

# 3. Geographic Distributions and Niche modelling

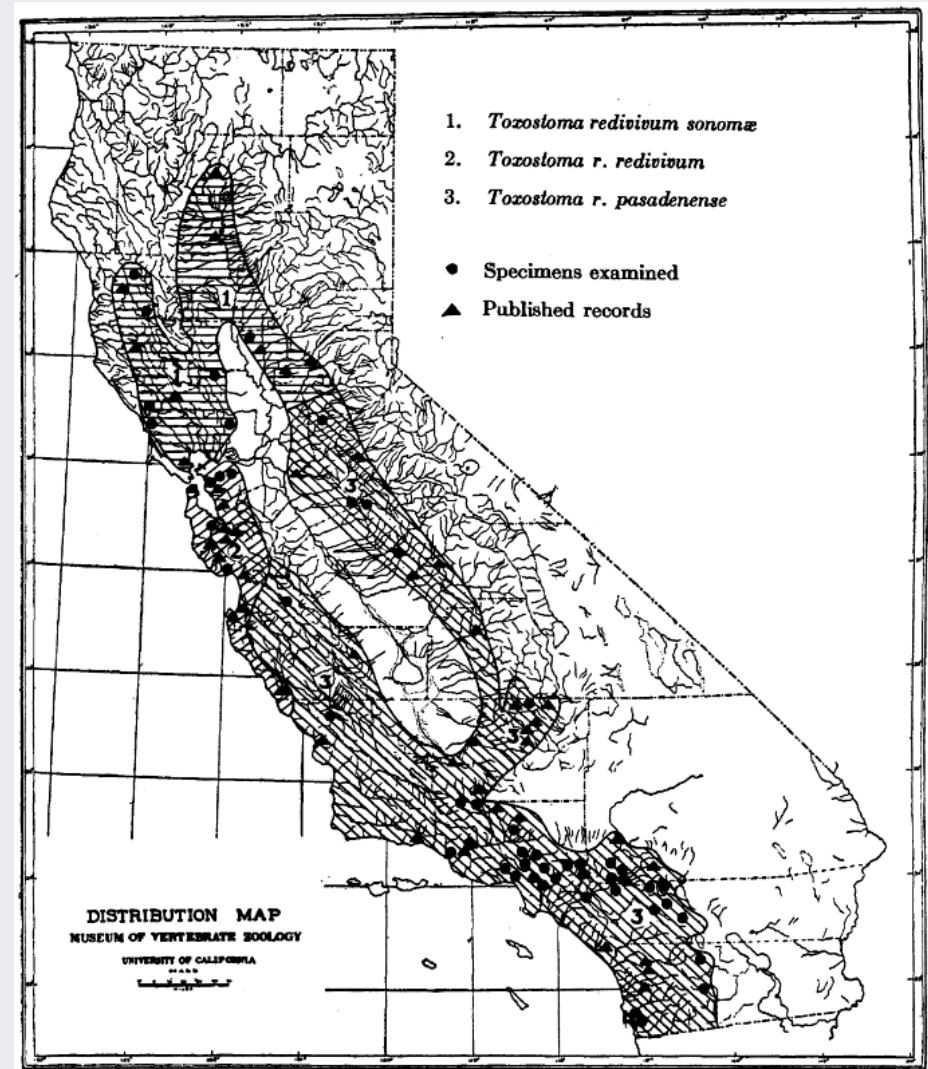
Jasper Slingsby, BIO2014F

2024-04-22

# The Grinnellian Niche

Focused on the **abiotic** by exploring species *habitat* based on the environmental requirements of organisms (temperature, rainfall, soils, etc).

Has largely become synonymous with species' geographic distributions.



Grinnell 1917

# The Hutchinsonian Niche

G Evelyn Hutchinson proposed that *the niche is an n-dimensional hypervolume within which a species is able to maintain a viable population* - **Hutchinson 1957**

This both aids our ability to think about the niche, but also allows us to explicitly **quantify the niche and niche space**.

