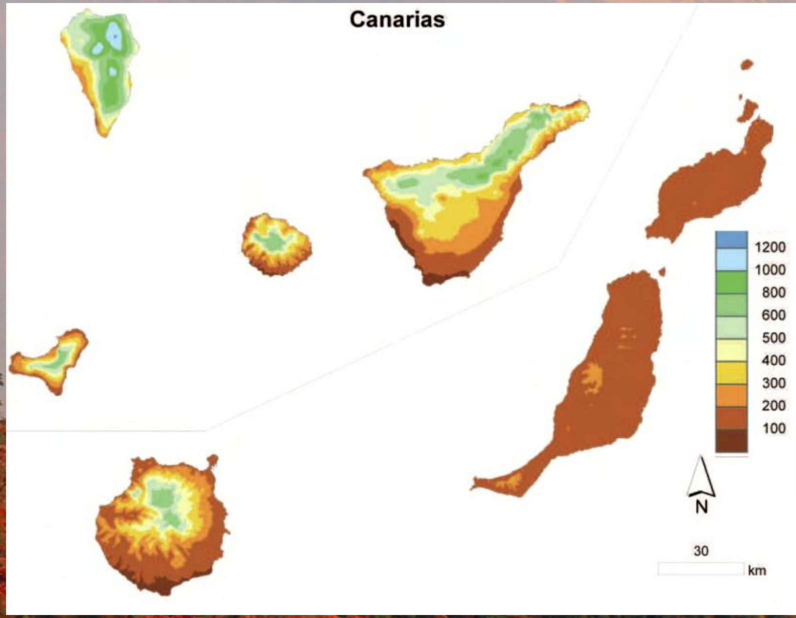
Conservation biogeography; migration, isolation, and barriers in changing climate.

Ole R. Vetaas (ole.vetaas@uib.no)

Conservation biogeography; migration, isolation, and barriers in changing climate.

prof. Ole R. Vetaas



Institute of Geography,
University of Bergen

Storyline of my talk

- **Development of Conservation Biogeography**
  - Historic biogeography (Darwin, Wallace, von Humbolt)
  - Environmental and Ecological biogeography (MacArthur and Wilson)
  - <u>**Conservation Biogeography**</u> (Whittaker, et al. Willis, DnD 2005)

- **Data bases, GBIF, EVA, Splot, grassplot, birdwatch, etc**
- Temporal data on processes

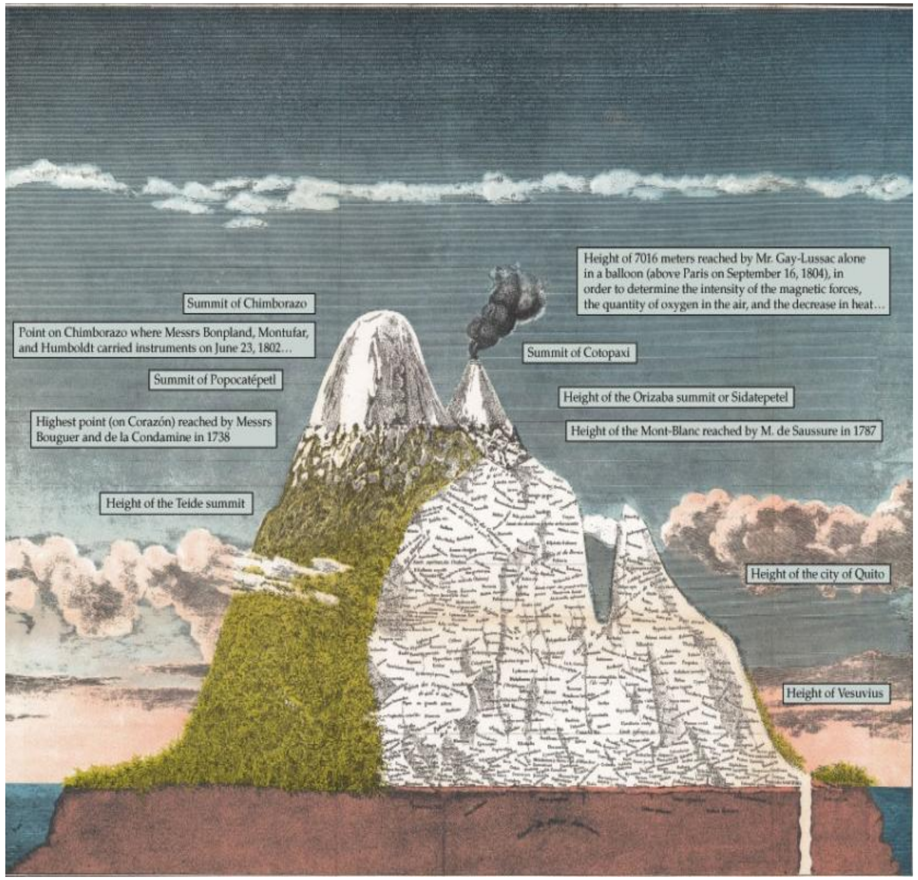
  - Shortfalls (Linnean, Wallace)

- **Conservation Biogeography: Species-Area relationship**
- **Why are islands and mountains so rich in diversity?**
- **Why do islands and mountains have a high risk of extinction?**
  - Migration and species pool

- **Elevation gradients: Mimicry of the planet: Endemics, richness, climate**
- **Mid elevation: high richness, rescue sites, Safe corridors**

- **Land use change, barriers and anthropogenic infrastructure**
- **Facilitate migration Dynamic conservation vs ‘tin-can-conservation’**
  - Corridors

History of Biogeography

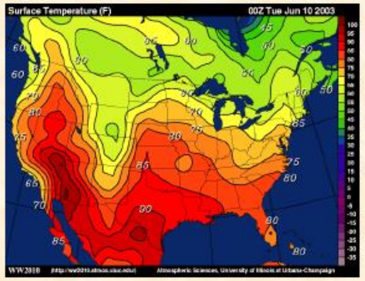


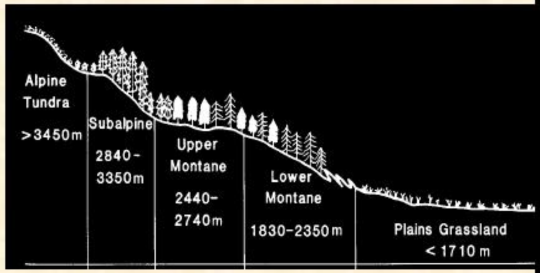
Age of Enlightenment

Alexander von Humboldt (1769-1859)

- Father of phytogeography
- Covariation of vegetation and climate
- Invented isobar and isotherm
- Expanded latitudinal biodiversity gradients into elevational gradients

> species richness increased with the increase in explored area





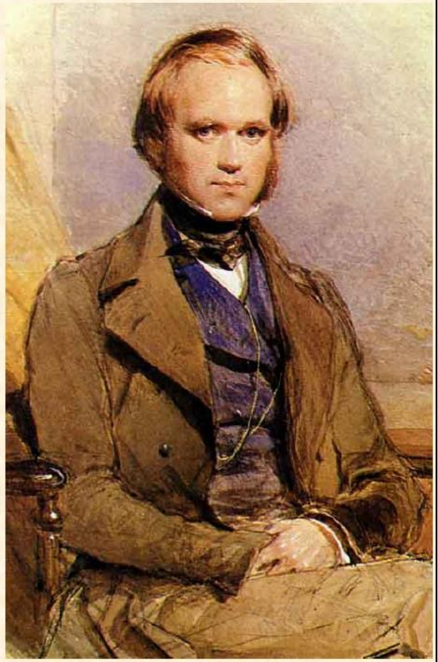
Histrory of Biogeography

Charles Lyell (1797-1875)

- Studied geology & fossils
- Uniformitarianism – physical processes now operating are timeless
- Earth's climate changes & so do species' distributions
- Species go extinct!
- Multiple creation events & sites
- Earth must be older than 6,000 yrs

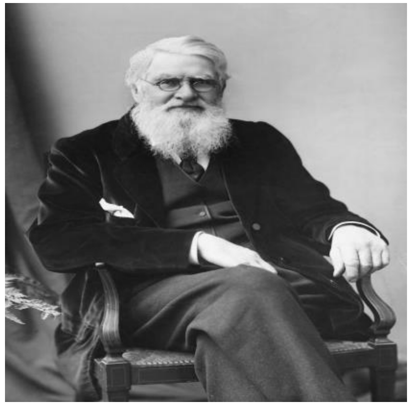
Charles Darwin (1809-1882)

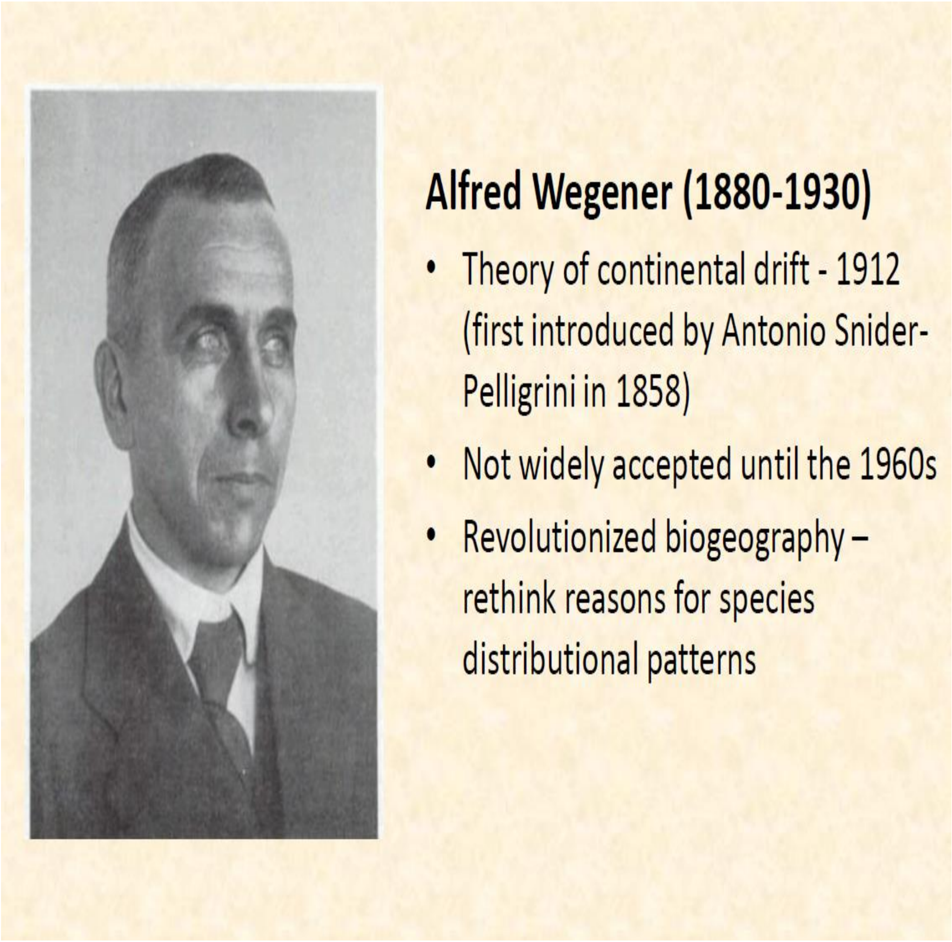
- 1831 – 5 year voyage on HMS Beagle to South America
- Collected samples of rocks, plants, animals, fossils
- Developed the theory of evolution by natural selection; *The Origin of Species* (1859)
- Emphasized importance of long-distance dispersal in biogeographic distribution of species

