



UNIVERSIDAD  
DE GRANADA

J-AIL 2023

# J-AIL INTERMEETING COURSE

# FRESHWATER BIOGEOGRAPHY

Dr. Jorge García-Girón (Universidad de León & University of Oulu)

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Ibérica de  
Limnología

Associação  
Ibérica de  
Limnologia

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Special features of aquatic environments

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Setting the scene for today's biosphere

01

# WHAT IS BIOGEOGRAPHY?



# WHAT IS BIOGEOGRAPHY?



*Attempts to understand spatial patterns of biological diversity*

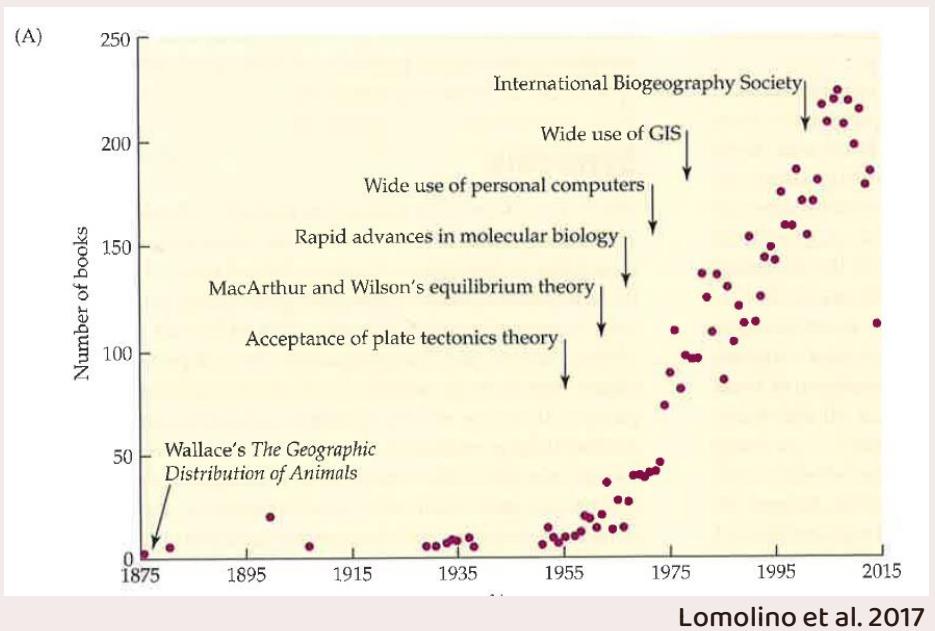
- Past, present, and future
- From genes and communities to ecosystems
- How biological diversity varies along geographical gradients?

## Subdisciplines

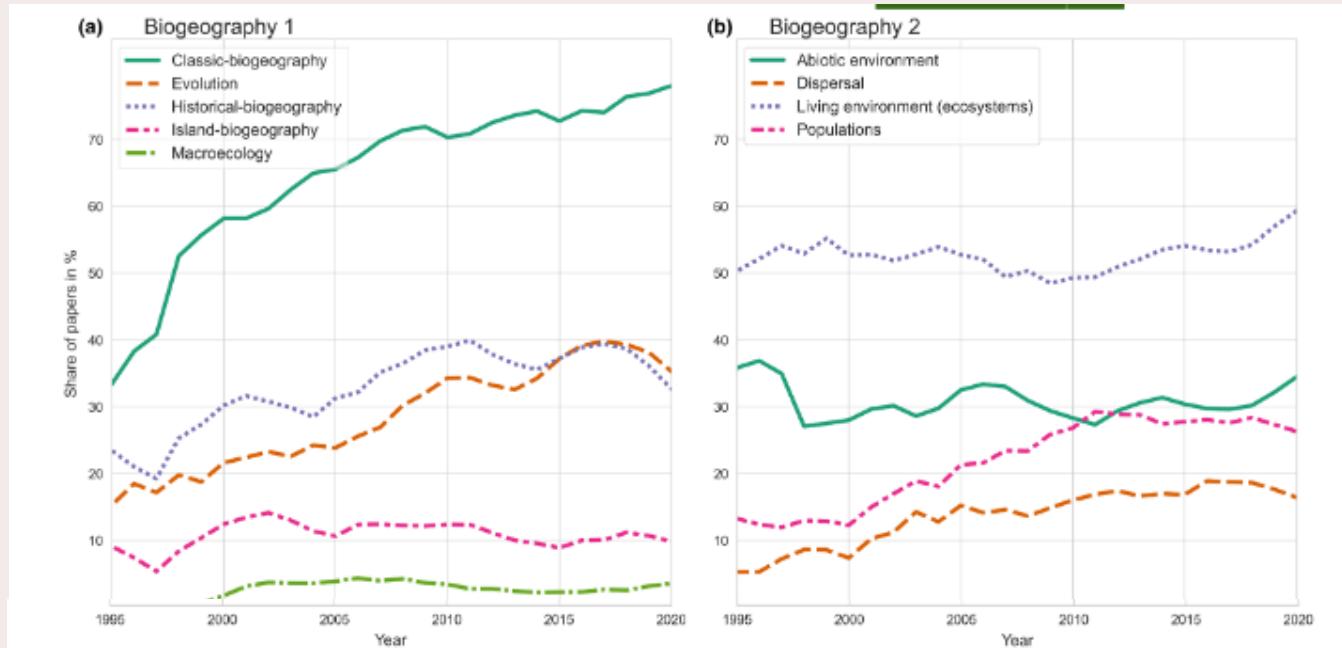
- Historical biogeography
- Ecological biogeography
- Phylogeography
- Conservation biogeography



# WHAT IS BIOGEOGRAPHY?



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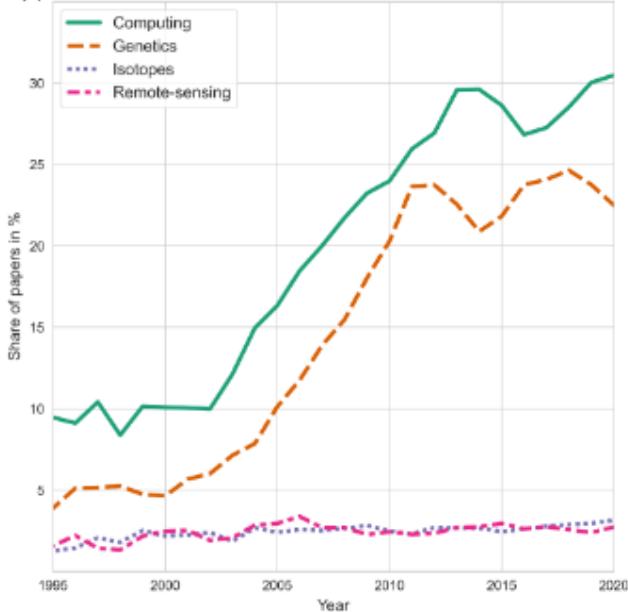


Renner & Skov 2023

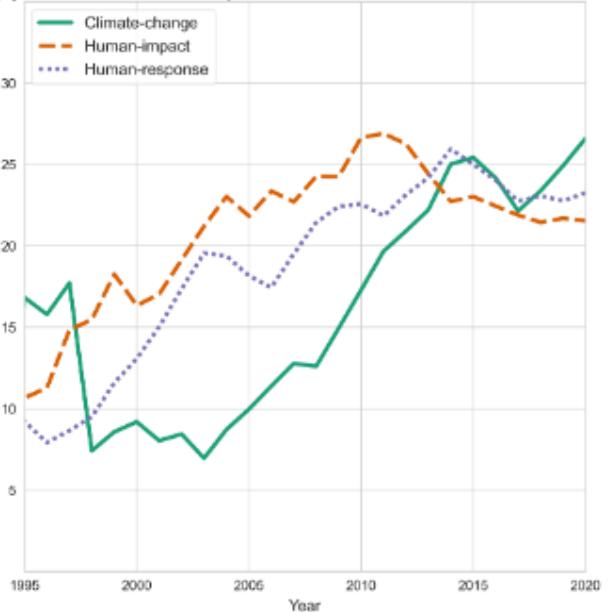
# WHAT IS BIOGEOGRAPHY?



(c) Methods

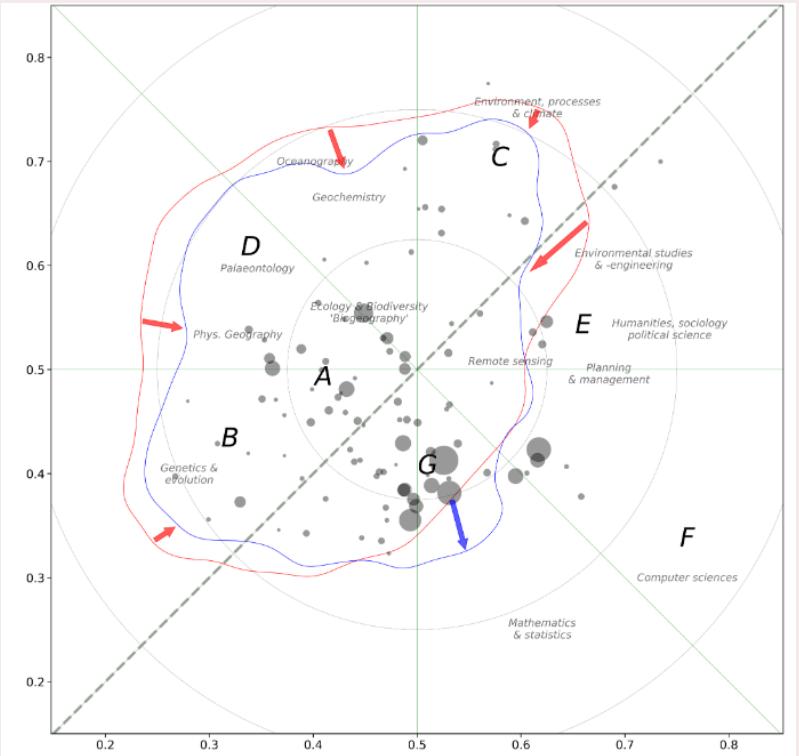


(d) Humans & Anthropocene



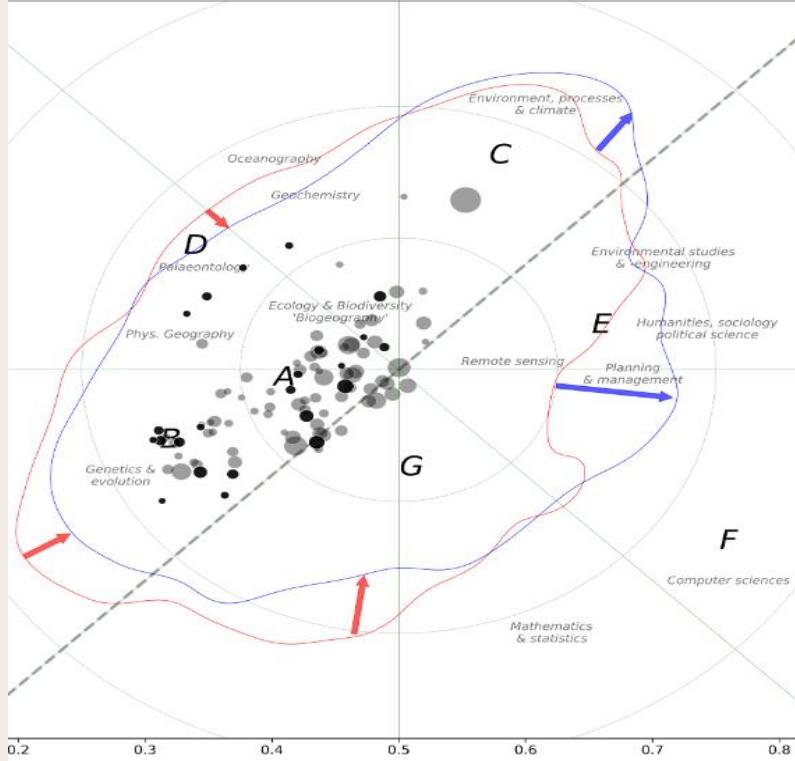
Renner & Skov 2023

# WHAT IS BIOGEOGRAPHY?



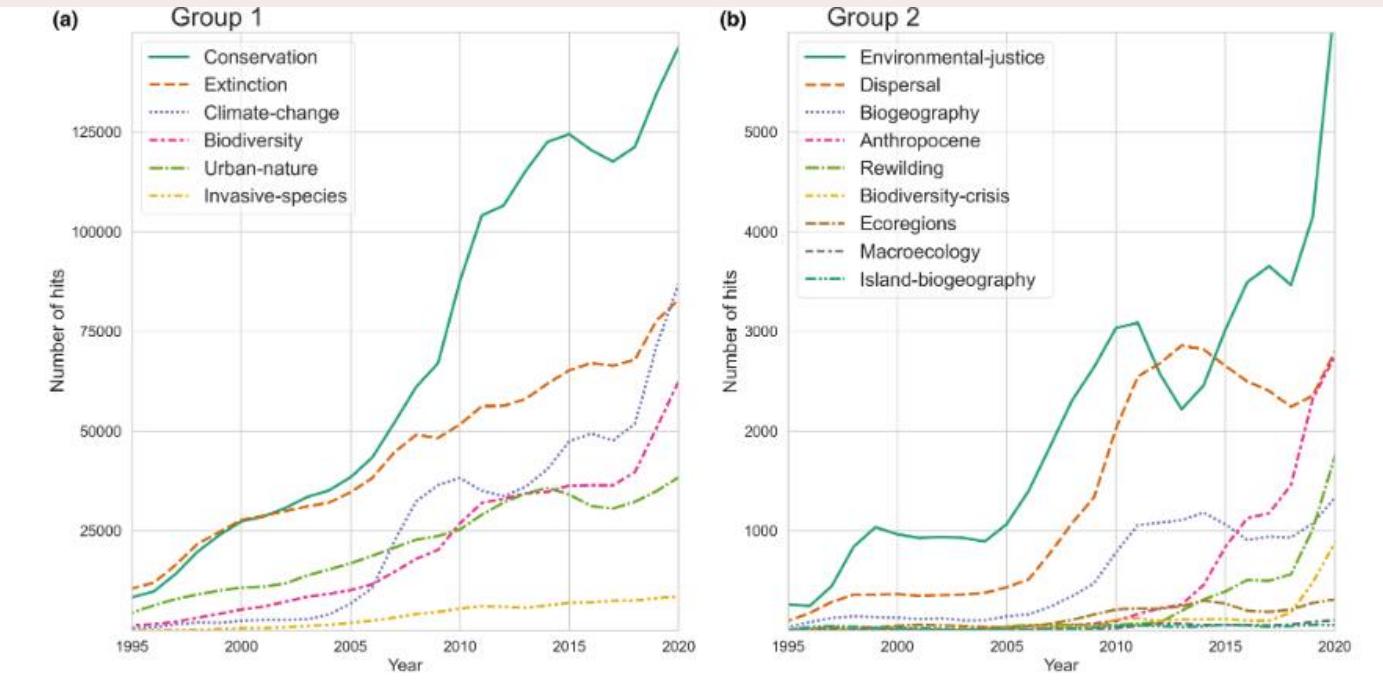
Renner & Skov 2023

# WHAT IS BIOGEOGRAPHY?



Renner & Skov 2023

# WHAT IS BIOGEOGRAPHY?

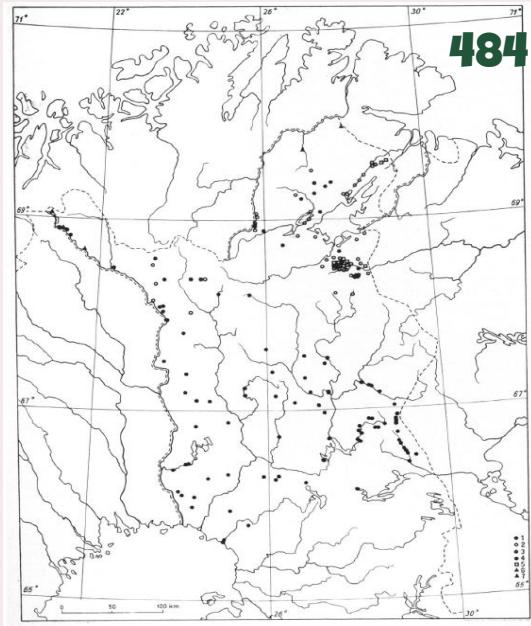
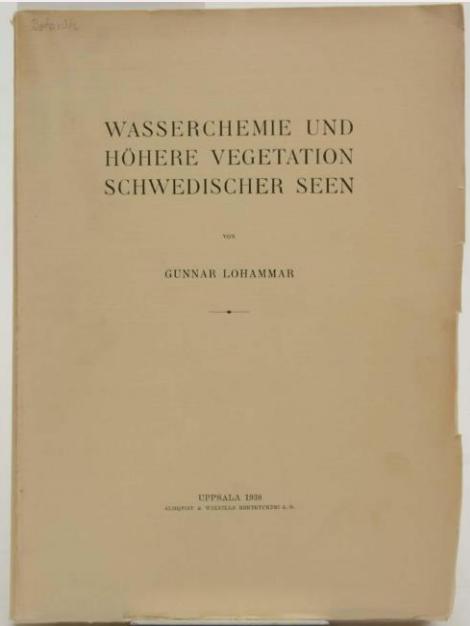
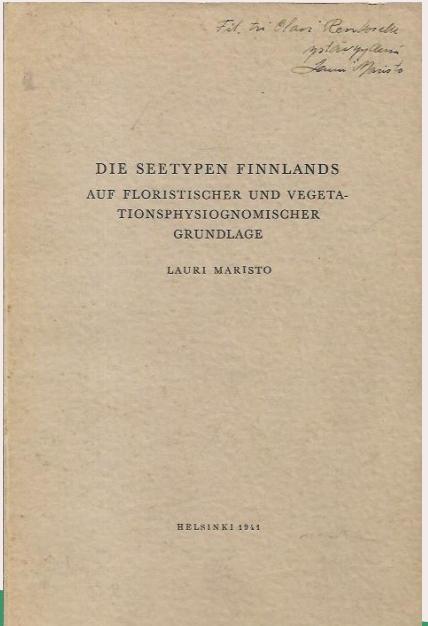


Renner & Skov 2023

# WHAT IS BIOGEOGRAPHY?



How well biogeography-focused journals capture  
freshwater-derived broad-scale research?



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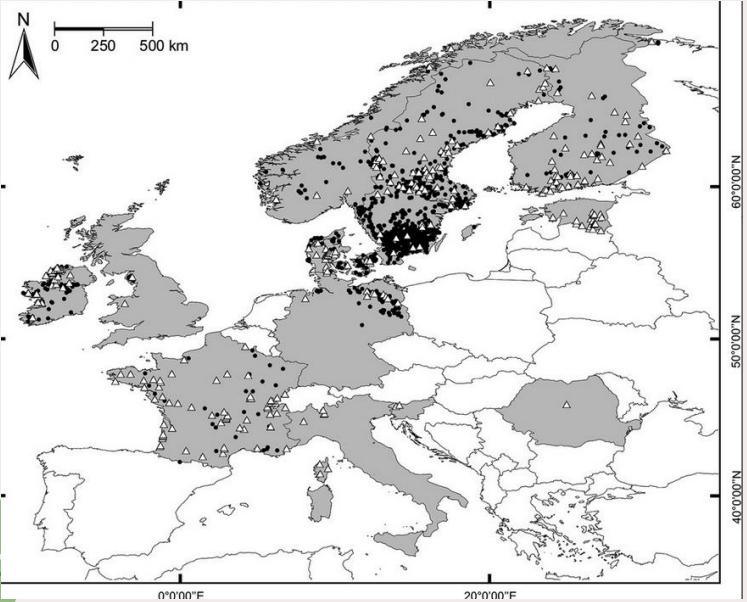
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Limnología



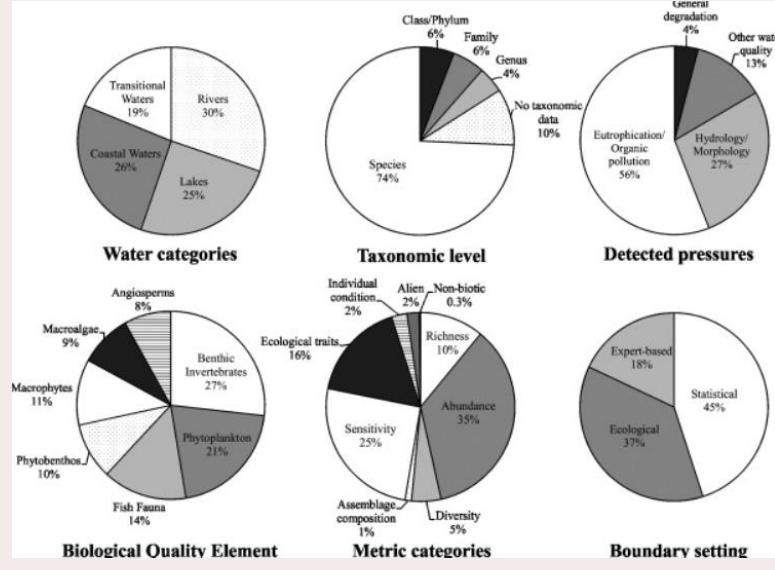
# WHAT IS BIOGEOGRAPHY?



How well biogeography-focused journals capture  
freshwater-derived broad-scale research?



Brucet et al. 2013.