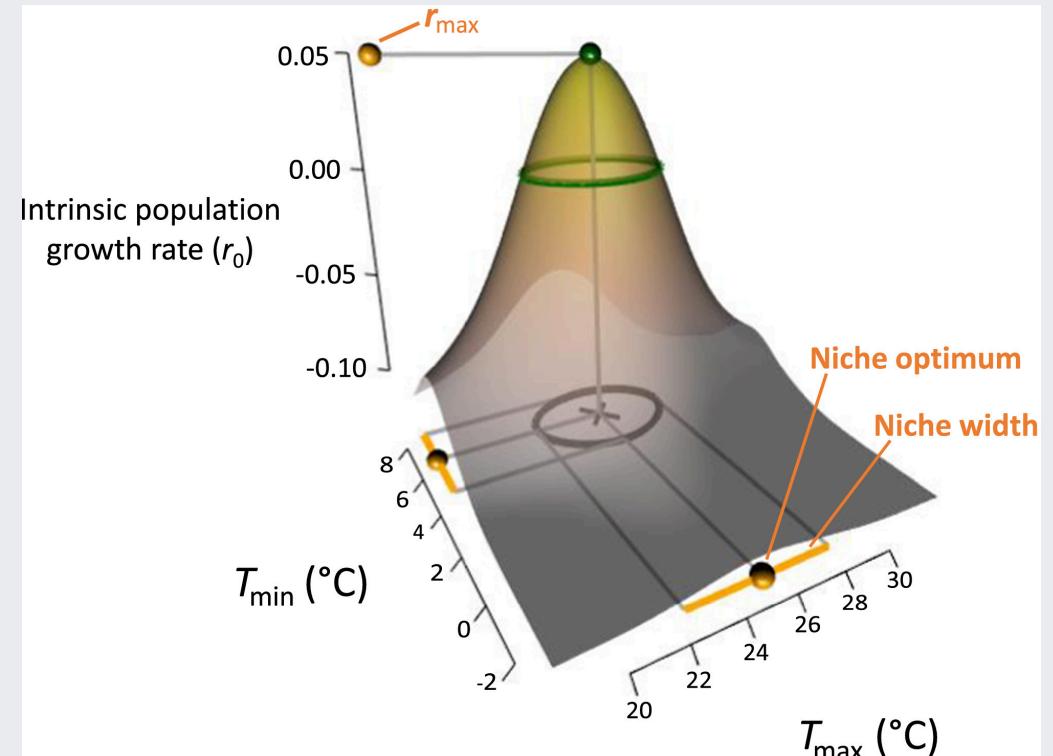


Figure from **Treurnicht et al. 2020**

# Species Distribution Models (SDMs)

Also referred to as Ecological Niche Models.

Utilise concepts proposed by Grinnell and Hutchinson to predict the geographic distribution (or range) of species.

SDMs propose that a species' distribution can be predicted