



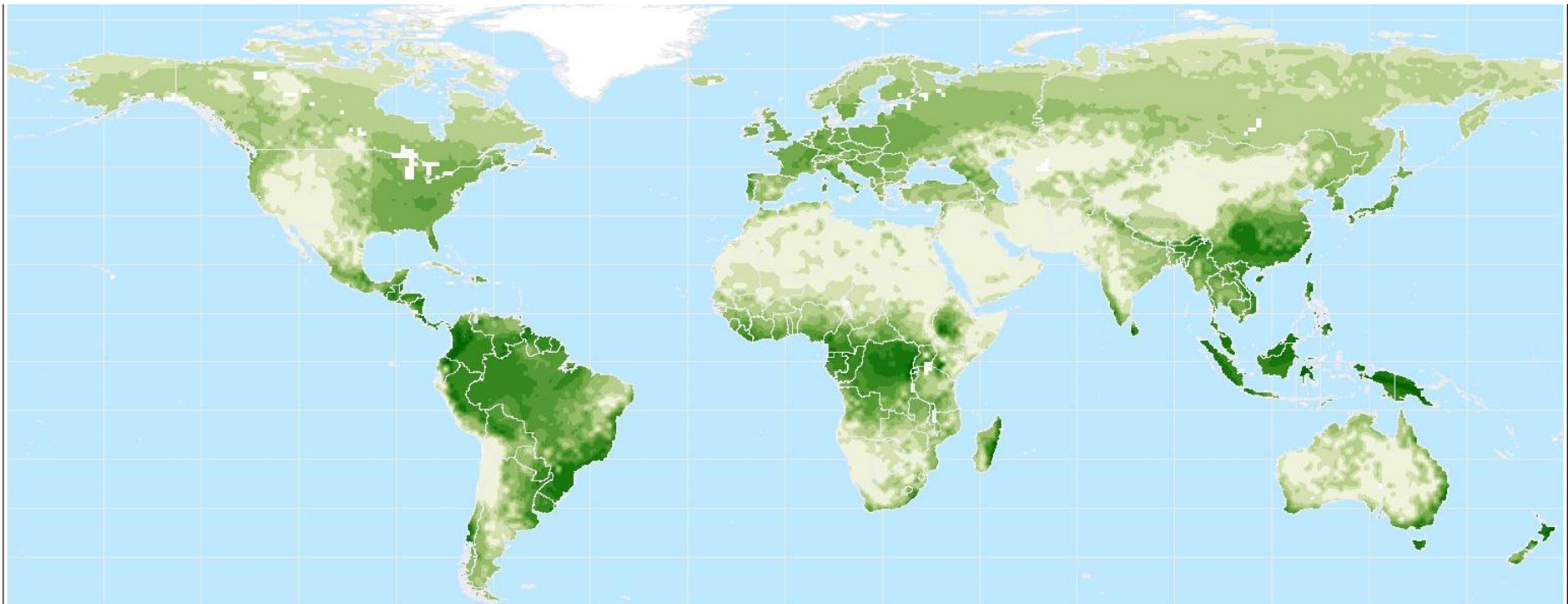
INVESTMENTS IN EDUCATION DEVELOPMENT

Mapping and modeling species distributions

Department of Botany and Zoology, Masaryk University

Bi9661 Selected issues in Ecology, Autumn 2013

Borja Jiménez-Alfaro, PhD



Part 2:

MODELING

THEORY BACKGROUND: the NICHE

Adapted from:

E. Martínez-Meyer, GBIF modelling workshop 2008

A. Guisan, W. Thuiller & N. Zimmerman, ECOCHANGE summer school 2009

Definition of niche in ecology

The American Heritage® Dictionary of the English Language, Fourth Edition 2000

- 1) The particular area within a habitat occupied by an organism
- 2) The function or position of an organism or population within an ecological community



THE NICHE

What is the niche?

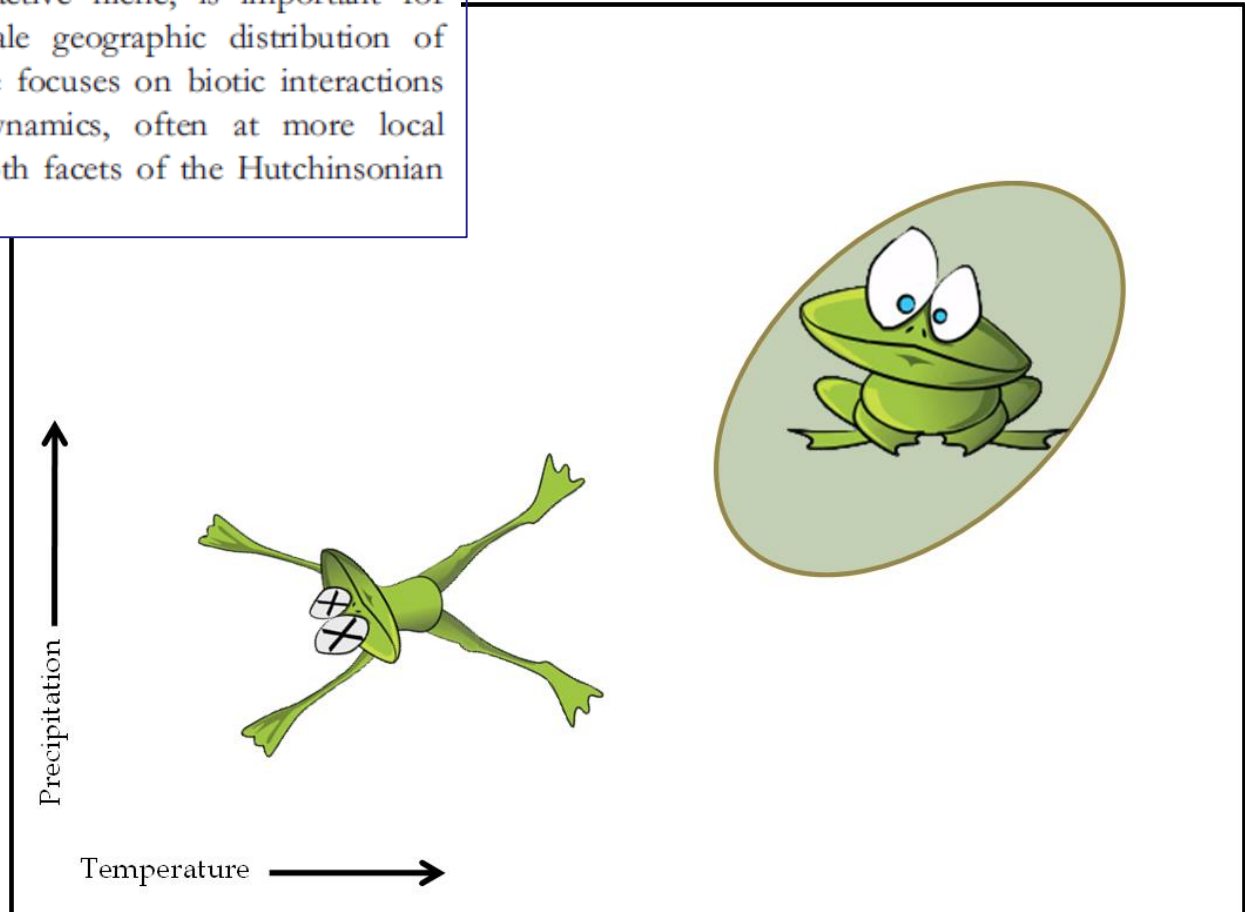
The niche has been defined in terms of the distribution of species, the functions they perform and the resources they consume (reviewed in Soberón 2007). These definitions can be separated into two classes (Soberón 2007). The Grinnellian niche or non-interactive niche, is important for understanding the large-scale geographic distribution of species. The Eltonian niche focuses on biotic interactions and resource–consumer dynamics, often at more local scales. NC is relevant to both facets of the Hutchinsonian niche.