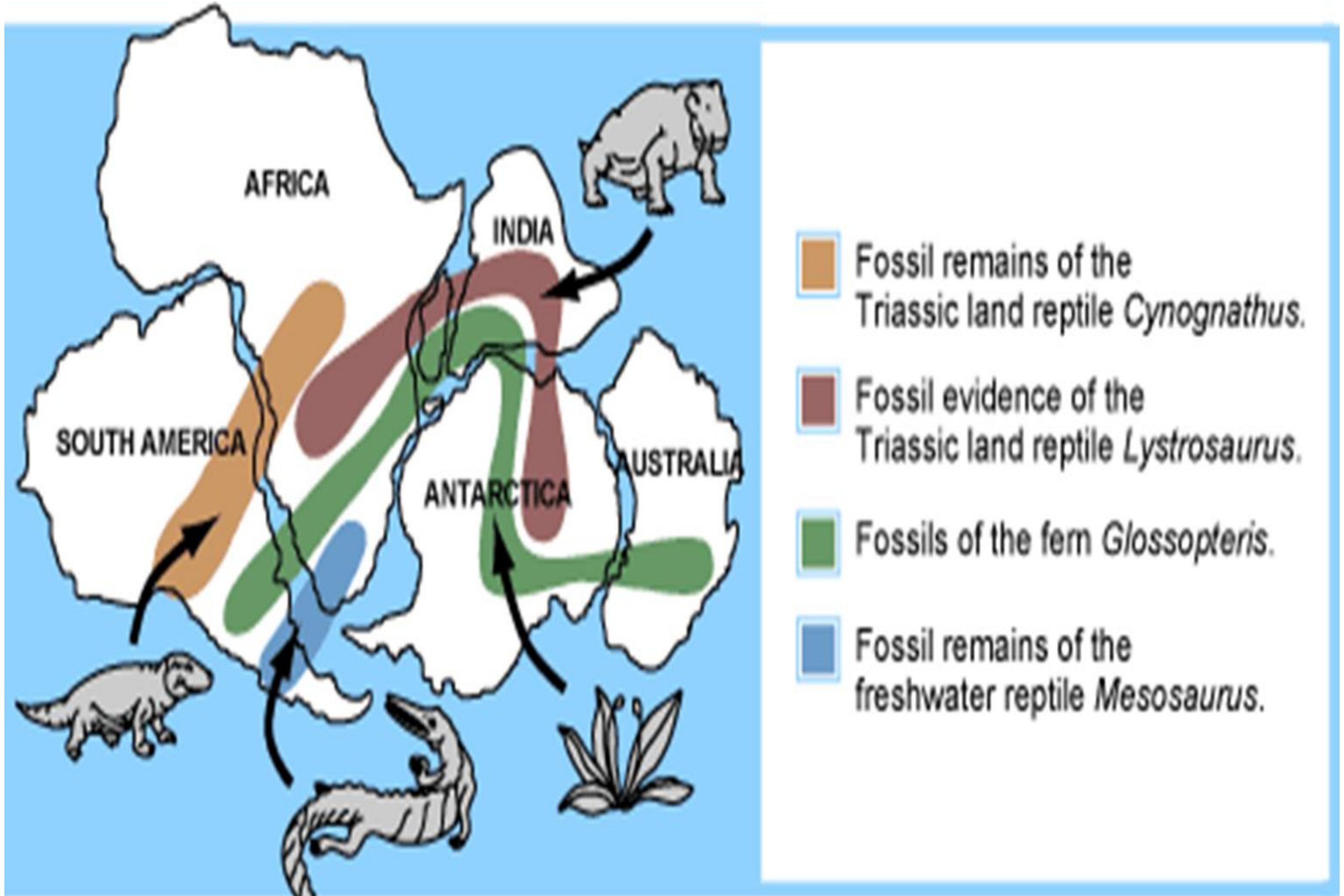


Darwin in 1840

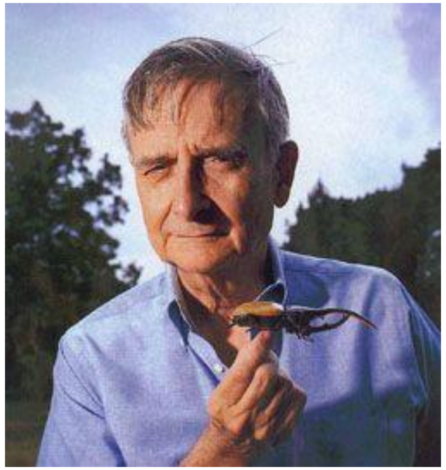
Wallace and Wegner understood Evolution



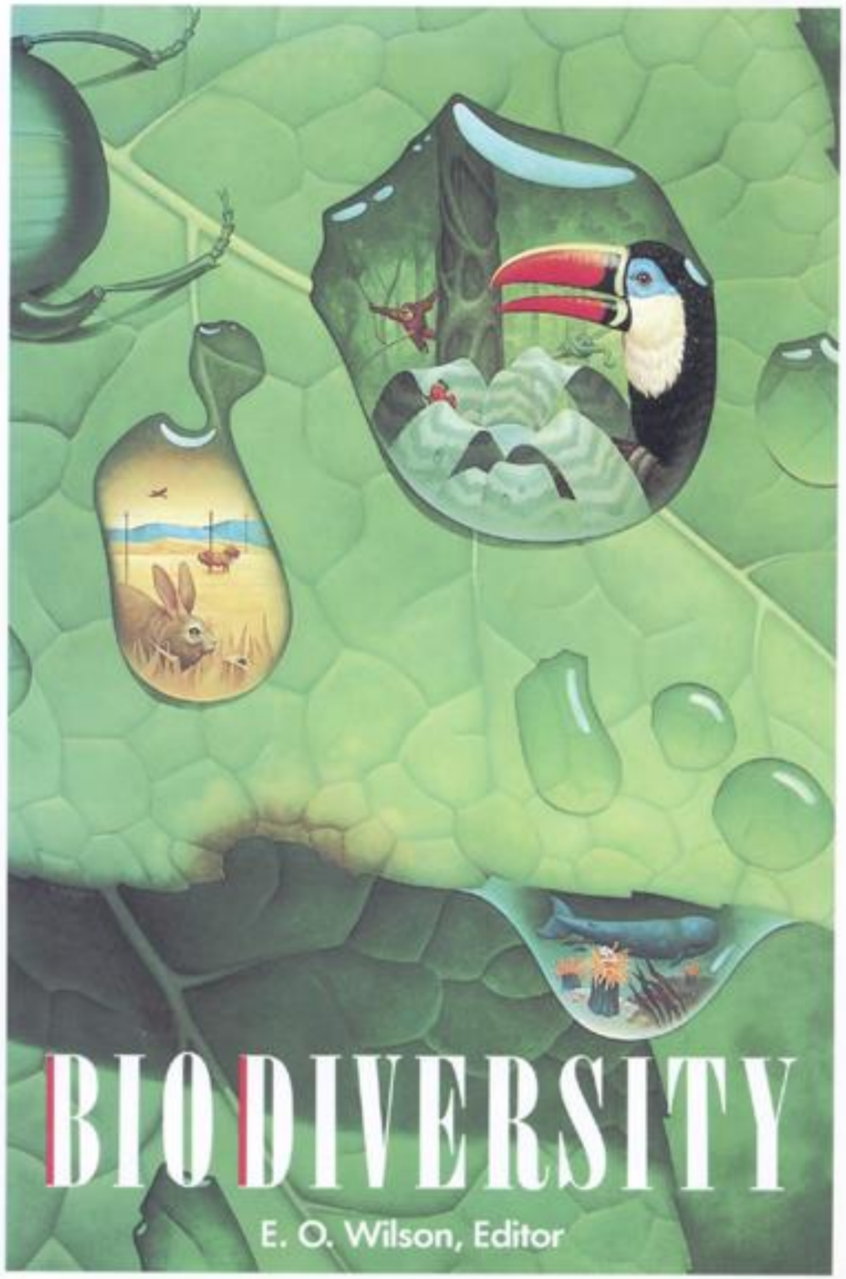


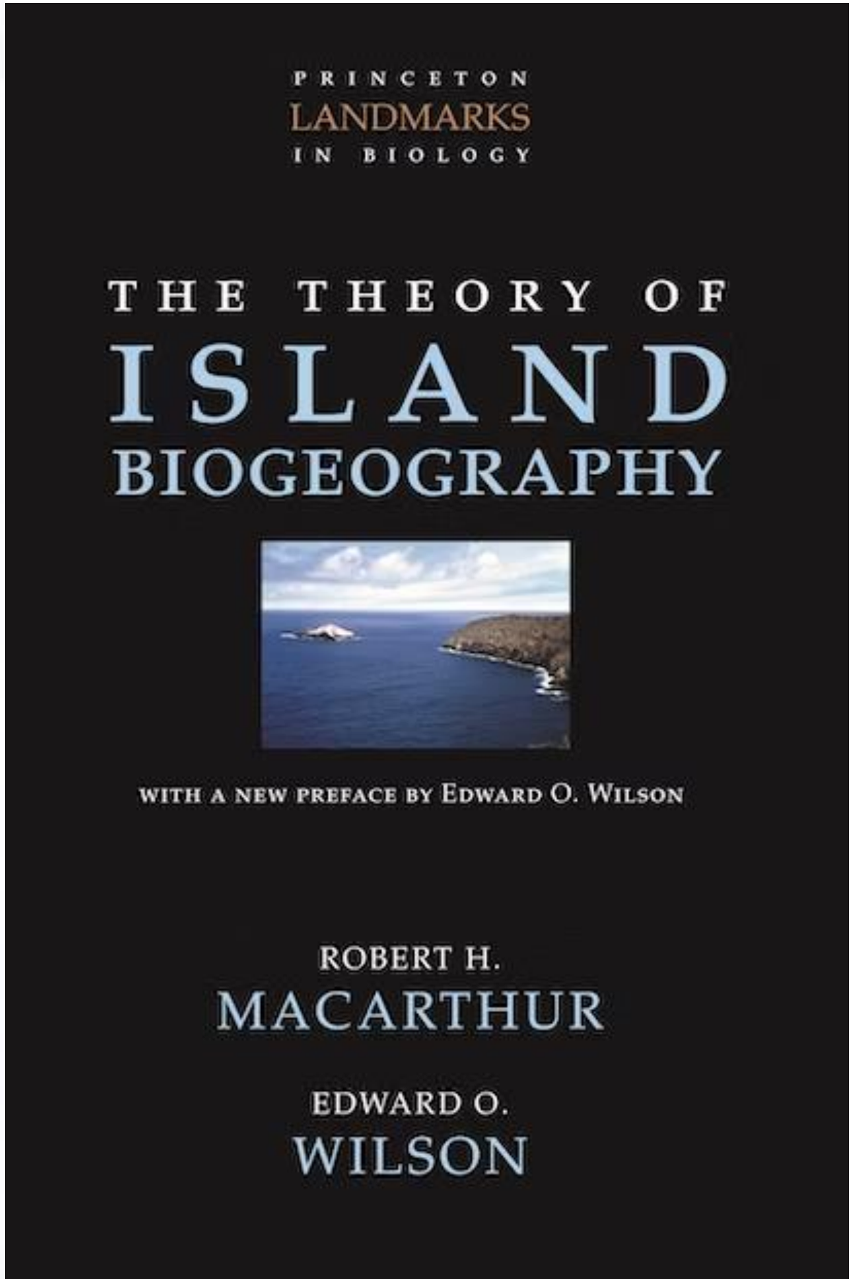


Environmental and Ecological Biogeography

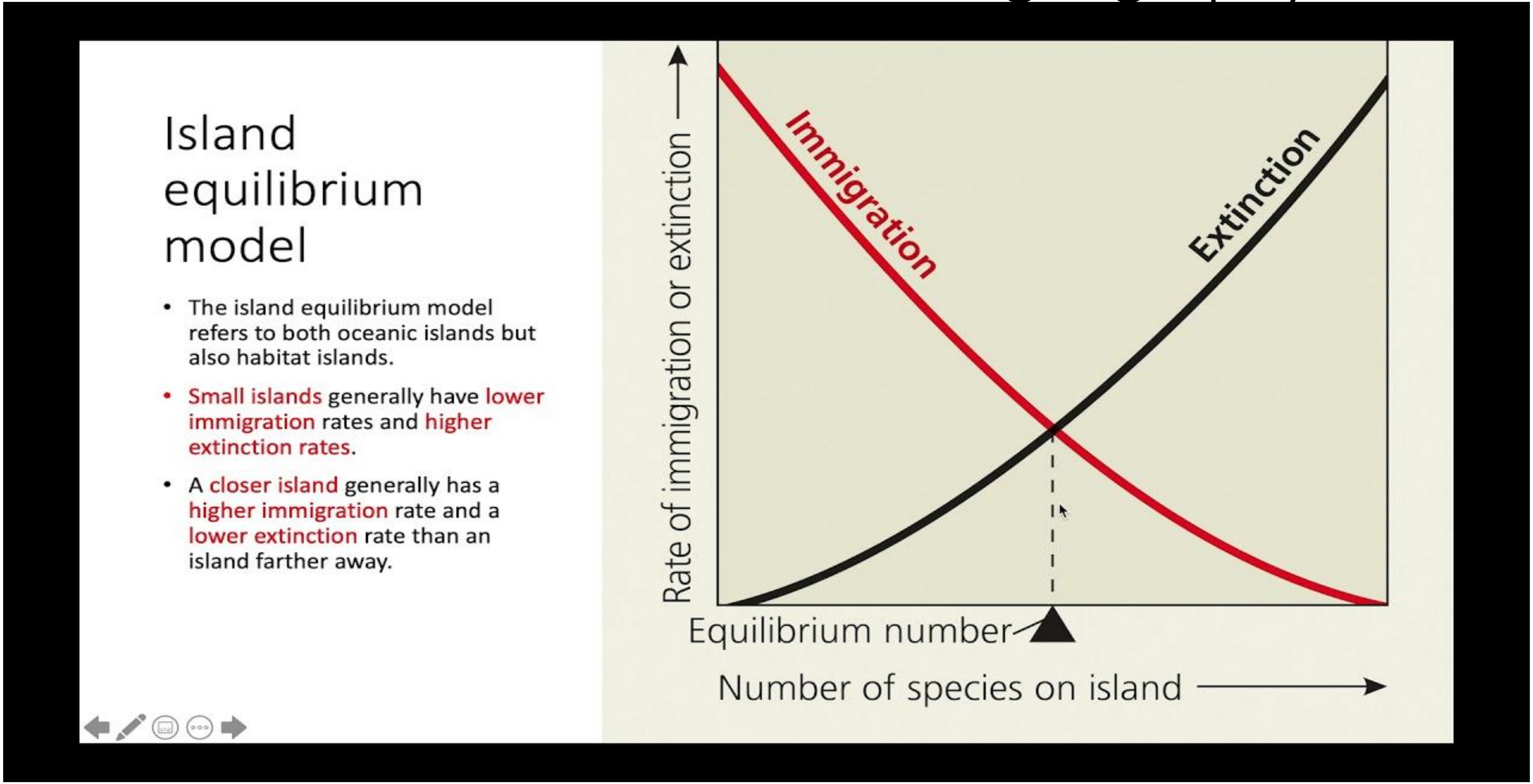


E.O. Wilson (1988)





MaCarthur and Wilson Island biogeography model



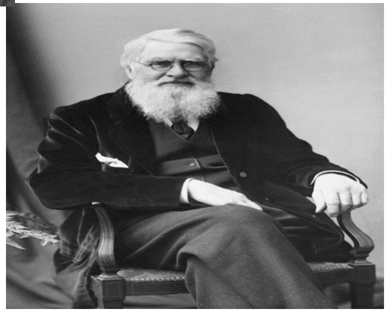
Standing on the shoulders of giants
What did they have in common?

The capability to view large spatial scale data and pattern and to interpret and speculate on long-term eco-evolutionary processes









What do we have: data bases on spatial data

- 1. **Accumulated knowledge**
- 2. Large data basis on species on a large spatial scale
- Long temporal scale is coming after, e.g. NEOTOMA
  - **Data mining**
- GBIF http://www.gbif.org or
- Splot: database on – global vegetation plot
- European Vegetation Archive database https://euroveg.org/eva-database/
- DRYFLOR, http://www.dryflor.info/
- world checklists (http://www.theplant- list.org/),
- protected area databases (https:// www.protectedplanet.net/c/world-database-on-protected-areas).
- Medis: Mediterranean island databases https://metadatacatalogue.lifewatch.euhttps://metadatacatalogue.lifewatch.eu/s

Hortal et al. 2015. Seven Shortfalls that Beset Large-Scale Knowledge of Biodiversity. Ecol & Evolution

-Diniz-Filho et al….Hortal, 2023, **Frontier of Biogeography**

3. We have an urgent biodiversity crisis

Constrained ability to think and analyse on long temporal scales
Big Challenge to explore the long temporal and spatial dimensions

What kind of data is needed:
Data that can help to interpret and predict temporal change on short and long-temporal scales

Conservation biogeography is an attempt to facilitate such analyses
To prevent biodiversity loss and facilitate species survival

Conservation Biogeography



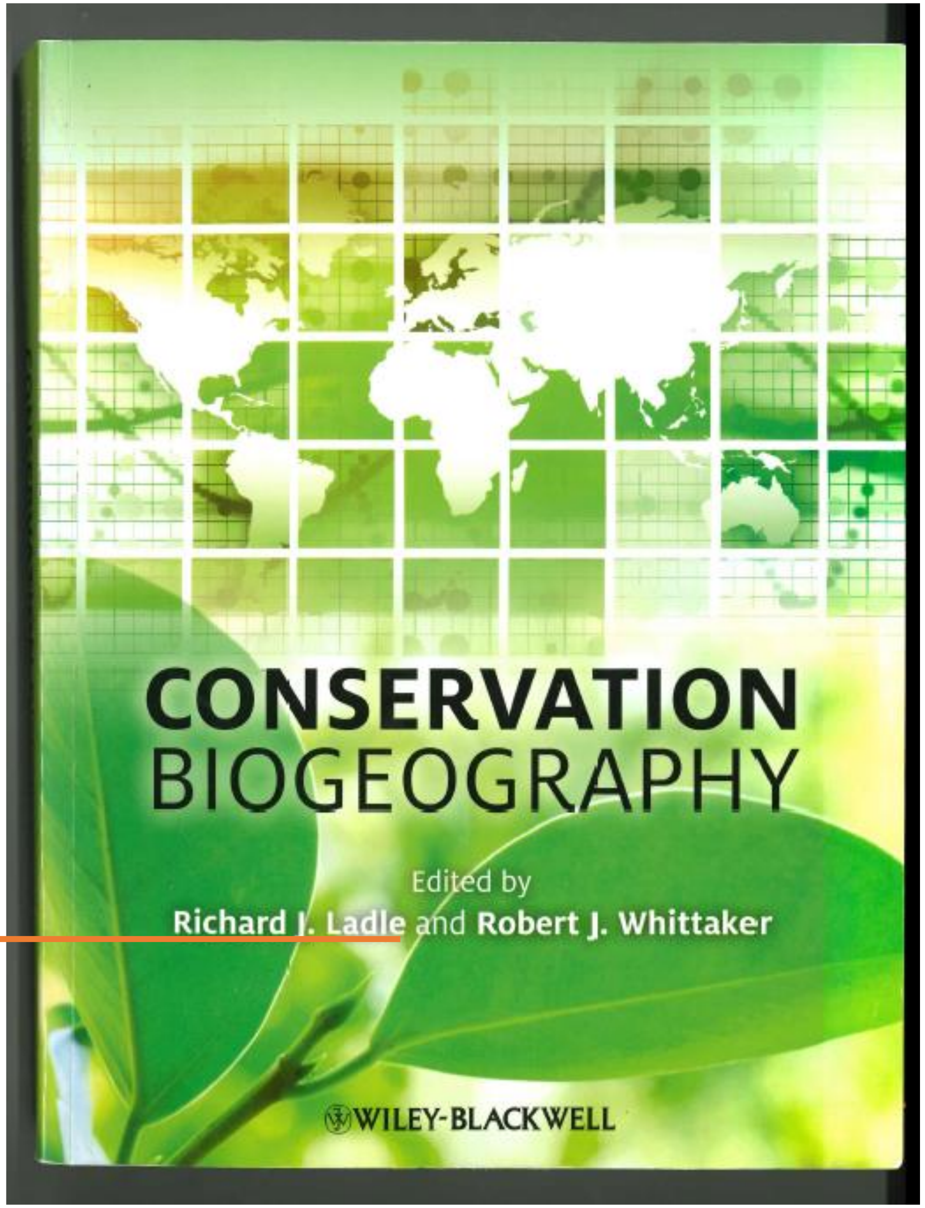
Robert J. Whittaker, Miguel B. Araújo, Paul Jepson, Richard J. Ladle, James E. M. Watson and Katherine J. Willis:
Diversity and Distributions 2005; 11:3-23

The Conservation Biogeography subfield of conservation biology is delimited as:
the application of biogeographical principles, theories, and analyses of:

I) Distributional dynamics on Species and assemblages,

II) To solve problems concerning the conservation of biodiversity

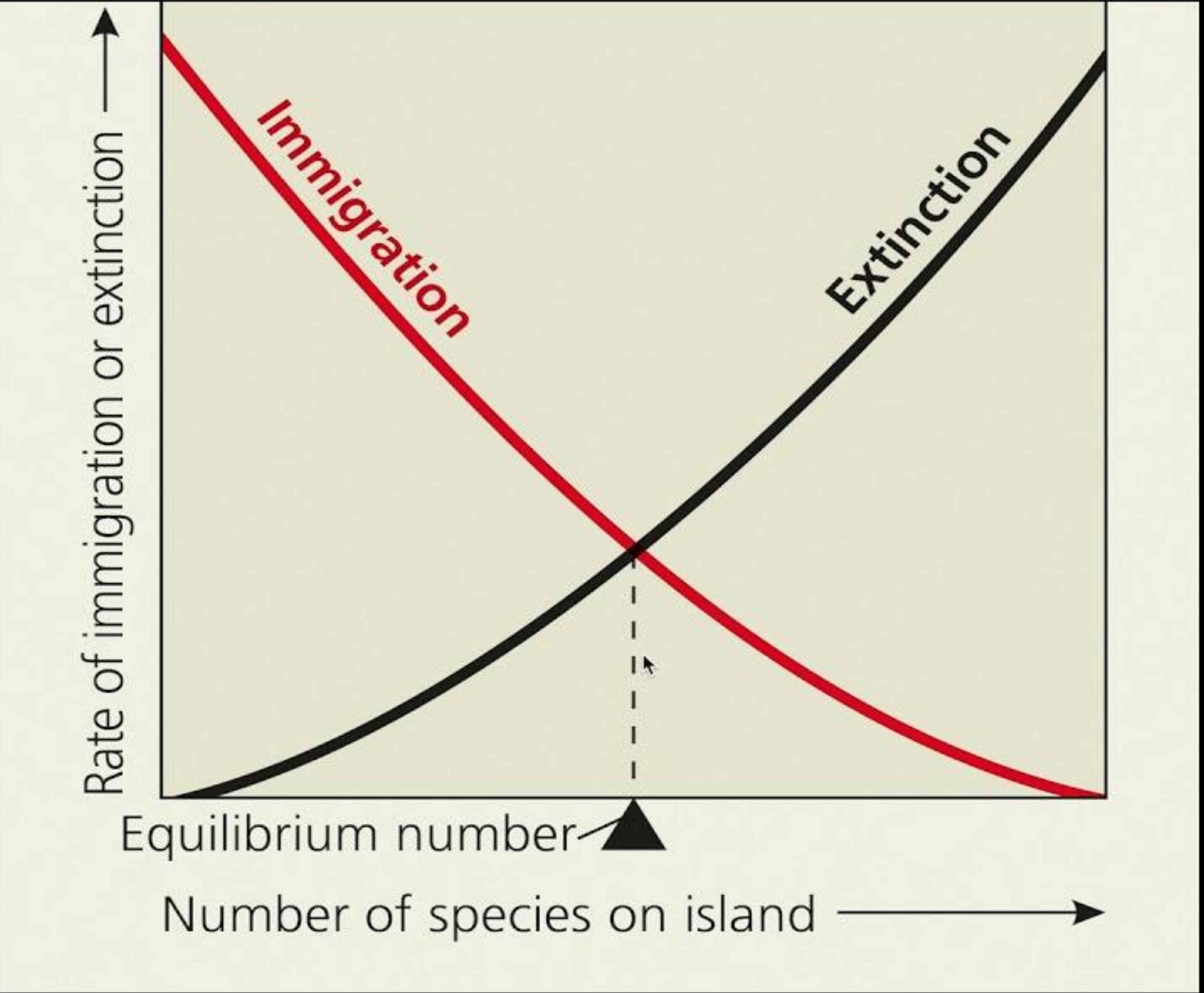
Textbook in Conservation Biogeography (2011)



MaCarthur and Wilson Island biogeography model

Island equilibrium model

- The island equilibrium model refers to both oceanic islands but also habitat islands.
- Small islands generally have lower immigration rates and higher extinction rates.
- Distance to the **nearest** species pool determines isolation and thereby immigration and richness both for endemics and total Species richness On Island and skyislands



Island biogeography model;
The equilibrium assumption has been challenged
Still the model is central in Conservation Biography

Gilbert, F.S. 1980 **The Equilibrium Theory** of Island Biogeography: Fact or Fiction?, Journal of Biogeography, 7: 209-235

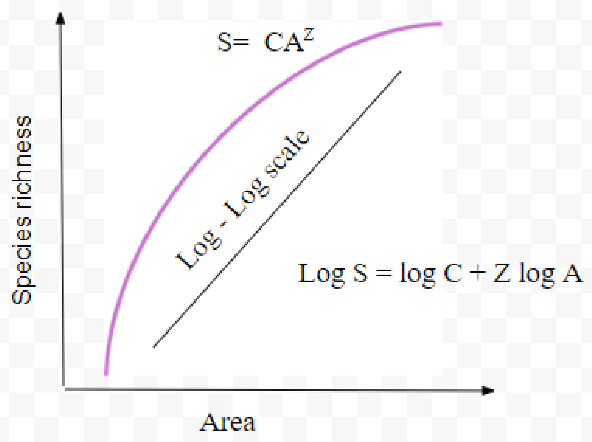
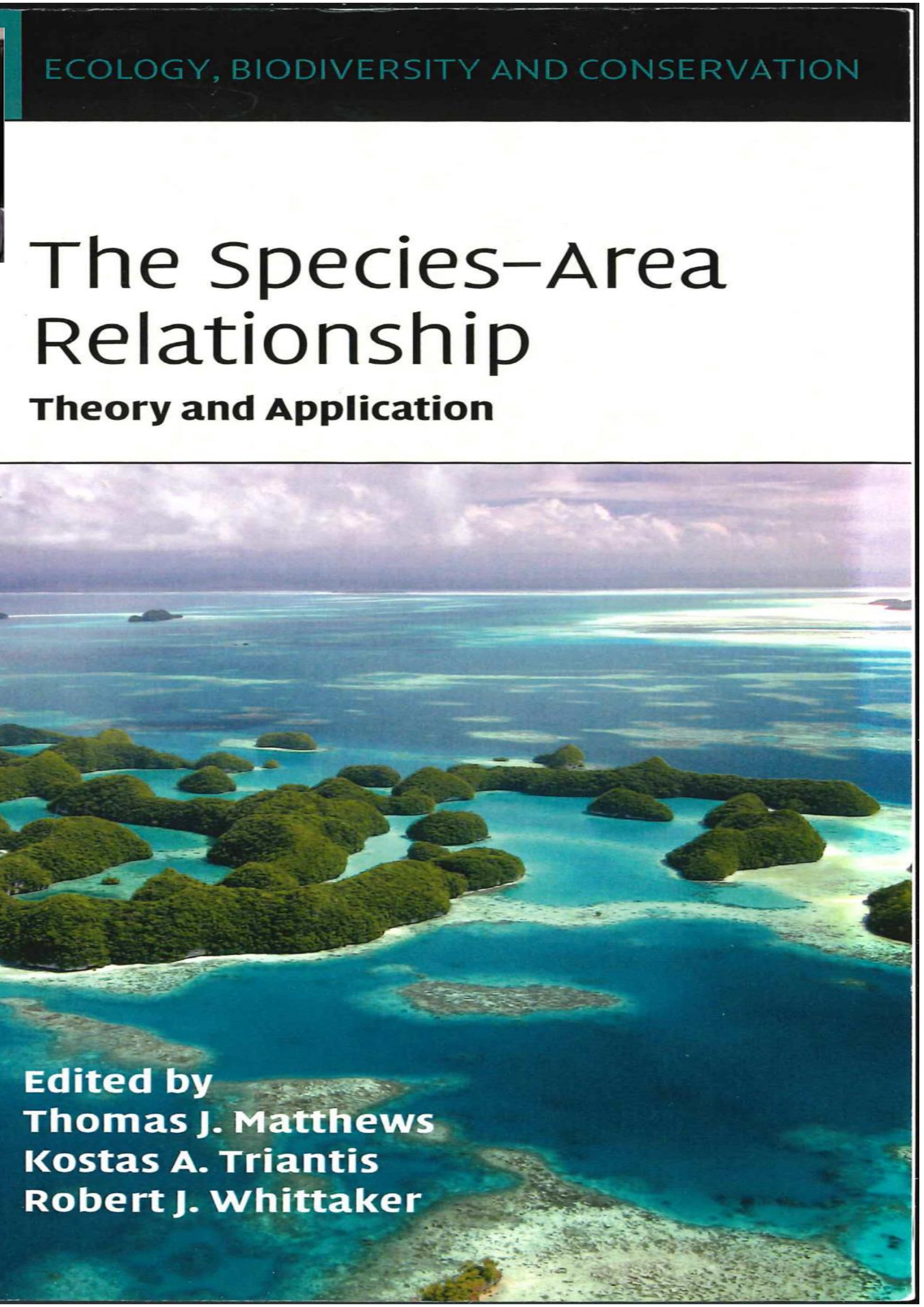
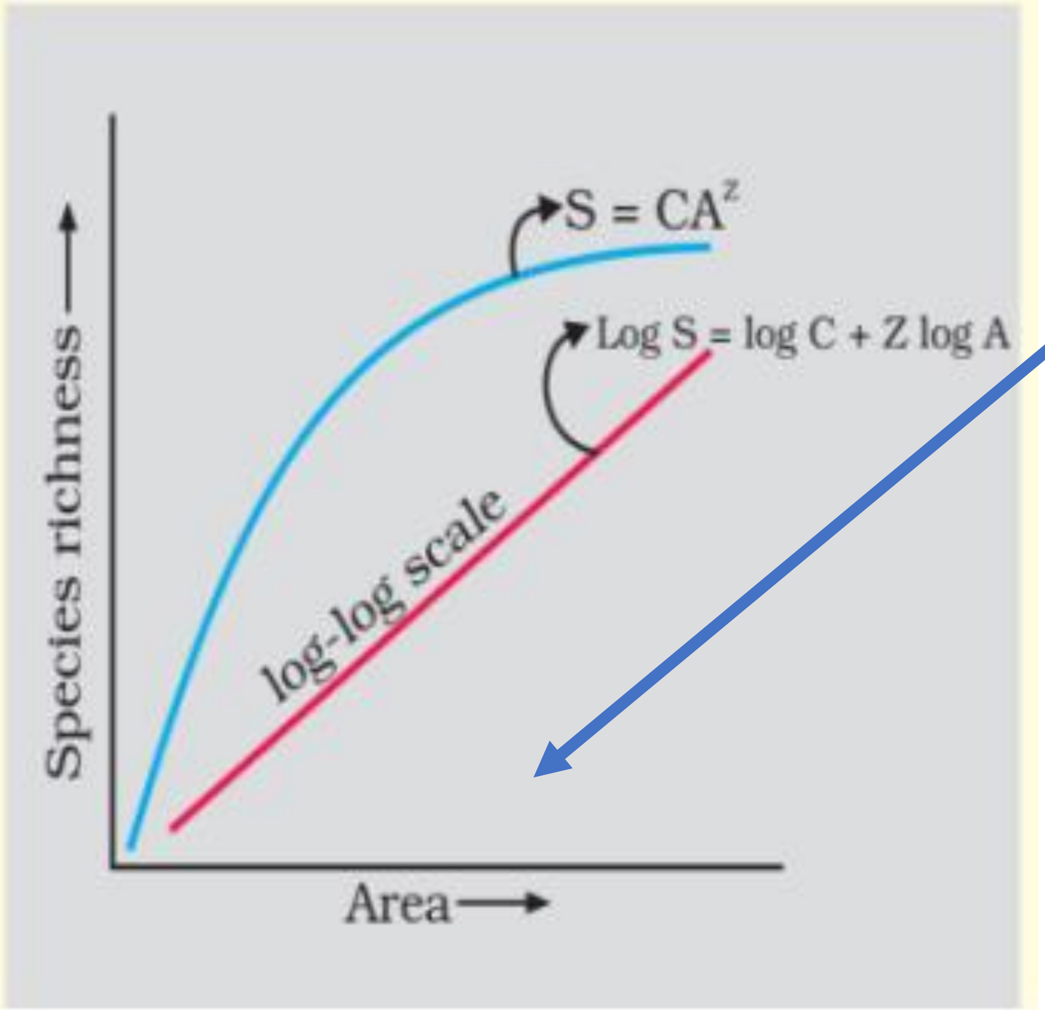