based on the environmental conditions at localities where they have been observed.

The "prediction" is usually based on a statistical model that uses the known localities to estimate the probability of a species occurring across the given environmental space.

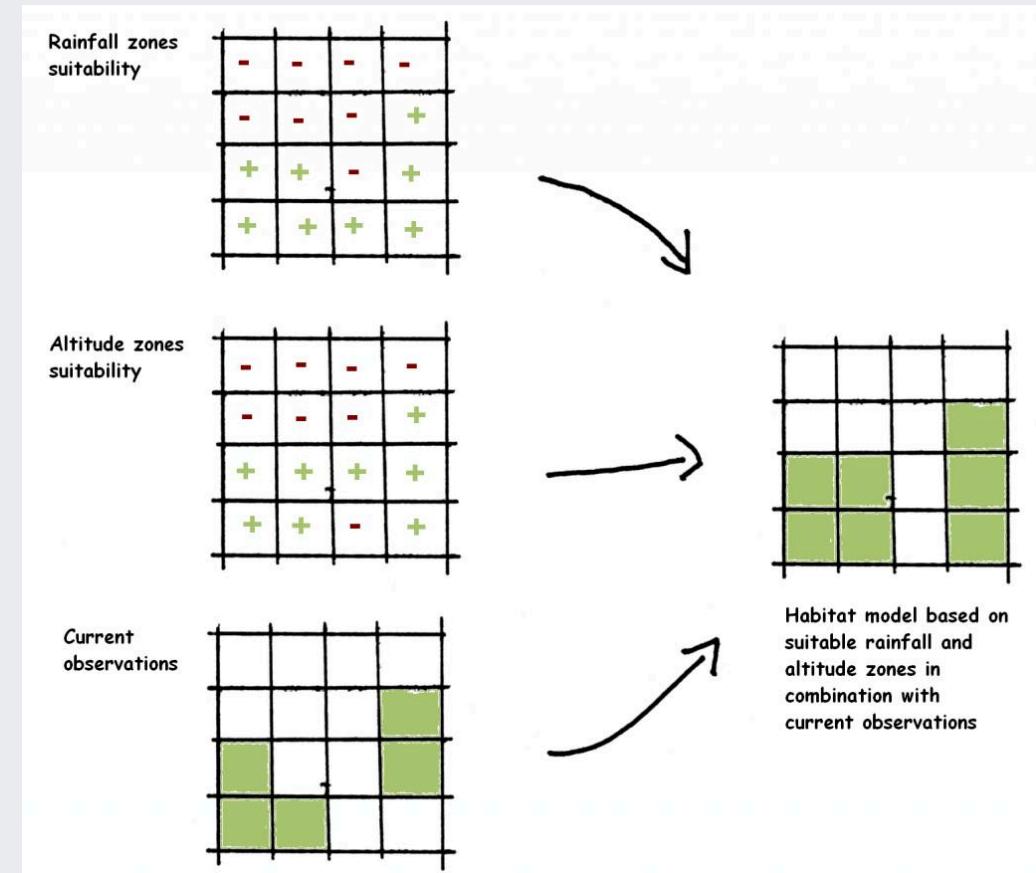
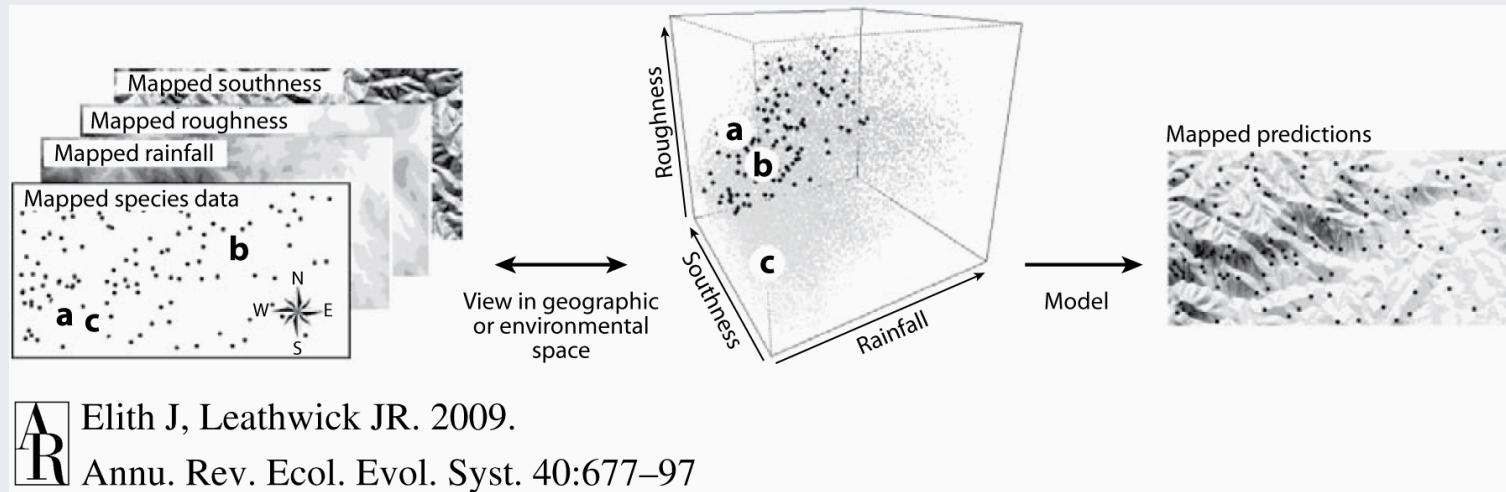