Wiens et al. (2010) *Ecology letters*
13: 1310-1324

Grinnellian?

Eltonian?

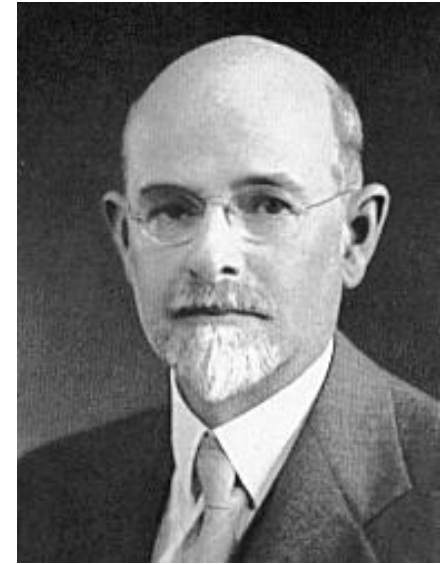
Hutchinsonian?



Joseph Grinnell (1916-28)

Niche is....

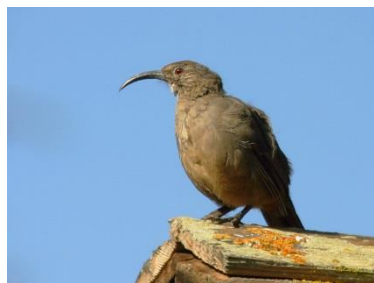
“...the ultimate **distributional** unit, within which each species is held by its structural and instinctive limitations” (1924).



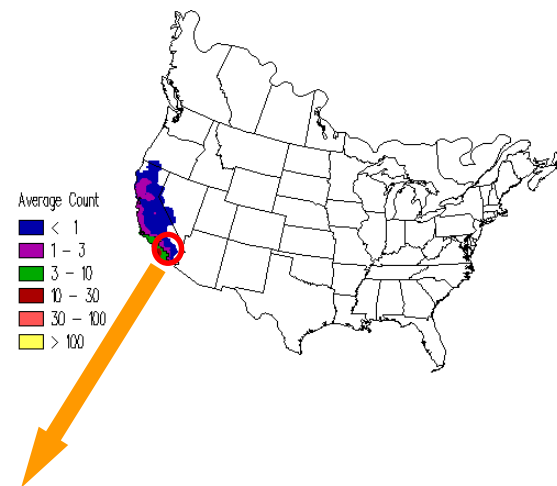
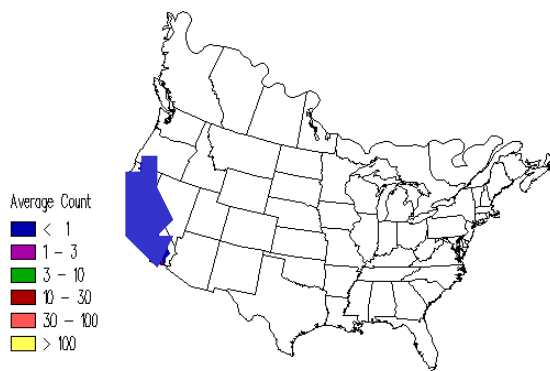
Every species has its own physiological, morphological, and behavioral **profile**, which makes it suitable to occupy particular spaces offered by nature.

Joseph Grinnell (1916-28)

He proposed a hierarchical classification of the environment that could be recognized as a measure of **distributional control**



California Thrasher
(*Toxostoma redivivum*)



Ecological or
Environmental
Niche

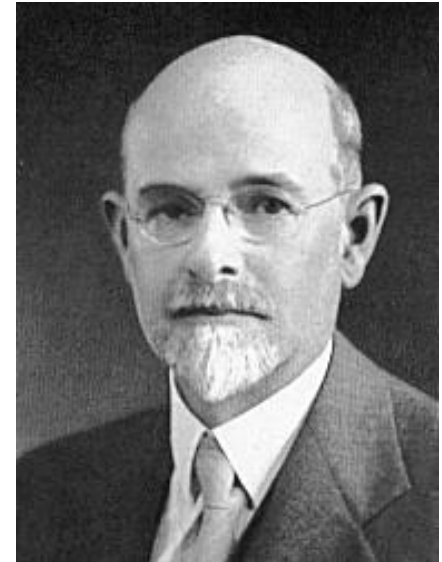
- Food
- Breeding sites
- Refuges from predators



Joseph Grinnell (1916-28)

The niche is a property of the environment
(not of its occupant):

“...the ecologic or environmental niche... is occupied by just one species...if a new ecologic niche arises, or if a niche is vacated, nature hastens to supply an occupant...” (1924).



Acknowledges the central role of interactions (Competitive Exclusion Principle): “No two species in the same general territory can occupy for long identically the same ecologic niche...” (1928). Similar niches are filled up with ecological equivalents.

Charles Elton (1927)

“...[‘Niche’ describes] the **status** of an animal in its community, to indicate **what is doing** and not merely what it looks like...”

“...the ‘niche’ of an animal means its place in the biotic environment, its relation to food and enemies.”



The focus is on the **functional role** of species within the food chain. Abiotic conditions are not taken into account.