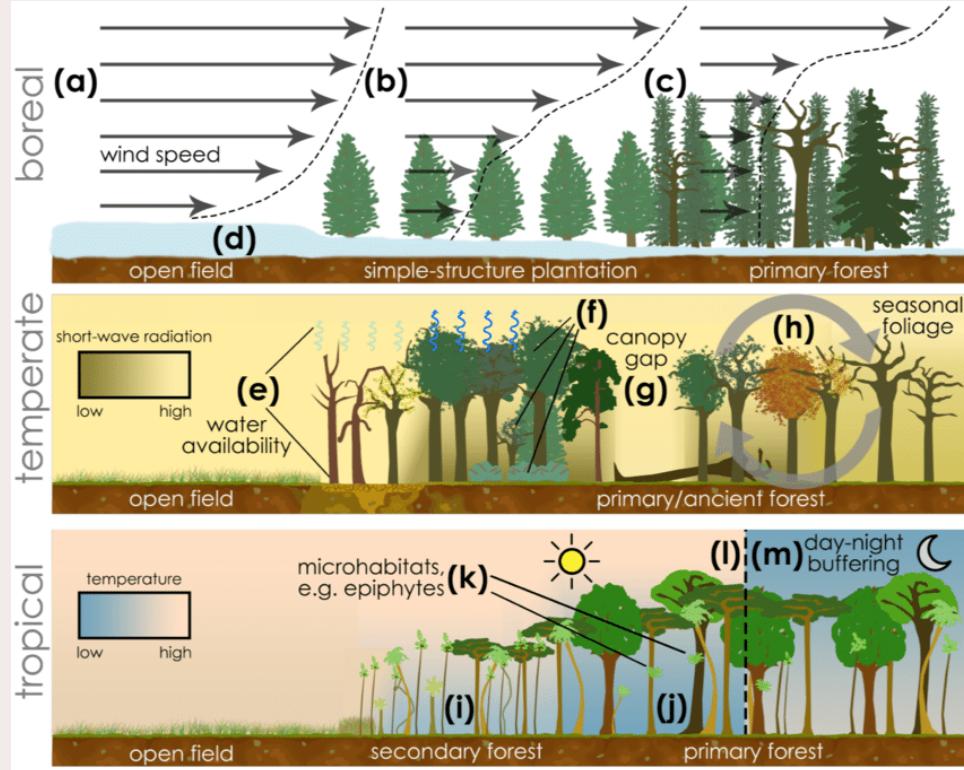


Birk et al. 2012

# WHAT IS BIOGEOGRAPHY?

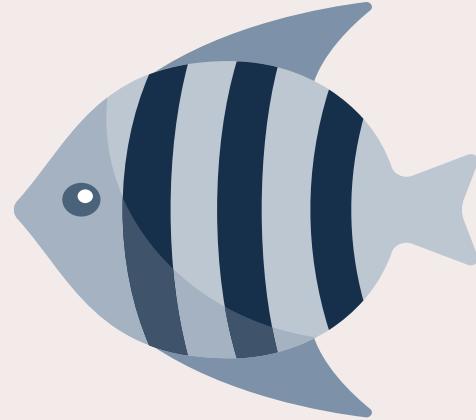
## Pioneering in the future?

- Microclimate
- Limnological time-series



02

# SPECIAL FEATURES OF AQUATIC ENVIRONMENTS



# SPATIAL SCALE IN FRESHWATERS

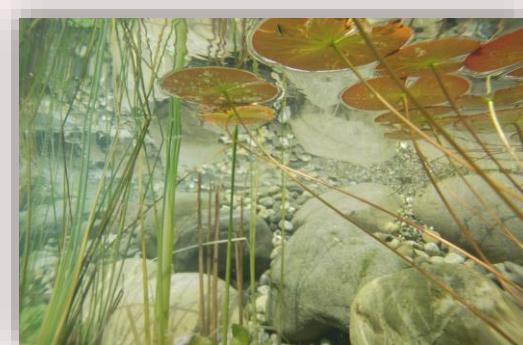
## Freshwaters in landscape

- Catchment area, with land cover and land use
- Catchment area vs. shoreline adjacent to water body



## Freshwaters as landscapes

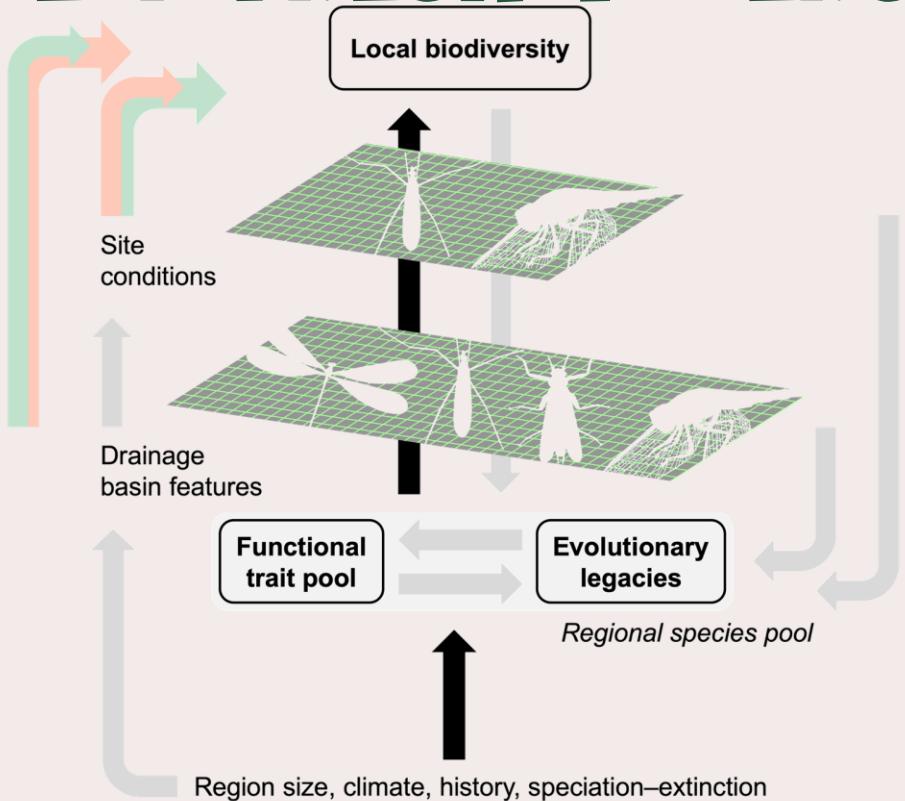
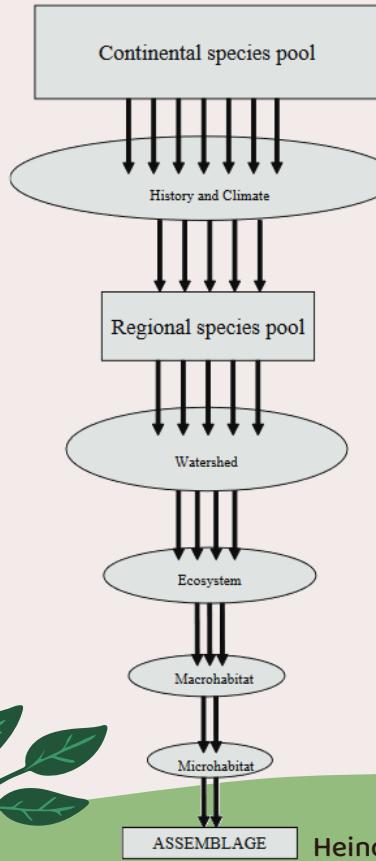
- Local habitats
- Geomorphology, water quality



# SPATIAL SCALE IN FRESHWATERS

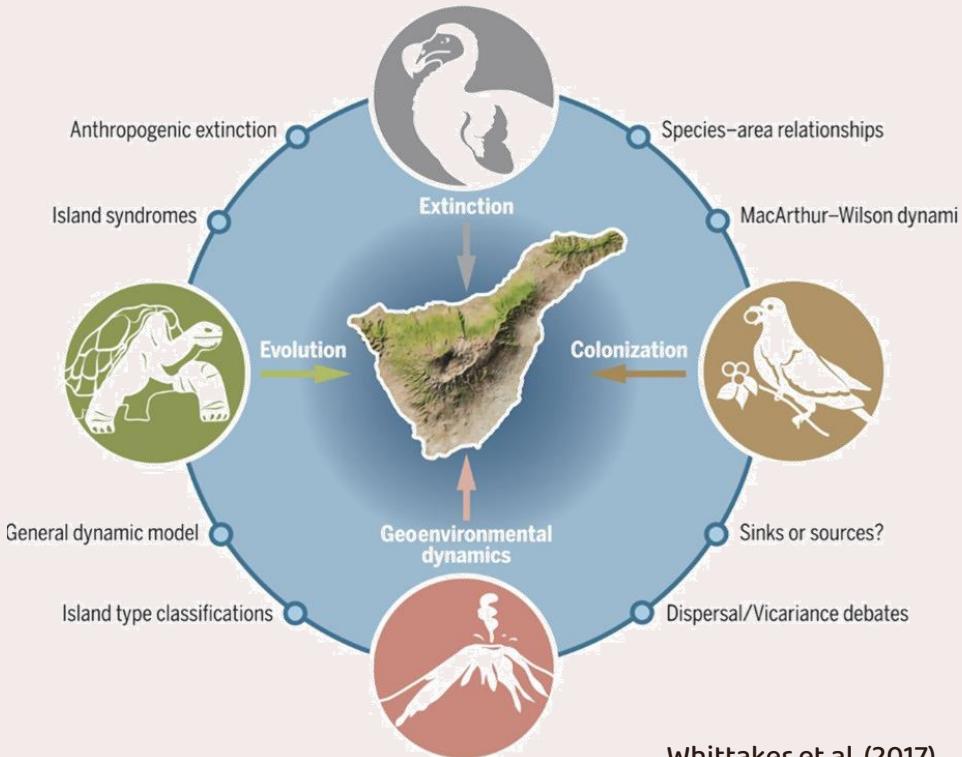


# SPATIAL SCALE IN FRESHWATERS



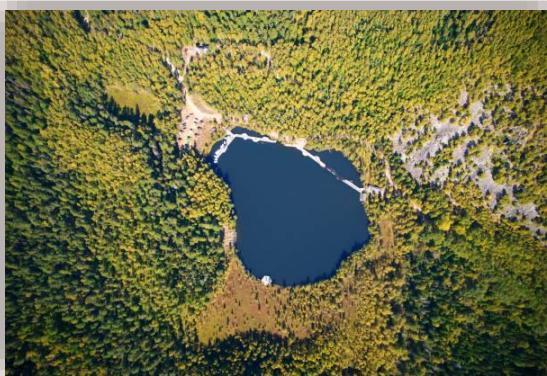
Gacía-Girón et al. (2023)

# LAKES AS ISLANDS

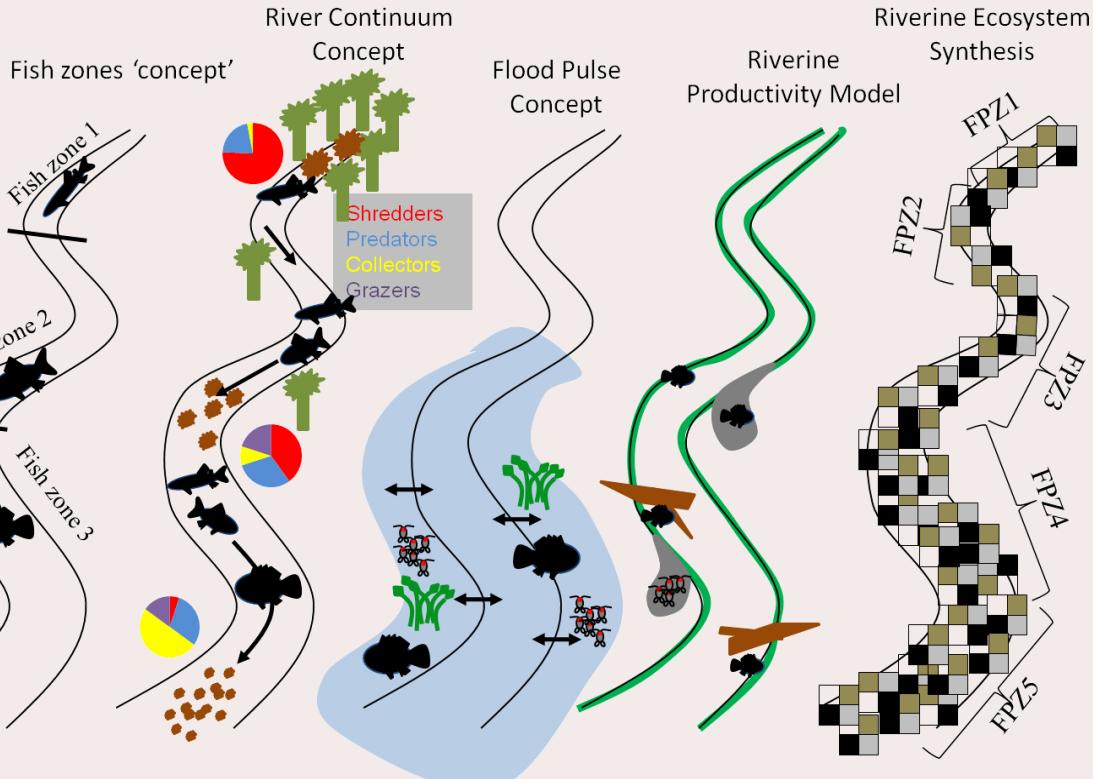


Whittaker et al. (2017)

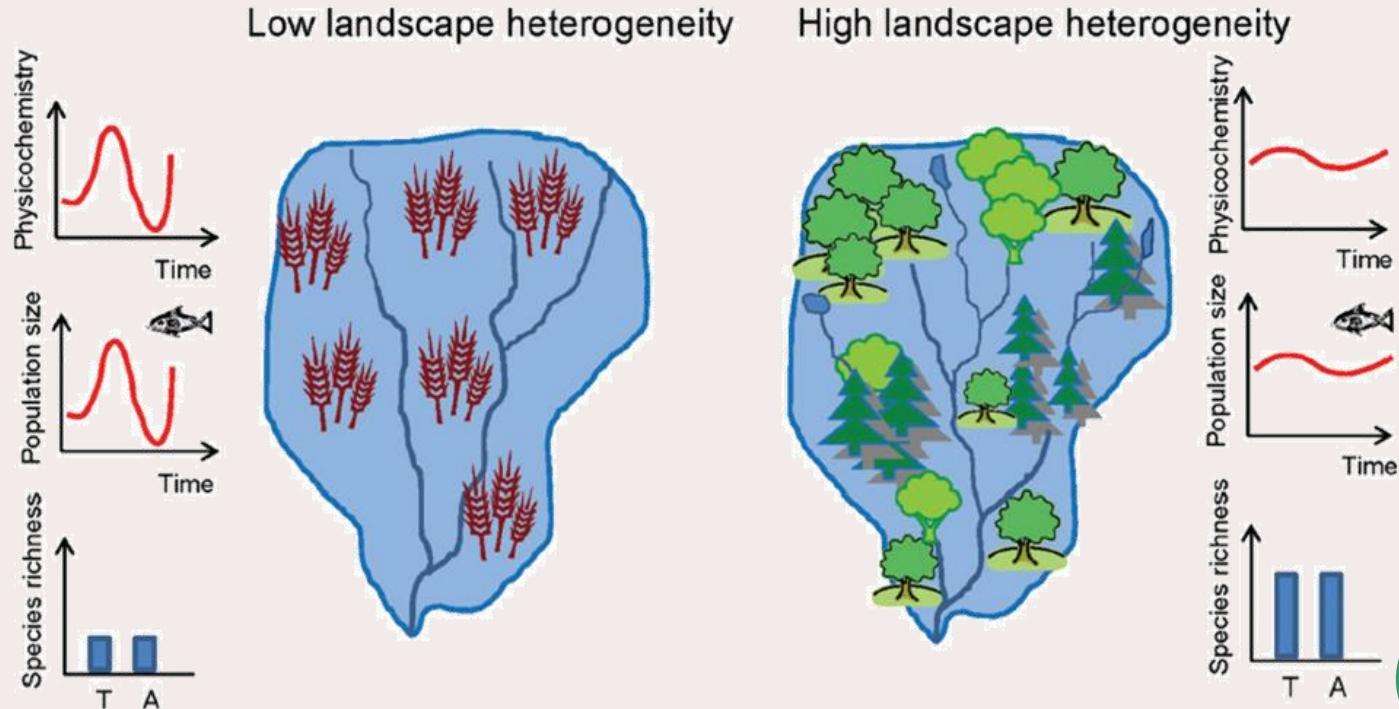
# LAKES AS ISLANDS



# RIVER CONTINUUM CONCEPT



# RIVER CONTINUUM CONCEPT



Soininen et al. (2015)

03



# BIOGEOGRAPHICAL PATTERNS IN FRESHWATERS

# BIOGEOGRAPHICAL PATTERNS



**GEOGRAPHY  
& HISTORY**



**LATITUDINAL  
GRADIENTS**



**RAPOPORT'S  
RULE**



**ALTITUDINAL  
GRADIENTS**

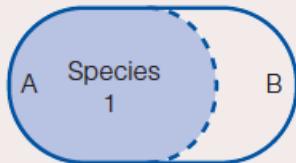


**SPECIES-AREA  
RELATIONSHIPS**

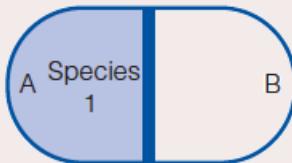


# GEOGRAPHY & HISTORY

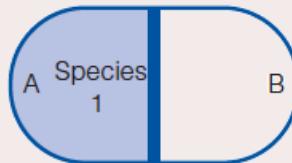
(a) Range extension



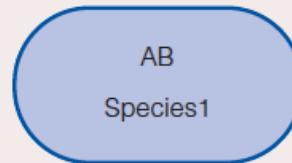
(b) Dispersion  
= geodispersal



(c) Jump dispersal



(d) Vicariance

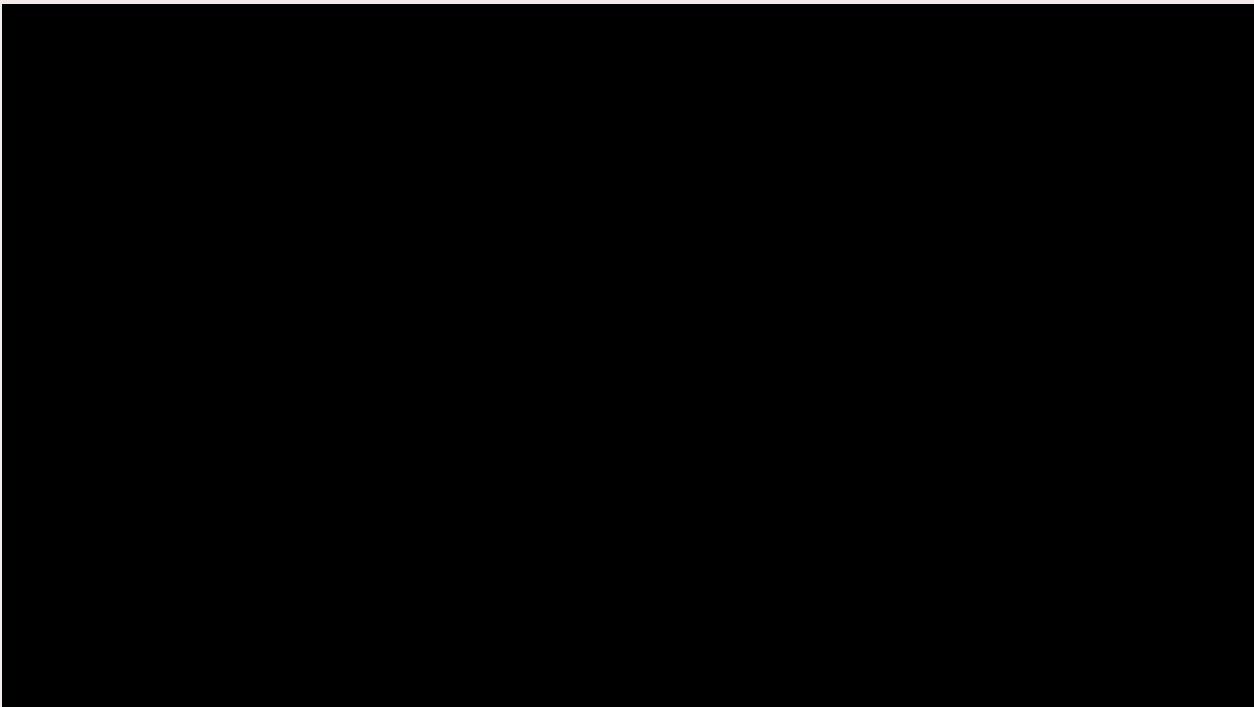


*Rhynchosciurus clavigera* in the Caño Cristales  
River (Sierra de la Macarena).

Cox et al. (2016; 9th ed.)