Figure by Ragnvald

# Species Distribution Models (SDMs)



**Left:** mapped species occurrences plus spatial data for environmental variables across a particular area.

**Centre:** a 3-dimentional volume showing species occurrences (black) in environmental space (grey). Occurrences are clearly non-random, allowing us to predict the probability of species occurrence at any point.

**Right:** The predicted geographic distribution of the species, with dark regions representing a high probability of species occurrence and light areas a low probability.

**Elith and Leathwick. 2009**

# What are SDMs used for?

SDMs can predict the present distribution of a species if it is poorly known, but have also been used extensively to explore species' vulnerability to climate change by projecting their potential range under future climates, among other uses.



*Leucadendron arcuatum* by Francois du Randt, iNaturalist

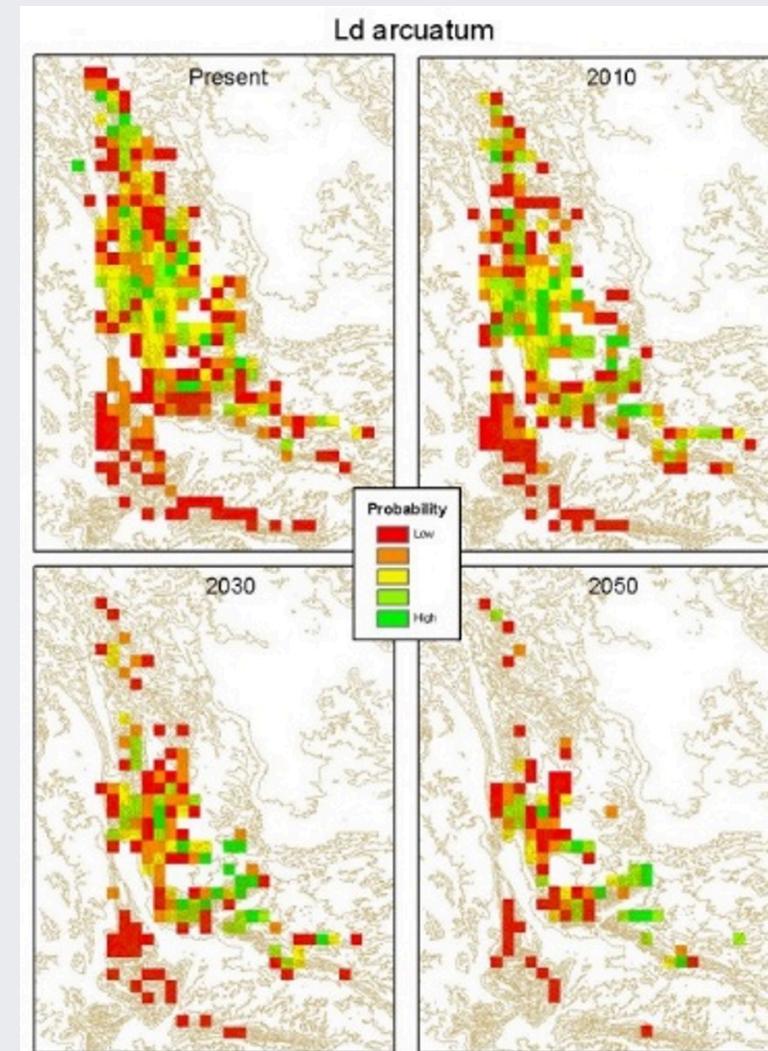


Figure from **The Protea Atlas Project**

# What are SDMs used for?

Projected species distributions are used in many ways, including in conservation. Our National Screening Tool for environmental impact authorizations for developments includes modelled distributions of animals. Sites where sensitive species occur are required to do more thorough site inspection studies.



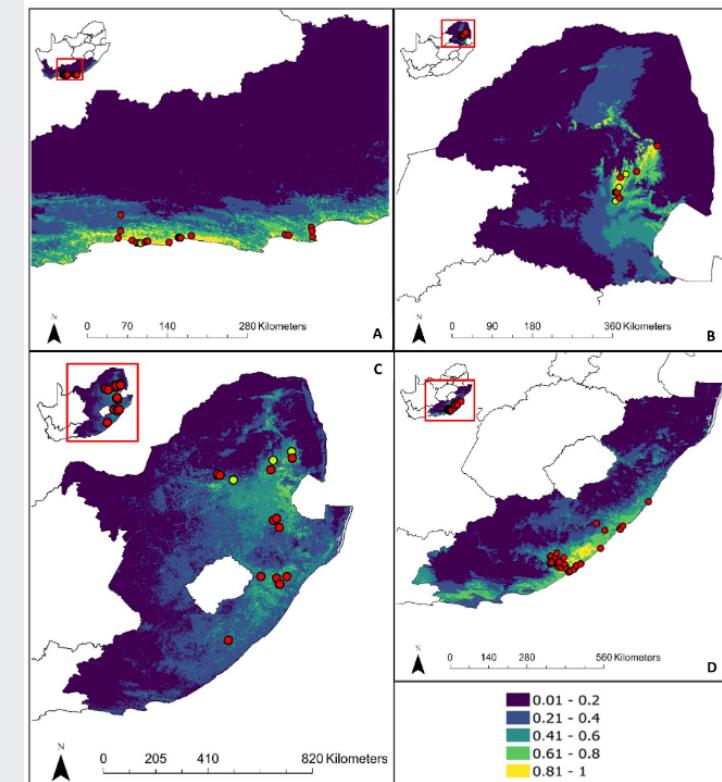
Cape Golden Mole, JP le Roux, iNaturalist

forestry, fisheries & the environment  
Department: Forestry, Fisheries and the Environment  
REPUBLIC OF SOUTH AFRICA

NATIONAL WEB BASED ENVIRONMENTAL SCREENING TOOL

Welcome to the National Screening Tool

The National Web based Environmental Screening Tool is a geographically based web-enabled application which allows a proponent intending to submit an application for environmental authorisation in terms of the Environmental Impact Assessment (EIA) Regulations 2014, as amended to screen their proposed site for any environmental sensitivity.



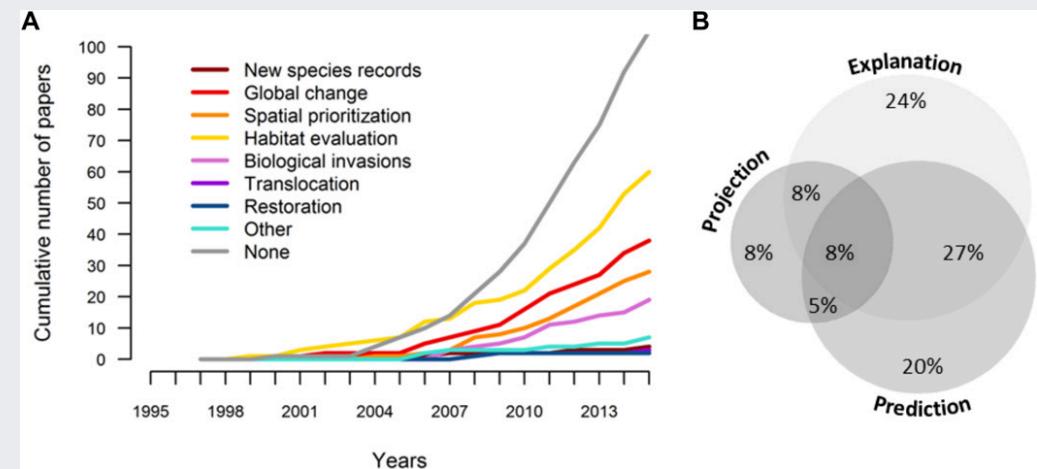
Golden mole distributions, Cowan et al. 2021

