Diversity Patterns III

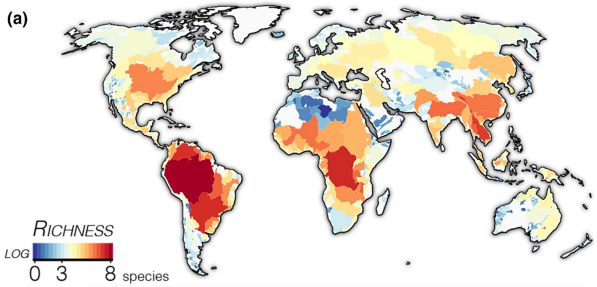
Today's Agenda:

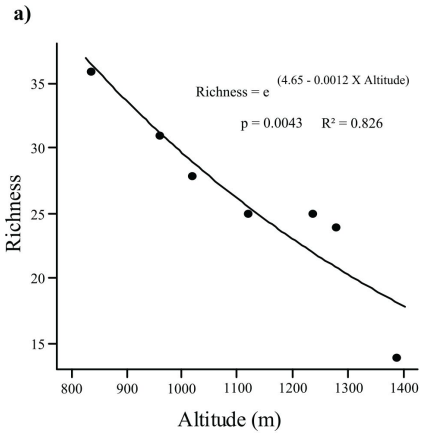
- Quiz
- Drivers of Diversity

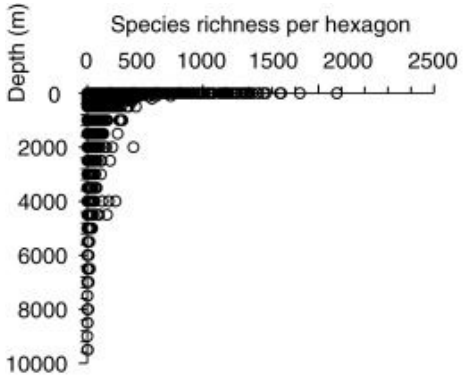
Diversity patterns

We’ve spent the last few classes discussing patterns of diversity, but…

What drives differences in diversity? Any thoughts?







Miller EC, Román-Palacios C. 2021; Nunes et al. 2016 ; Costella and Chaudhary, 2017

Groups of hypothesized drivers

Your book splits hypothesized drivers in 4 groups:

1) Null model explanations
2) Ecological explanations
3) Historical explanations
4) Evolutionary explanations

Groups of hypothesized drivers

Your book splits hypothesized drivers in 4 groups:

1) Null model explanations
2) Ecological explanations
3) Historical explanations
4) Evolutionary explanations

Note that although these are discussed in terms of the latitudinal diversity gradient, they can be applied to other diversity patterns

Null explanations of diversity

What do we mean by “null model”?

Null explanations of diversity

What do we mean by “null model”?

“The null model is used as a term of comparison, to verify whether the object in question displays some non-trivial features (properties that wouldn't be expected on the basis of chance alone or as a consequence of the constraints), such as community structure” - Wikipedia

Null explanations of diversity

What do we mean by “null model”?

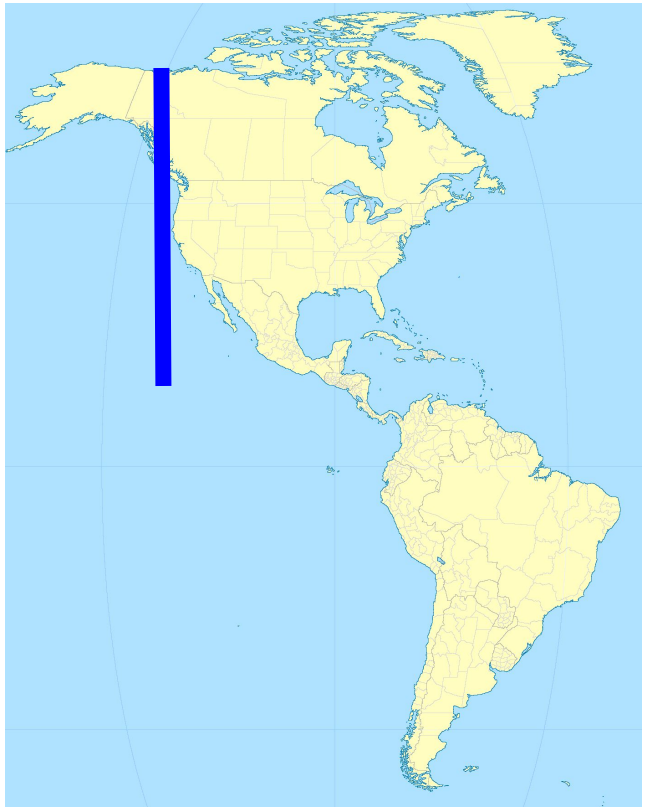
“The null model is used as a term of comparison, to verify whether the object in question displays some non-trivial features (properties that wouldn't be expected on the basis of chance alone or as a consequence of the constraints), such as community structure” - Wikipedia

Note that null models can differ widely in how much biology is included!

Null expectations: the mid-domain

Species randomly added to a bounded region will tend to overlap more in the center

Null expectations: the mid-domain



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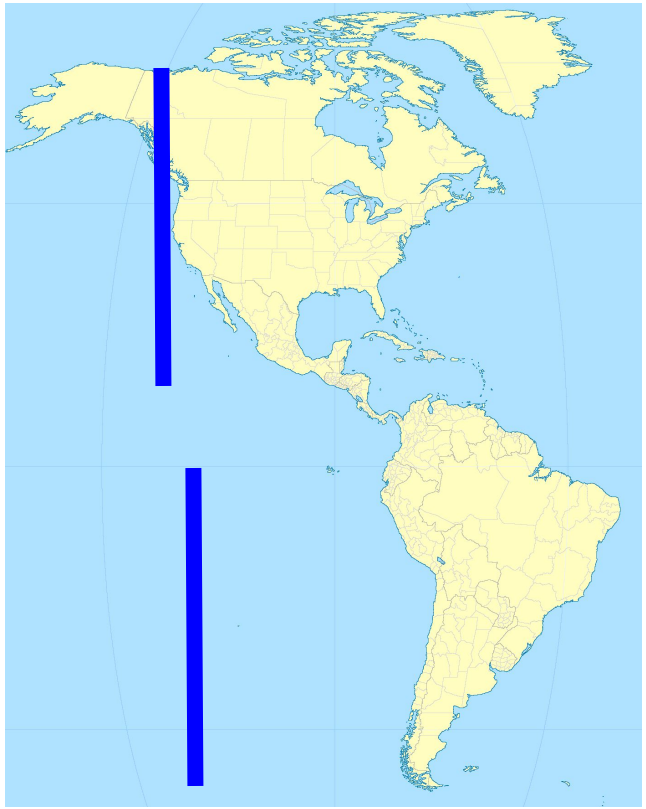
Null expectations: the mid-domain



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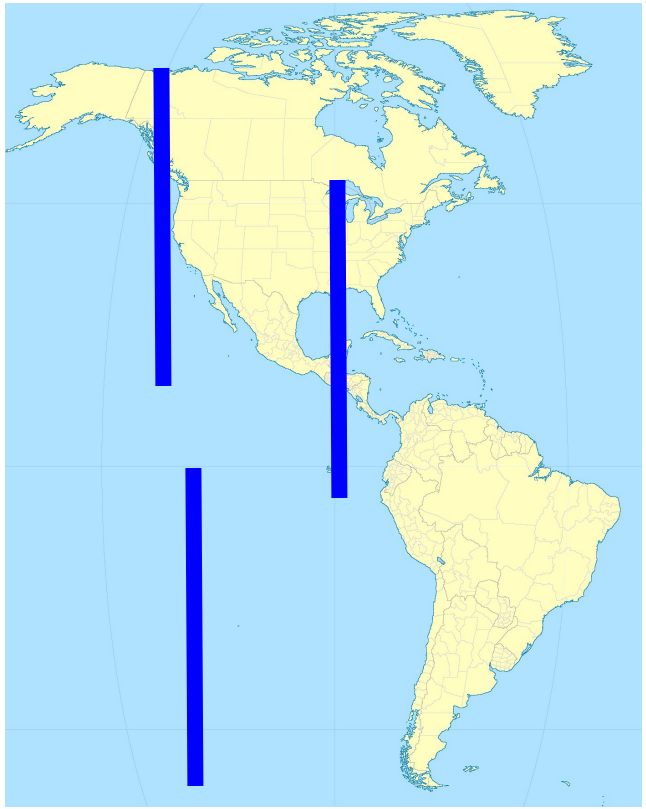

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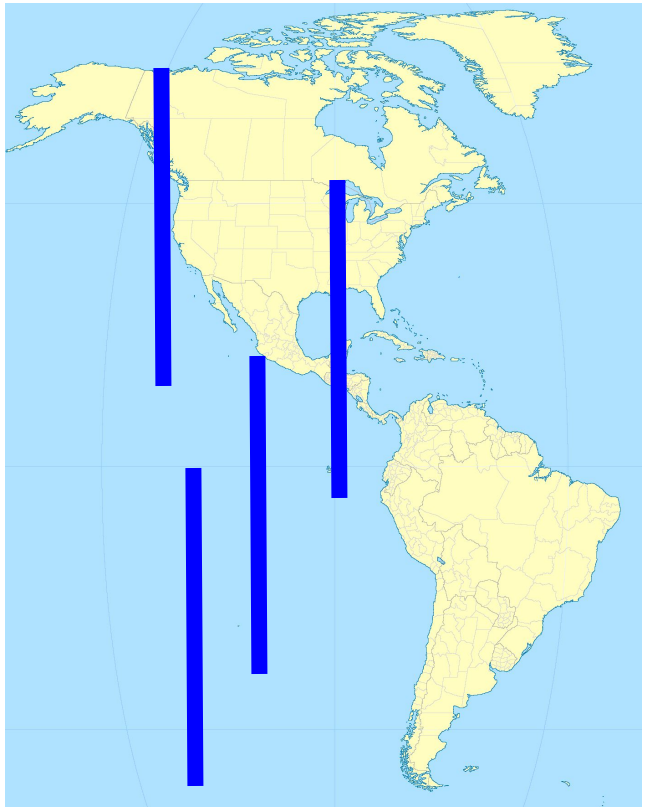