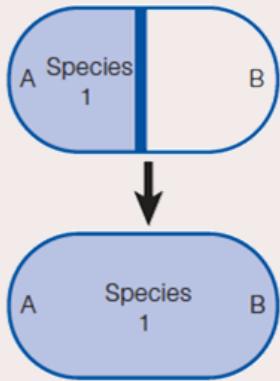
# GEOGRAPHY & HISTORY

*Rhynchosciadis clavigera*, a southern tropical endemic riverweed from Colombia

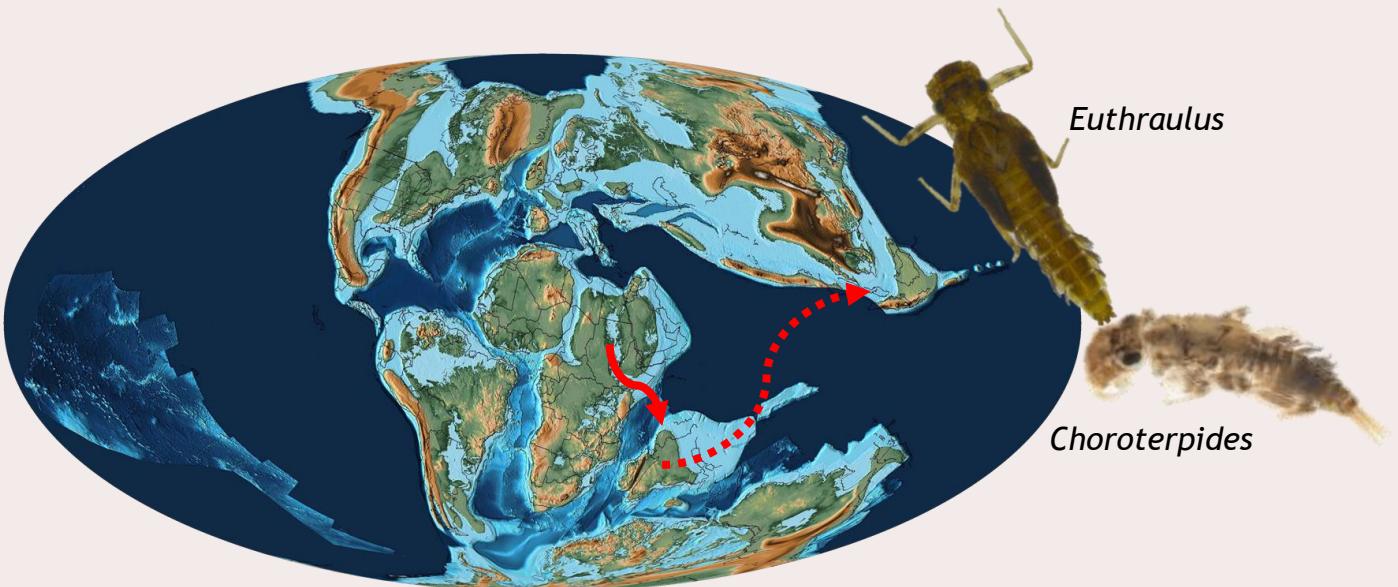


# GEOGRAPHY & HISTORY

(b) Dispersion  
= geodispersal



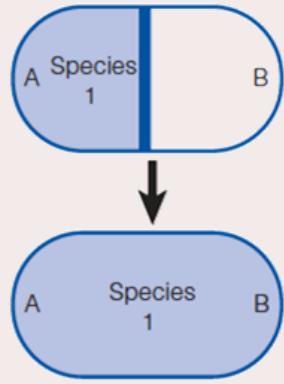
**Example 1:** Trans-marine dispersal postdating the early separation of India from mainland explains affinities of atalophlebiine leptophlebiids



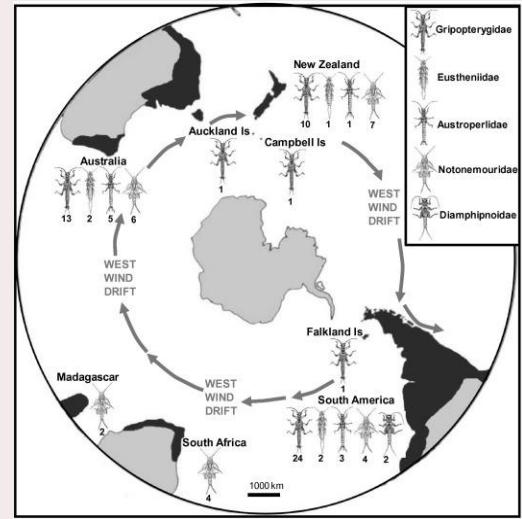
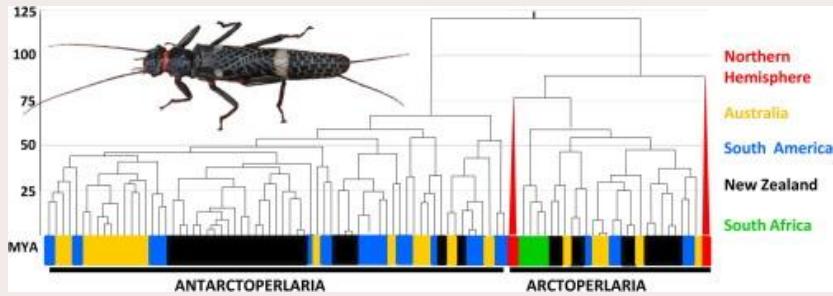
# GEOGRAPHY & HISTORY



(b) Dispersion  
= geodispersal



**Example 2:** Circumpolar Cenozoic connections among Gondwana antarctoperlarian stoneflies with disjunct distributions



McCulloch et al. (2016)



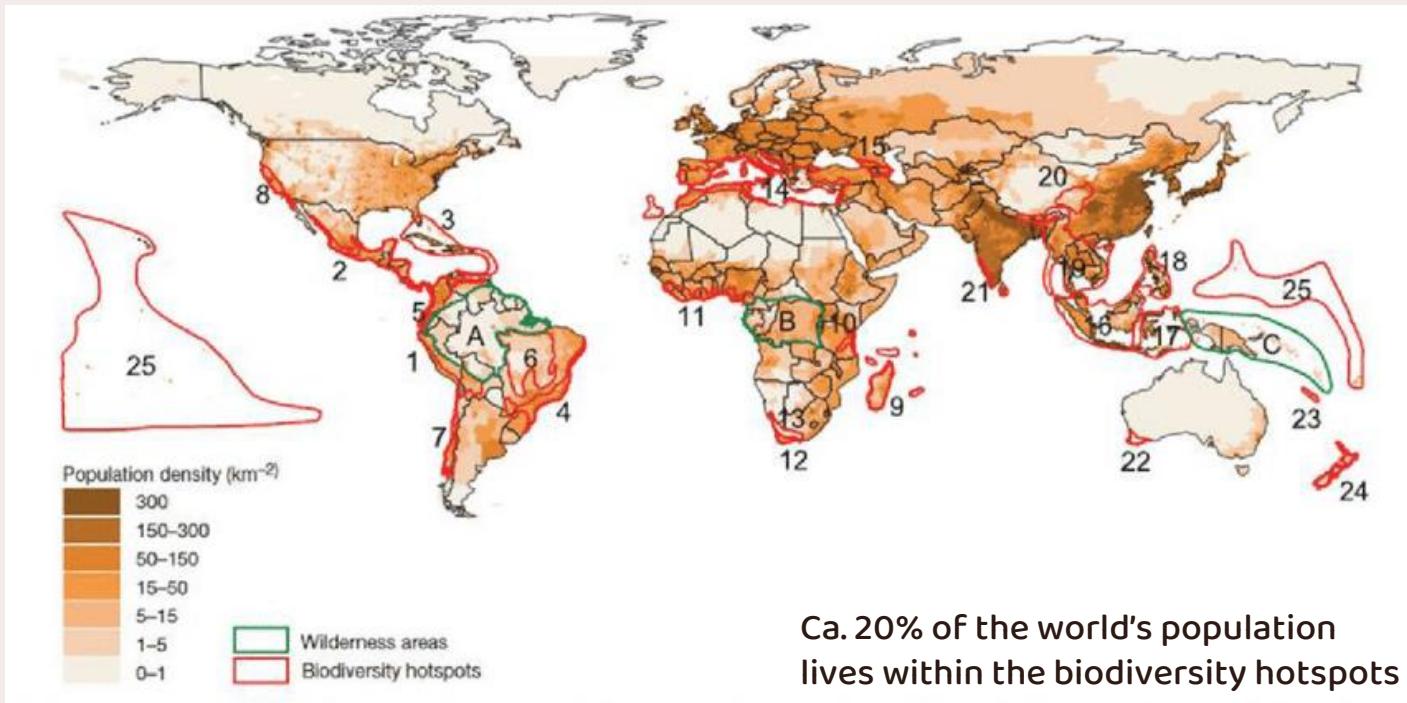
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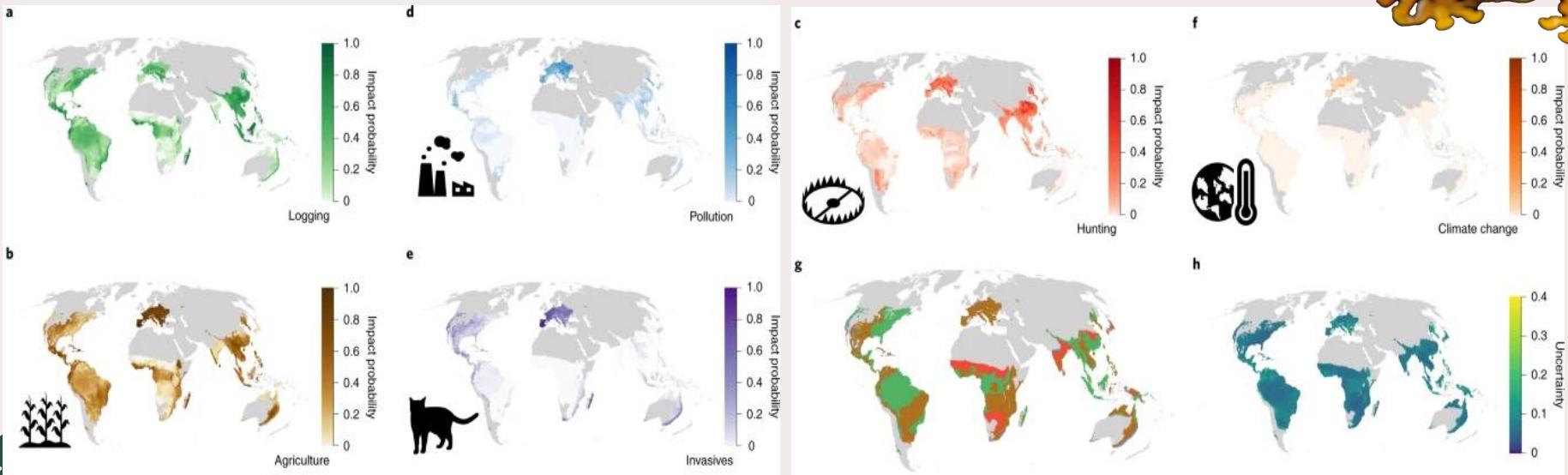
# GEOGRAPHY & HISTORY

Hotspots as centres of evolution for endemic organisms



# GEOGRAPHY & HISTORY

Hotspots as centres of evolution for endemic organisms



Harfoot et al. (2021)

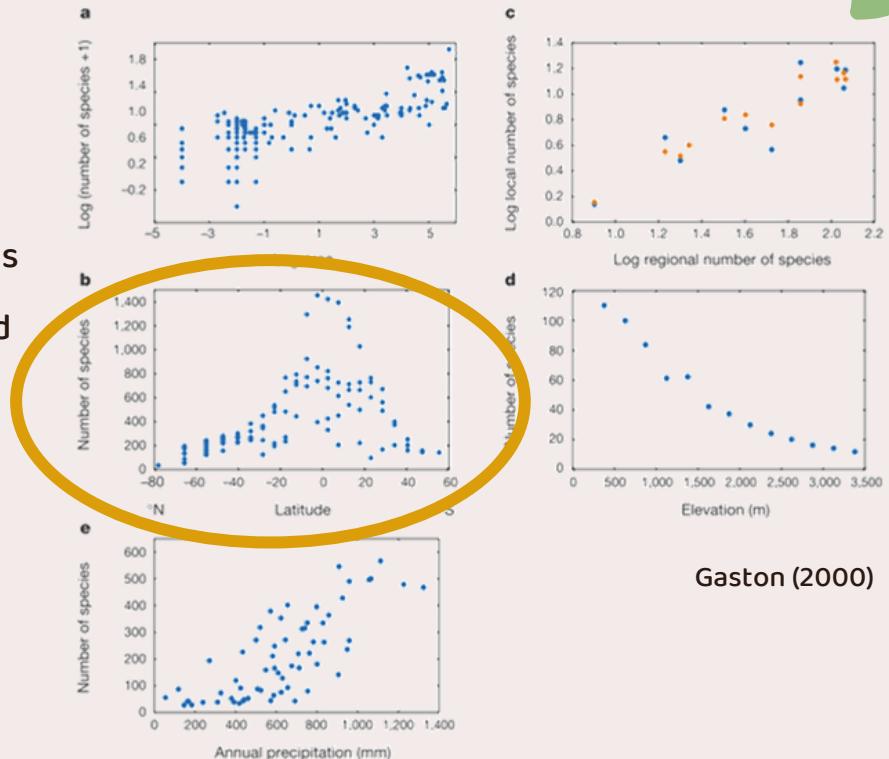
# LATITUDINAL GRADIENTS

General assumption is that **species richness decreases from the equator towards the Poles**



Mostly based on terrestrial organisms

Also differences among taxonomic, functional, and phylogenetic facets



Gaston (2000)

# LATITUDINAL GRADIENTS

**Time period:** January 2003–September 2015.

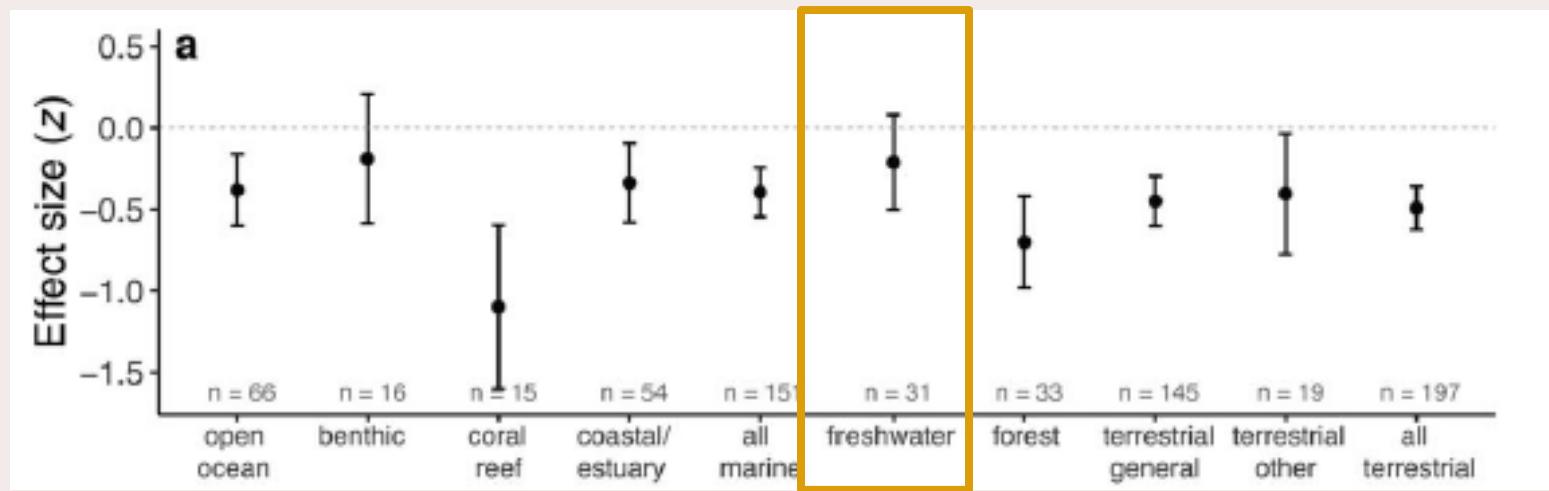
**Major taxa studied:** Bacteria, protists, plants, fungi and animals.

**Methods:** We synthesized the outcomes of 389 individual cases of LDGs from 199 papers published since 2003, using hierarchical mixed-effects meta-analysis and multiple meta-regression. Additionally, we re-analysed Hillebrand's original dataset using modern methods.

**Results:** We confirmed the generality of the LDG, but found the pattern to be weaker than was found in Hillebrand's study. We identified previously unreported variation in LDG strength and slope across longitude, with evidence that the LDG is strongest in the Western Hemisphere. Locational characteristics, such as habitat and latitude range, contributed significantly to LDG strength, whereas organismal characteristics, including taxonomic group and trophic level, did not. Modern meta-analytical models that incorporate hierarchical structure led to more conservative and sometimes contrasting effect size estimates relative to Hillebrand's initial analysis, whereas meta-regression revealed underlying patterns in Hillebrand's dataset that were not apparent with a traditional analysis.

Kinlock et al. (2018)

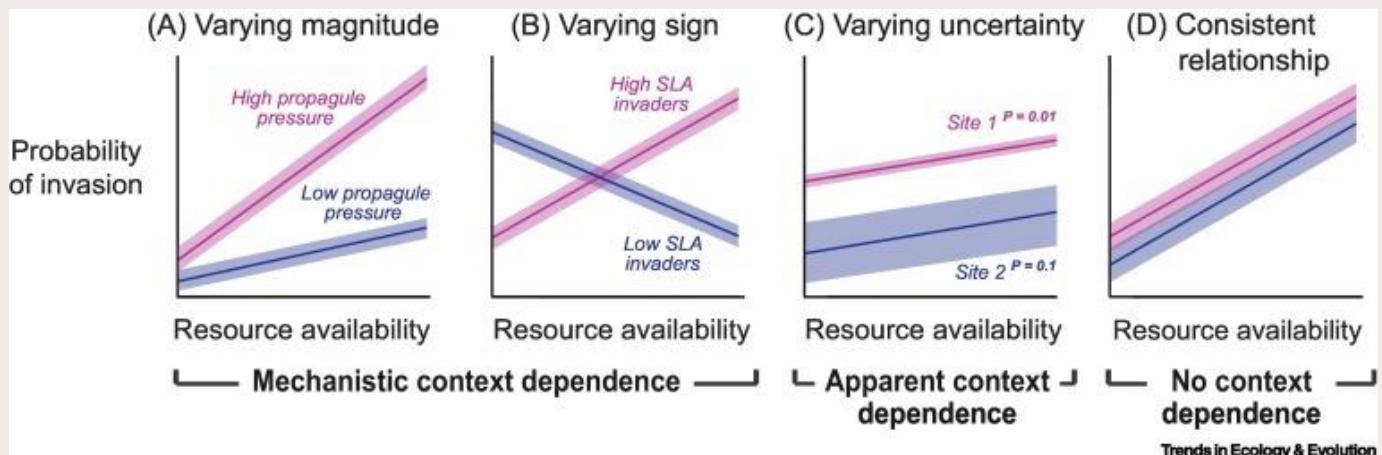
# LATITUDINAL GRADIENTS



Kinlock et al. (2018)

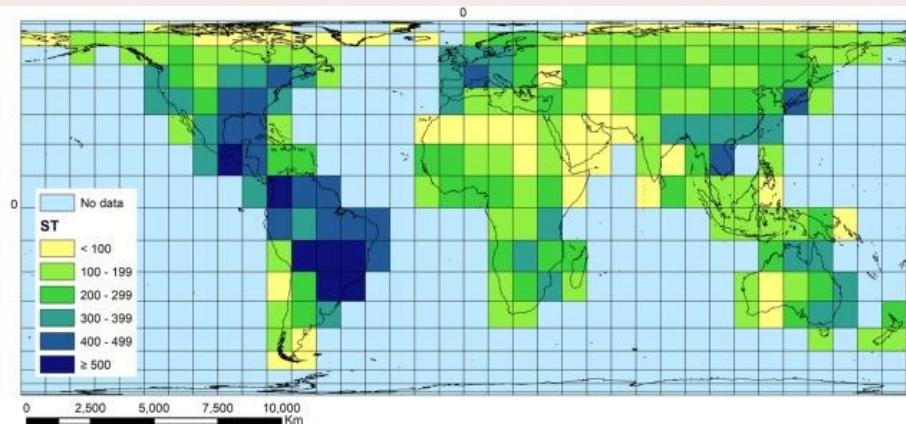
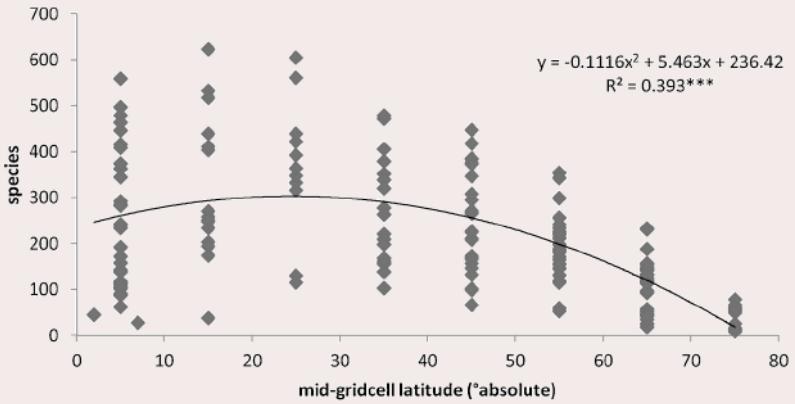
# LATITUDINAL GRADIENTS

- Decreasing trend found for fish richness (also endemism)
- Drainage basins in the Tropics and sub-Tropics harbour high species richness of crayfish, amphibians, aquatic birds, and aquatic mammals
- Hump-shaped patterns have been found for many freshwater organismal groups (e.g., aquatic macrophytes)



