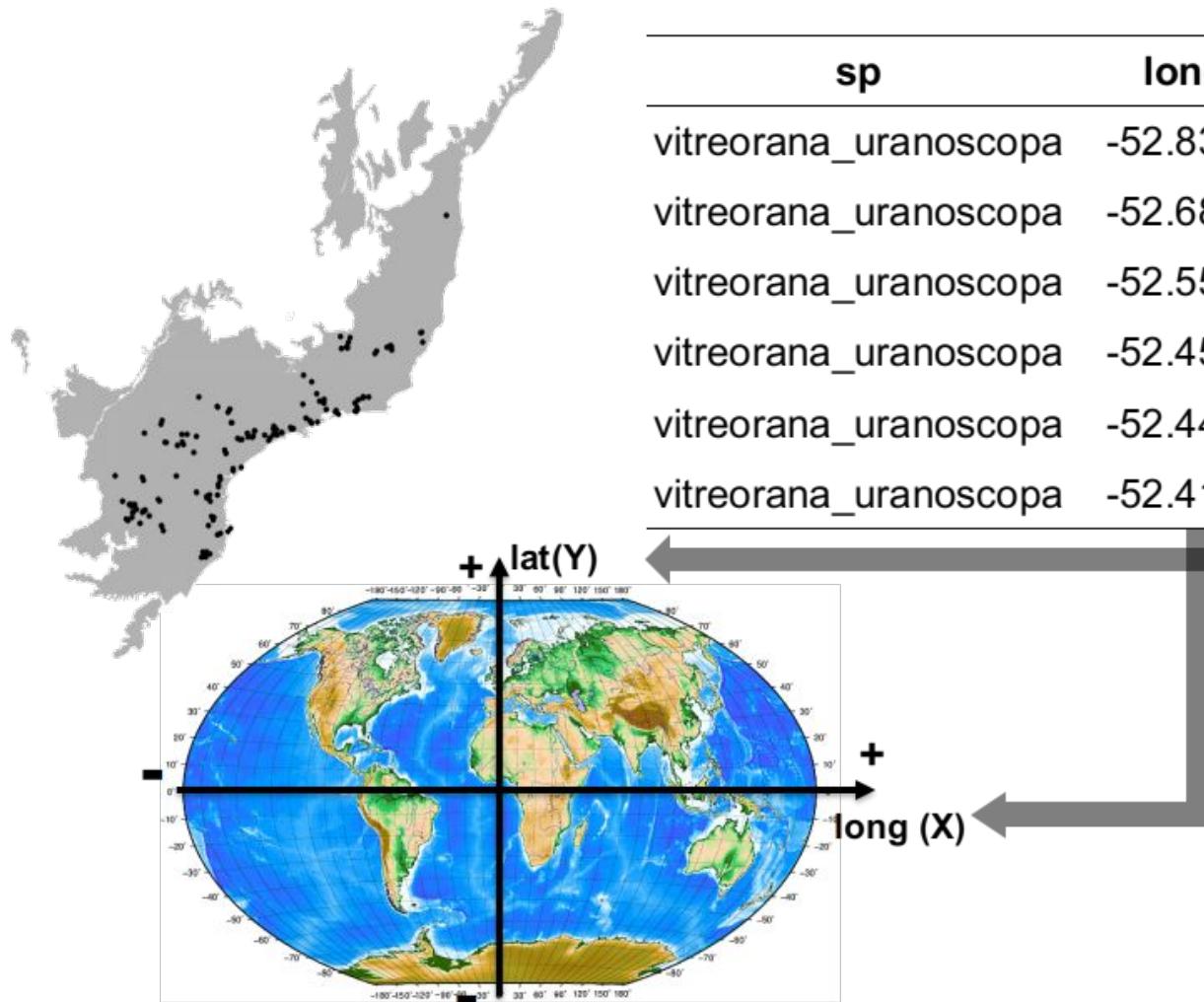
1. Coletas em campo
2. Literatura (artigos, data papers, ...)
3. Naturalistas e ciência cidadã (e-Bird, iNaturalist, ...)
4. Coleções científicas e museus (Museu Nacional, MZUSP, CFHB, ...)
5. Banco de dados (GBIF, SpeciesLink, ...)

The screenshot shows the homepage of SpeciesLink. It features a large image of a red flower. Below it, there's a section titled "o projeto" with the text "SpeciesLink é um sistema distribuído de informação que integra em tempo real dados primários de coleções científicas. O sistema foi desenvolvido através do apoio das instituições: FAPESP, CNPq, PGC, Fundação DCM, UFG, UFSC, UFSJ e CRIA". There are also sections for "novedades" and "dados e ferramentas". At the bottom left, there's a "Indicadores" section with some small icons and text. At the bottom right, there's a "dados e ferramentas" section with a small image of a specimen card.



Ocorrências

Formato

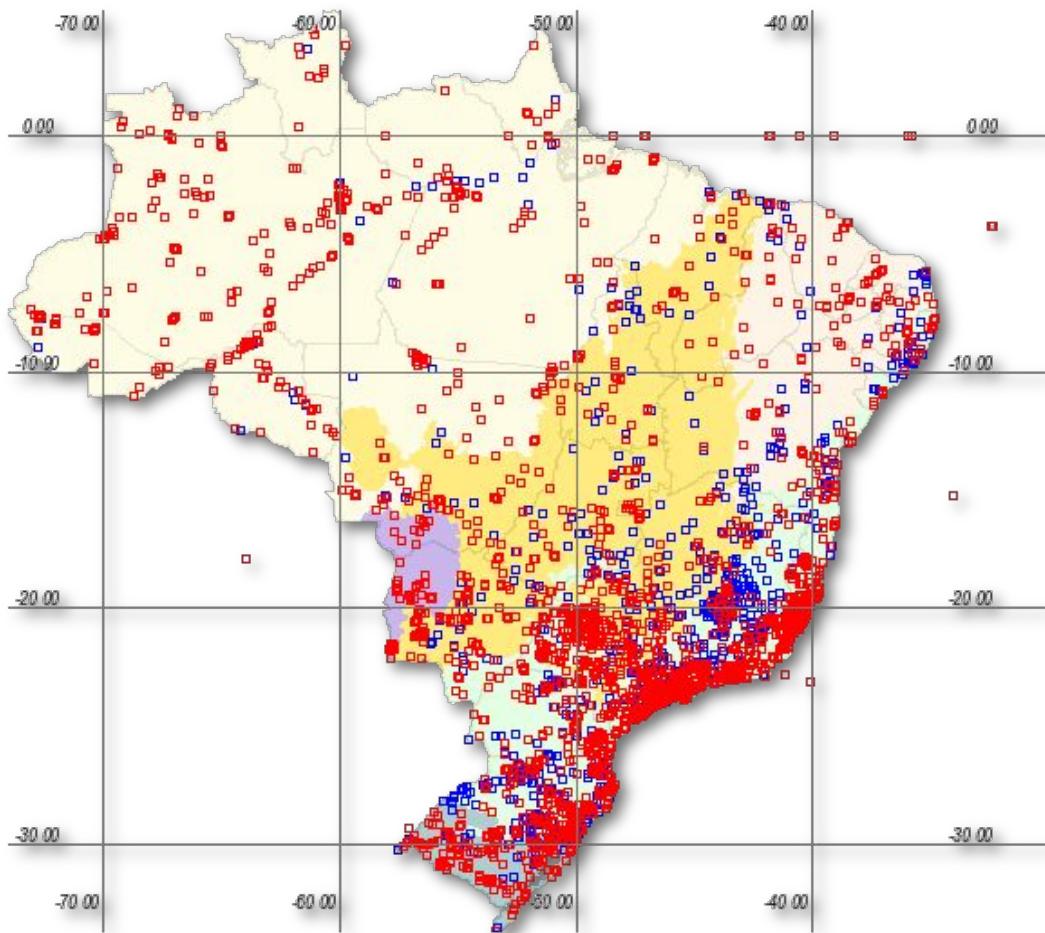


sp	long	lat
vitreorana_uranoscopa	-52.8300	-26.4400
vitreorana_uranoscopa	-52.6836	-27.1253
vitreorana_uranoscopa	-52.5569	-26.5642
vitreorana_uranoscopa	-52.4500	-26.5667
vitreorana_uranoscopa	-52.4489	-27.0689
vitreorana_uranoscopa	-52.4147	-26.8667

Desafios: Viés de amostragem

Ocorrências

Viés de amostragem

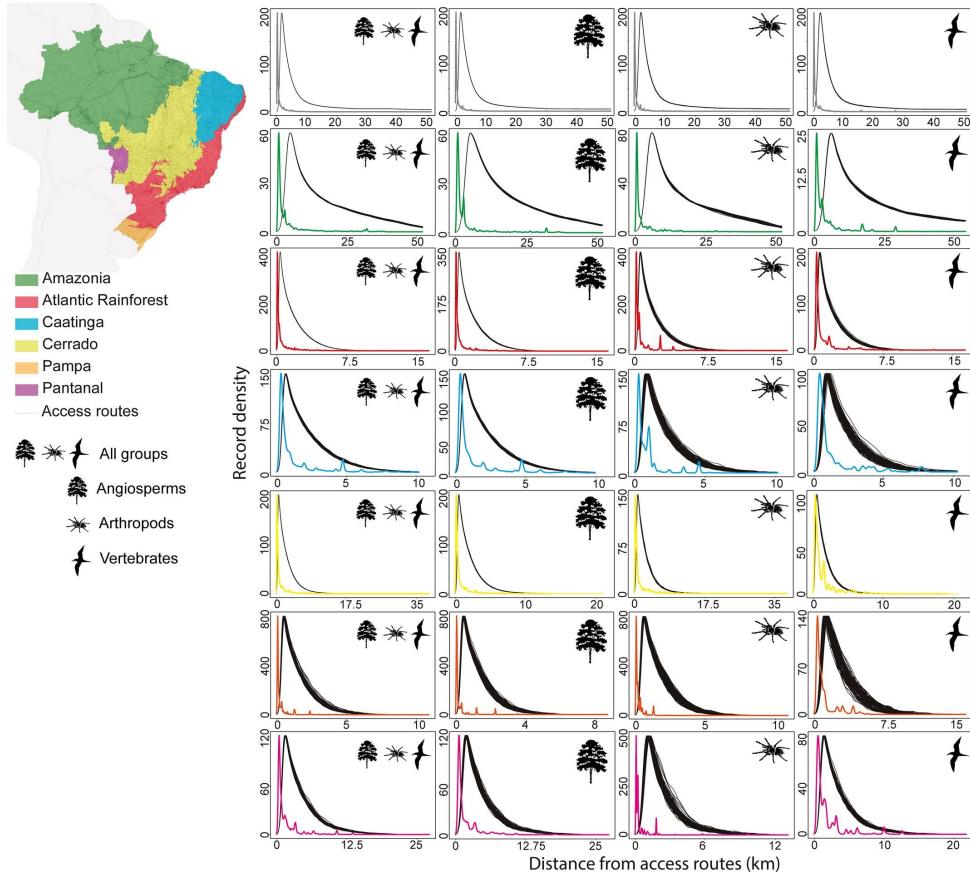


Boana faber

species link

Ocorrências

Viés de amostragem

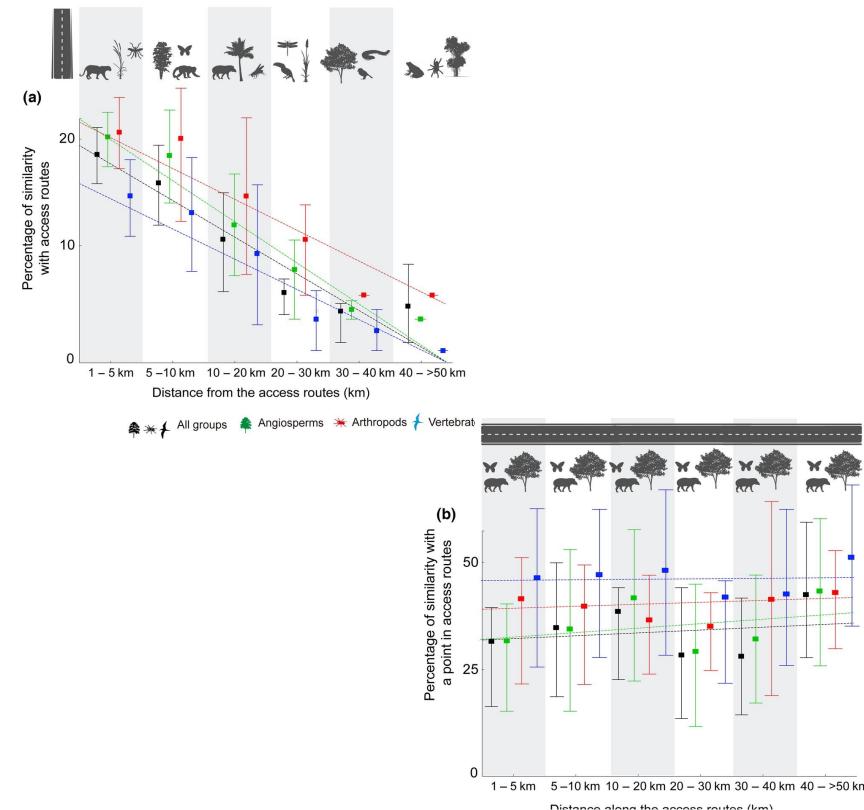


Diversity and Distributions, (Diversity Distrib.) (2016) 22, 1232–1244



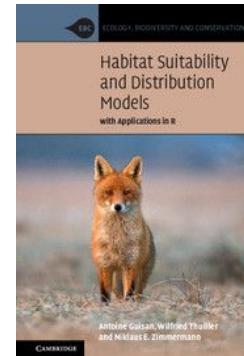
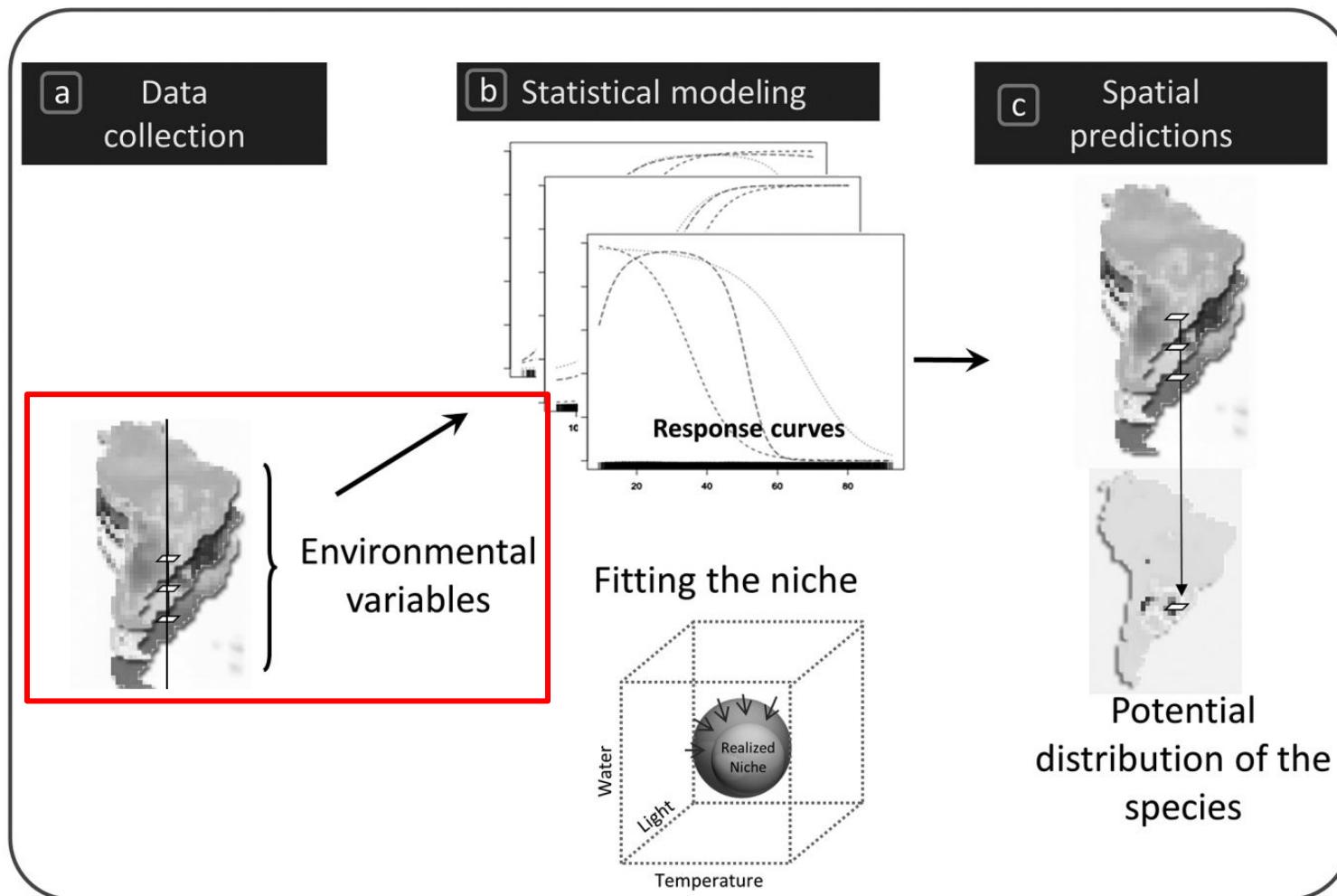
The strong influence of collection bias on biodiversity knowledge shortfalls of Brazilian terrestrial biodiversity

Ubirajara Oliveira^{1,2*}, Adriano Pereira Paglia³, Antonio D. Brescovit⁴, Claudio J. B. de Carvalho⁵, Daniel Paiva Silva⁶, Daniella T. Rezende⁷, Felipe Sá Fortes Leite⁸, João Aguiar Nogueira Batista⁹, João Paulo Peixoto Pena Barbosa⁴, João Renato Stehmann⁹, John S. Ascher¹⁰, Marcelo Ferreira de Vasconcelos^{11,12}, Paulo De Marco Jr¹³, Peter Löwenberg-Neto¹⁴, Priscila Guimarães Dias¹⁵, Viviane Gianluppi Ferro¹³ and Adalberto J. Santos²



Variáveis ambientais

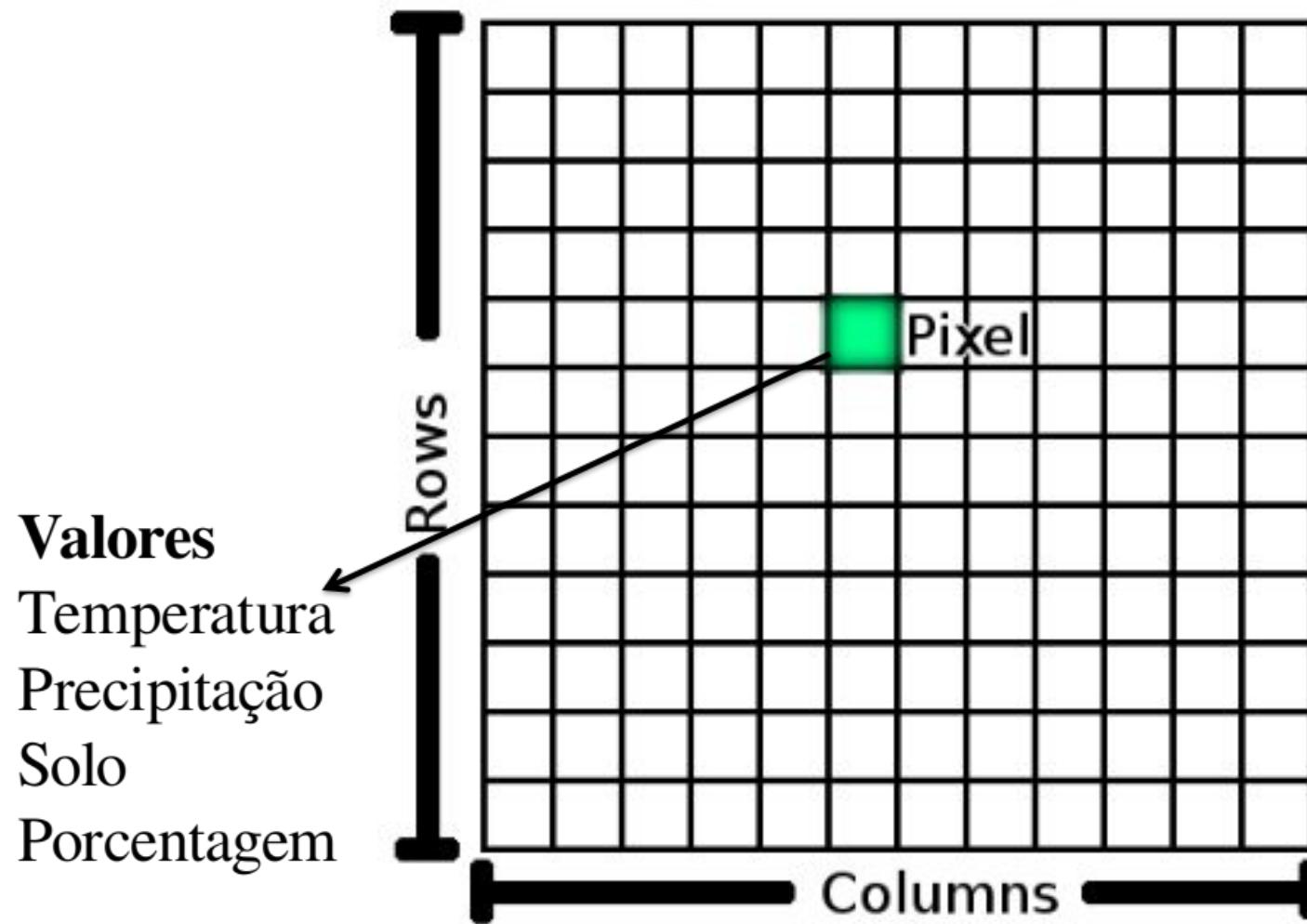
Visão geral



Guisan et al. (2017)

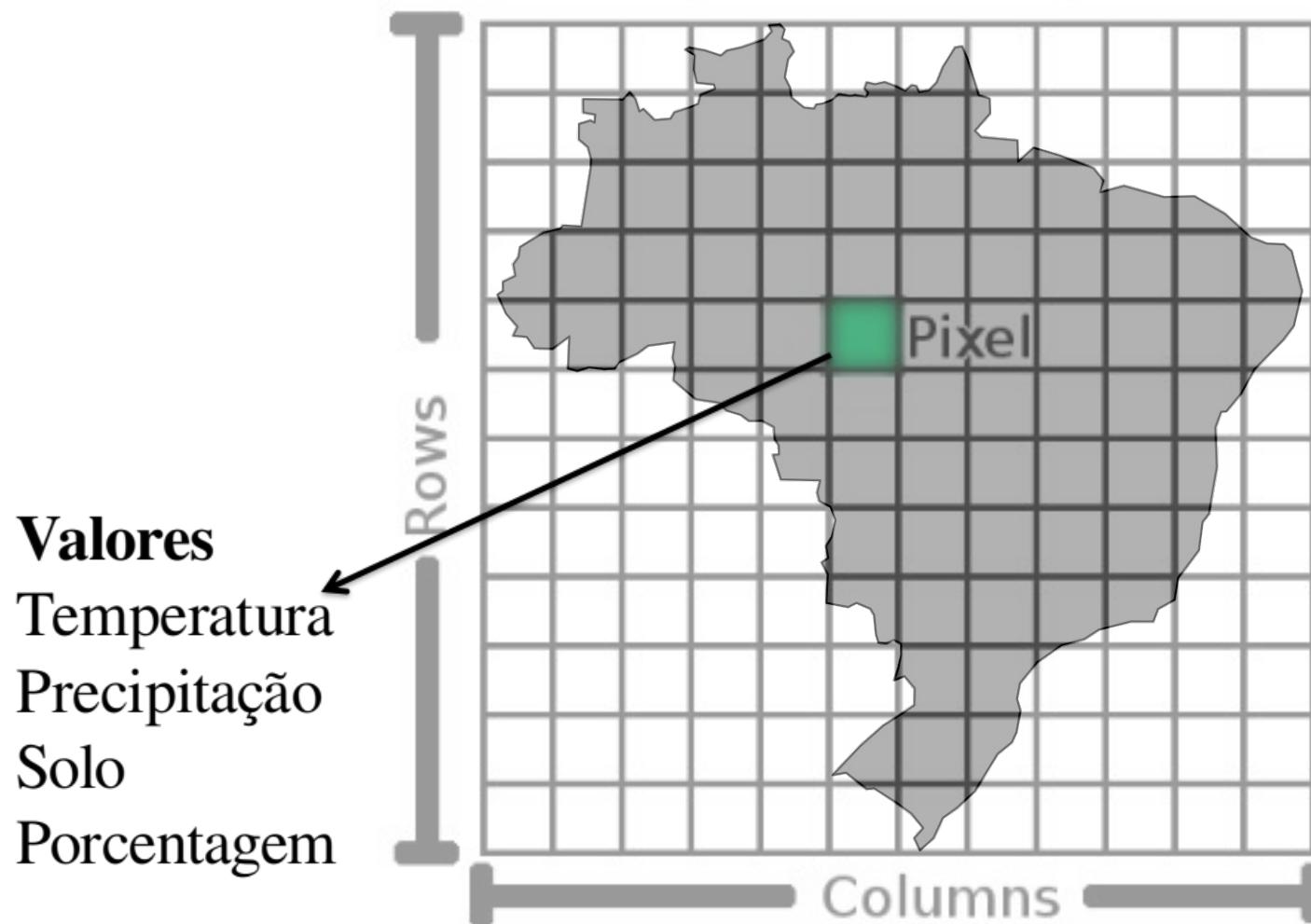
Variáveis ambientais

Raster - Extensão e resolução



Variáveis ambientais

Raster - Extensão e resolução

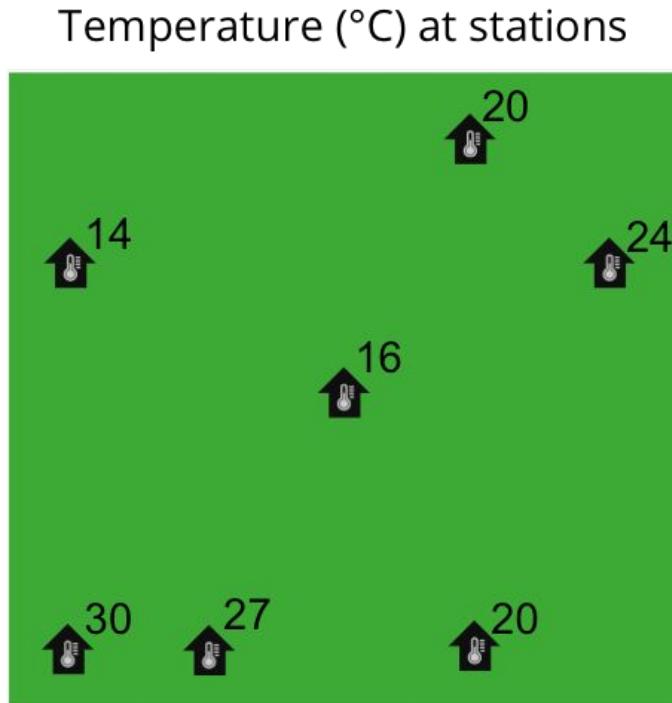


Variáveis ambientais

Raster - Interpolação



<https://support.bccvl.org.au/support/home>



Temperature ($^{\circ}\text{C}$) interpolated

A 5x5 grid of temperature values ($^{\circ}\text{C}$) representing interpolated data. The values are arranged as follows:

13	14	16	20	23
14	14	16	19	24
18	16	16	18	22
24	22	19	19	21
30	27	23	20	20

The grid uses color coding where darker shades represent higher temperatures. Specific cells are outlined in green: the top row (13, 14, 16), the second row (14, 14, 16), the third row (18, 16, 16), the fourth row (24, 22, 19), and the bottom row (30, 27, 23). The last cell in each row (20, 24, 18, 19, 20) is also outlined in green.

Adapted from http://planet.botany.uwc.ac.za/nisl/GIS/spatial/chap_1_11.h

Variáveis ambientais

WorldClim - Bioclimáticas

WorldClim - Global Climate Data
Free climate data for ecological modeling and GIS
Contact

Home

Bioclimatic variables

Bioclimatic variables are derived from the monthly temperature and rainfall values in order to generate more biologically meaningful variables. These are often used in **species distribution modeling** and related ecological modeling techniques. The bioclimatic variables represent annual trends (e.g., mean annual temperature, annual precipitation) seasonality (e.g., annual range in temperature and precipitation) and extreme or limiting environmental factors (e.g., temperature of the coldest and warmest month, and precipitation of the wet and dry quarters). A quarter is a period of three months (1/4 of the year).