Charles Elton (1927)

The niche is a property of the **biotic community** (not of its occupant) – same principle as Grinnell

The niche is not restricted to a single species:

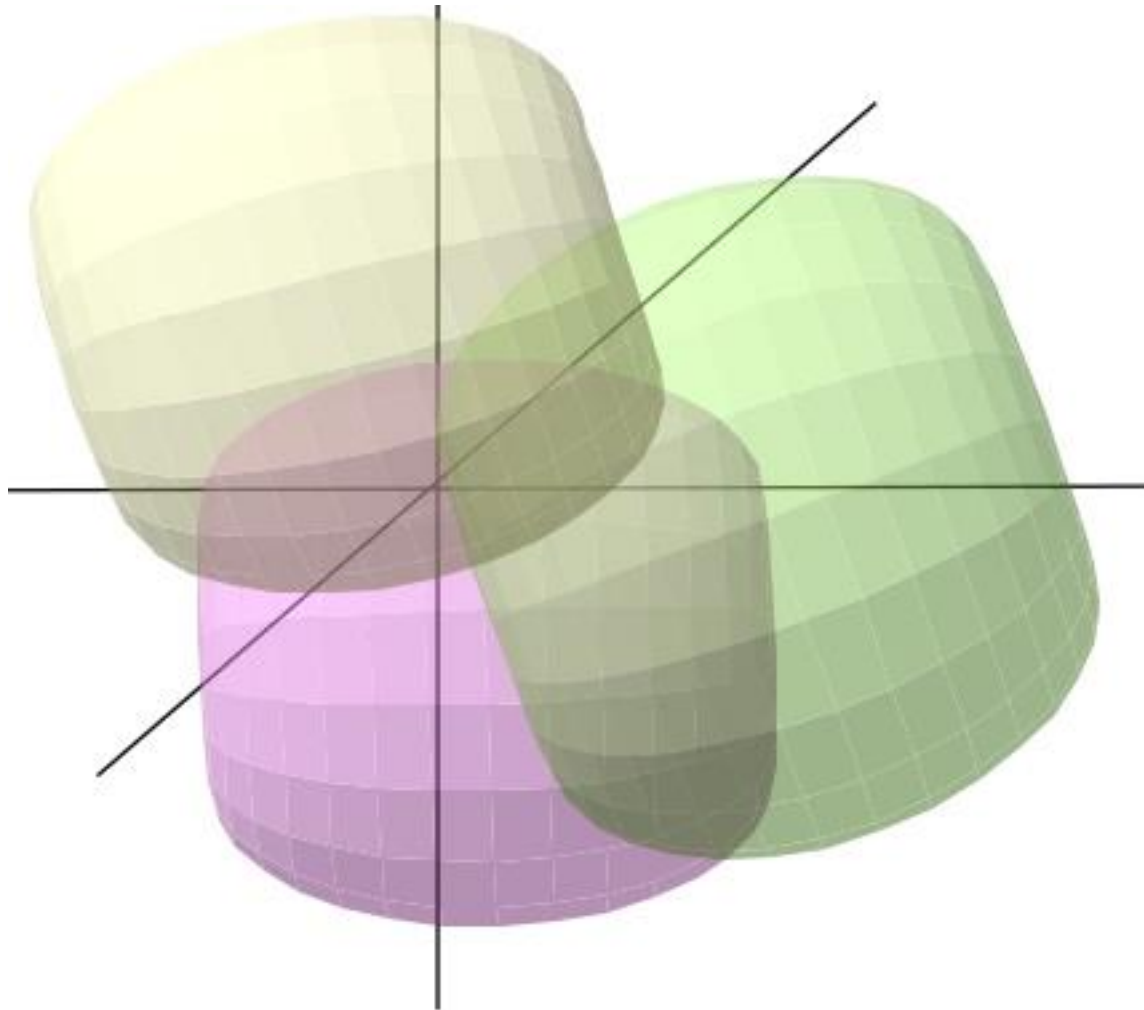
“...we might take as a niche all the carnivores which prey upon small mammals, and distinguish them from those who prey upon insects...”

Ecological equivalents are an indication of similar niches:

“There is often an extraordinarily parallel between niches in widely separated communities.”



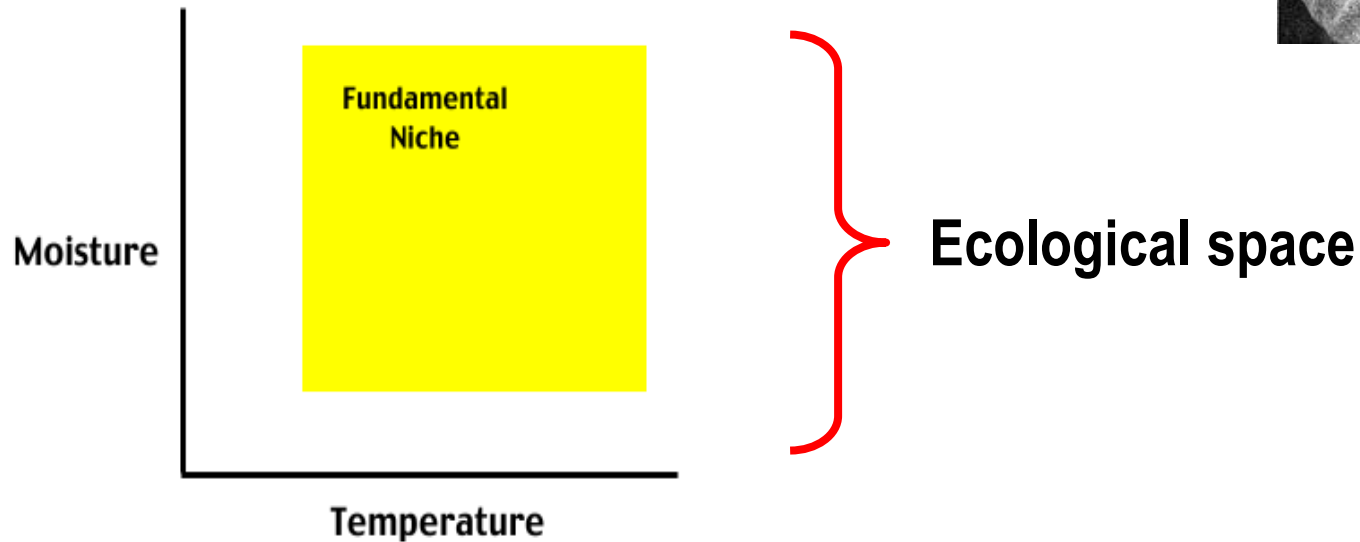
G. Evelyn Hutchinson (1944-58)



Multi-dimensional
niche

G. Evelyn Hutchinson (1944-58)

“The term niche... Is defined as the sum of all the **environmental factors** acting on the organism; the niche thus defined is a region of an n-dimensional hyper-space...” (1944).

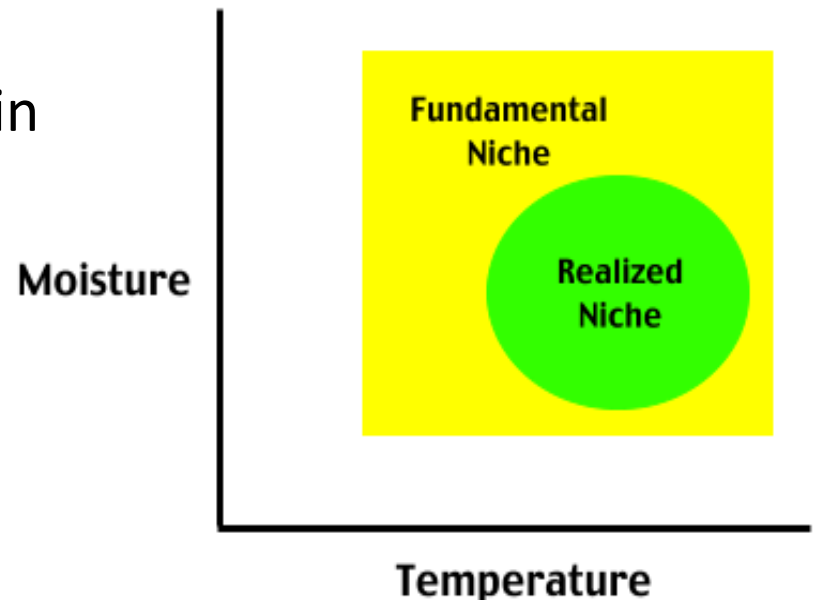


G. Evelyn Hutchinson (1944-58)

Conditions in which species could feasibly live are often greater than those where the organism actually lives, and this is typically caused by biotic interactions.