Fig: Specie area relationship which is linear on log scale

Matthews; Triantis
2021



SAR: how many species increase pr unit are NOT the same as how many species are lost with less area



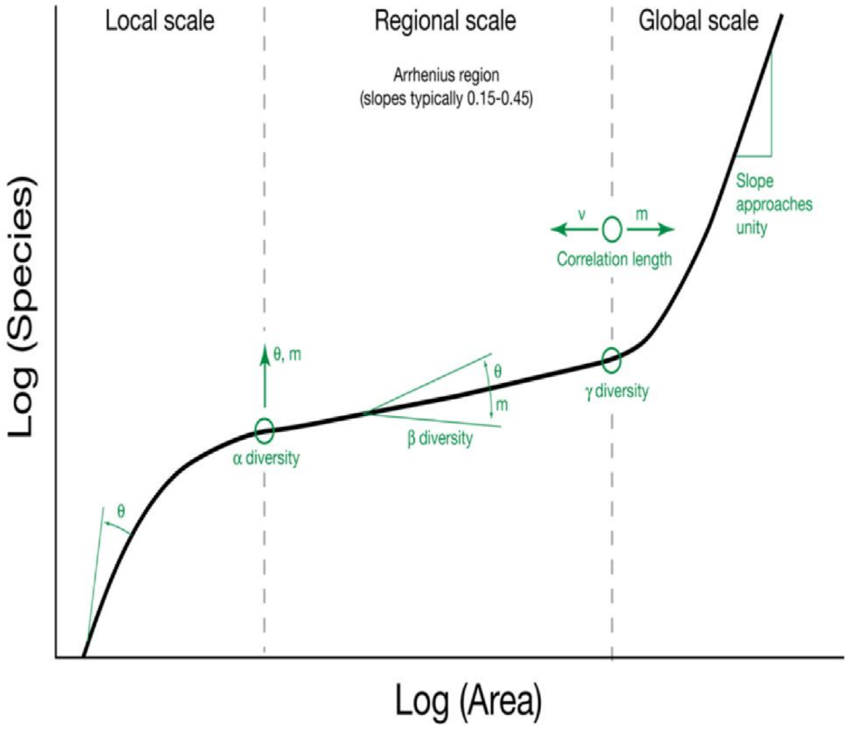
Species–area relationships always overestimate extinction rates from habitat loss, **He & Hubbell 2011**

Fangliang He[1,2] & Stephen P. Hubbell[3,4]

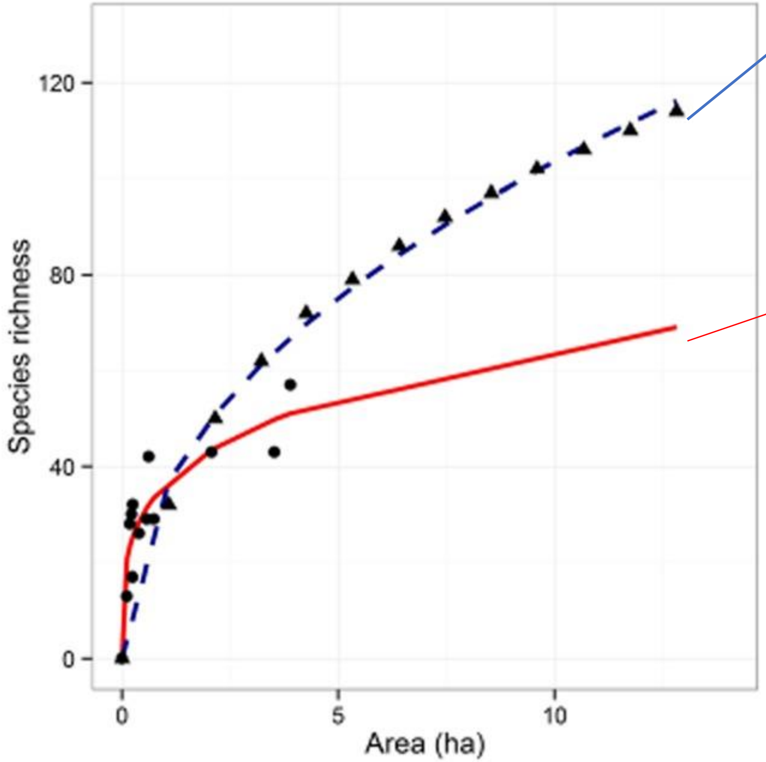
Can not extrapolate the other way, i.e. decreasing area, but see

Fattorini et al. 2023, Using the SAR to predict extinction resulting from habitat loss, chp. 14 in SAR – book Mathews et al.

SAR dependent on scale and degree of beta diversity



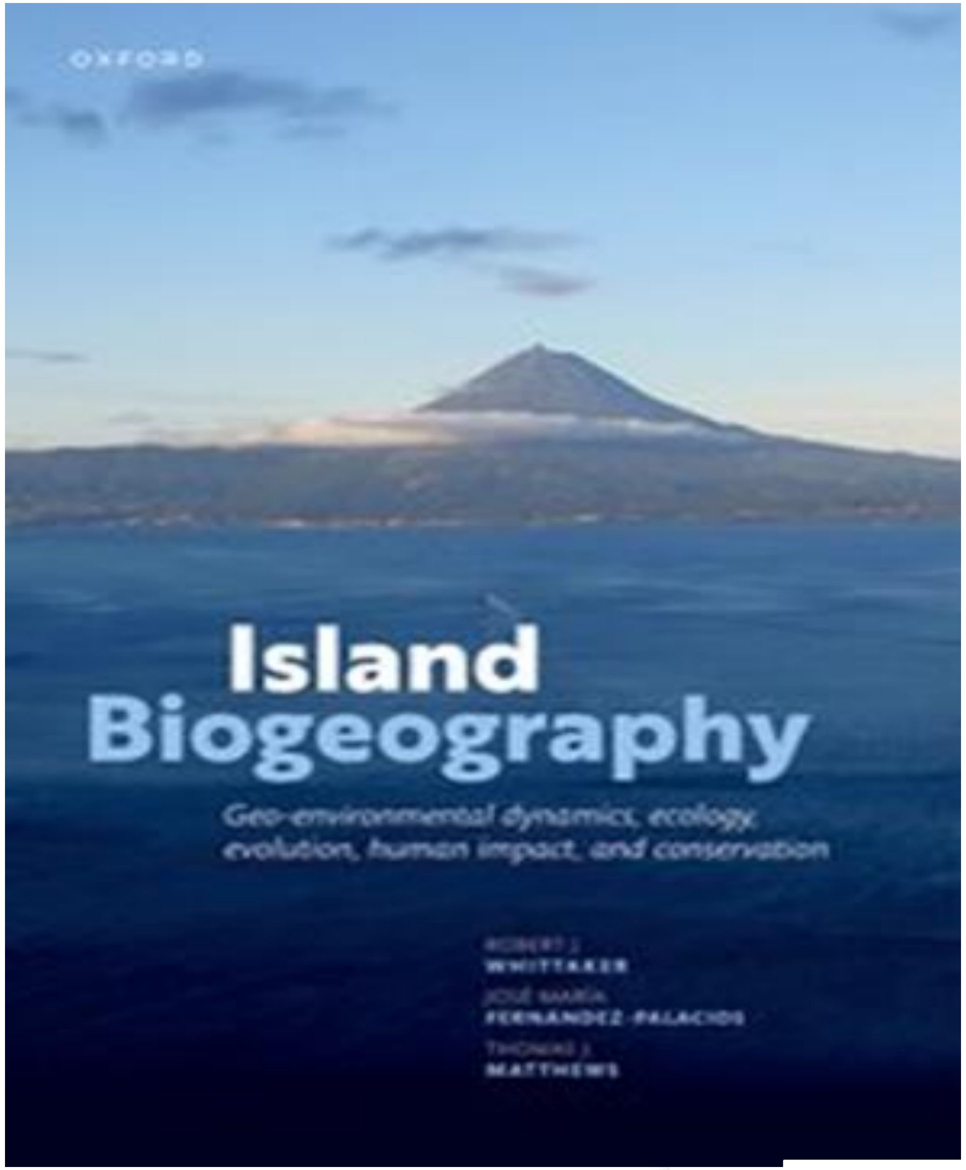
Island species–area relationships and species accumulation curves are not equivalent: an analysis of habitat island datasets
Thomas J. Matthew 2016, GEB.

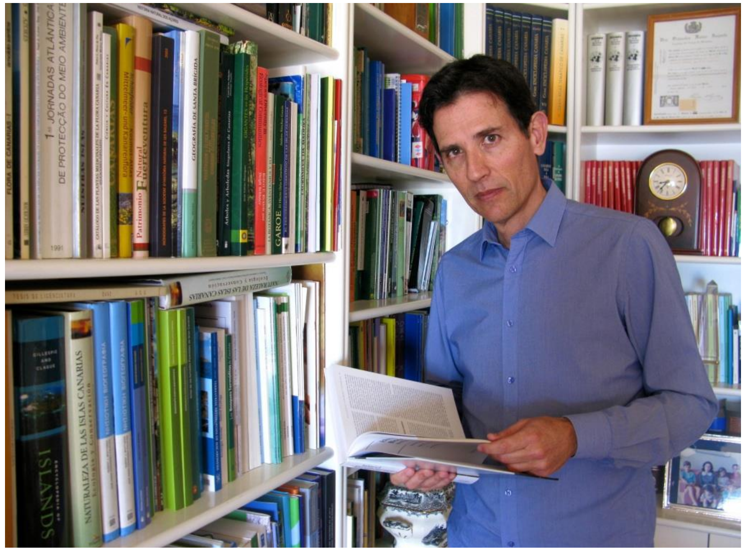


The randomized species accumulation curve (Ran-SAC) data the dashed line is the model fit)

The fits of the power model (nonlinear) to the island species–area relationship (ISAR) data (solid circles; the solid line is the model fit)

Main conclusions
Slopes of the ISAR and SAC for the same data set can vary substantially, revealing their non-equivalence, with implications for applications of species–area curve parameters in conservation science.





Whittaker R. Fernandez-Palacios, J.M and Matthews, T.

Why are island biodiversity hot spot When they are species poor

- Geographic Isolation causes allopatric speciation processes
- Many islands in tropical and subtropical favourable climate
- Biodiversity hot spot because of incredible many endemics

  of single islands or archipelagos
- 20 % of the world's biodiversity is found on islands

- Endemics specialists versus generalists
- The long-term survival of specialists may be jeopardized when introduced species become invasive
- Introduced and invasive species and endemic species:

  core topics in **Conservation biogeography**

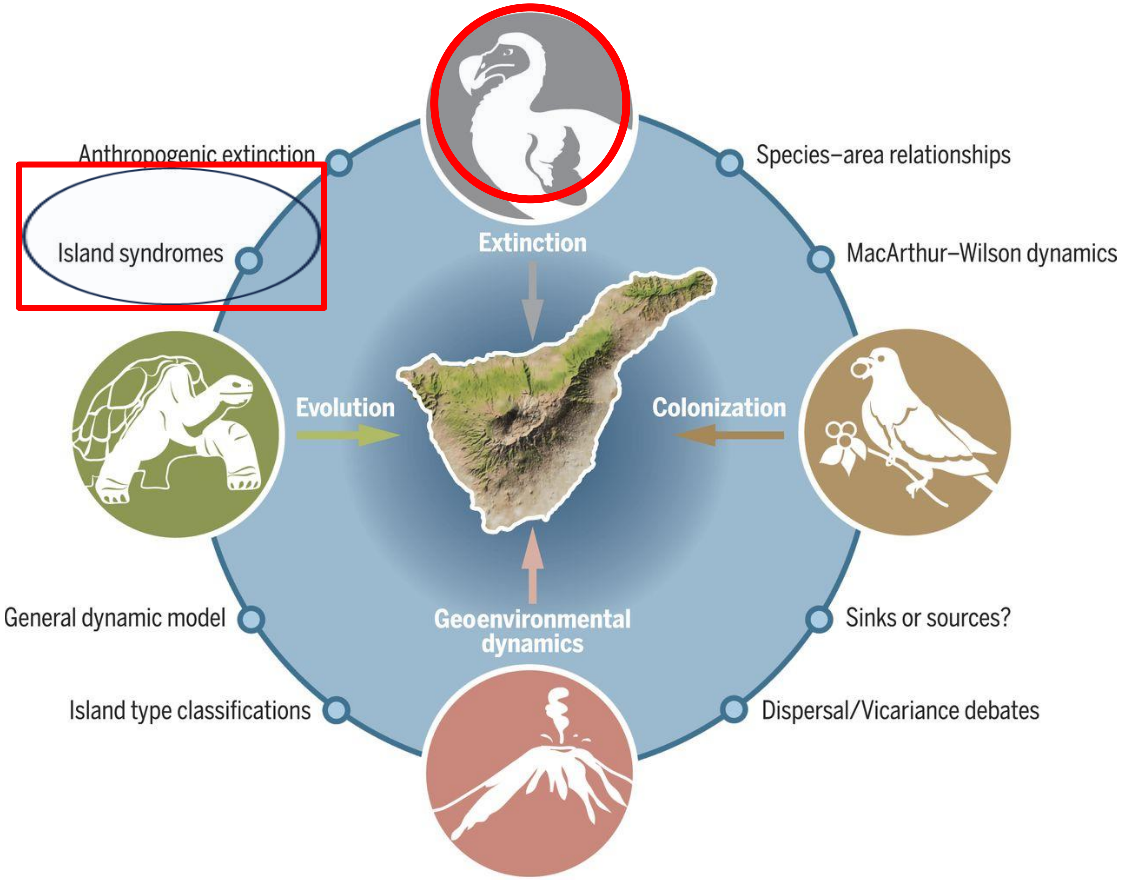
RESEARCH

REVIEW SUMMARY Science 2017.