# What are SDMs used for?

*"A search of articles in peer-reviewed journals over the past 20 years found more than 6000 studies using or mentioning one of the most common classes of biodiversity modeling: species distribution models (SDMs)."*

Araújo et al. 2019

They are clearly very useful in many fields!!!



A) type of biodiversity assessment accomplished with the trend in the numbers of studies shown over time

B) purpose of the model

Figure from Araújo et al. 2019

**Can you foresee any issues with SDMs?**

# 1. Statistical models vs reality?

*Statistical models are simplifications of reality, and their predictions always come with some error (i.e. uncertainty).*

Sources of error in SDMs:

- the choice of variables included in the model
  - have all of the most important determinants of a species distribution been included?
  - are all the variables independent? Correlation among variables (autocorrelation) creates bias
- biases in the occurrence data
  - easy-to-access areas are usually over-represented (e.g. near roads)
- quality of the occurrence and environmental data...
  - GIGO (garbage in - garbage out)
- the type and structure of the statistical model...
  - continuous (abundance), discrete (presence/absence), frequentist vs Bayesian, etc

There are ways to account for some of these issues, if you are aware of them.

Ideally one quantifies and reports the uncertainty for your model, but that is a topic for **BIO3019S...**

## 2. SDMs and the realised niche?

Hutchinson made a distinction between the *fundamental* versus the *realised niche* - **Hutchinson 1957**

- The **fundamental niche** is the range of conditions (biotic and abiotic) and resources in which a species could survive and reproduce if free of interference from other species.
- The **realised niche** is a subset of the fundamental niche where a species actually occurs due to interference from other species (e.g. interspecific competition).

Which do SDMs represent? Why is this a problem?

### What is an ecological niche?

**Background:** Considers all abiotic factors such as pH, sunlight, moisture, salinity, and temperature

**Fundamental niche:** The total range of environmental conditions that a species could theoretically tolerate.

**Realized niche:** A portion of the fundamental niche which takes into account the biotic factors such as food availability, hosts, and competitive exclusion. This is where a species will actually be found.

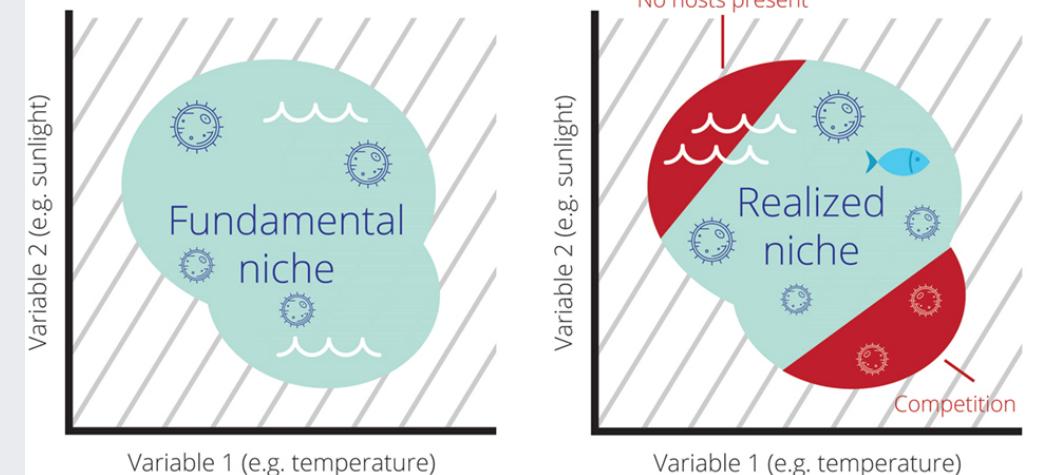
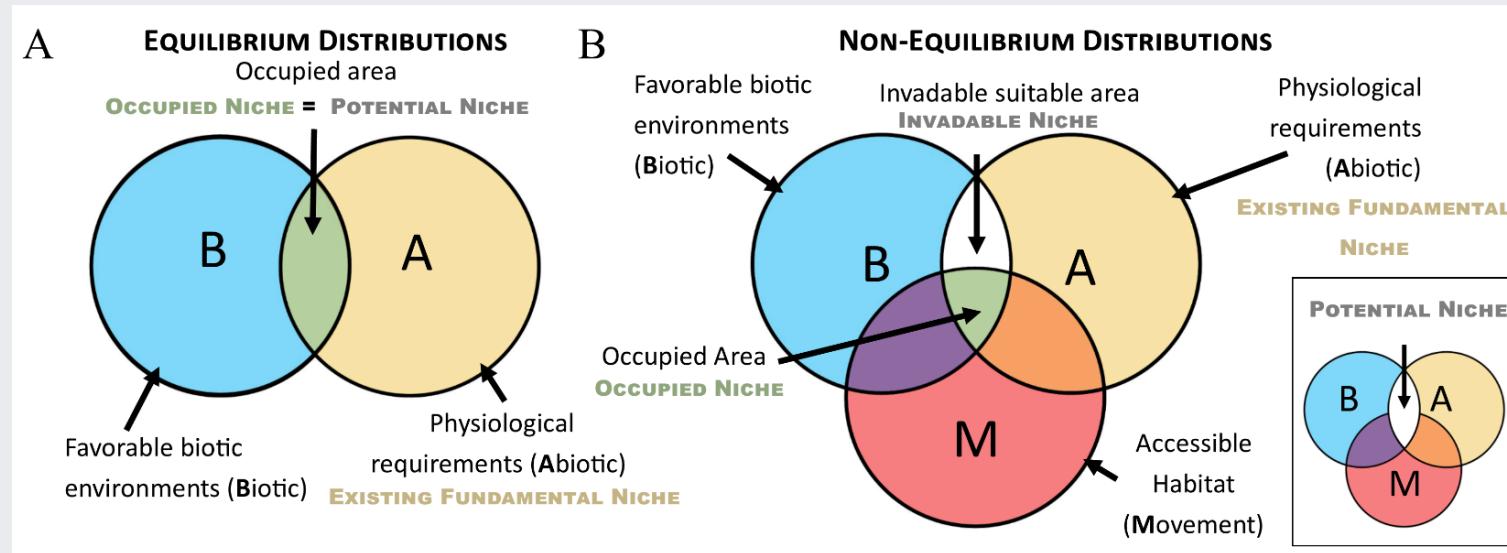