They are coded as follows:

BIO1 = Annual Mean Temperature
BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO3 = Isothermality (BIO2/BIO7) (* 100)
BIO4 = Temperature Seasonality (standard deviation *100)
BIO5 = Max Temperature of Warmest Month
BIO6 = Min Temperature of Coldest Month
BIO7 = Temperature Annual Range (BIO5-BIO6)
BIO8 = Mean Temperature of Wettest Quarter
BIO9 = Mean Temperature of Driest Quarter
BIO10 = Mean Temperature of Warmest Quarter
BIO11 = Mean Temperature of Coldest Quarter
BIO12 = Annual Precipitation
BIO13 = Precipitation of Wettest Month
BIO14 = Precipitation of Driest Month
BIO15 = Precipitation Seasonality (Coefficient of Variation)
BIO16 = Precipitation of Wettest Quarter
BIO17 = Precipitation of Driest Quarter
BIO18 = Precipitation of Warmest Quarter
BIO19 = Precipitation of Coldest Quarter

BIO01 = Temperatura média anual
BIO02 = Variação Diurna Média de Temperatura (Média mensal (Tmax-Tmin))
BIO03 = Isothermalidade ((BIO2/BIO7) (* 100))
BIO04 = Sazonalidade da Temperatura (desvio padrão * 100)
BIO05 = Temperatura máxima do mês mais quente
BIO06 = Temperatura mínima do mês mais frio
BIO07 = Amplitude térmica anual (BIO5-BIO6)
BIO08 = Temperatura média do trimestre mais úmido
BIO09 = Temperatura média do trimestre mais seco
BIO10 = Temperatura média do trimestre mais quente
BIO11 = Temperatura média do trimestre mais frio

Temperatura

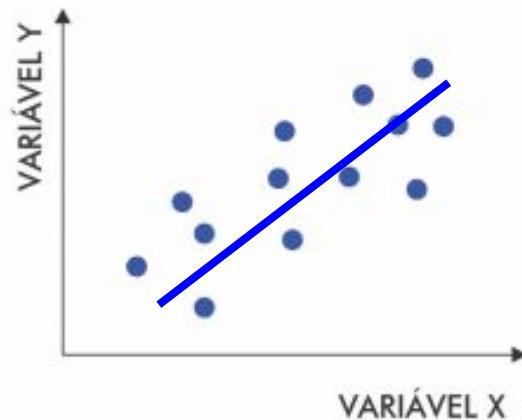
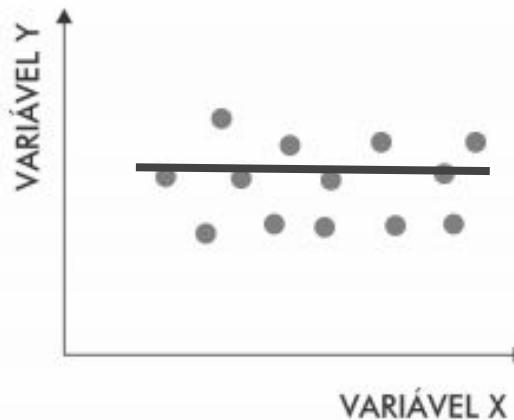
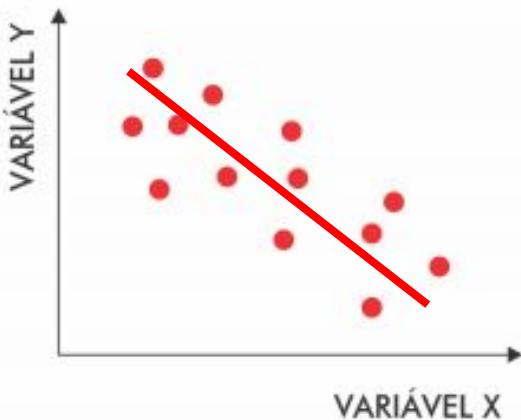
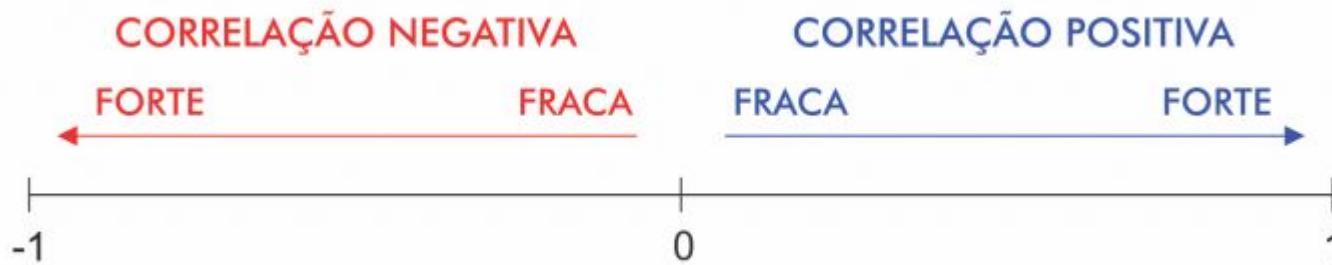
BIO12 = Precipitação Anual
BIO13 = Precipitação do mês mais chuvoso
BIO14 = Precipitação do mês mais seco
BIO15 = Sazonalidade da Precipitação (coeficiente de variação)
BIO16 = Precipitação do trimestre mais chuvoso
BIO17 = Precipitação do trimestre mais seco
BIO18 = Precipitação do trimestre mais quente
BIO19 = Precipitação do trimestre mais frio

Precipitação

Desafios: Colinearidade

Variáveis ambientais

Colinearidade - Correlação



SDM passo a passo

Estrutura dos ENMs

ECOGRAPHY

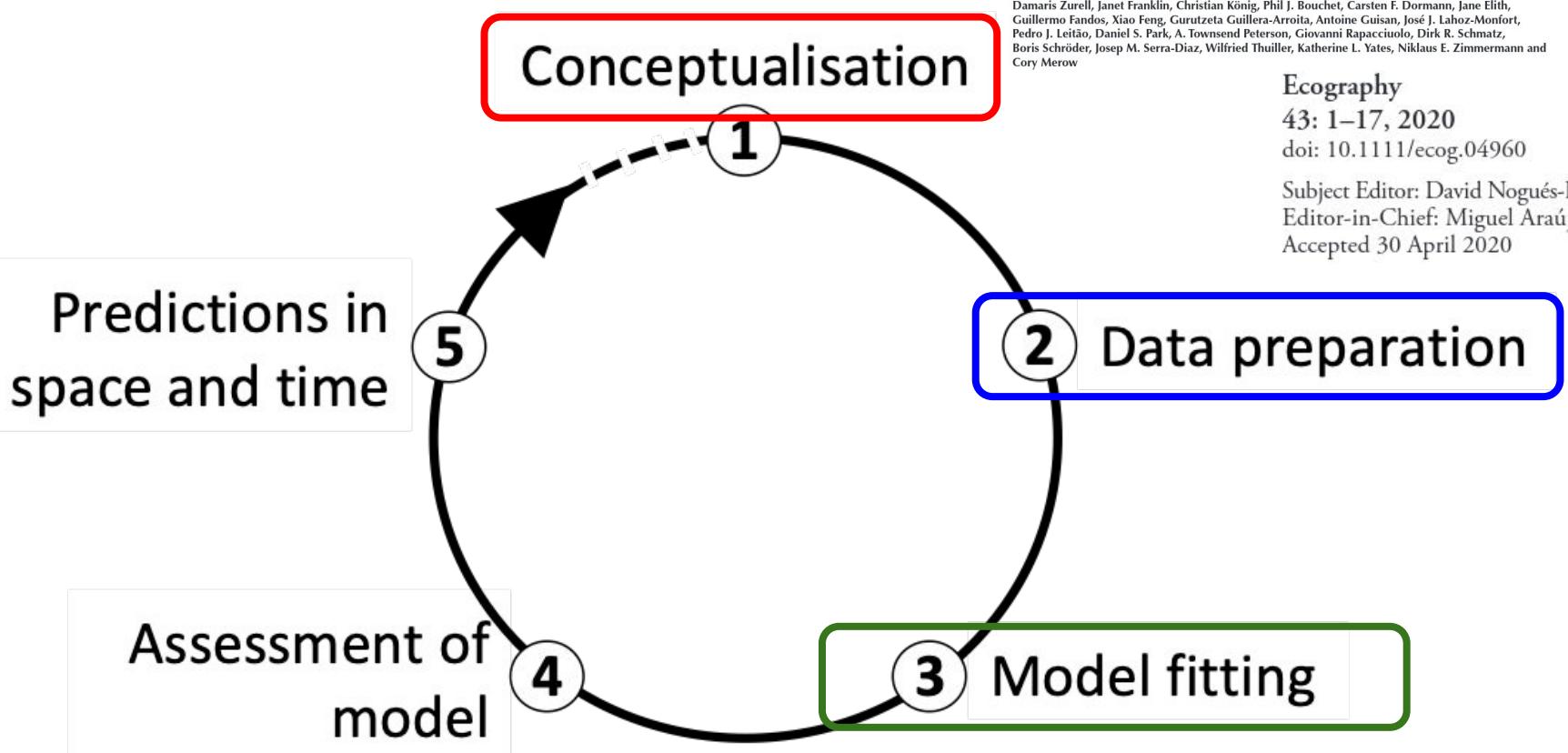
Review and synthesis

A standard protocol for reporting species distribution models

Damaris Zurell, Janet Franklin, Christian König, Phil J. Bouchet, Carsten F. Dormann, Jane Elith, Guillermo Fandos, Xiao Feng, Gurutzeta Guillera-Arroita, Antoine Guisan, José J. Lahoz-Monfort, Pedro J. Leitão, Daniel S. Park, A. Townsend Peterson, Giovanni Rapacciulo, Dirk R. Schmaltz, Boris Schröder, Josep M. Serra-Díaz, Wilfried Thuiller, Katherine L. Yates, Niklaus E. Zimmermann and Cory Merow

Ecography
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doi: 10.1111/ecog.04960

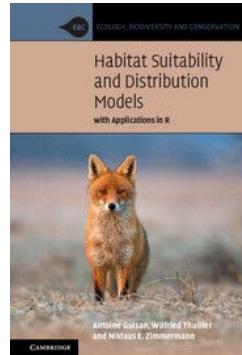
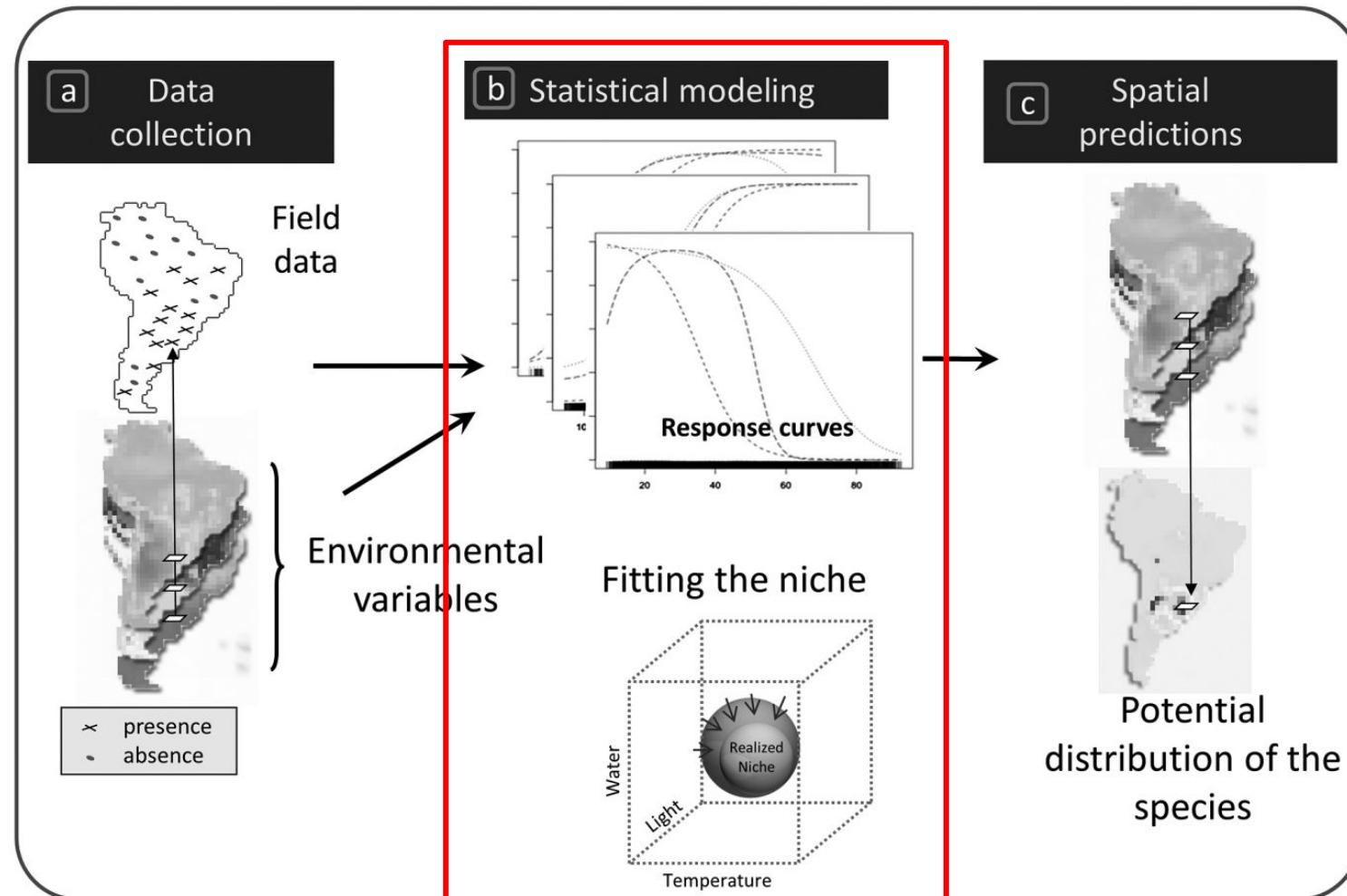
Subject Editor: David Nogués-Bravo
Editor-in-Chief: Miguel Araújo
Accepted 30 April 2020



6. Ajuste dos modelos

Ajuste dos ENMs

Algoritmos estimam o nicho realizado



Guisan et al. (2017)

Ajuste dos ENMs

Muitos tipos de algoritmos



Lima-Ribeiro &
Diniz-Filho (2013)

Apenas presença

Bioclim

Aquário

Dist. Euclidiana

Dist. Mahalanobis

Domain (dist. Gower)

ENFA (ecological niche factor analysis)

Presença/Background

GARP (genetic algorithm for rule-set production)

Maxent (maximum entropy)

SVM (support vector machine)

Aprendizado de Máquina
(machine learning)
“cofre”

Presença/Ausência

Estatístico (“turbina”)

GLMz (generalized linear model)

GAM (generalized additive model)

FDA (flexible discriminant analysis)

MARS (multivariate adaptive reg. splines)

BRT (boosted regression trees)

→ GBM (gradient boosting machine)

CART (classification and regression trees)

RDNFOR (random forest)

NNET (neural networks)

→ ANN (artificial neural networks)

Ajuste dos ENMs

Mais utilizado - MaxEnt

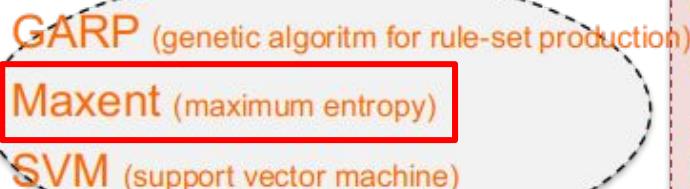


Lima-Ribeiro &
Diniz-Filho (2013)

Apenas presença

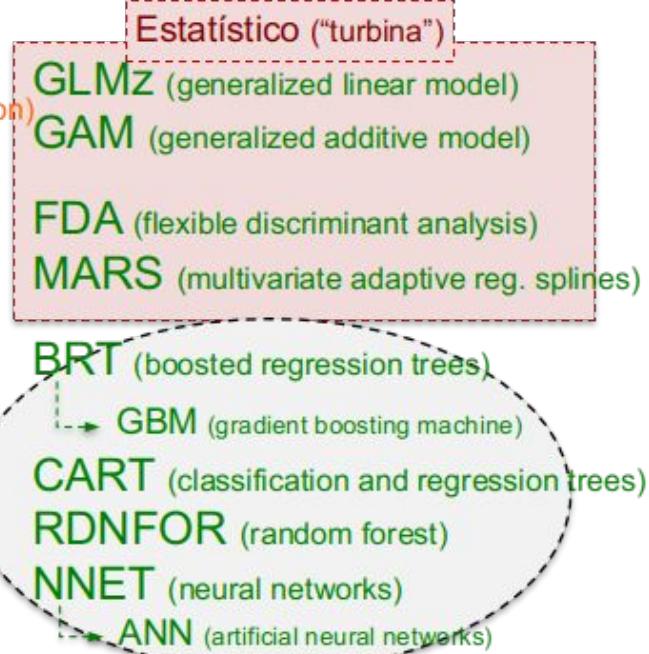


Presença/Background



Aprendizado de Máquina
(machine learning)
“cofre”

Presença/Ausência



Ajuste dos ENMs

Apenas Presença

Apenas presença

Bioclim Aquário
Dist. Euclidiana
Dist. Mahalanobis
Domain (dist. Gower)
ENFA (ecological niche factor analysis)

Presença/Background

GARP (genetic algorithm for rule-set production)
Maxent (maximum entropy)
SVM (support vector machine)

Aprendizado de Máquina
(*machine learning*)
“cofre”

Presença/Ausência

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GLMz (generalized linear model)
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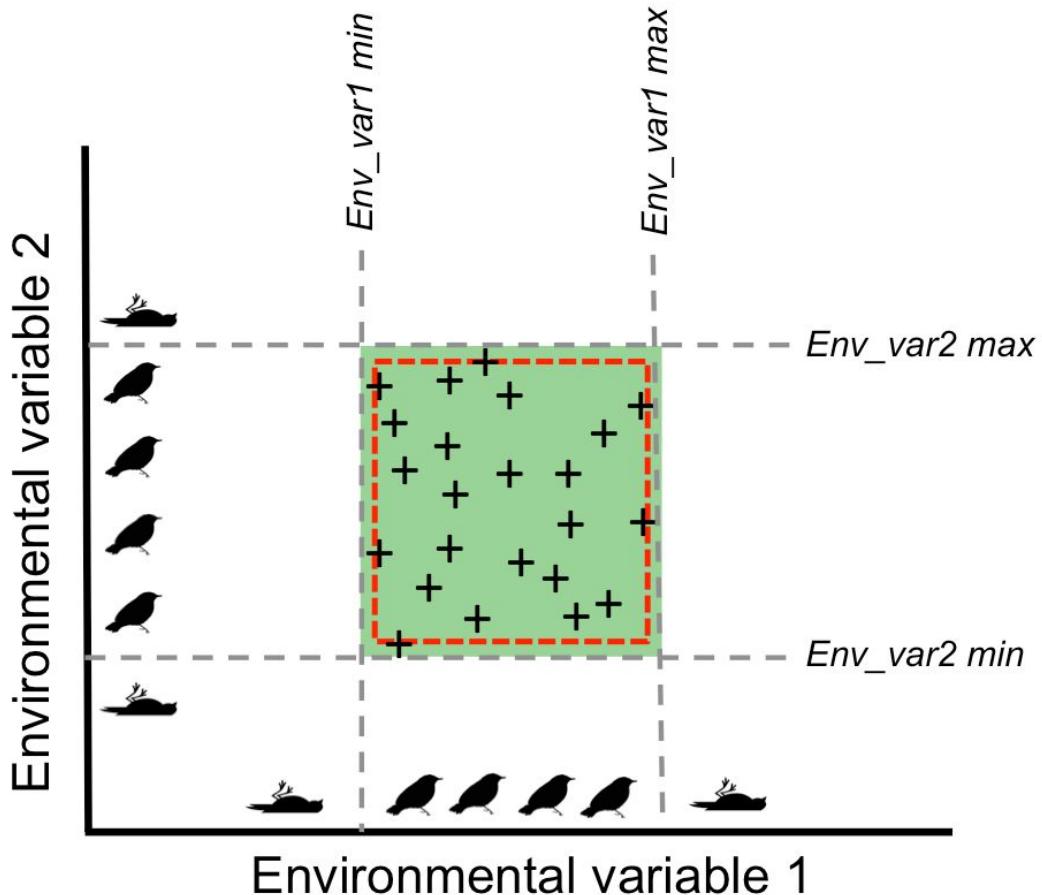
BRT (boosted regression trees)
→ **GBM** (gradient boosting machine)
CART (classification and regression trees)
RDNFOR (random forest)
NNET (neural networks)
→ **ANN** (artificial neural networks)



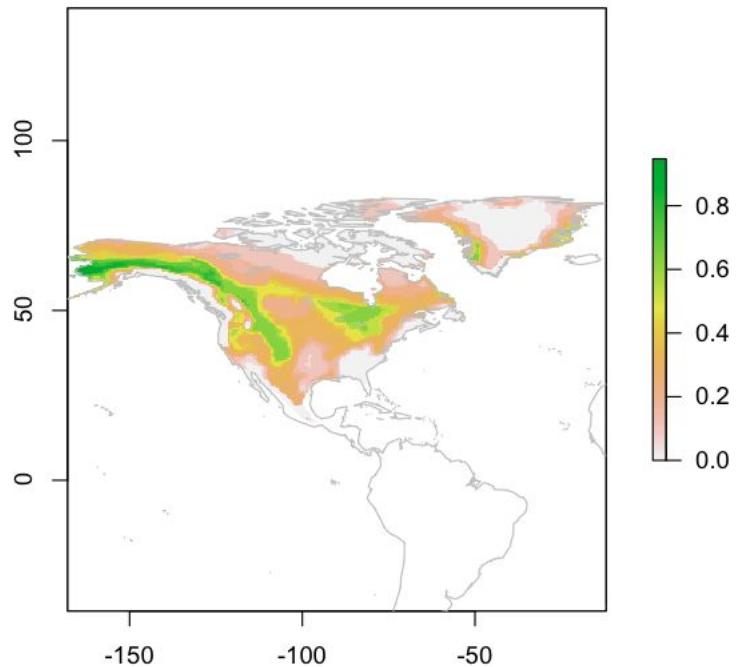
Lima-Ribeiro &
Diniz-Filho (2013)

Ajuste dos ENMs

BIOCLIM - Envelope Climático

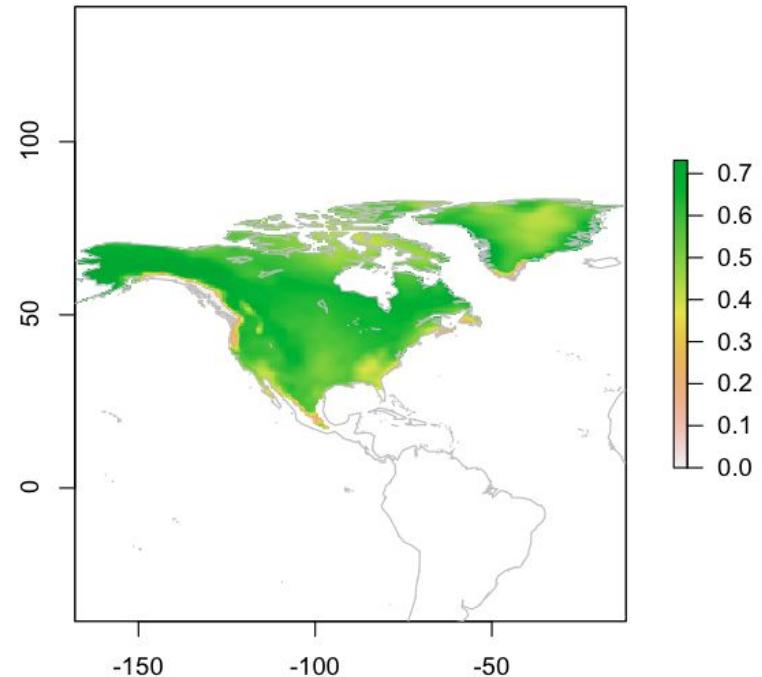
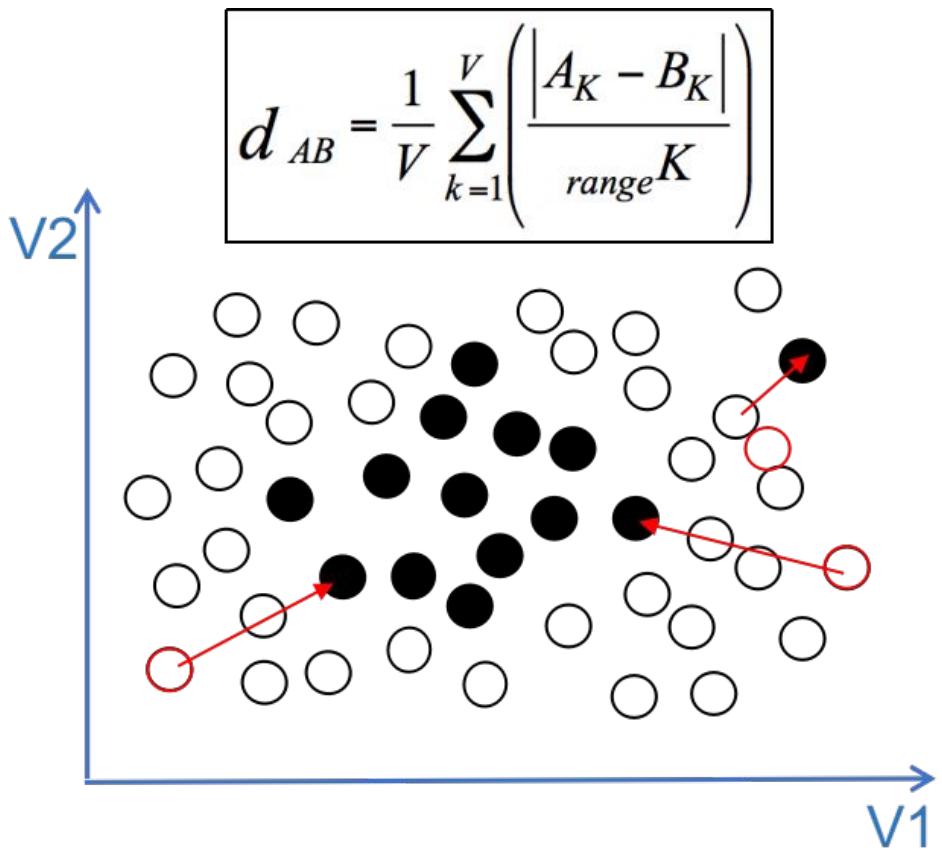


Lima-Ribeiro &
Diniz-Filho (2013)



Ajuste dos ENMs

DOMAIN - Distância de Gower



Lima-Ribeiro &
Diniz-Filho (2013)



Ajuste dos ENMs

Presença/Background (plano de fundo)



Lima-Ribeiro &
Diniz-Filho (2013)

Apenas presença

Bioclim
Dist. Euclidiana
Dist. Mahalanobis
Domain (dist. Gower)
ENFA (ecological niche factor analysis)

Aquário

Presença/Background

GARP (genetic algorithm for rule-set production)
Maxent (maximum entropy)
SVM (support vector machine)

Aprendizado de Máquina
(*machine learning*)
“cofre”