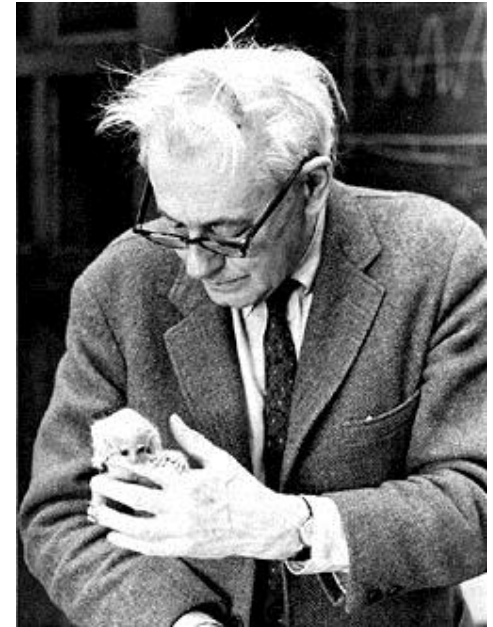
Fundamental niche: all aspects of the n-dimensional hyper-volume in the absence of other species.

Realized niche: the part of the fundamental niche to which the species was restricted due to interspecific interactions.



G. Evelyn Hutchinson (1944-58)

- The niche is a property of the **occupant** (not of the environment) – **new concept !**
- Niches have a temporal dimension
- Competitive exclusion is part of the formalization: “...realised niches do not intersect”
- Niches are mutable (i.e. evolve)

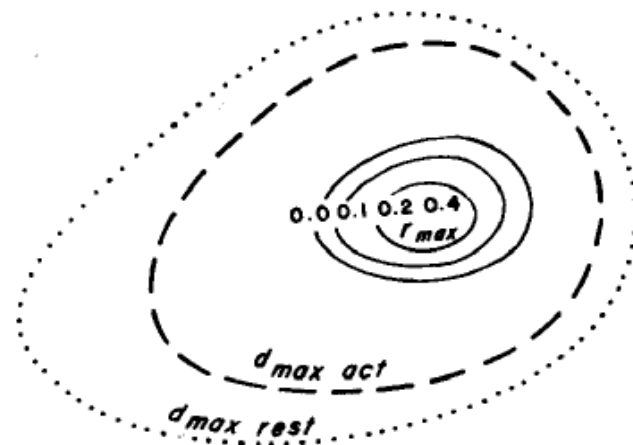
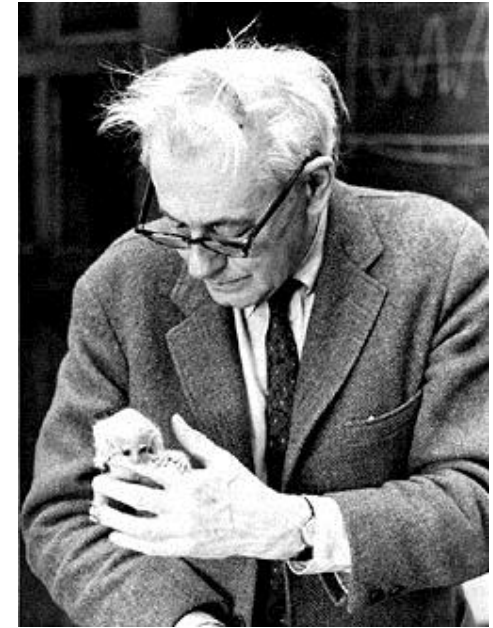


G. Evelyn Hutchinson (1944-58)

The niche became **quantifiable** because both:

A) Environmental variables could be expressed along continuous axes, and

B) The internal structure of the niche is determined by the species' performance (measured in terms of population fitness)



Development of the niche theory (1966-84)

Levins, MacArthur, Pianka, Roughgarden, Schoener, Colwell, May, Diamond

A group of theoretical models designed to investigate how many and how similar coexisting species could be within a given community. Competition for resources is the primary underlying mechanism driving ecology

The focus was on measuring:

- **Niche breath:** the variety of resources/habitats used by a species
- **Niche partitioning:** differential resource use by coexisting species
- **Niche overlap:** mutual resource use by different species
- **Niche assembly:** organization of species in new and abandoned habitats

Decline of the niche concept (1981-2001)

Connor, Simberloff, Lewin, Hubbell



Major critiques:

Lack of adequate null hypothesis and statistical rigor

Competition is not necessarily the driving process in ecology

Confusing and ambiguous use of the term 'niche'

New conceptual frameworks (the so-called 'neutral theories') claim that the niche concept is unnecessary to understand fundamental, broad-scale patterns in ecology

Reformulation of the Niche Concept

Chase and Leibold (2003) Ecological Niches: Linking Classic and Contemporary Approaches. University of Chicago Press

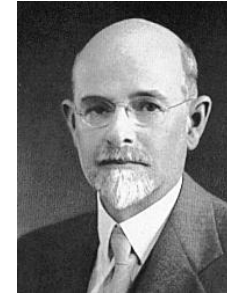
“The niche of a species is the **joint description of the environmental conditions** that allow a species to satisfy its minimum requirements so that the birth rate of a local population is equal or greater than its death rate along with the set of per capita impacts of that species on these environmental conditions.”

“The niche concept is important both as a tool for thinking about ecological and evolutionary phenomena and as a synthetic device for integrating these phenomena across levels of organizations [and scales] (e.g. individuals to ecosystems).”

What is the niche?

The niche has been defined in terms of the distribution of species, the functions they perform and the resources they consume (reviewed in Soberón 2007). These definitions can be separated into two classes (Soberón 2007). The Grinnellian niche or non-interactive niche, is important for understanding the large-scale geographic distribution of species. The Eltonian niche focuses on biotic interactions and resource–consumer dynamics, often at more local scales. NC is relevant to both facets of the Hutchinsonian niche.

