# INTRODUCTION TO ECOLOGICAL NICHE MODELLING THEORY

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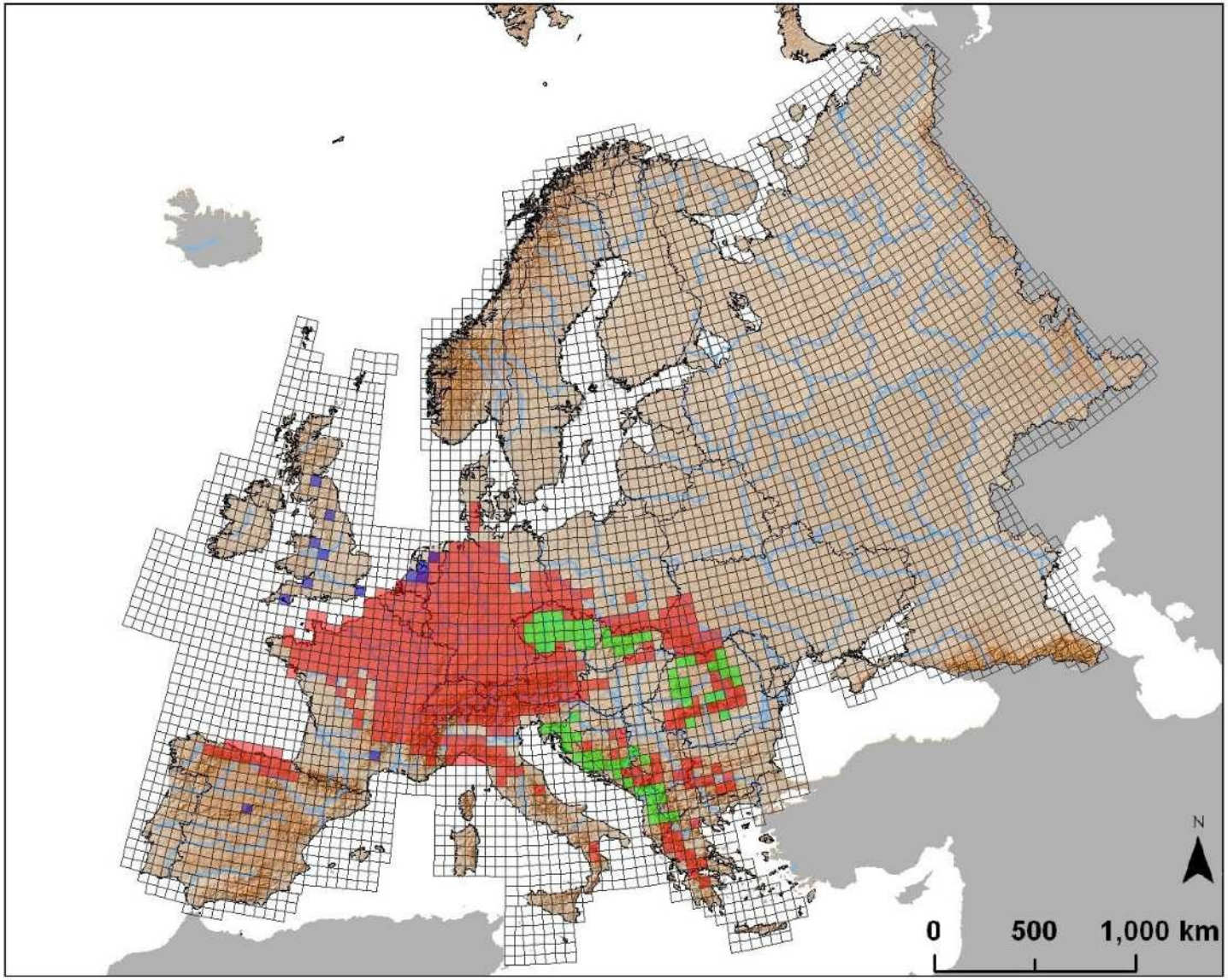
# WHERE DO SPECIES OCCUR?

**Sillero et al 2014**

*Ichthyosaura alpestris*

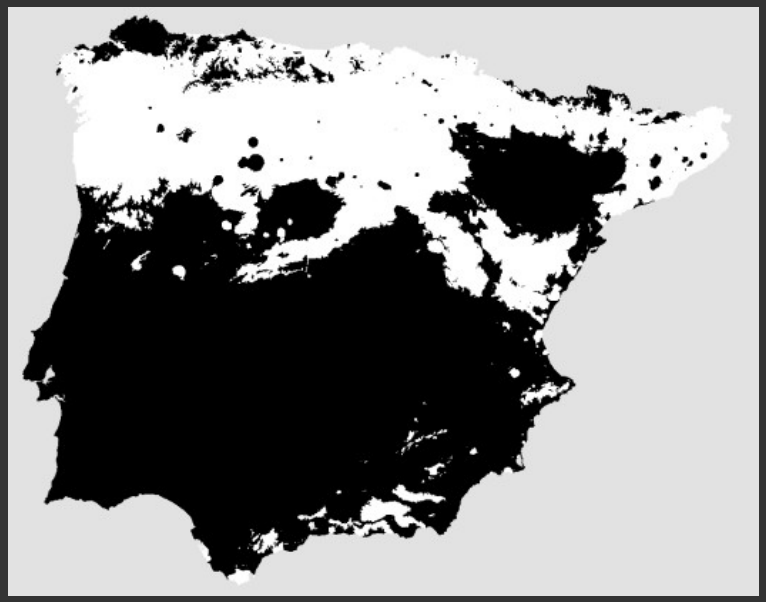


# DO WE KNOW THE WHOLE DISTRIBUTION?

# WHERE DO SPECIES POTENTIALLY OCCUR?

## AUTHOR KNOWLEDGE

## STATISTICAL PROCEDURES



## AUTHOR KNOWLEDGE

## STATISTICAL PROCEDURES

# ECOLOGICAL NICHE MODELS

# OBSERVED DISTRIBUTION

# ≠

# POTENTIAL DISTRIBUTION

# AN EXAMPLE OF DISTRIBUTION

# AN EXAMPLE OF DISTRIBUTION

EXTERNAL OBSERVER

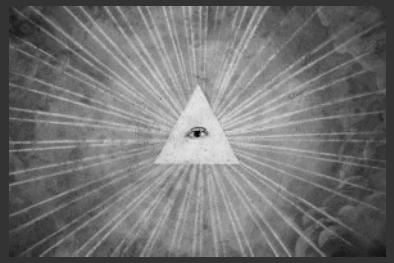
STUDY AREA

THE SPECIES
IN STUDY

# AN EXAMPLE OF DISTRIBUTION

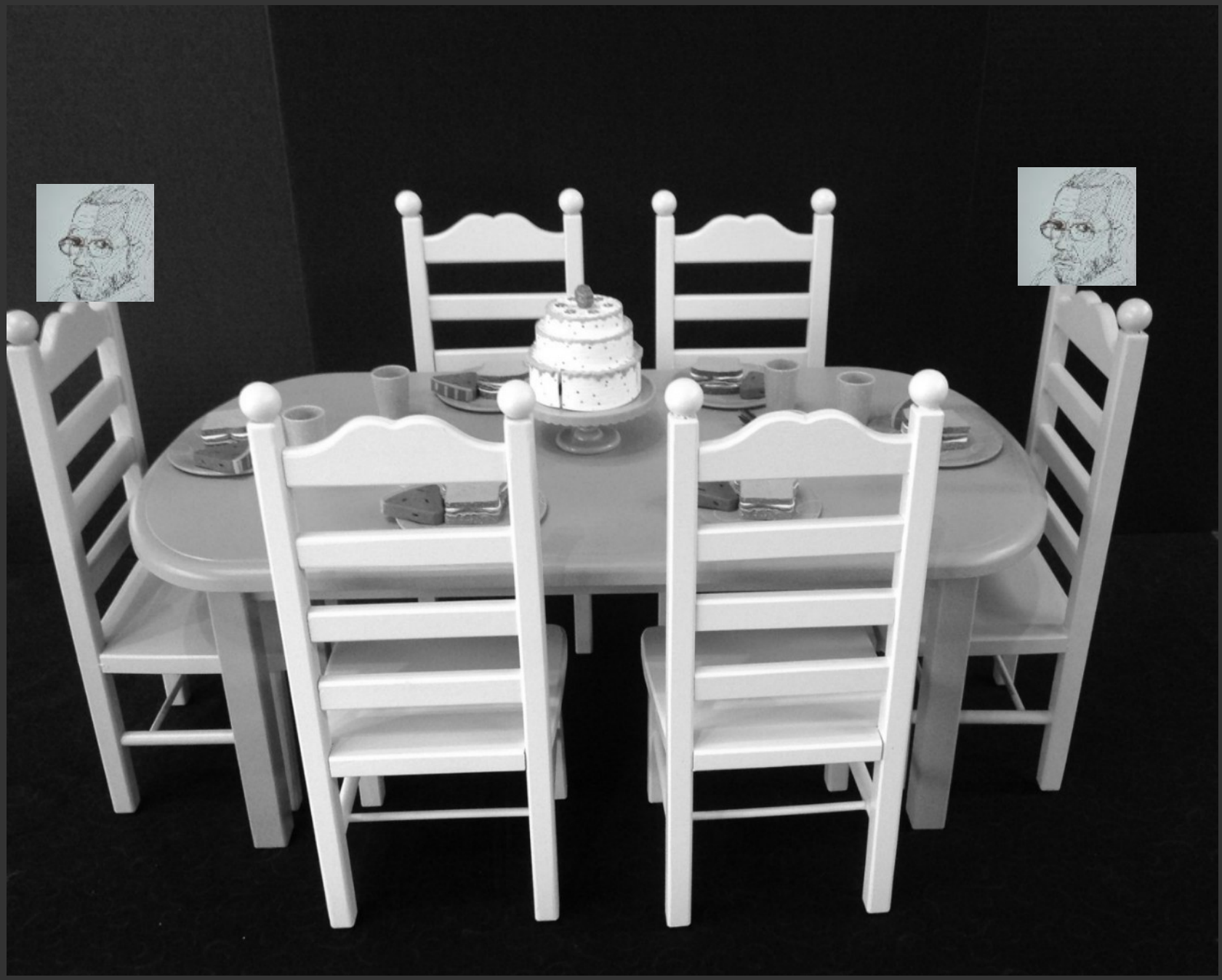
# AN EXAMPLE OF DISTRIBUTION

# I LIKE TO SIT DOWN BUT ONLY ON YELLOW CHAIRS



# BUT THE EXTERNAL OBSERVED HAS SIGHT PROBLEMS

# AN EXAMPLE OF DISTRIBUTION



# AN EXAMPLE OF DISTRIBUTION

# AN EXAMPLE OF DISTRIBUTION

**WE KNOW WHERE THE SPECIES OCCURS AND WHERE THE SPECIES DOES NOT OCCURS**

**WE ONLY KNOW SUITABLE AREAS FOR THE SPECIES OCCURRENCE**

# AN EXAMPLE OF DISTRIBUTION

| SUITABLE HABITATS WHERE THE SPECIES OCCURS | SUITABLE HABITATS WHERE THE SPECIES DOES NOT OCCUR | UNSUITABLE HABITATS WHERE THE SPECIES DOES NOT OCCUR |
|---|---|---|

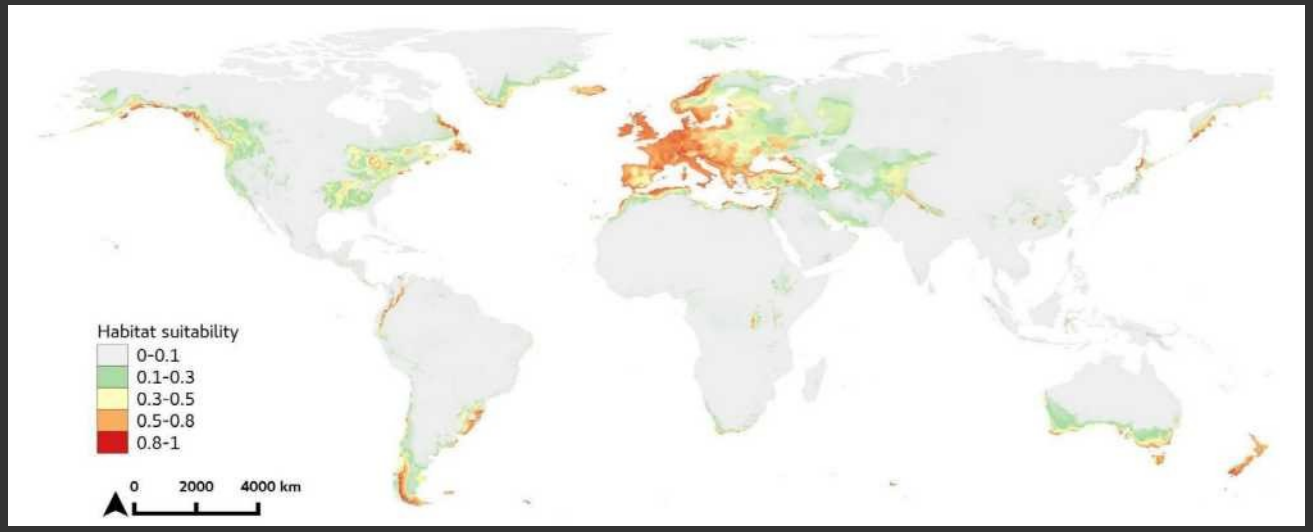
# A MORE COMPLICATED EXAMPLE: BIOTIC INTERACTIONS

# A MORE COMPLICATED EXAMPLE: BIOTIC INTERACTIONS

# WHAT IS AN ECOLOGICAL NICHE MODEL?

- **Ecological niche modelling**
- **Species distribution modelling**
- **Habitat distribution modelling**
- **Climate envelope modelling**

**Algorithms for predicting the distribution of species in geographic space on the basis of a mathematical representation of their known distribution in environmental space.**



# Empirical or mathematical approximations to a species' ecological niche

## Barbosa et al 2012

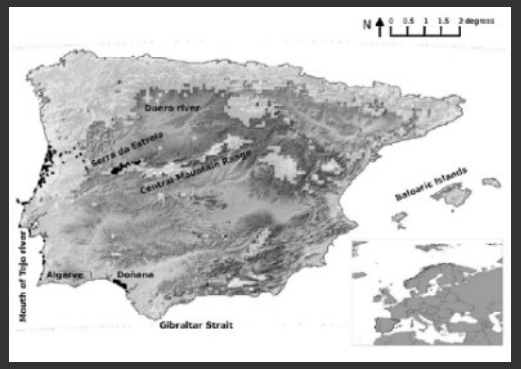
*Chapter 8*

## ECOLOGICAL NICHE MODELS IN MEDITERRANEAN HERPETOLOGY: PAST, PRESENT AND FUTURE

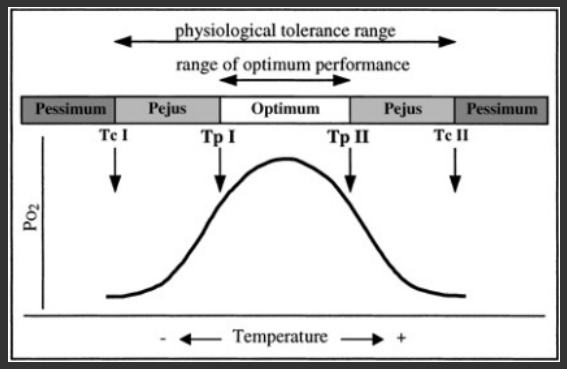
*A. Márcia Barbosa[1,2]*, Neftalí Sillero[3], Fernando Martínez-Freiría[4] and Raimundo Real[5]*