# LATITUDINAL GRADIENTS

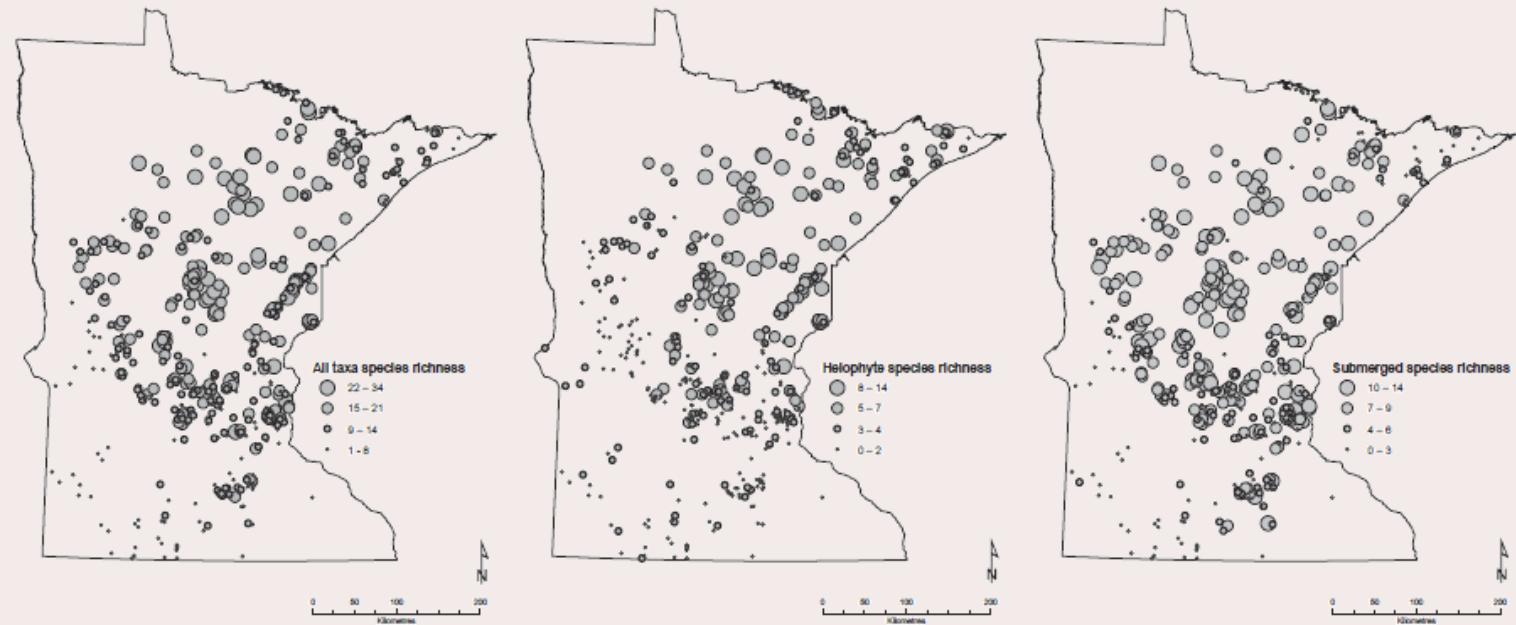
MACROPHYTES



Murphy et al. (2019)

# LATITUDINAL GRADIENTS

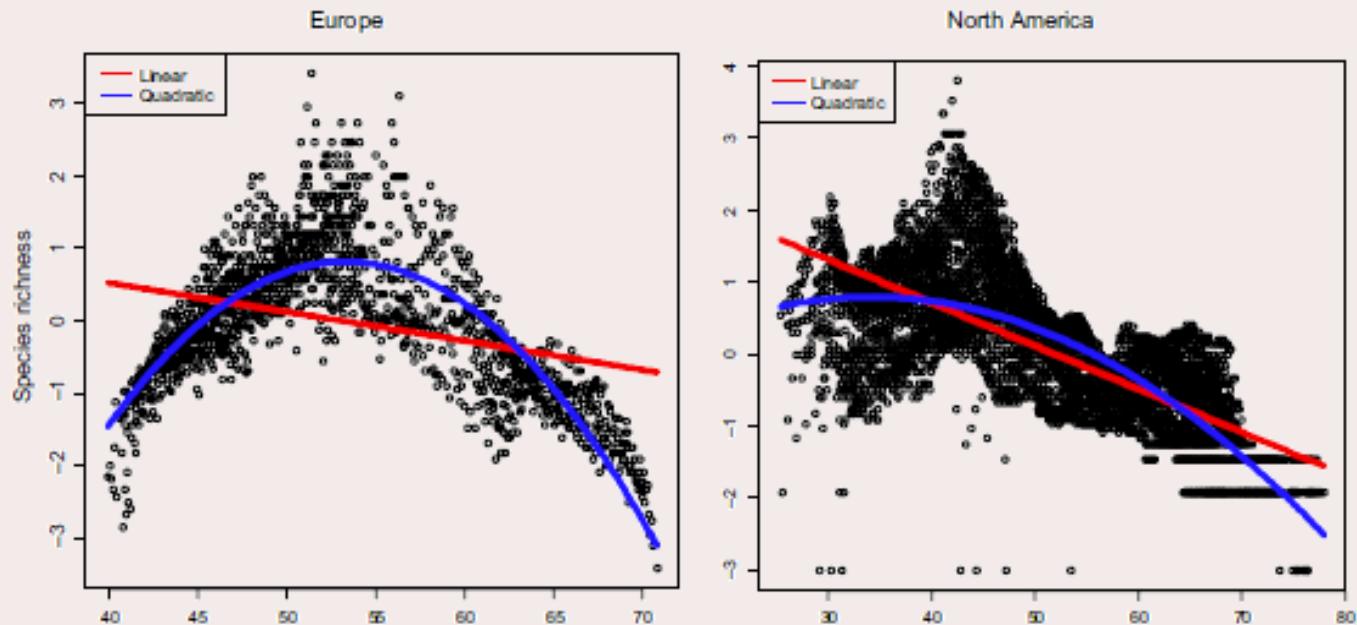
## MACROPHYTES



Alahuhta (2015)

# LATITUDINAL GRADIENTS

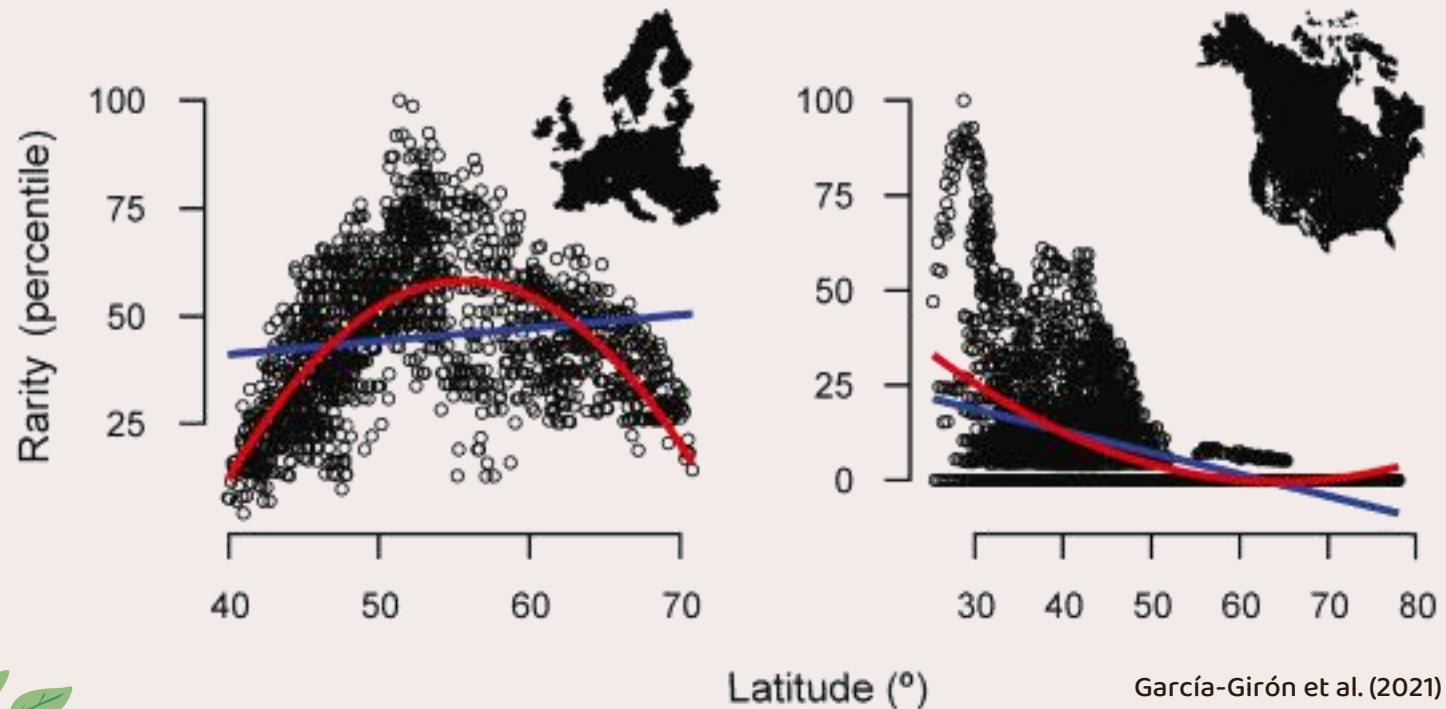
## MACROPHYTES



Alahuhta et al. (2020)

# LATITUDINAL GRADIENTS

MACROPHYTES



García-Girón et al. (2021)



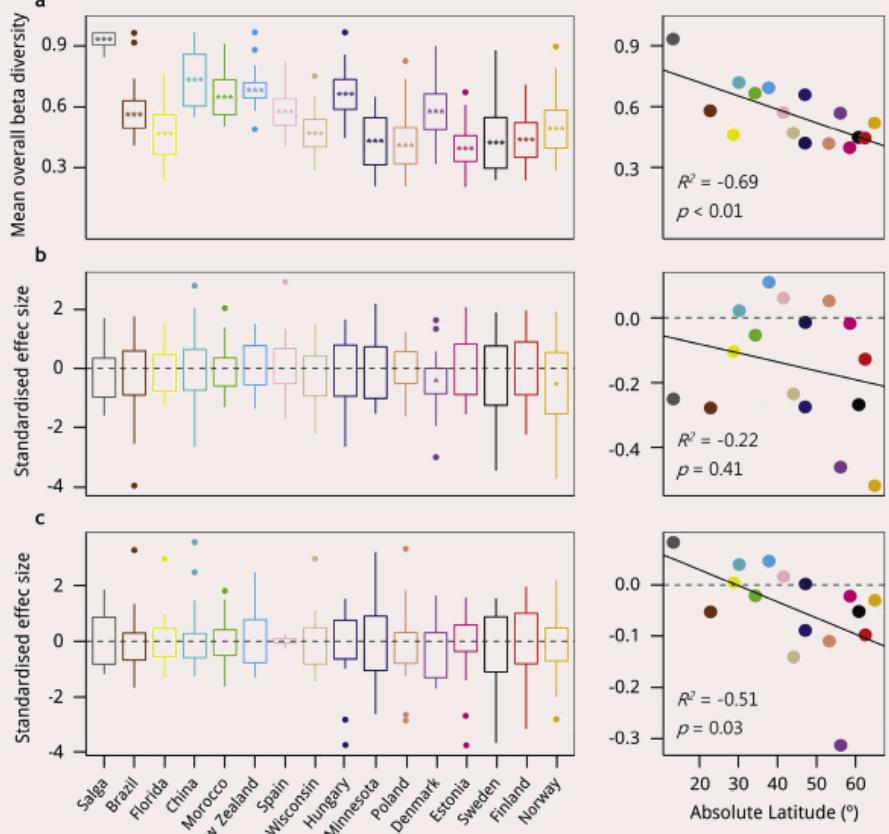
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# LATITUDINAL GRADIENTS

MACROPHYTES



García-Girón et al. (2021)



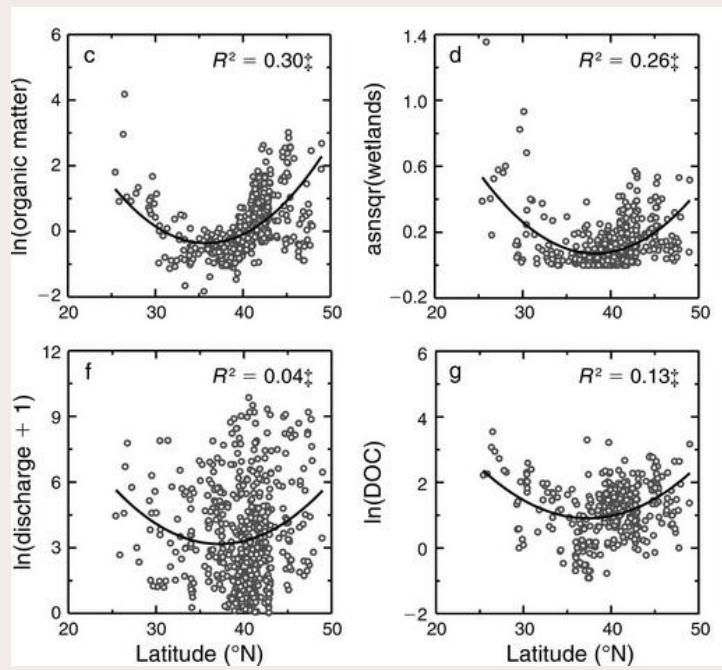
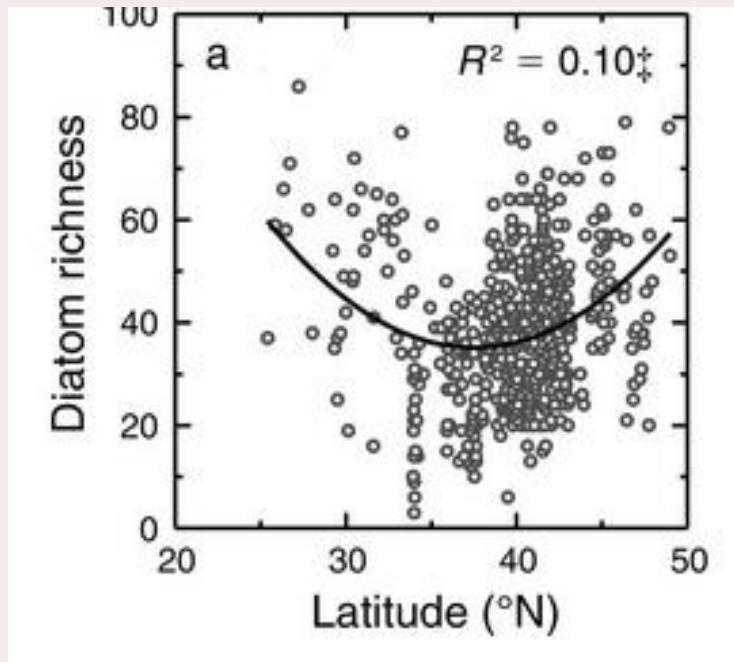
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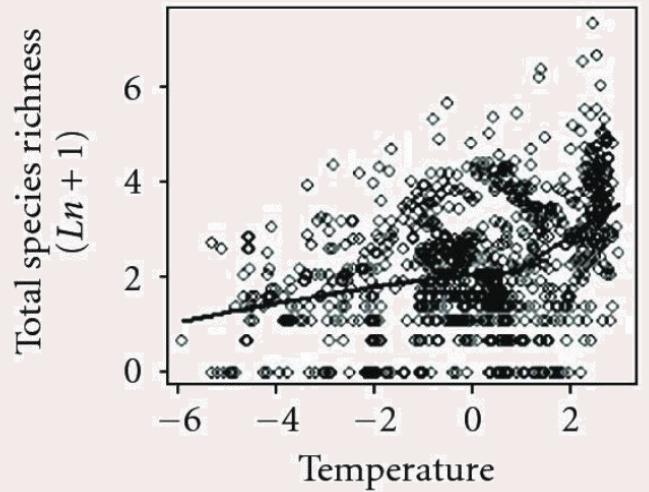
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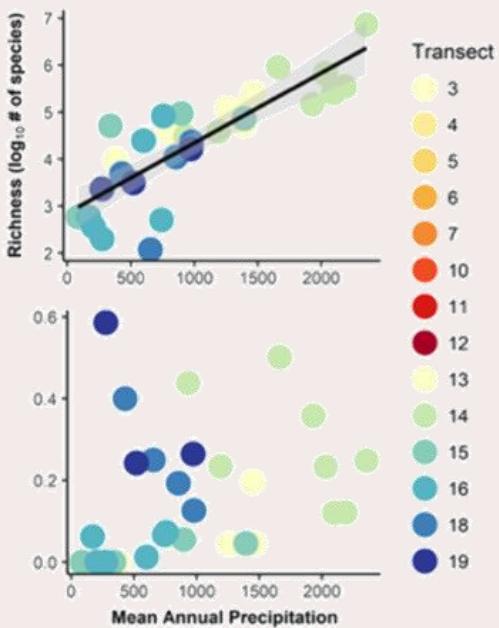
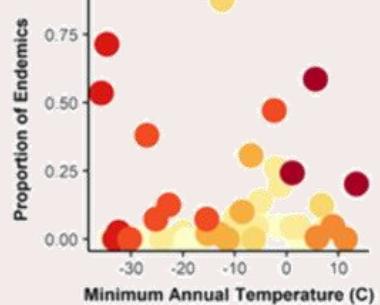
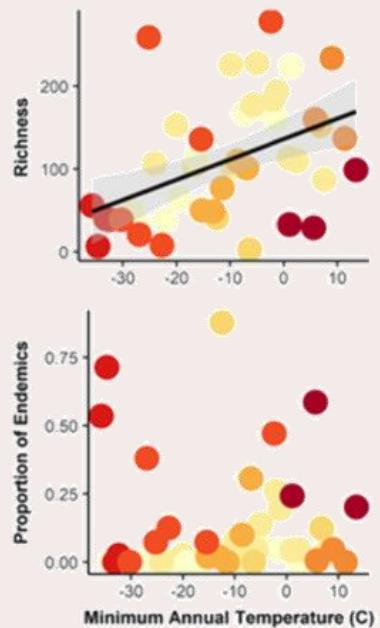
DIATOMS



# LATITUDINAL GRADIENTS



Oberdorff et al. (2011)



Dodds et al. (2019)



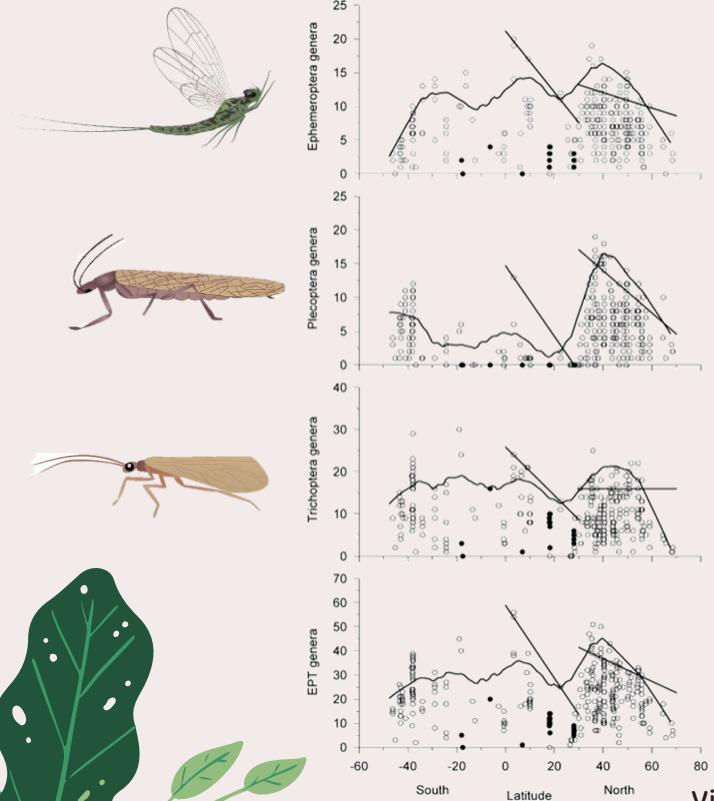
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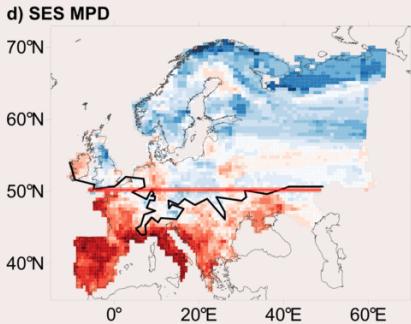
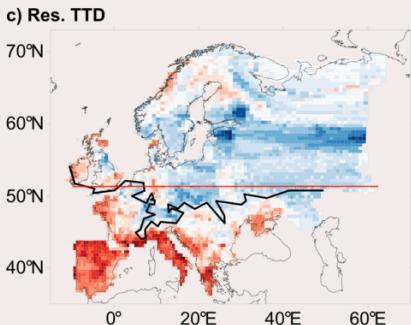
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# LATITUDINAL GRADIENTS

## INSECTS



Vinson & Hawkins (2003)



Pinkert et al. (2017)