Following Hutchinson (1957), we consider the niche as describing the set of biotic and abiotic conditions where a species can persist (Holt 2009). This includes both the distribution of a species and its interactions with other



Wiens et al. (2010) *Ecology letters* 13: 1310-1324



Guisan & Zimmerman 2000, fig. 3

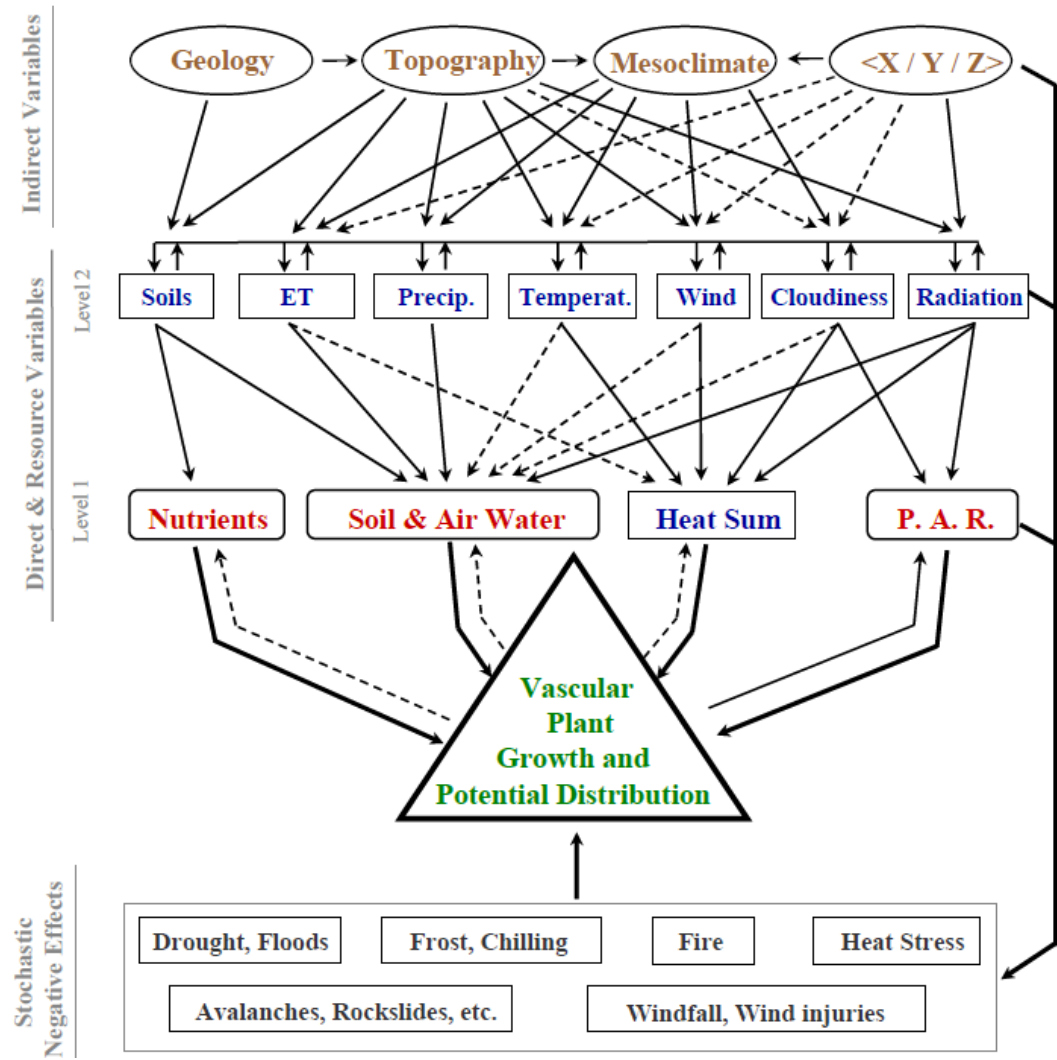
What defines a species' fundamental environmental niche?