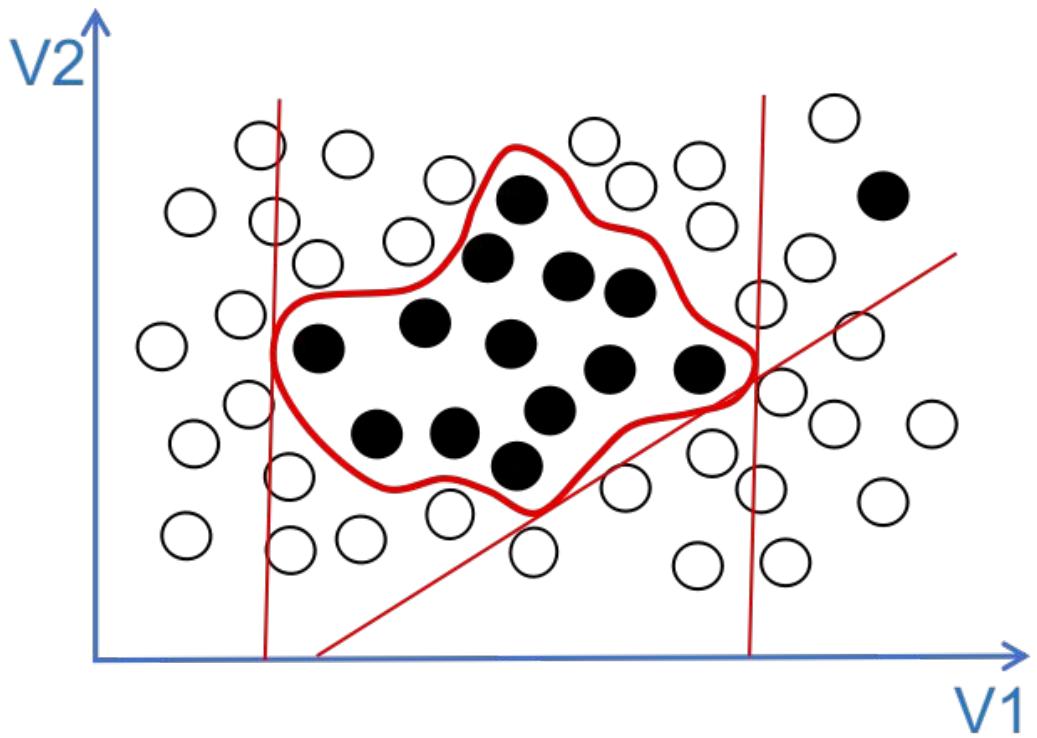
Presença/Ausência

Estatístico (“turbina”)
GLMz (generalized linear model)
GAM (generalized additive model)
FDA (flexible discriminant analysis)
MARS (multivariate adaptive reg. splines)

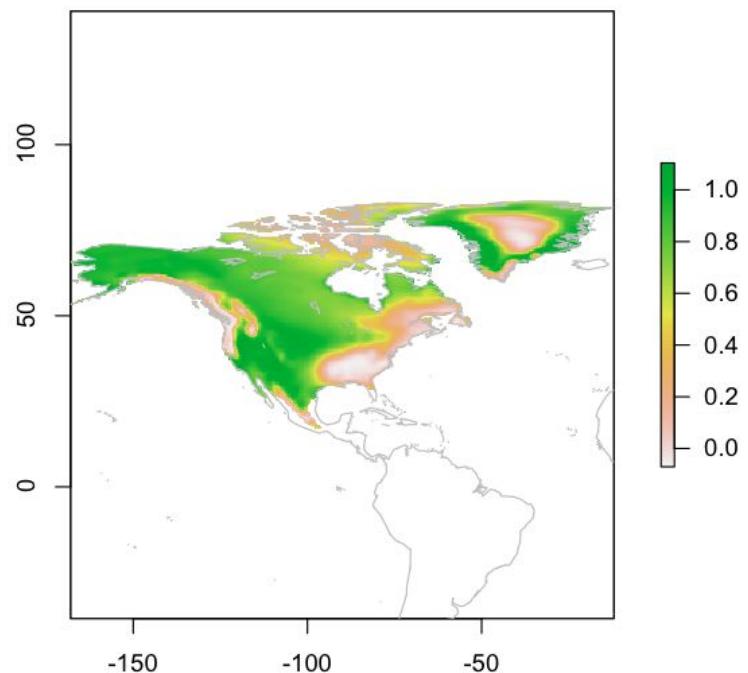
BRT (boosted regression trees)
→ GBM (gradient boosting machine)
CART (classification and regression trees)
RDNFOR (random forest)
NNET (neural networks)
→ ANN (artificial neural networks)

Ajuste dos ENMs

Support Vector Machine (SVM)

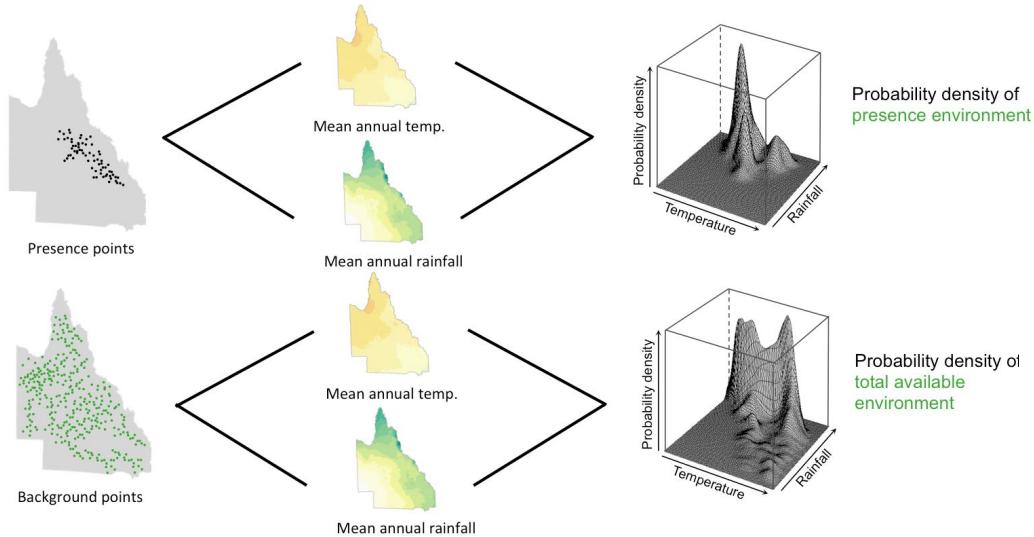


Lima-Ribeiro &
Diniz-Filho (2013)

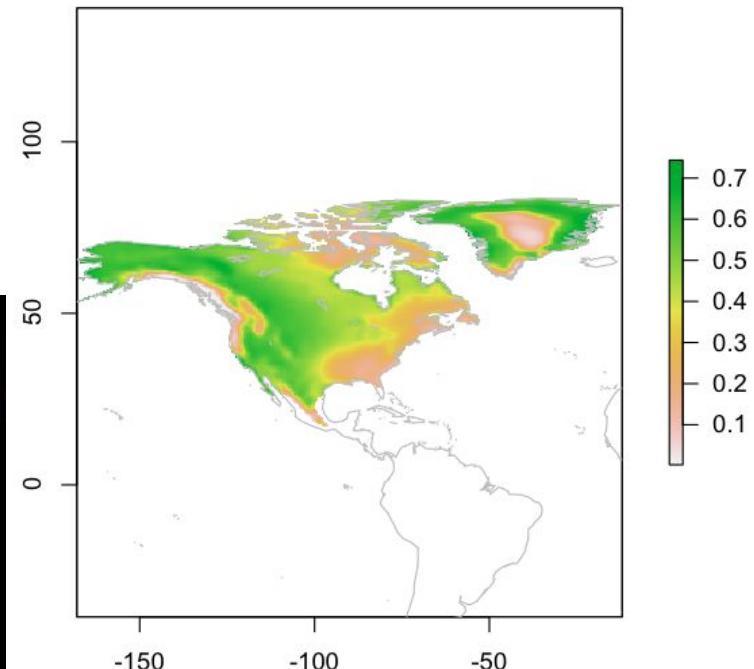
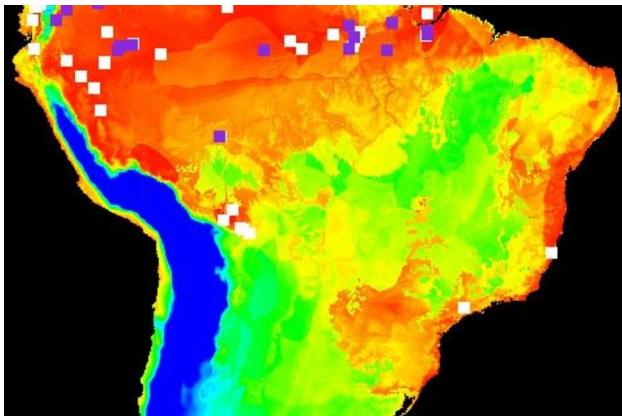
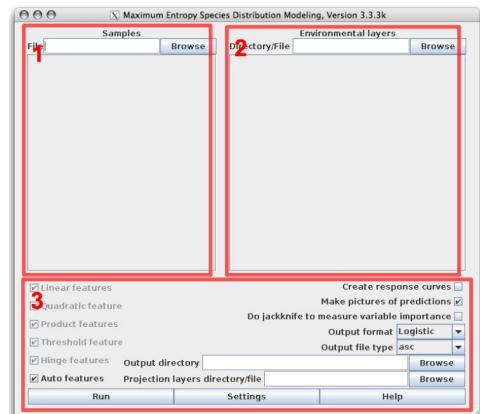


Ajuste dos ENMs

Maximum Entropy (MaxEnt)



Adapted from Elith et al. (2011) A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions*, 17, 43-57.

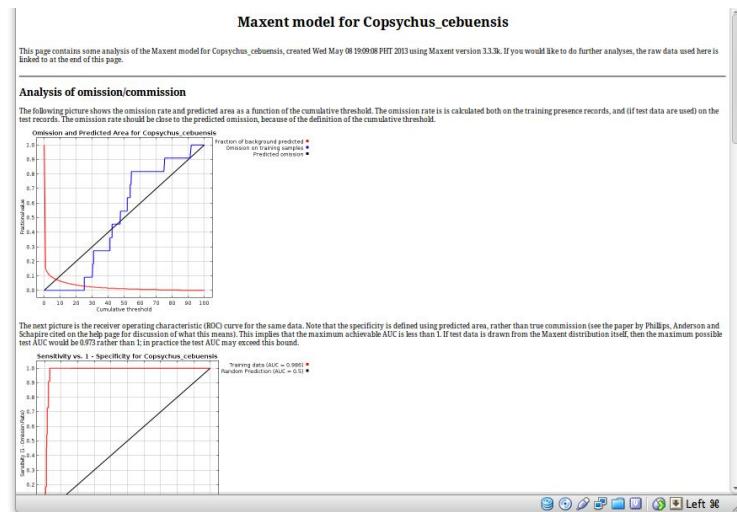
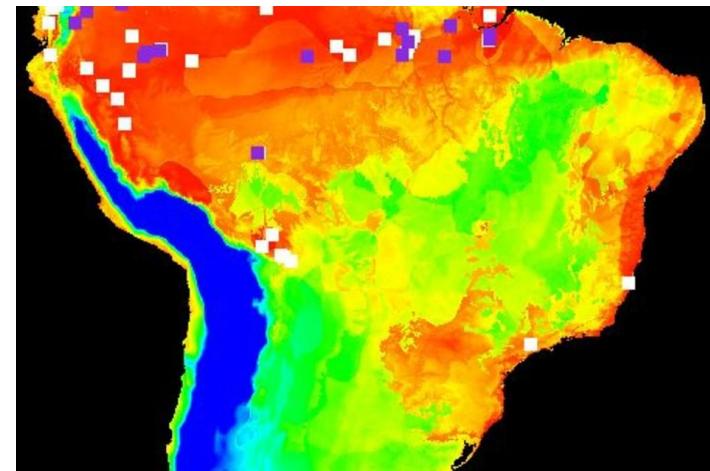
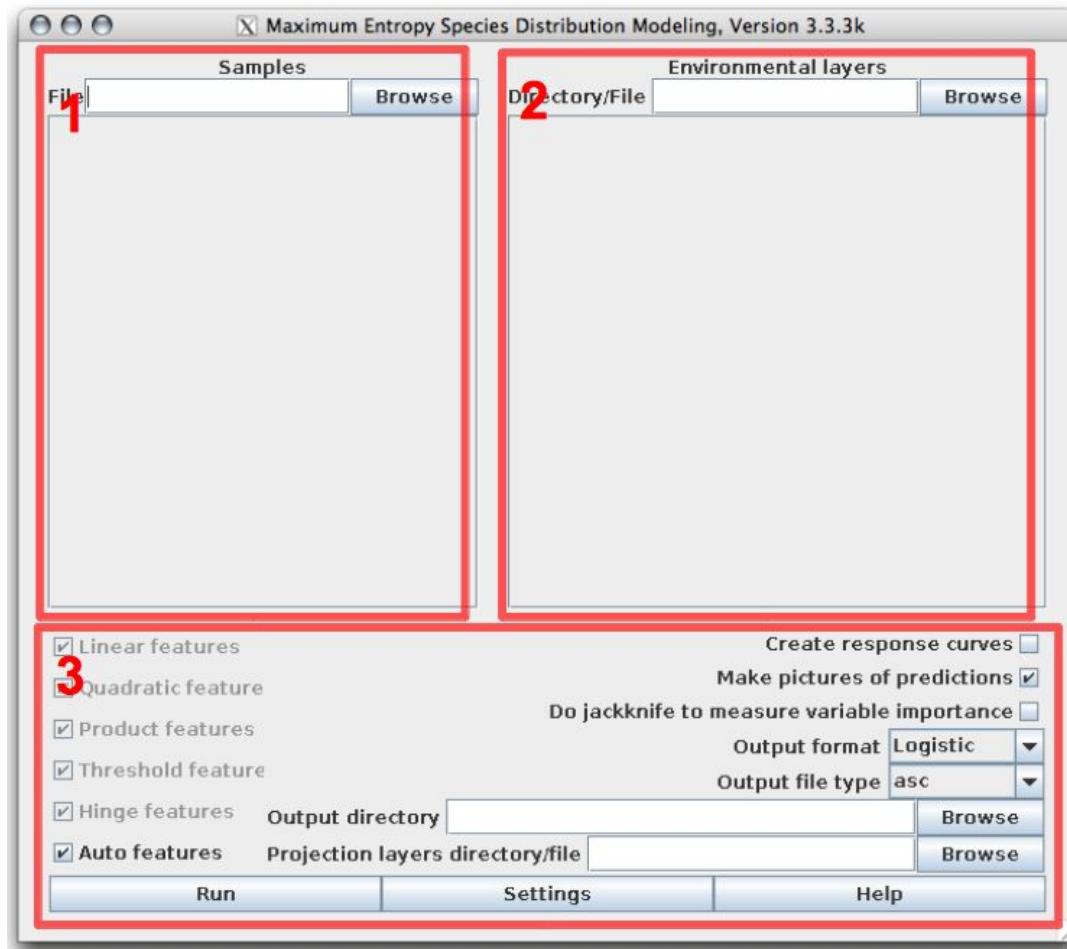


Lima-Ribeiro & Diniz-Filho (2013)



Ajuste dos ENMs

Maximum Entropy (MaxEnt)



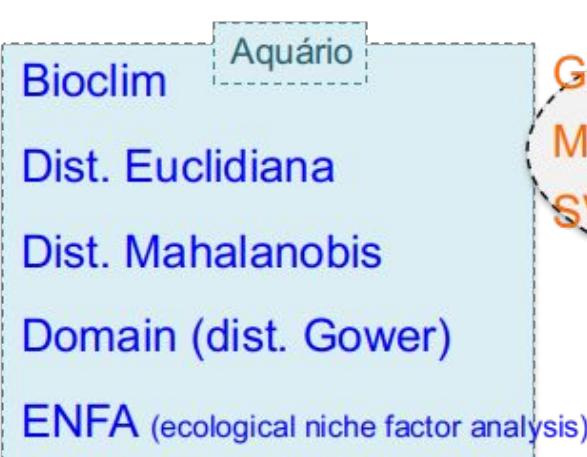
Ajuste dos ENMs

Presença e ausência



Lima-Ribeiro &
Diniz-Filho (2013)

Apenas presença



Presença/Background

GARP (genetic algorithm for rule-set production)
Maxent (maximum entropy)
SVM (support vector machine)

Aprendizado de Máquina
(machine learning)
“cofre”

Presença/Ausência

Estatístico (“turbina”)
GLMz (generalized linear model)
GAM (generalized additive model)

FDA (flexible discriminant analysis)
MARS (multivariate adaptive reg. splines)

BRT (boosted regression trees)
→ **GBM** (gradient boosting machine)
CART (classification and regression trees)
RDNFOR (random forest)
NNET (neural networks)
→ **ANN** (artificial neural networks)

Onde encontrar dados de
ausência?

Ajuste dos ENMs

Ausência “real” (modelos de ocupação)

Modelling of species distributions, range dynamics and communities under imperfect detection: advances, challenges and opportunities

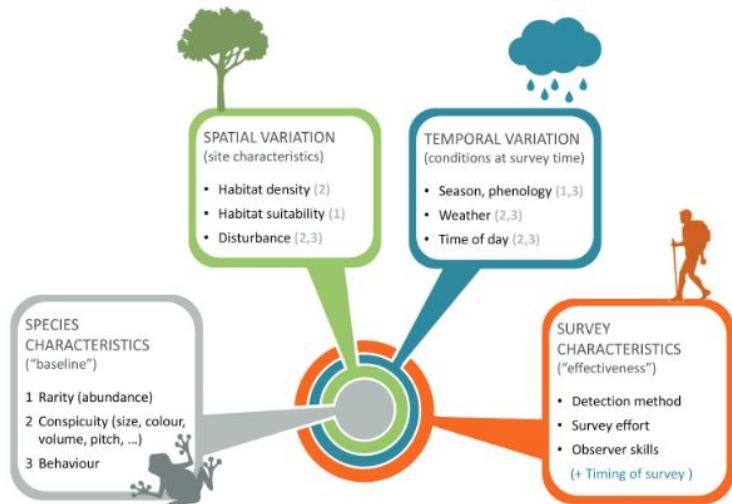
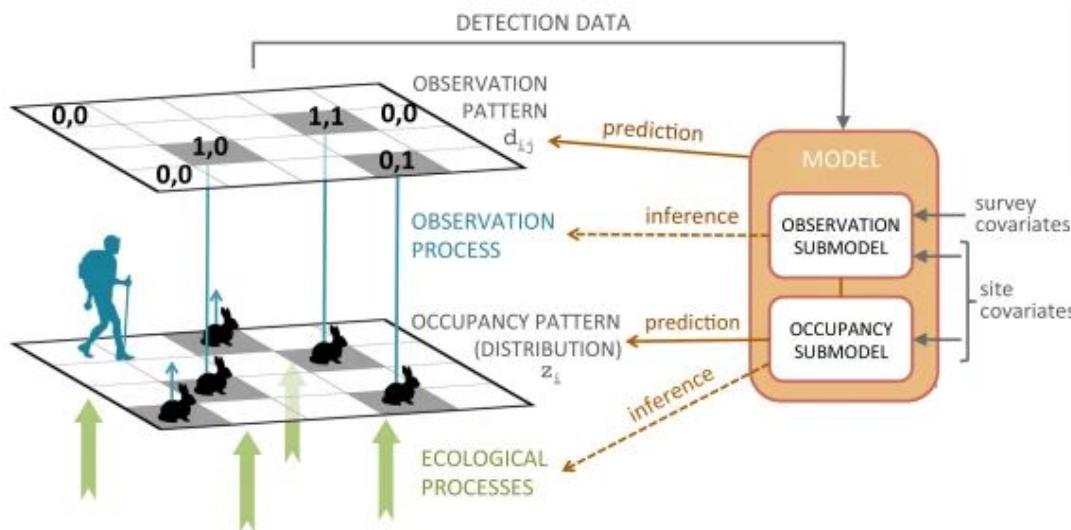
Gurutzeta Guillera-Arroita

Ecography 40: 281–295, 2017

doi: 10.1111/ecog.02445

© 2016 The Author. Ecography © 2016 Nordic Society Oikos

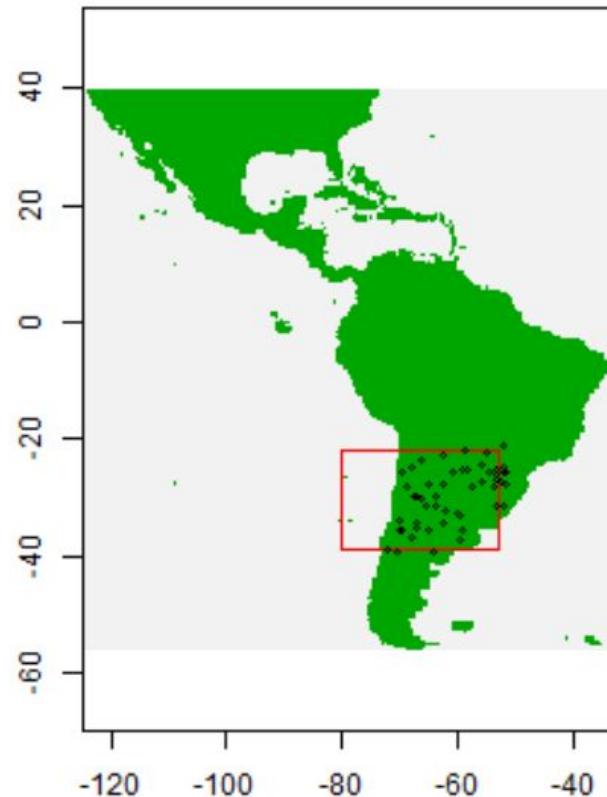
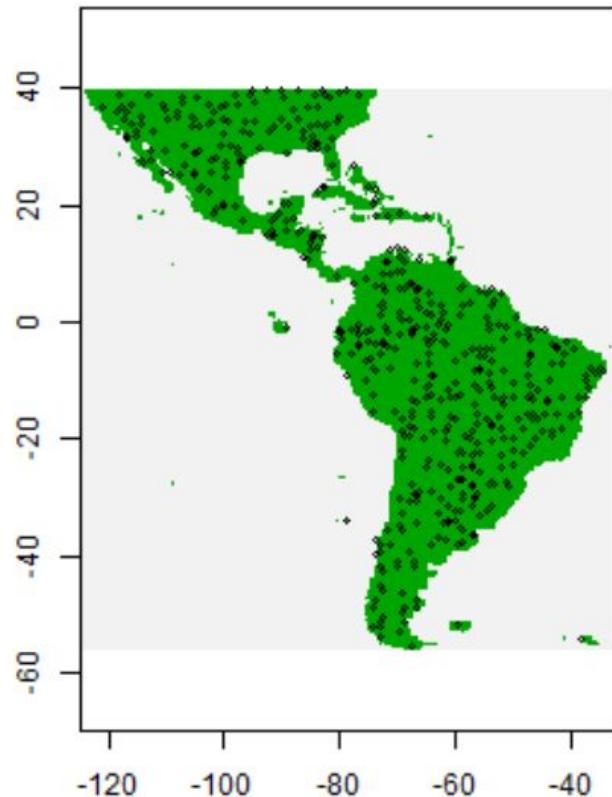
Subject Editor: Miguel Araújo. Editor-in-Chief: Miguel Araújo. Accepted 15 June 2016



Ajuste dos ENMs

Pseudo-ausência

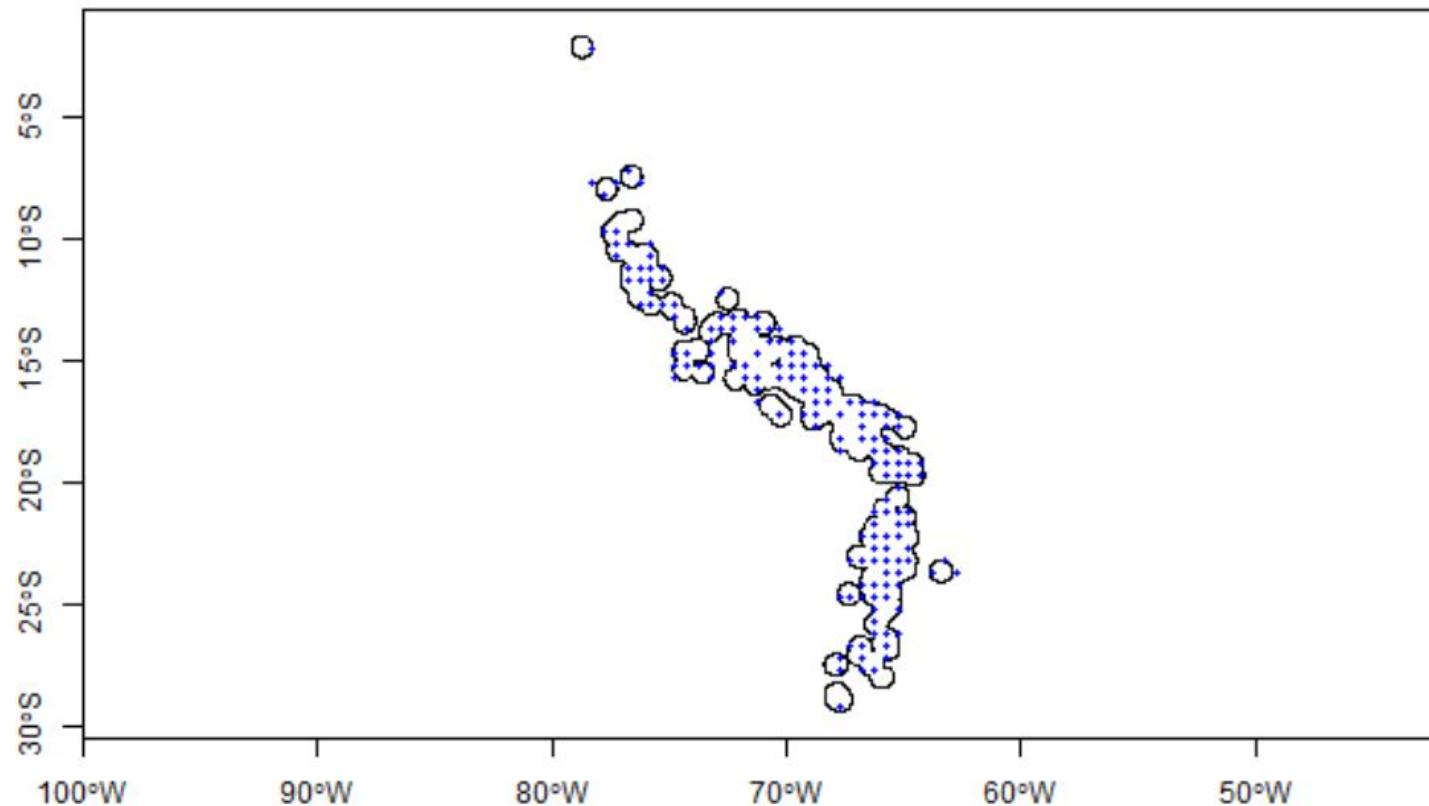
Sorteio de **pontos aleatórios** (sem **padrão espacial**) para serem considerados como **ausência verdadeira**



Ajuste dos ENMs

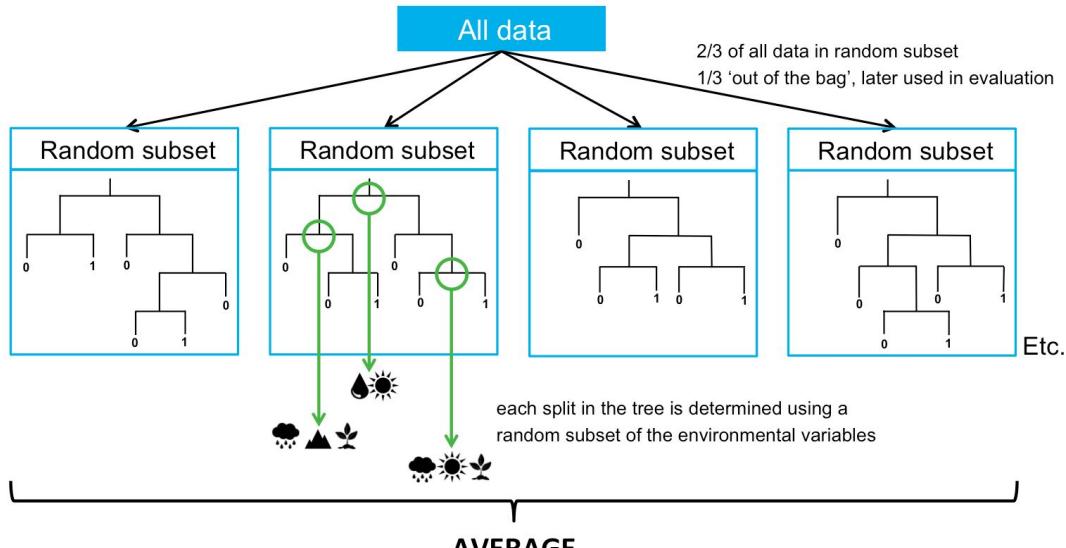
Pseudo-ausência

Sorteio de **pontos aleatórios** (com **padrão espacial**) para serem considerados como **ausência verdadeira**