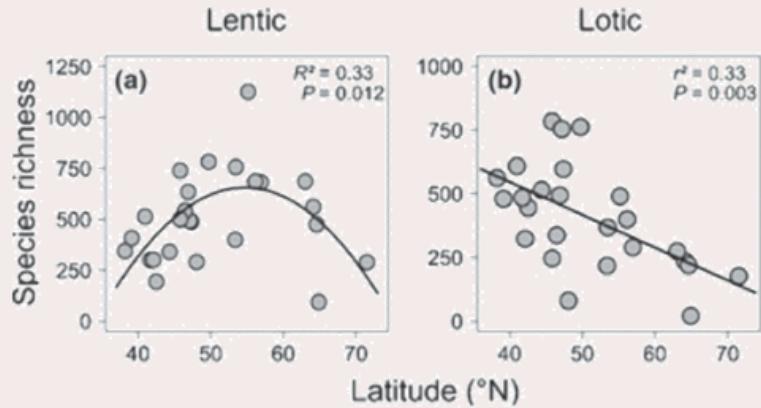
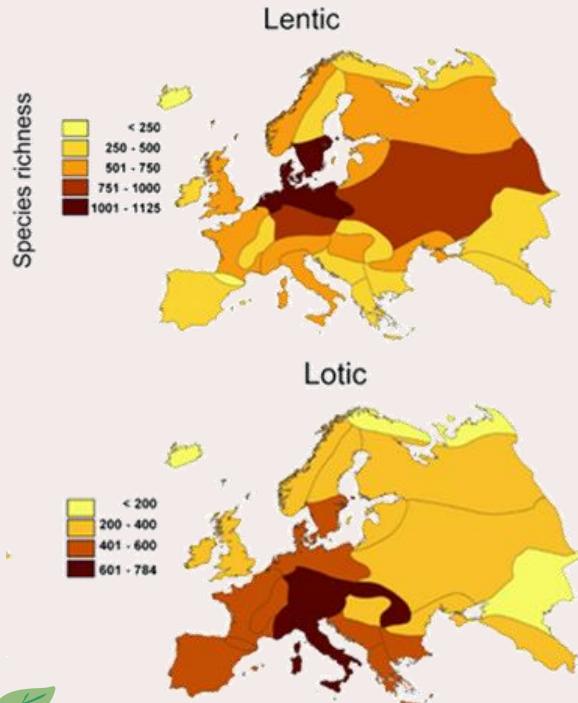
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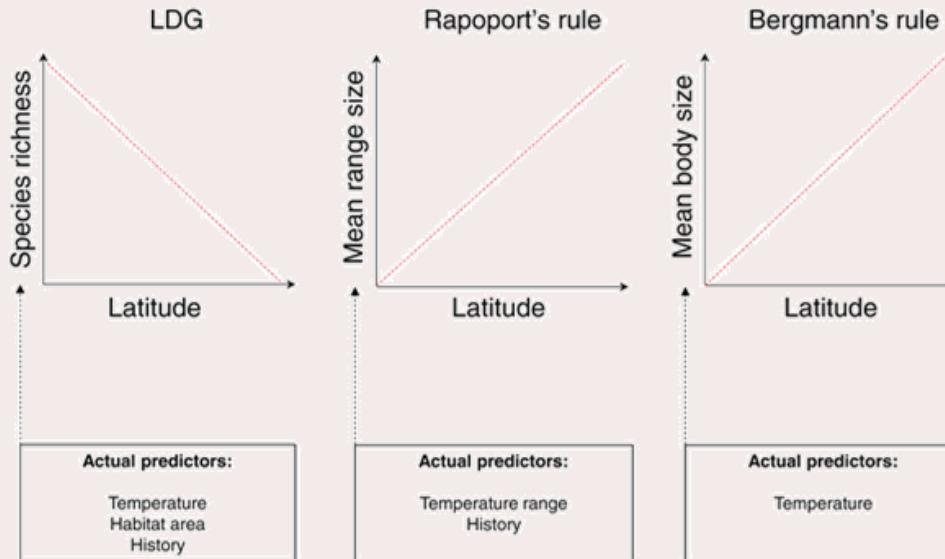
## Lentic vs. Lotic across ecoregions



Dehling et al. (2010)

# RAPOPORT'S RULE

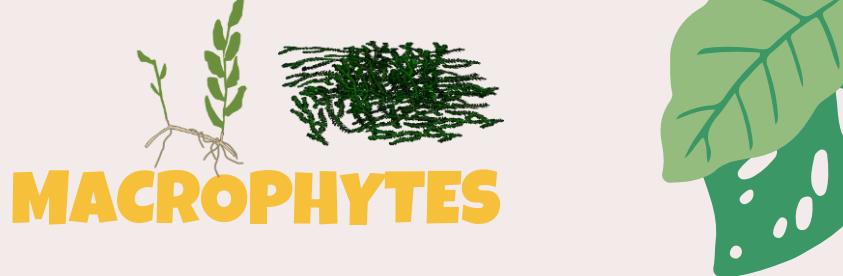
"Latitudinal ranges of plants and animals are generally smaller at lower latitudes than at higher latitudes"



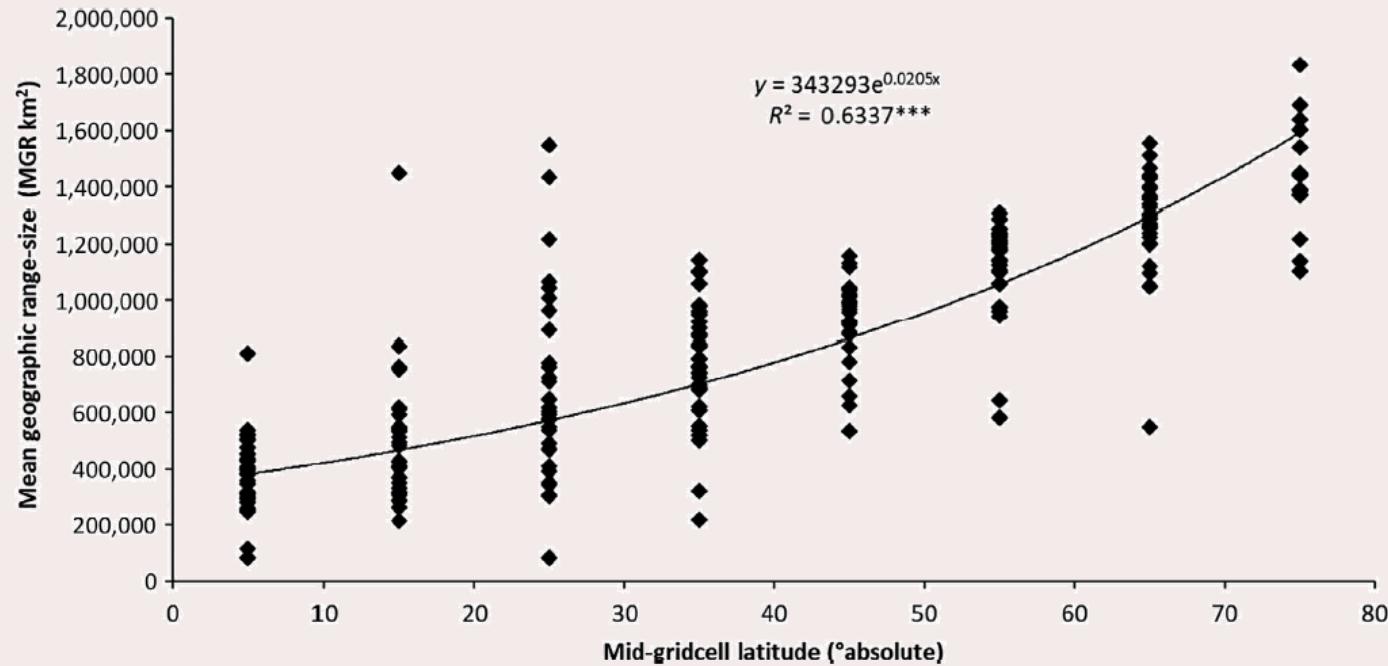
Heino & Alahuhta (2019)



# RAPORT'S RULE



## MACROPHYTES

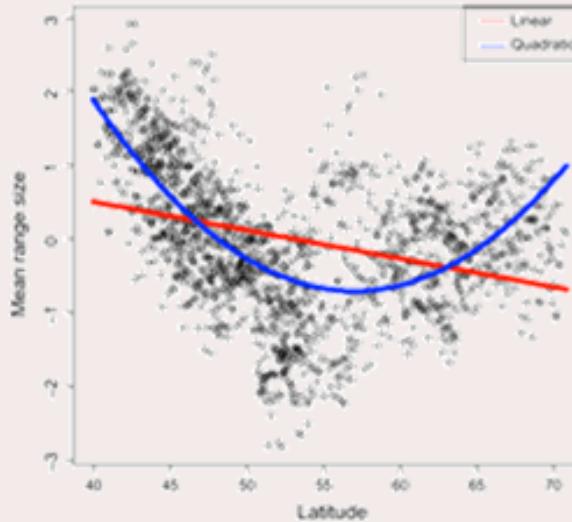
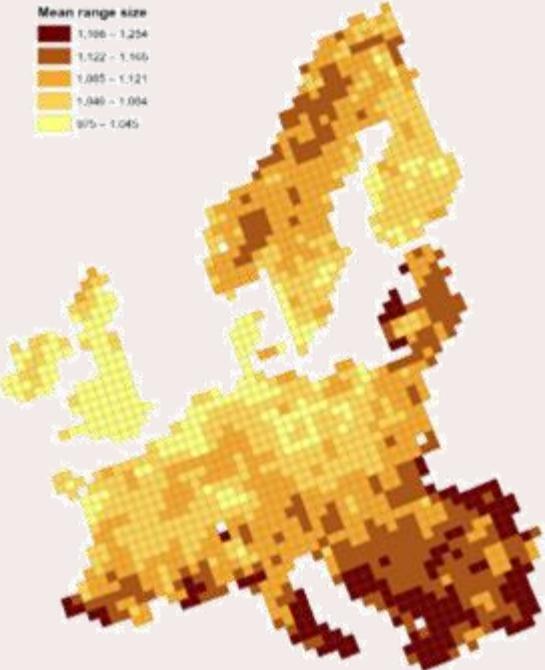


Murphy et al. (2021)

# RAPORT'S RULE

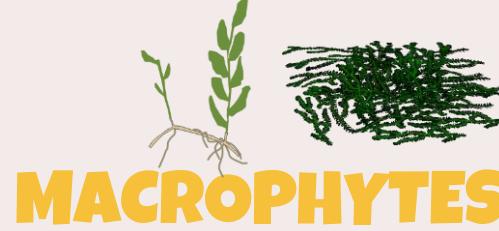


## MACROPHYTES

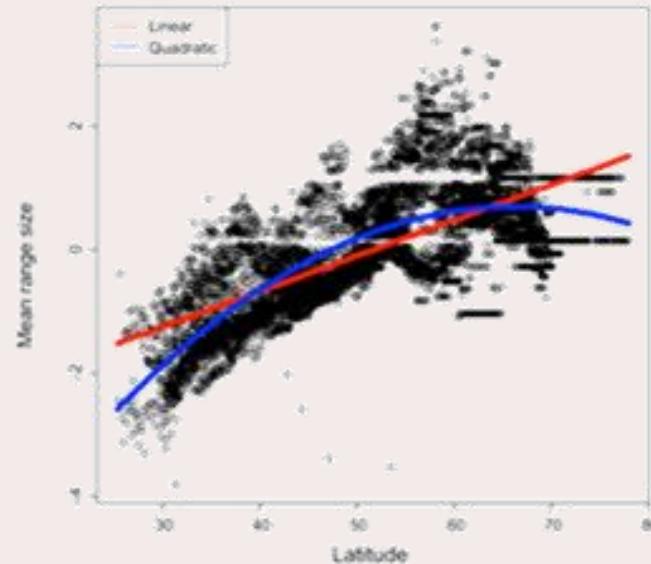
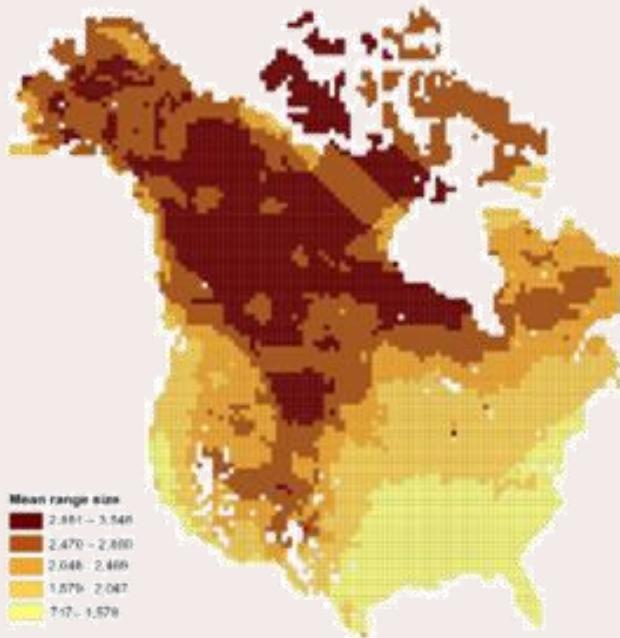


Alahuhta et al. (2020)

# RAPPORT'S RULE



## MACROPHYTES



Alahuhta et al. (2020)

# RAPOPORT'S RULE

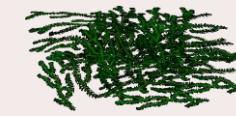
$$A_1 > A_2 > A_3 > A_4 > A_5$$



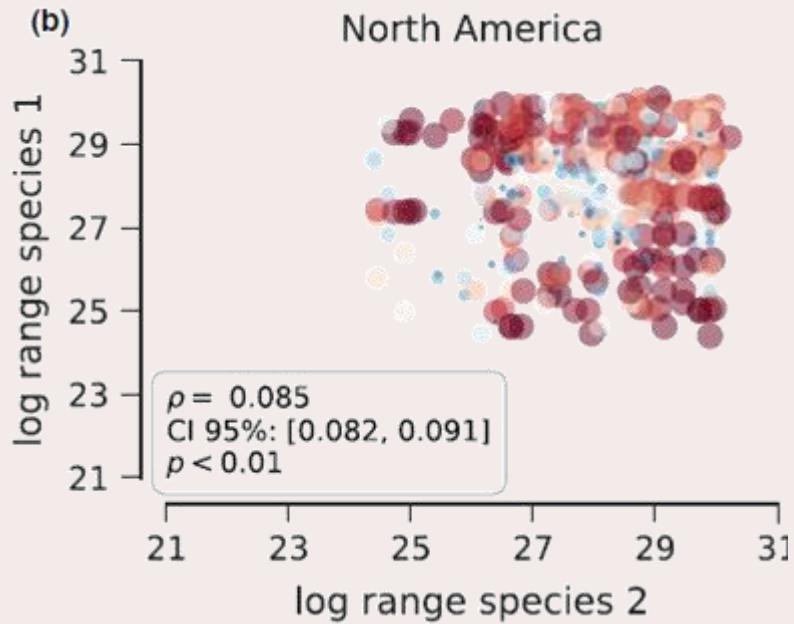
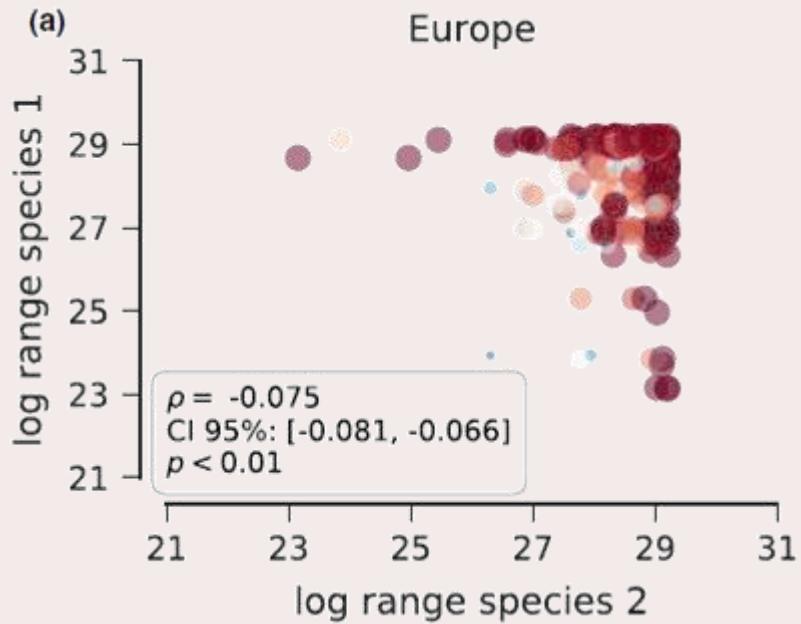
## MACROPHYTES

"Range size conservatism refers to a tendency of closely related species to maintain geographical ranges of similar extent"

# RAPOPORT'S RULE

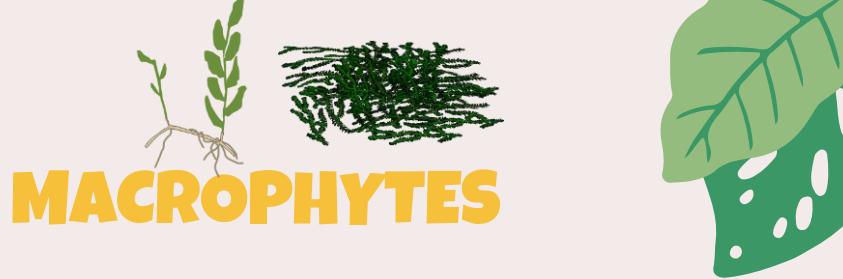


## MACROPHYTES

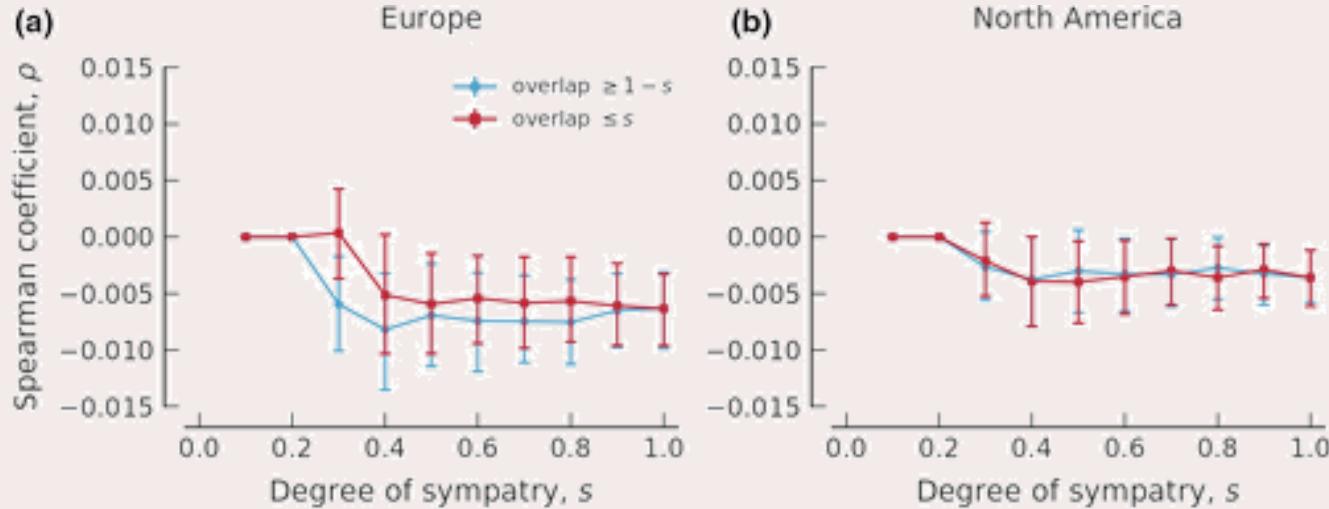


Vieira et al. (2021)

# RAPORT'S RULE



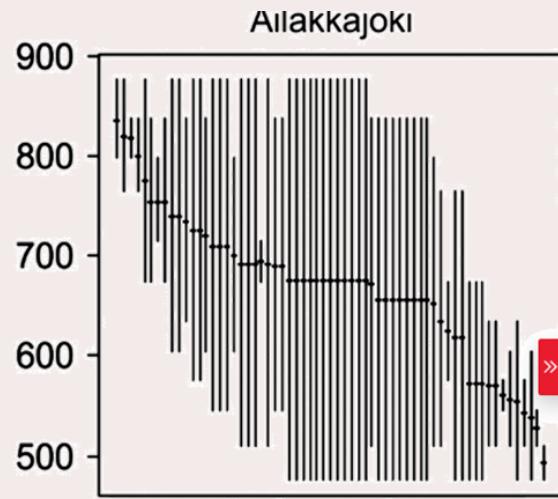
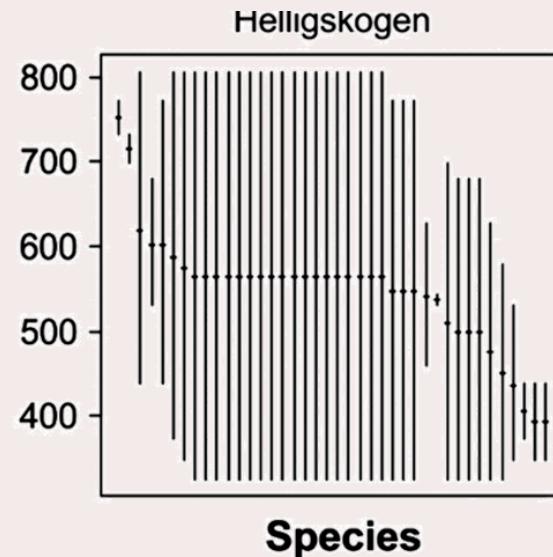
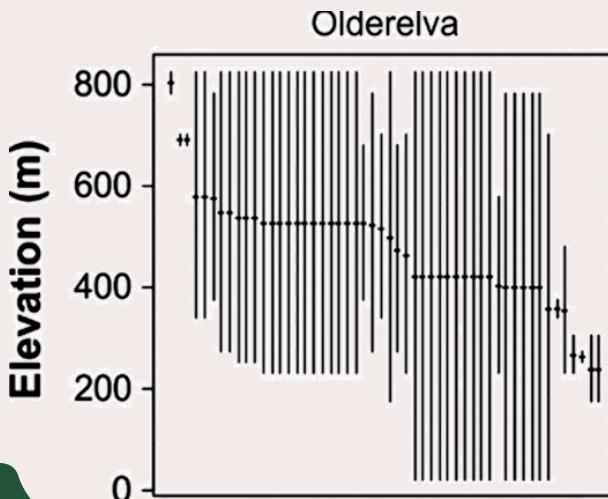
## MACROPHYTES