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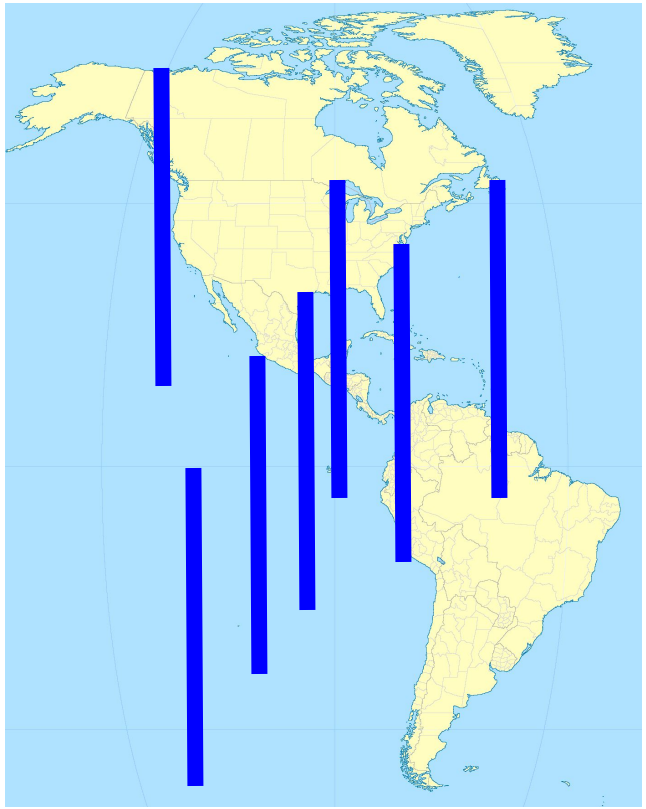


Species randomly added to a bounded region will tend to overlap more in the center

Randomly placing species might give you a latitudinal diversity gradient

Problems with the mid-domain hypothesis

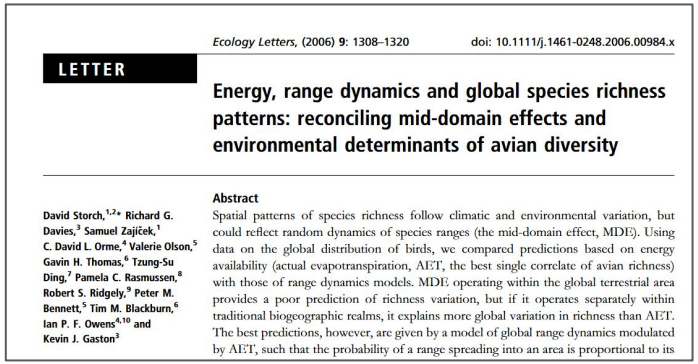
- It should apply to ANY bounded regions (e.g., enters of continents, islands, etc.) in ANY direction (i.e., longitudinal as well as latitudinal)

- Is a globe really a bounded region?

- Inconsistent support when tested

Testing the mid-domain hypothesis

Storch et al. tested this idea



Ecology Letters, (2006) 9: 1308–1320 doi: 10.1111/j.1461-0248.2006.00984.x

LETTER

Energy, range dynamics and global species richness patterns: reconciling mid-domain effects and environmental determinants of avian diversity

David Storch,[1,2]* Richard G. Davies,[3] Samuel Zajíček,[1] C. David L. Orme,[4] Valerie Olson,[5] Gavin H. Thomas,[6] Tzung-Su Ding,[7] Pamela C. Rasmussen,[8] Robert S. Ridgely,[9] Peter M. Bennett,[5] Tim M. Blackburn,[6] Ian P. F. Owens[4,10] and Kevin J. Gaston[3]

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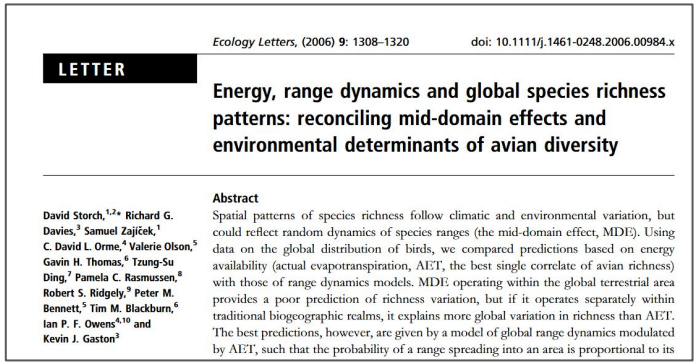
Spatial patterns of species richness follow climatic and environmental variation, but could reflect random dynamics of species ranges (the mid-domain effect, MDE). Using data on the global distribution of birds, we compared predictions based on energy availability (actual evapotranspiration, AET, the best single correlate of avian richness) with those of range dynamics models. MDE operating within the global terrestrial area provides a poor prediction of richness variation, but if it operates separately within traditional biogeographic realms, it explains more global variation in richness than AET. The best predictions, however, are given by a model of global range dynamics modulated by AET, such that the probability of a range spreading into an area is proportional to its

- Randomly placed species using a spreading-dye algorithm
  - For each species, a random point was selected
  - then, adjacent areas were added until reaching the size of the species actual range

- Replicated 100 times

Testing the mid-domain hypothesis

Storch et al. tested this idea



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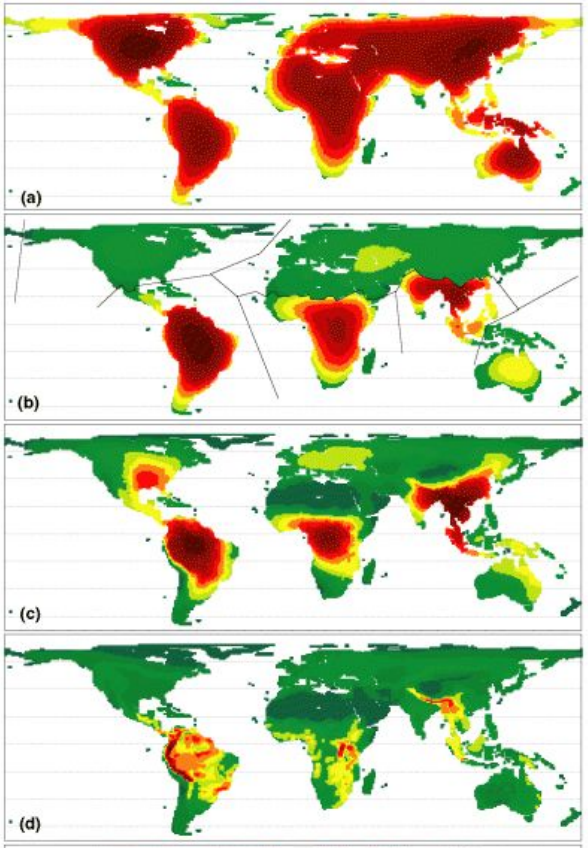
- Tested different models:
  - Species were randomly placed globally
  - Species were placed/expanded within ecoregions
  - Species were placed randomly, but preferentially expanded toward more productive regions

Testing the mid-domain hypothesis



Global Model

Ecoregion Model

Productivity-biased Model

Species richness

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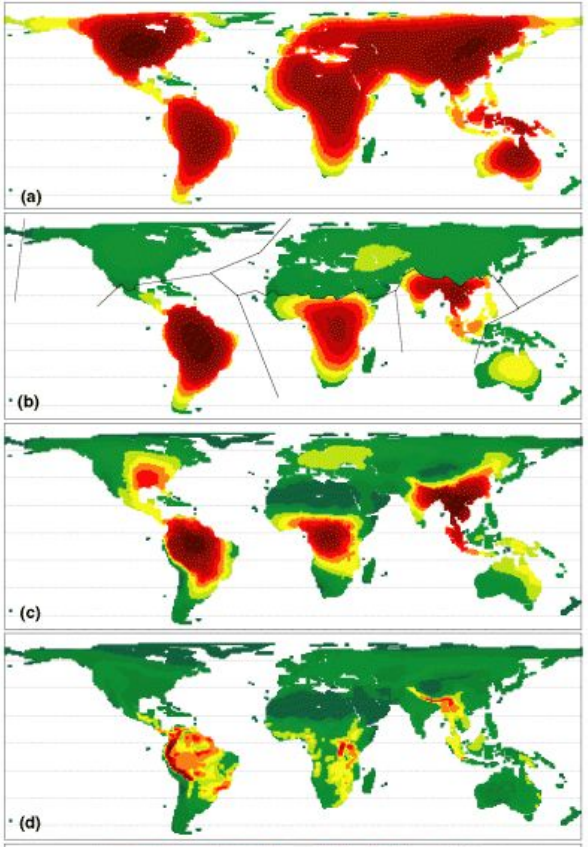
Testing the mid-domain hypothesis



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Does not strongly support the MDE, but does suggest some neutral dynamics may be important

Ecological hypotheses for diversity

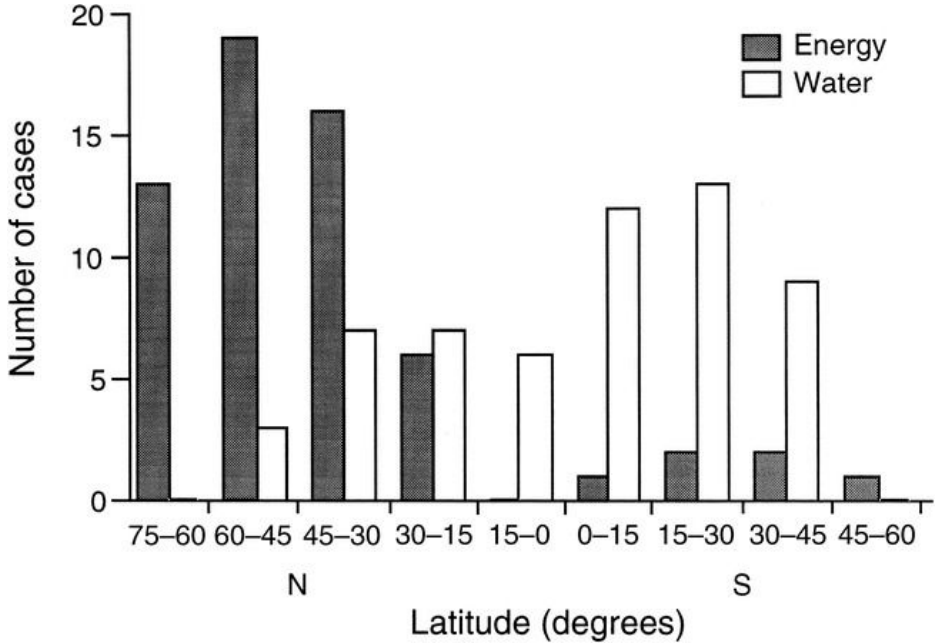
- Climate-related hypotheses
- Productivity-related hypotheses
- Note that there is some overlap between these!