Figure from **Escobar et al 2017**

Answer: The realised niche, because the model is trained on where the species actually occurred. This can be a problem, because the model doesn't usually include spatial information about factors that determine the realised niche (competition, etc), so the predicted/projected distribution may be neither the fundamental nor the realised niche...

### 3. SDMs and the assumption of equilibrium?

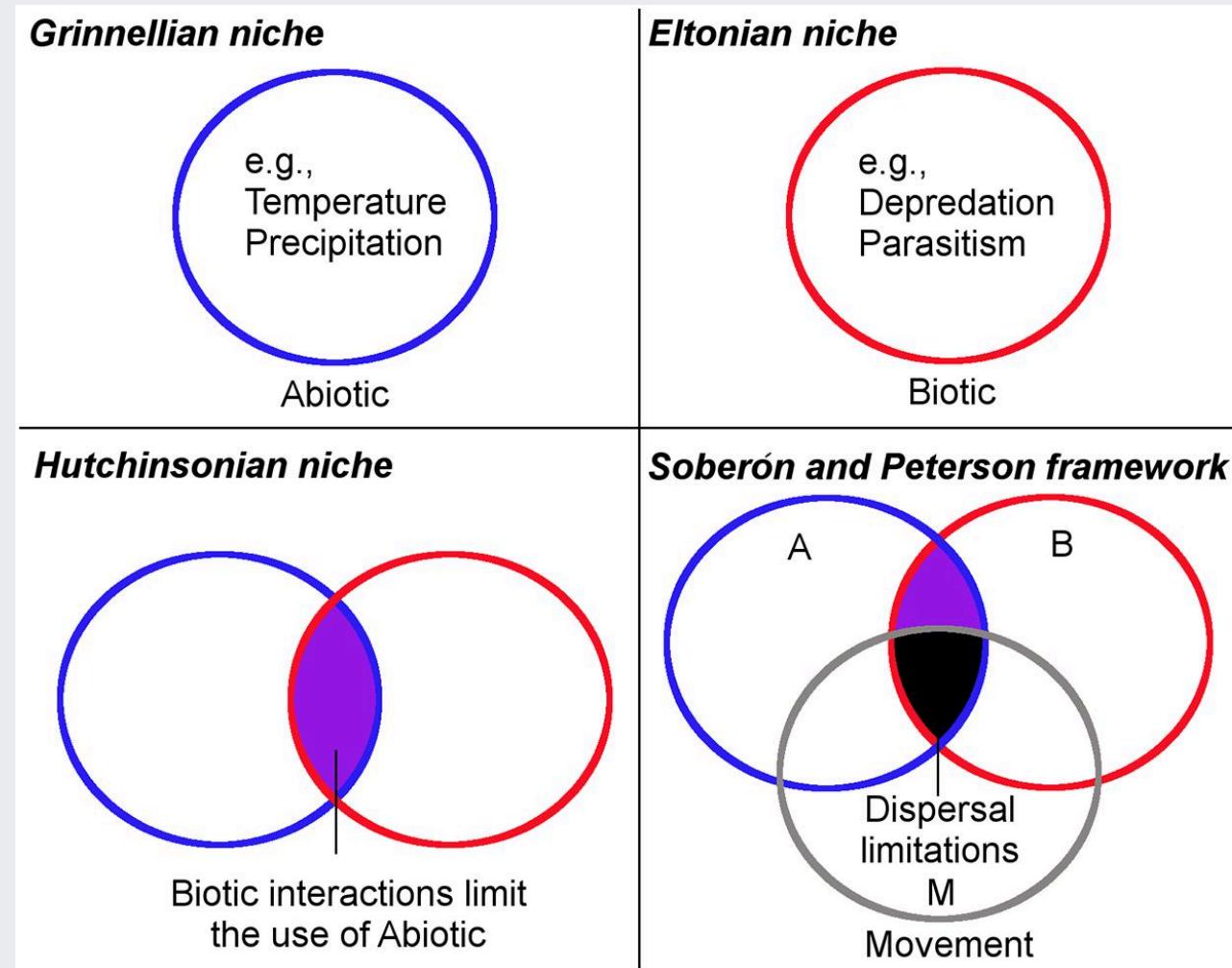


- A) If a species has an equilibrium distribution, it is occupying all of the potentially suitable habitats in the world (the potential niche is completely filled).
- B) If a species is in a non-equilibrium distribution, its potential niche is not fully occupied due to inaccessible habitat due to dispersal (movement) constraints: distance or barriers to dispersal, inability to recolonise habitats affected by seasonal or long-term dynamism.