BIOGEOGRAPHY

Island biogeography: Taking the long view of nature's laboratories

Robert J. Whittaker,* José María Fernández-Palacios, Thomas J. Matthews, Michael K. Borregaard, Kostas A. Triantis



Temporal scale:
What select for secondary woodiness

Earlier hypothesis

Lack of herbivores

No seasonal change

No lean season

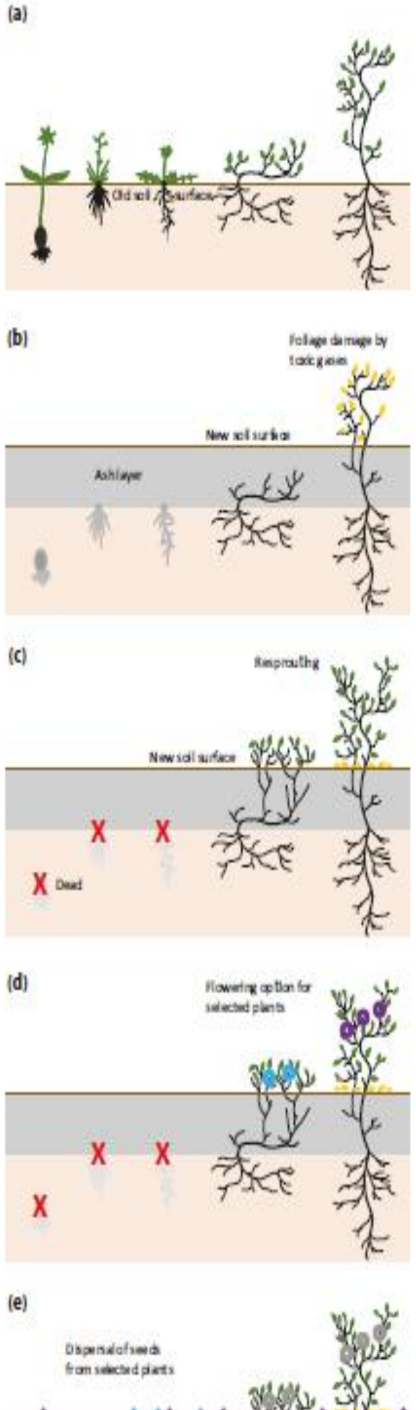
If there is one eruption every century

Small islands 2 million years= 20.000 eruptions

Thus, a plausible selection pressure for plants

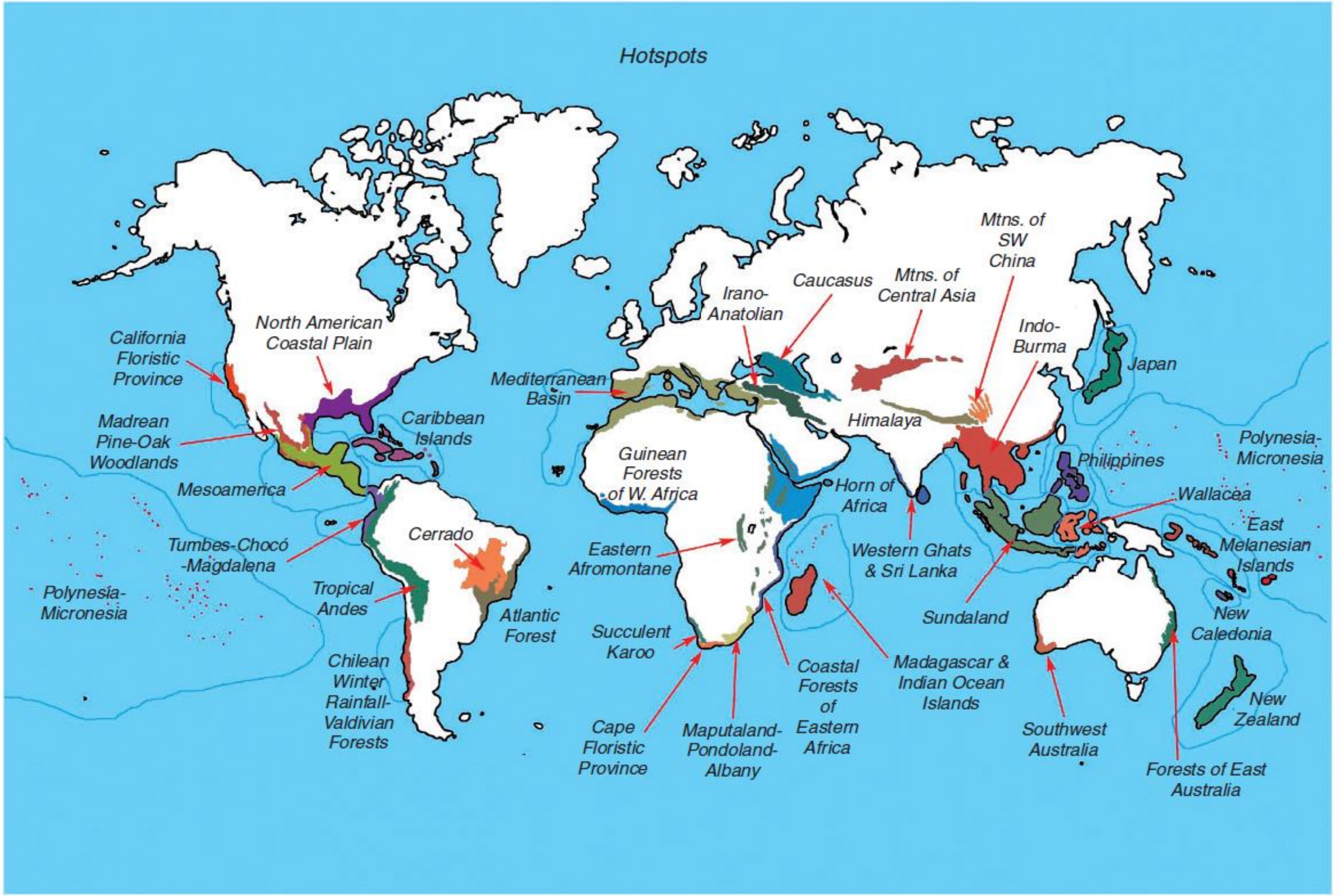
Beierkuhnlein et al. 2023,

Postulate that volcanic ash selects for woodiness through an increased ability to avoid burial of plant organs by ash, and to re-emerge above the new land surface



Major world centres of endemism experiencing high rates of habitat loss

30% of these hot spots are island archipelagos or contain island archipelagos, e.g. Mediterranean basin.

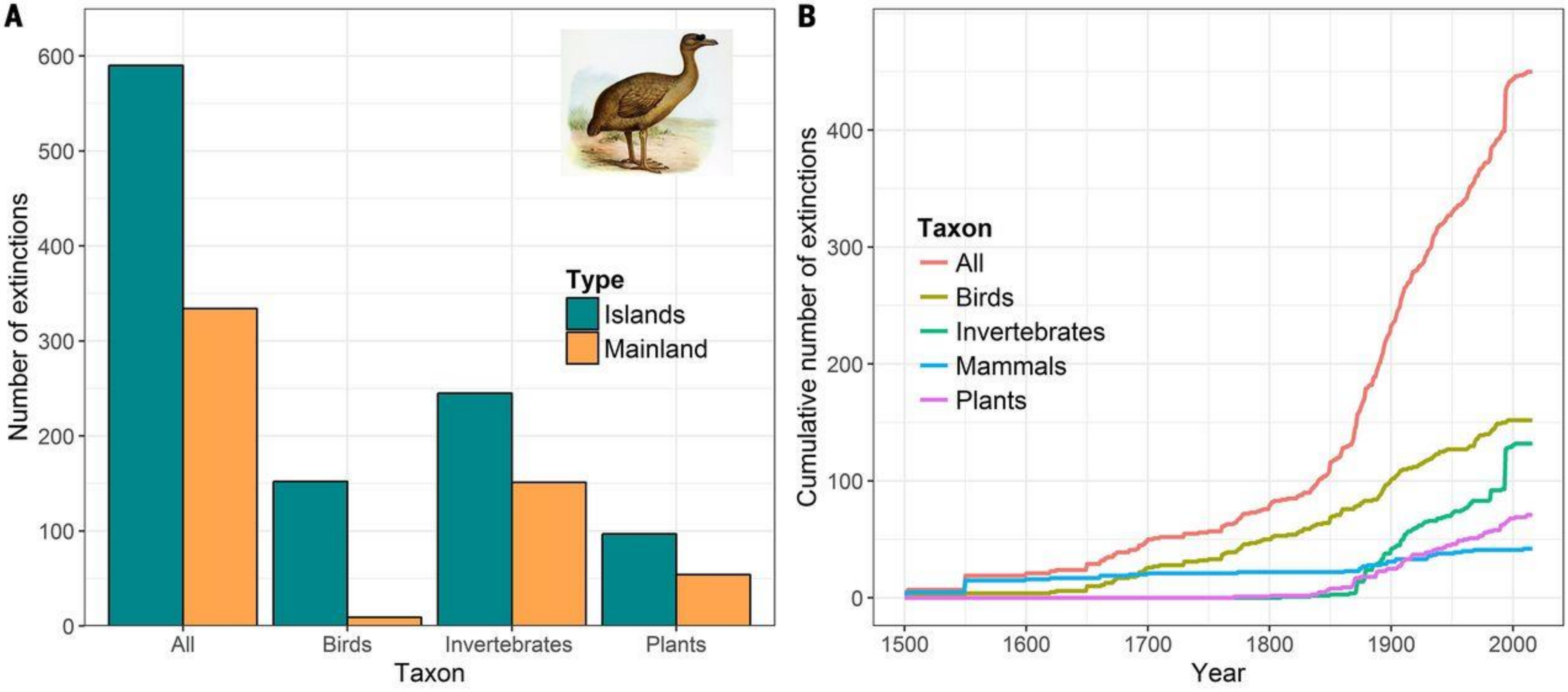


1. Currently recognized global hotspots of plant endemism, which are defined as having >1500 endemic plant species and >70 % habitat conversion. Ste
D. Nash © Conservation International.

Extinction and isolation

- 50 % of all endangered species (red listed) live on islands
- 75 % of all recoded extinctions

- 85 % of these extinction on islands are linked to invasive species

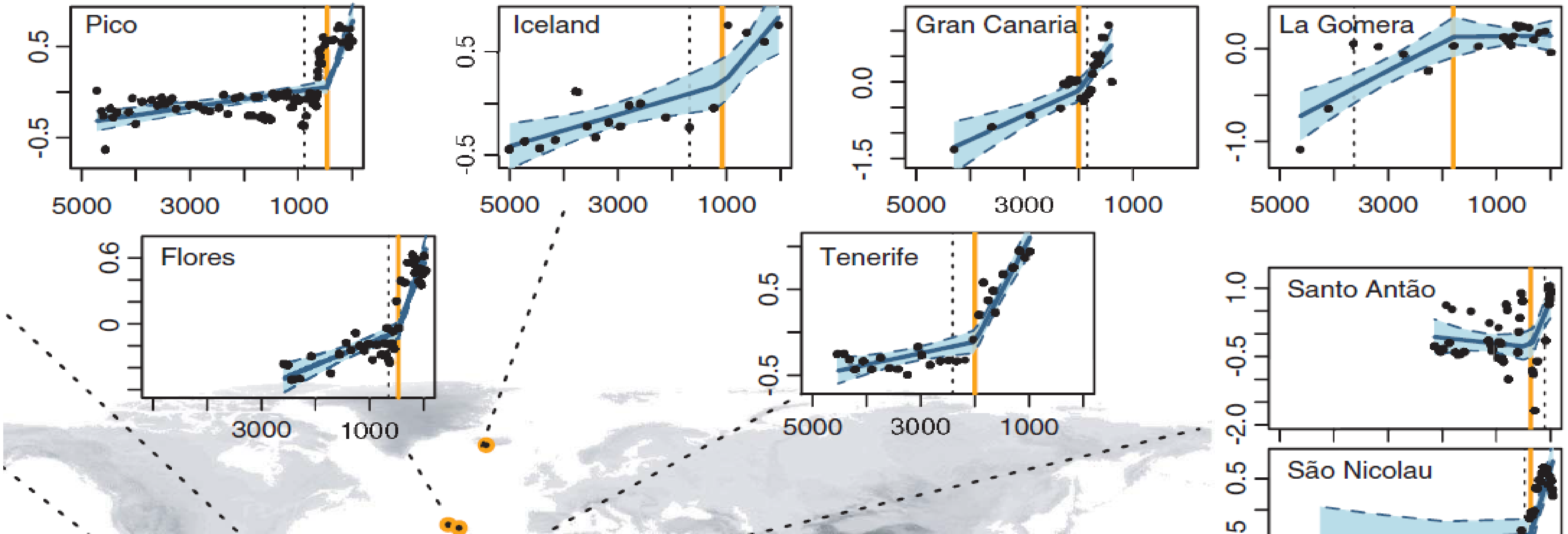

A
600
500
400
300
200
100
0
Number of extinctions
Type
Islands
Mainland
All
Birds
Invertebrates
Plants
Taxon
B
400
300
200
100
0
Cumulative number of extinctions
Taxon
All
Birds
Invertebrates
Mammals
Plants
1500
1600
1700
1800
1900
2000
Year

Reasons for extinction

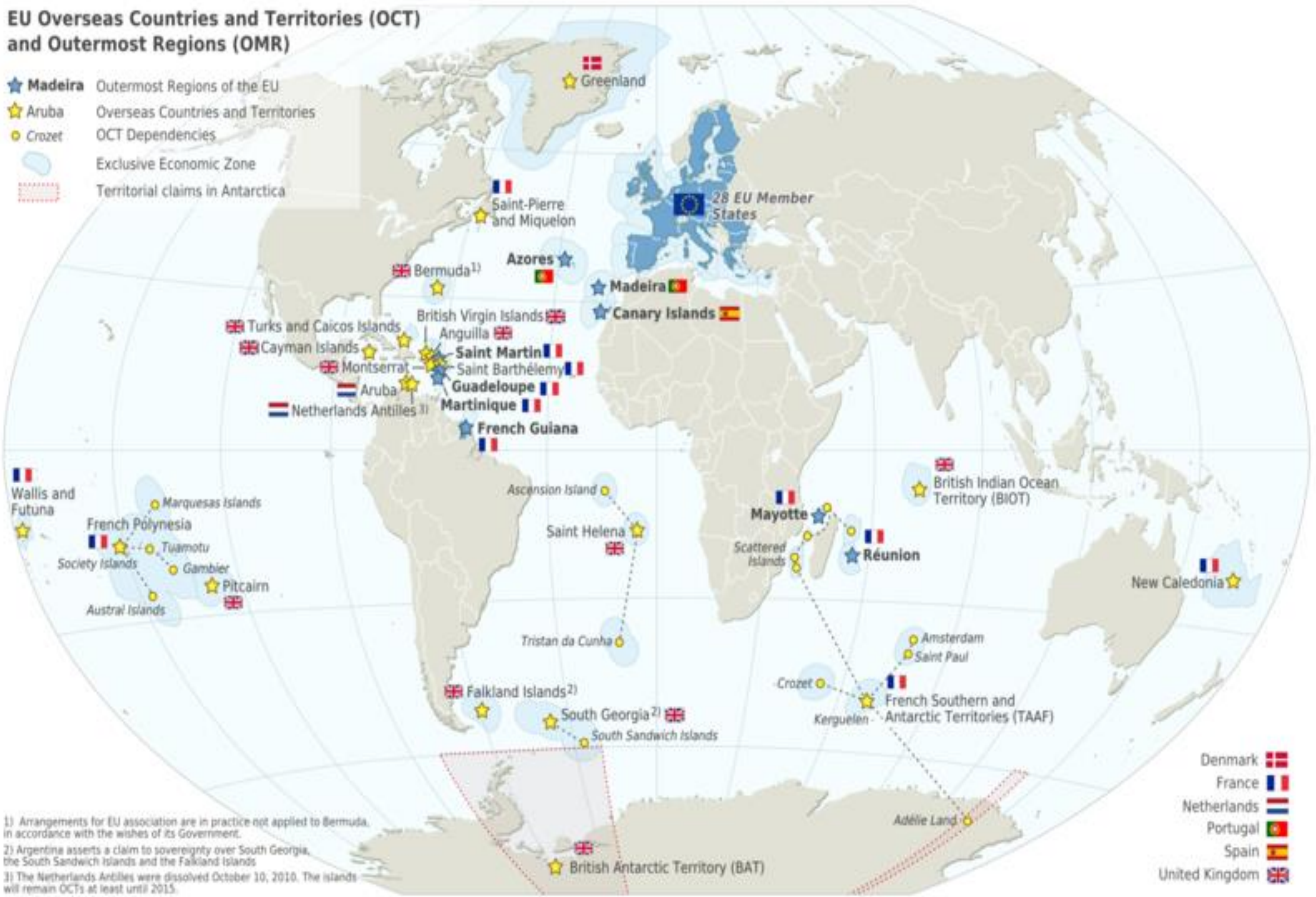
- Volcano
- Landslides
- Sea level rise and sink
- Subsidence
- Hurricanes
- Intrinsic population
- Close to minimum viable population number
- Fonder effect, i.e. low genetic diversity
- Few enemies, but then came the humas and altered the ecosystem (Sandra Nogue and Manuel Steinbauer, science paper)

The human dimension of biodiversity changes on islands

Sandra Nogué[1]†*, Ana M. C. Santos[2,3,4,5], H. John B. Birks[6,7], Svante Björck[8], Alvaro Castilla-Beltrán Simon Connor[9,10], Erik J. de Boer[11], Lea de Nascimento[12,13], Vivian A. Felde[6], José María Fernández-Palacios[12], Cynthia A. Froyd[14], Simon G. Haberle[9,10], Henry Hooghiemstra[15], Karl Ljung[8], Sietze J. Norder[16], Josep Peñuelas[17,18], Matthew Prebble[9,19], Janelle Stevenson[9,10], Robert J. Whittaker[20,21], Kathy J. Willis[22], Janet M. Wilmshurst[13,23], Manuel J. Steinbauer[24,25]†*

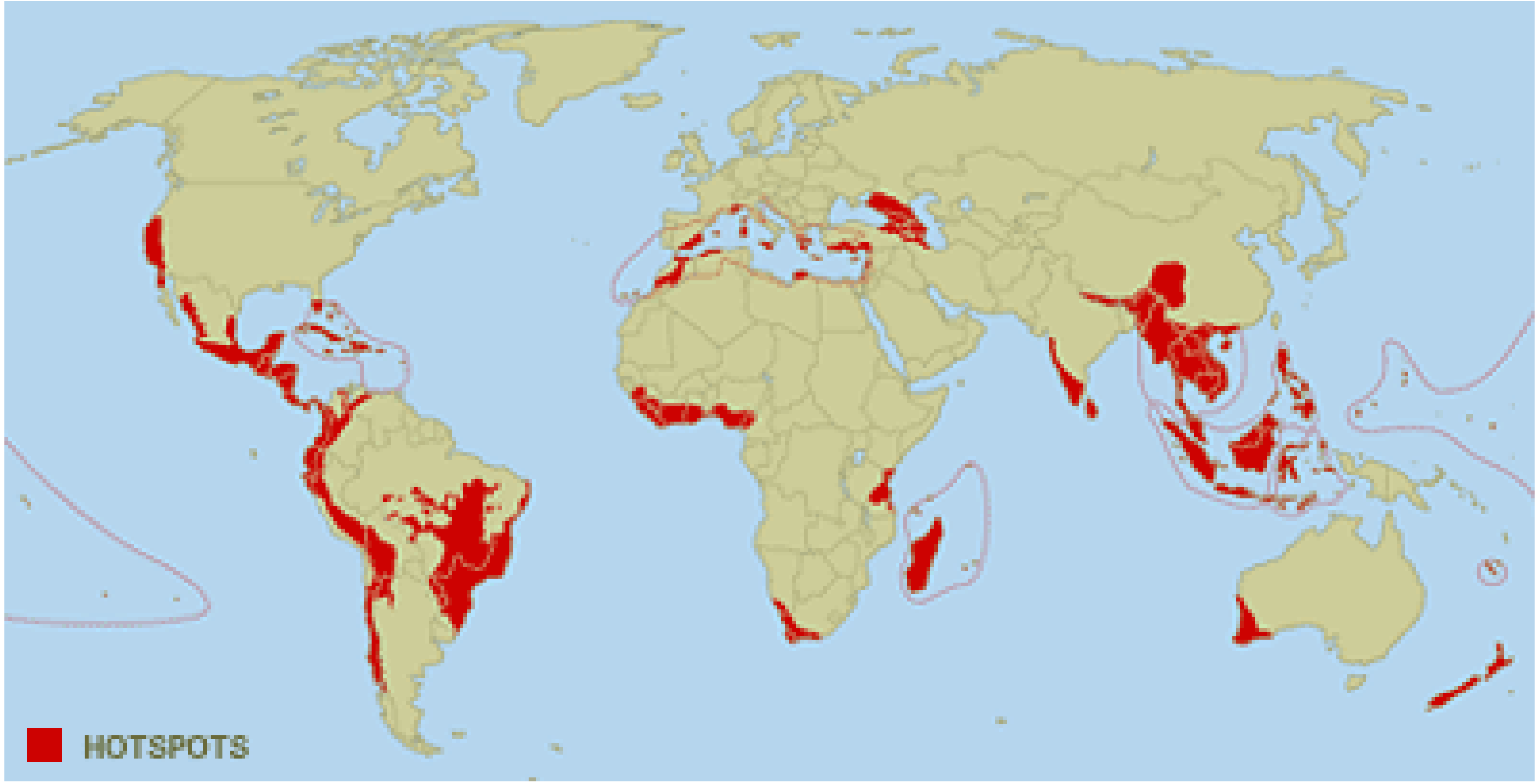


Data to be collected and EU-directives to be implemented



80 % of EU biodiversity on the island belongs to EU states,
ought to be committed to implementing the **habitat & water directives**!!!!.