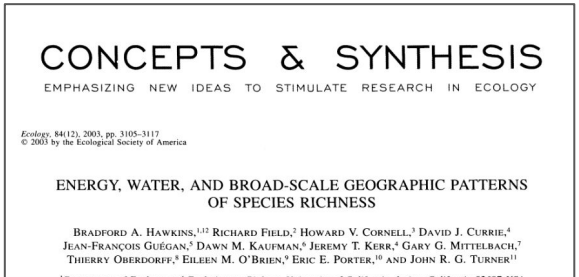
Climatic Drivers of Diversity

Climate correlated with richness

- Animals: driver varies by latitude

- Plants: usually water, or water + energy





CONCEPTS & SYNTHESIS

EMPHASIZING NEW IDEAS TO STIMULATE RESEARCH IN ECOLOGY

Ecology, 84(12), 2003, pp. 3105–3117
© 2003 by the Ecological Society of America

ENERGY, WATER, AND BROAD-SCALE GEOGRAPHIC PATTERNS OF SPECIES RICHNESS

BRADFORD A. HAWKINS,[1,12] RICHARD FIELD,[2] HOWARD V. CORNELL,[3] DAVID J. CURRIE,[4] JEAN-FRANÇOIS GUÉGAN,[5] DAWN M. KAUFMAN,[6] JEREMY T. KERR,[4] GARY G. MITTELBACH,[7] THIERRY OBERDORFF,[8] EILEEN M. O'BRIEN,[9] ERIC E. PORTER,[10] AND JOHN R. G. TURNER[11]

Climate and Diversity

… but WHY?

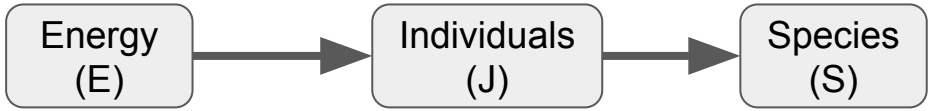
Climate and Diversity

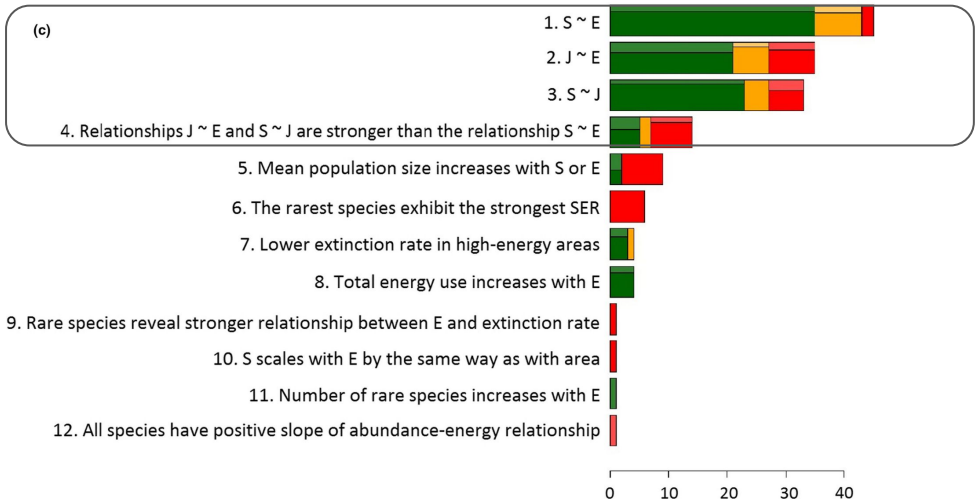
… but WHY?

More Individuals Hypothesis:

- Assumes more individuals can be supported where there is higher productivity
- Assumes more individuals translates to more species
- Hence, high productivity should yield more species

Testing the More Individuals Hypothesis





ECOLOGY LETTERS

Review and Synthesis | Full Access

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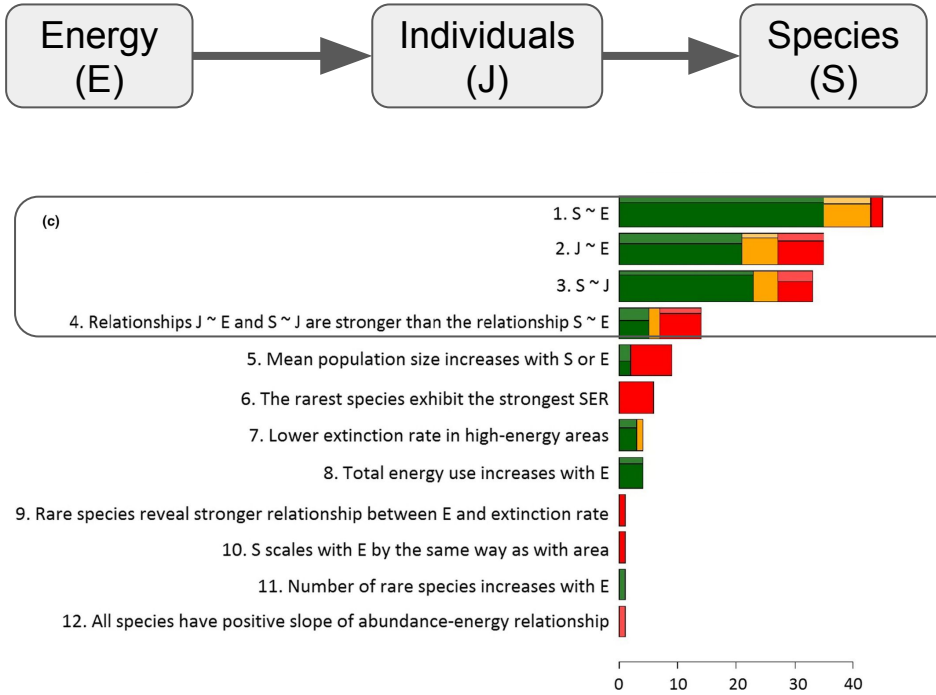
David Storch, Eliška Bohdalková, Jordan Okie

First published: 16 April 2018 | https://doi.org/10.1111/ele.12941 | Citations: 154

Testing the More Individuals Hypothesis



- Relationships between E,J,S have mixed support
- Poor support when considering relative strengths

ECOLOGY LETTERS

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Issues with MIH

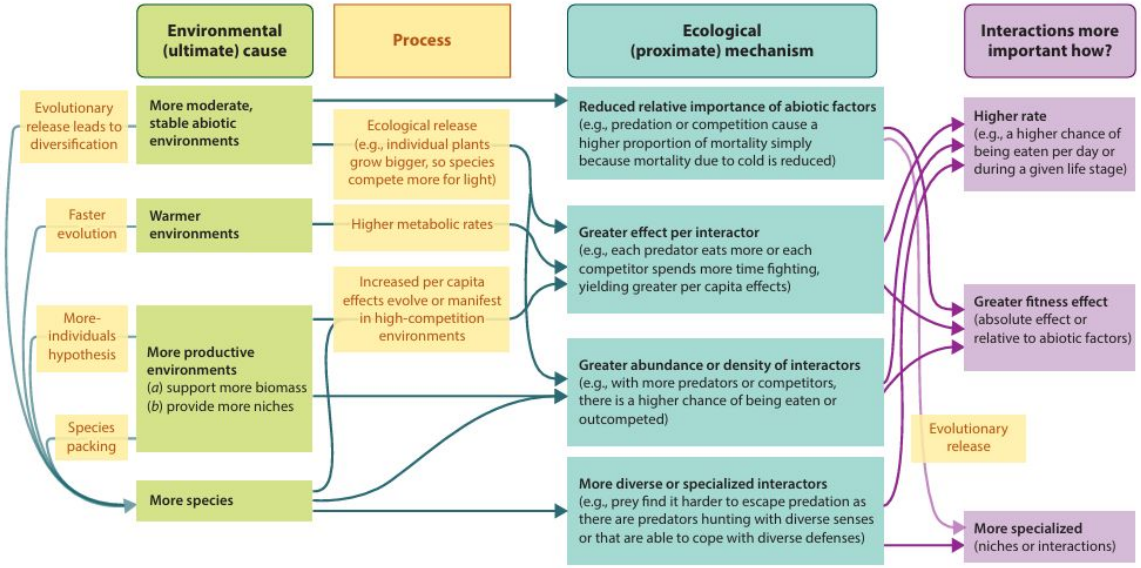
- Confounding relationships between species richness and productivity
- Plants often fail to show the pattern
- Quantitative analyses don’t stand up well
- Recent work suggests that variation in abundances may also play a role