An example with plants

Regulators

Resource Gradients

Indirect Gradients



The niche can be represented along few factors

Ellenberg 1953

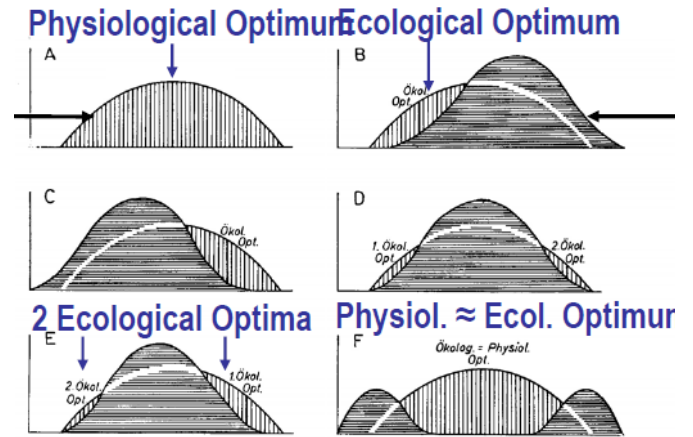
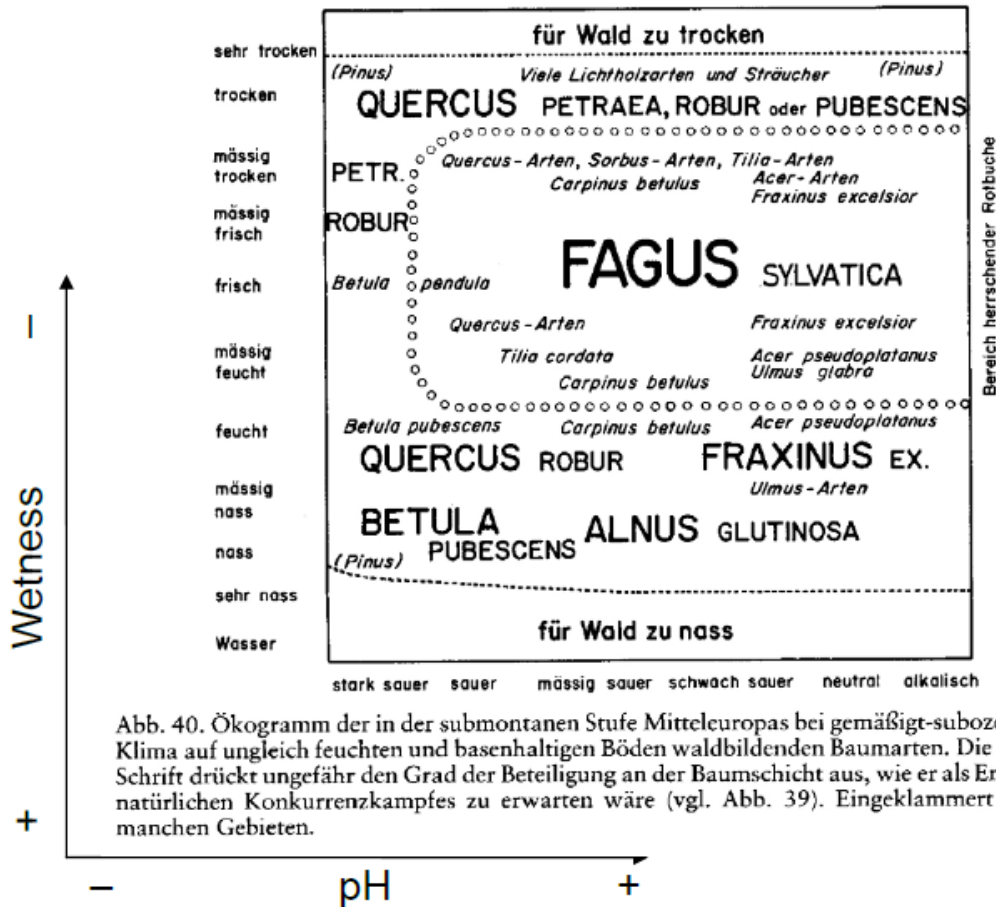
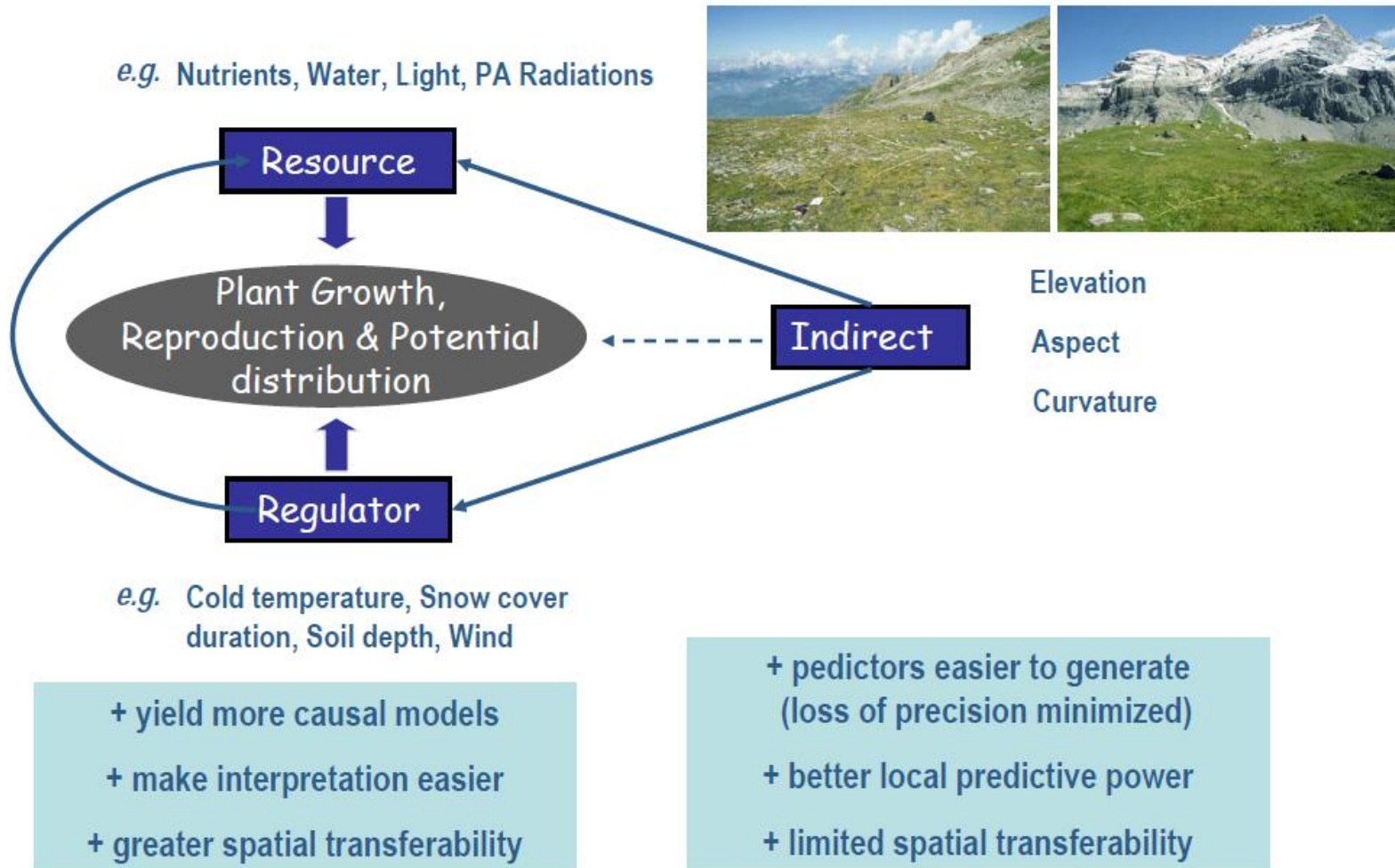
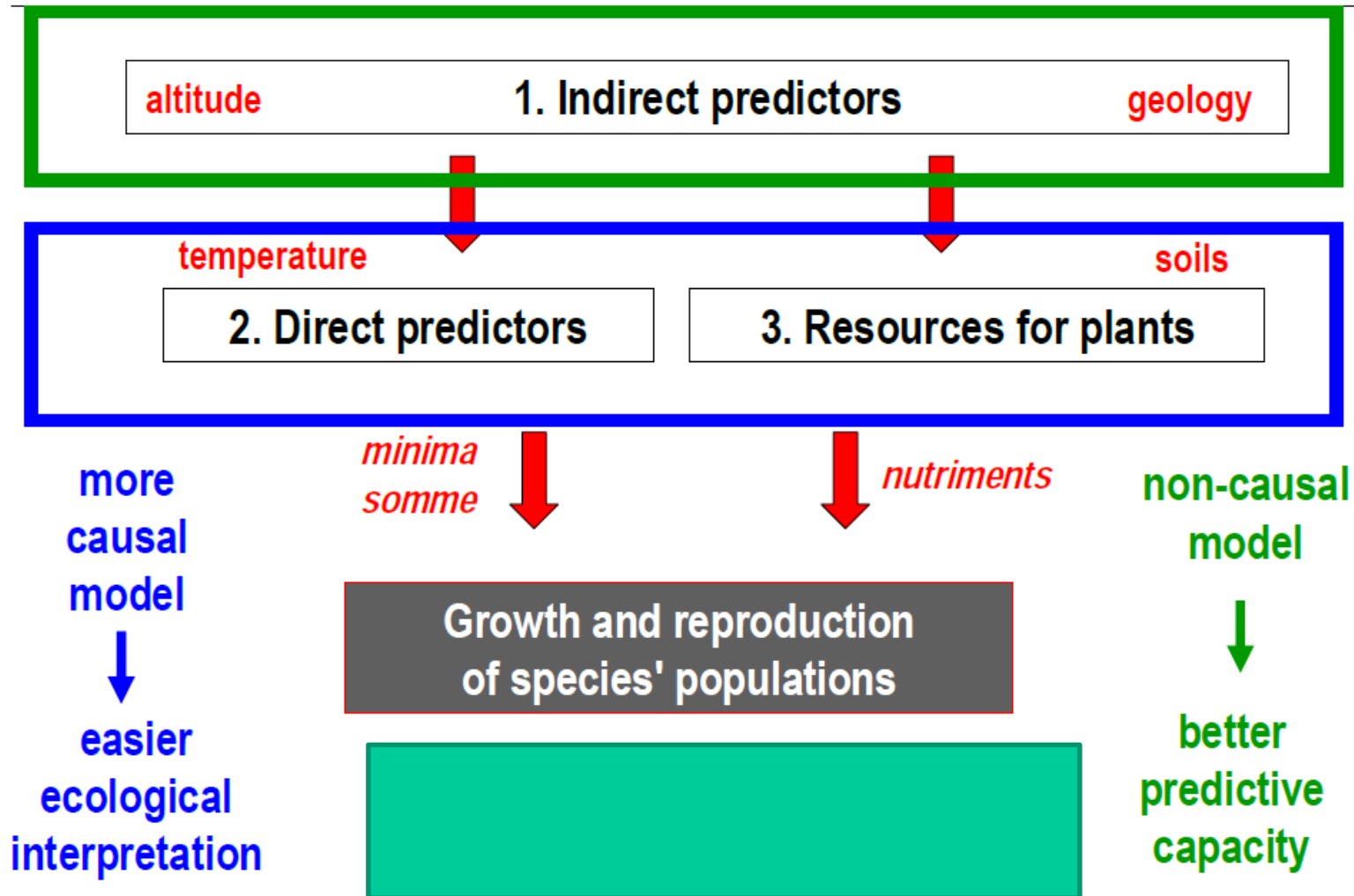