# WHAT IS AN ECOLOGICAL NICHE MODEL?

## Data about species' distribution

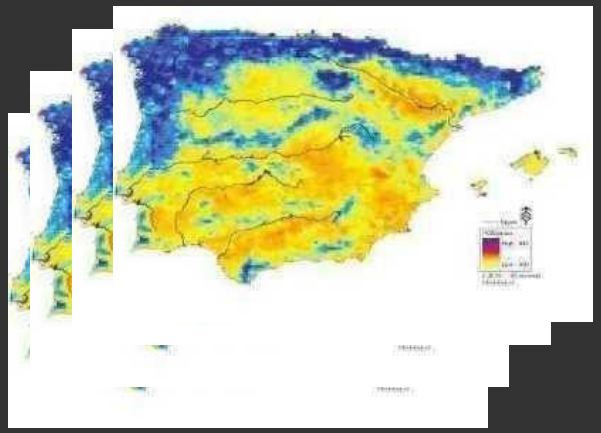



GPS points



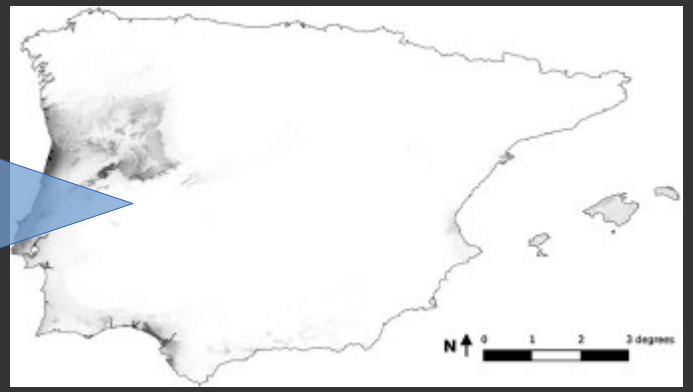

Physiological limits

Climatic variables

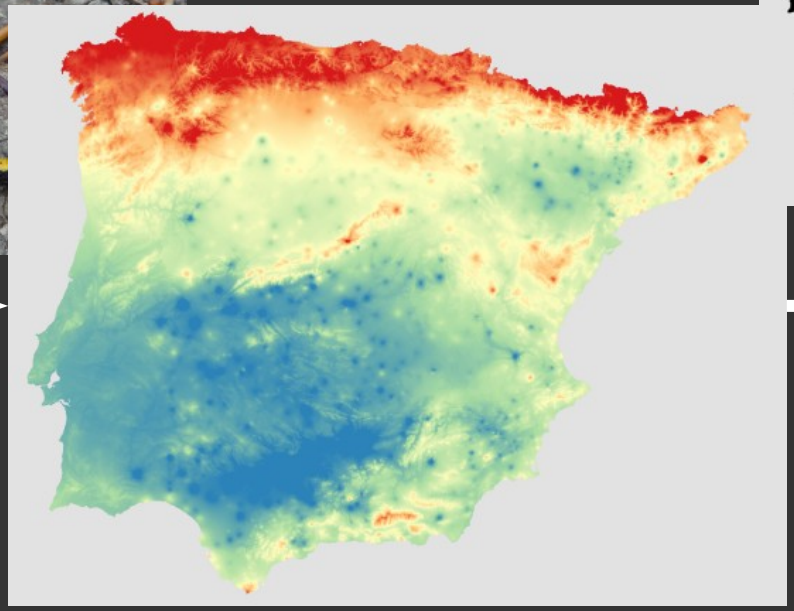


Algorithm

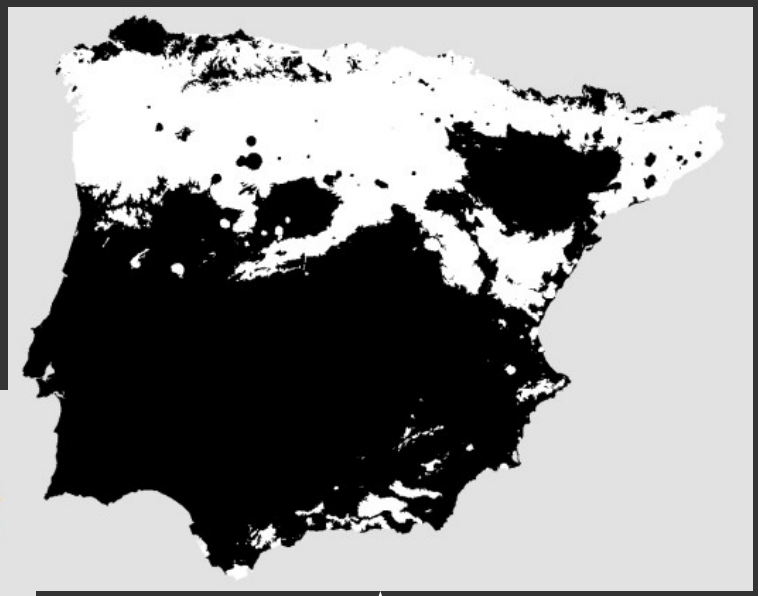
## Model



**Salamanders do not survive**
**T>5º - T<20º**

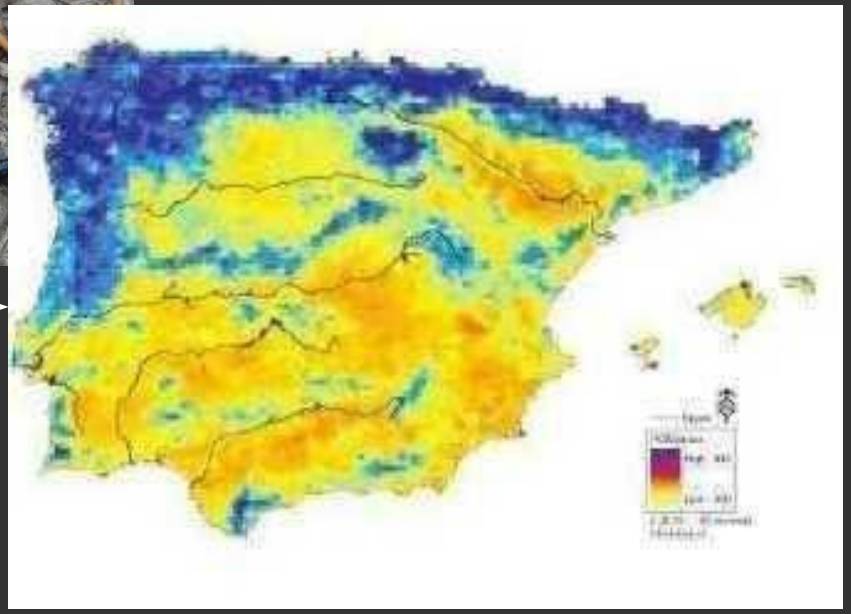


**Layer temperature**



**>5º - <20º**

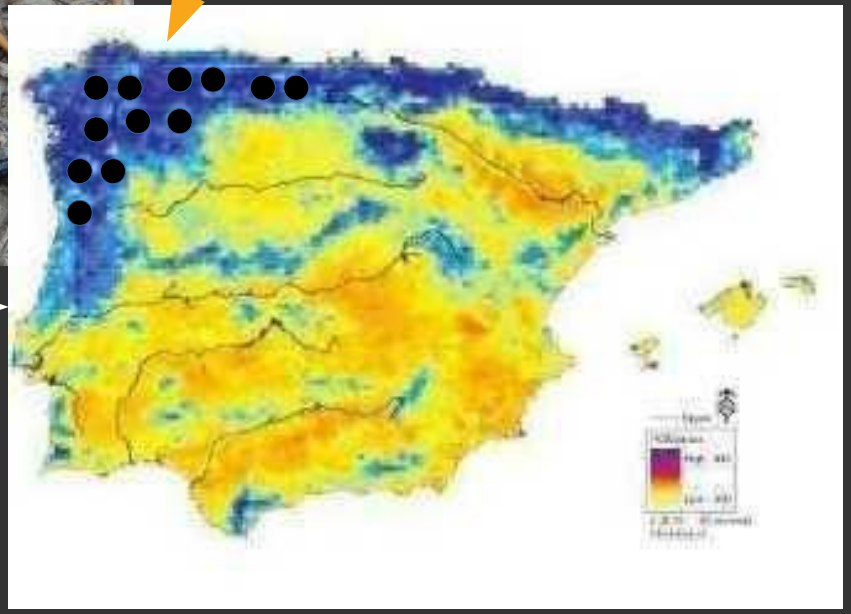
## Salamanders like humid areas



Layer precipitation

## Salamanders like humid areas

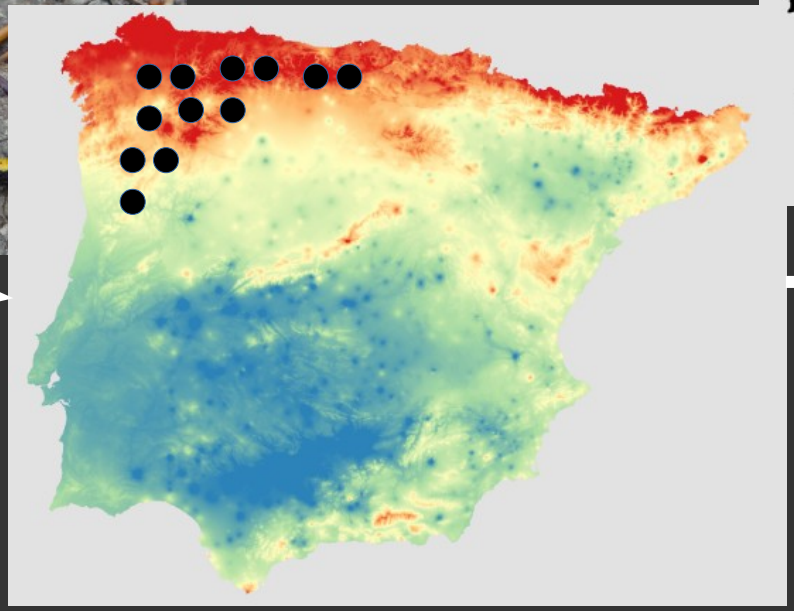
Species' records



Layer precipitation

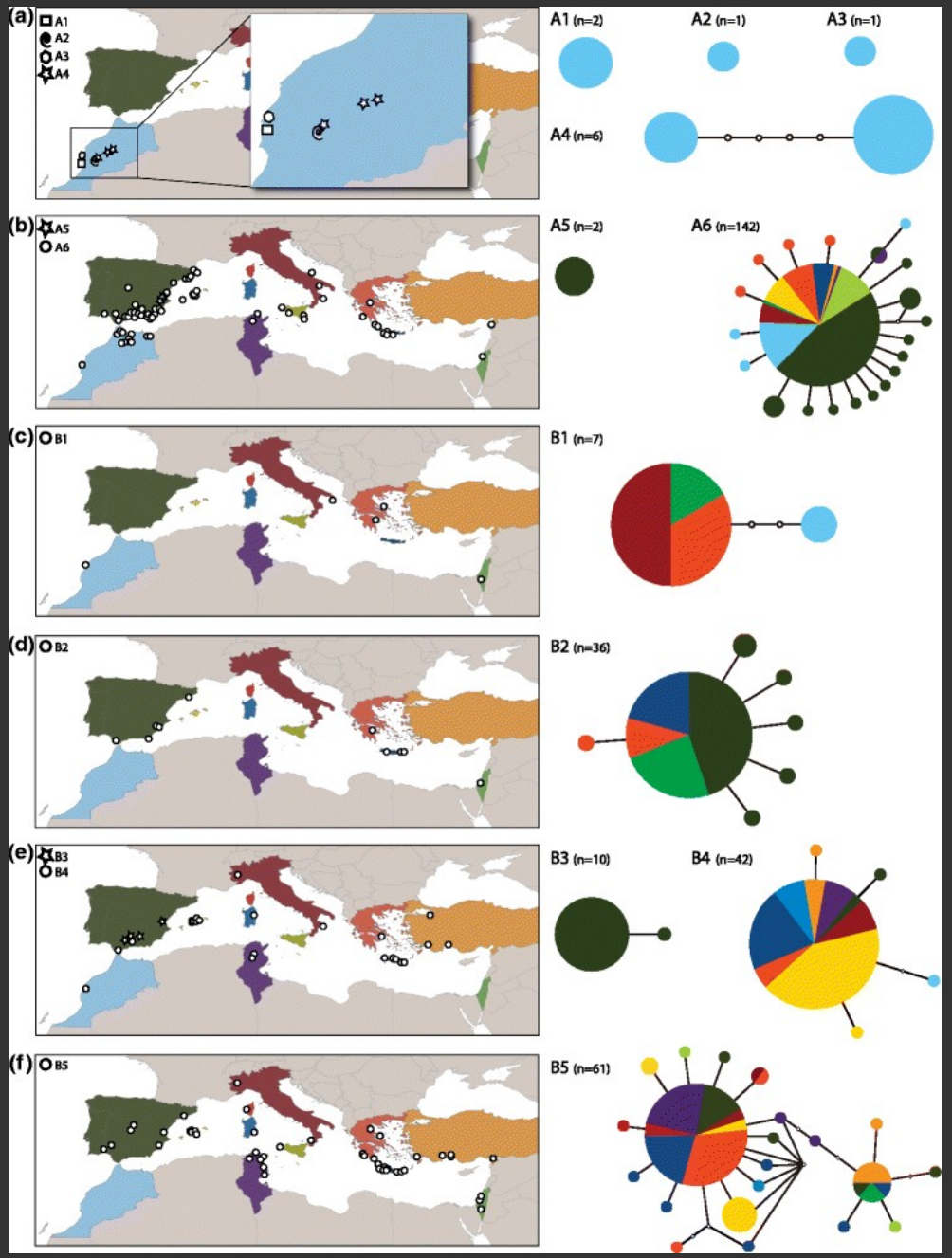
## Salamanders like humid areas

Look for similar places



Layer precipitation

- Conservation biology
- Ecology
- Evolution
- Phylogeography
- Protected areas design



# LIMITING FACTORS

- nature, complexity, and accuracy of the modelling method
- quality of the available environmental data layers
- availability of sufficient and reliable species distribution data
- influence of various factors such as barriers to dispersal, geological history, or biotic interactions, that increase the difference between the realised niche and the fundamental niche

**What are the fundamental and realised niches?**

# WHAT IS A SPECIES' NICHE?

**Grinnell (1917) niche** → a subdivision of the habitat containing the environmental conditions that enable individuals of a species to survive and reproduce