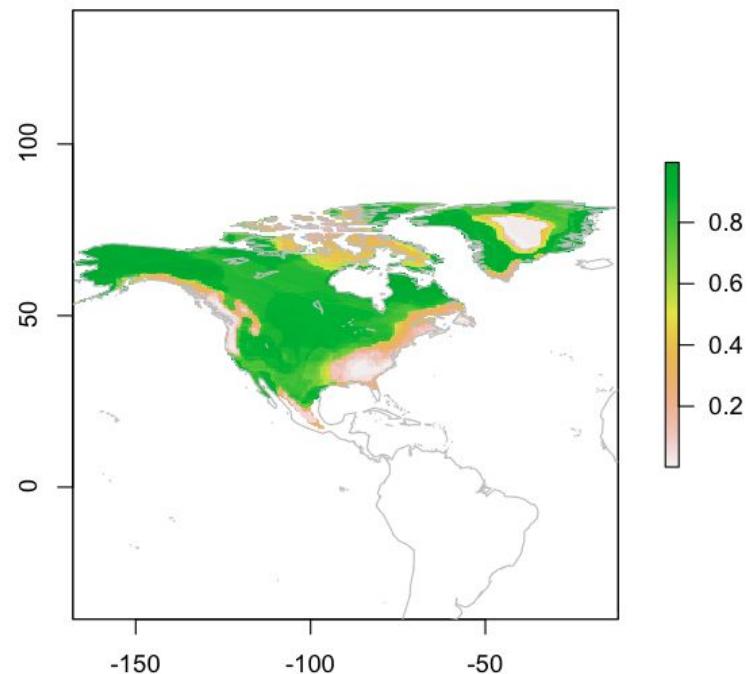
Ajuste dos ENMs

Random Forest



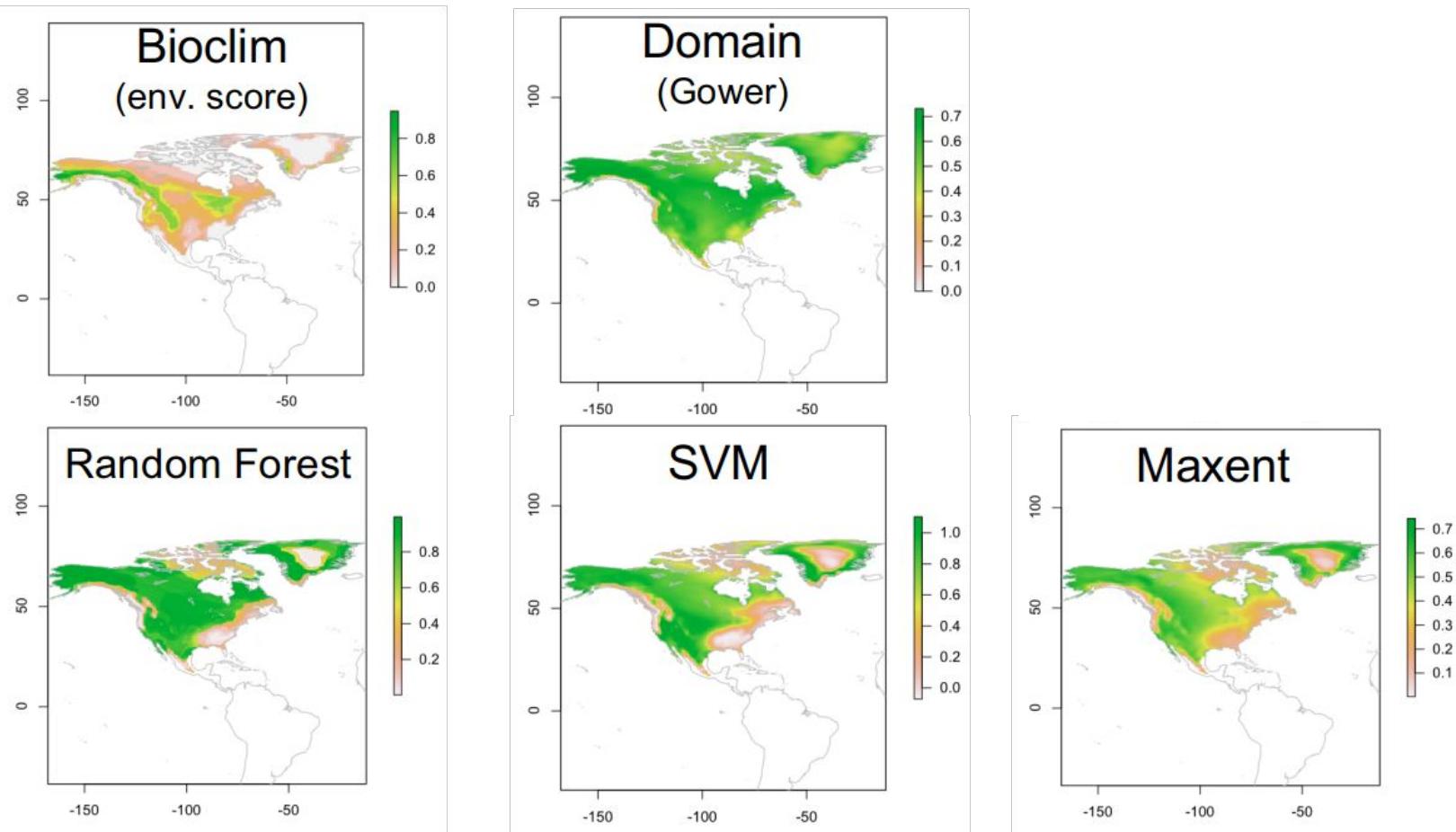
> find the set of predictor variables that produce the strongest classification model

Lima-Ribeiro &
Diniz-Filho (2013)



Ajuste dos ENMs

Qual algoritmo usar?



Ajuste dos ENMs

Consenso (*Ensemble*)



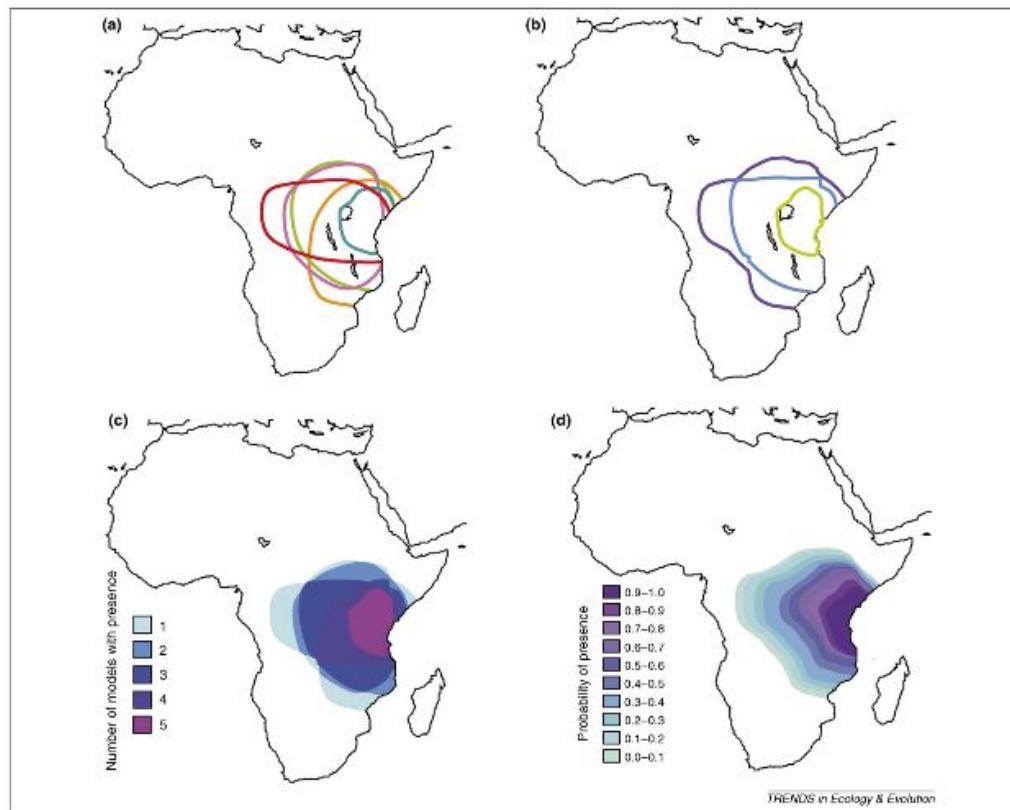
Review

TRENDS in Ecology and Evolution Vol.22 No.1

Full text provided by www.sciencedirect.com
ScienceDirect

Ensemble forecasting of species distributions

Miguel B. Araújo¹ and Mark New²



SDM passo a passo

Estrutura dos ENMs

ECOGRAPHY

Review and synthesis

A standard protocol for reporting species distribution models

Damaris Zurell, Janet Franklin, Christian König, Phil J. Bouchet, Carsten F. Dormann, Jane Elith, Guillermo Fandos, Xiao Feng, Gurutzeta Guillera-Arroita, Antoine Guisan, José J. Lahoz-Monfort, Pedro J. Leitão, Daniel S. Park, A. Townsend Peterson, Giovanni Rapacciulo, Dirk R. Schmaltz, Boris Schröder, Josep M. Serra-Díaz, Wilfried Thuiller, Katherine L. Yates, Niklaus E. Zimmermann and Cory Merow

Ecography

43: 1–17, 2020

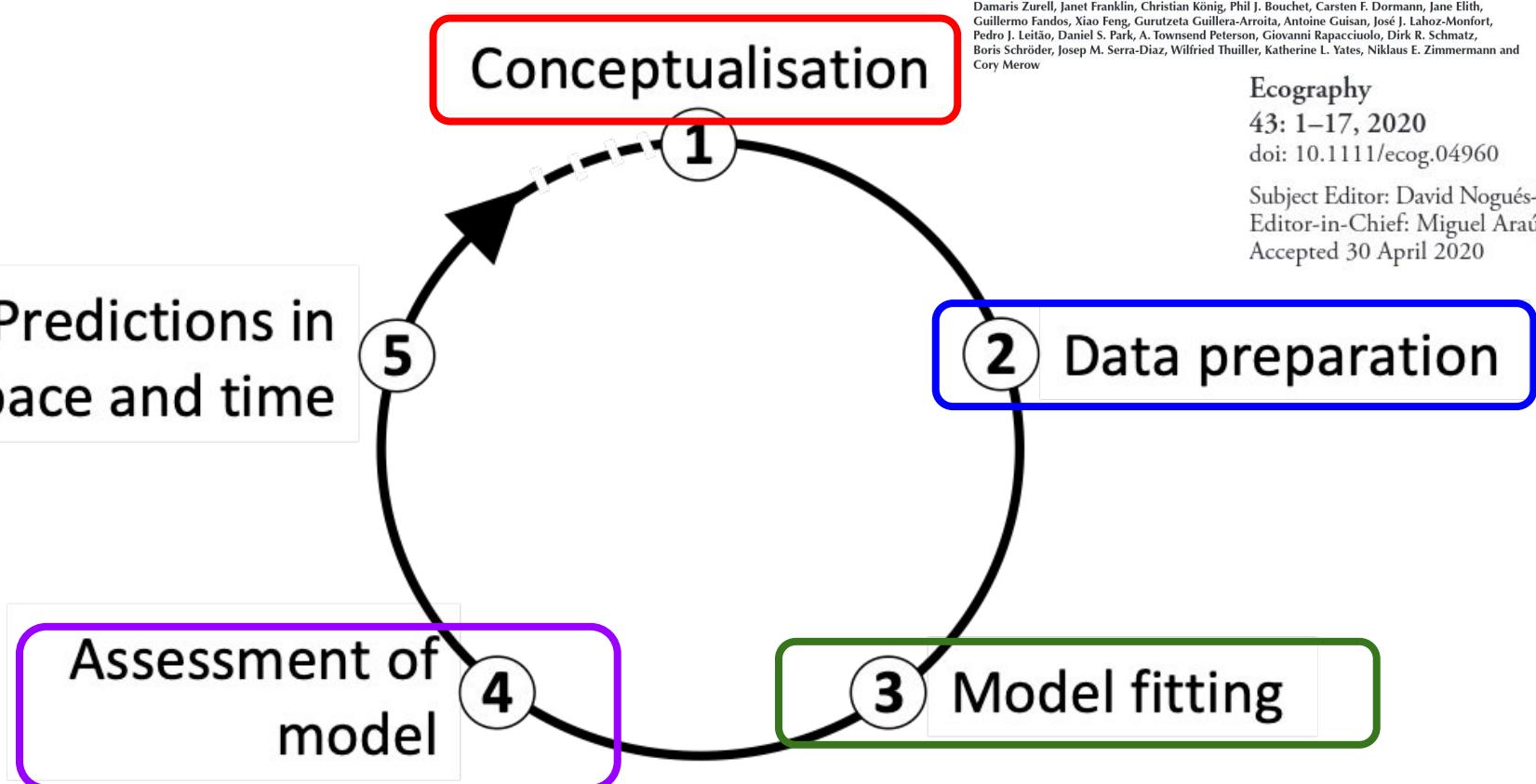
doi: 10.1111/ecog.04960

Subject Editor: David Nogués-Bravo

Editor-in-Chief: Miguel Araújo

Accepted 30 April 2020

Predictions in
space and time

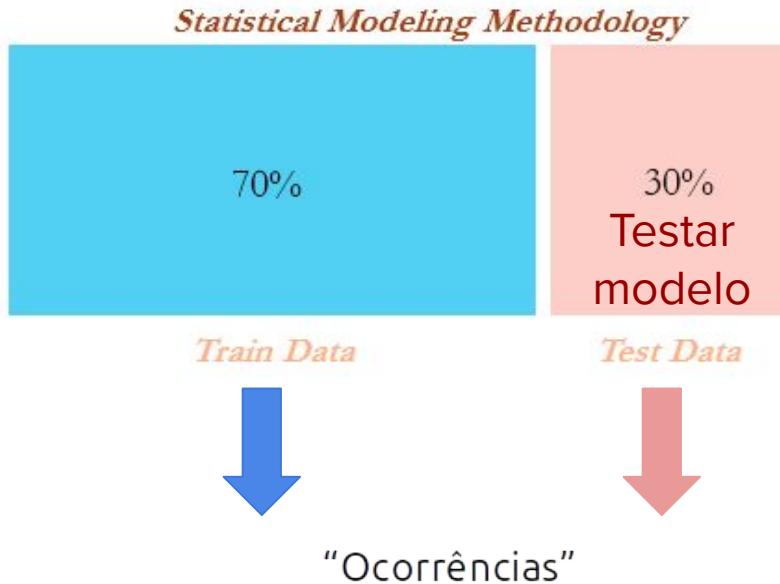


7. Avaliação dos modelos

Como saber se meu modelo se
aproxima da realidade?

Avaliação dos ENMs

Partição dos dados em **treino** e **teste**



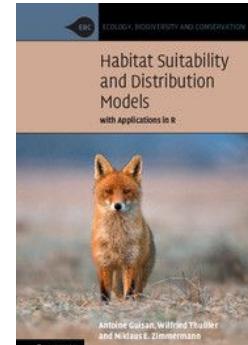
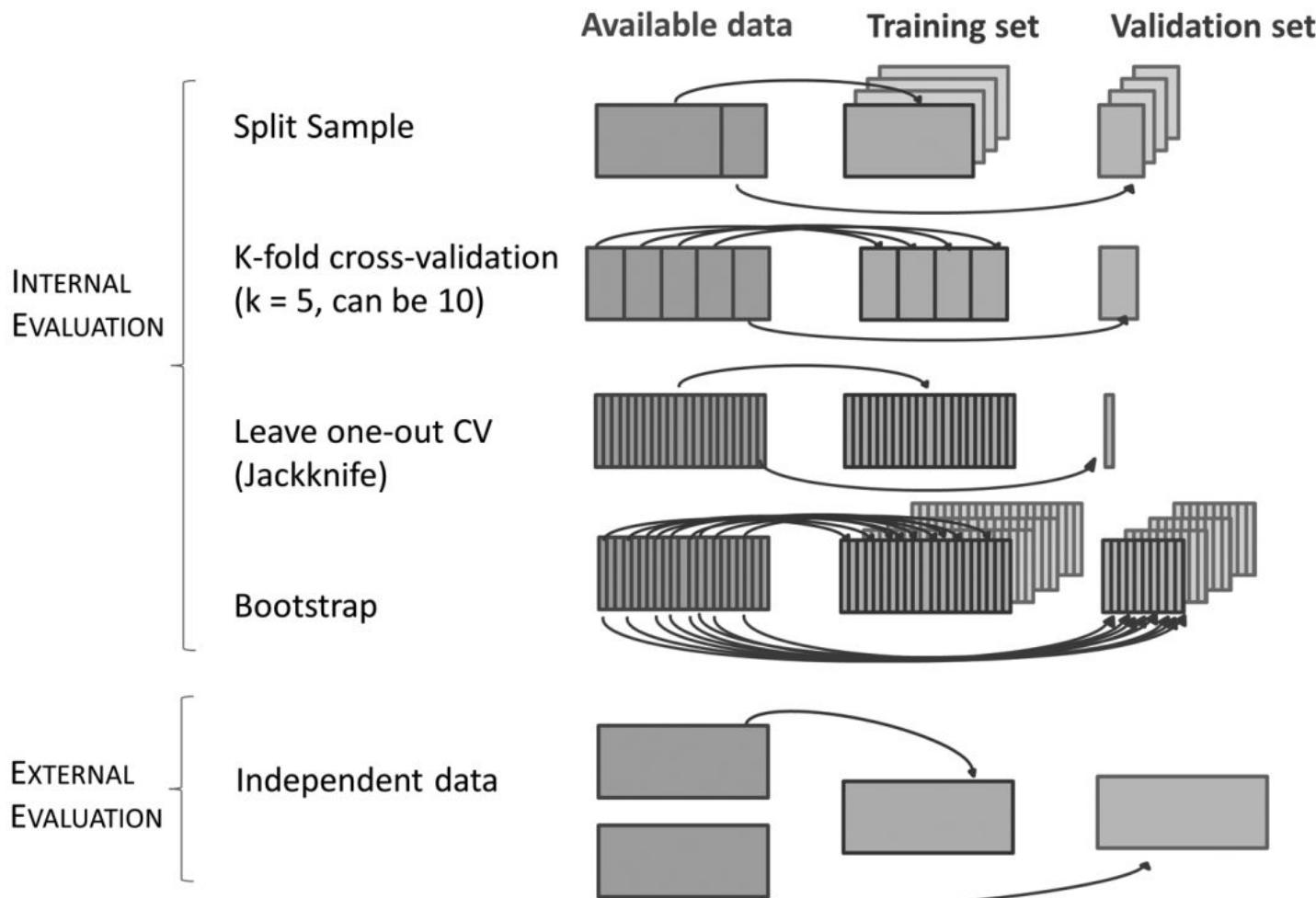
ATENÇÃO!!!

Presenças
e
Pseudo-ausências

species	lon	lat	
sp1	-40.2	-23.4	Treino
sp1	-38.8	-20.3	Teste
sp1	-43.3	-19.9	Treino

Avaliação dos ENMs

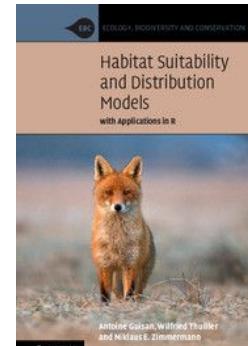
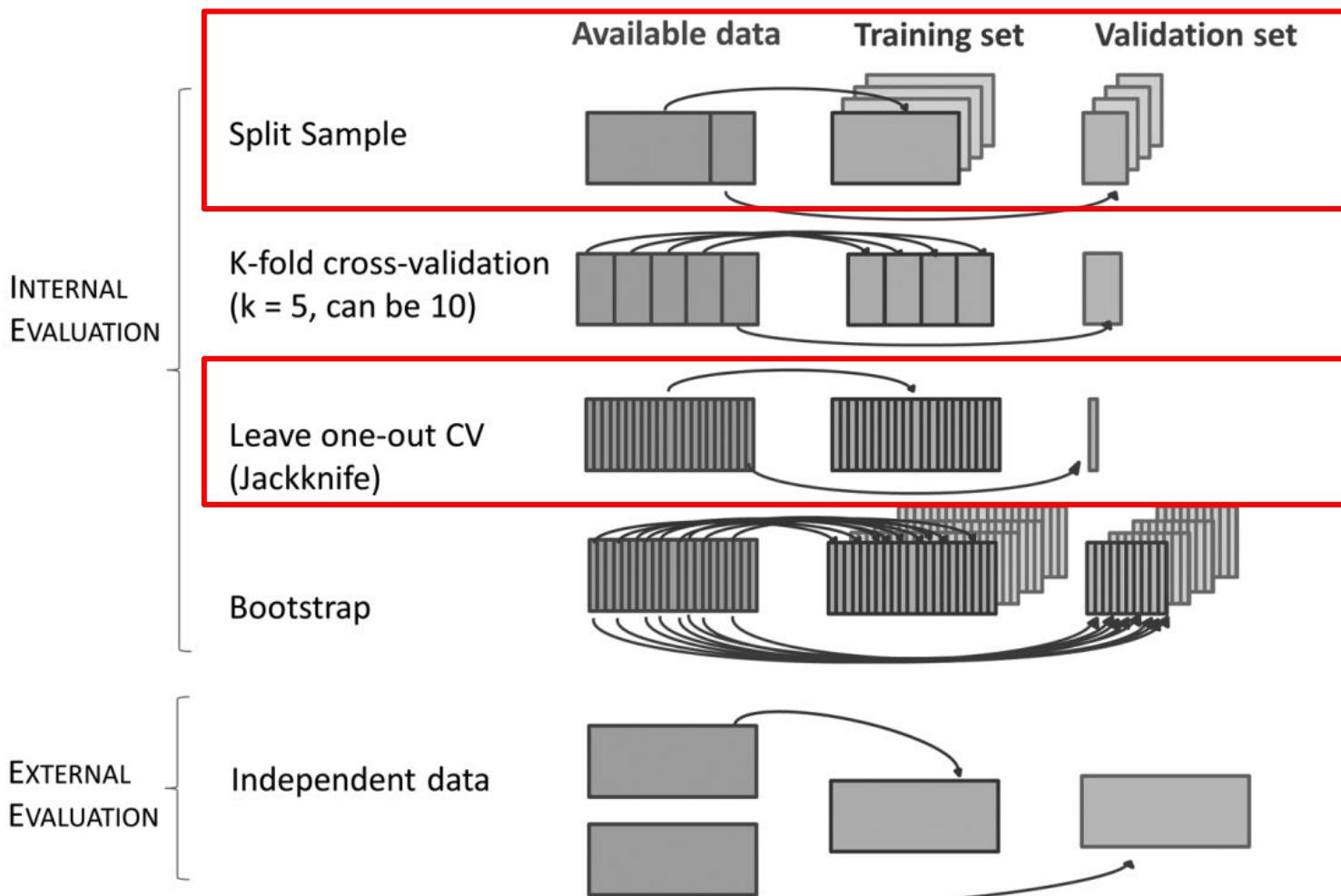
Tipos de avaliação



Guisan et al. (2017)

Avaliação dos ENMs

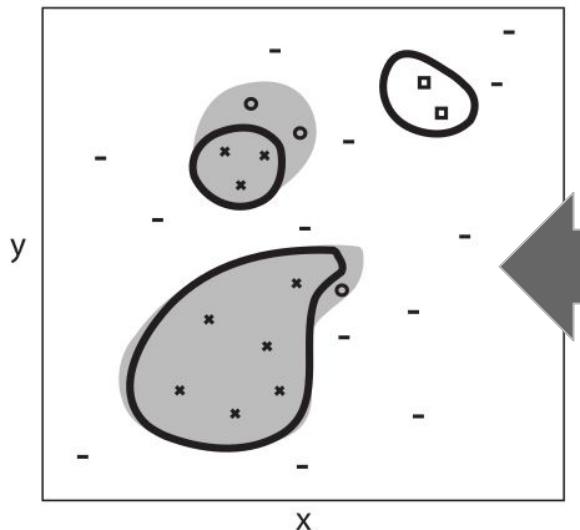
Tipos de avaliação



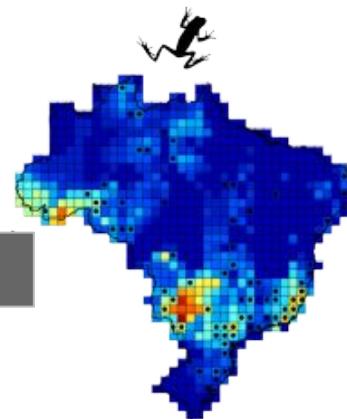
Guisan et al. (2017)

Avaliação dos ENMs

Como saber se o modelo acerta a realidade?



- Occupied distributional area, G_O
- Areas predicted by an ecological niche model
 - ✗ True positive
 - True negative
 - False negative
 - False positive

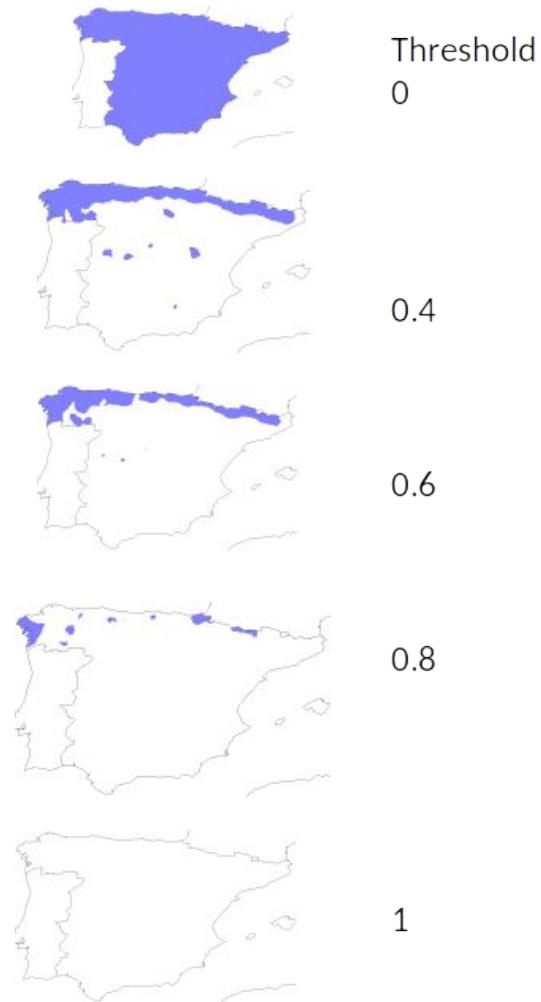
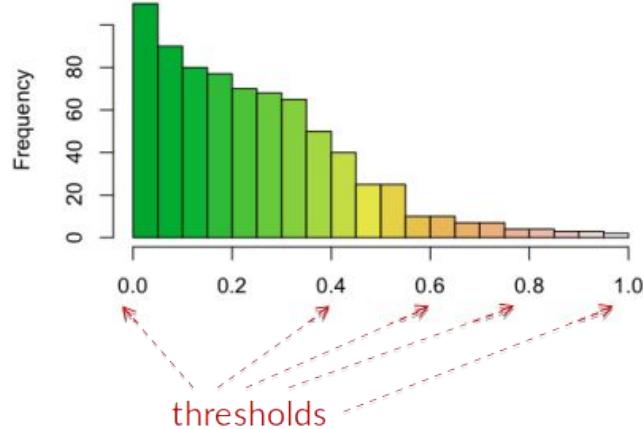
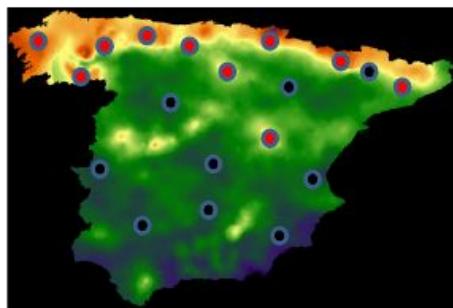


Adequabilidade

valores
0
até
1

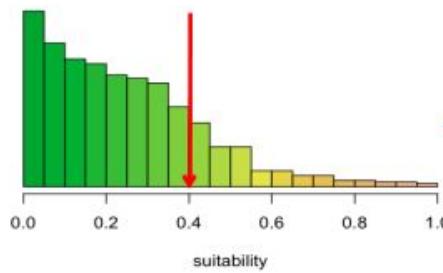
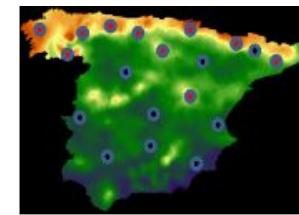
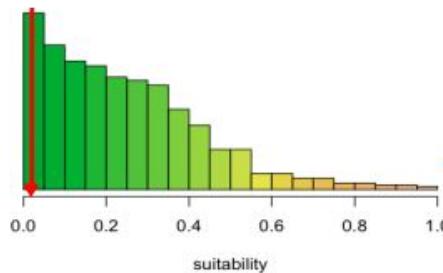
Avaliação dos ENMs