Abb. 40. Ökogramm der in der submontanen Stufe Mitteleuropas bei gemässigt-subozeanischem Klima auf ungleich feuchten und basenhaltigen Böden waldbildenden Baumarten. Die Grösse der Schrift drückt ungefähr den Grad der Beteiligung an der Baumschicht aus, wie er als Ergebnis des natürlichen Konkurrenzkampfes zu erwarten wäre (vgl. Abb. 39). Eingeklammert = nur in manchen Gebieten.

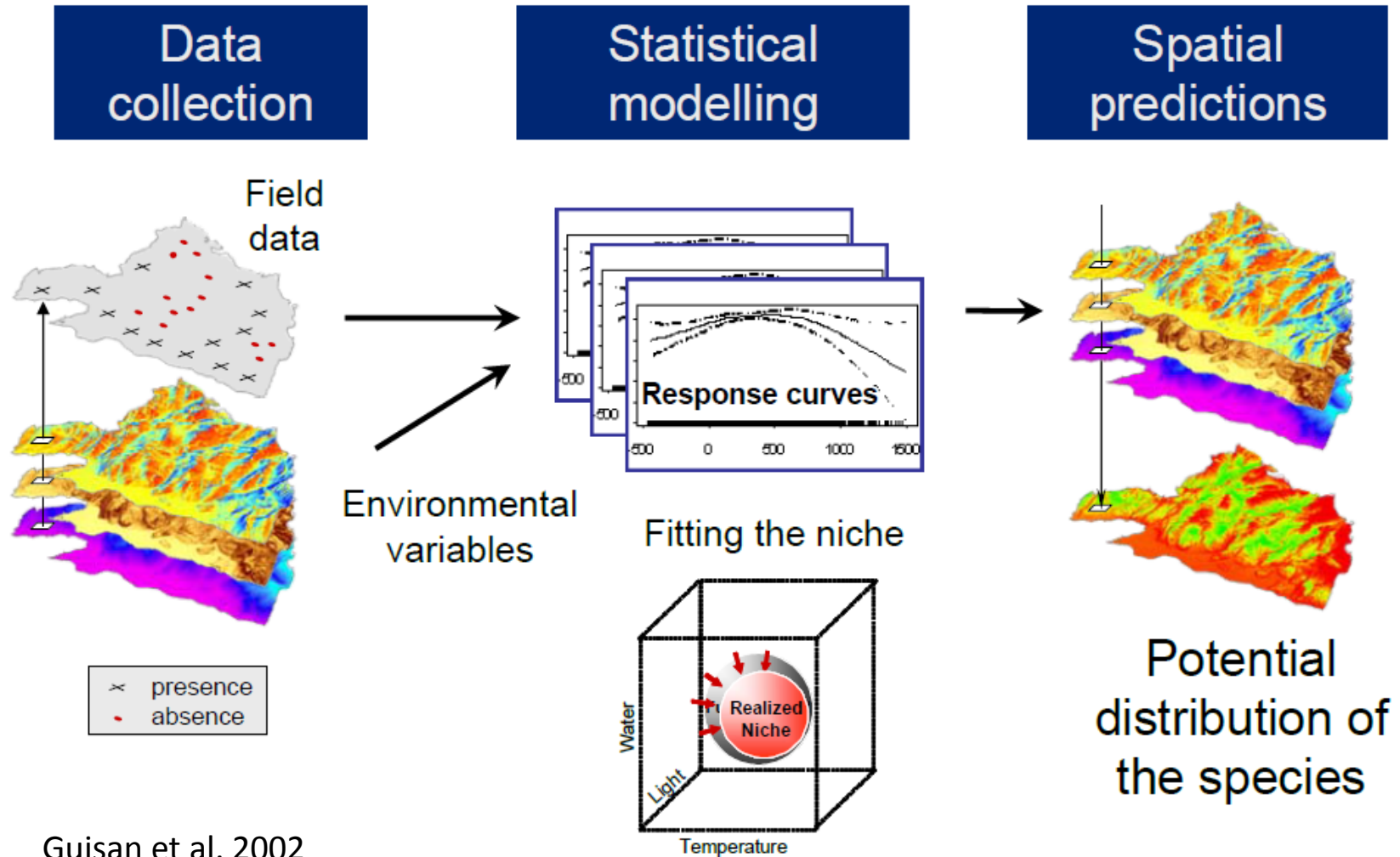
Causality of predictors in alpine plants



Predictors for spatial modeling

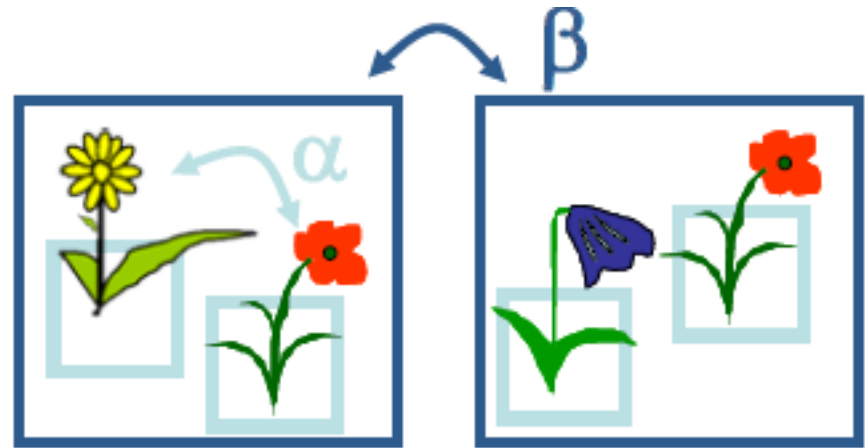


Niche and the SPATIAL prediction of species distributions



What are we modelling?