Endemism worldwide (hotspots)



Mountains as mimicry of the global zonation in latitude = many habitats short spatial distance

Alpine Tundra

Montane Coniferous Forest

Deciduous Forest

Tropical Forest

high

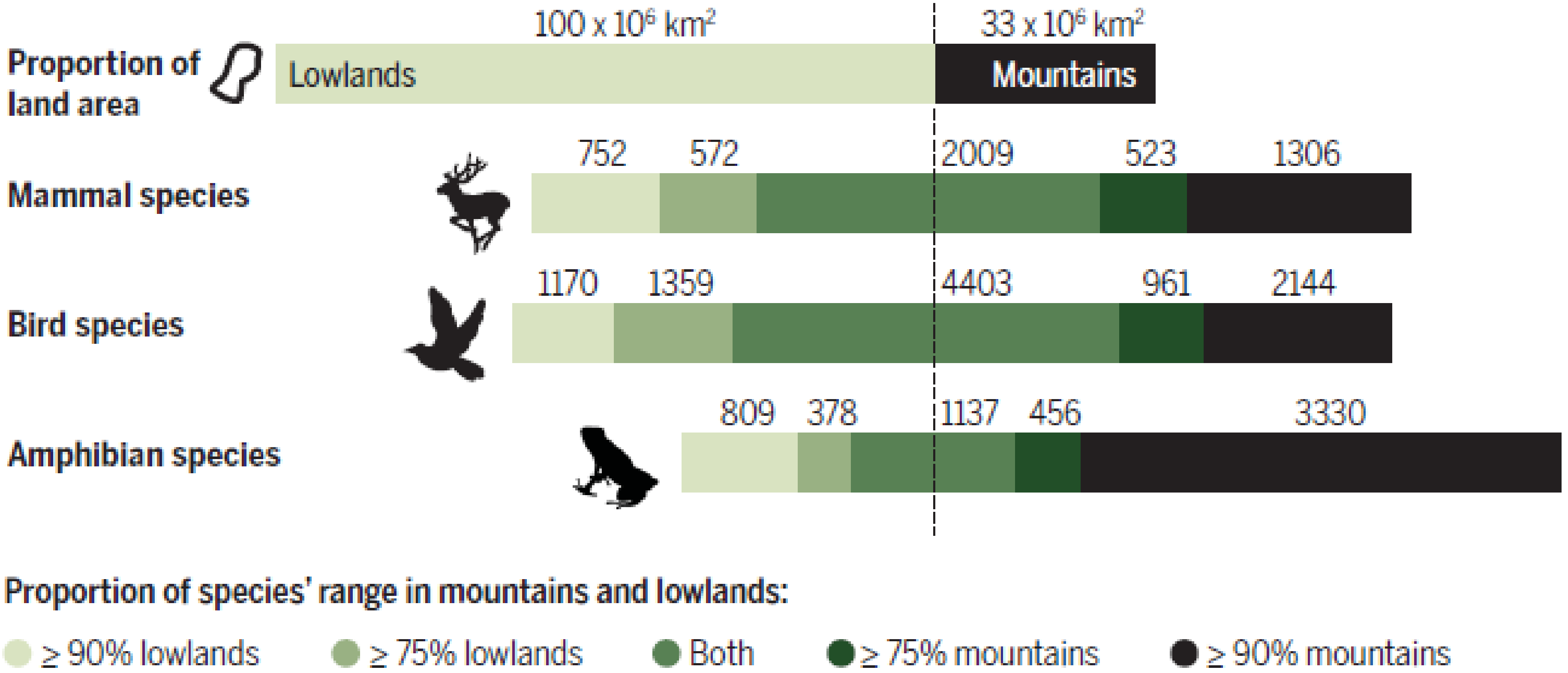
Elevation

low

Tropical Forest | Temperate Deciduous Forest | Northern Coniferous Forest | Arctic Tundra

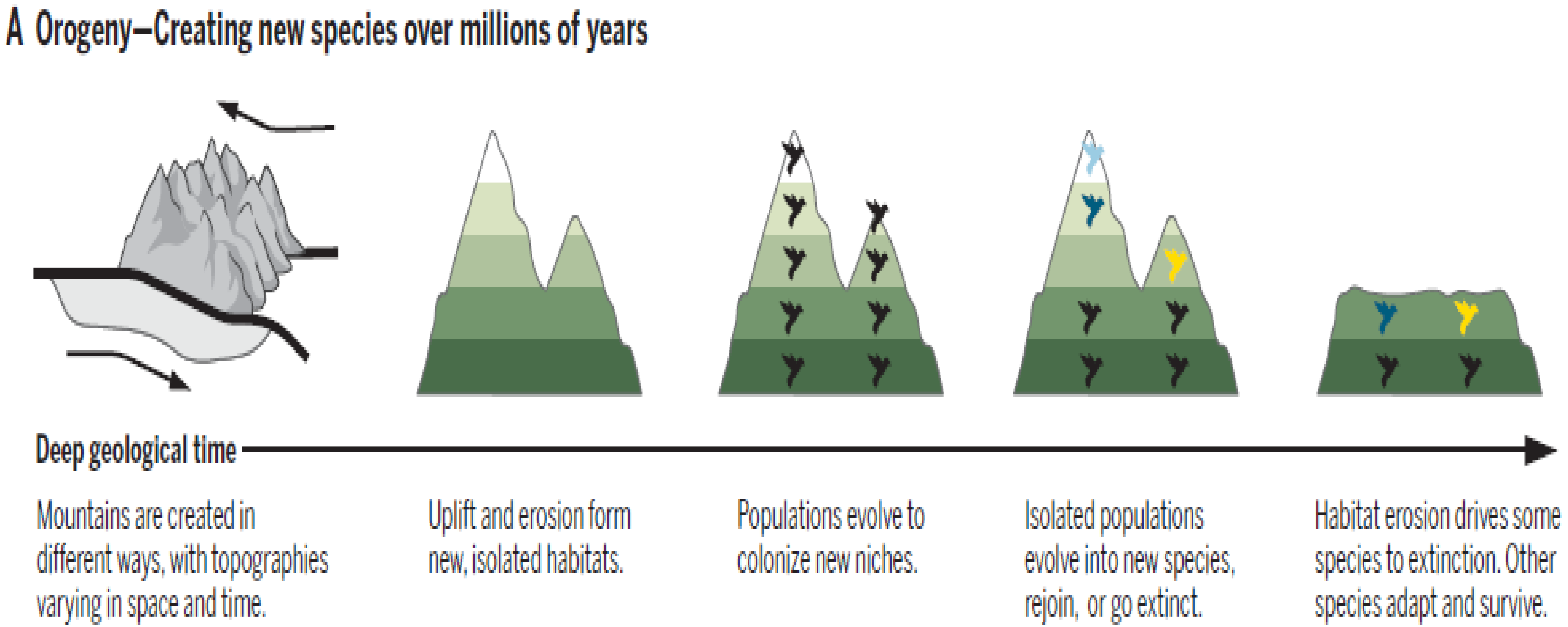
High **Temperature & Moisture availability** Low

High proportion of biodiversity in mountain ranges

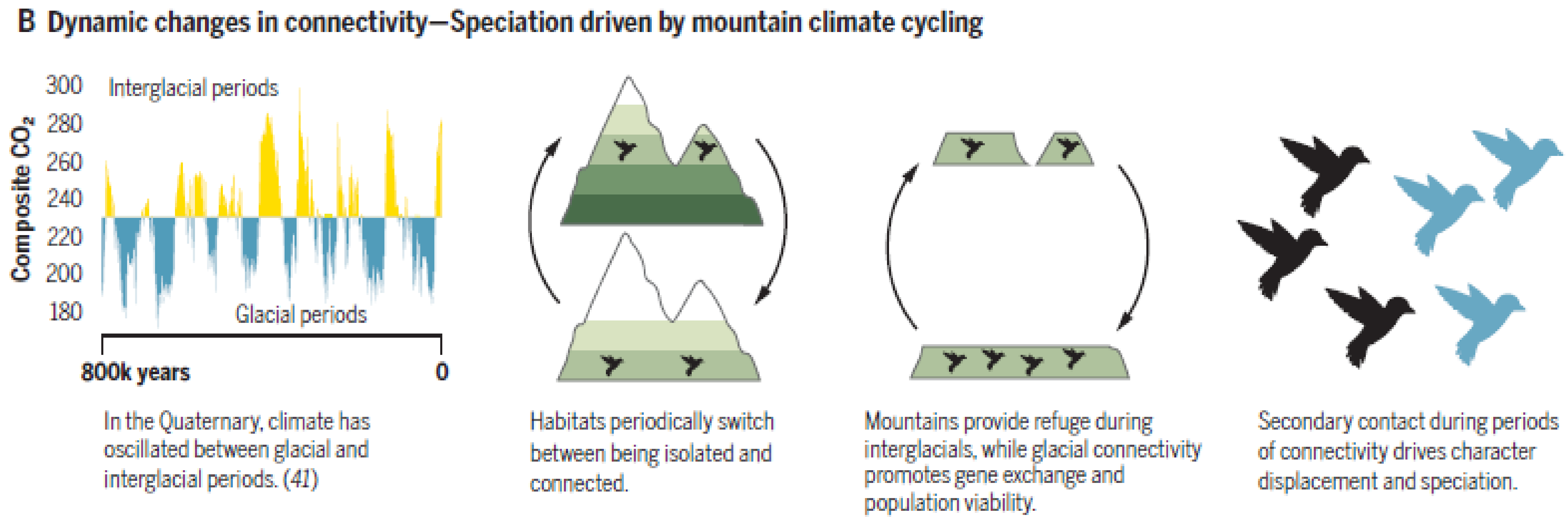


Mountain regions and adjacent lowland foothills host roughly 87% of terrestrial global biodiversity despite constituting only 25% of the world's land area

Rahbek et al. 2019a, Science


A Orogeny—Creating new species over millions of years
Deep geological time
Mountains are created in different ways, with topographies varying in space and time.
Uplift and erosion form new, isolated habitats.
Populations evolve to colonize new niches.
Isolated populations evolve into new species, rejoin, or go extinct.
Habitat erosion drives some species to extinction. Other species adapt and survive.

Long-term variation in glacial and interglacial climate the last 2.5 years facilitated speciation and extinction = **many neo-endemic species**



Rahbek et al. 2019, Science

Glacier and fragmentation

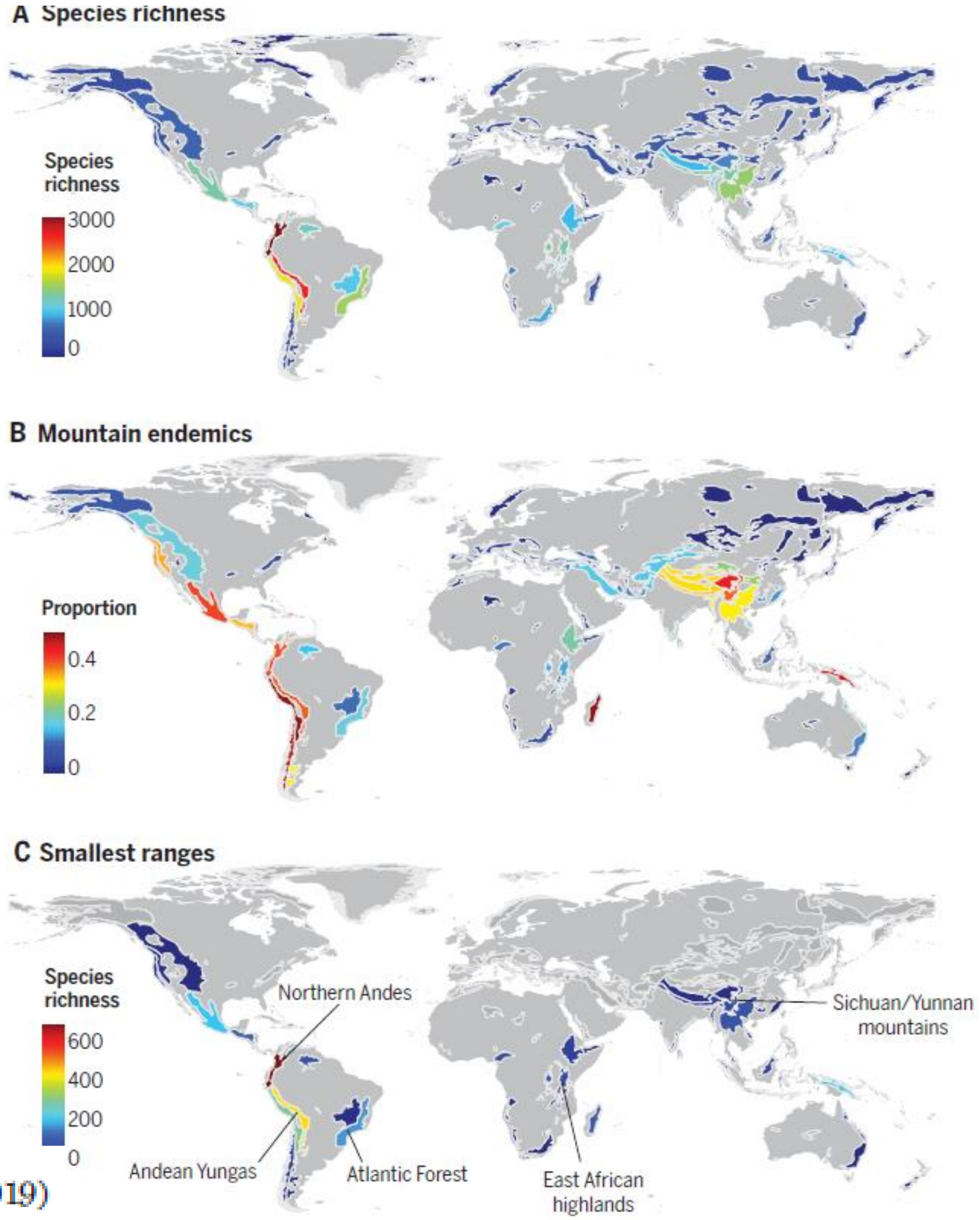
Vetaas & Grytnes (2002):
Many endemic species may have originated in a landscape fragmented by glacial advances and retreats.
The glacier arms that covered the valley bottoms below the ELA must have acted as dispersal barriers, which enhanced the physical barriers created by the mountains providing a mechanism for increased isolation.

.
Stebbins (1984) argues that large-scale glacier dynamics may facilitate hybridization between previously isolated populations, followed by either polyploidy or introgression at the diploid level, which may generate new species adapted to the conditions following ice retreat.

Richness

Endemic

Narrow range,

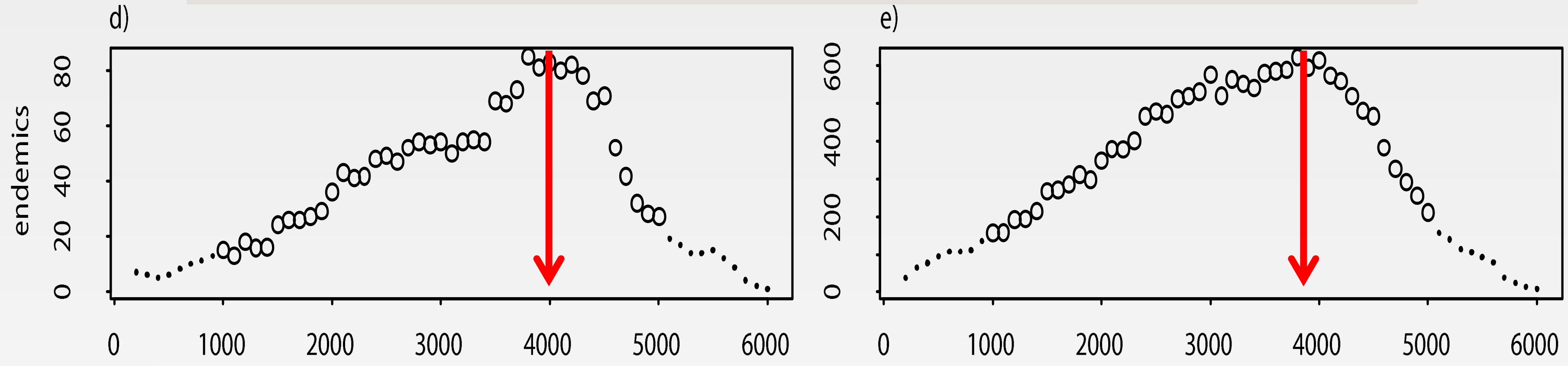


Rahbek *et al.*, *Science* **365**, 1108–1113 (2019)

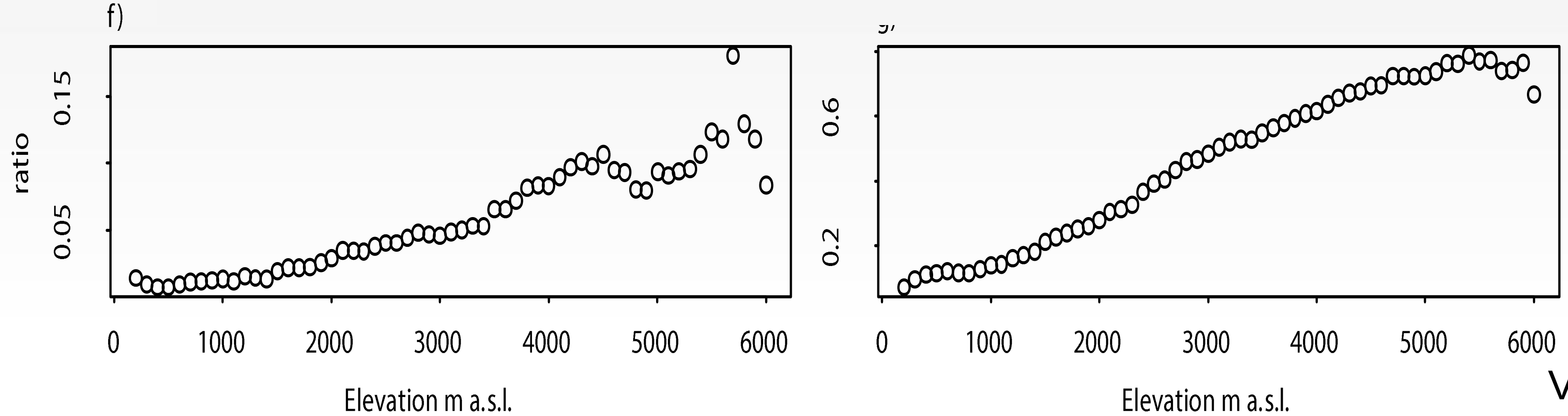
Hotspots have many endemism: mountains
Same elevations maximum biodiversity or not?

Endemic plants peaks at ca 4000 masl

Nepal   Himalaya



ratio endem/total   monotonic increase



Vetaas & Grytnes 2003

Steinbauer et al 2016 , GEB

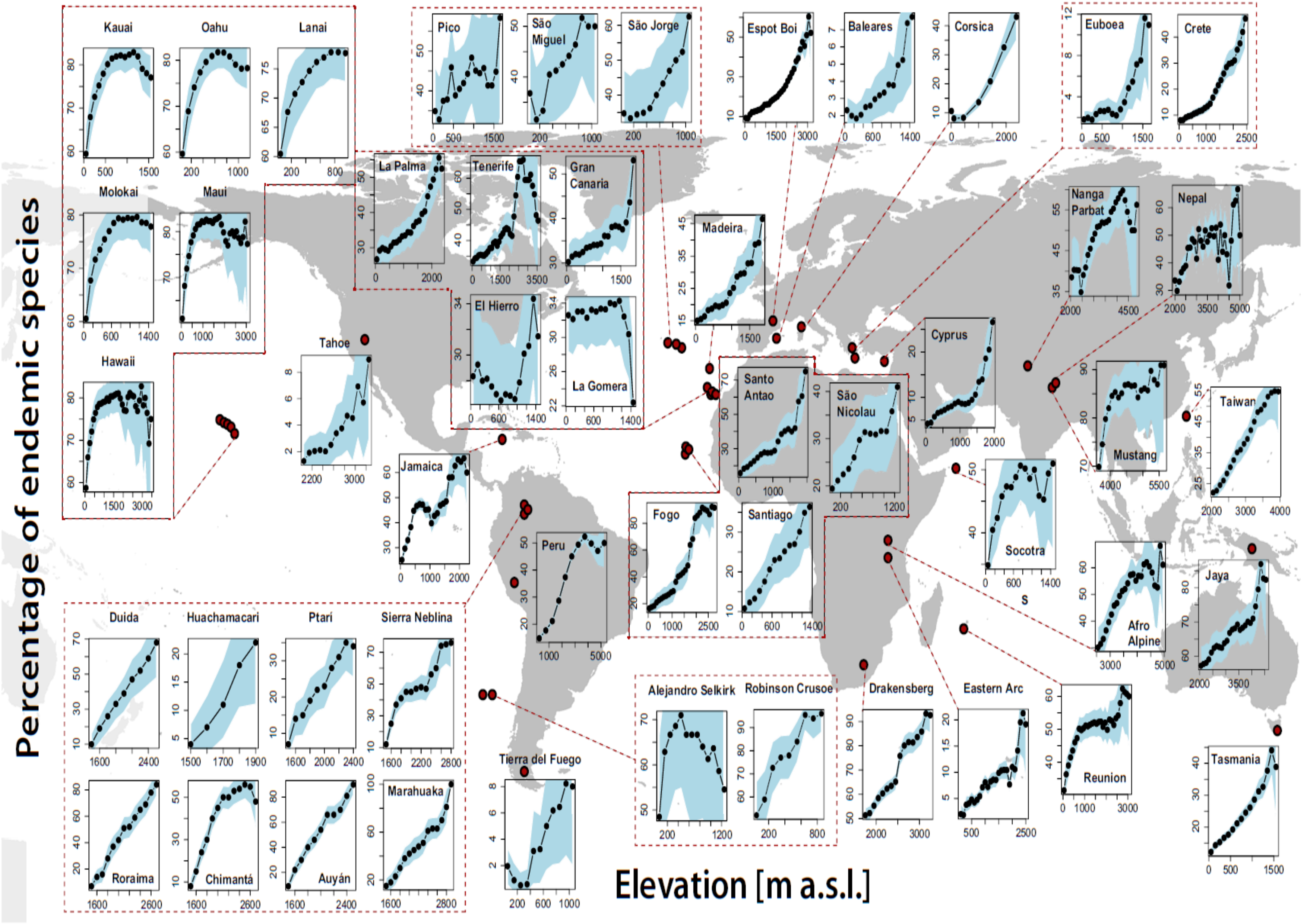


Figure 2 Elevation–percent endemism relationships globally. Vertical axes show the percentage of native species that are endemic (note the varying scales); horizontal axes show elevation in 100-m bands. Blue shading indicates 95% envelopes from bootstrap resampling (see Methods). Graphs surrounded by dashed boxes belong to the same archipelago or region. Assessed individually using generalized linear models (binomial), 28 of the 32 islands and all of the 18 continental mountain relationships are significantly positive ($P < 0.001$ for all except Pico, where $P < 0.05$). The other four (Alejandro Selkirk, La Gomera, El Hierro, Tierra del Fuego) were non-significant.