Limiares (*Thresholds*) - transformar em 1 e 0

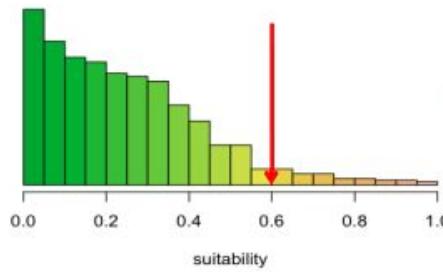


Avaliação dos ENMs

Limiares (*Thresholds*)



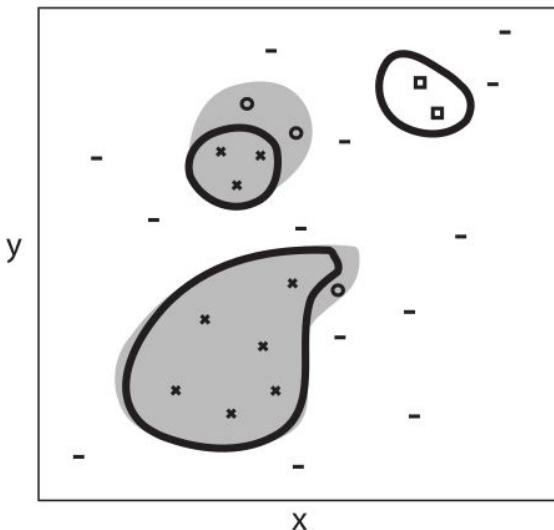
Zero omissão



Maximiza
sensitividade +
especificidade

Avaliação dos ENMs

Matriz de confusão - para os **dados de teste**



● Occupied distributional area, G_O

○ Areas predicted by an ecological niche model

✗ True positive

- True negative

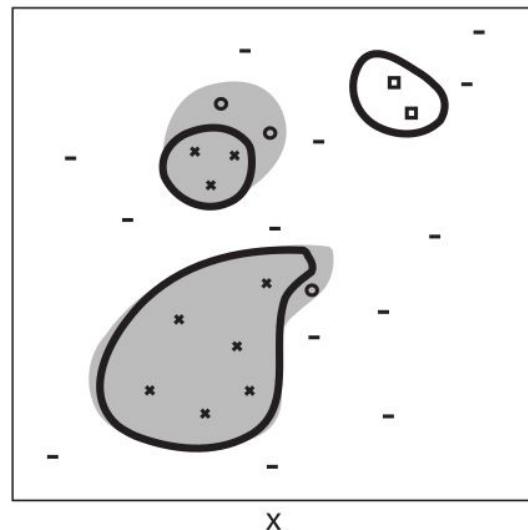
○ False negative

□ False positive

		Observation	
		Present	Absent
Prediction	Present	True positive	False positive
	Absent	False negative	True negative

Avaliação dos ENMs

Matriz de confusão - para os **dados de teste**



Occupied distributional area, G_O

Areas predicted by an ecological niche model

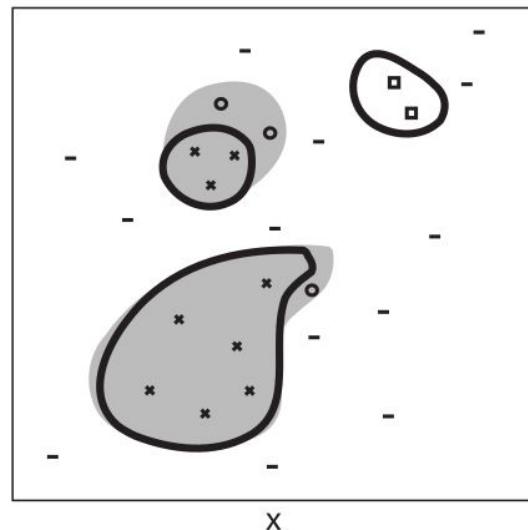
- ✗ True positive
- True negative
- False negative
- False positive

		Observation	
		Present	Absent
Prediction	Present	✗ True positive	False positive
	Absent	False negative	True negative

Ocorrência que o modelo previu
como **presença (acerto)**

Avaliação dos ENMs

Matriz de confusão - para os **dados de teste**



Occupied distributional area, G_o



Areas predicted by an ecological niche model

✗ True positive

- True negative

○ False negative

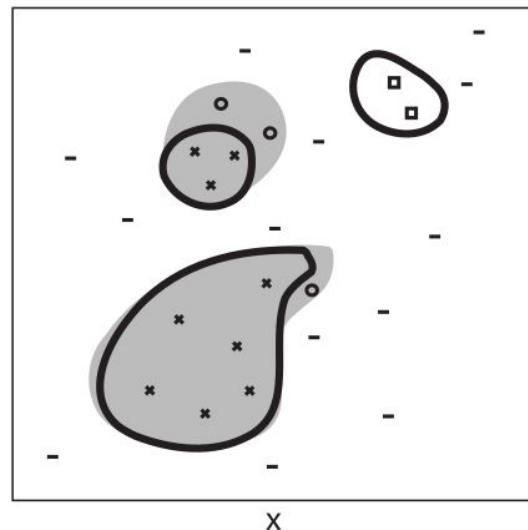
□ False positive

		Observation	
		Present	Absent
Prediction	Present	True positive	False positive
	Absent	False negative	True negative

Pseudo-ausência que o modelo previu como ausência (acerto)

Avaliação dos ENMs

Matriz de confusão - para os **dados de teste**



Occupied distributional area, G_o



Areas predicted by an ecological niche model

✗ True positive

- True negative

○ False negative

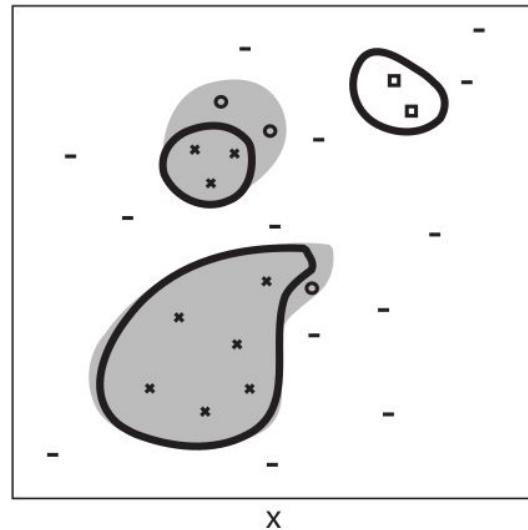
□ False positive

		Observation	
		Present	Absent
Prediction	Present	True positive	False positive
	Absent	○ False negative	True negative

Ocorrência que o modelo previu
como **ausência (erro de omissão)**

Avaliação dos ENMs

Matriz de confusão - para os **dados de teste**



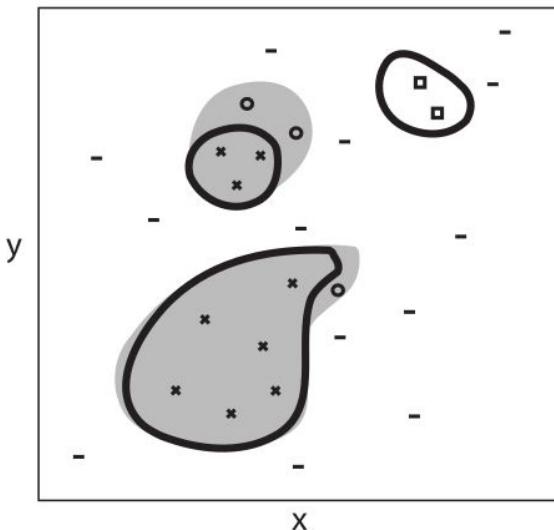
- Occupied distributional area, G_O
- Areas predicted by an ecological niche model
 - ✗ True positive
 - True negative
 - False negative
 - False positive

		Observation	
		Present	Absent
Prediction	Present	True positive	False positive
	Absent	False negative	True negative

Pseudo-ausência que o modelo previu como **presença (erro de comissão)**

Avaliação dos ENMs

Matriz de confusão - para os **dados de teste**



- Occupied distributional area, G_O
- Areas predicted by an ecological niche model
 - ✗ True positive
 - True negative
 - False negative
 - False positive

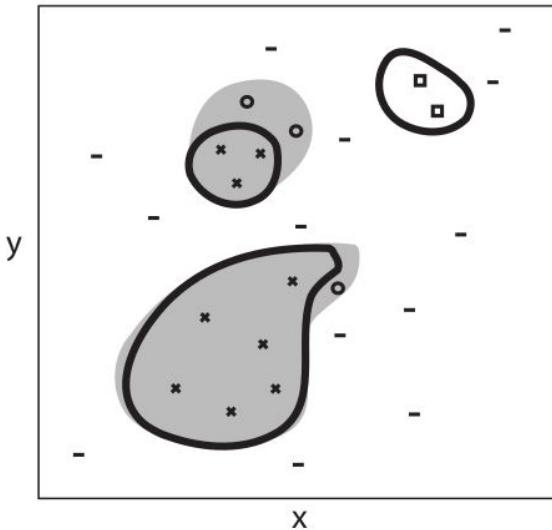
		Observation	
		Present	Absent
Prediction	Present	True positive	False positive
	Absent	False negative	True negative



Sensitividade: presenças corretas total de presenças

Avaliação dos ENMs

Matriz de confusão - para os **dados de teste**



- Occupied distributional area, G_O
- Areas predicted by an ecological niche model
 - ✗ True positive
 - True negative
 - False negative
 - ◻ False positive

		Observation	
		Present	Absent
Prediction	Present	True positive	False positive
	Absent	False negative	True negative

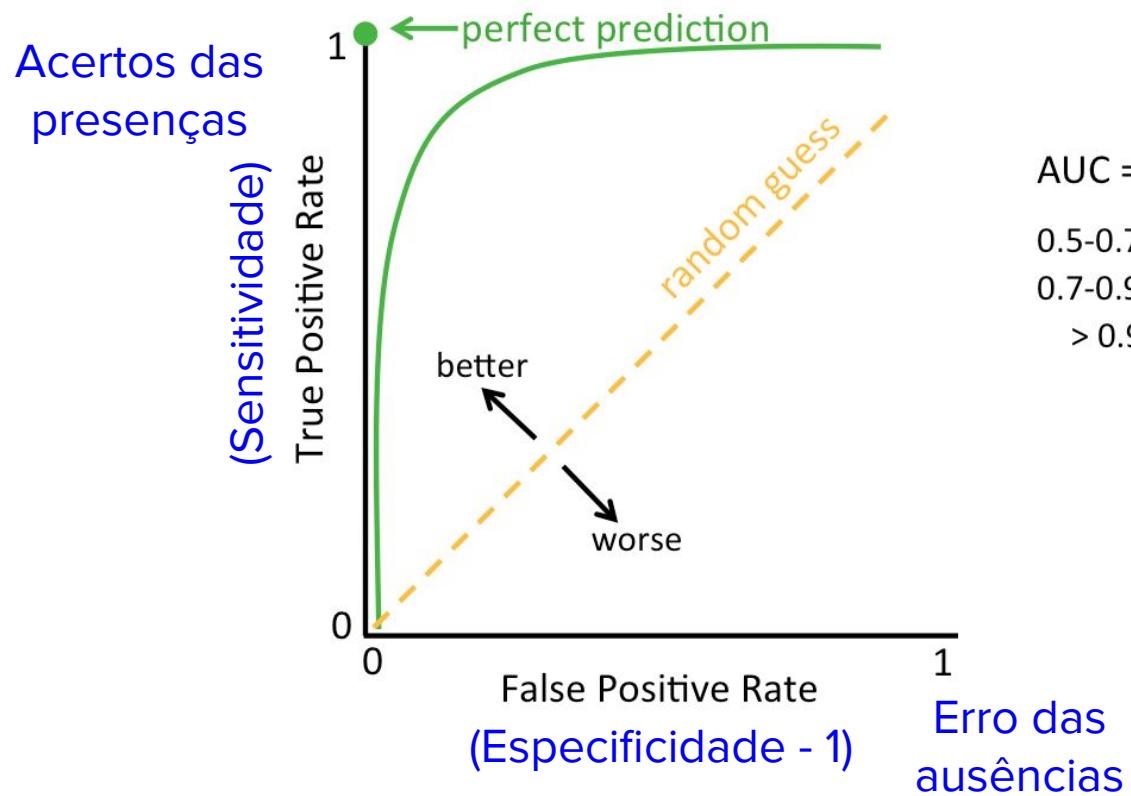


Especificidade: pseudo-ausências corretas
total de pseudo-ausências

Avaliação dos ENMs

Curva ROC

Relative Operating Characteristic (ROC)



AUC = area under the curve

0.5-0.7 = poor model performance

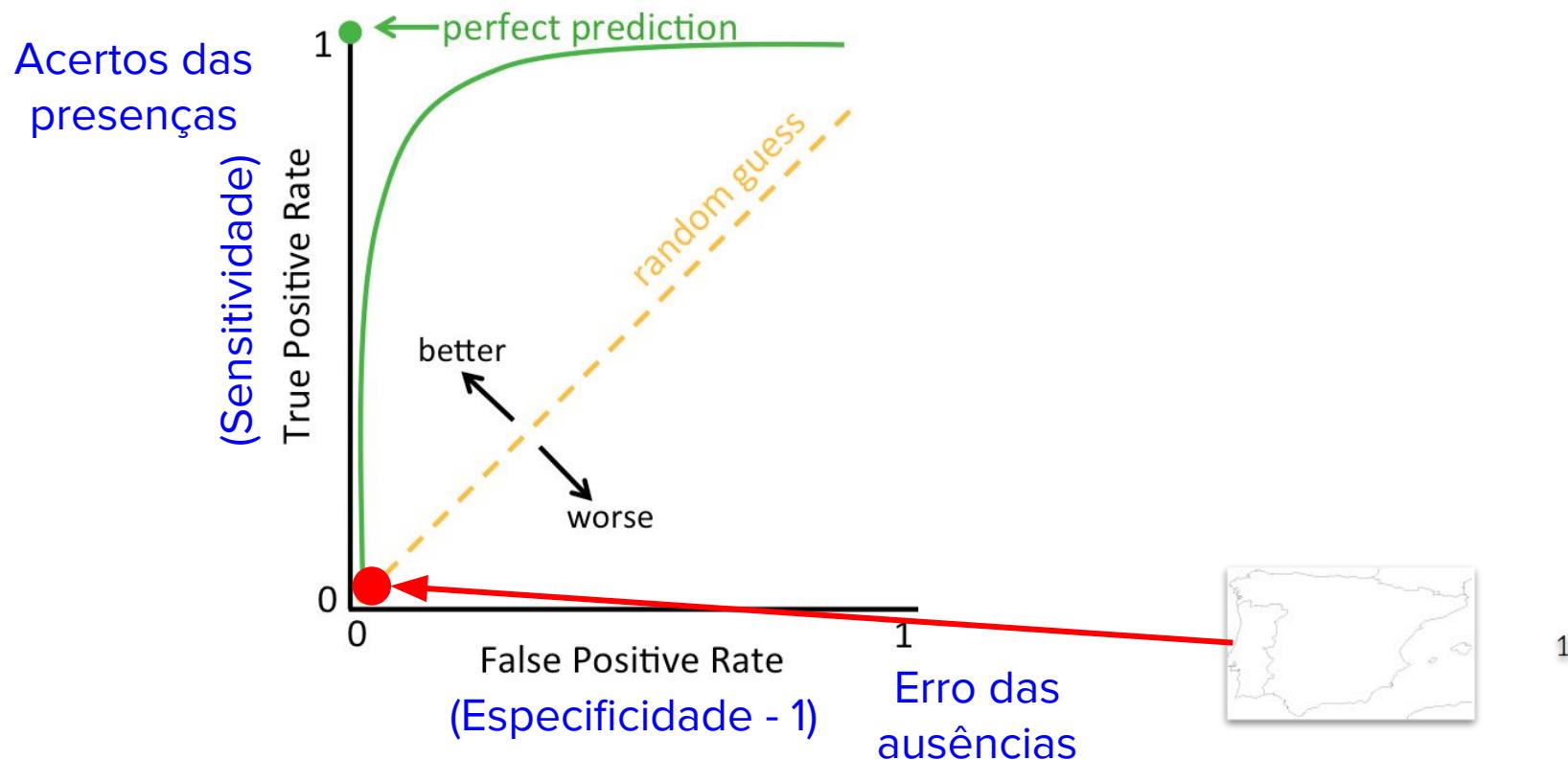
0.7-0.9 = moderate

> 0.9 = excellent

Avaliação dos ENMs

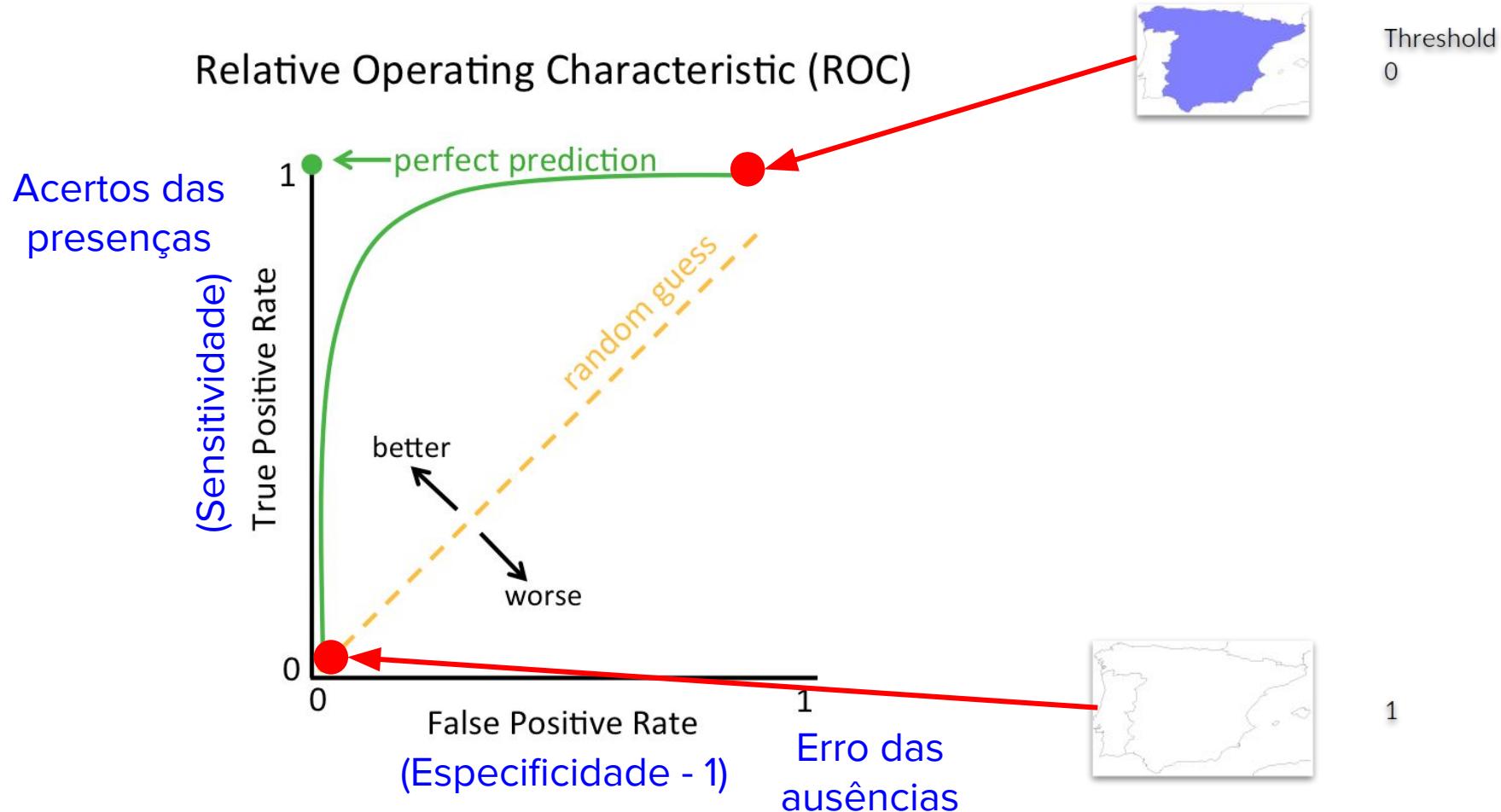
Curva ROC

Relative Operating Characteristic (ROC)