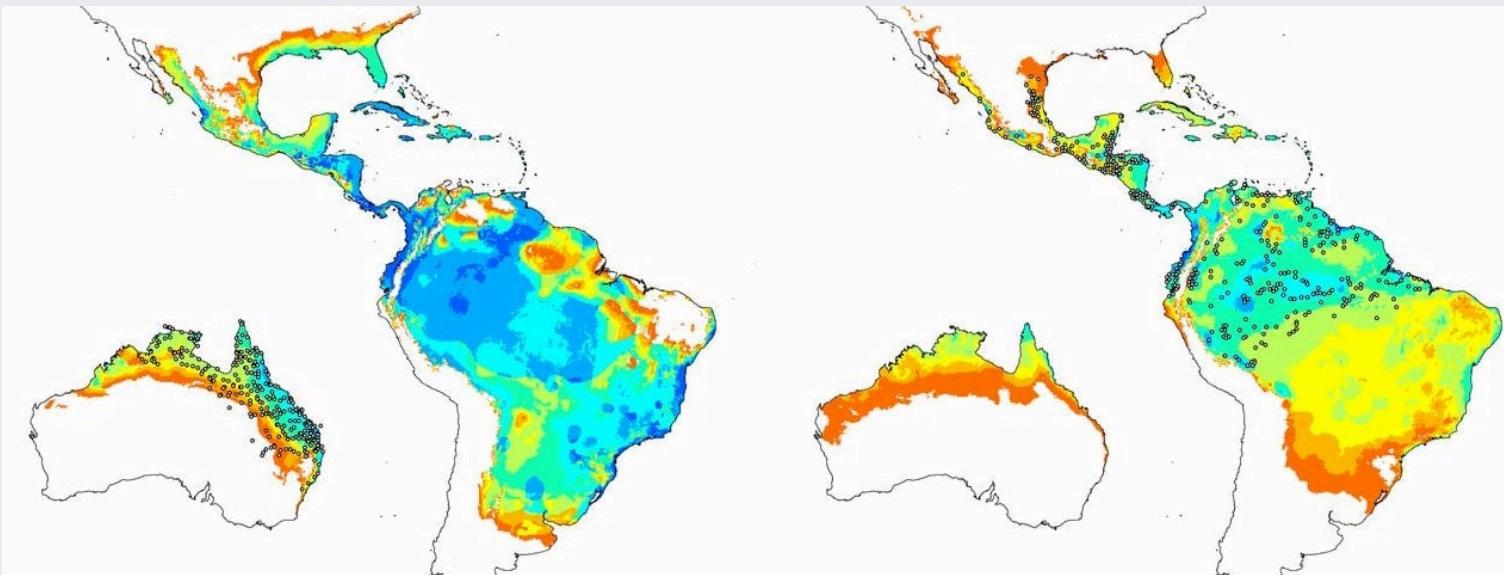
Species rarely occupy their full potential niche!

Figure from Brown and Carnaval 2019

# A simplified summary of how the approaches fit together



## e.g. Invasive species and the assumption of equilibrium



Reciprocal projections of models calibrated using data from either the invasive Australian (left) or native South American (right) occurrence of the cane toad, *Rhinella marina*, and projected into the other.

Invasive (left): predicted a broader latitudinal distribution in the native South American range than is observed

Native (right): failed to predict invasive populations in drier and cooler regions to the SE of Australia

- Why???