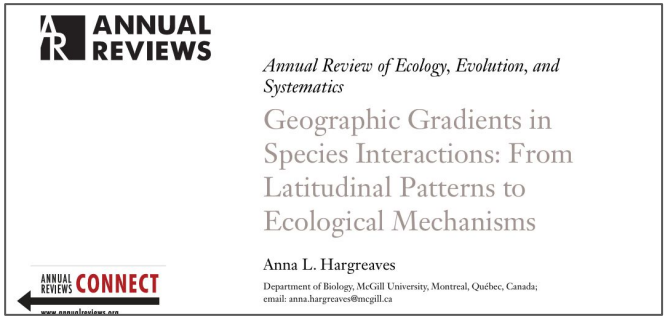
Productivity and Diversity

We’ll spend time on this when we cover Biodiversity and Ecosystem Functioning

Other ecological hypotheses

- Species interactions
  - E.g., a greater role of natural enemies or mutualists in the tropics





Historical Explanations

Historical Explanations

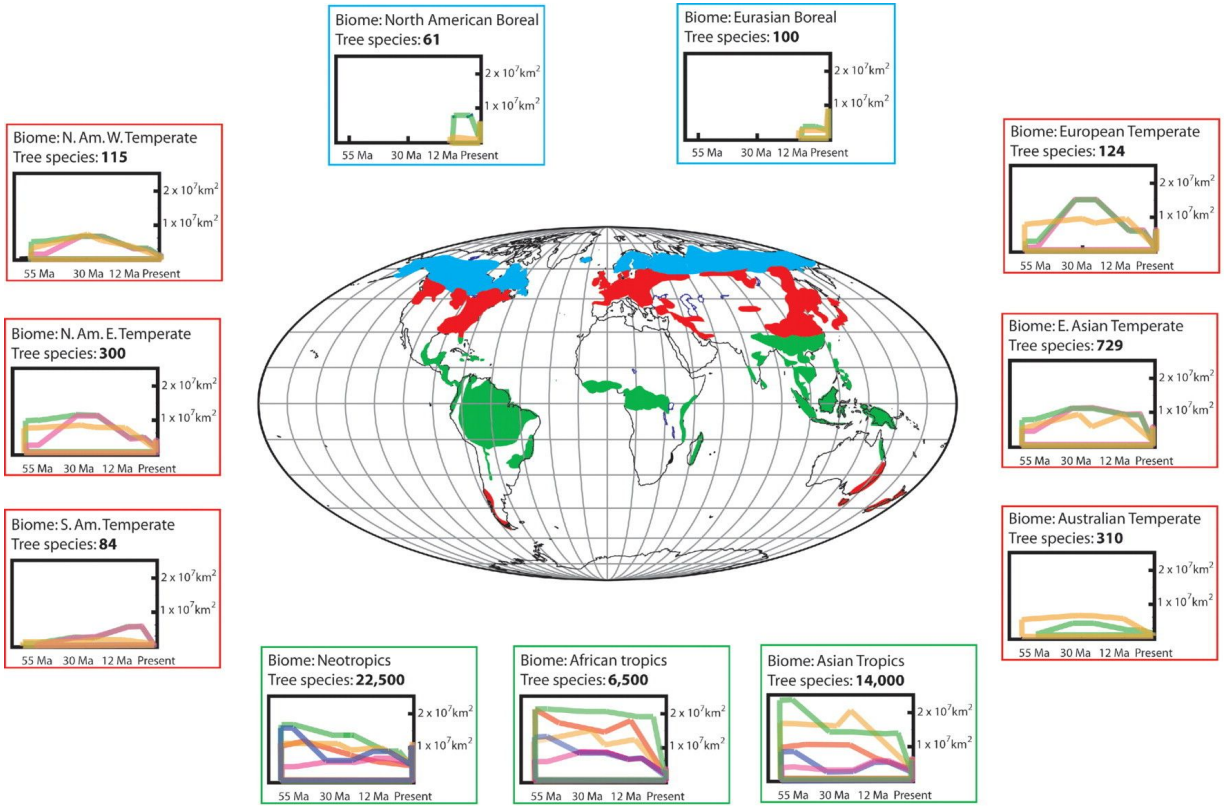
Time-integrated area hypothesis

Historical Explanations

Time-integrated area hypothesis

- Larger area have more species
  - Higher speciation rates
  - Lower extinction rates
  - etc.
- Older areas have more species
  - More time to accumulate diversity

Time-integrated area hypothesis



VOL. 168, NO. 6 THE AMERICAN NATURALIST DECEMBER 2006

Notes and Comments

Evidence for a Time-Integrated Species-Area Effect on the Latitudinal Gradient in Tree Diversity

Paul V. A. Fine[1,*] and Richard H. Ree[2,†]

Time-integrated area hypothesis

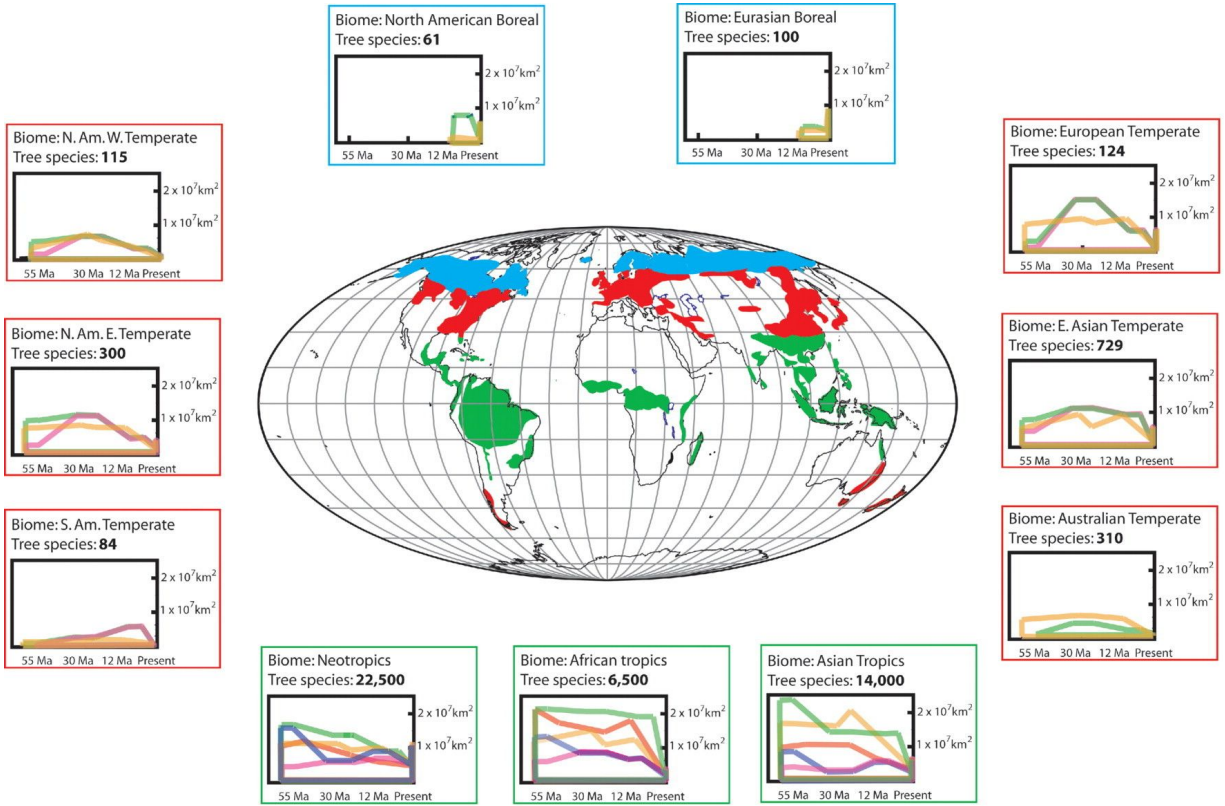


Table 2: Results of the correlations between log (tree diversity) and log (time-integrated area) for the five interpretations shown in figure 1

Interpretation (source), cumulative time since	R^2	P
Modern (Olson et al. 2001):		
Present	.13	.283
1 (Beerling and Woodward 2001):		
Eocene	.21	.151
Oligocene	.17	.211
Miocene	.01	.730
2 (Morley 2000):		
Eocene	.37	**.046**
Oligocene	.17	.211
Miocene	.01	.730
3 (Ziegler et al. 2003):		
Eocene	.47	**.021**
Oligocene	.39	**.041**
Miocene	.07	.426
4 (Scotese 2003):		
Eocene	.51	**.014**
Oligocene	.59	**.006**
Miocene	.61	**.005**
5 (Willis and McElwain 2002):		
Eocene	.57	**.007**
Oligocene	.53	**.012**
Miocene	.42	**.030**

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Evolutionary Explanations

Evolutionary Explanations

- Variation in speciation rates
- Variation in extinction rate
- Tropical niche conservatism

Cradles vs Museums

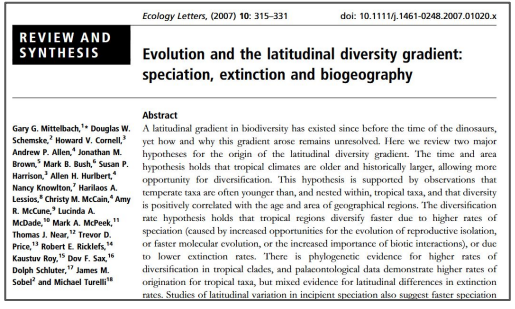
Diversification (speciation - extinction) rates may vary with latitude

- Could play a role in latitudinal diversity patterns
- However, this could be due to either
  - More speciation
  - Less extinction
  - A combination of the two

Cradles vs Museums: Proposed mechanisms

Speciation:

- Genetic Drift (higher in tropics, increases speciation)
- Climatic variation (higher in temp, decreases speciation)
- Speciation mechanisms (differ between temp and tropical)
- Geographic area (larger area = more speciation…or less)
- Evolutionary speed (higher in tropics, increases speciation)
- Biotic interaction (higher in tropics, increases speciation)