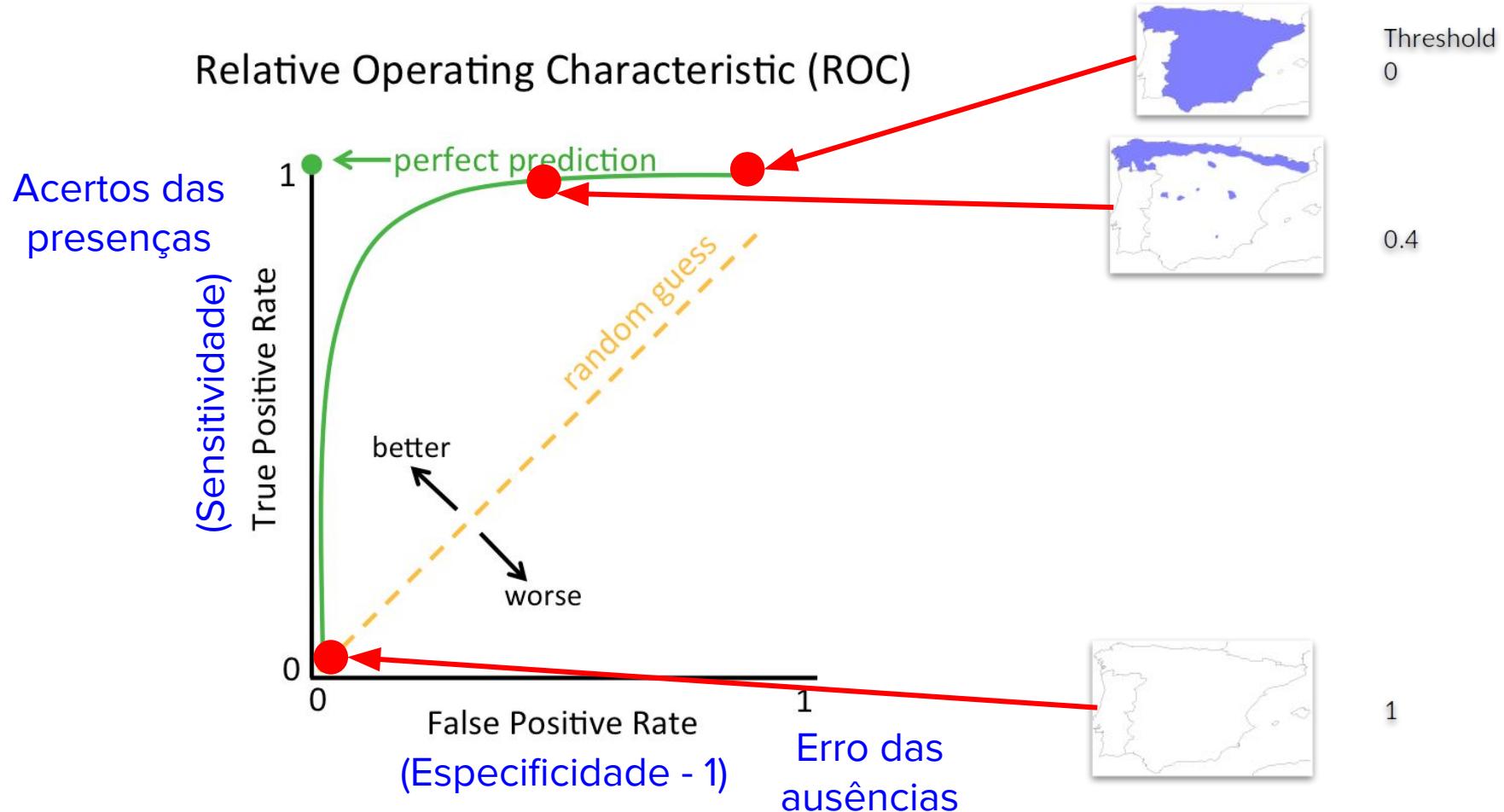
Avaliação dos ENMs

Curva ROC



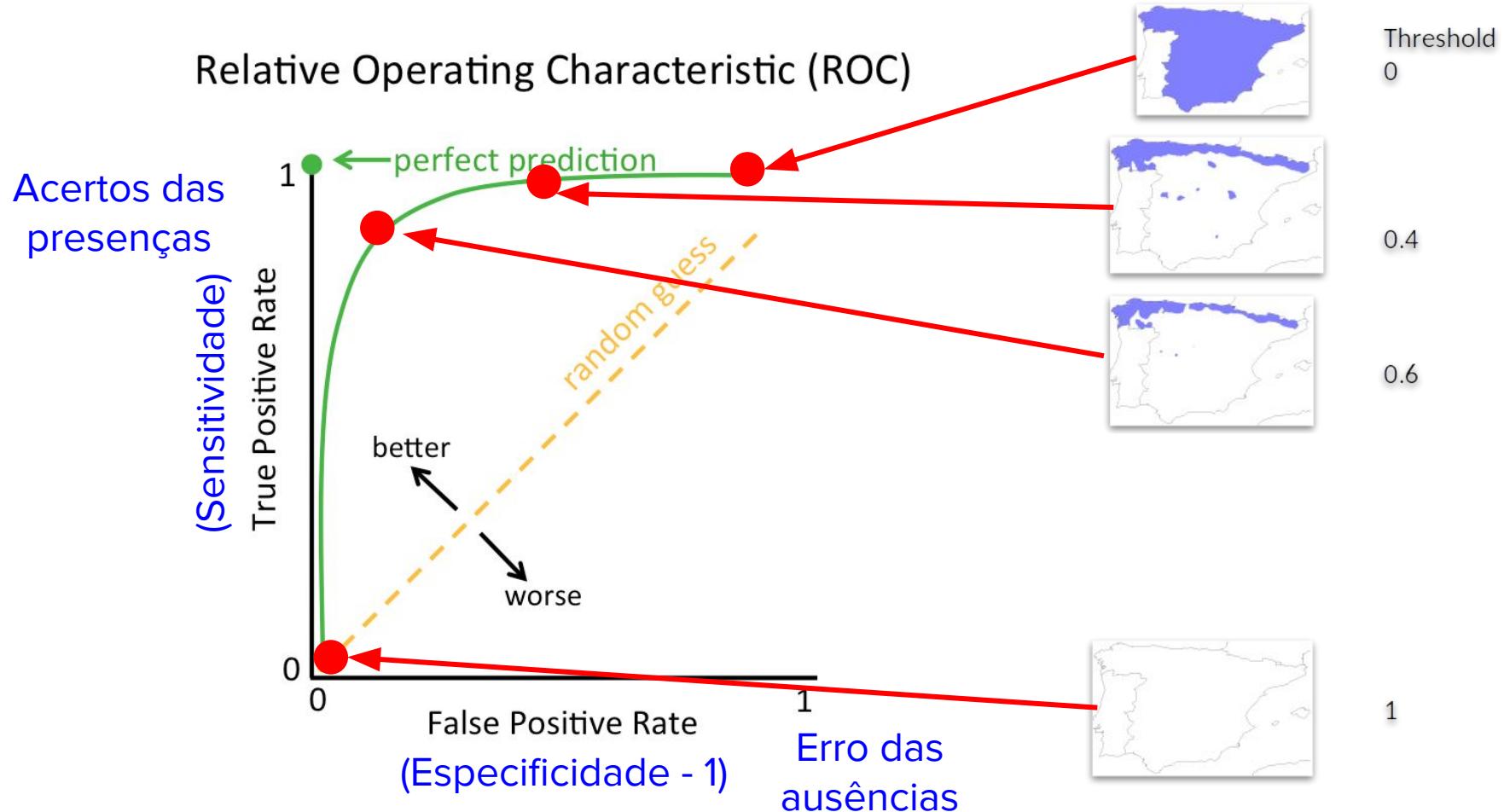
Avaliação dos ENMs

Curva ROC



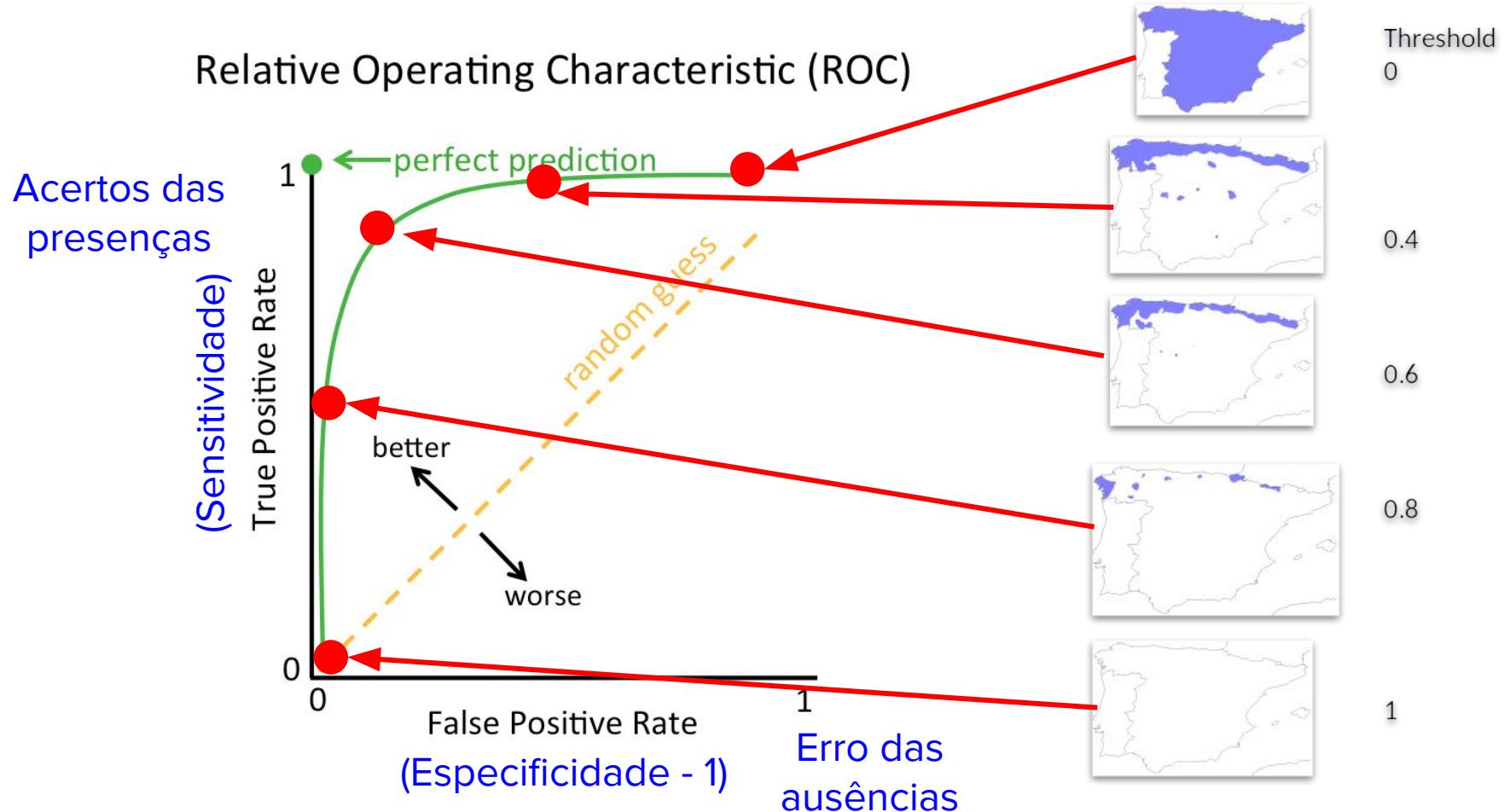
Avaliação dos ENMs

Curva ROC



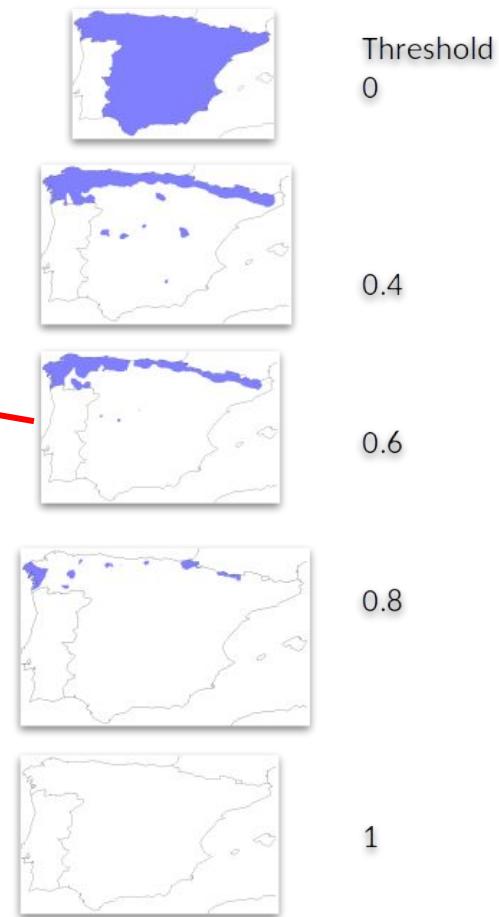
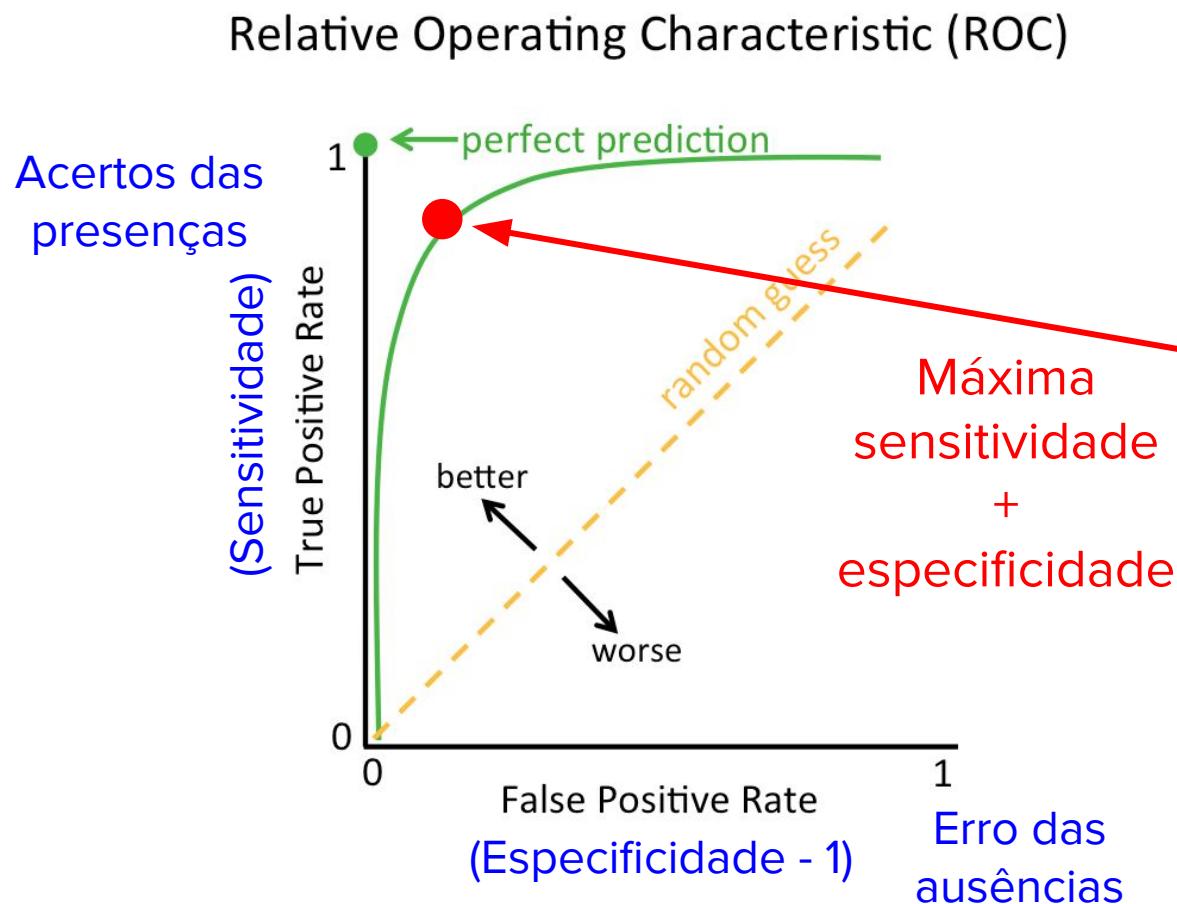
Avaliação dos ENMs

Curva ROC



Avaliação dos ENMs

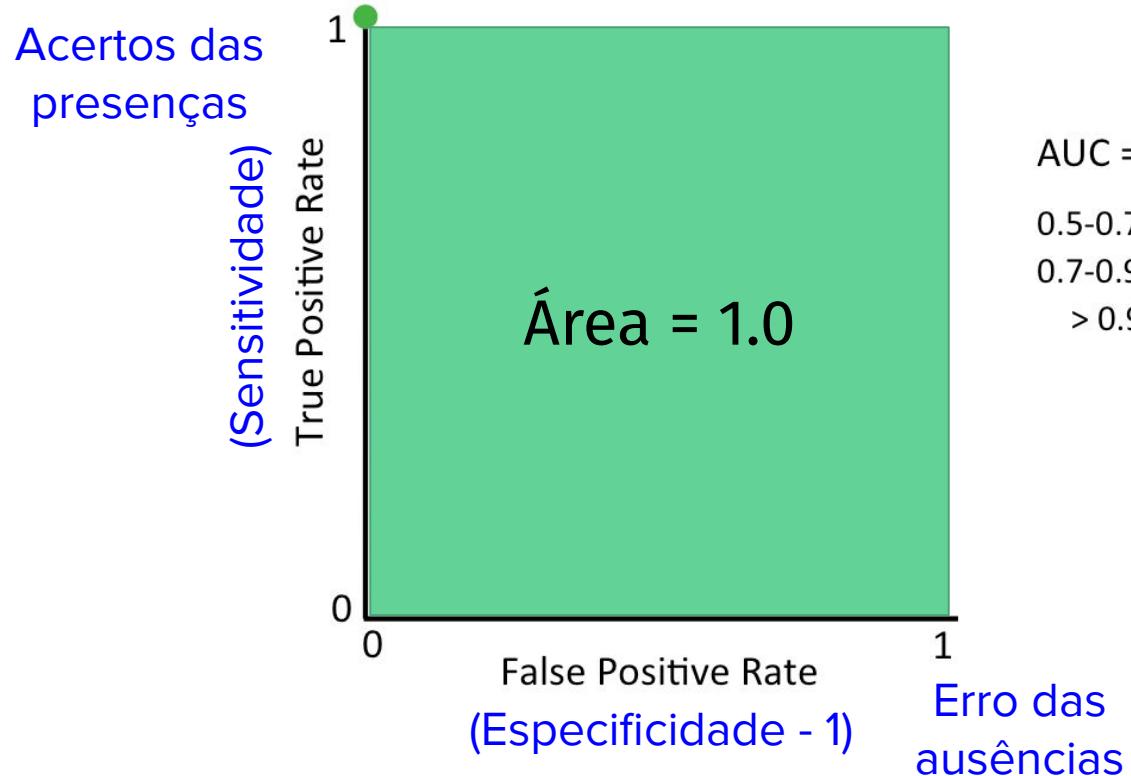
Curva ROC



Avaliação dos ENMs

AUC

Relative Operating Characteristic (ROC)



AUC = area under the curve

0.5-0.7 = poor model performance

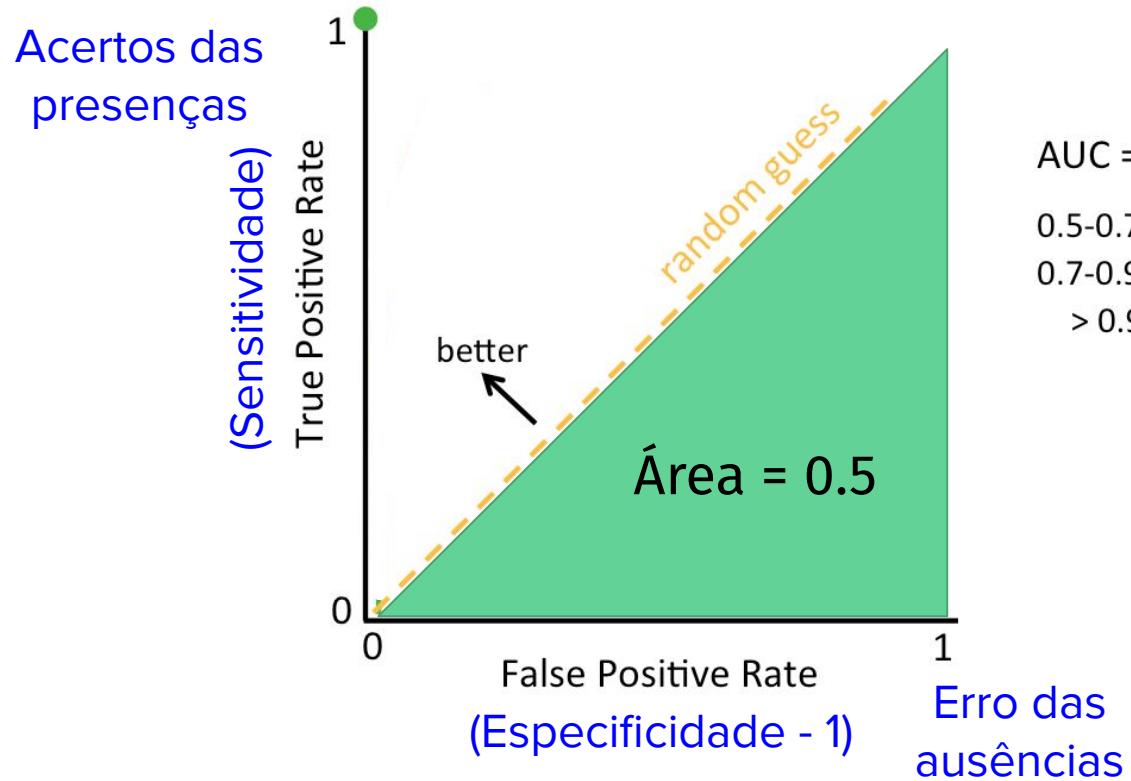
0.7-0.9 = moderate

> 0.9 = excellent

Avaliação dos ENMs

AUC

Relative Operating Characteristic (ROC)



AUC = area under the curve

0.5-0.7 = poor model performance

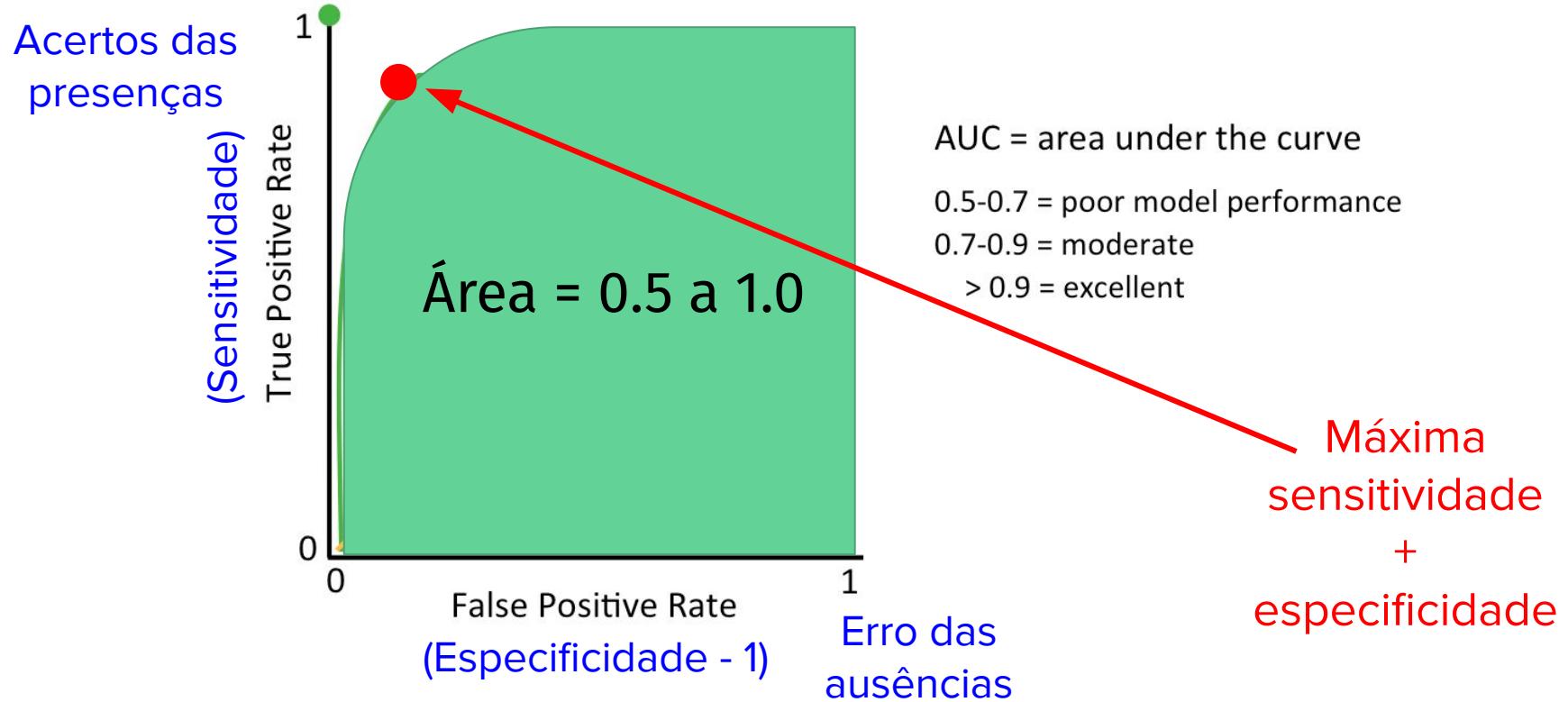
0.7-0.9 = moderate

> 0.9 = excellent

Avaliação dos ENMs

AUC

Relative Operating Characteristic (ROC)



Avaliação dos ENMs

TSS (*True skill statistic*)

Número de sucessos menos o número de sucessos aleatórios

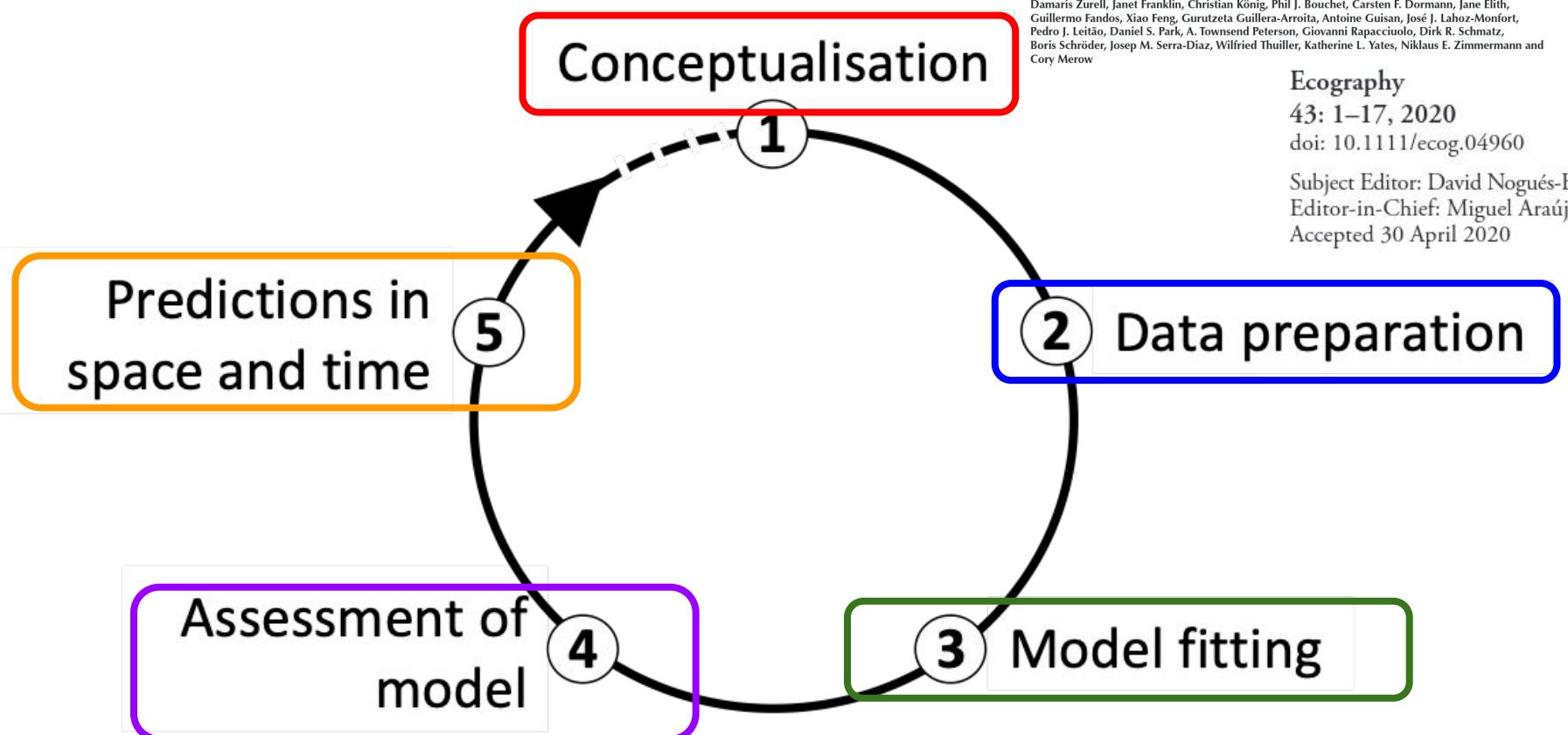
Varia de -1 to 1. Valores próximos a 0 modelos não diferentes do aleatórios

Depende de um valor de corte (*threshold*)

$$\text{TSS} = \text{sensitividade} + \text{especificidade} - 1$$

SDM passo a passo

Estrutura dos ENMs



ECOGRAPHY

Review and synthesis

A standard protocol for reporting species distribution models

Damaris Zurell, Janet Franklin, Christian König, Phil J. Bouchet, Carsten F. Dormann, Jane Elith, Guillermo Fandos, Xiao Feng, Gurutzeta Guillera-Arroita, Antoine Guisan, José J. Lahoz-Monfort, Pedro J. Leitão, Daniel S. Park, A. Townsend Peterson, Giovanni Rapacciulo, Dirk R. Schmatz, Boris Schröder, Josep M. Serra-Díaz, Wilfried Thuiller, Katherine L. Yates, Niklaus E. Zimmermann and Cory Merow

Ecography

43: 1–17, 2020

doi: 10.1111/ecog.04960

Subject Editor: David Nogués-Bravo

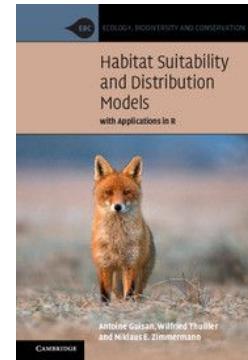
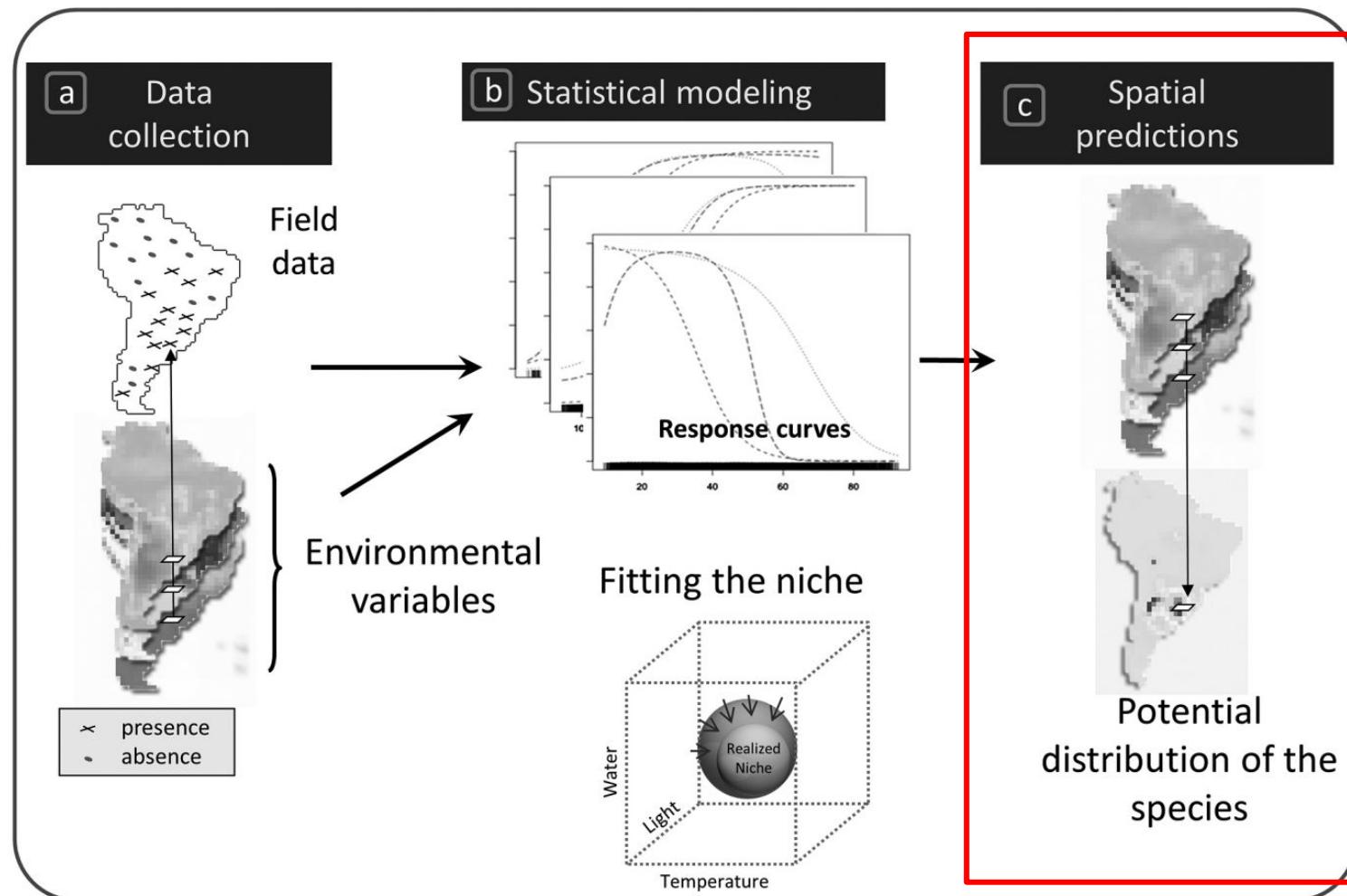
Editor-in-Chief: Miguel Araújo

Accepted 30 April 2020

8. Predições no espaço e no tempo

Predições no espaço e no tempo

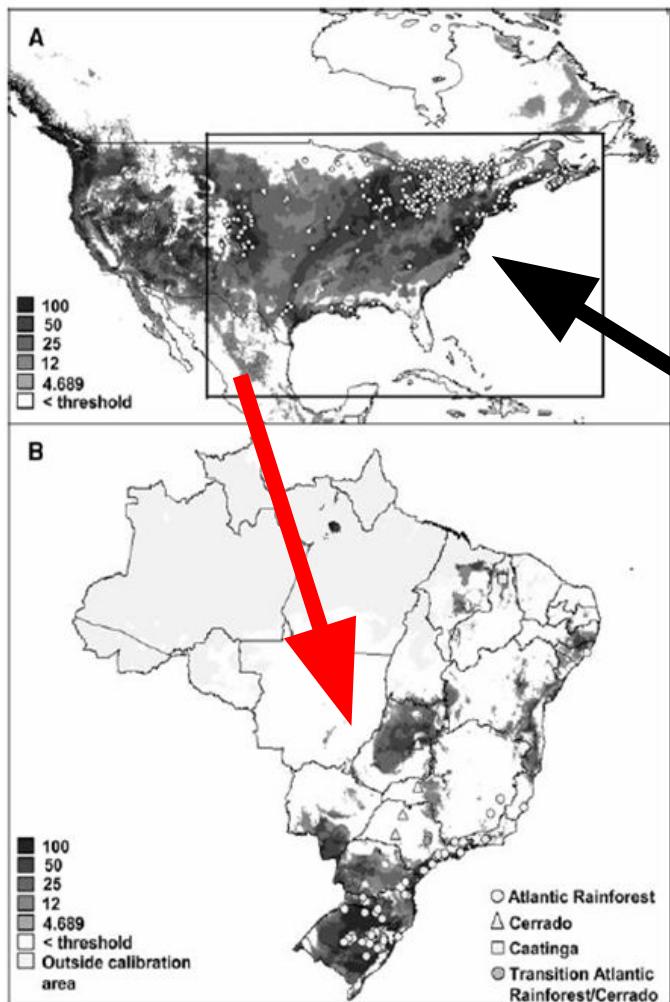
Predições (espaço e no tempo)