Four exceptions

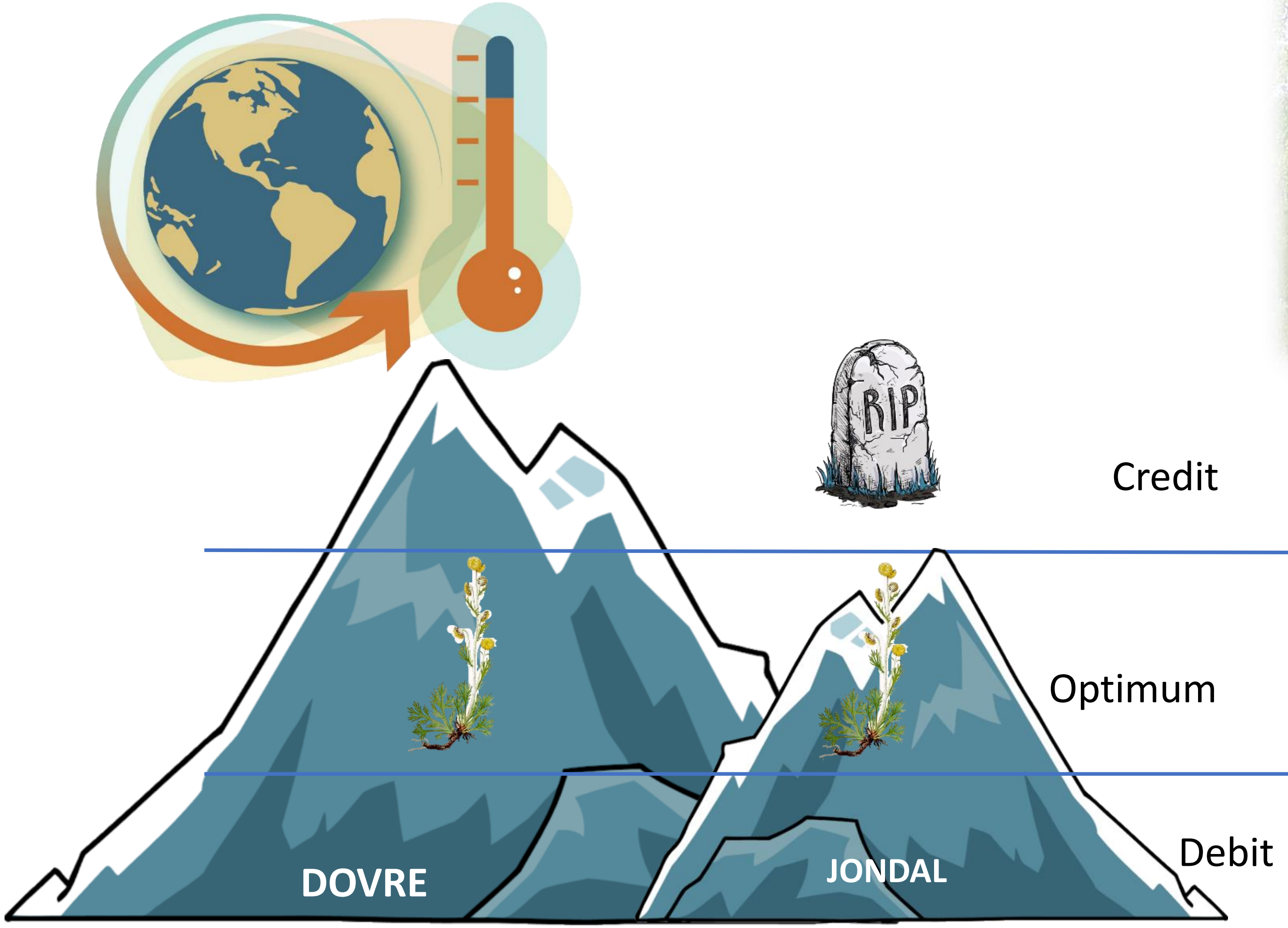
Artemesia norwegica; endemic to Norway climate and biotic interaction

Global biological information facilities: GBIF

Artemisia norvegica Fr.

Wrongly identified, another Artemisia species

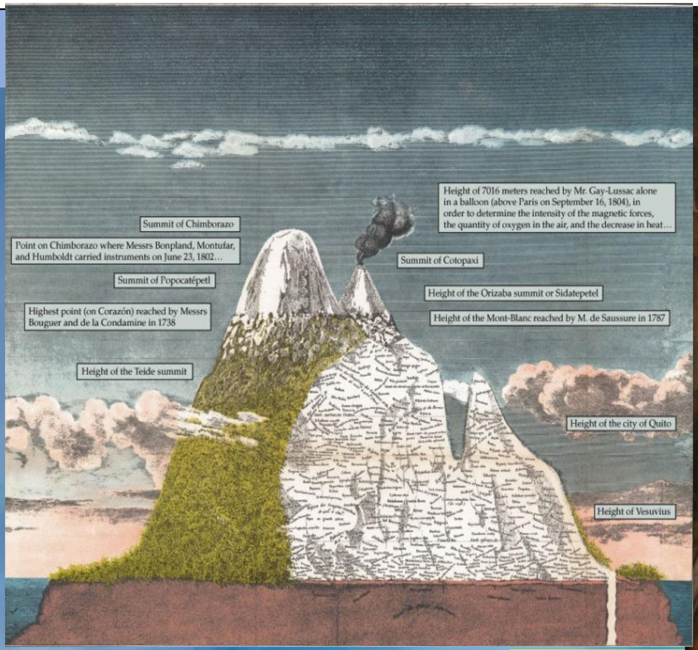
Mountain top Extinction: *Artemisia norvegica, Fr.*
Norway



Freeman et al. 2018, PENAS on birds, Steinbauer et al. 2018, Nature, on plants
Rehm & Feeley 2016, Frontiers of Biogeography, on plants

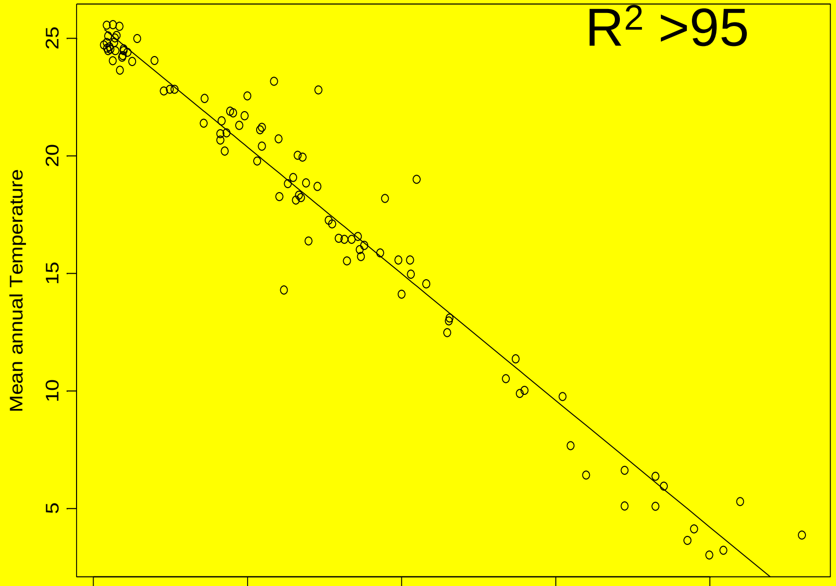
Temperature-elevation gradients are superior in situ experimental sites

Elevation Gradient

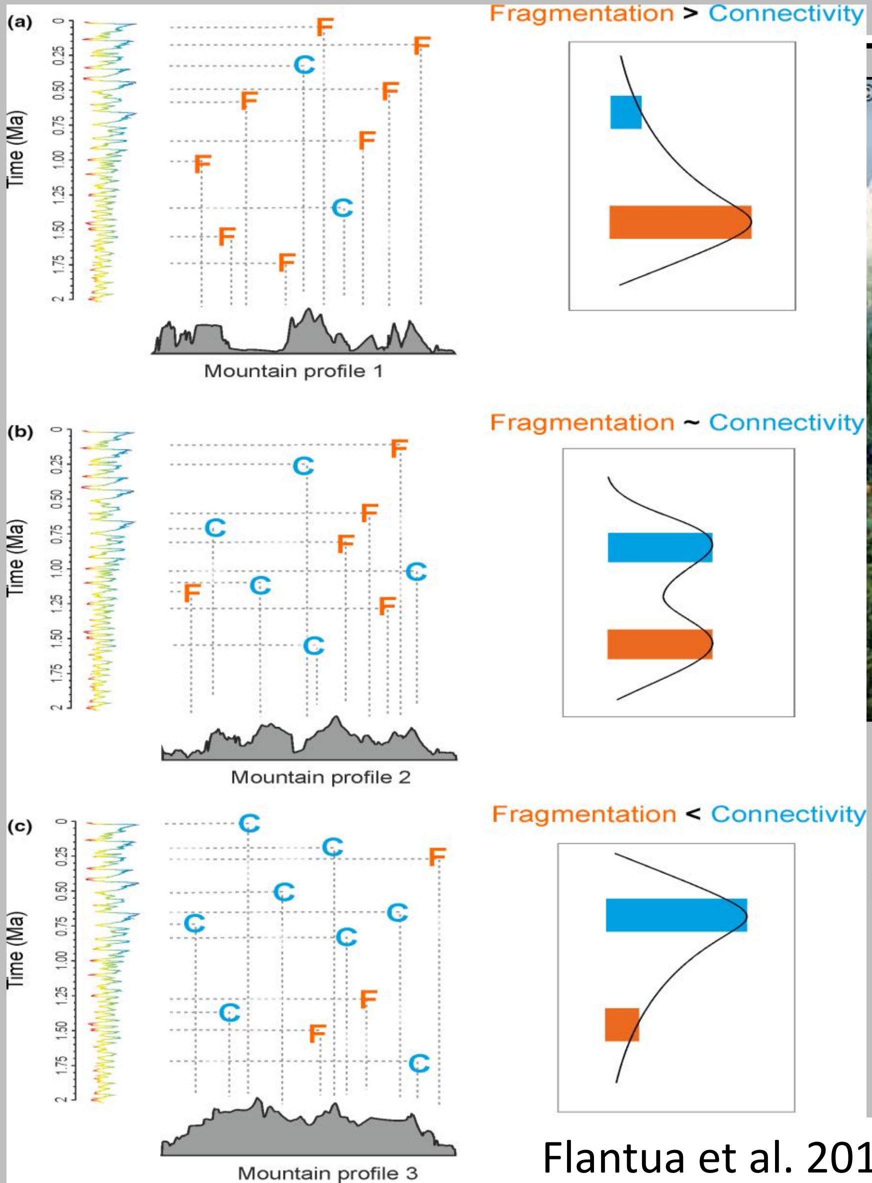


Laps rate = 0.5+/-0.15 °C pr 100m

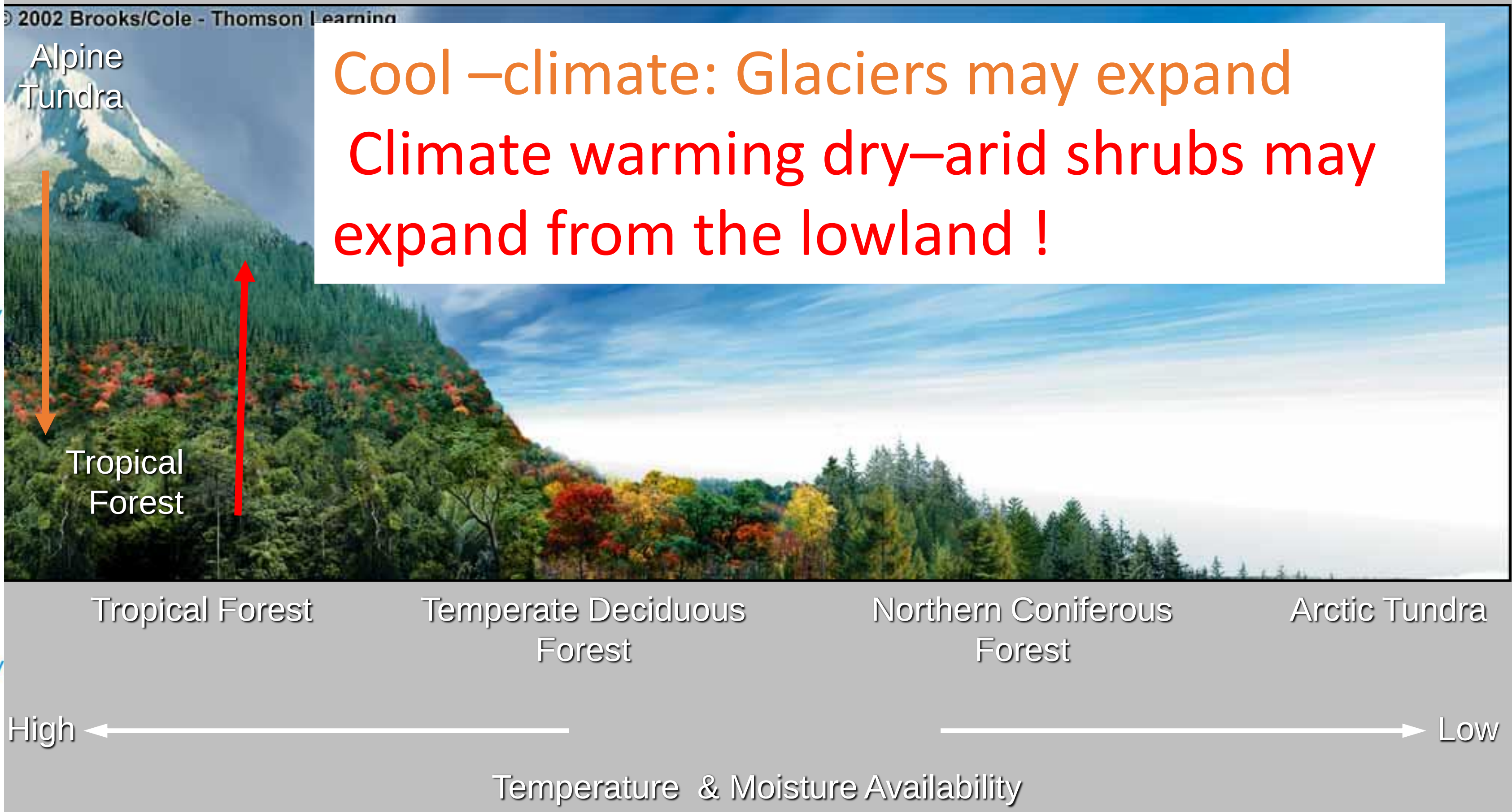
R^2 >95



Mid-elevation habitats as refugia or rescue places



Flantua et al. 2019



Cool –climate: Glaciers may expand

Climate warming dry–arid shrubs may expand from the lowland !

O’Brien 2006: WED: Water-Energy-Dynamics

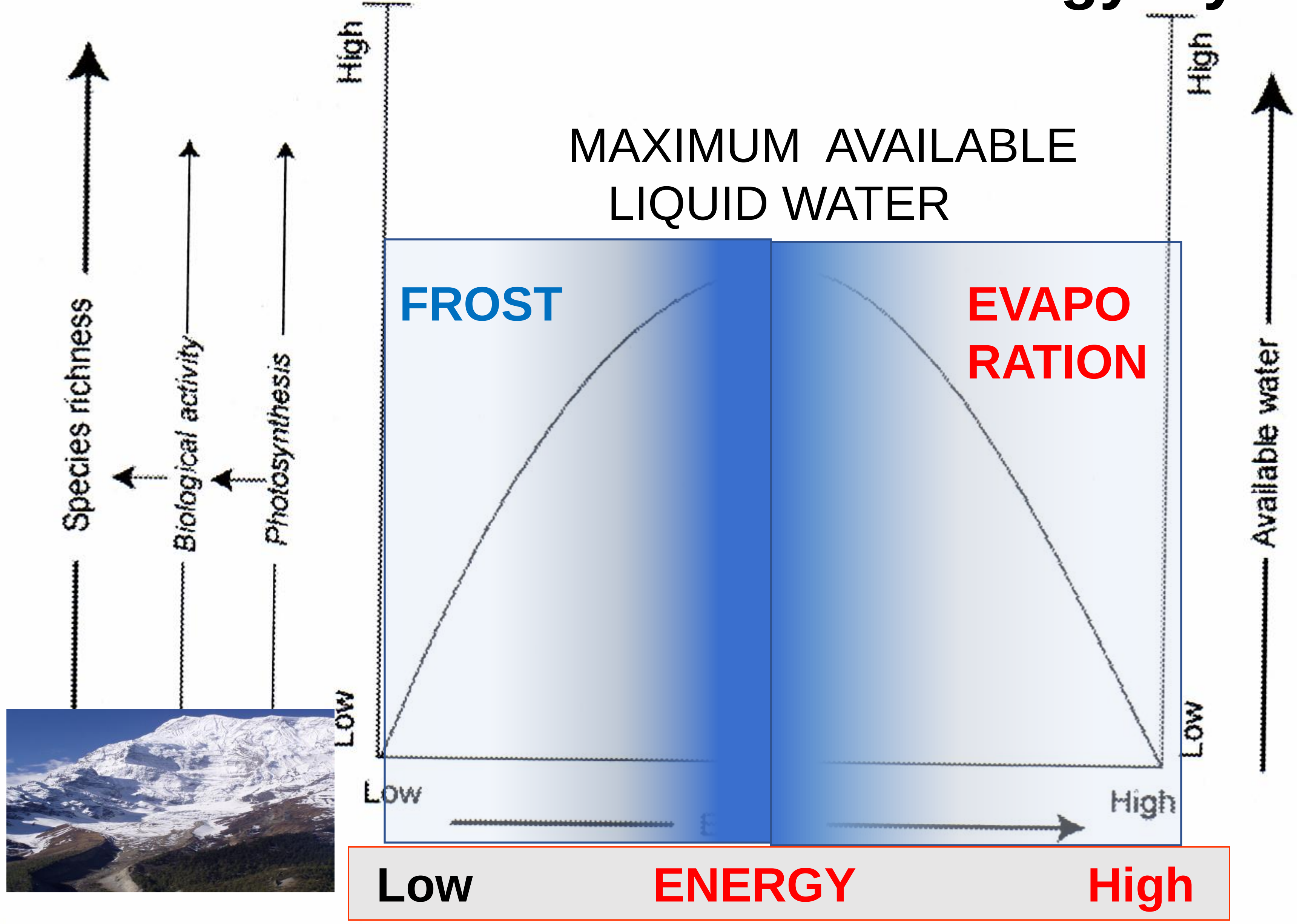


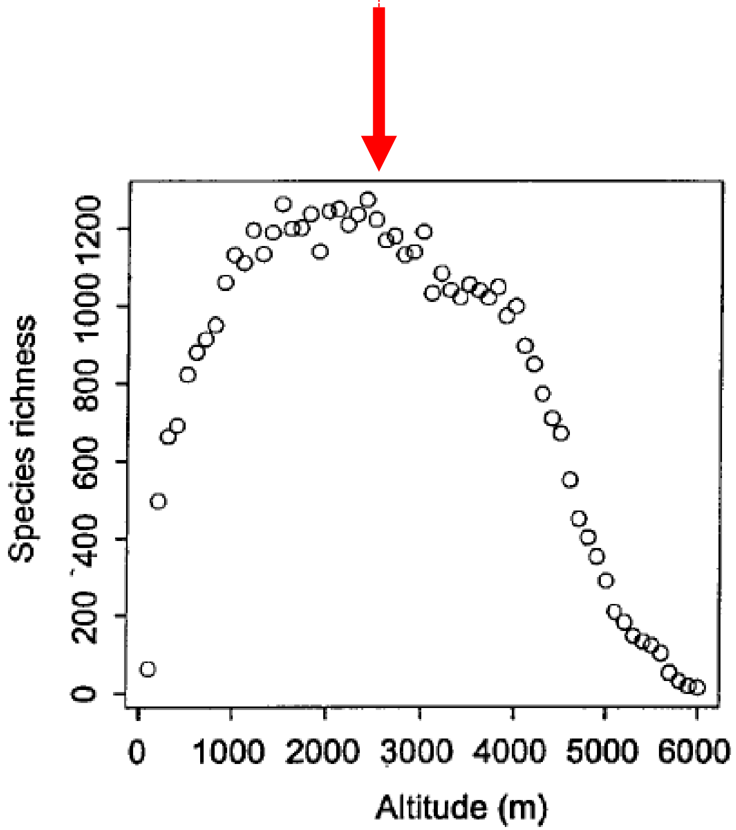
Fig. 3 *Water-energy dynamics model proposed by O’Brien (1993,1998)*

O'Brien, K. Field, R. and Whittaker R.