Vieira et al. (2021)

# RAPOPORT'S RULE

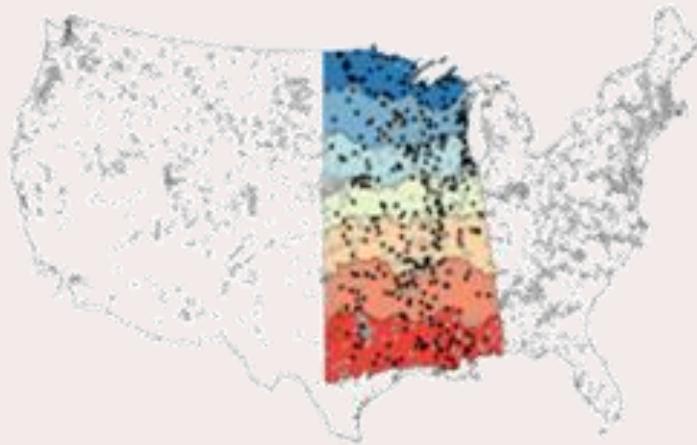
DIATOMS



Teittinen et al. (2016)

# RAPORT'S RULE

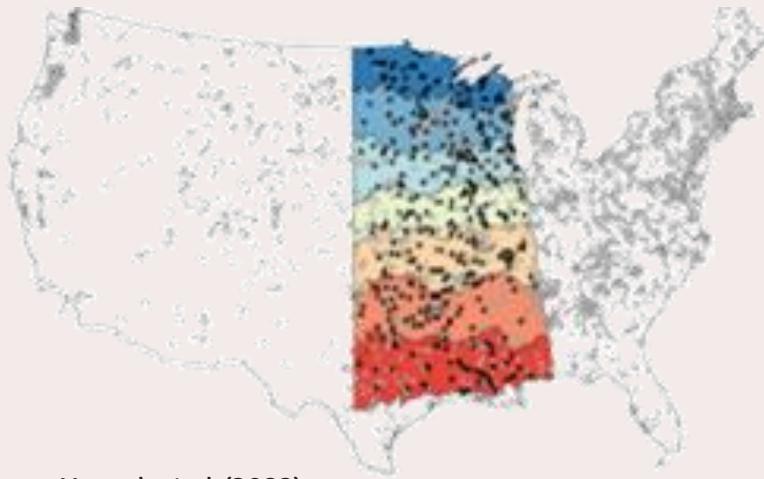
## DIATOMS



Mruzek et al. (2022)

# RAPORT'S RULE

FISH



Mruzek et al. (2022)

"In contrast, the rule applies to North American (720 species) and North European (61 species) freshwater fish above a latitude of approximately 40°N".

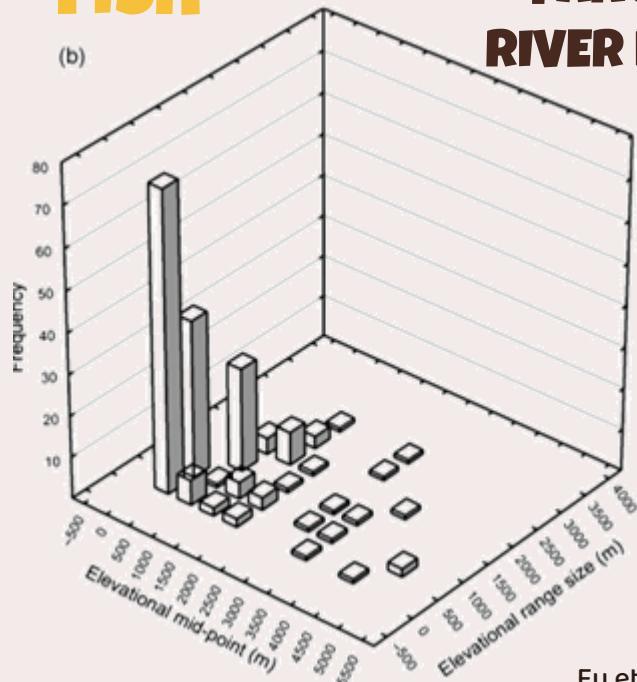
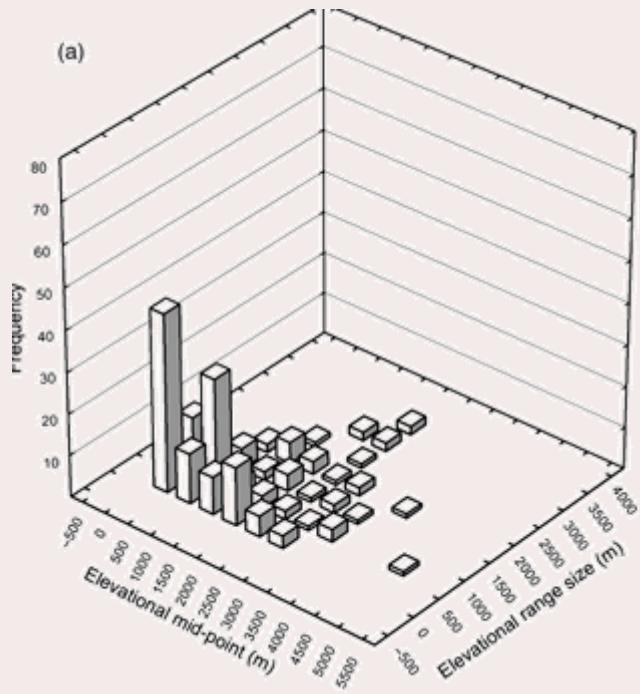
Rohde et al. (1993). *American Naturalist*

# RAPORT'S RULE



FISH

YANGTZE  
RIVER BASIN



Fu et al. (2014)



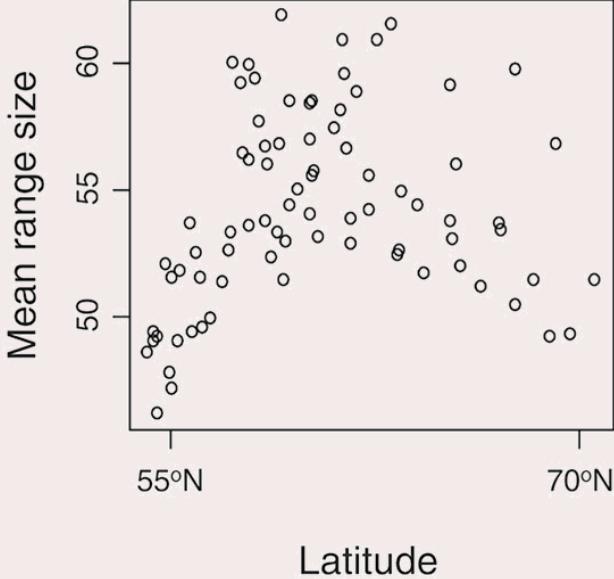
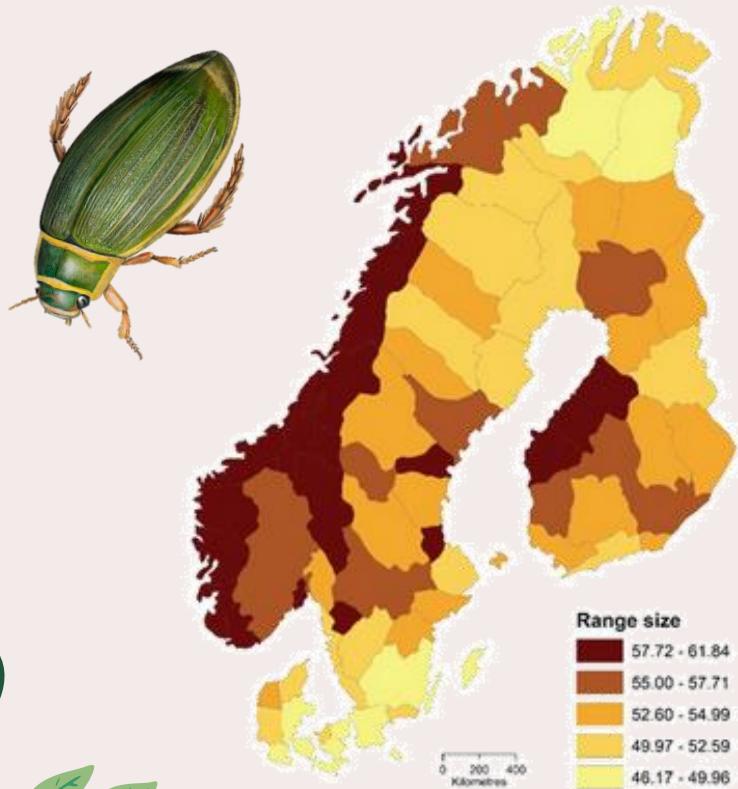
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# RAPOPORT'S RULE

INSECTS



Heino & Alahuhta (2019)



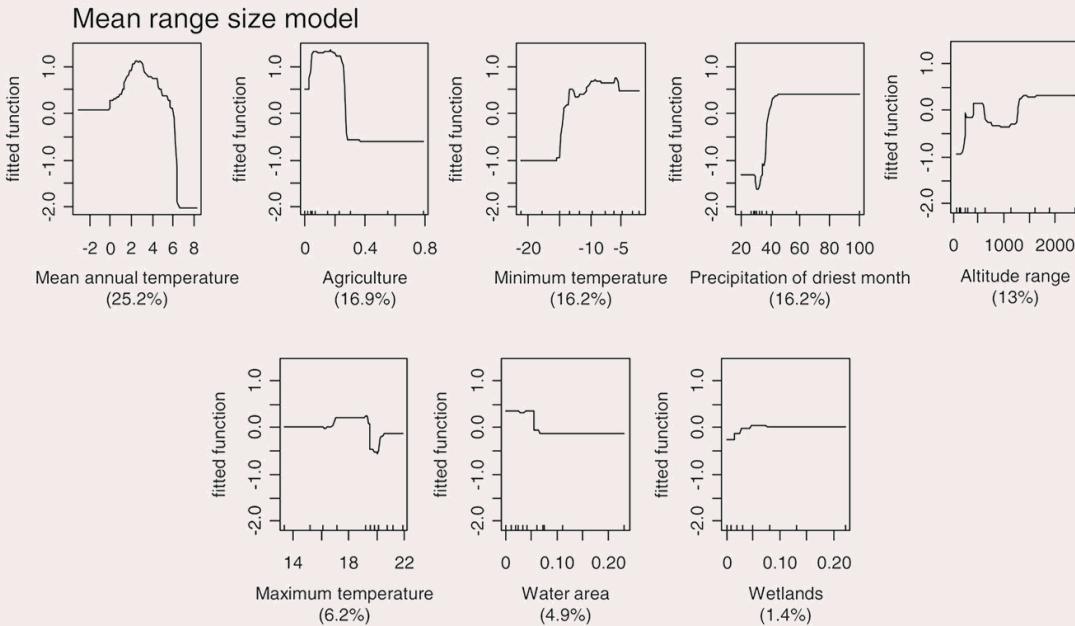
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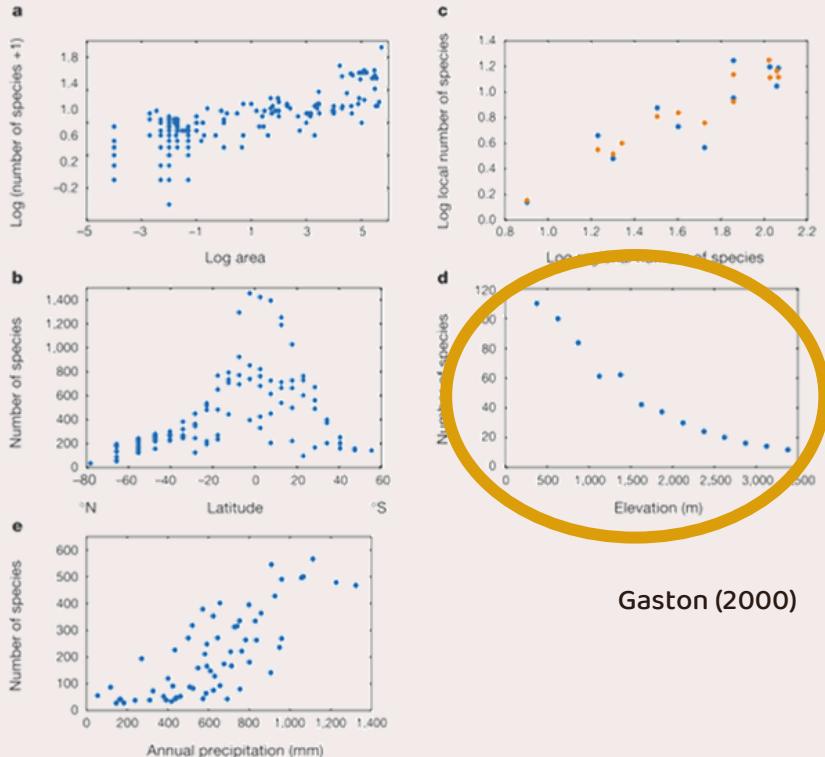
# RAPORT'S RULE

## INSECTS



Heino & Alahuhta (2019)

# ALTITUDINAL GRADIENTS

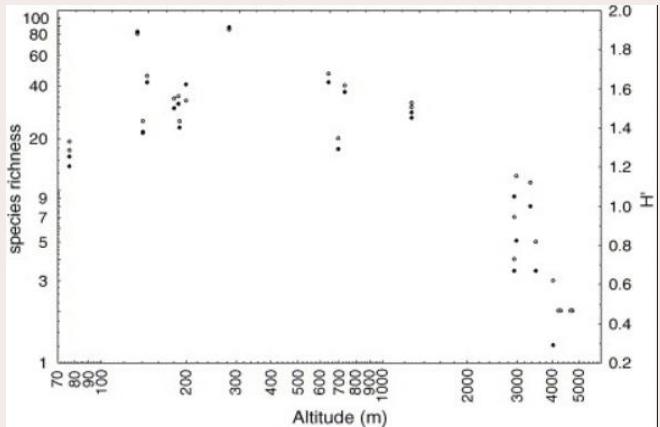


Gaston (2000)

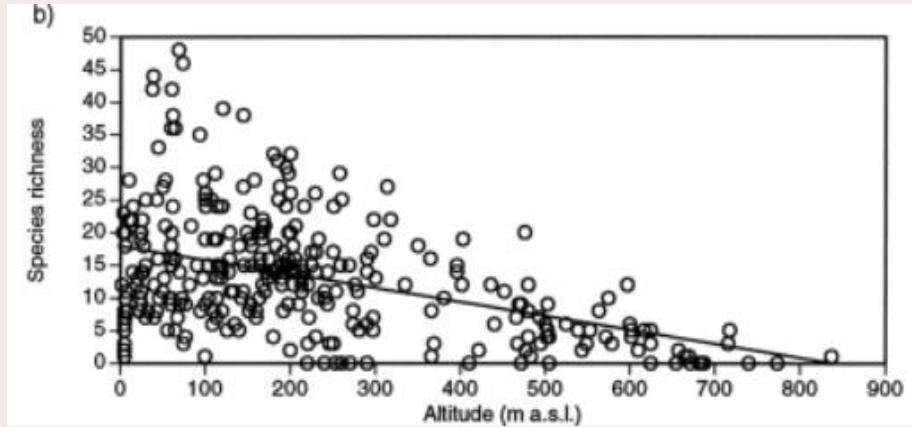
# ALTITUDINAL GRADIENTS



## MACROPHYTES



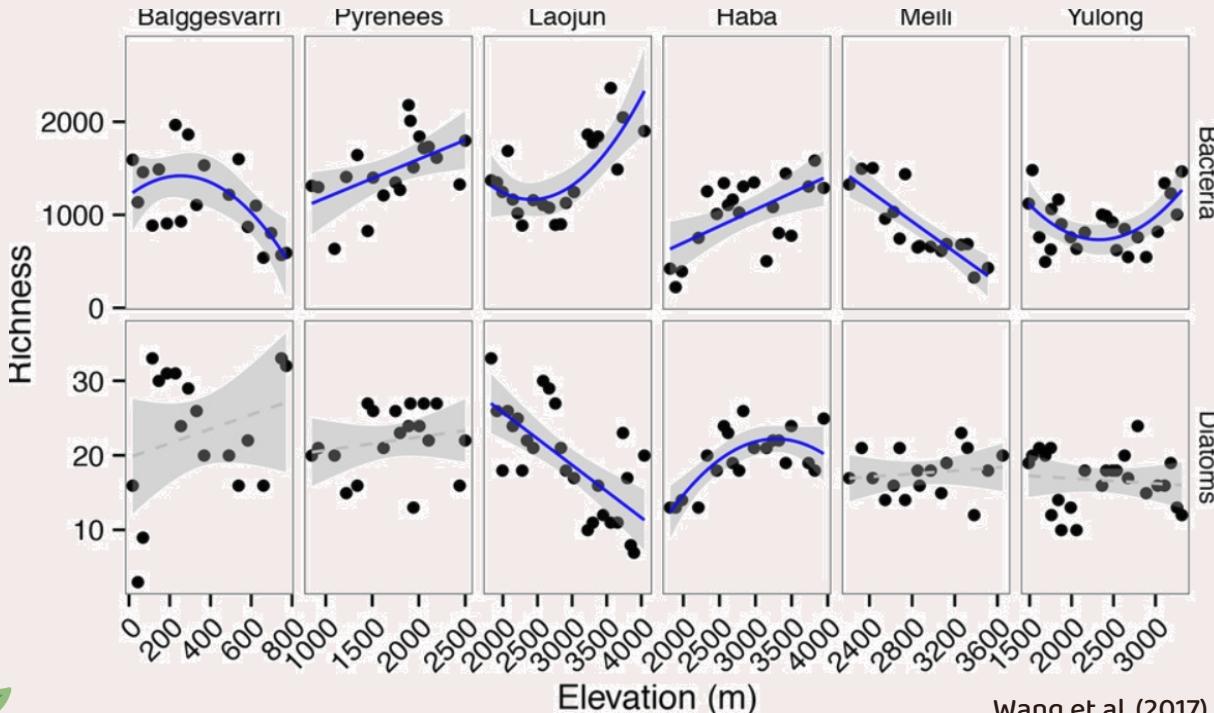
Lacoul & Freedman (2006)



Jones et al. (2003)

# ALTITUDINAL GRADIENTS

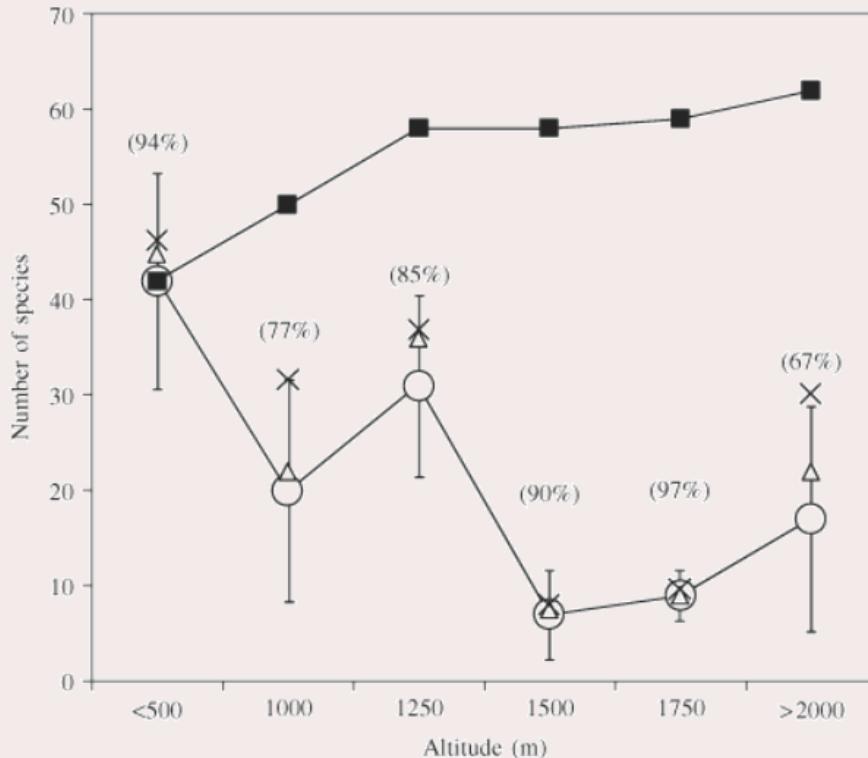
## DIATOMS



# ALTITUDINAL GRADIENTS



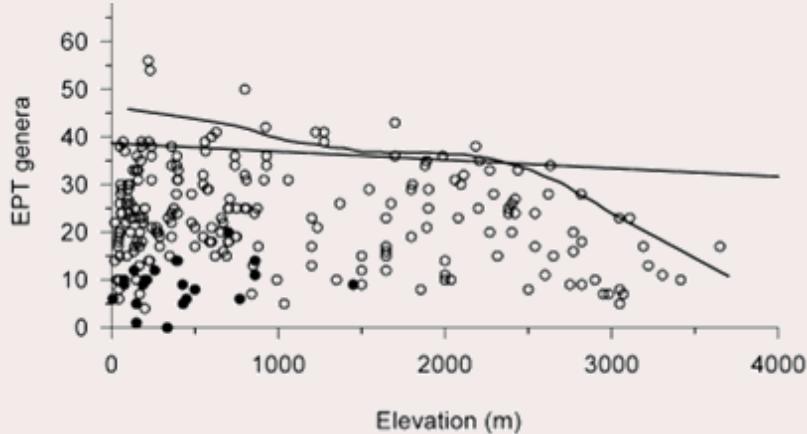
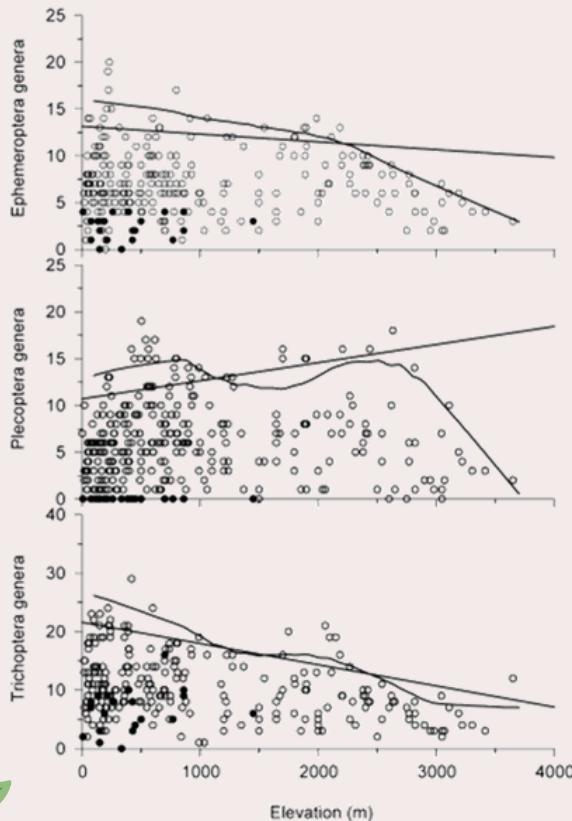
FISH