→ based on **broad-scale variables** (climate) that are not affected by species density (Hirzel and Le Lay, 2008; Wiens et al., 2009)

**Elton (1927) niche** → functional role of a species in a community, especially its position in food webs

→ based on **fine-scale variables** (nutrients) that may be consumed or modified by the species

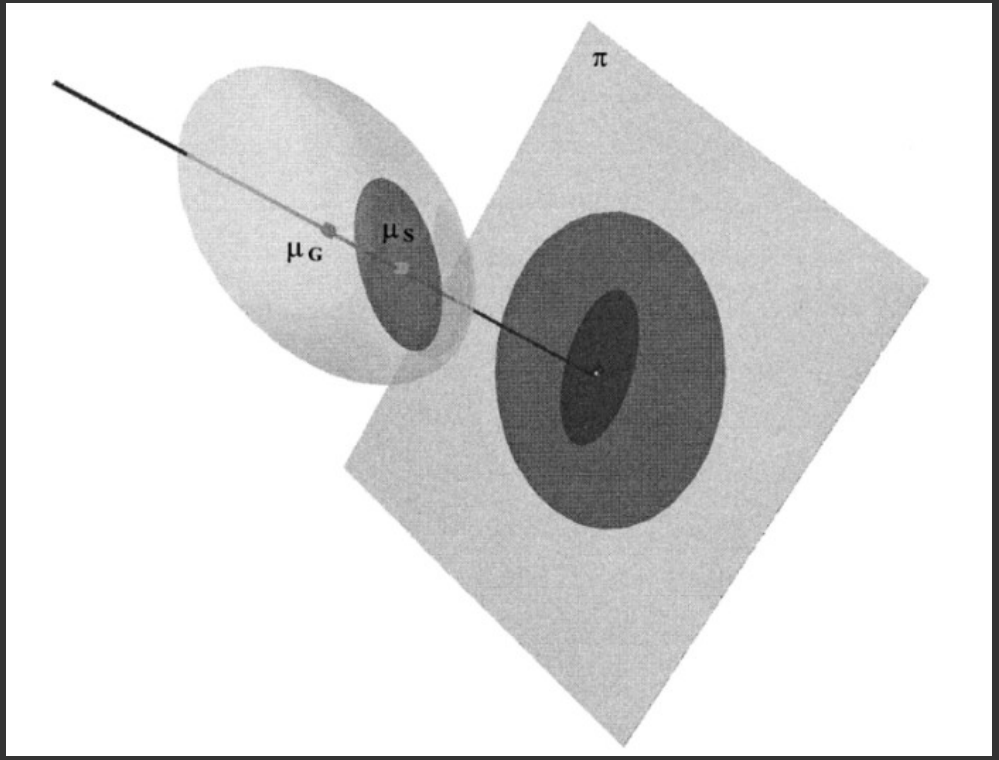
**Species' fundamental niche → the n-dimensional volume in the environmental space where a species can maintain a viable population and persist along time.**

**Species' realised niche → when a species does not occupy its entire fundamental niche due to niche exclusion by competition**

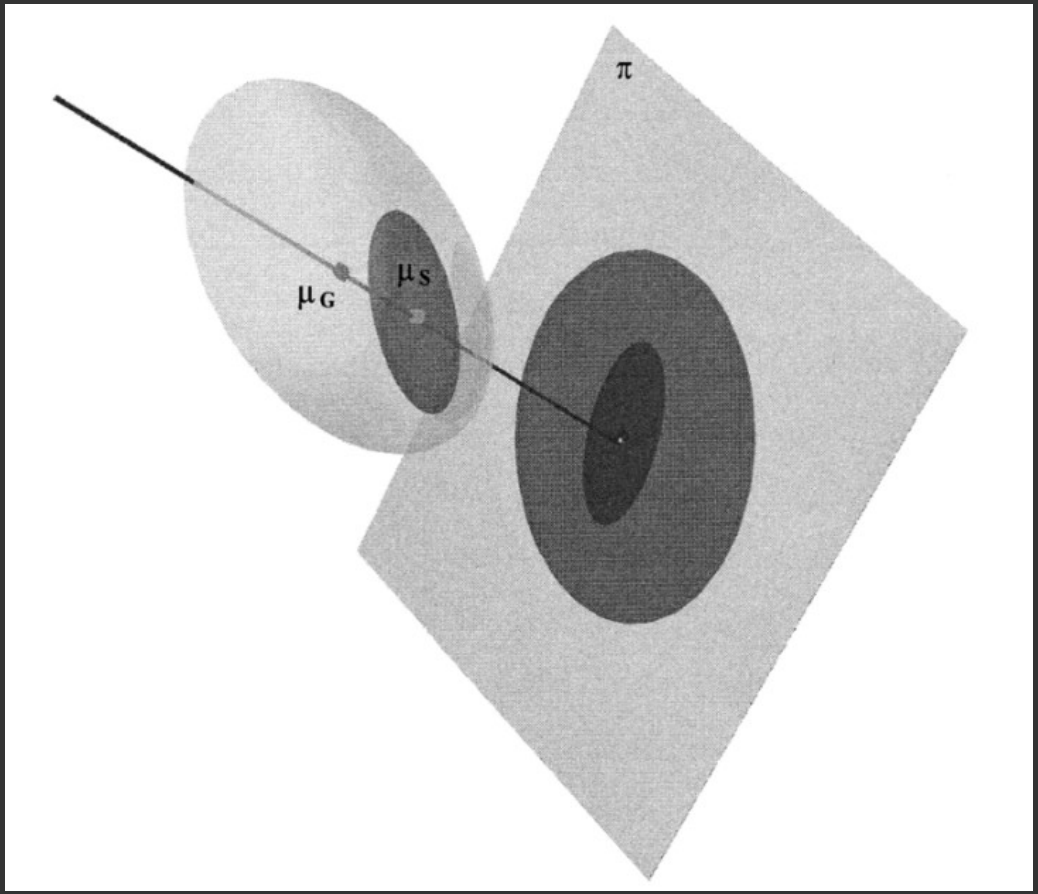
## Concluding Remarks

G. Evelyn Hutchinson

*Yale University, New Haven, Connecticut*



## ENVIRONMENTAL SPACE




## GEOGRAPHICAL SPACE

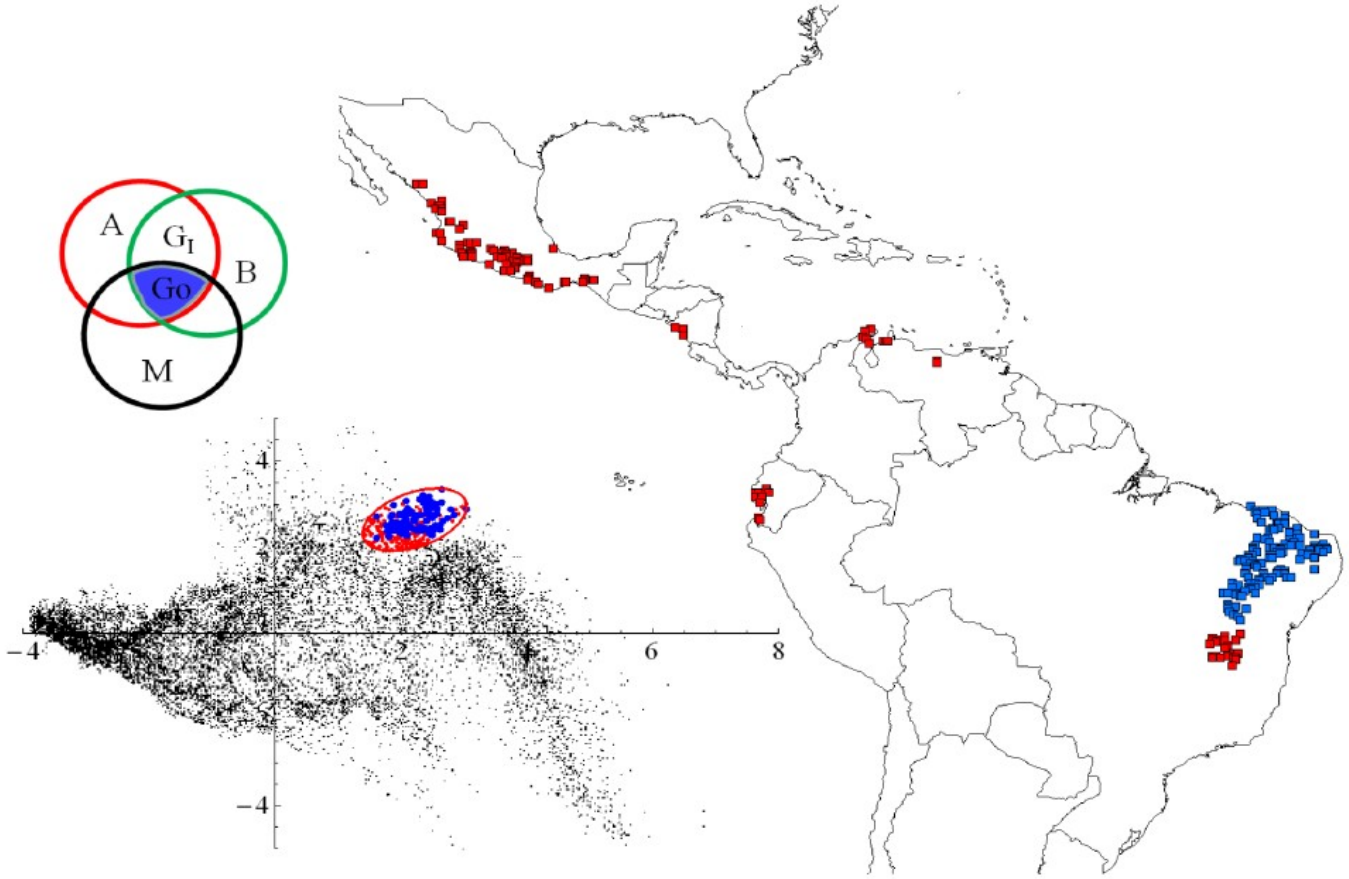



**Figure 1.** Major symbols used in the paper and their correspondence in geographic and environmental spaces. The first 2 principal components of the environmental space **E** of the Americas are represented. The Venn diagram is an abstract representation of the geographic space **G**. The green circle (B) represent the regions of the planet that are biologically favorable to the species and the black (M) circle the regions that have been accessible to the species over an appropriate period of time. The red circle, in the Venn diagram, symbolized with an **A**, represents regions with environments within the fundamental niche (the red points inside the ellipse). In the map these correspond to the red and the blue points. In environmental space the existing points inside $\mathbf{N}_F$ constitute the existing fundamental niche. The blue points in the map represent those areas that are: i) environmentally favorable, ii) accessible, and iii) biologically suitable. This is the occupied area **Go**. Finally, depending on biological suitability, all (or none) of the remaining, unoccupied red points represents a potentially invadable region ($\mathbf{G}_I$).

The species can be absent from suitable habitats

- due to **historical reasons**
- due to **limitations in their ability to disperse**

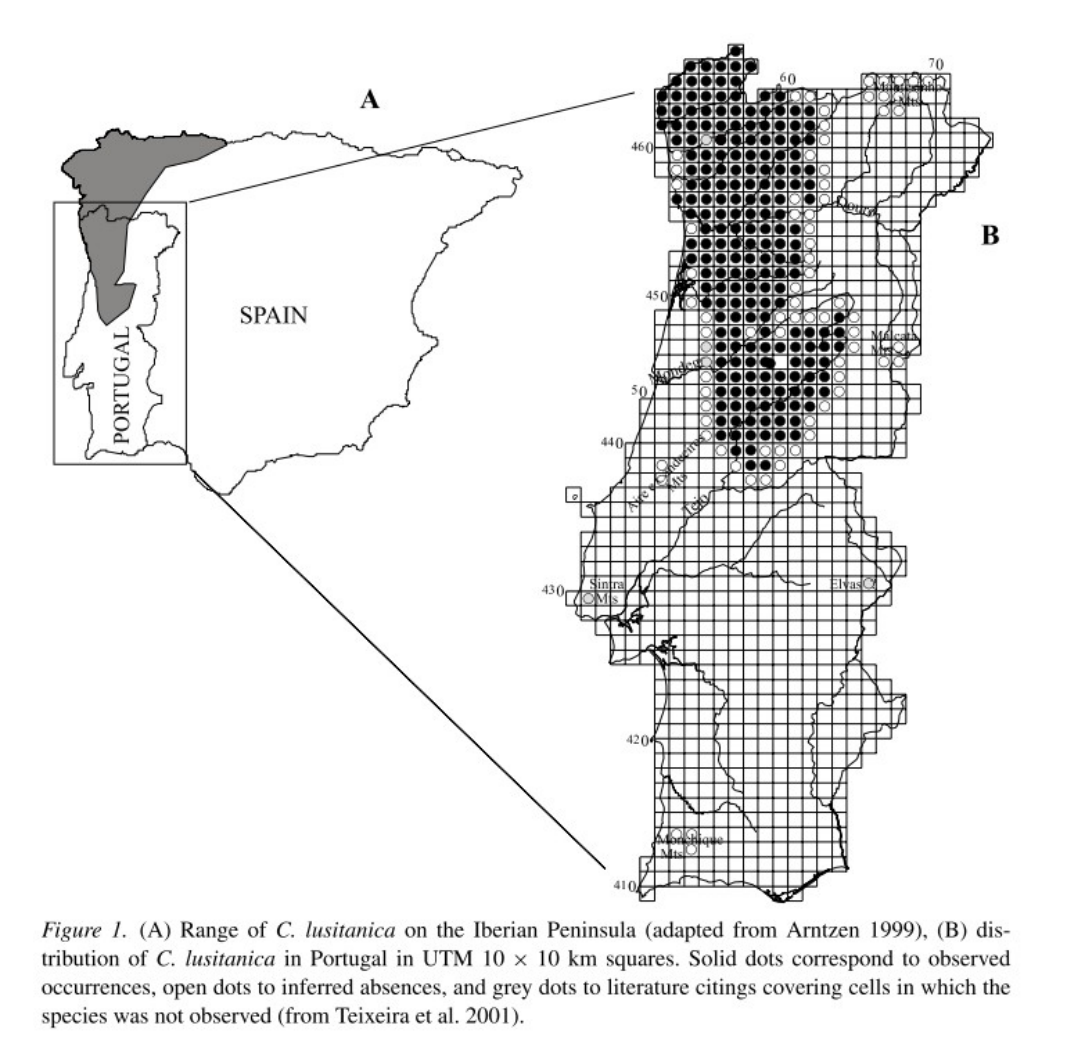
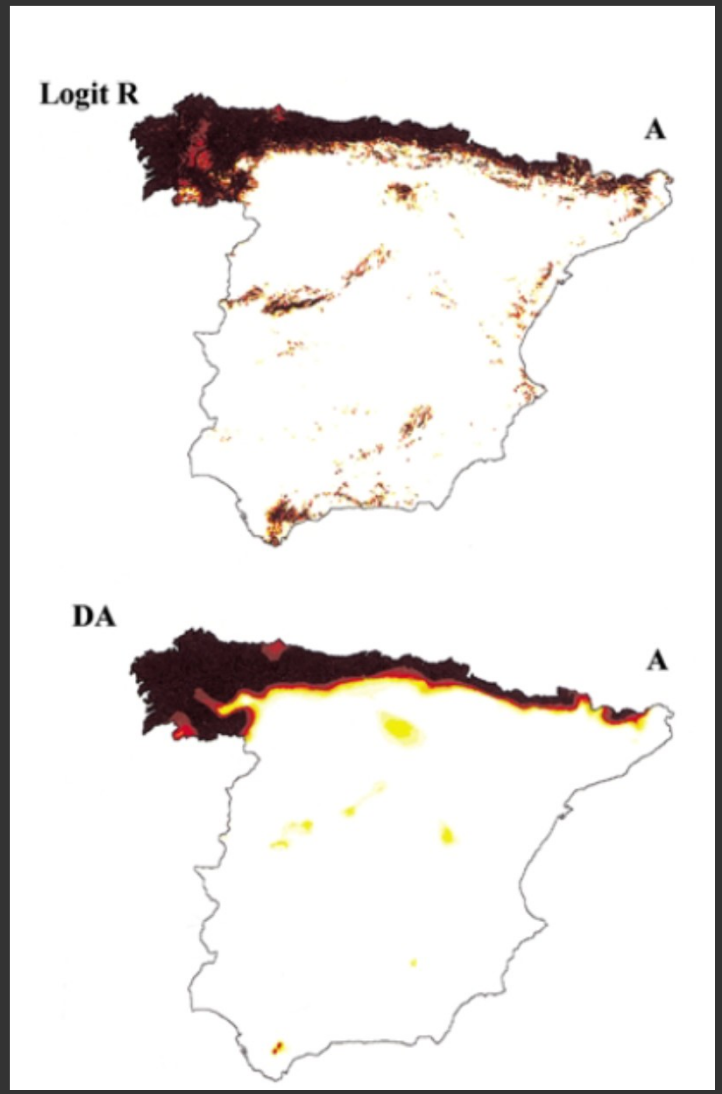