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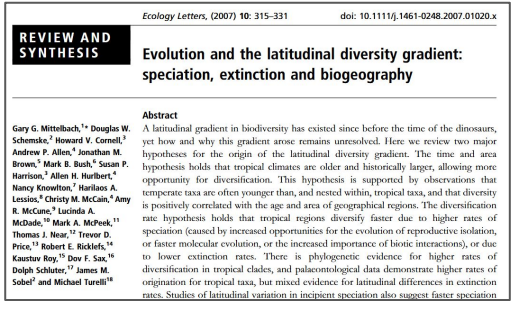
Cradles vs Museums: Proposed mechanisms

Extinction:

- Climatic variation (more stable climate in tropics, lower extinction rate)
- Geographic area (more area in tropics, lower extinction rate)



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Cradles vs Museums: Testing with Phylogeny

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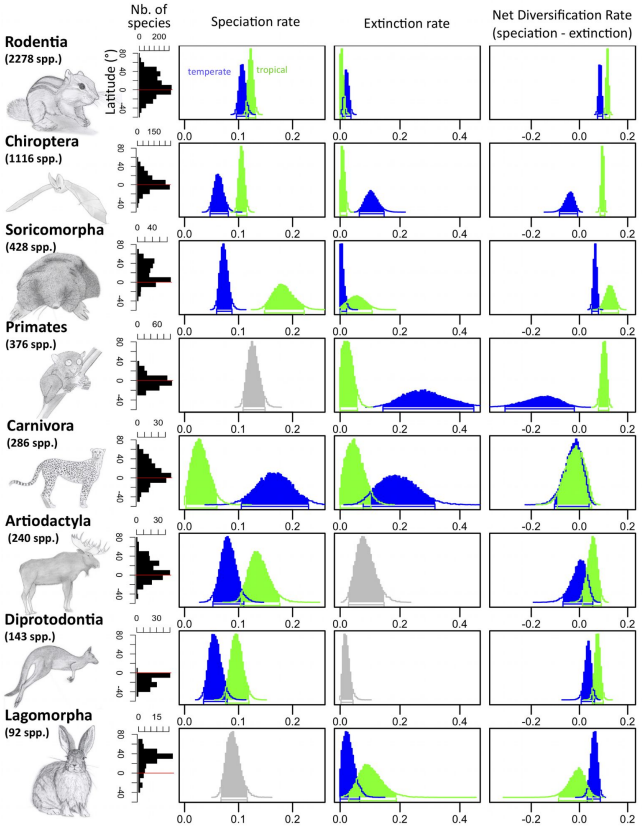

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PLOS | BIOLOGY

Faster Speciation and Reduced Extinction in the Tropics Contribute to the Mammalian Latitudinal Diversity Gradient

Jonathan Rolland[1,2*], Fabien L. Condamine[1], Frederic Jiguet[2], Hélène Morlon[1*]

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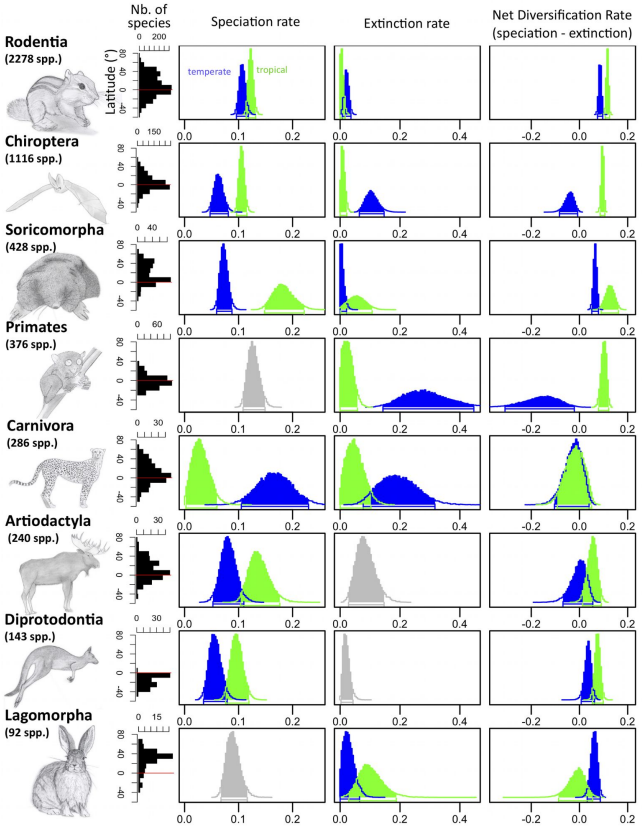

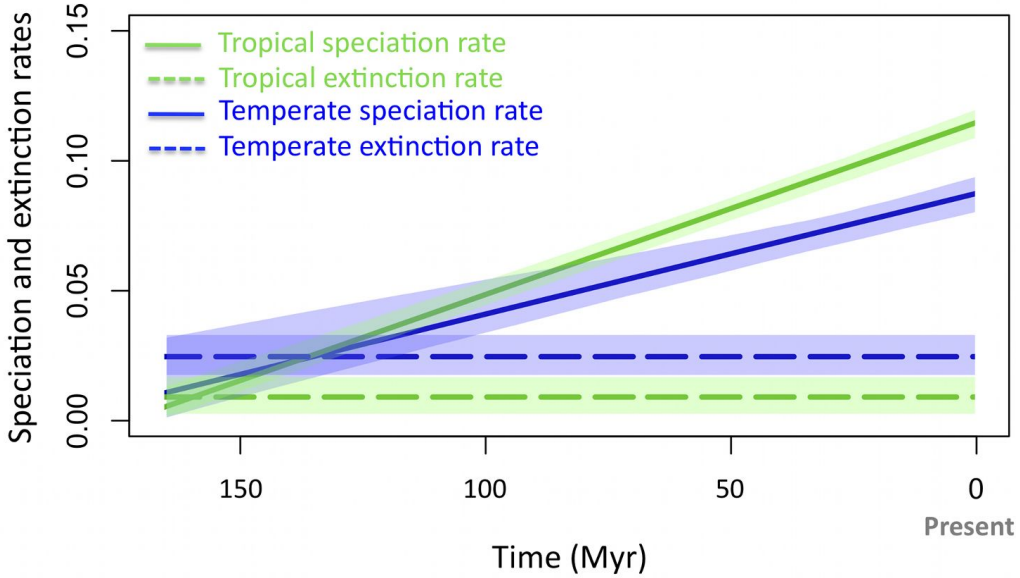

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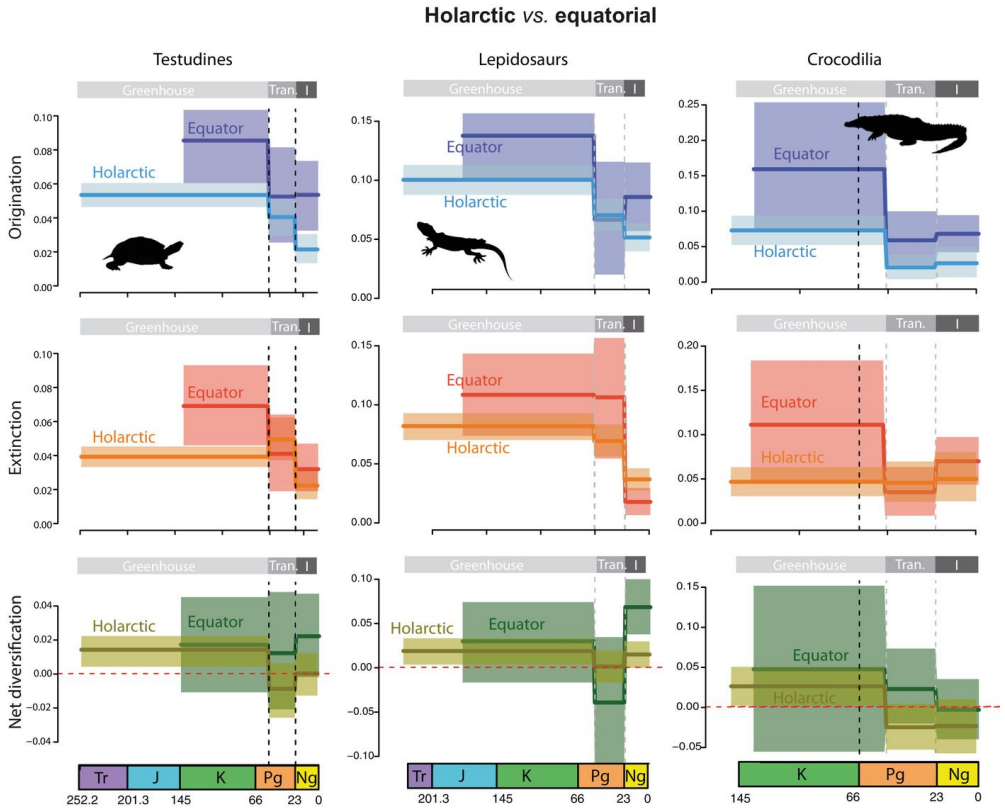
Jonathan Rolland[1,2*], Fabien L. Condamine[1], Frederic Jiguet[2], Hélène Morlon[1*]

Cradles vs Museums: Testing with Fossils



doi:10.1111/evo.13967

Ancient tropical extinctions at high latitudes contributed to the latitudinal diversity gradient*

Andrea S. Meseguer[1,2,3,4] and Fabien L. Condamine[2]