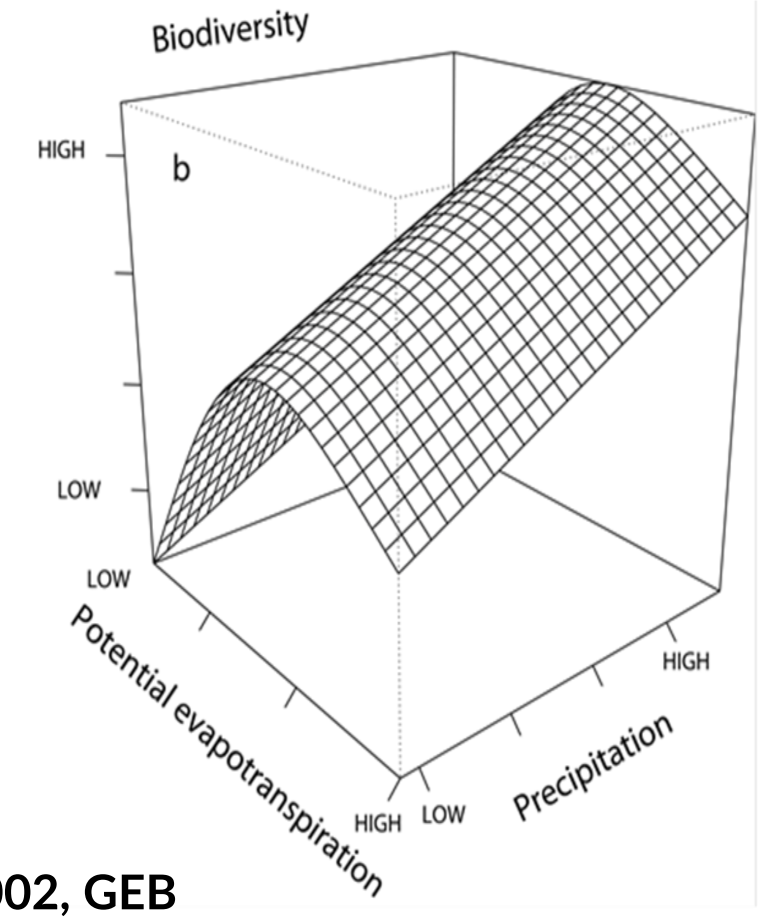
Water energy dynamics (WED).

"No water no life"

Safe to be at the middle elevation range



WED – model of diversity



Grytnes & Vetaas 2002, GEB
Vetaas et al. J. Biogeog. 2019
Bhatta et al. 2021 Frontiers of Biogeography

The dominant pattern in large mountain ranges e.g. Andes, Himalayas

PNAS

Global patterns of protection of elevational gradients in mountain ranges

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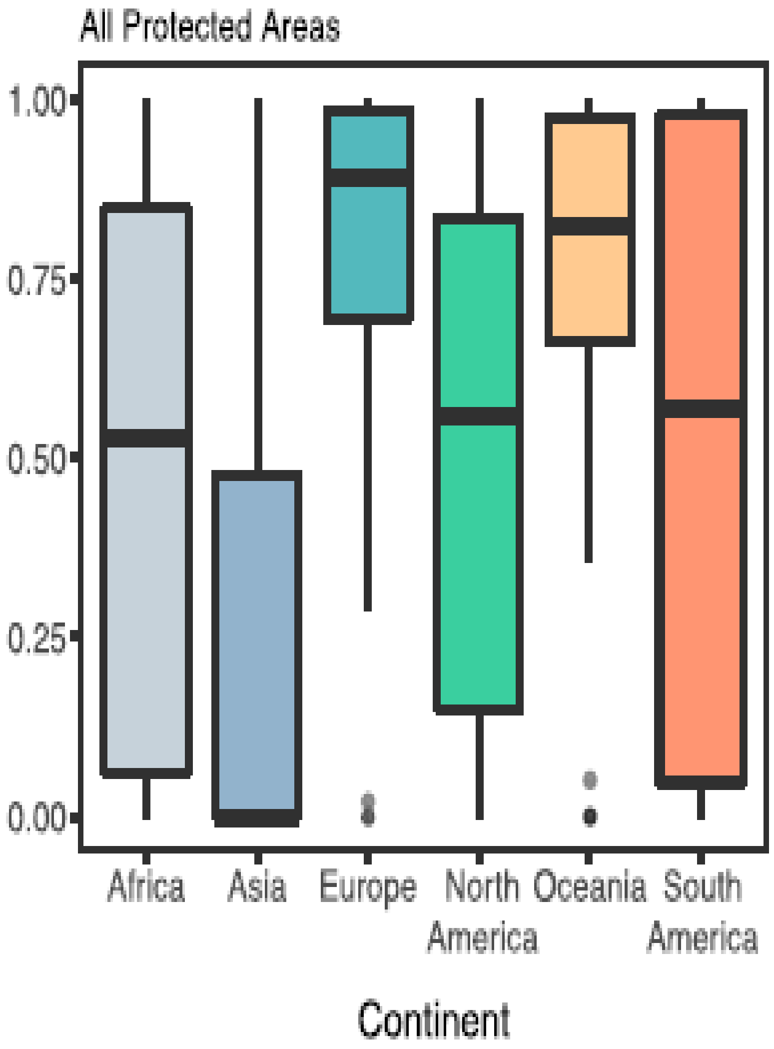
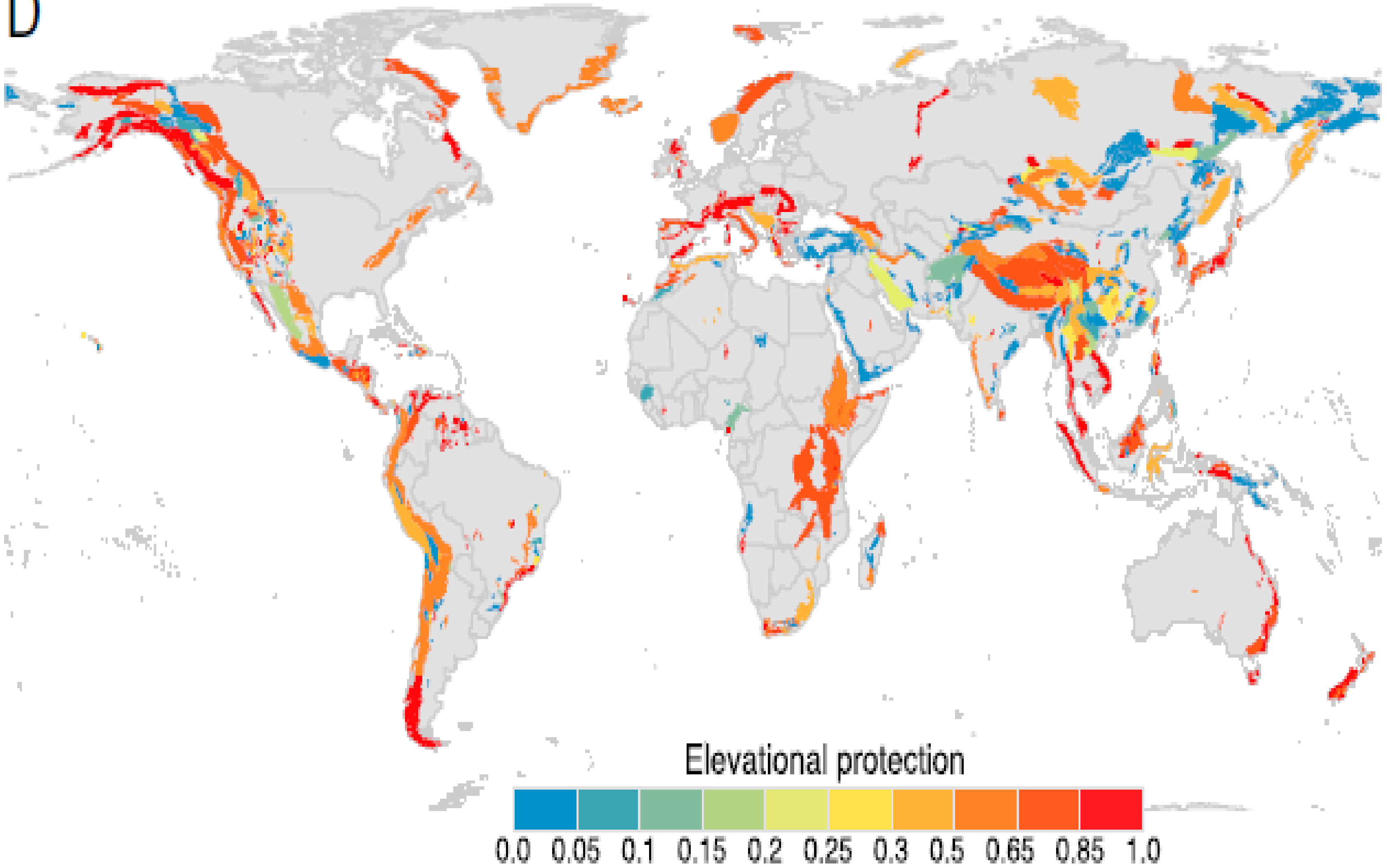
Edited by Nils Chr. Stenseth, University of Oslo, Oslo, Norway, and approved April 23, 2018 (received for review November 18, 2017)

Significance

Mountain ranges constitute biodiversity hotspots, and montane species are shifting their ranges in elevation in response to climate change. Protecting elevational gradients can help fully capture montane biodiversity patterns and facilitate species range shifts.


All Protected Areas
1.00
0.75
0.50
0.25
0.00
Africa
Asia
Europe
North America
Oceania
South America
Continent