*Figure 1.* (A) Range of *C. lusitanica* on the Iberian Peninsula (adapted from Arntzen 1999), (B) distribution of *C. lusitanica* in Portugal in UTM 10 × 10 km squares. Solid dots correspond to observed occurrences, open dots to inferred absences, and grey dots to literature citings covering cells in which the species was not observed (from Teixeira et al. 2001).

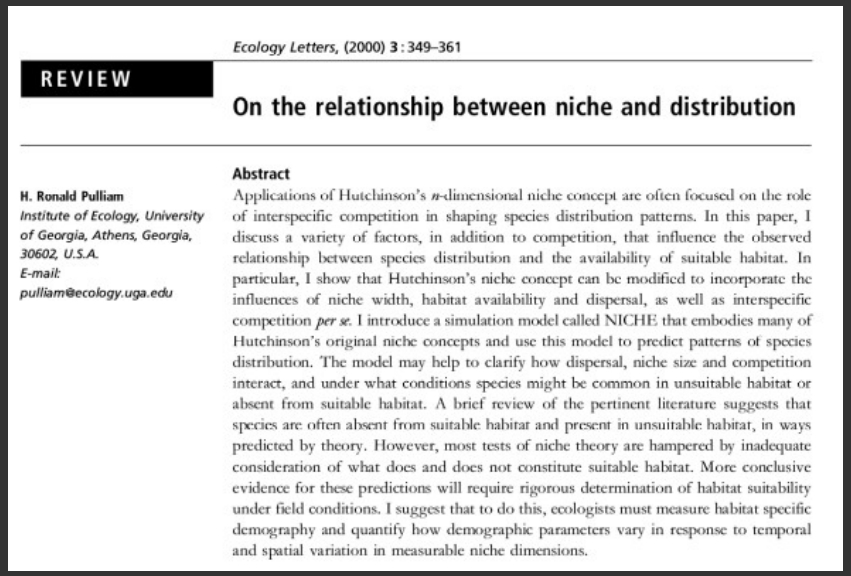


# SOURCE-SINK THEORY (Pulliam, 2000)

Some populations may occupy unsuitable habitats (sinks) due to immigration from healthier nearby populations (sources)

Individuals in the sinks may die by adverse conditions → they are replaced by new immigrants

The realised niche is larger than the fundamental one → species occupies habitats that are inadequate and not contained in the fundamental niche



*Ecology Letters*, (2000) **3** : 349–361

REVIEW

## On the relationship between niche and distribution

**H. Ronald Pulliam**
*Institute of Ecology, University of Georgia, Athens, Georgia, 30602, U.S.A.*
*E-mail: pulliam@ecology.uga.edu*

**Abstract**

Applications of Hutchinson's *n*-dimensional niche concept are often focused on the role of interspecific competition in shaping species distribution patterns. In this paper, I discuss a variety of factors, in addition to competition, that influence the observed relationship between species distribution and the availability of suitable habitat. In particular, I show that Hutchinson's niche concept can be modified to incorporate the influences of niche width, habitat availability and dispersal, as well as interspecific competition *per se*. I introduce a simulation model called NICHE that embodies many of Hutchinson's original niche concepts and use this model to predict patterns of species distribution. The model may help to clarify how dispersal, niche size and competition interact, and under what conditions species might be common in unsuitable habitat or absent from suitable habitat. A brief review of the pertinent literature suggests that species are often absent from suitable habitat and present in unsuitable habitat, in ways predicted by theory. However, most tests of niche theory are hampered by inadequate consideration of what does and does not constitute suitable habitat. More conclusive evidence for these predictions will require rigorous determination of habitat suitability under field conditions. I suggest that to do this, ecologists must measure habitat specific demography and quantify how demographic parameters vary in response to temporal and spatial variation in measurable niche dimensions.

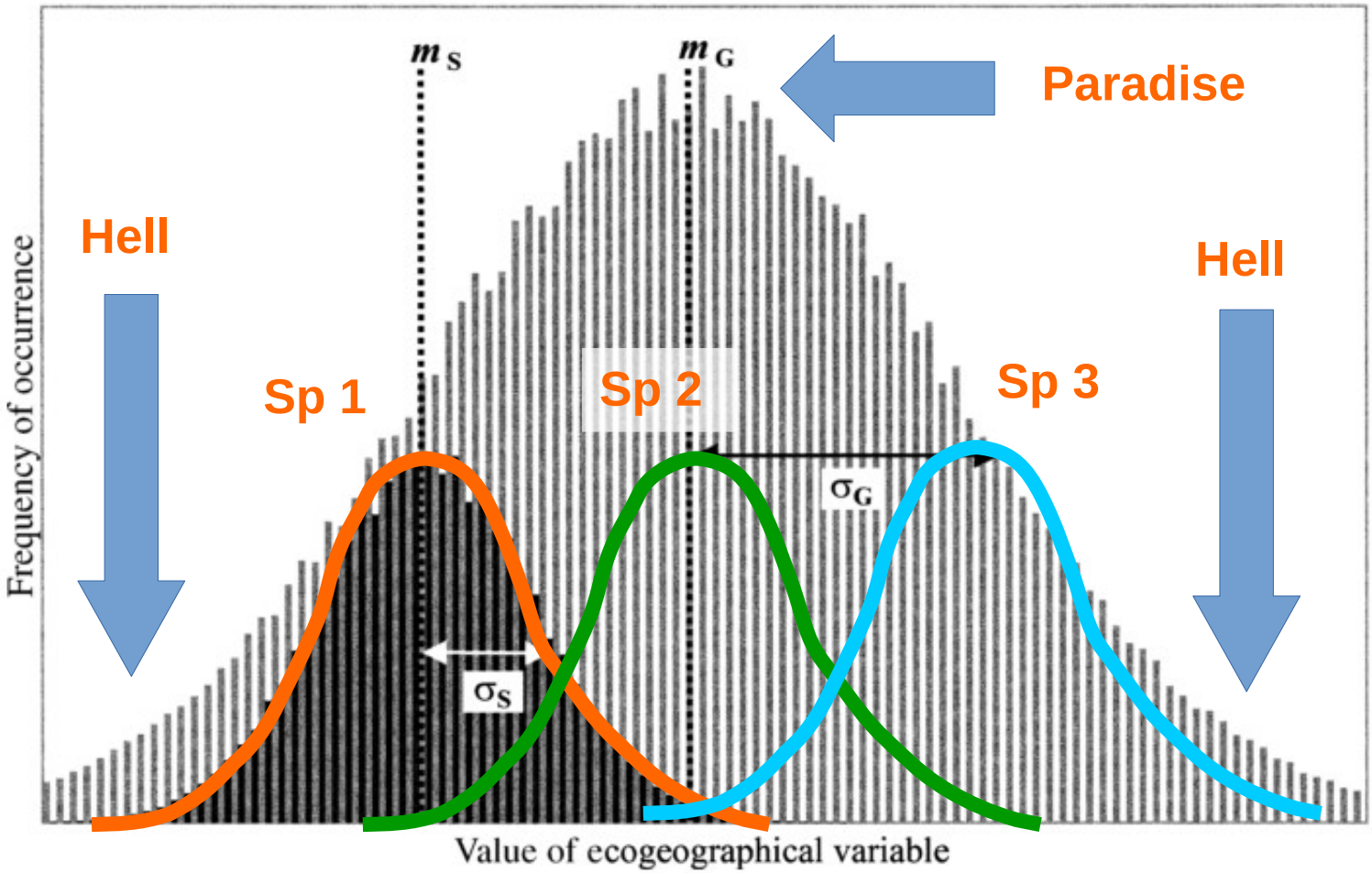
# CONCLUSION!

NOT ALL SPECIES LIVE IN THE PARADISE

NOT ALL SPECIES LIVE IN OPTIMAL CONDITIONS

NOT ALL SPECIES LIVE IN THE MOST SUITABLE HABITATS

# ECOLOGICAL NICHE MODELS vs. ENVIRONMENT



- Grinnellian niche
- Eltonian niche
- Hutchinson's fundamental niche
- Hutchinson's realised niche

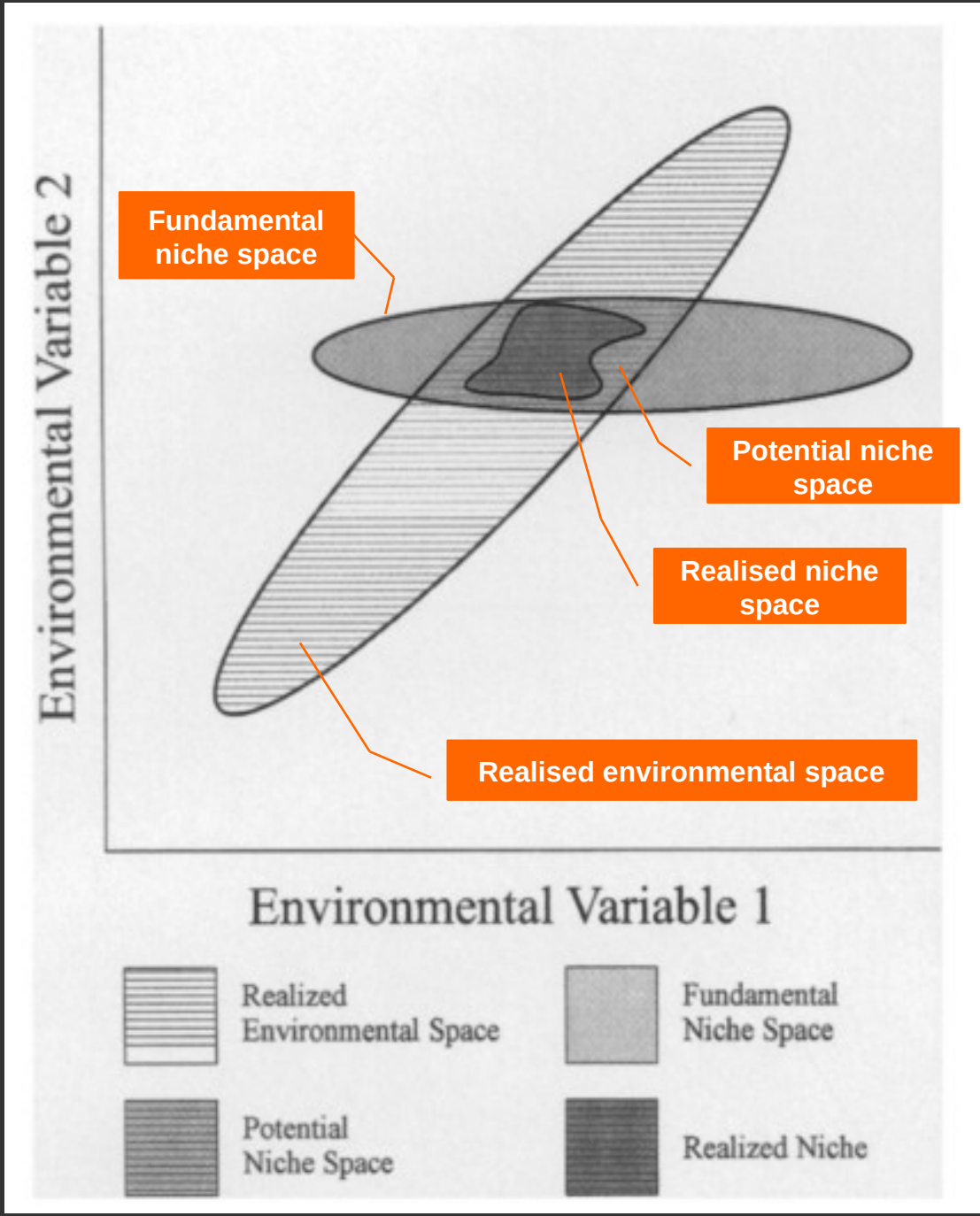
**BUT THERE ARE MORE TYPES OF ECOLOGICAL NICHES**

# POTENTIAL NICHE CONCEPT (Jackson and Overpeck, 2000)

**Potential niche → intersection between the fundamental niche space and the available environmental space**

**Some portion of the fundamental niche space may lie outside the environmental space at a particular time.**

**The realised niche is a subset of the potential niche**



**Occupied niche** → **the species distributions are constrained by geographical and historical factors, as well as biotic interactions (competition, predation, symbiosis and parasitism).**

**Hutchinson (1957)** → **the realised niche was only constrained by species competition, not by other factors such as dispersal limitations.**

**The occupied niche is smaller than the realised one.**

## Species' Distribution Modeling for Conservation Educators and Practitioners

Richard G. Pearson
Center for Biodiversity and Conservation & Department of Herpetology
American Museum of Natural History