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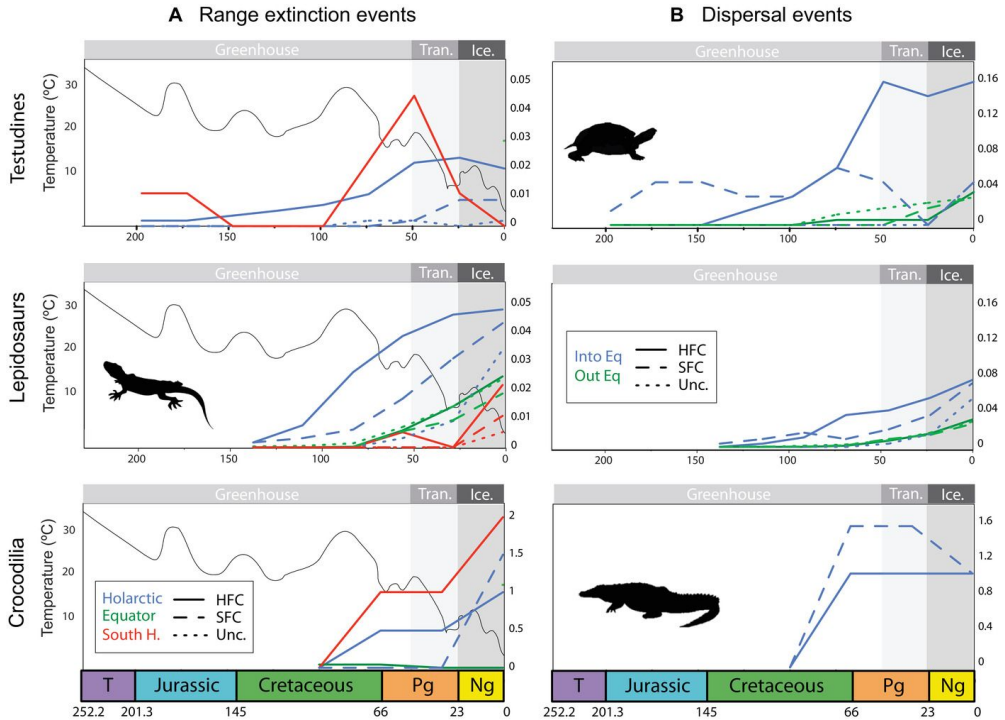

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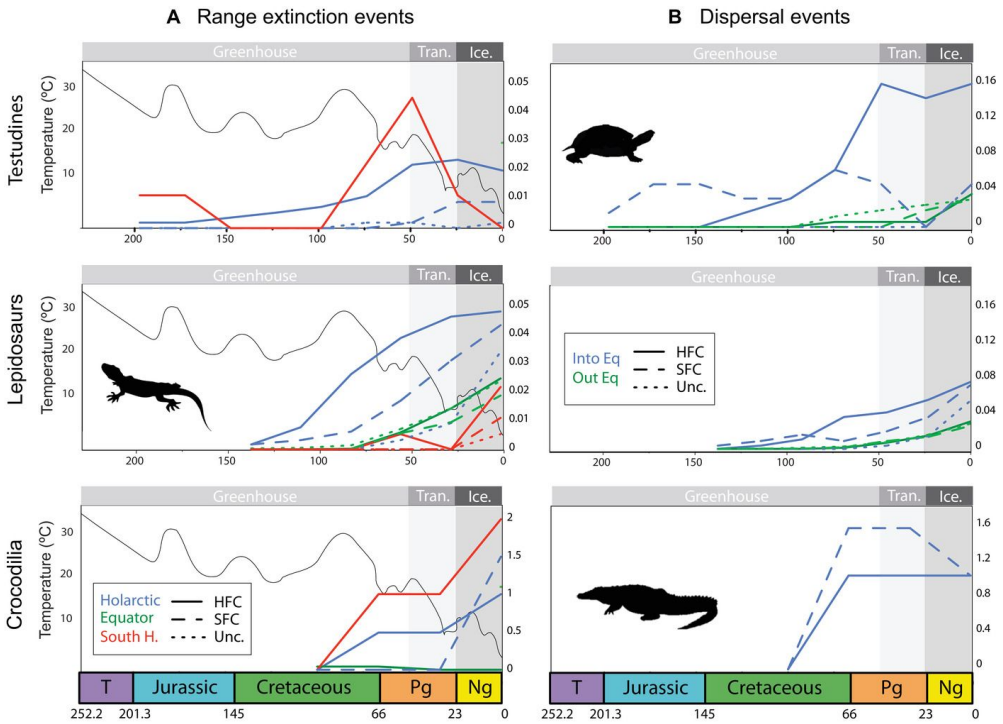

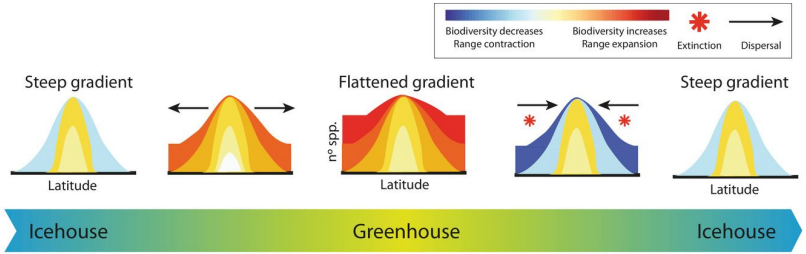

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Evolutionary Explanations: Tropical Niche Conservatism

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Niche conservatism: tendency for niches to remain unchanged

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Phylogenetic niche conservatism: tendency for niches to remain unchanged along evolutionary lineages

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Niche conservatism: tendency for niches to remain unchanged

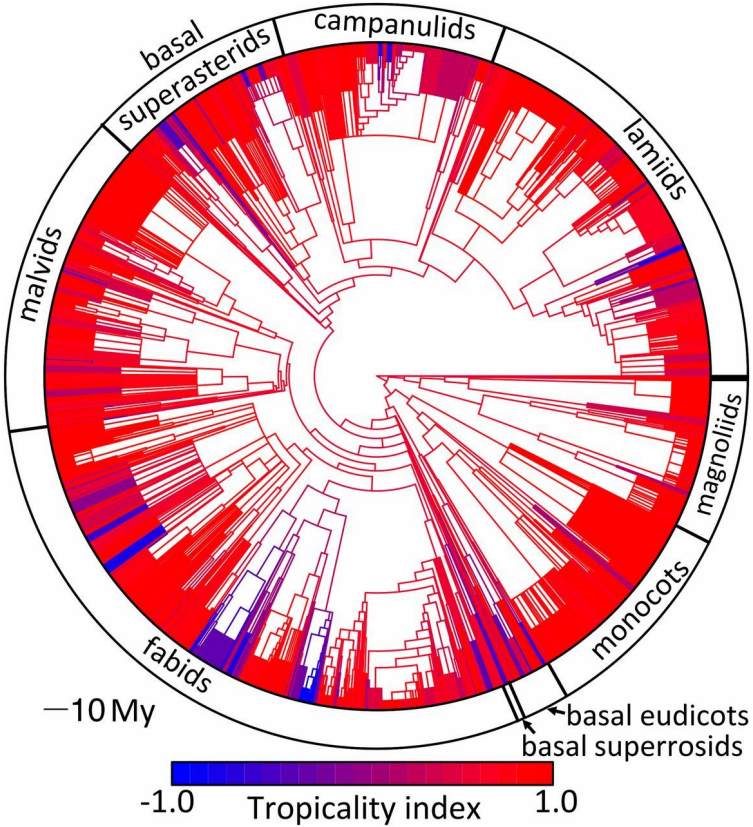
Phylogenetic niche conservatism: tendency for niches to remain unchanged along evolutionary lineages

Tropical niche conservatism hypothesis:

Its relatively difficult to evolve traits needed to persist in temperate areas

- Due to asymmetry of colonization and historical dominance of tropics, most species today are tropical with only fewer, younger lineages in temperate areas

Evolutionary Explanations: Tropical Niche Conservatism



The latitudinal species richness gradient in New World woody angiosperms is consistent with the tropical conservatism hypothesis
Andrew J. Kerkhoff[a,1], Pamela E. Moriarty[a,b], and Michael D. Weiser[c]

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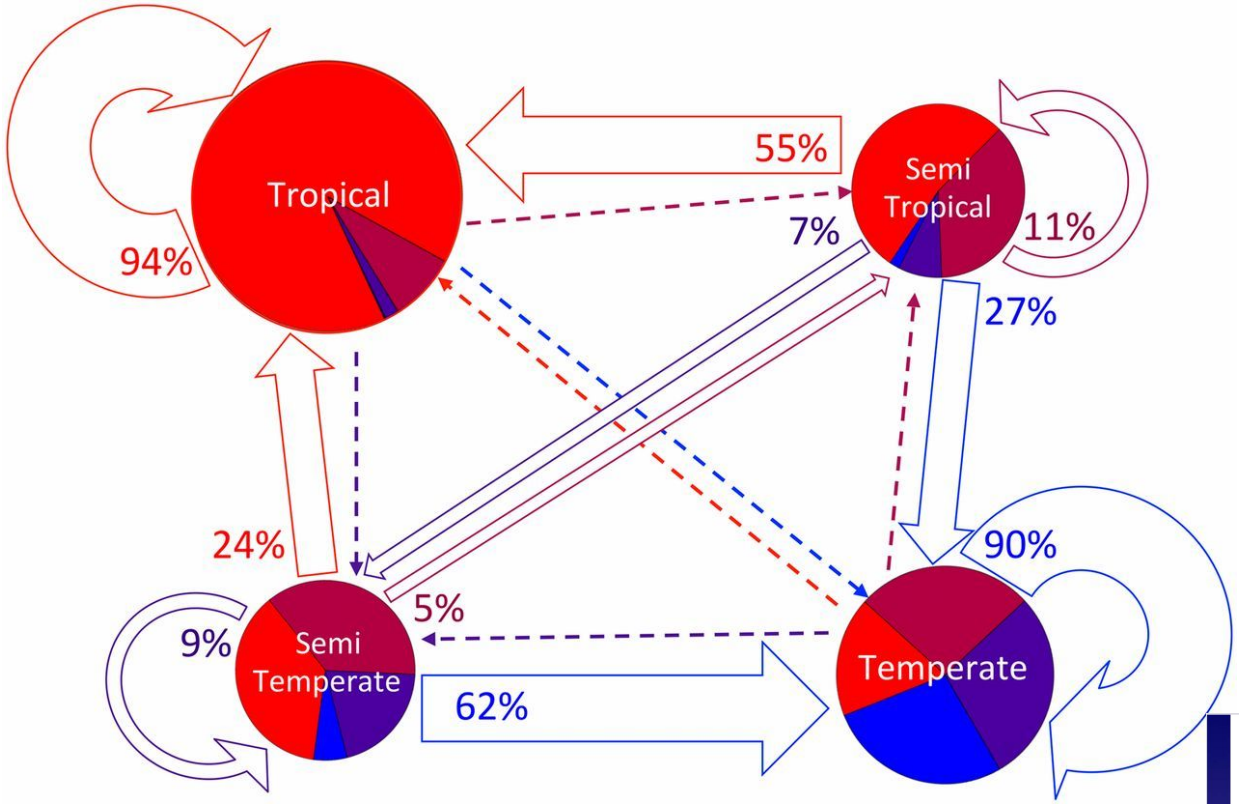