Jaramillo-Villa et al. (2010)

# ALTITUDINAL GRADIENTS

## INSECTS



Elevation (m)

Vinson & Hawkins (2003)

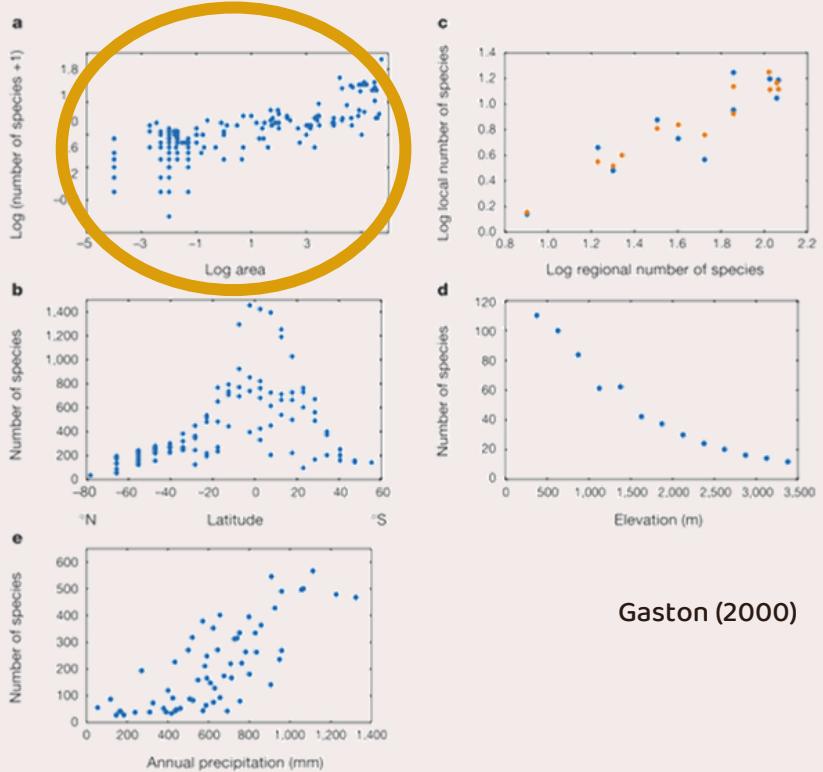


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# SPECIES-AREA

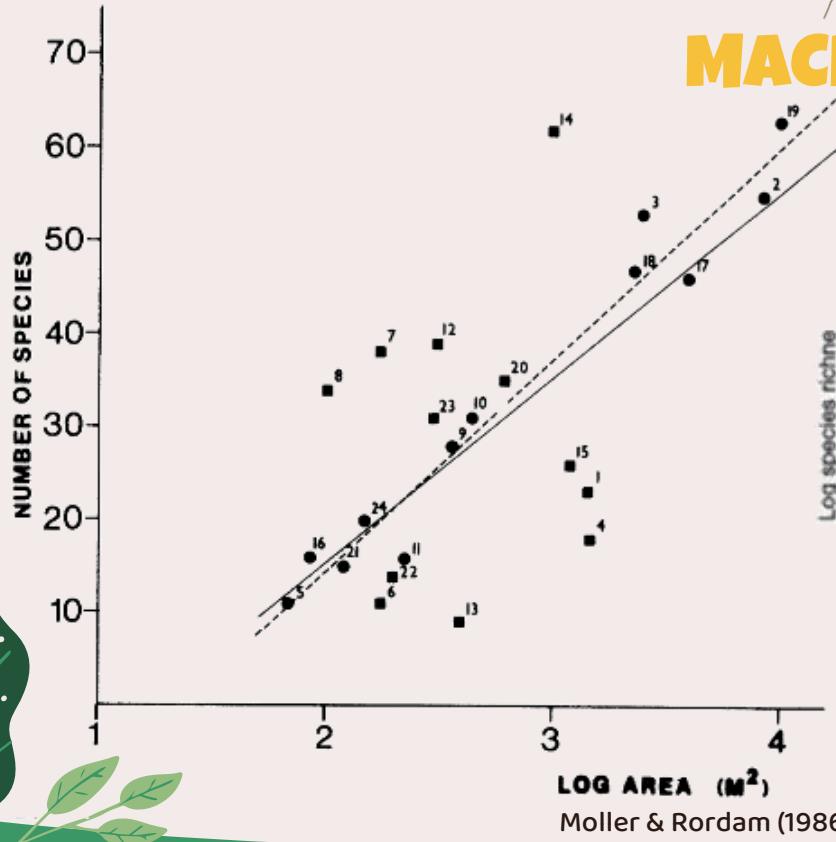


Gaston (2000)

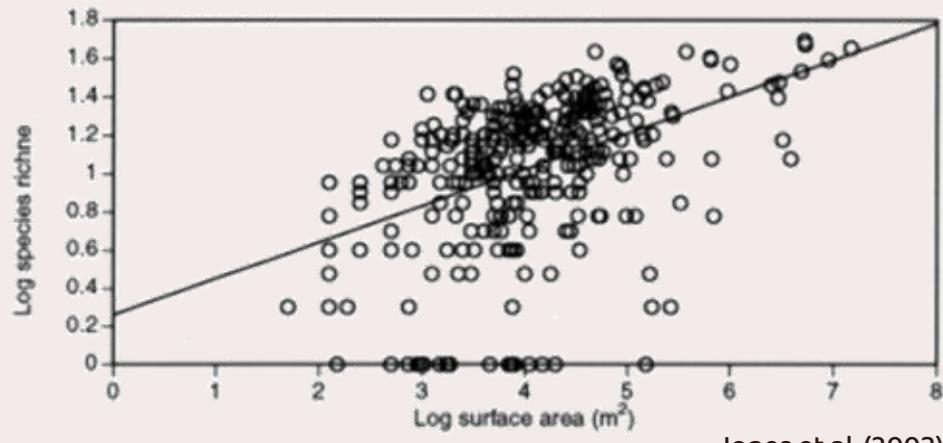
# SPECIES-AREA



## MACROPHYTES



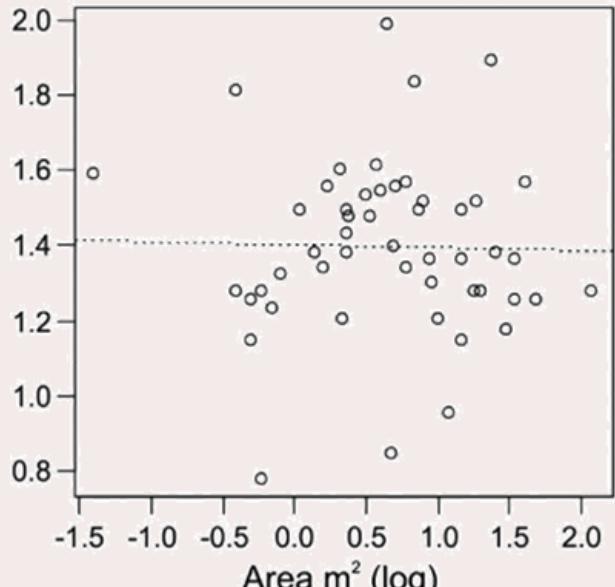
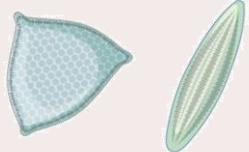
Moller & Rordam (1986)



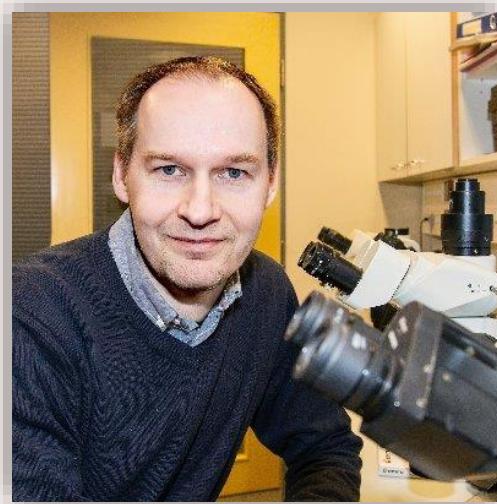
Jones et al. (2003)

# SPECIES-AREA

## DIATOMS



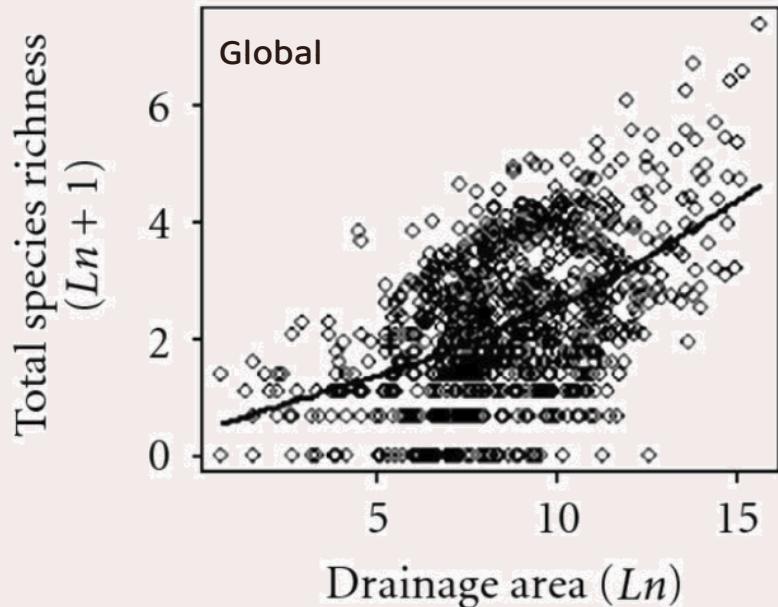
Teittinen & Soininen (2015)



# SPECIES-AREA

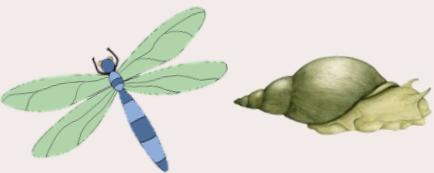


FISH

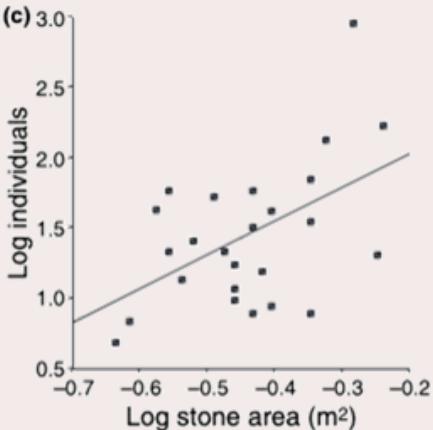
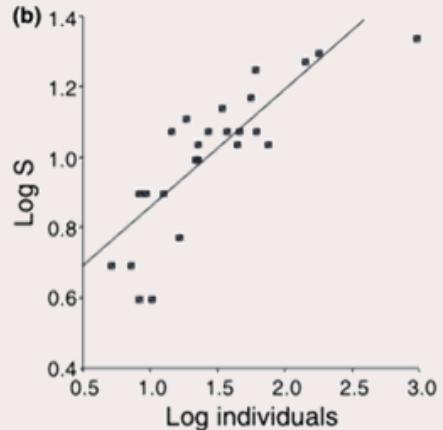
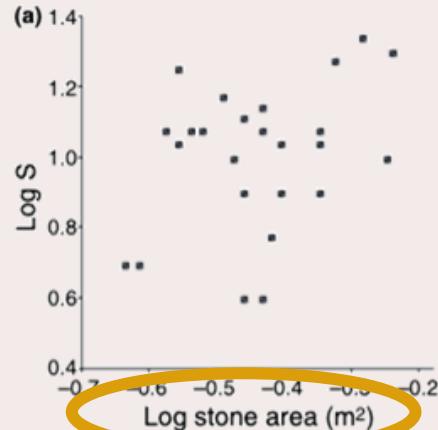


Oberdorff et al. (2011)

# SPECIES-AREA

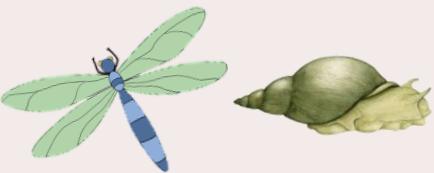


## MACROINVERTEBRATES

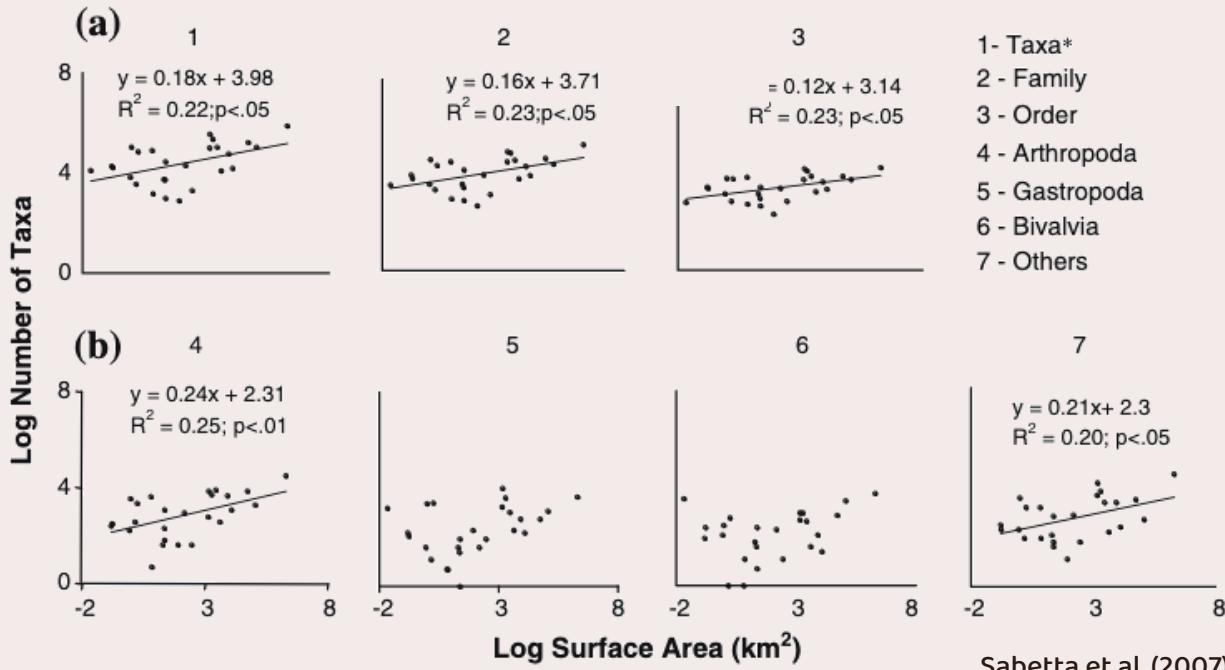


Heino & Korsu (2007)

# SPECIES-AREA

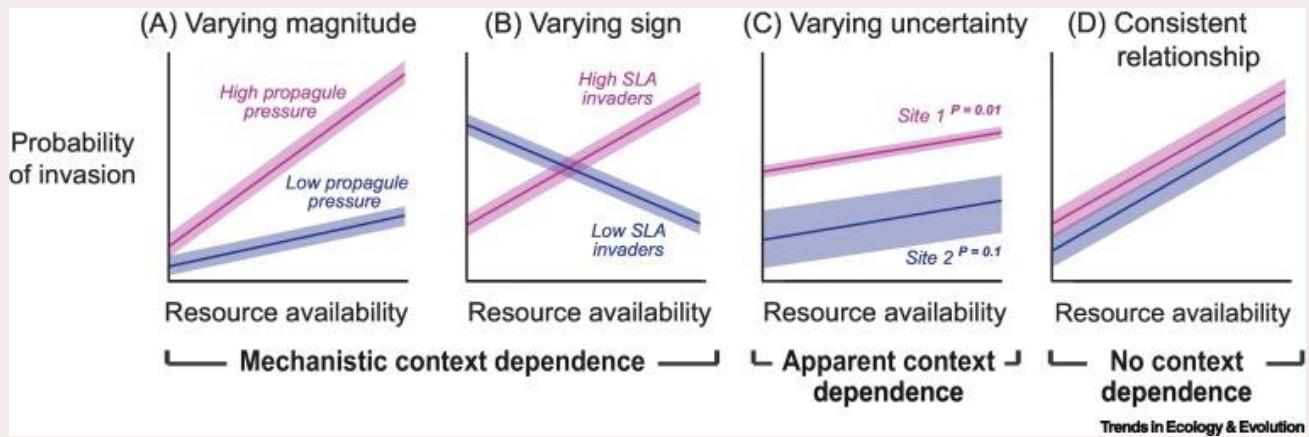


## MACROINVERTEBRATES

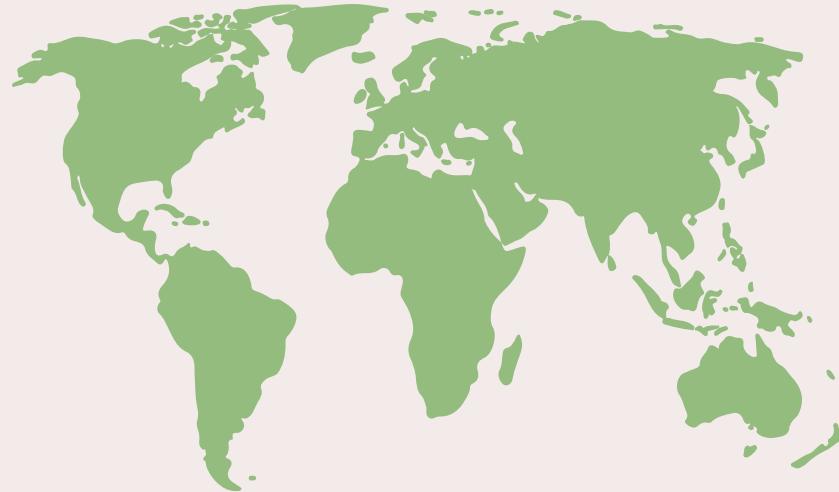


Sabetta et al. (2007)