Guisan et al. (2017)

Predições no espaço e no tempo

Espaço - Espécies invasoras



Biol Invasions
DOI 10.1007/s10530-007-9154-5

ORIGINAL PAPER

Predicting the potential distribution of the alien invasive American bullfrog (*Lithobates catesbeianus*) in Brazil

João G. R. Giovanelli · Célio F. B. Haddad ·
João Alexandrino

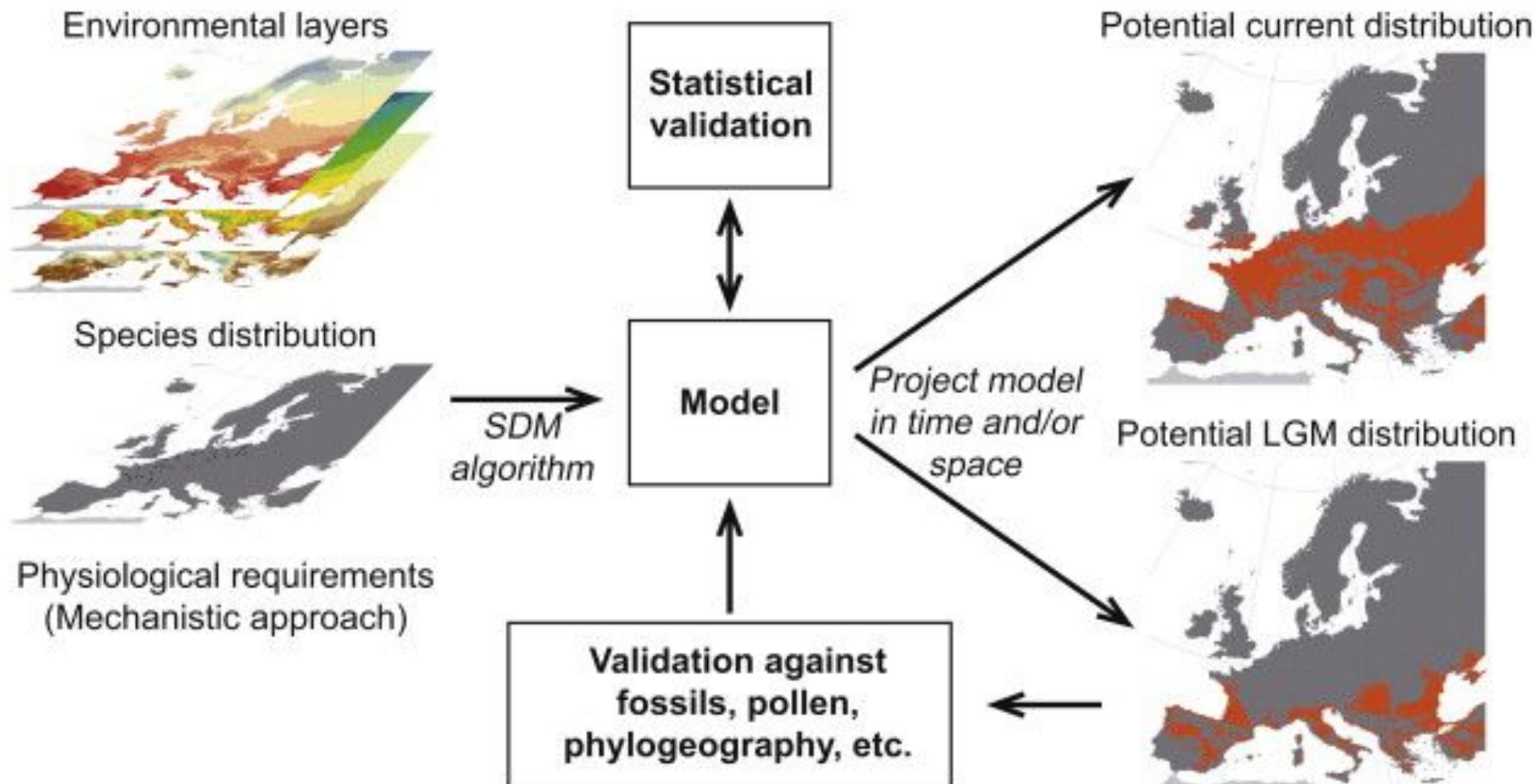


Foto: Carl D. Howe

Giovanelli et al., 2008. Biological Invasions

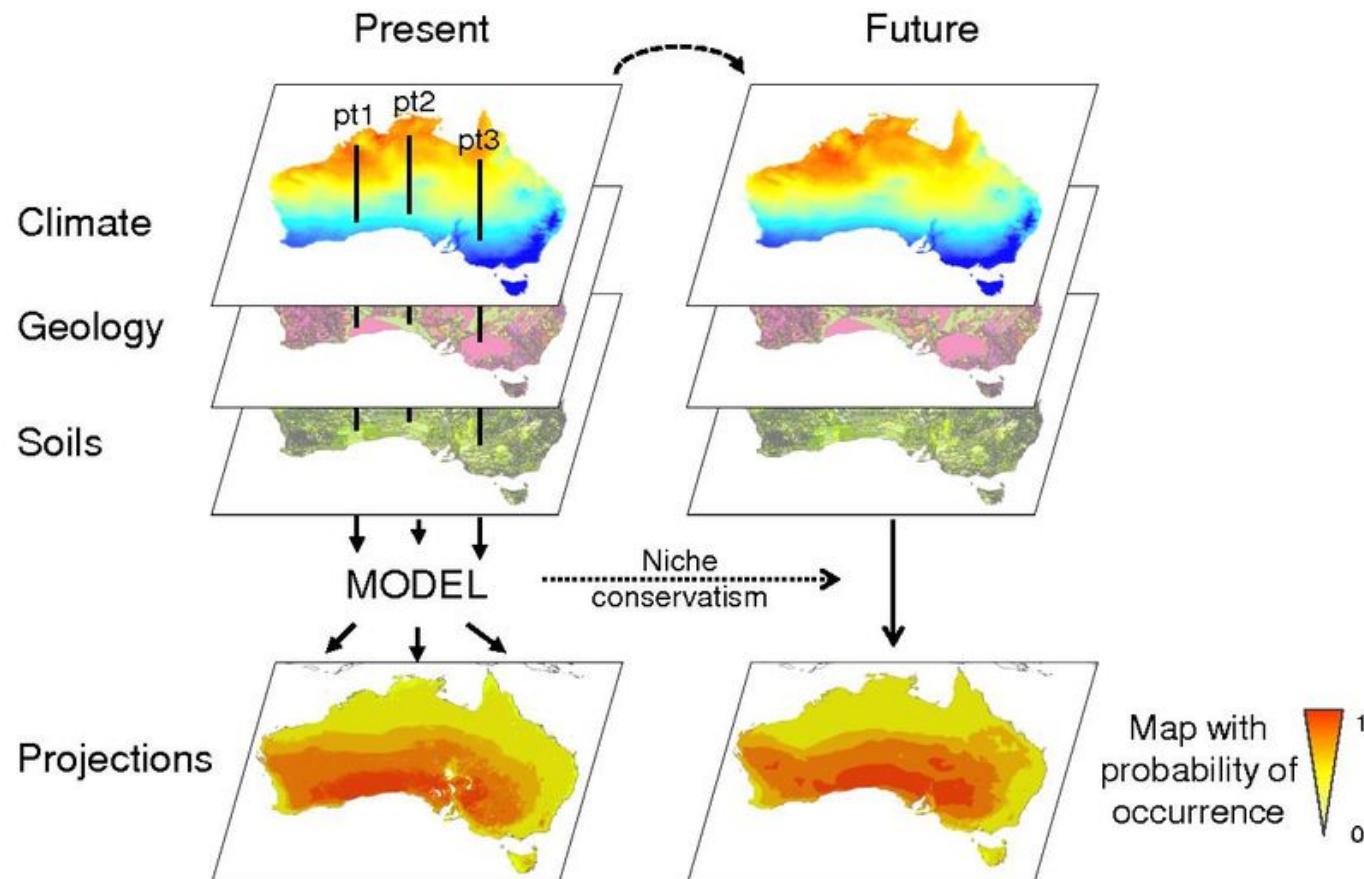
Predições no espaço e no tempo

Tempo - passado



Predições no espaço e no tempo

Tempo - futuro

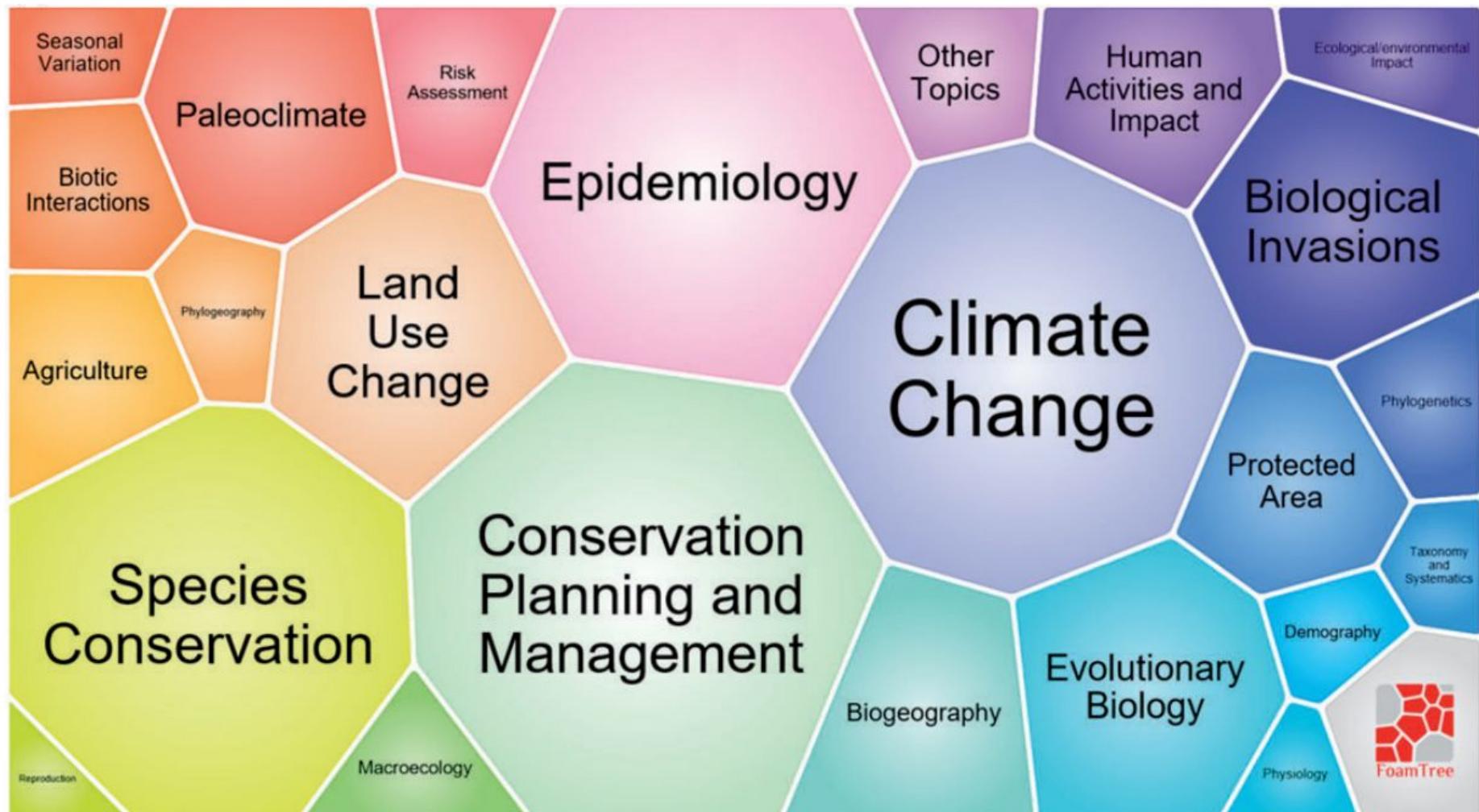


9. Aplicações e mais informações

Aplicações

Áreas de aplicação

Urbina-Cardona, N. et al. "Species Distribution Modeling in Latin America: A 25-Year Retrospective Review." *Tropical Conservation Science* 12 (2019).



Diferentes respostas às mudanças climáticas de duas palmeiras de buritis na América do Sul

Perspectives in Ecology and Conservation

Marcones Ferreira Costa

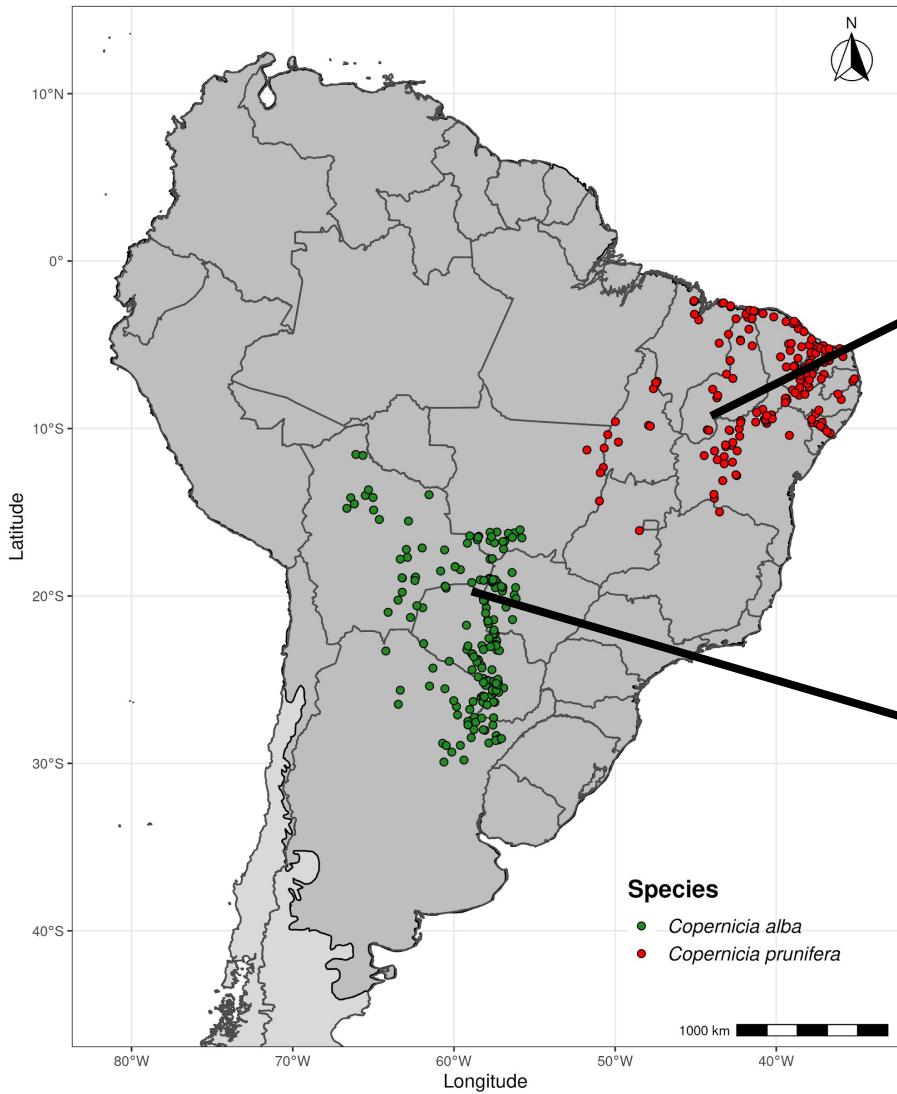
Maurício H. Vancine

Maria Imaculada Zucchi

07/07/2019



Ocorrências e limite



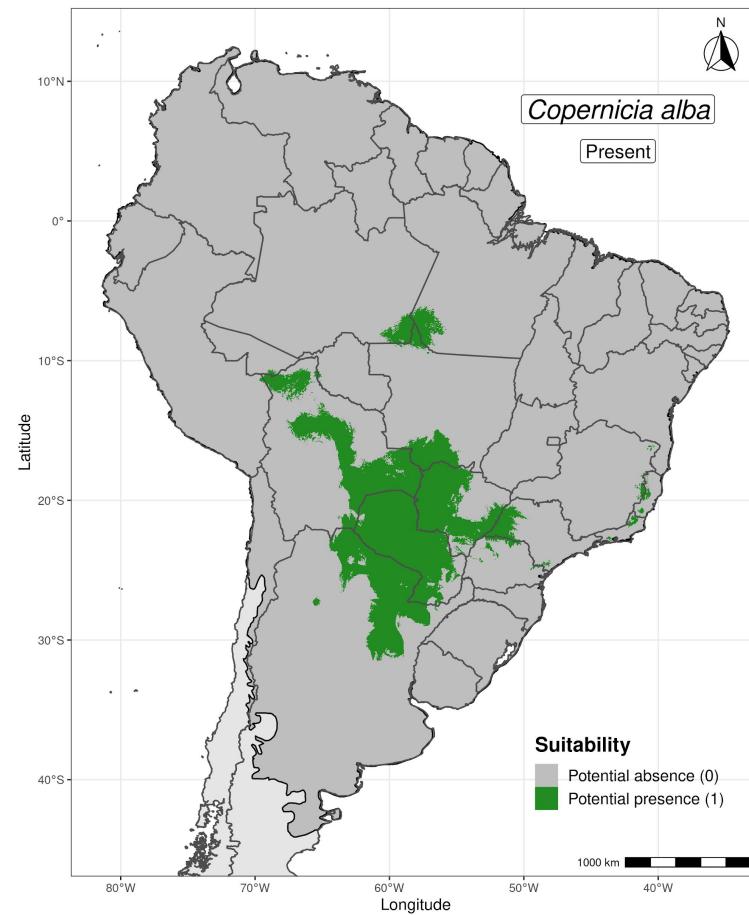
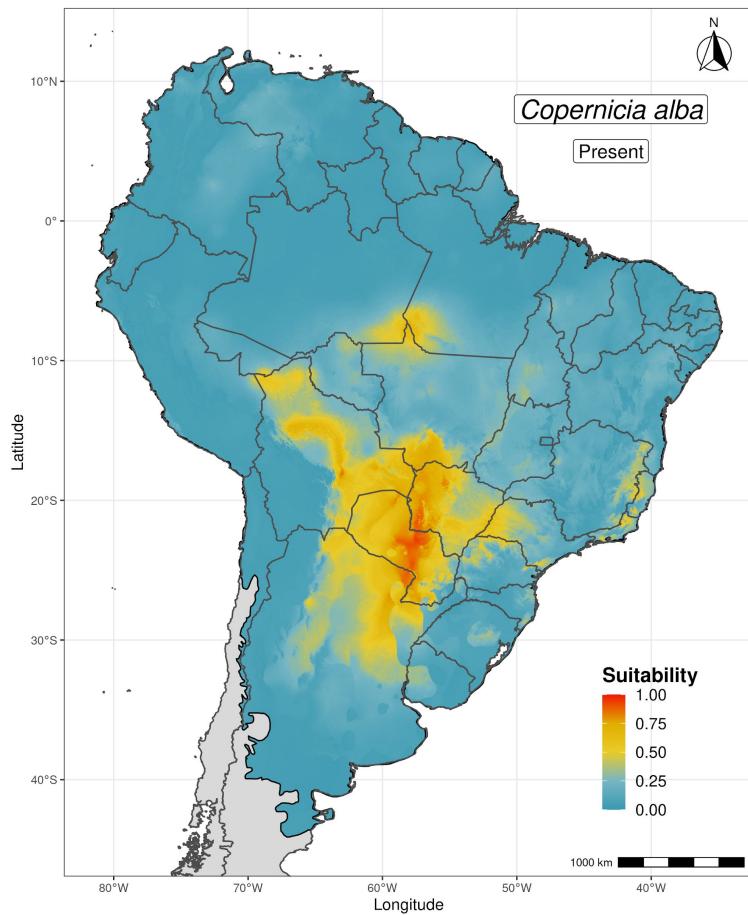
Copernicia prunifera



Copernicia alba

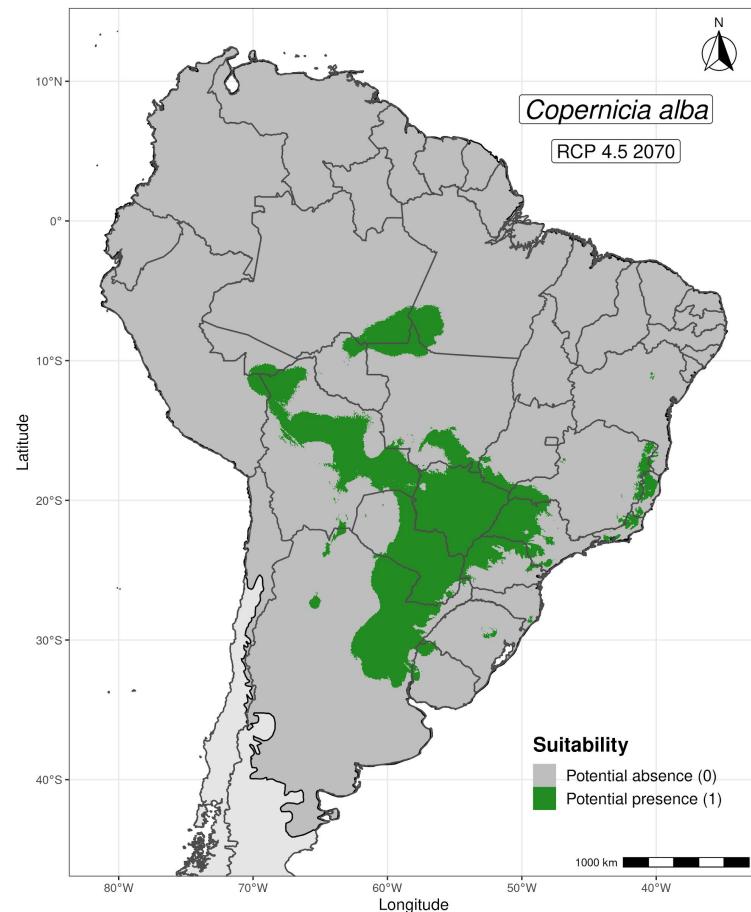
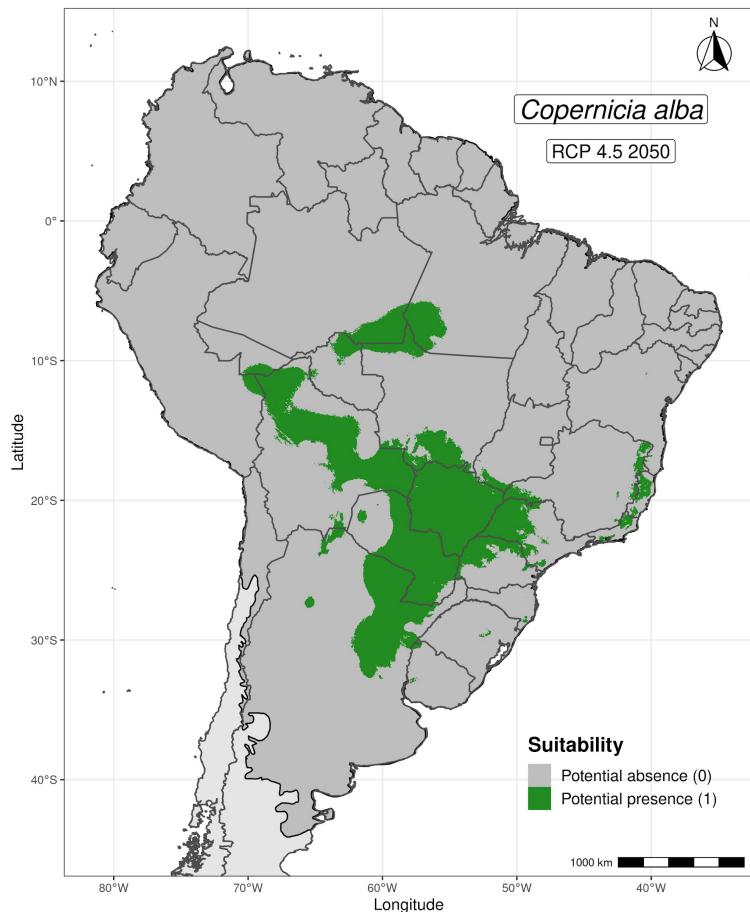
ENMs - Presente

Copernicia alba



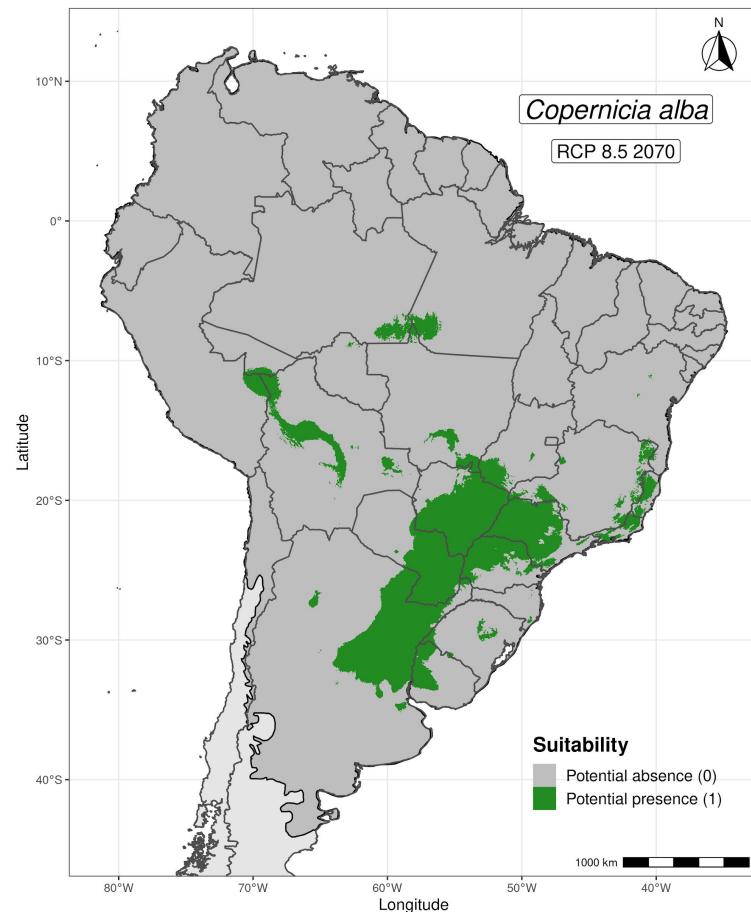
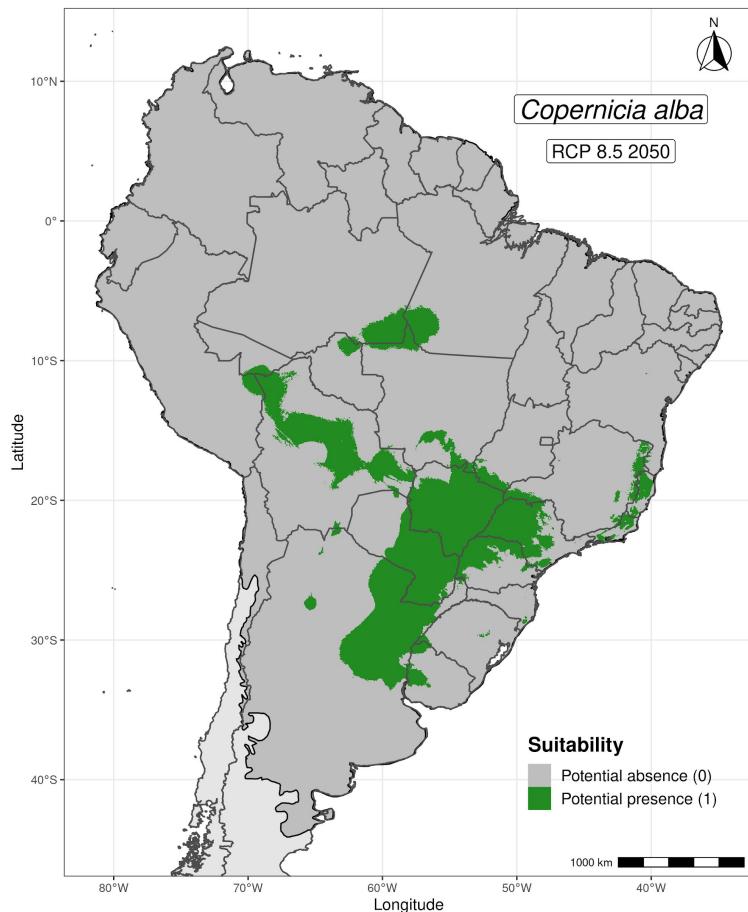
ENMs - Cenário otimista (RCP 4.5)