# TYPES OF ECOLOGICAL NICHE MODELS

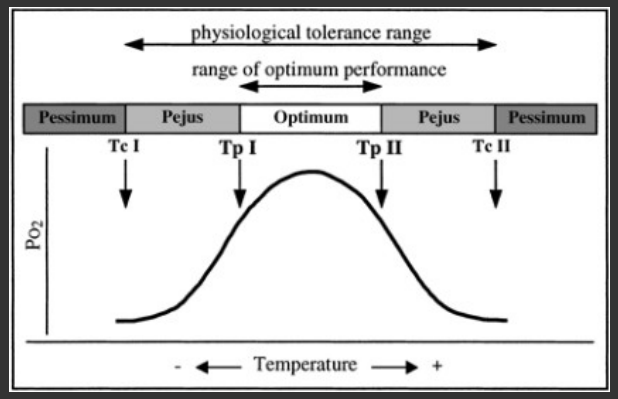
## Mechanistic models

**Mathematical or empirical process using bio-physiological data to generate the conditions in which the species can ideally persist, based on observations made in controlled field or laboratory studies.**

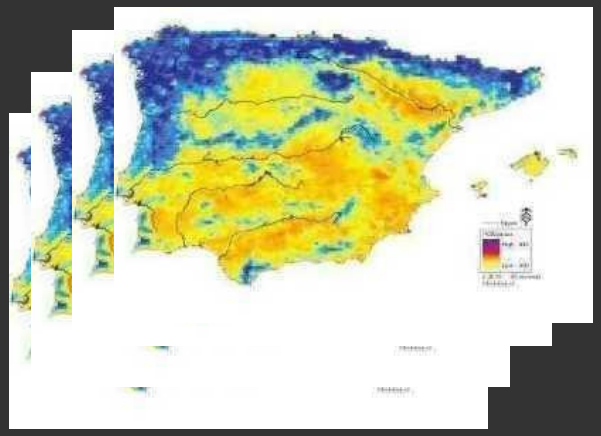
## Correlative models

**Mathematical models where field observations are related with environmental predictor variables based on statistically or theoretically derived response surfaces.**

## Physiological limits

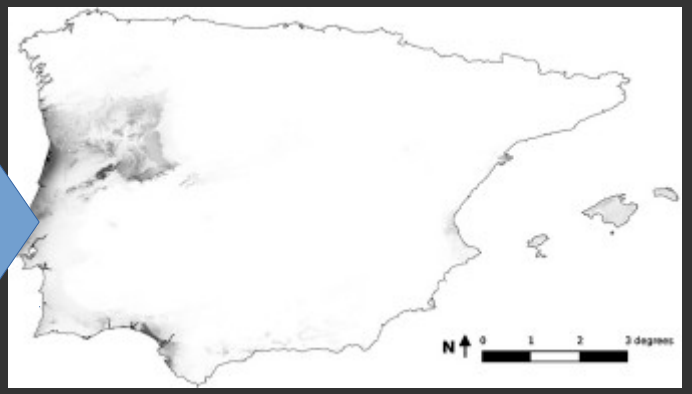



## Climatic variables

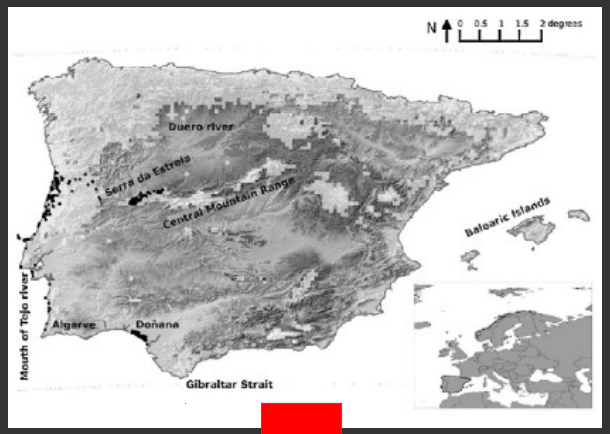


## Algorithm

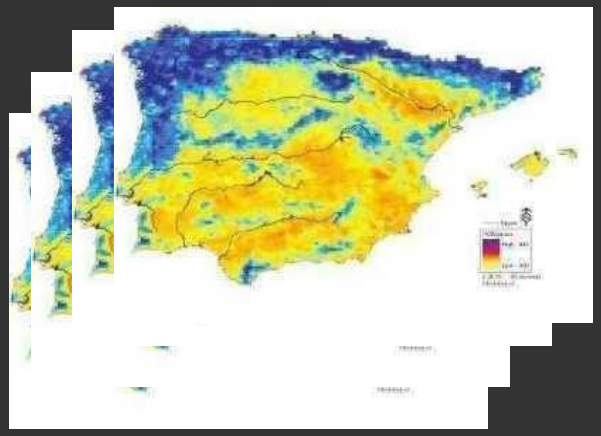
## Model



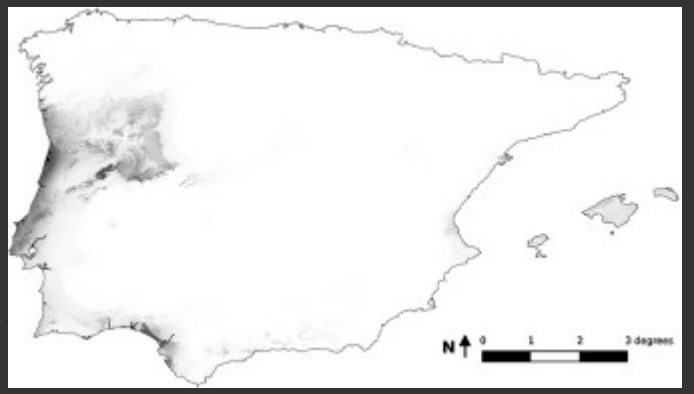
GPS points

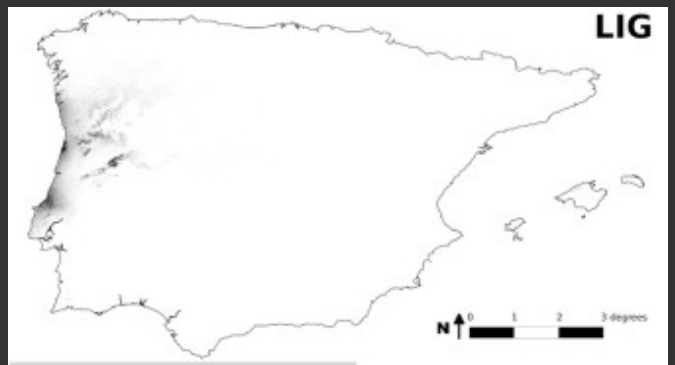


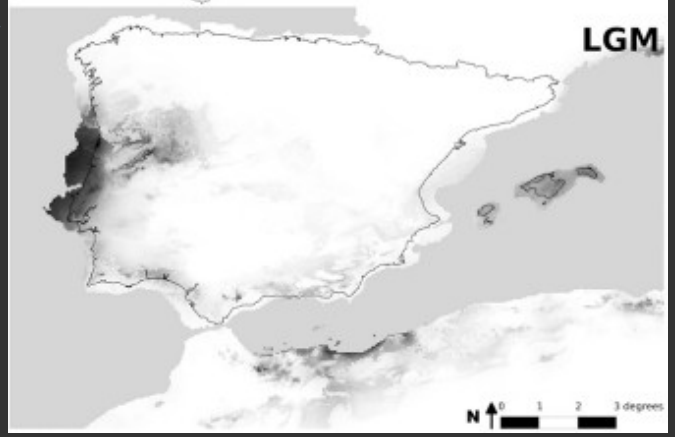

Climatic variables



Algorithm






Projection

# FEATURES OF ECOLOGICAL NICHE MODELS

## Mechanistic models

Physiological data

Empirical method to relate physiological variables

Mathematical method to relate physiological variables

## Correlative models

Field or bibliographic species' locations

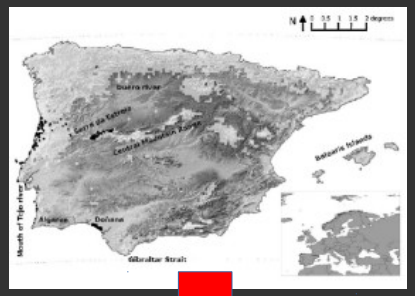
- Presence data
- Absence data
- Pseudo-absence data
- Background data

Environmental variables

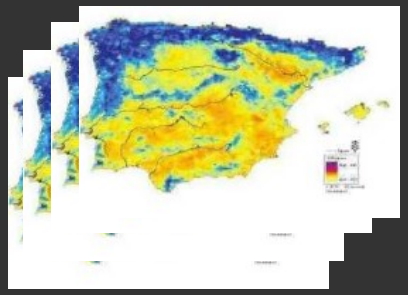
# We will focus only on CORRELATIVE MODELS

## As they are the most used and easier to do

GPS points

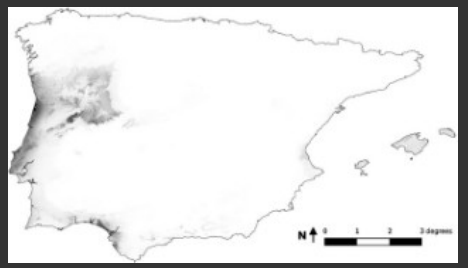


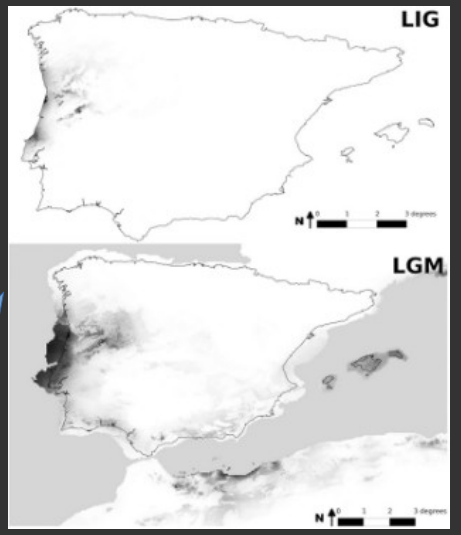
Climatic variables



Algorithm

Model






Projection

Field or bibliographic species' locations

- Presence data → observation points collected in places where the species occurs
- Absence data → observation points collected in places where the species does not occur
- Pseudo-absence data → observation points where the species is supposed not to occur
- Background data → environmental data from the whole study area

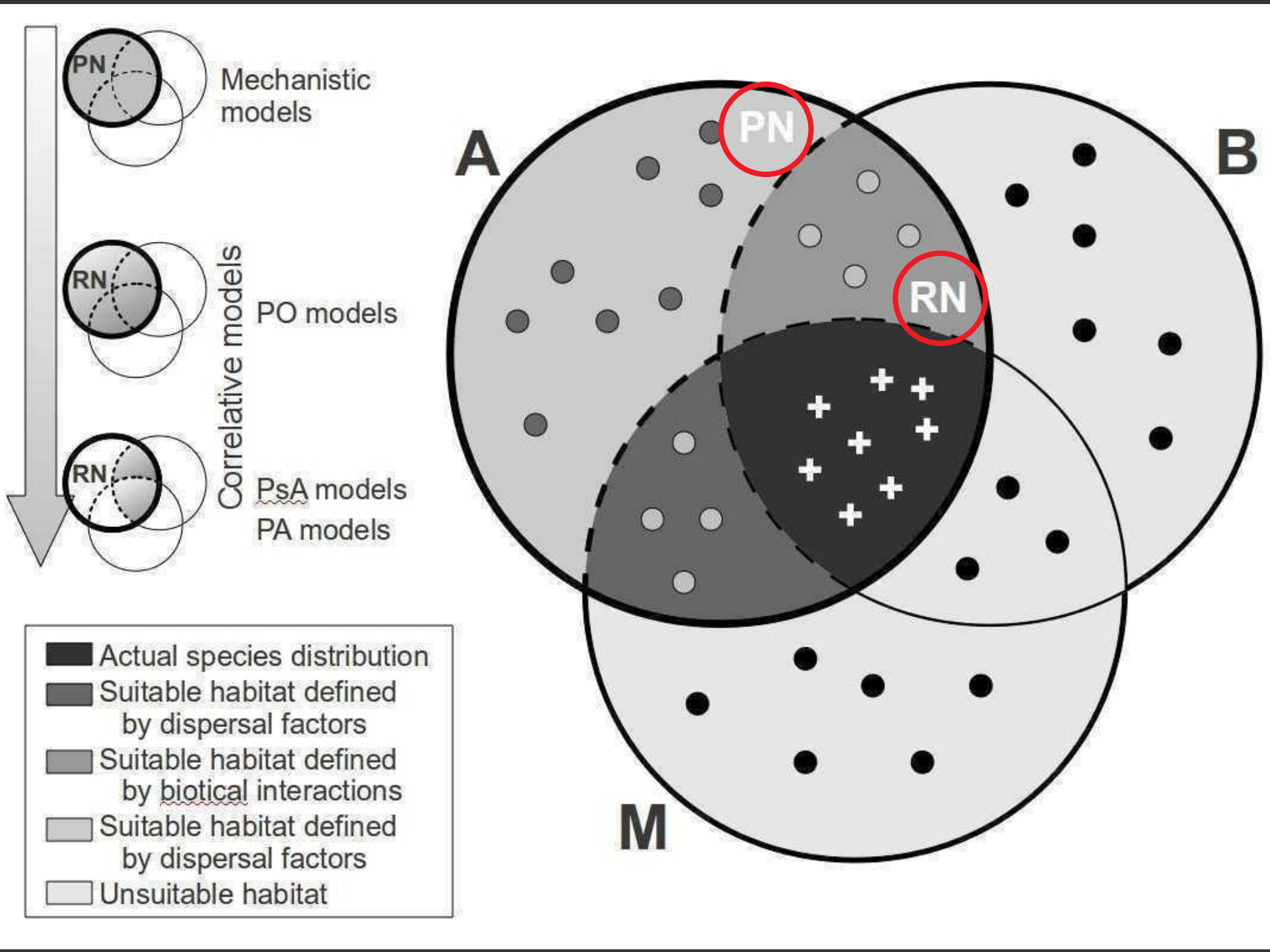
# TYPES OF ABSENCES (Lobo et al., 2010)

- **Contingent absences**: which correspond to environmentally suitable areas that are not occupied for historical or biotic reasons
    - outside the occupied niche but inside the realised/fundamental one