# CONTEXT DEPENDENCY

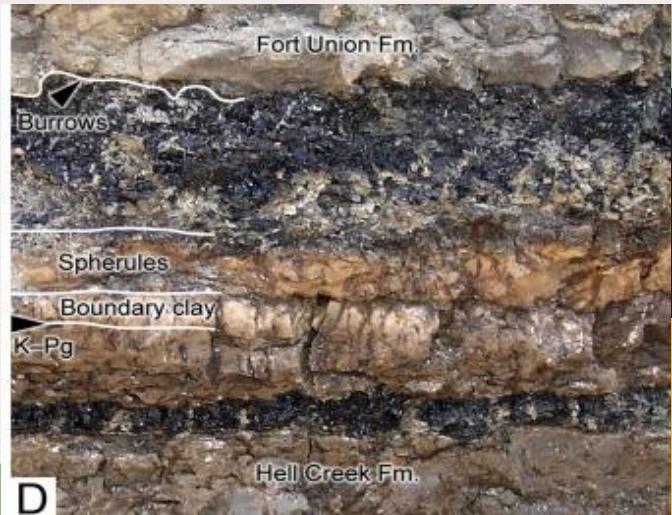


04



# SETTING THE SCENE FOR TODAY'S BIOSPHERE

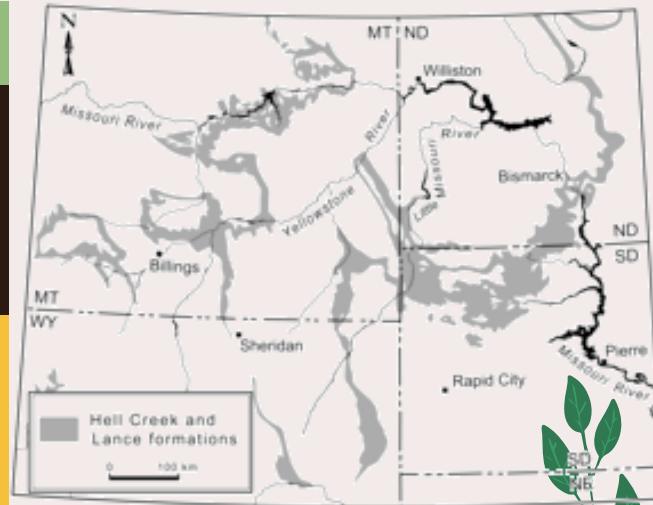
# THE END-CRETACEOUS MASS EXTINCTION



PALEogene

BURROWS

CRETACEOUS



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# THE END-CRETACEOUS MASS EXTINCTION



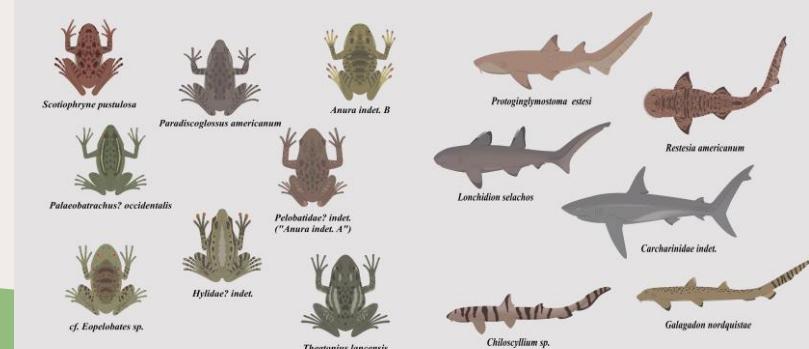
## TESTUDINES

- They occupied an array of largely aquatic niches
- No significant extinctions in turtle faunas across the K/Pg boundary



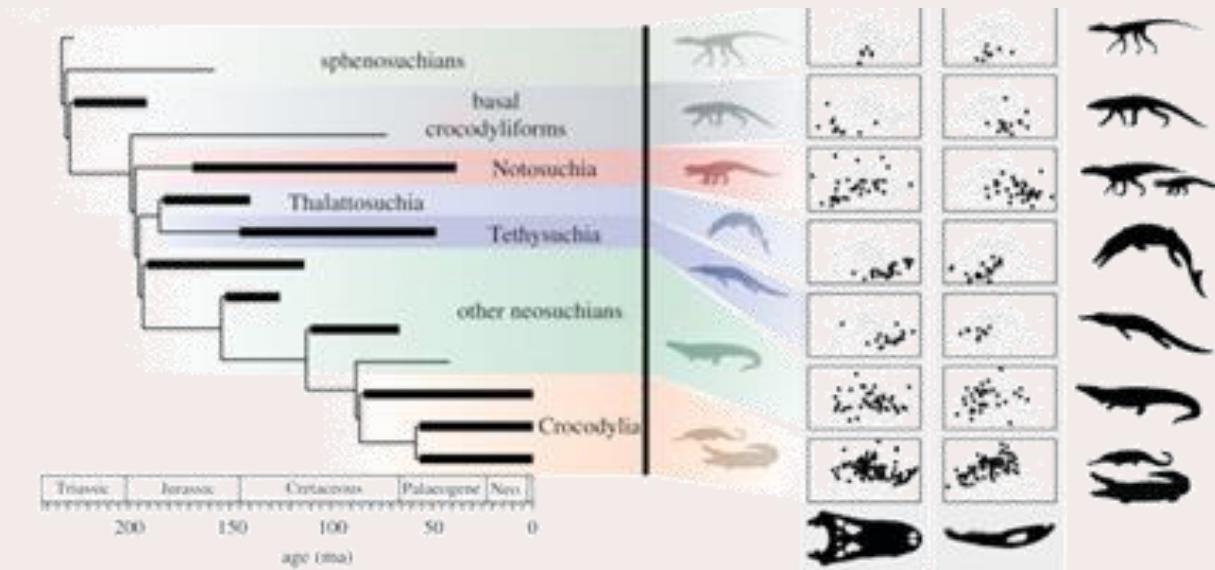
## LISSAMPHIBIA, ELASMOBRANCHII & ACTINOPTERYGII

- Complex, multi-causal mass extinction dynamics across both caudates and allocaudates
- Not yet well studied in fish



# THE END-CRETACEOUS MASS EXTINCTION

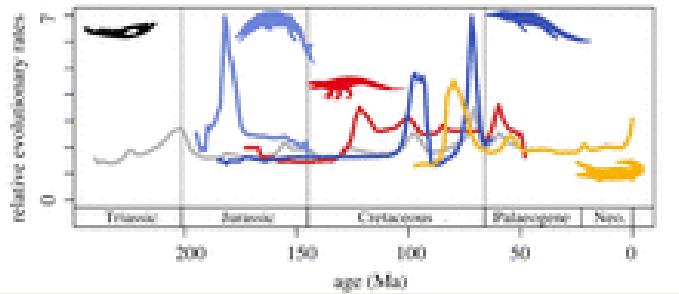
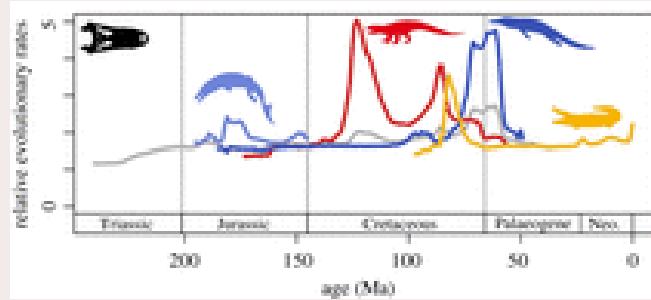
## CROCODYLOMORPHA



Stubbs et al. (2021)

# THE END-CRETACEOUS MASS EXTINCTION

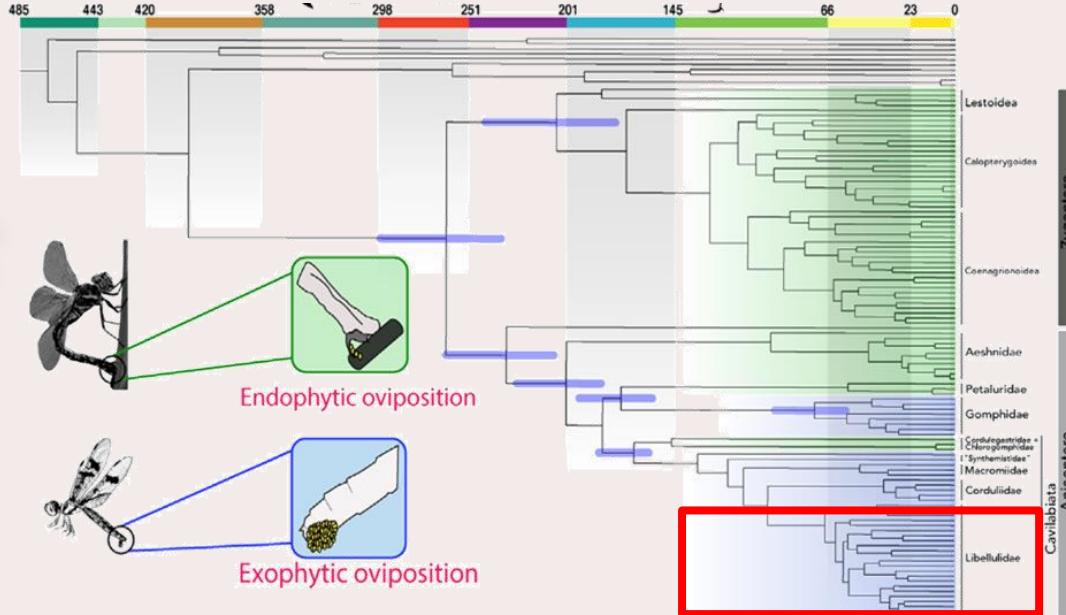
## CROCODYLOMORPHA



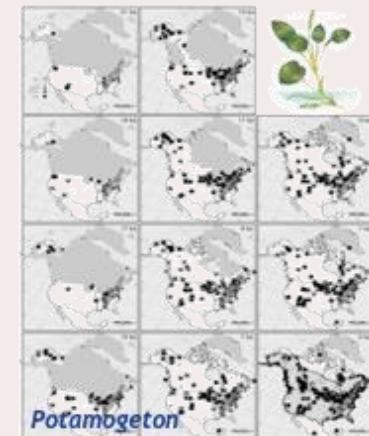
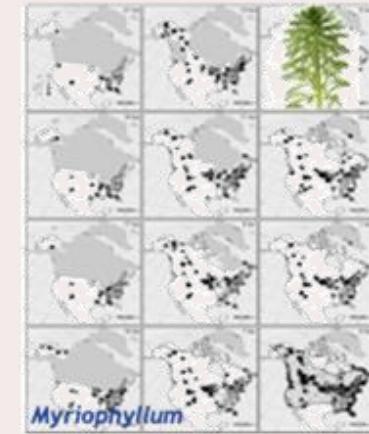
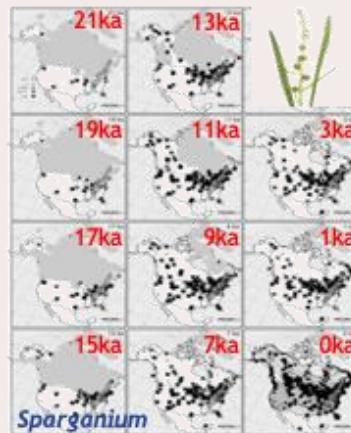
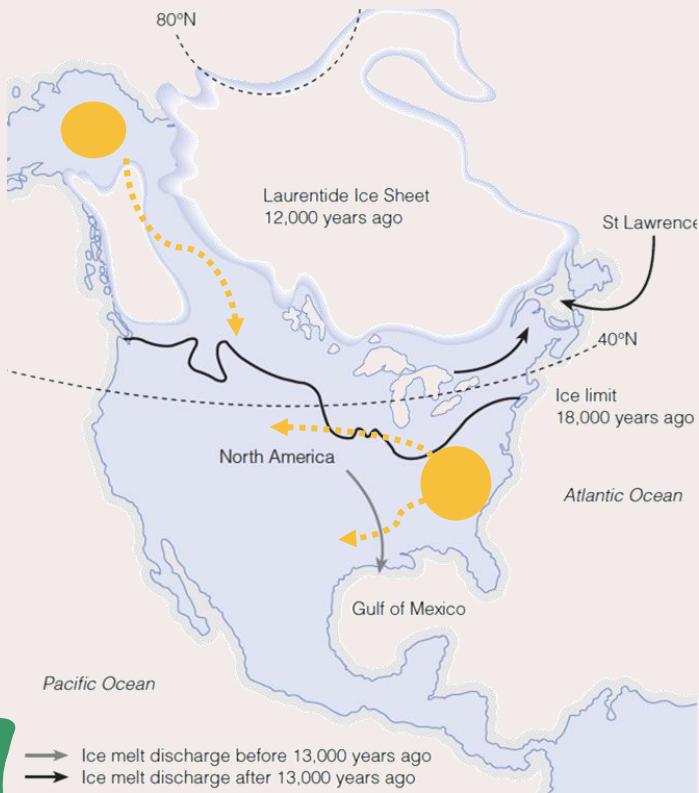
Stubbs et al. (2021)

# THE END-CRETACEOUS MASS EXTINCTION

## ODONATES

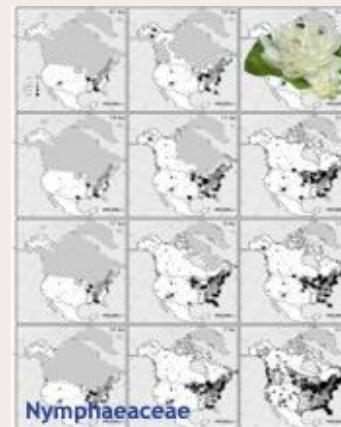
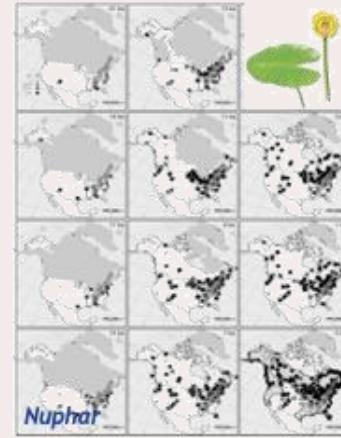
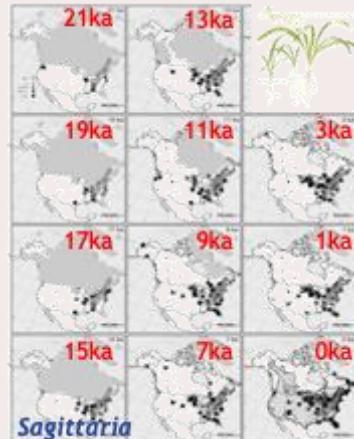


# LASTING THROUGH THE ICE AGE



Sawada et al. (2003)

# LASTING THROUGH THE ICE AGE



Sawada et al. (2003)

# PRESENT-DAY FRESHWATER BIOGEOGRAPHICAL UNITS OF THE WORLD

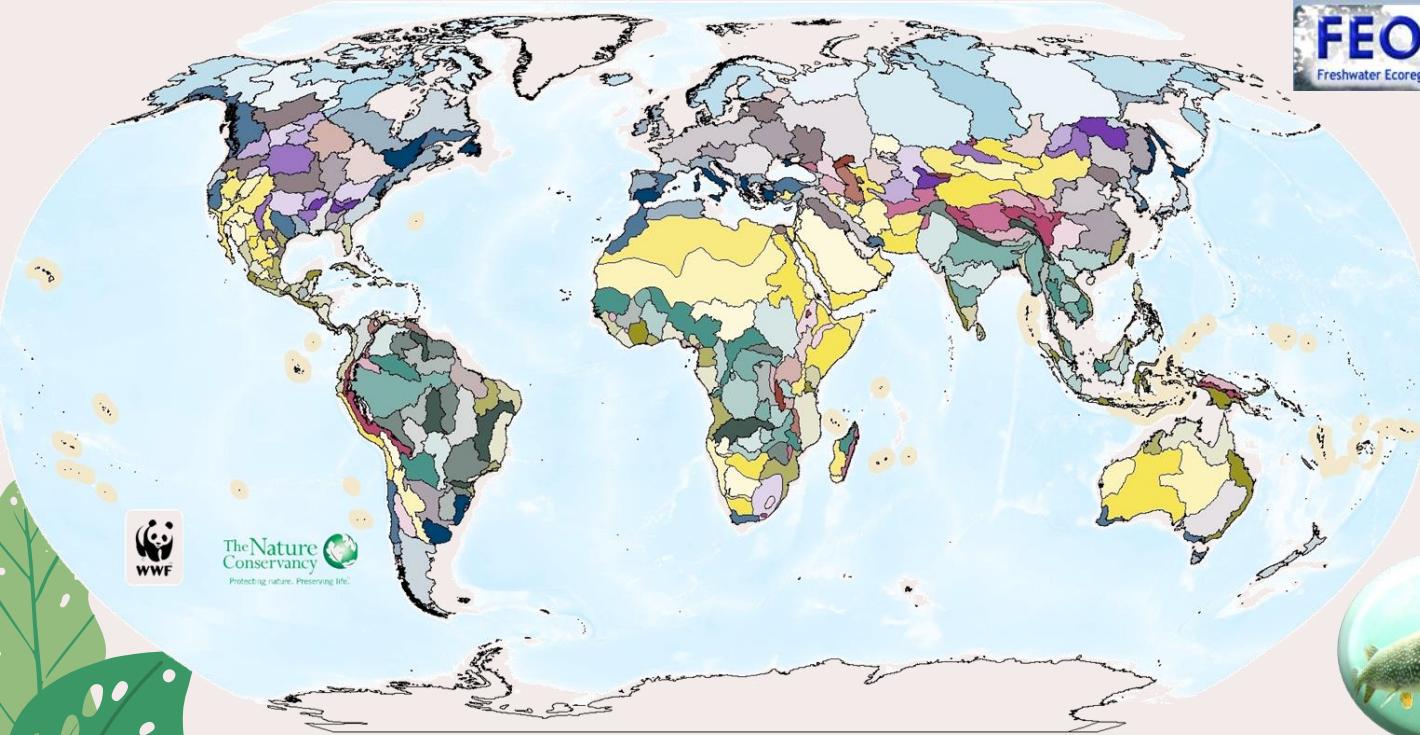


**FEOW**

Freshwater Ecoregions Of the World



Abell et al. (2008)



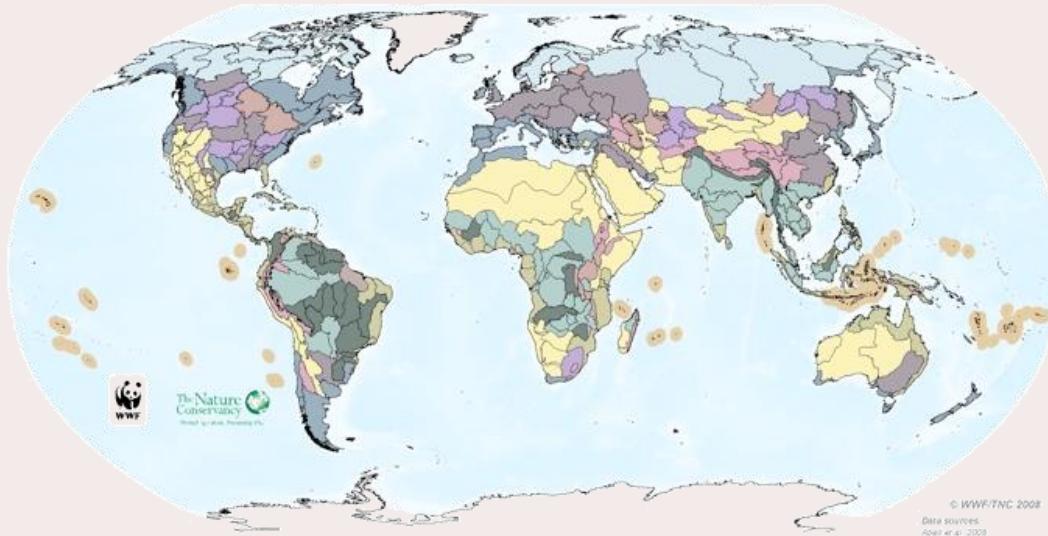
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# PRESENT-DAY FRESHWATER BIOGEOGRAPHICAL UNITS OF THE WORLD



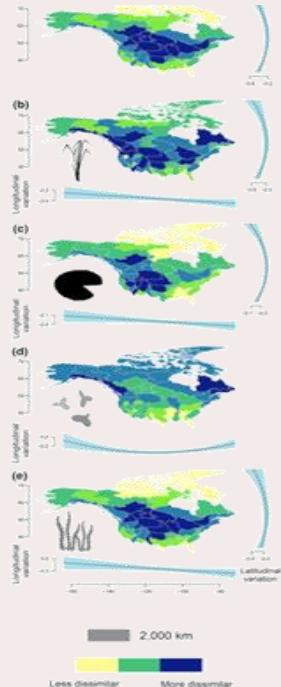
Major Habitat Types

- |  |   |
|--|---|
| ■ Large Lakes                              | ■ Temperate Upland Rivers                                 |
| ■ Large River Deltas                       | ■ Tropical and Subtropical Coastal Rivers                 |
| ■ Polar Freshwaters                        | ■ Tropical and Subtropical Floodplain Rivers and Wetlands |
| ■ Montane Freshwaters                      | ■ Tropical and Subtropical Upland Rivers                  |
| ■ Temperate Coastal Rivers                 | ■ Xeric Freshwaters and Endorheic Basins                  |
| ■ Temperate Floodplain Rivers and Wetlands | ■ Oceanic Islands   |

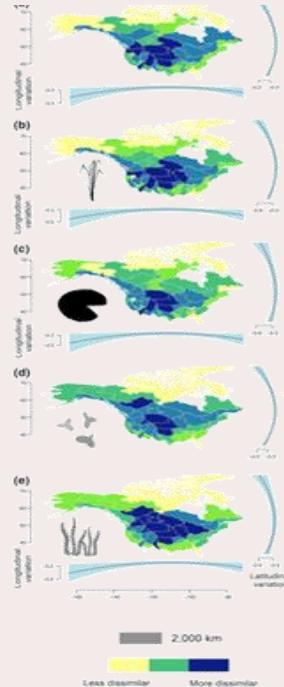
# PRESENT-DAY FRESHWATER BIOGEOGRAPHICAL UNITS OF THE WORLD



Within-ecoregion homogeneity



Cross-boundary heterogeneity



Geographical regionalisations founded on a particular organismal group may not be directly applicable for all freshwater taxa...

*but can be a good basis for further adjustments!!!*

Alahuhta & García-Girón (2022)



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