Tingley et al. 2014

## e.g. Invasive species and the assumption of equilibrium

Why the difference between the native and invasive realised niches of the cane toad? - **Tingley et al. 2014**

### Hypothesis 1

Dispersal limitation or absence of drier, cooler climate  
in South America?

### Hypothesis 2

Difference in biotic interactions experienced on each  
continent?

# e.g. Invasive species and the assumption of equilibrium

Why the difference between the native and invasive realised niches of the cane toad? - **Tingley et al. 2014**

## Hypothesis 1

Dispersal limitation or absence of drier, cooler climate in South America?

*"...our findings demonstrate that novel climates colonized by *R. marina* in Australia were available, but unoccupied, in the species' native range..."*

## Hypothesis 2

Difference in biotic interactions experienced on each continent?

*"One possibility is that the presence of a closely related species (*R. schneideri*) in cooler and drier regions of Southern Brazil may be preventing *R. marina* from colonizing suitable environments south of its present range. ...these two species hybridize..., and even low rates of interspecific hybridization can enforce stable range boundaries"*

This example highlights that acknowledging the issues or assumptions of SDMs can be very useful for learning about the species and testing hypotheses. The issues are only a problem if not acknowledged and accounted for in some way!

**What else have we missed?**

# The Hutchinsonian Niche

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Does the occurrence of a species at a locality mean it is able to maintain a viable population there...?

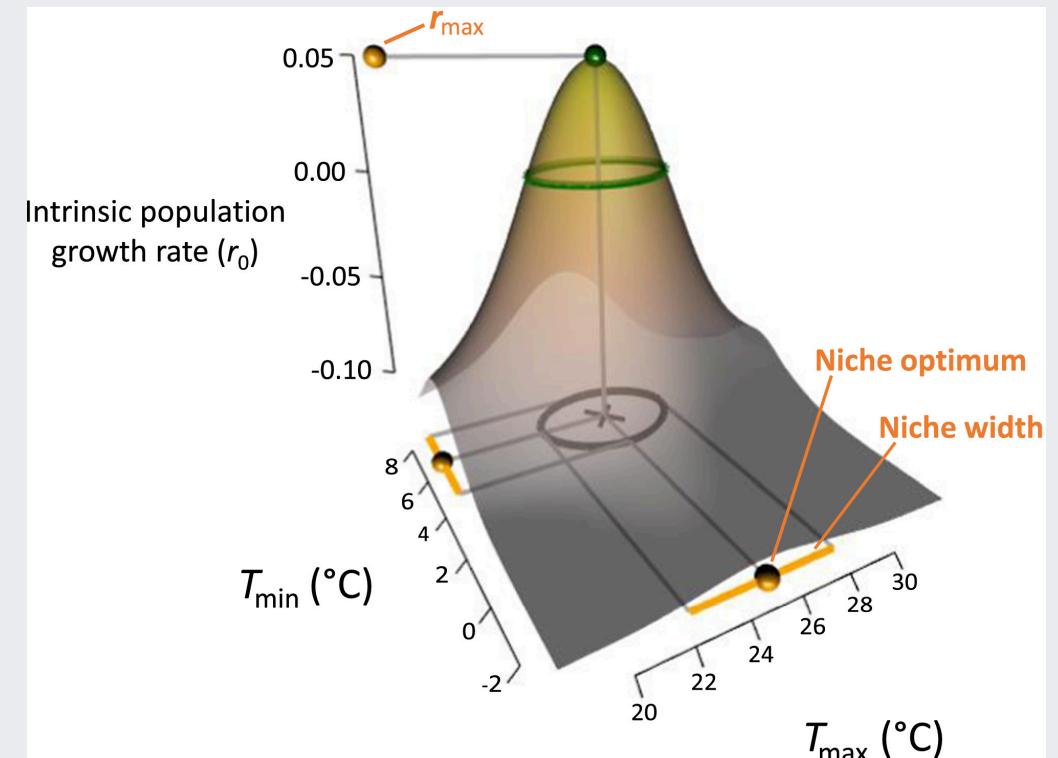


Figure from Treurnicht et al. 2020

# **What does maintaining a viable population even mean?**

The topic of our next lecture...

# Take-home

*One of the most common applications of the concept of the niche is Species Distribution Modelling (also known as Ecological Niche Modelling).*

*While SDMs can be very useful, they have many issues and assumptions that need to be taken into account.*

*Acknowledging the issues or assumptions of SDMs can actually be very useful for learning about species and testing hypotheses.*

**Proviso:** *There are many ways to build SDMs and it is a rapidly moving field. There are methods to address some of the issues I highlight, but they are less commonly used and since I am covering SDMs in one lecture for this course I'm not going to go there...*

# Thanks!

Slides created via the R packages:

**xaringan**  
gadenbuie/xaringanthemer

The chakra comes from remark.js, **knitr**, and R Markdown.