Copernicia alba



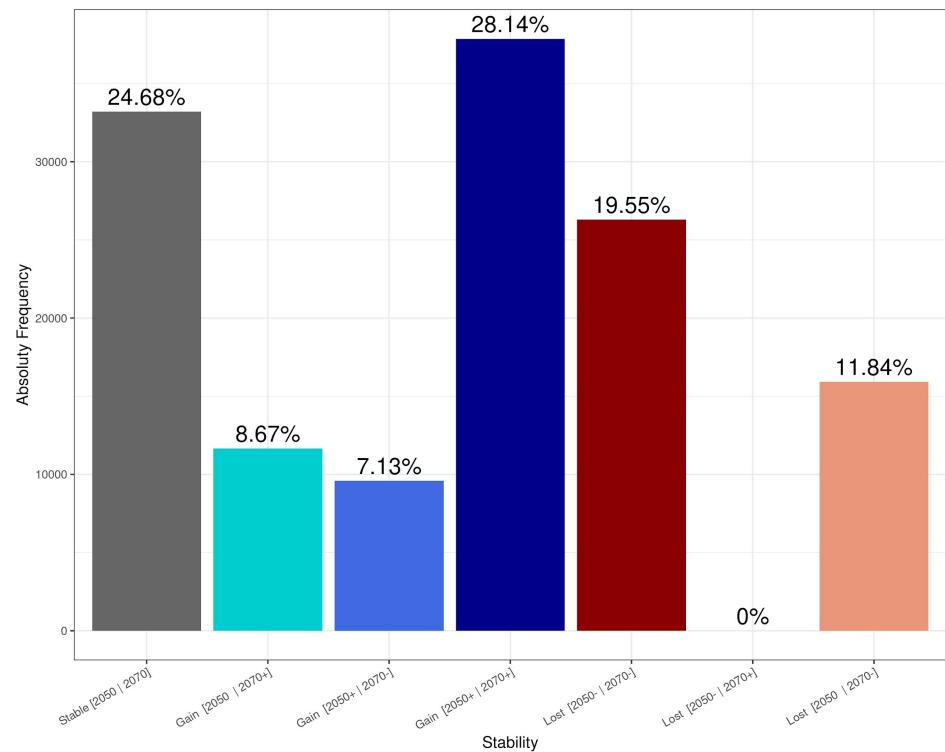
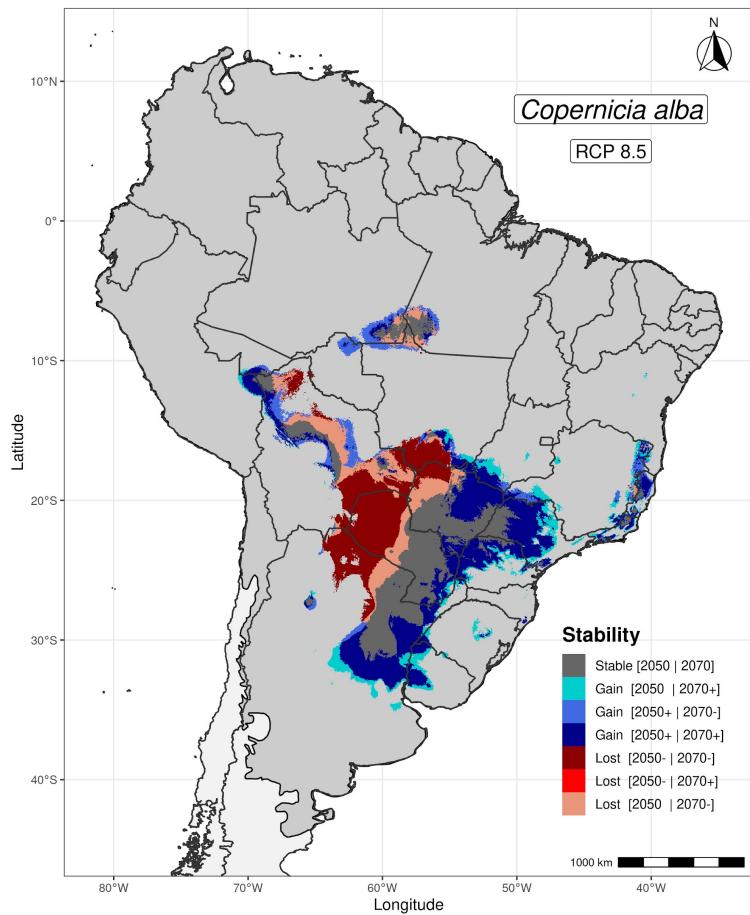
ENMs - Cenário pessimista (RCP 8.5)

Copernicia alba



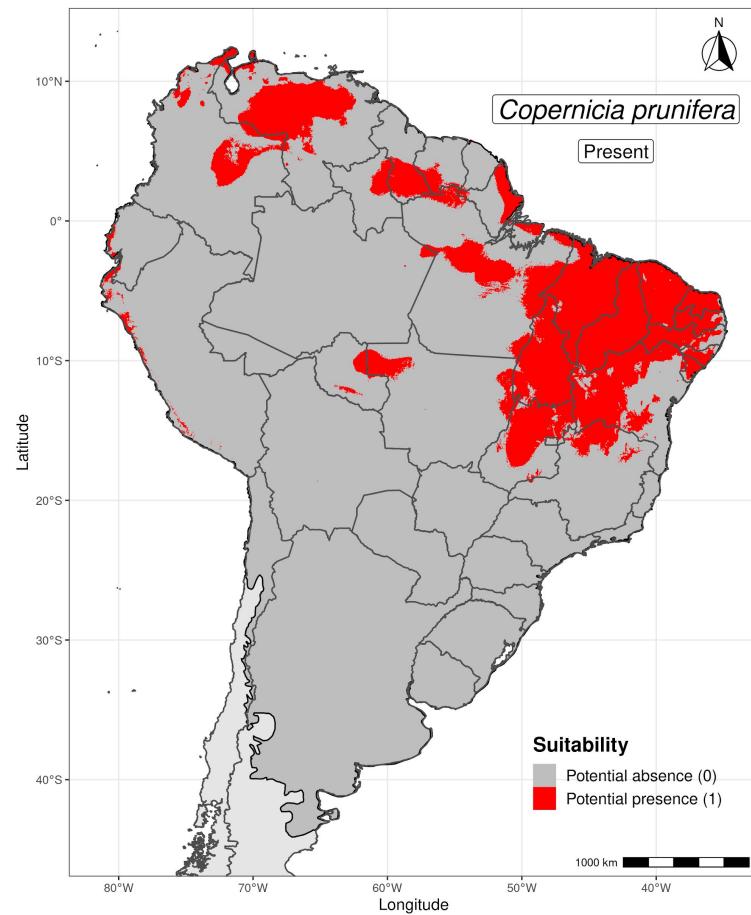
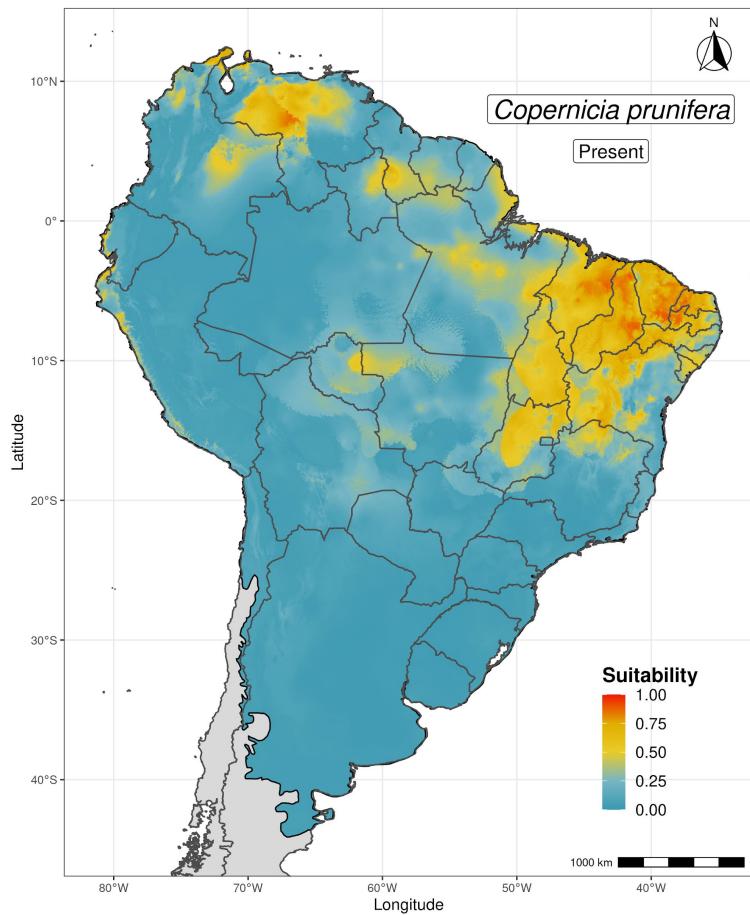
ENMs - Estabilidade (RCP 8.5)

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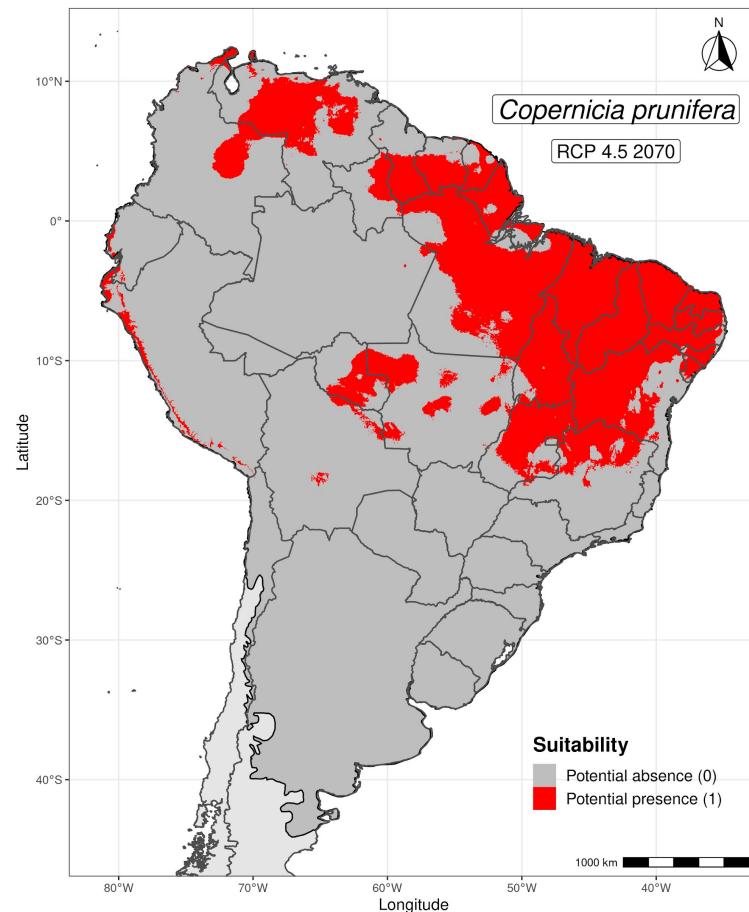
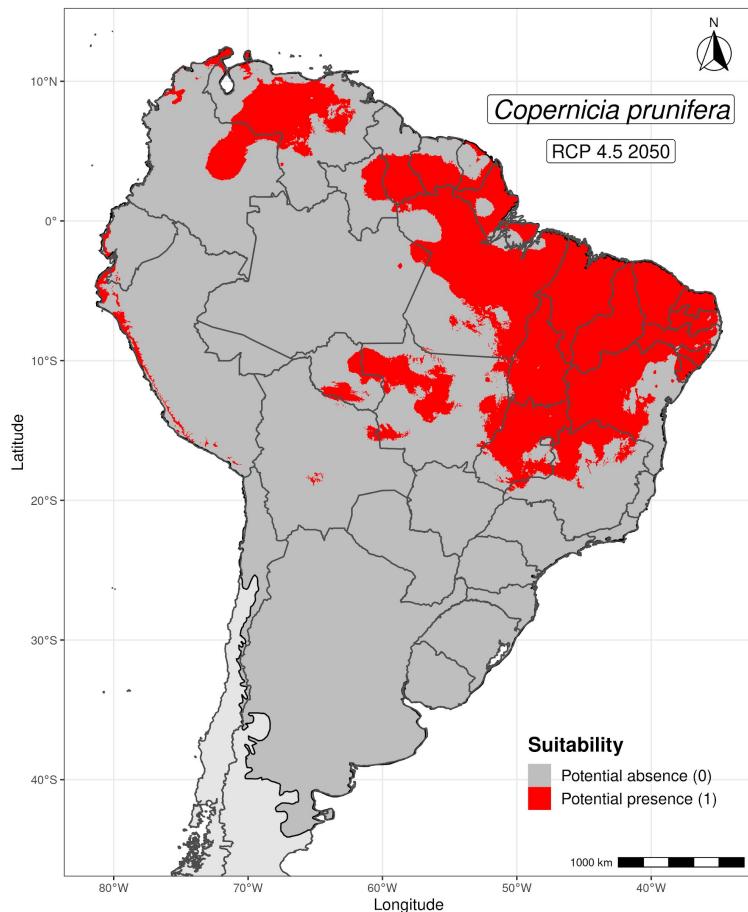
ENMs - Presente

Copernicia prunifera



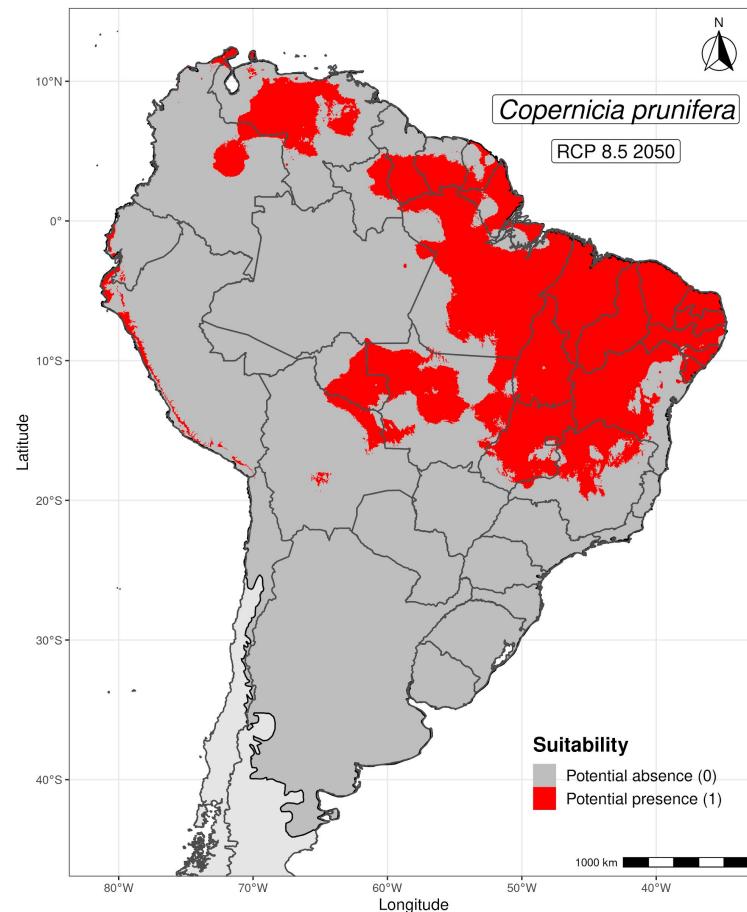
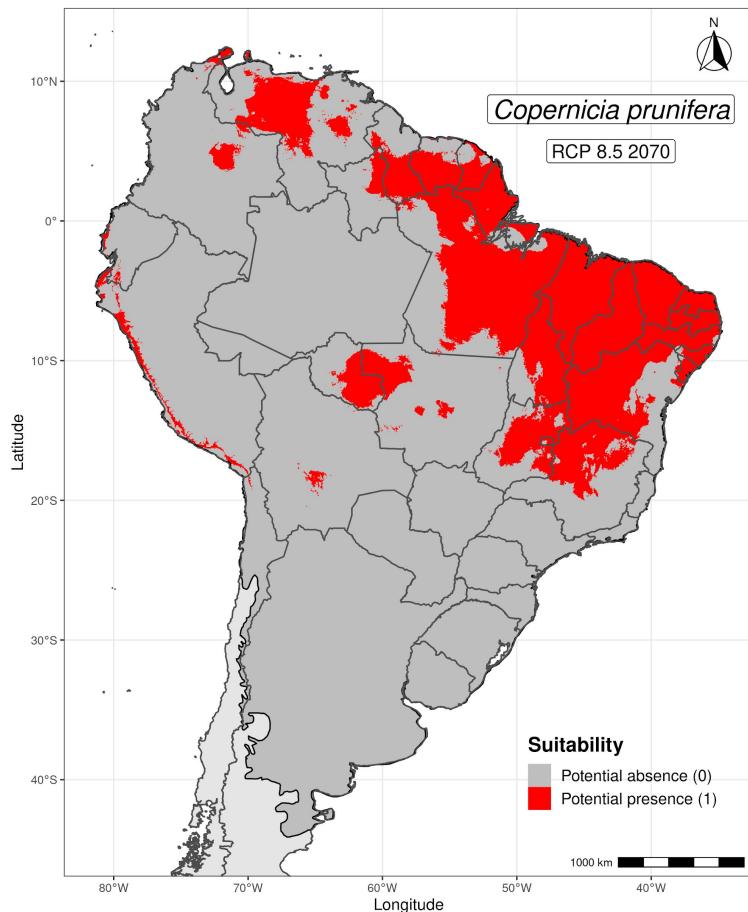
ENMs - Cenário otimista (RCP 4.5)

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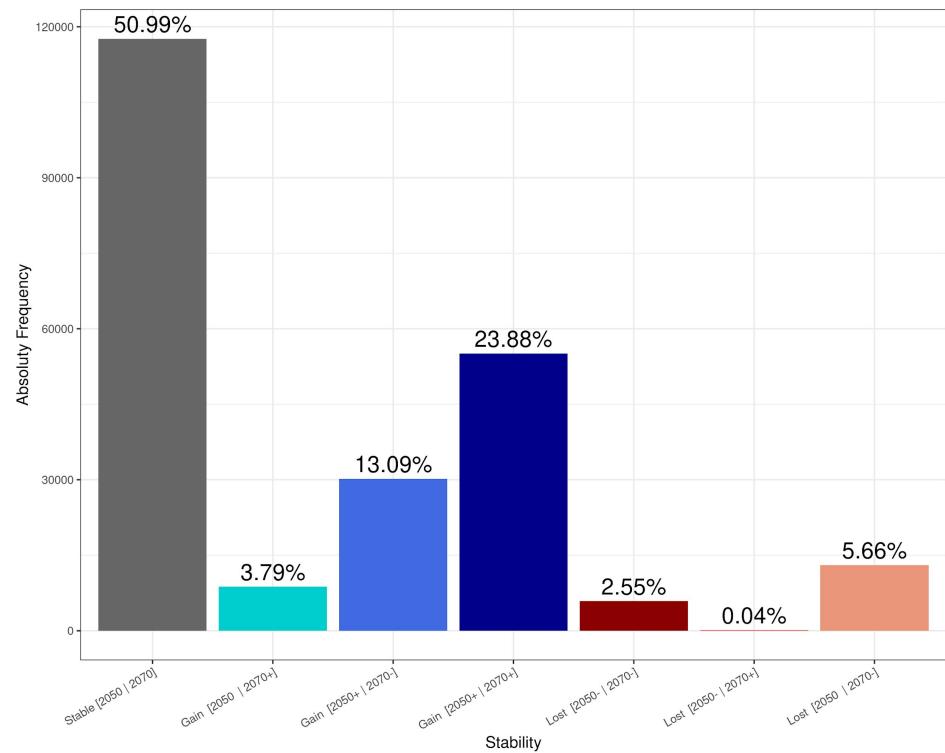
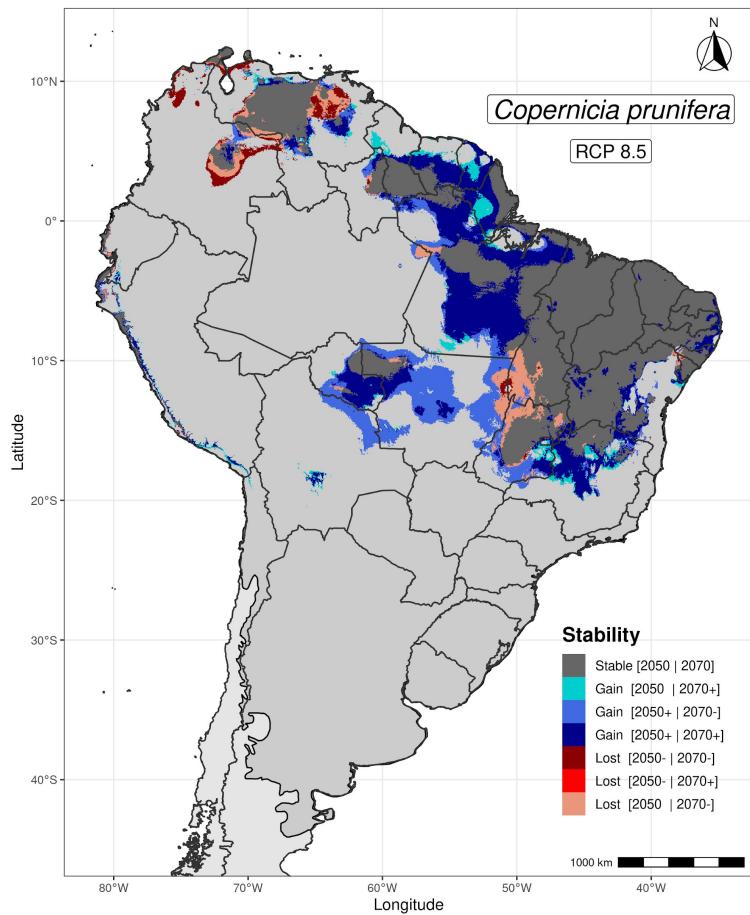
ENMs - Cenário pessimista (RCP 8.5)

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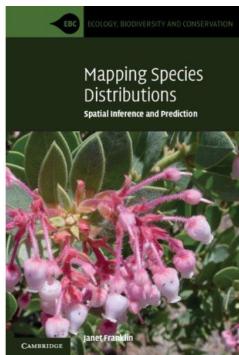
ENMs - Estabilidade (RCP 8.5)

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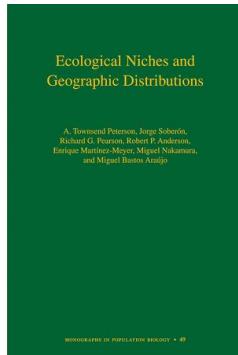


Mais informações

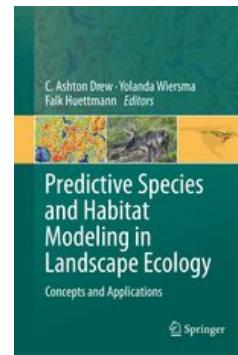
Livros



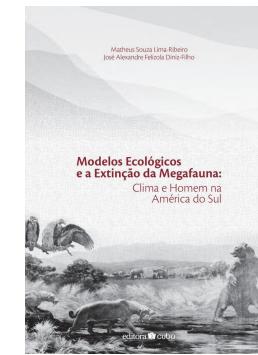
Franklin (2009)



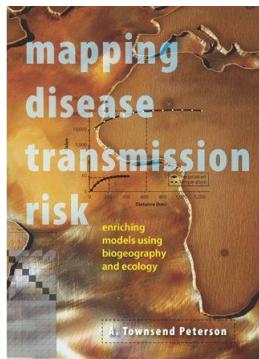
Peterson et al. (2011)



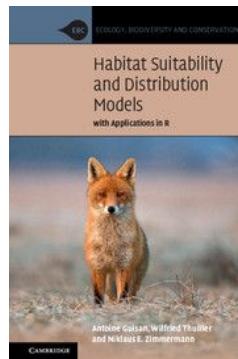
Drew et al. (2011)



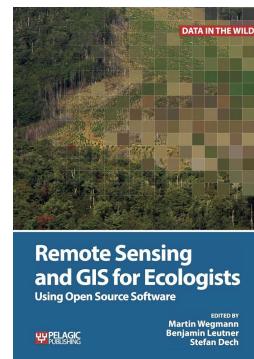
Lima-Ribeiro & Diniz-Filho (2013)



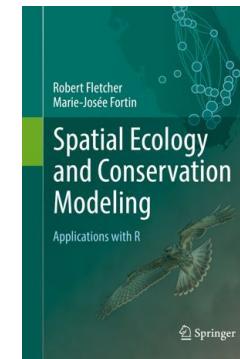
Peterson (2014)



Guisan et al. (2017)



Wegmann et al. (2016)
Cap. 13

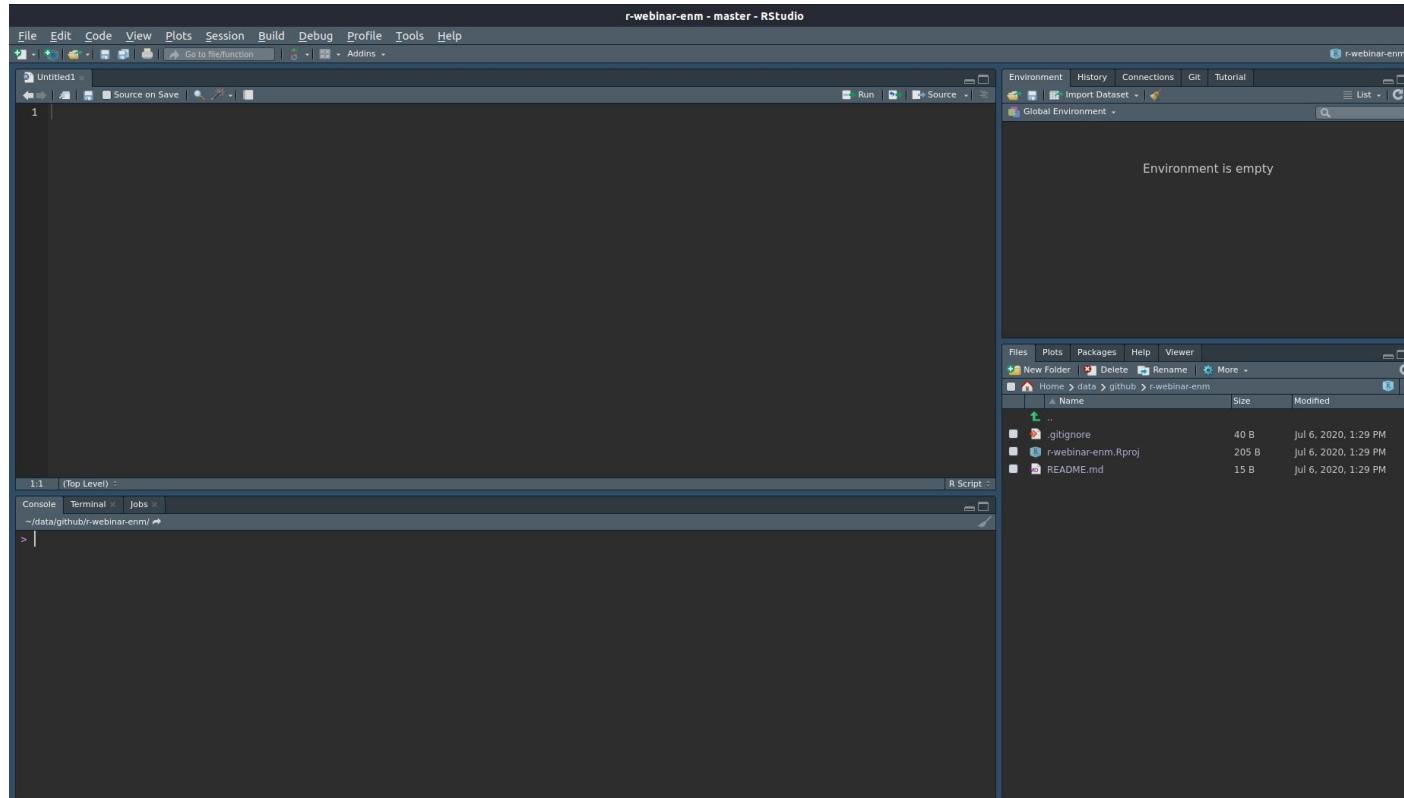


Fletcher and Fortin (2018)
Cap. 07

Prática

R

<https://github.com/mauriciovancine/r-webinar-enm>



Muito obrigado!



Contato e informações pessoais

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