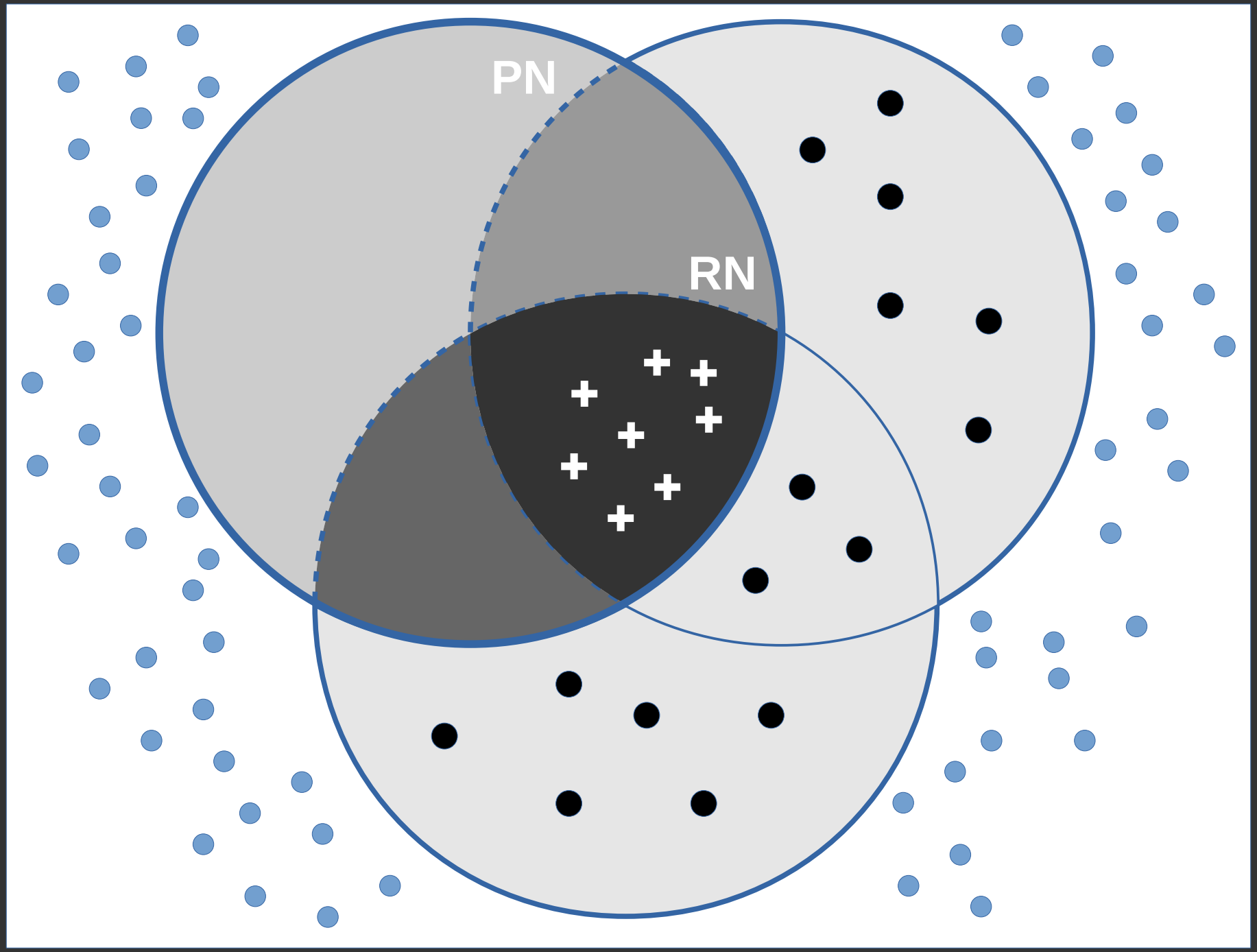
- **Environmental absences**: when the environment is in fact unsuitable for species presence
    - outside both niches

- **Methodological absences**: caused by survey deficiency
    - included in both niches

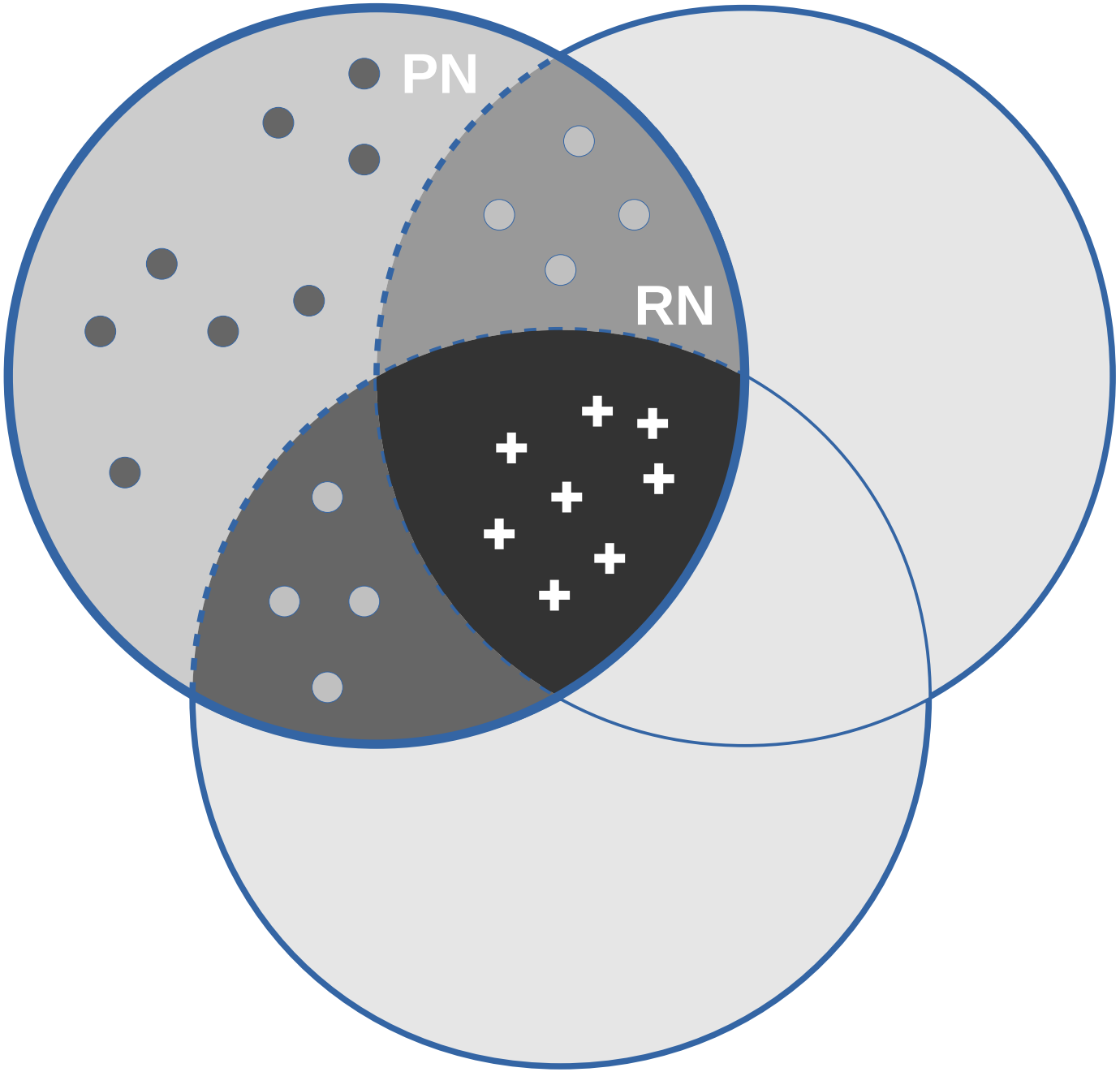
# DIAGRAM BAM: BIOTIC-ABIOTIC-MOVEMENT



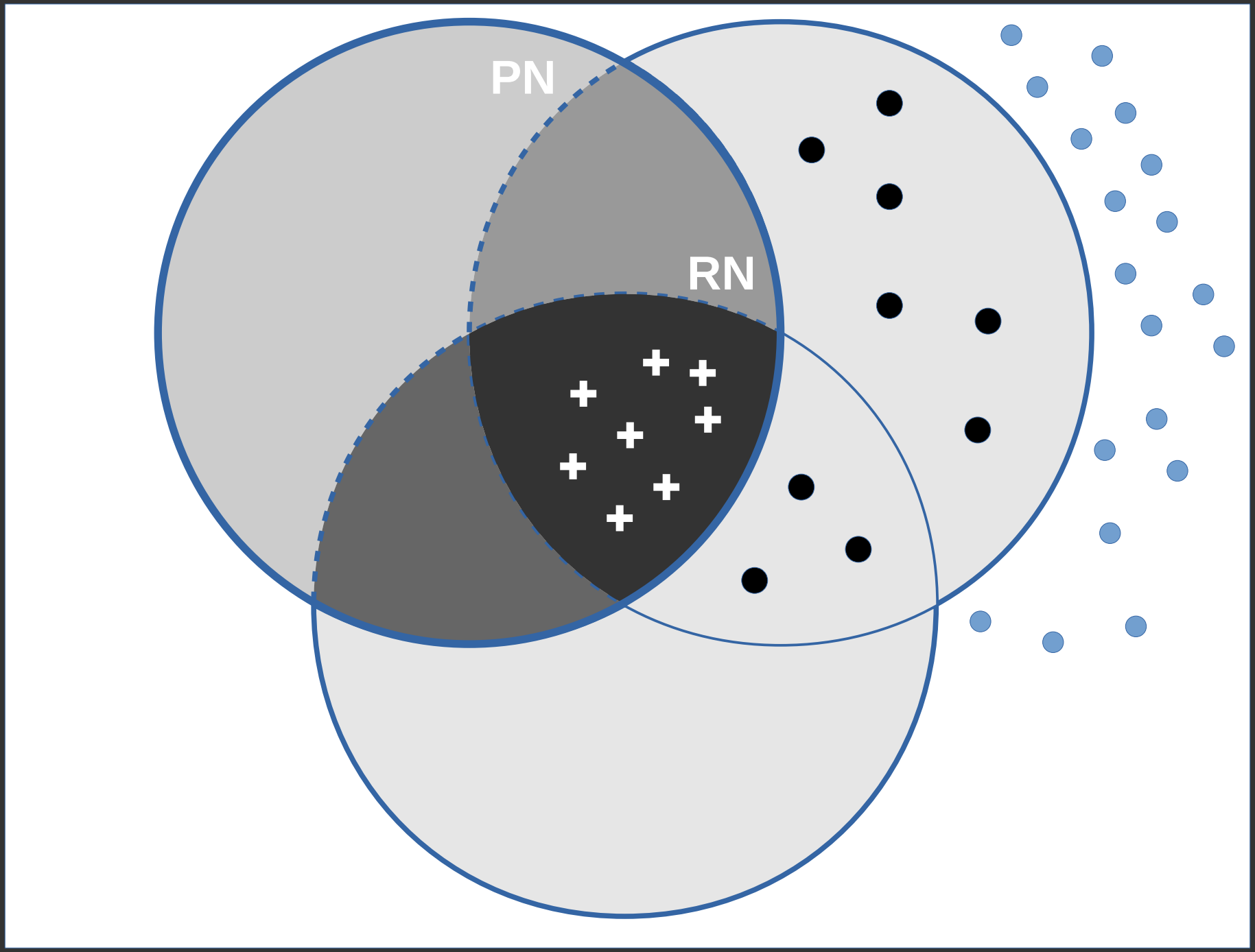
# ENVIRONMENTAL ABSENCES



# CONTINGENT ABSENCES



# METHODOLOGICAL ABSENCES



**Fundamental niche → derived by mechanistic models**

- **Mechanistic models are calculated with physiological data.**
  **They establish a causal relationship among the species distribution and the variables, independently of the species records (Kearney and Porter, 2004; Kearney et al., 2008; Kearney and Porter, 2009).**

**Realised niche → derived by correlative models**

- **Correlative models are calculated with species distribution records (presence/absence, presence and pseudo-absence, or presence-only data).**
  **Depending on the type of species' records, each model is a different representation of the realised niche.**

**Biotic and historical factors are included through presence data: the distribution and number of presence records determine directly the result of the model.**

**As species are never in equilibrium with their environment due to dispersal limitations or historical factors**
**→ presence data do not reflect the fundamental niche but rather the realised one (Lobo et al., 2010).**

Research

Ecography 33: 103–114, 2010
doi: 10.1111/j.1600-0587.2009.06039.x

Subject Editors: Núria Roura-Pascual and Nathan K. Sanders. Accepted 30 November 2009

The uncertain nature of absences and their importance in species distribution modelling