The so called **Beta-niche**



SCALE: grid information at resolution of meters or kilometres

DESCRIBING: niche attributes of species distribution across (scale-dependent) environmental and geographic gradients

OUTPUT: raster models reflecting mean conditions in which species predictions are not exclusive (more than one specie can occur)

What are we modelling, fundamental or realized niches?

Biodiversity Informatics, 2, 2005, pp. 1-10

INTERPRETATION OF MODELS OF FUNDAMENTAL ECOLOGICAL NICHES AND SPECIES' DISTRIBUTIONAL AREAS

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Instituto de Ecología, UNAM, México*

AND

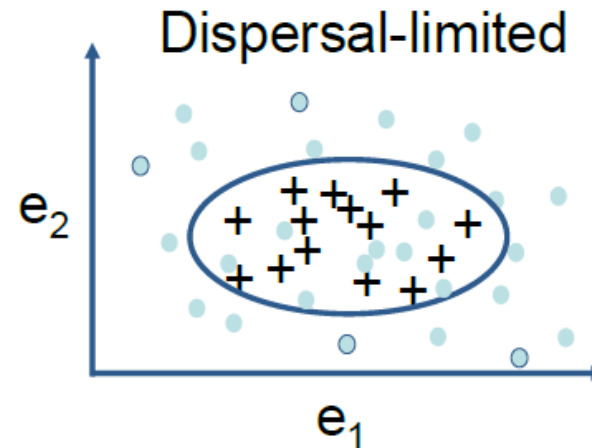
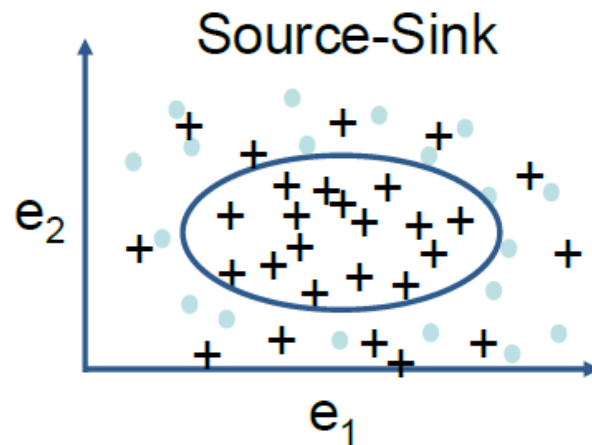
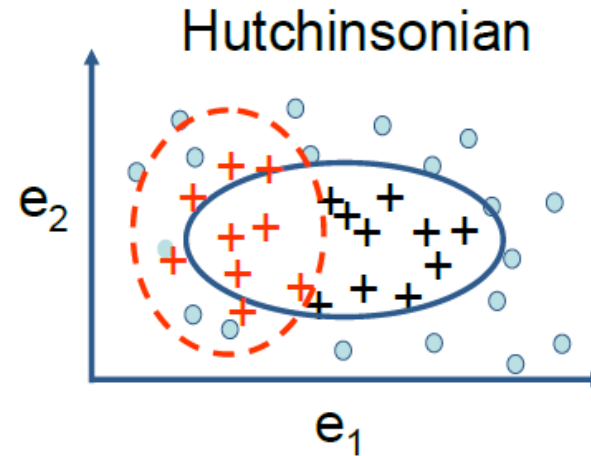
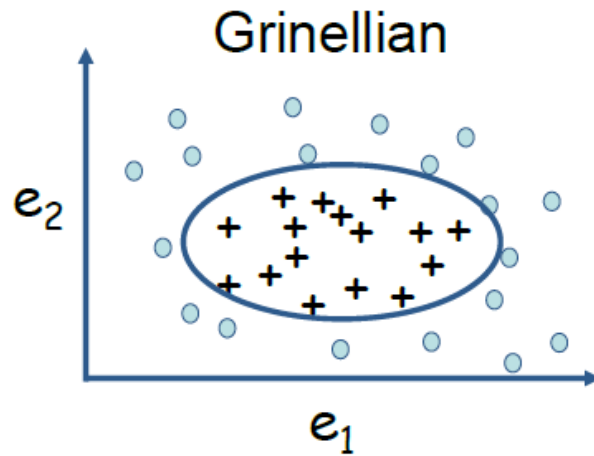
A. TOWNSEND PETERSON

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Kansas 66045 USA*

Abstract.—Estimation of the dimensions of fundamental ecological niches of species to predict their geographic distributions is increasingly being attempted in systematics, ecology, conservation, public health, etc. This technique is often (of necessity) based on data comprising records of presences only. In recent years, modeling approaches have been devised to estimate these interrelated expressions of a species' ecology, distributional biology, and evolutionary history—nevertheless, a formal basis in ecological and evolutionary theory has largely been lacking. In this paper, we outline such a formal basis to clarify the use of techniques applied to the challenge of estimating 'ecological niches;' we analyze example situations that can be modeled using these techniques, and clarify interpretation of results.

Key words.—ecological niche, fundamental niche, realized niche, geographic distribution

What are we modelling, fundamental or realized niches?



Two main assumptions

Equilibrium: species in equilibrium with their environment?

(Franklin 1995; Guisan & Theurillat 2000; but see Svenning & Skov 2004)

partial
range
filling

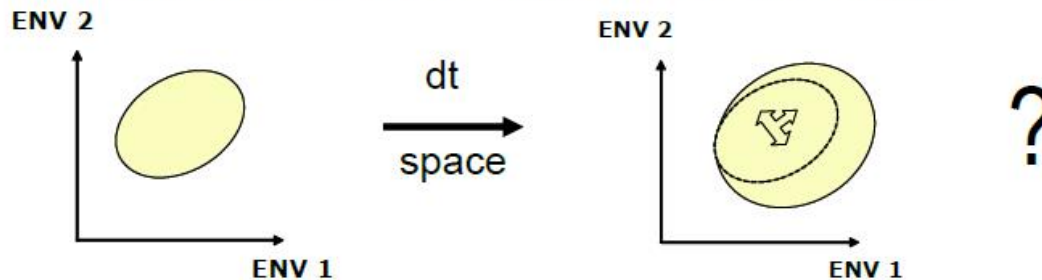


complete
range
filling



Niche conservatism: fitted niche constant over time and space?

(Peterson et al. 1999, Wiens & Graham 2005, Pearman et al. 2008)



What are we modelling? – CONCLUSION

Species distribution modeling (SDM)

Environmental niche modeling (ENM)

Using empirical data, biotic interactions and dispersal limitation are included if they are correlated with the predictors

If this is true, we can assume that the model outputs reflect the realized niche, although we cannot test it

Different study cases have found evidence of Grinnellian / Hutchinsonian niches, source-sink and dispersal limitations models