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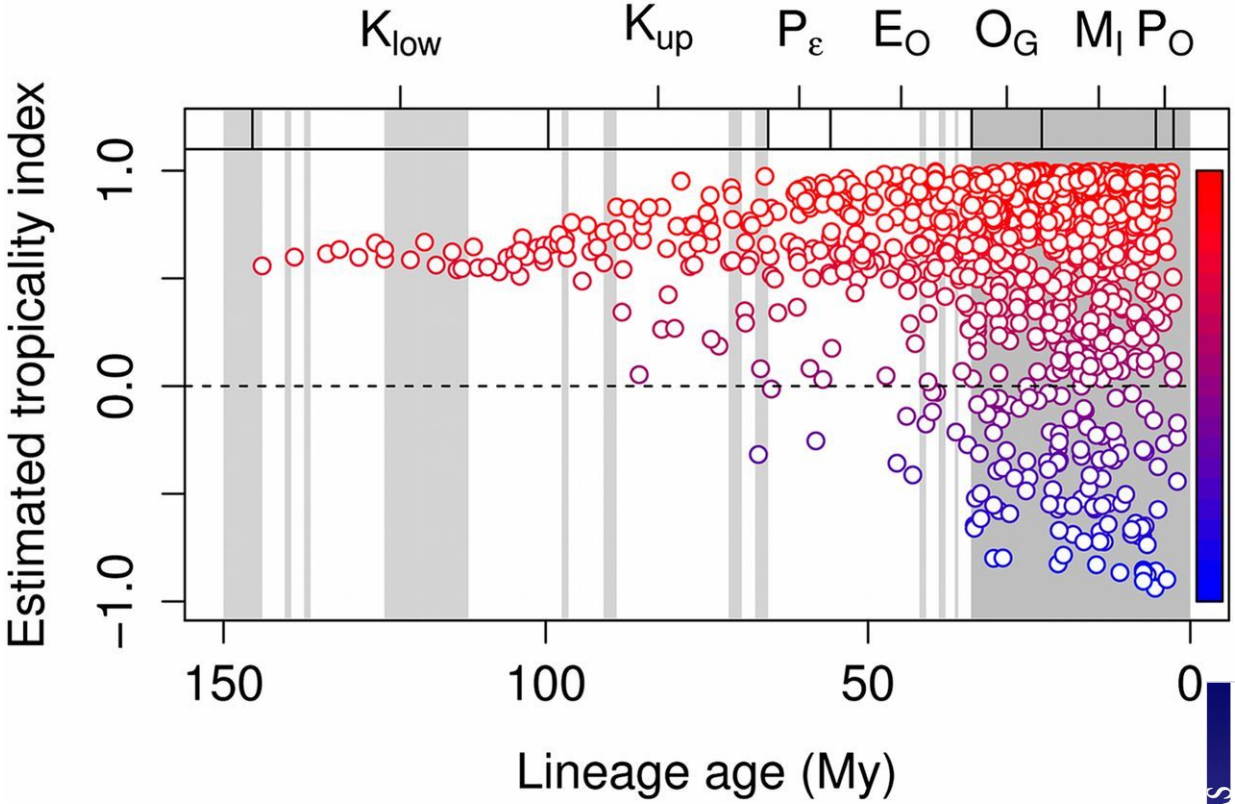


The latitudinal species richness gradient in New World woody angiosperms is consistent with the tropical conservatism hypothesis

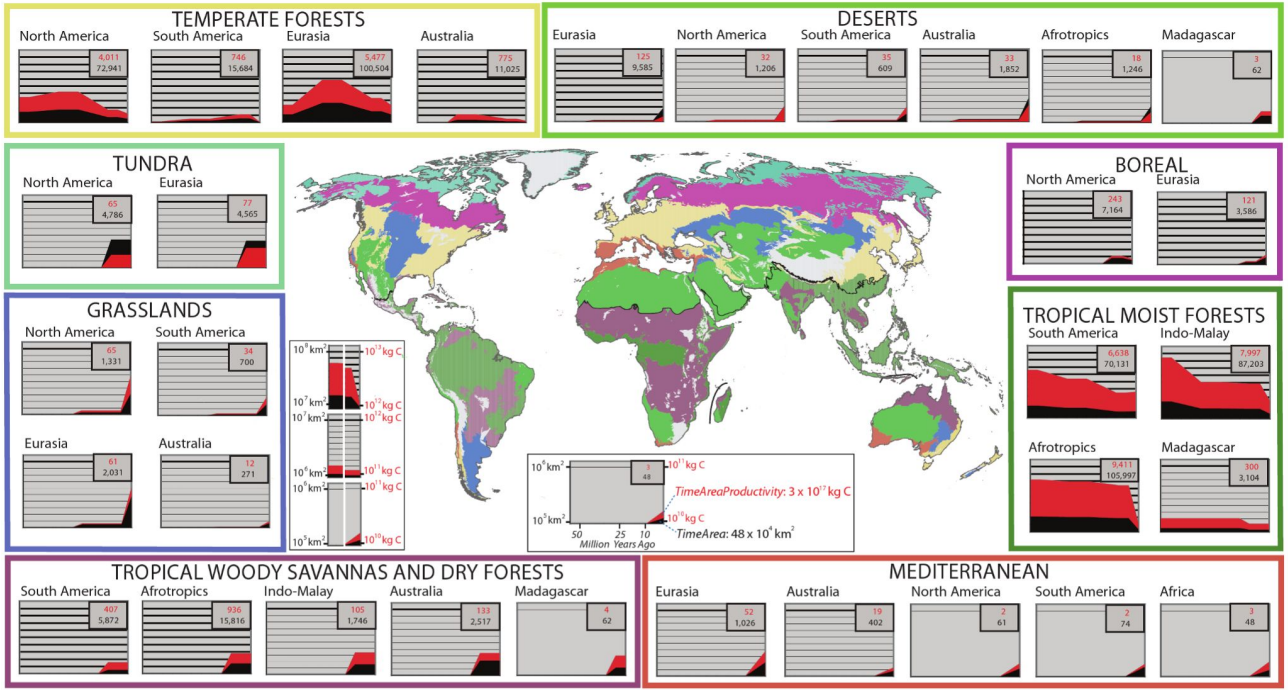
Andrew J. Kerkhoff[a,1], Pamela E. Moriarty[a,b], and Michael D. Weiser[c]

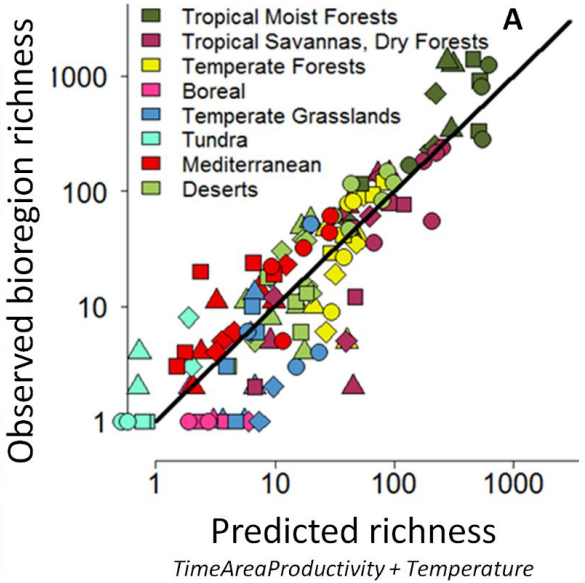
Which one is it?

Which one is it?

- Probably a combination
- Studies that test multiple mechanisms are useful

Combinations of factors





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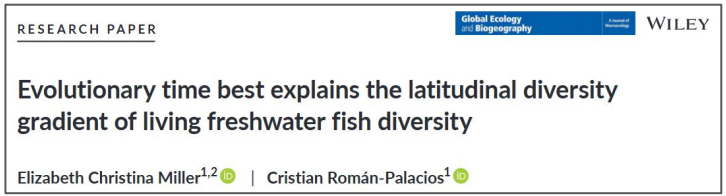
PLoS BIOLOGY

Global Gradients in Vertebrate Diversity Predicted by Historical Area-Productivity Dynamics and Contemporary Environment

Walter Jetz[1]*, Paul V. A. Fine[2]

Testing Competing Mechanisms



RESEARCH PAPER

Global Ecology and Biogeography

WILEY

Evolutionary time best explains the latitudinal diversity gradient of living freshwater fish diversity

Elizabeth Christina Miller[1,2] | Cristian Román-Palacios[1]