Jorge M. Lobo, Alberto Jiménez-Valverde and Joaquín Hortal

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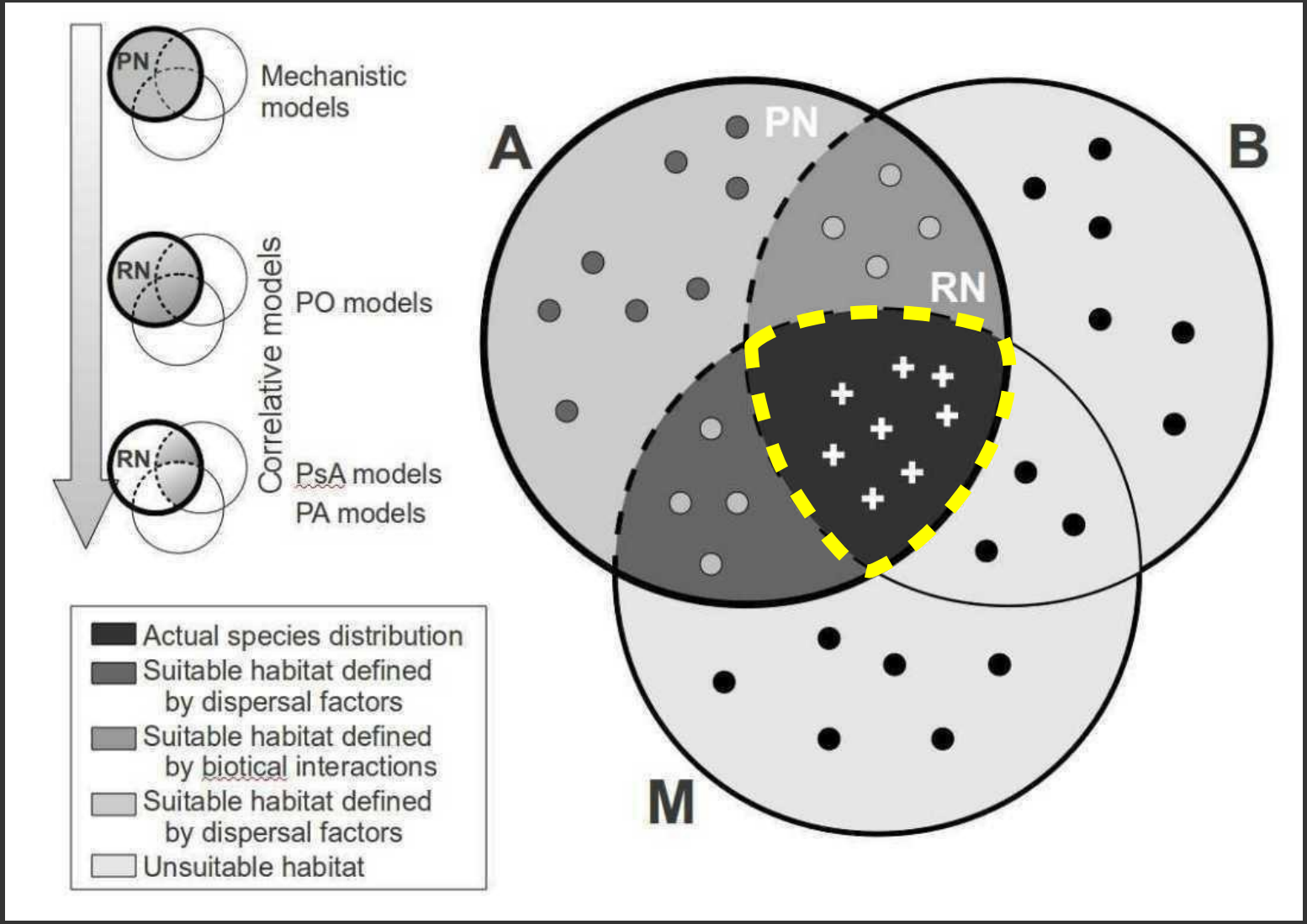
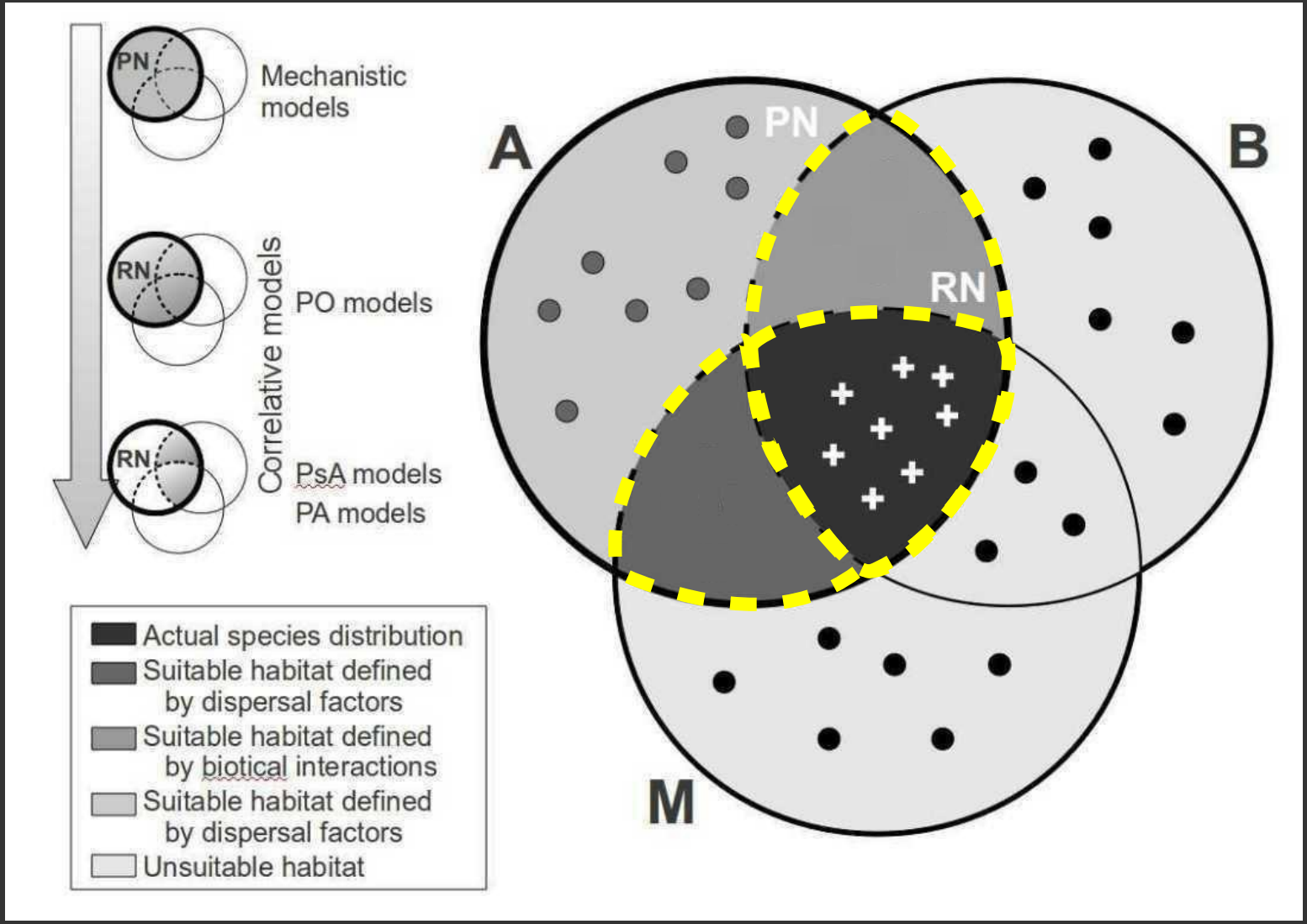
**If we use a well distributed dataset of true absences (including all absences from suitable habitats)**
**→ the ENM approximates to the occupied niche (Pearson, 2007).**

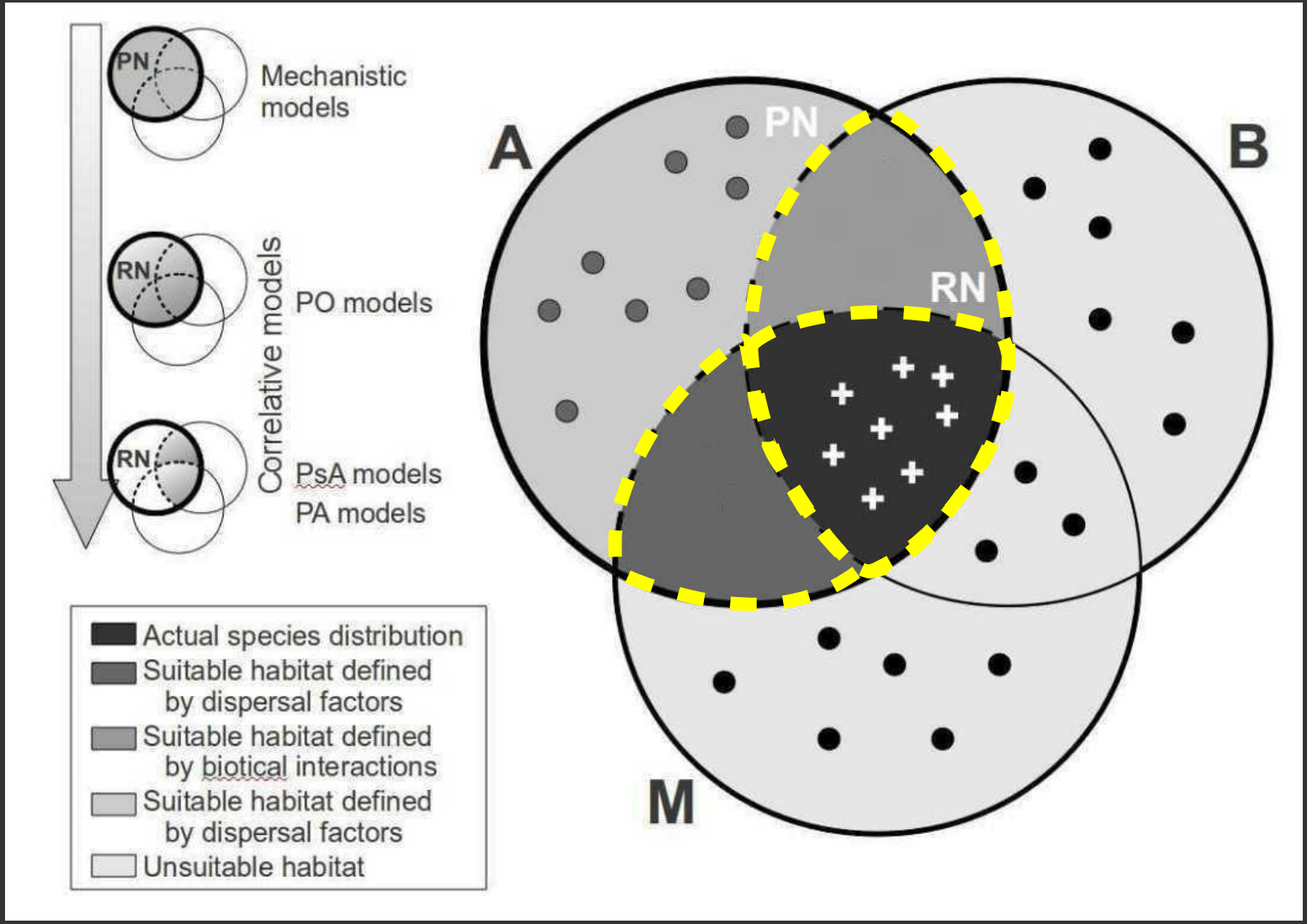


**If instead we use an incomplete distribution of true absences or different sets of pseudo-absences**
**→ the ENM represents the realised niche.**



# APPROXIMATION TO REALISED NICHE

**If presences from some suitable and occupied habitats are the only data available → the ENM will be located somewhere between the occupied and the realised niche.**



# PRESENCE ONLY MODELS

Using presence-only data → the ENM represents the realised niche
→ because correlations among the species distribution and the environmental factors are obtained through the presence data.

If the position of species records change, the values of the variables also change (Lobo et al., 2010).

→ presence data include biotic and historical information.

Depending on the quality and spatial resolution of environmental data, as well as the size of the study area
→ this realised niche model can be more or less similar to the fundamental one.

*Global Ecology and Biogeography, (Global Ecol. Biogeogr.)* (2015) **24**, 276–292

RESEARCH REVIEW

# Is my species distribution model fit for purpose? Matching data and models to applications

Gurutzeta Guillera-Arroita[1]*, José J. Lahoz-Monfort[1], Jane Elith[1], Ascelin Gordon[2], Heini Kujala[1], Pia E. Lentini[1], Michael A. McCarthy[1], Reid Tingley[1] and Brendan A. Wintle[1]

# JIMÉNEZ-VALVERDE ET AL 2008 DIAGRAM

**The different ecological niches are located on a gradient from the fundamental to the occupied niche.**

**The exact position where ENM lies on the niche gradient depends on:**

- **species biology**
- **spatial resolution considered**
- **variables included in the model**
- **modelling method**

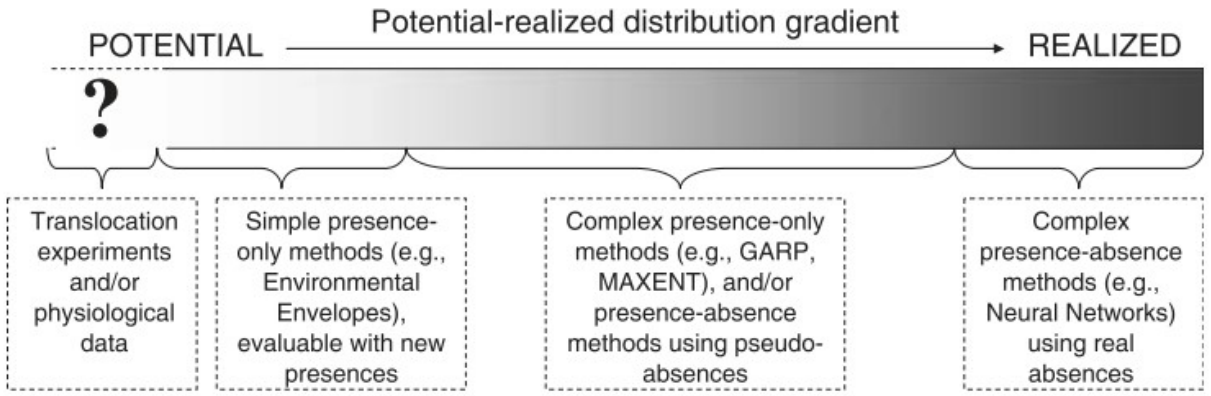



Figure 1 A conceptual potential-realized distribution gradient showing the modelling techniques and the characteristics of the training (and evaluation) data that are more adequate to describe each portion of this gradient. The discontinuous lines in the extreme left of the gradient mean that the potential distribution is a hypothetical concept that is hard to describe without a high amount of evidence from different sources.

**1. Each ENM is a different approximation to the species niche,**
**→ we cannot expect to obtain similar potential species distributions from different ENM.**

**2. Following the previous reasoning, when calculating ensemble models (Araújo and New, 2007)**
**→ we are mixing different species niches.**

Review TRENDS in Ecology and Evolution Vol.22 No.1



# Ensemble forecasting of species distributions

**Miguel B. Araújo[1] and Mark New[2]**

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[2] Climate Research Laboratory, Oxford University Centre for the Environment, South Parks Road, Oxford, UK, OX1 3QY

# DIFFERENT TERMS FOR THE SAME OBJECT

- Ecological niche model
- species distribution model
- Habitat distribution model
- Habitat suitability model
- Climatic envelope model

**Sillero 2011 proposed the following terms:**

- Ecological niche model
- Potential niche model
- Realised niche model
- Habitat suitability map

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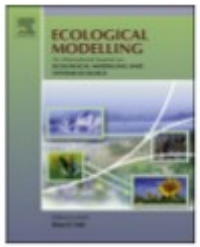
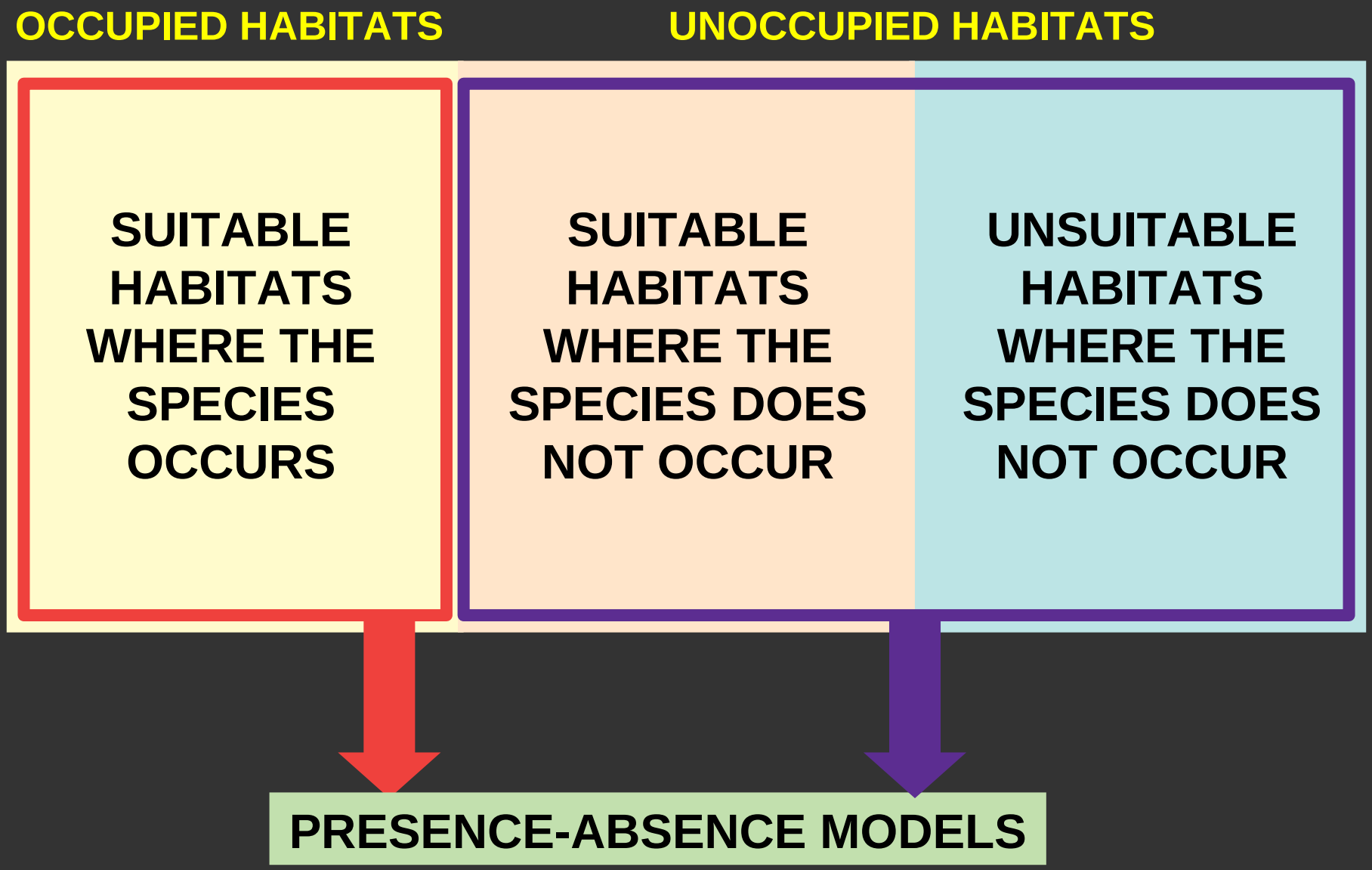