D

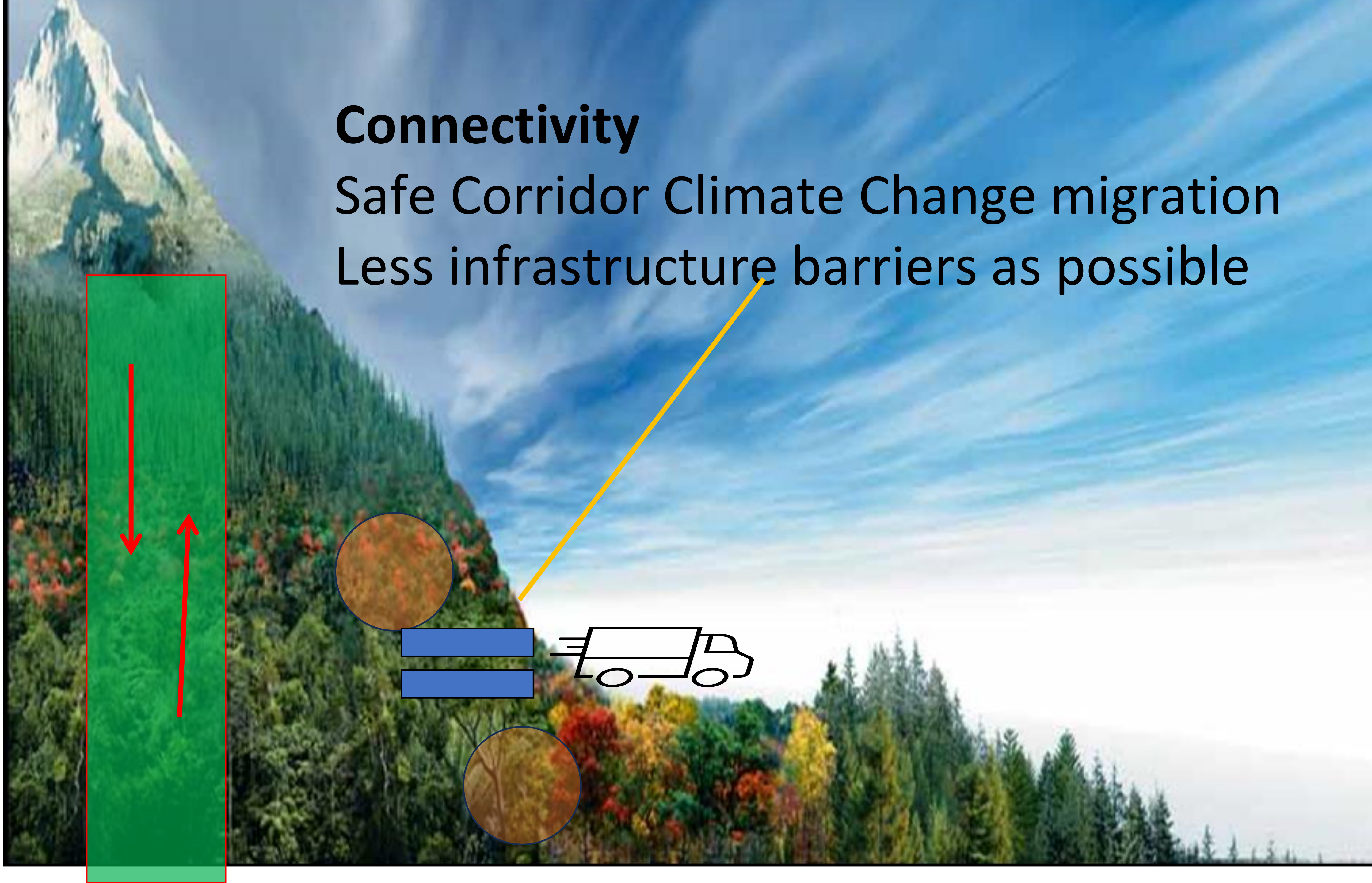

Elevational protection
0.0
0.05
0.1
0.15
0.2
0.25
0.3
0.5
0.65
0.85
1.0

Climate and land use changes are both very active and interactive

Connectivity

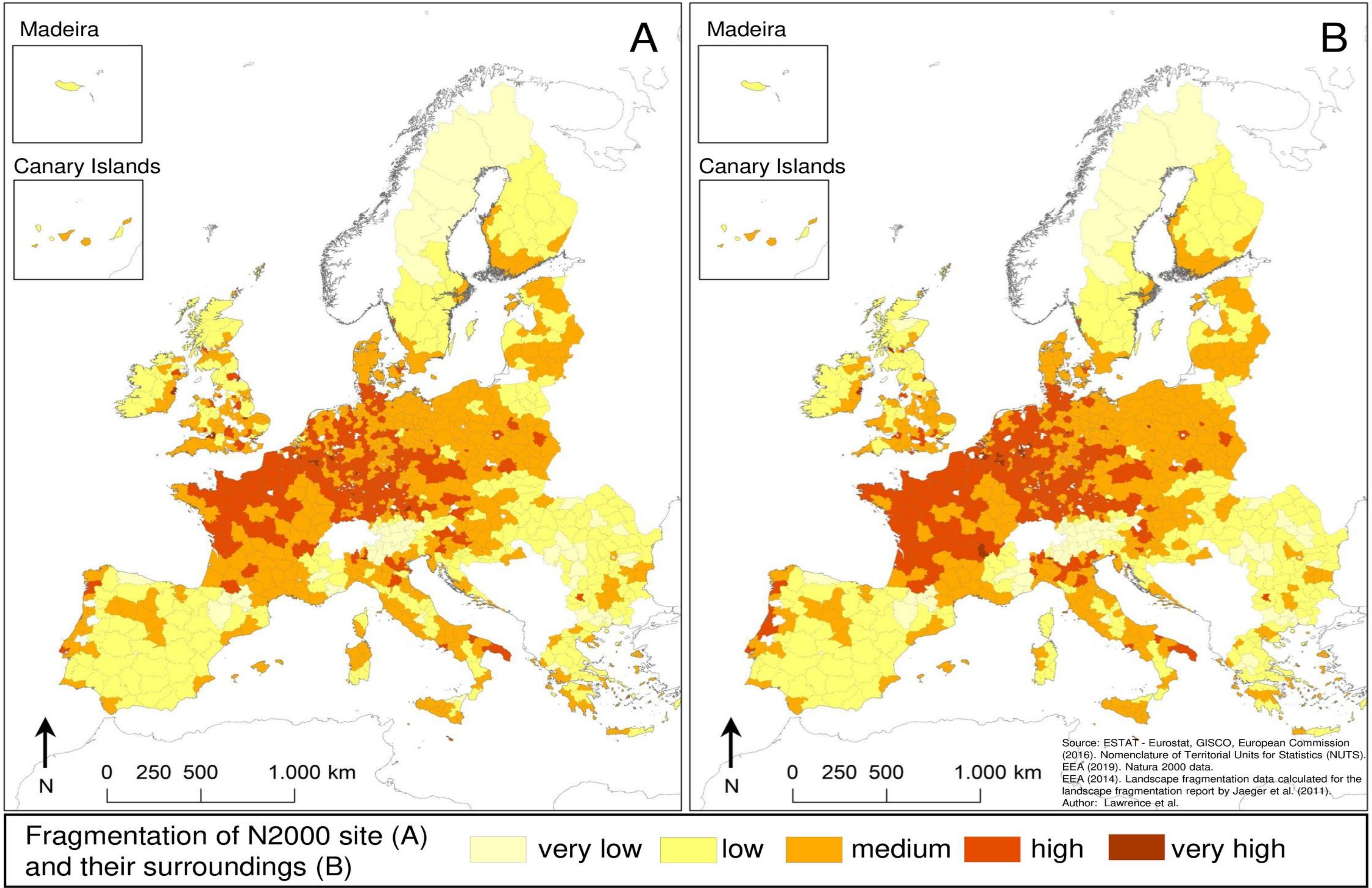
Safe Corridor Climate Change migration

Less infrastructure barriers as possible

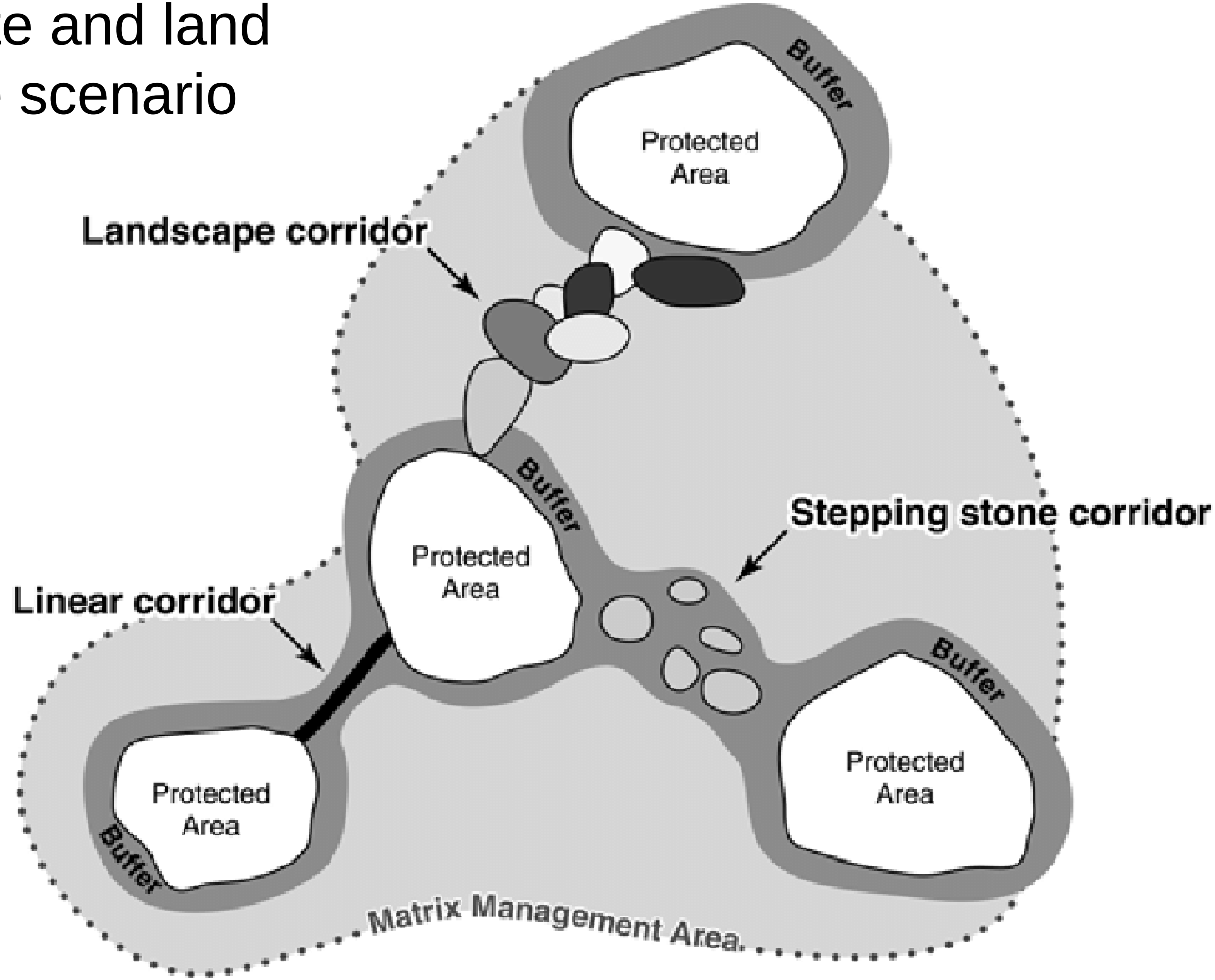


Lawrence, Friedrich & Beierkuhnlein, 2021,

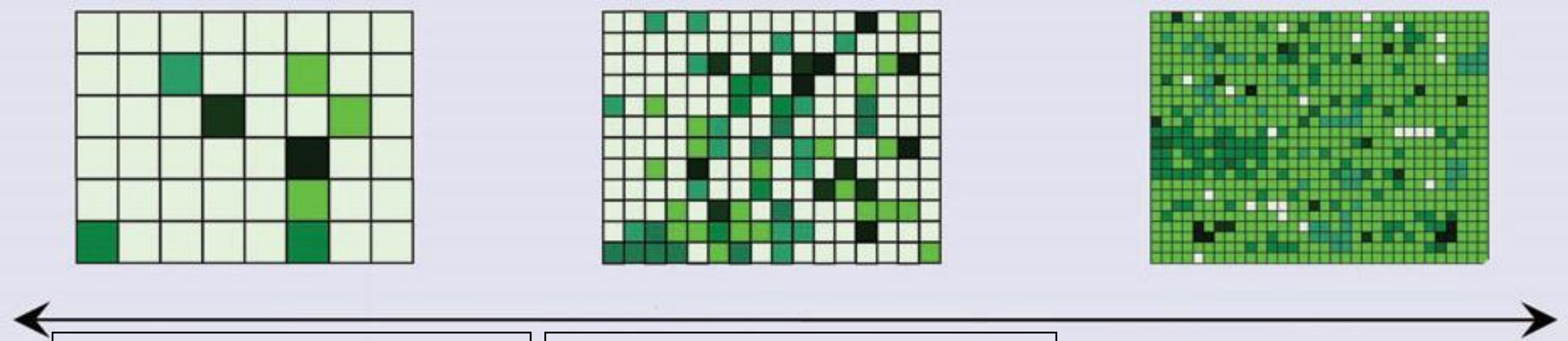
https://doi.org/10.1371/journal.pone.0258615



PA in climate and land use change scenario



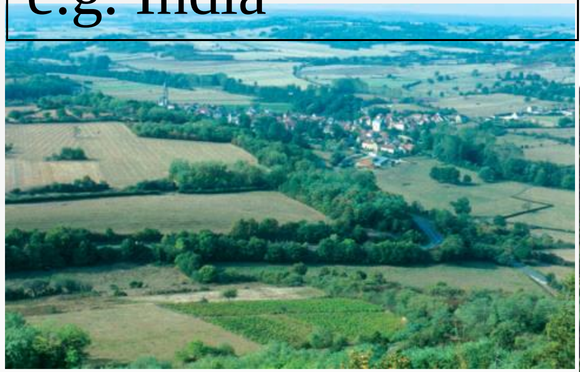
A spectrum of sparing vs sharing

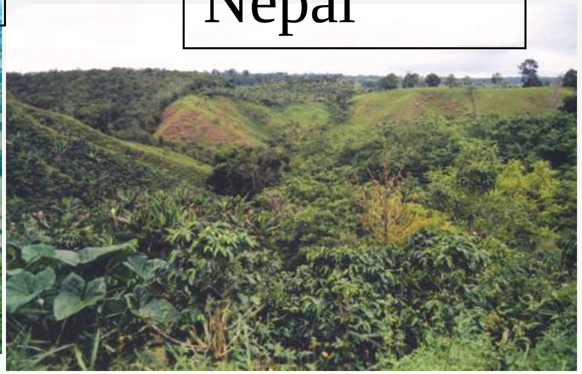


Sparing, e.g. China

Sparing + Sharing e.g. India

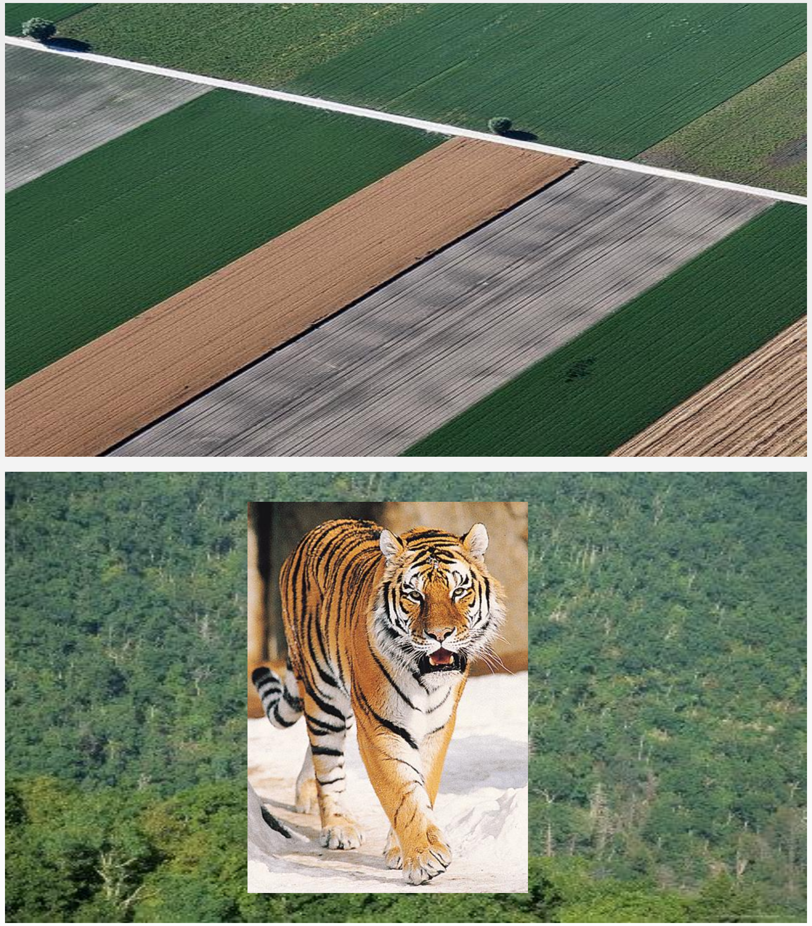
Sharing, Nepal

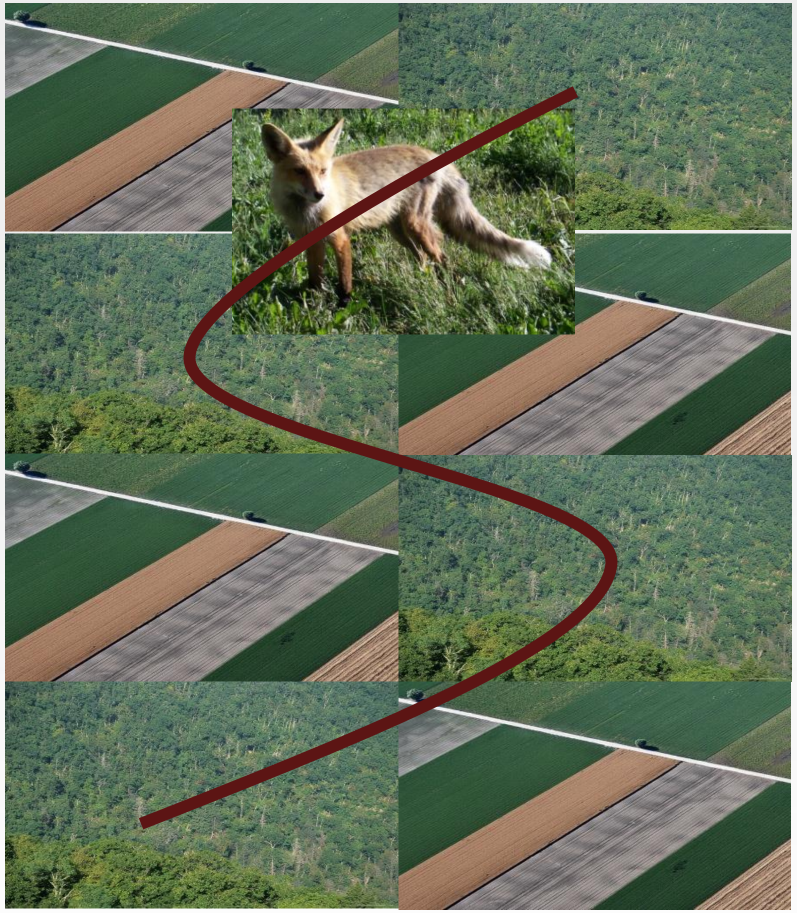




Fischer et al. 2008 *Frontiers in Ecology and the Environment*

Land sparing vs Land sharing





Agroforestry: a refuge for tropical biodiversity?
Bhagwat, et al. 2008, TREE

local connectivity

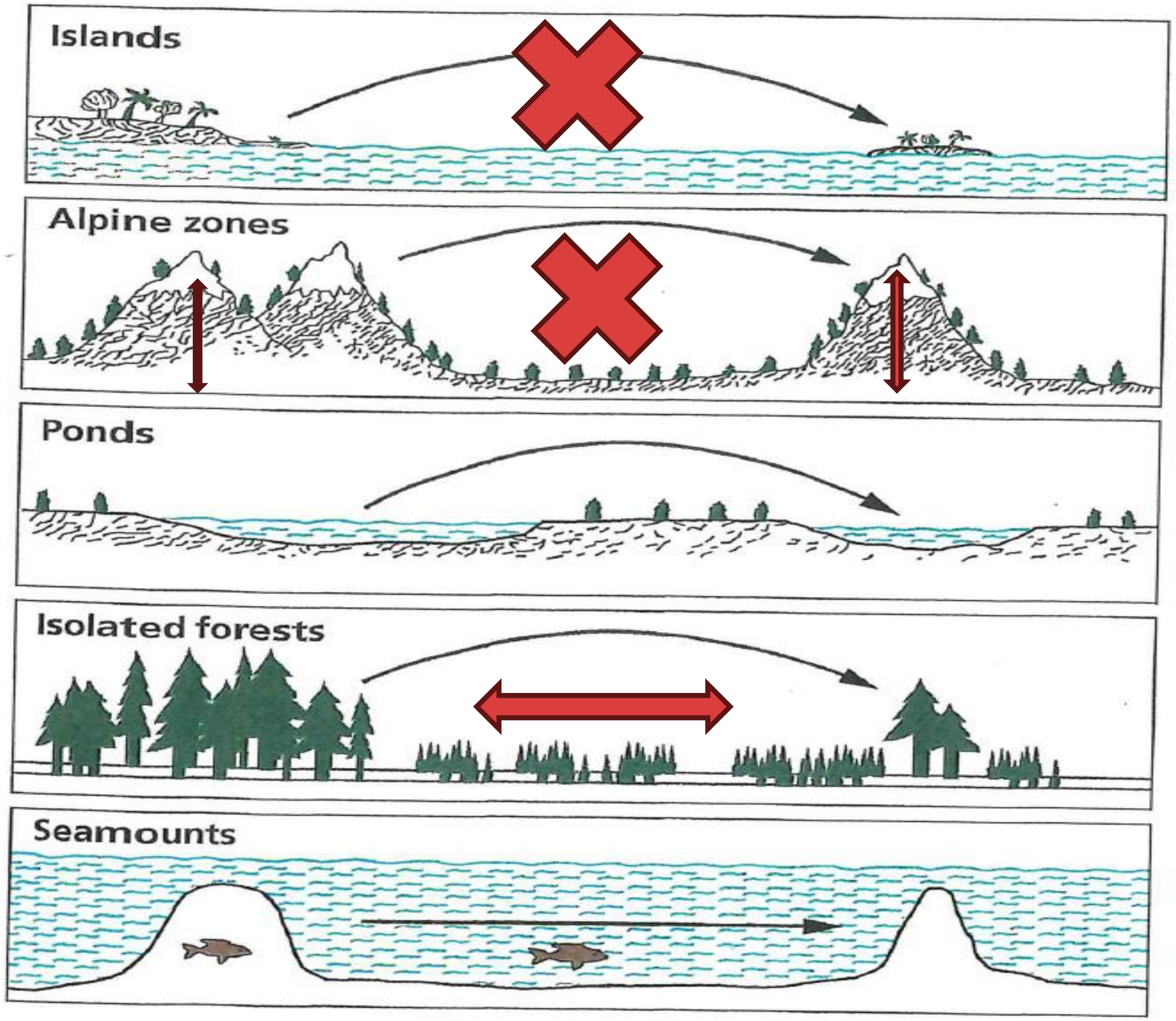
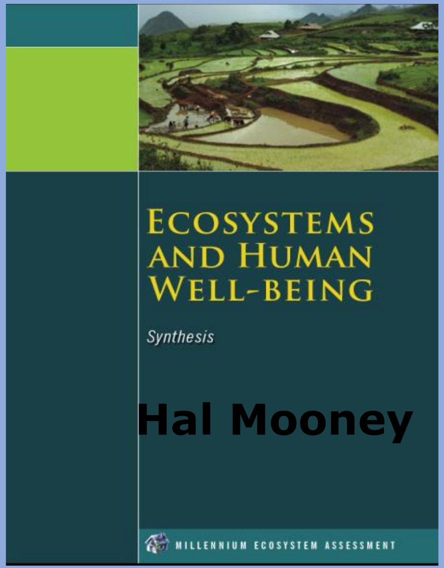


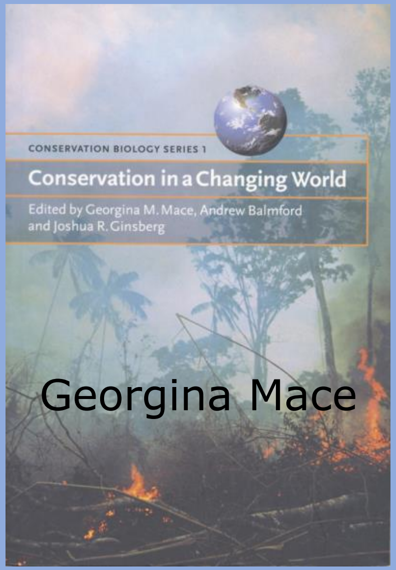
Figure 1.1 There are many different types of insular environment in addition to the principal class we discuss here: restricted areas of land surrounded by water. This figure illustrates just a few of them. Modified from an original in Wilson and Bossert (1971).

More connectivity



UN commissioned MEA concluded that

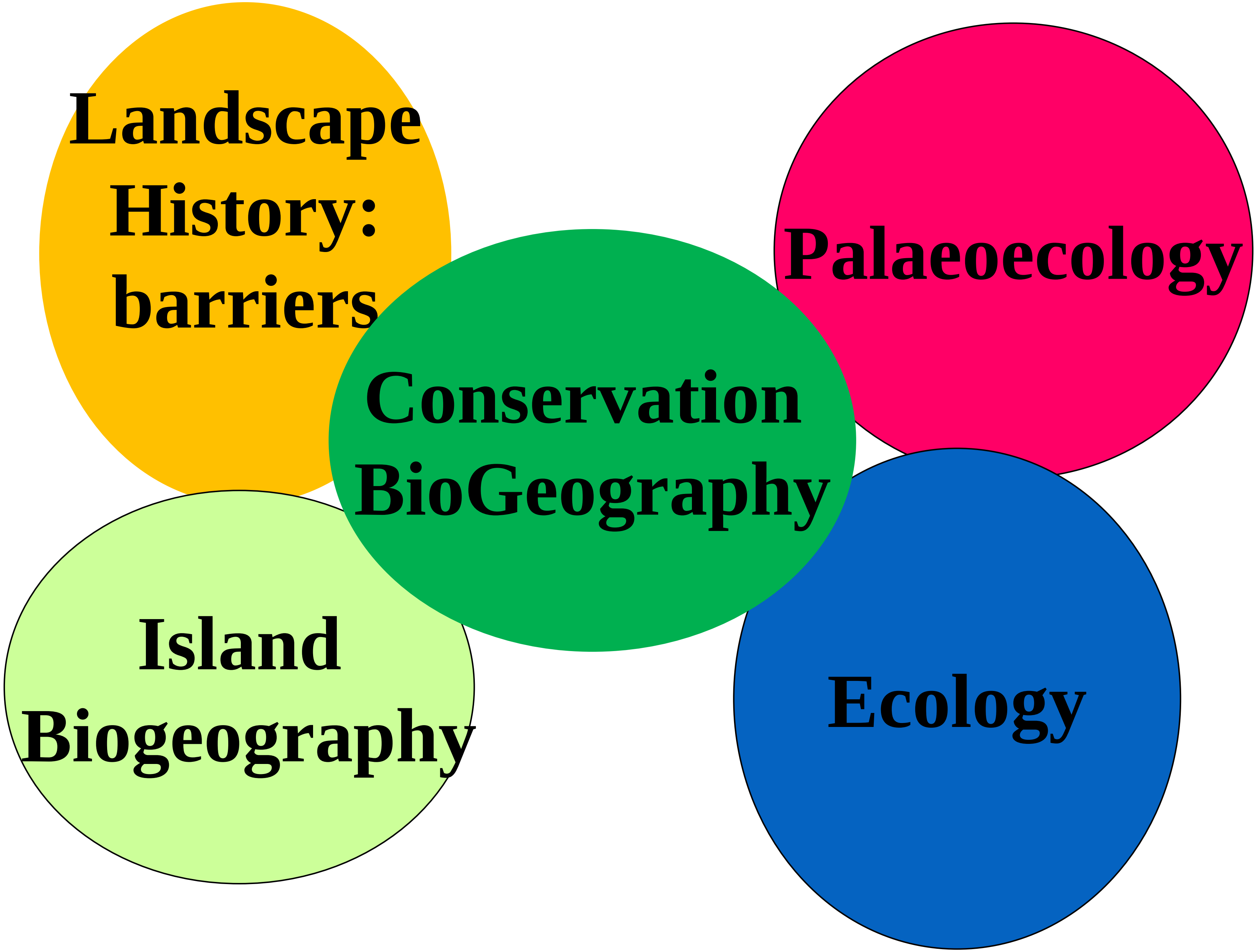
- Long-term ecological data is critical in order to develop policies and **conservation strategies** to cope with current climate and future land use changes



Must build an understanding of biological **processes** in management and planning.

Conservation planners need to deal with the dynamic **processes** of species and their ability to migrate in the landscape

Facilitate migration and connectivity rather than just freeze certain nature types, “tin-can-conservation”


Landscape History: barriers
Palaeoecology
Conservation BioGeography
Island Biogeography
Ecology

Summary conclusion

- Long-term speciation depends on isolation on **islands** and **mountain** summits
- These endemic-rich locations are very vulnerable to extinction caused by climate change and land use changes
- **Data on temporal changes**
- More skills in interpreting **temporal processes** from spatial changes
- More analyses on connectivity between habitat islands and protected areas.

Facilitate Dynamic process-based conservation vs ‘tin-can-conservation’
Follow up Bologna June: European Congress of Conservation biology

Thank you for your attention