Short communication

## What does ecological modelling model? A proposed classification of ecological niche models based on their underlying methods

Neftalí Sillero *

*Centro de Investigação em Ciências Geo-Espaciais (CICGE), Universidade do Porto Faculdade de Ciências, R. Campo Alegre, 687, 4169-007 Porto, Portugal*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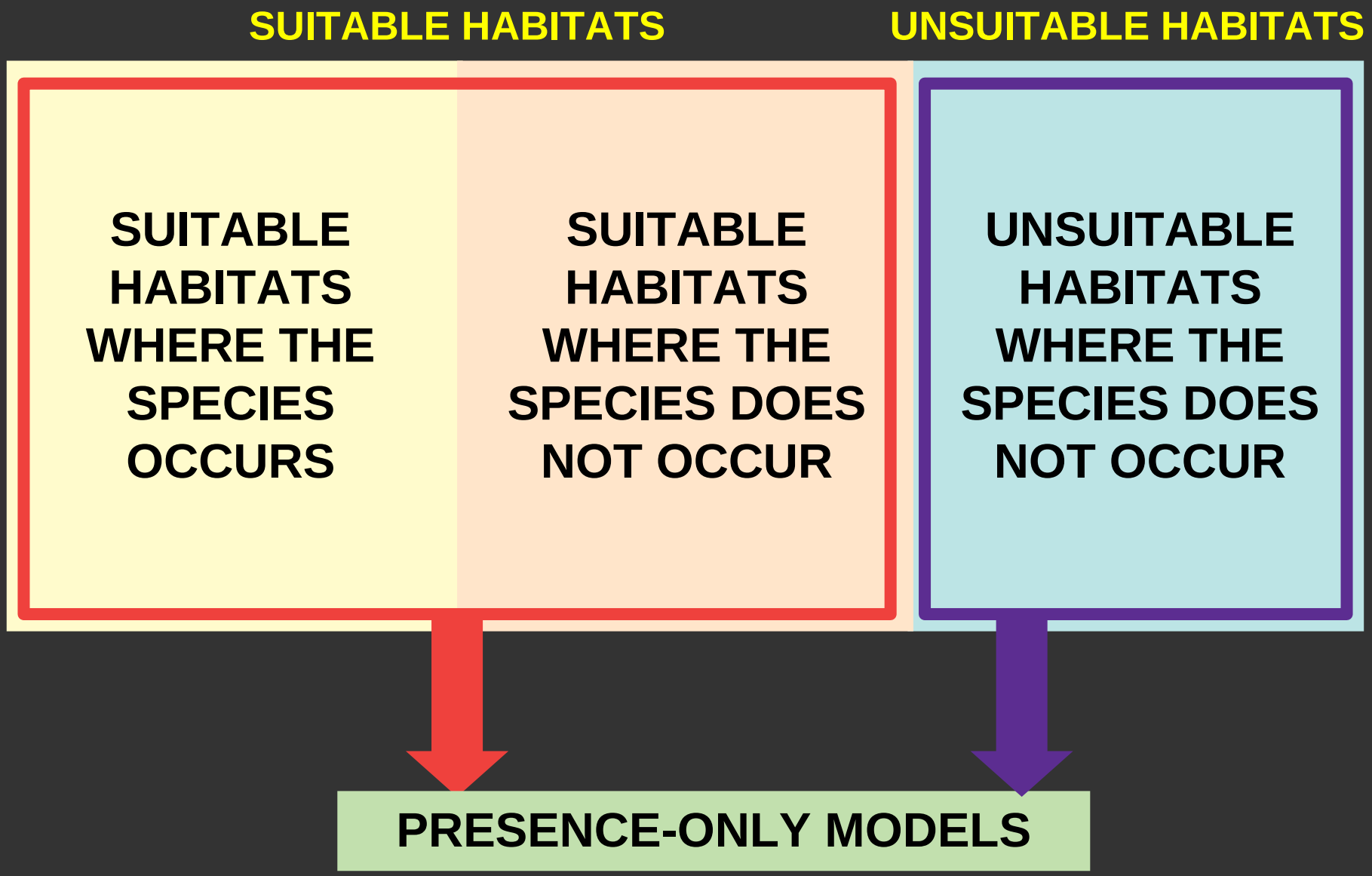
PRESENCE-ABSENCE MODELS


SUITABLE HABITATS
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PRESENCE-ONLY MODELS

Ecological niche models are continuous functions trying to represent the species' ecological niche model.

We cannot expect that all individuals live in wonderful conditions.

ENMs try to represent the quality of the habitats for a particular species.

We will have individuals (presence records):

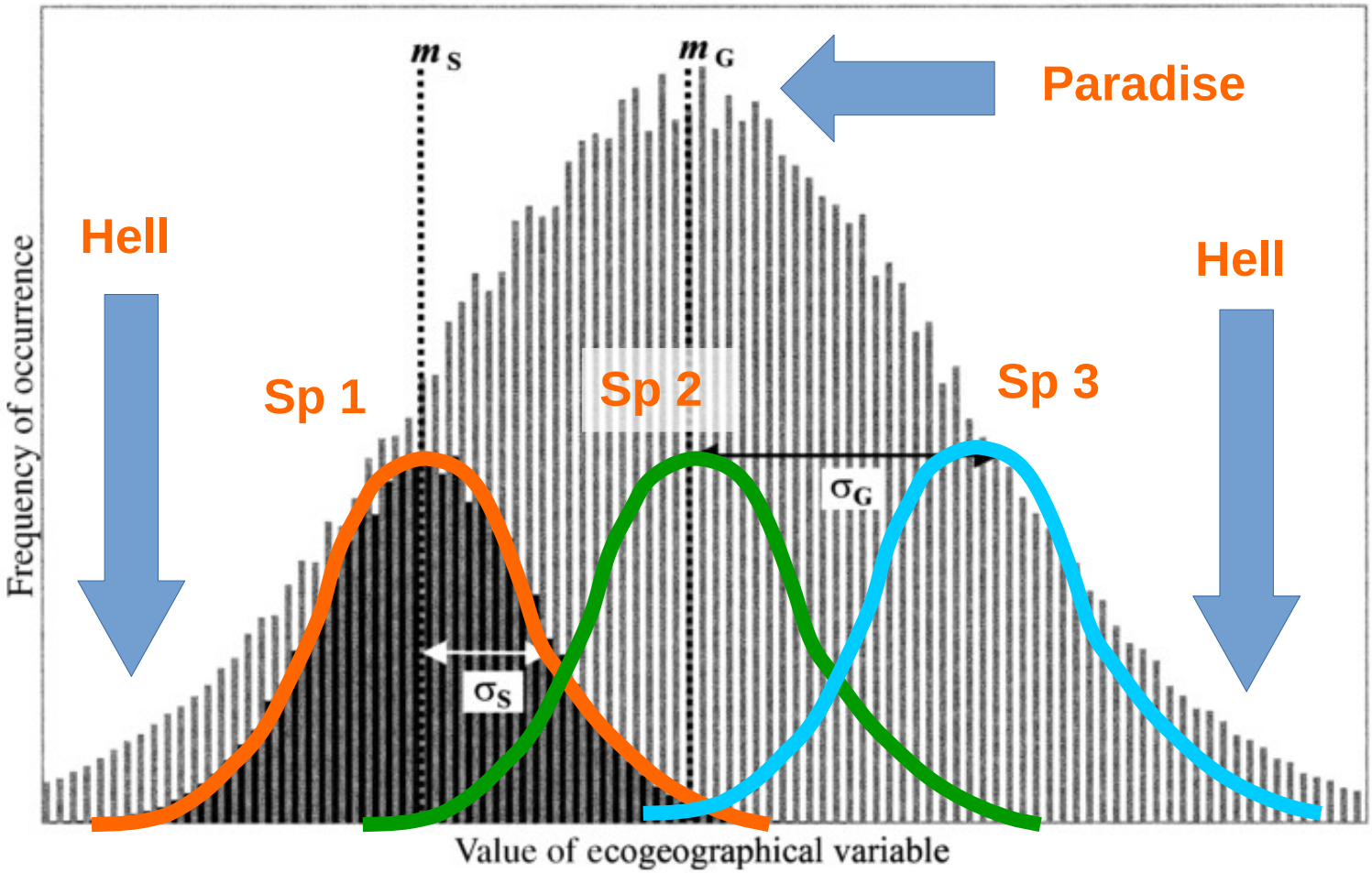
- Living in the paradise (one extreme of the normal distribution)
- Living in acceptable conditions (average conditions)
- And living in the hell (the other extreme of the distribution)

This means that we can have presence records classified as absences or in unsuitable habitats
→ the ENM will be correct

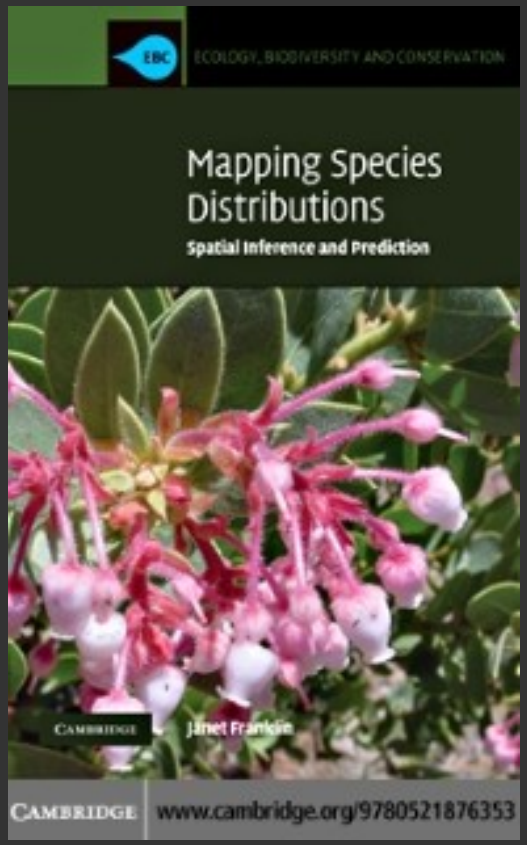
## REMEMBER!

According to the source-sink theory (Pulliam, 2000):
→ some populations may occupy unsuitable habitats (sinks) due to immigration from healthier nearby populations (sources)

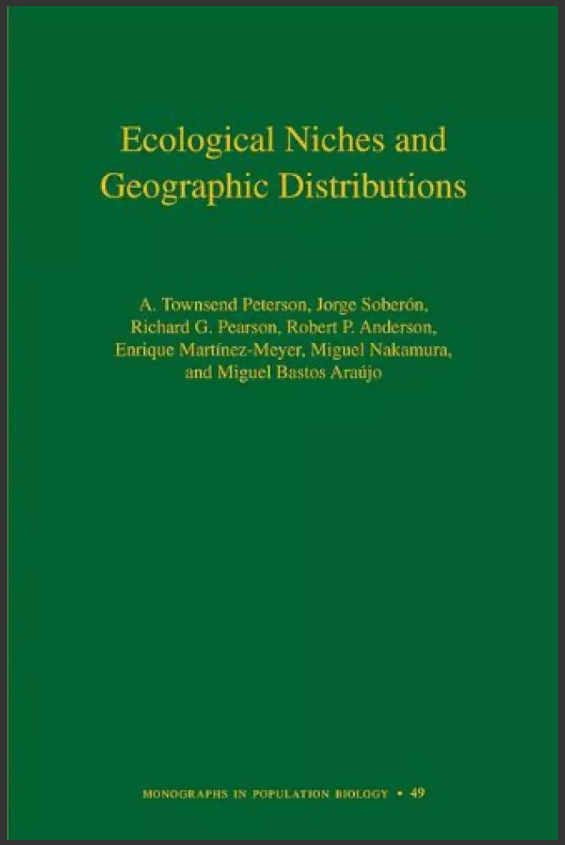
# ECOLOGICAL NICHE MODELS vs. ENVIRONMENT



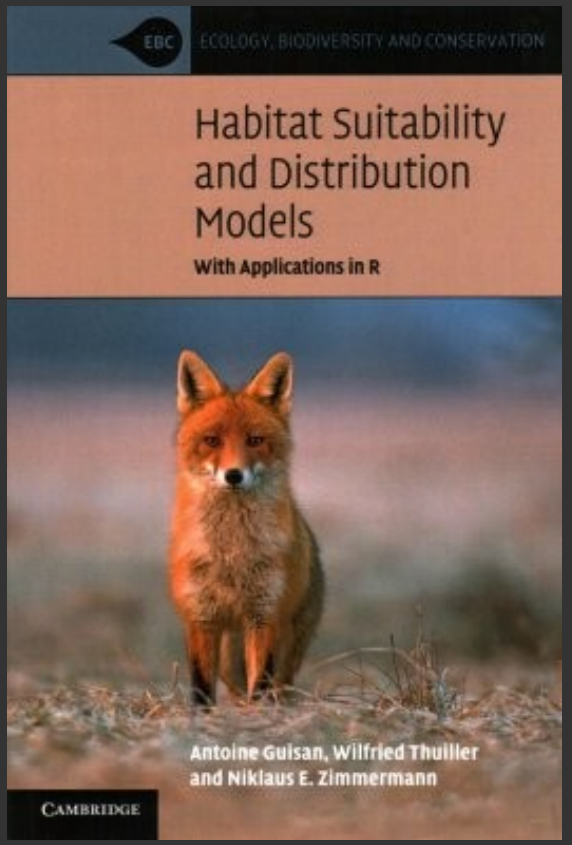
# ENM TEXT BOOKS




2009




2011

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# QUESTIONS?