Tested for relative importance of diversification rates vs. diversification time

Testing Competing Mechanisms

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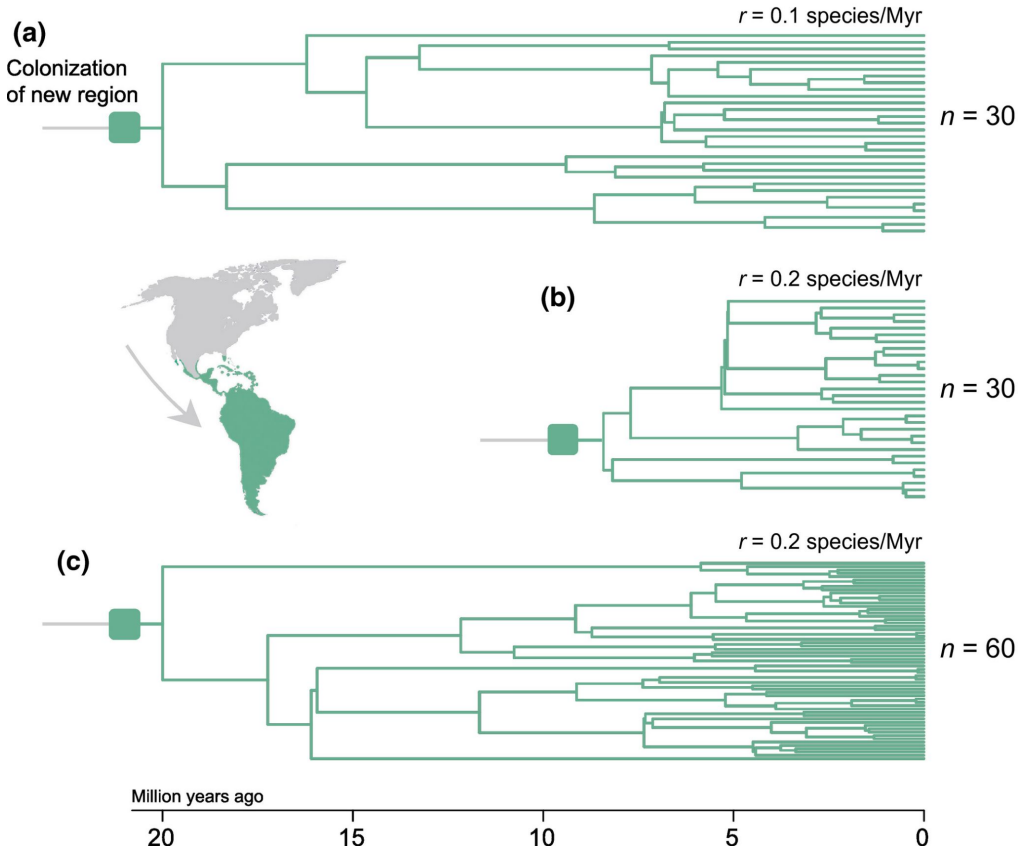

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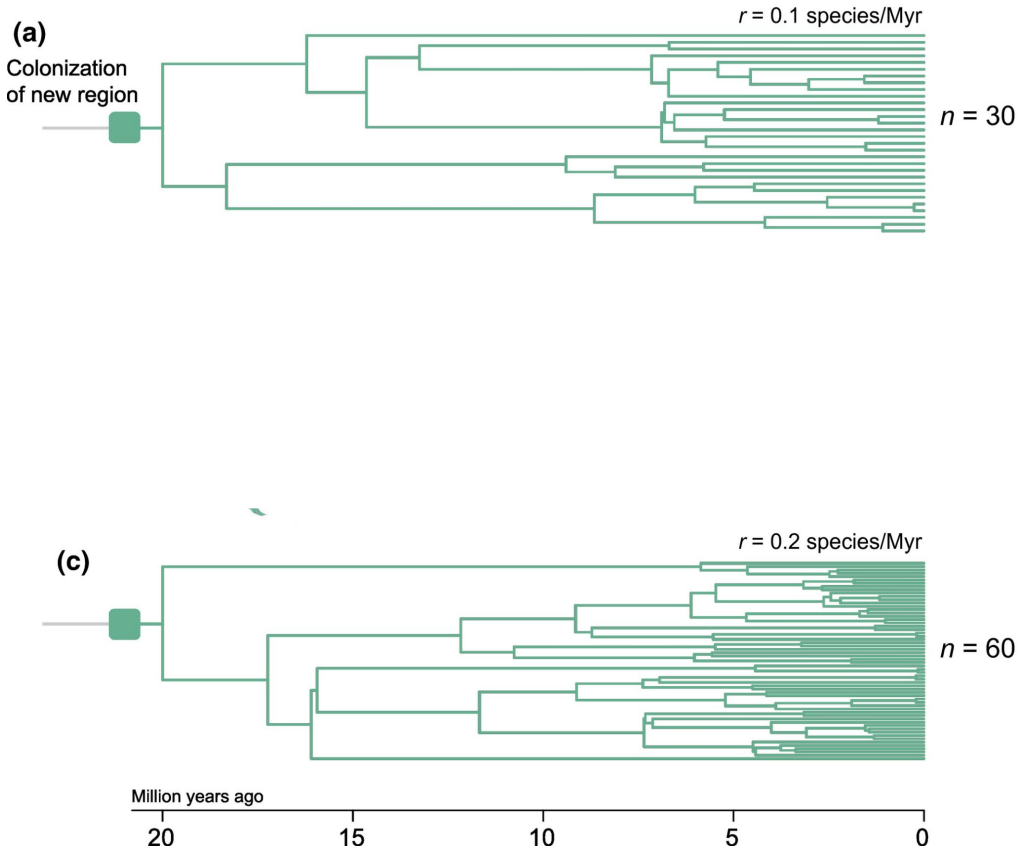

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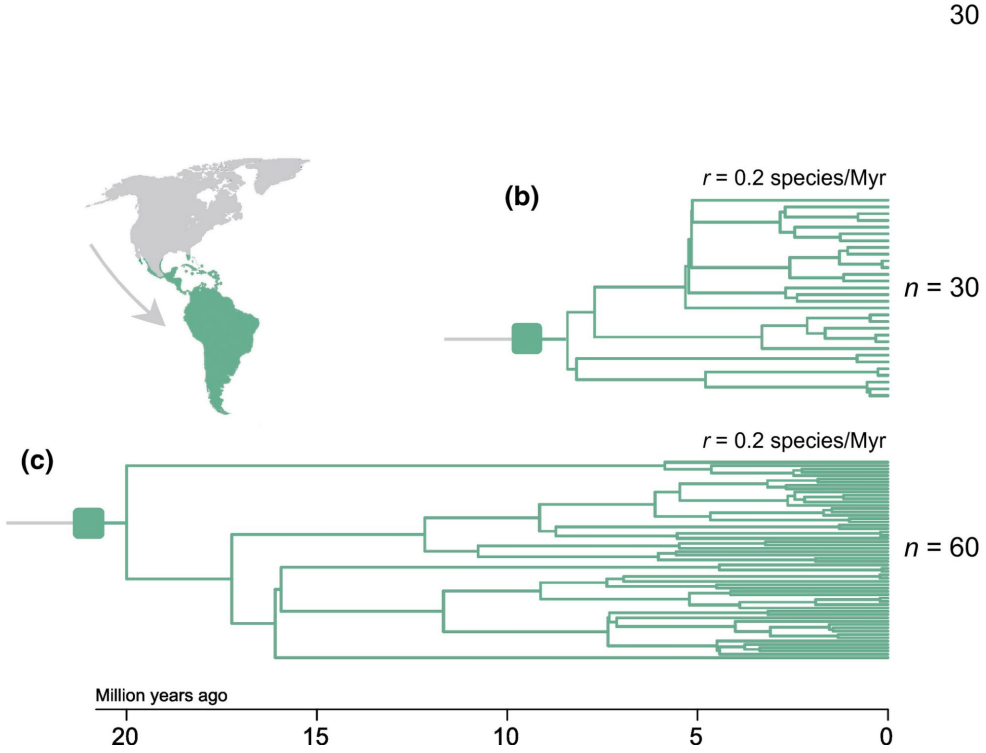

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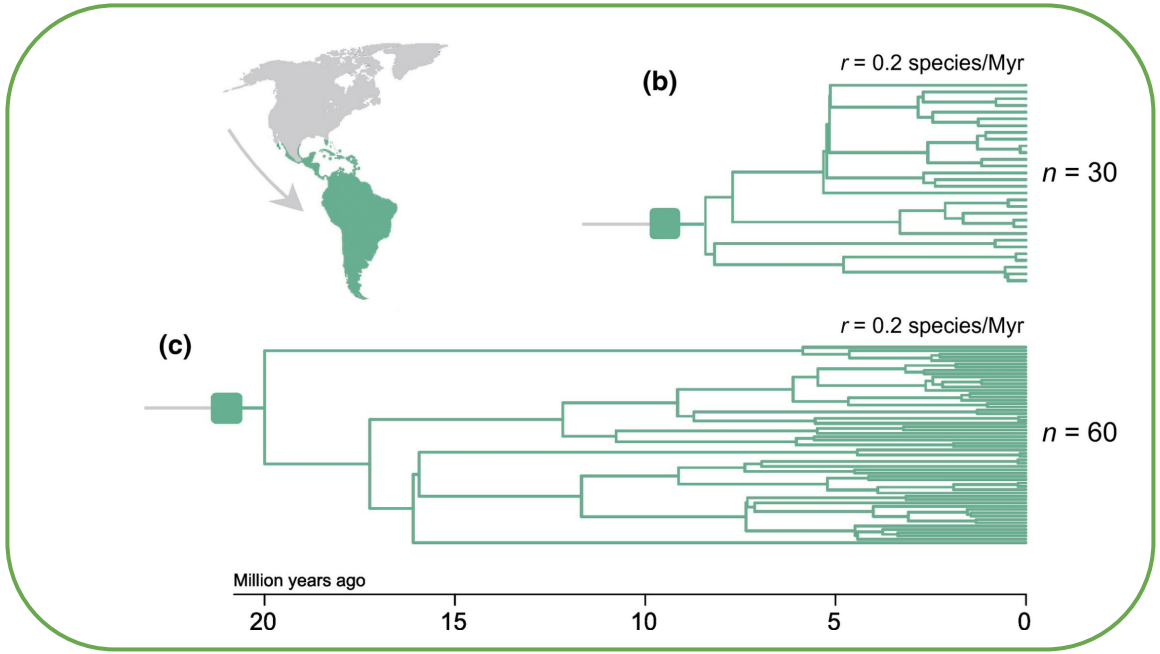
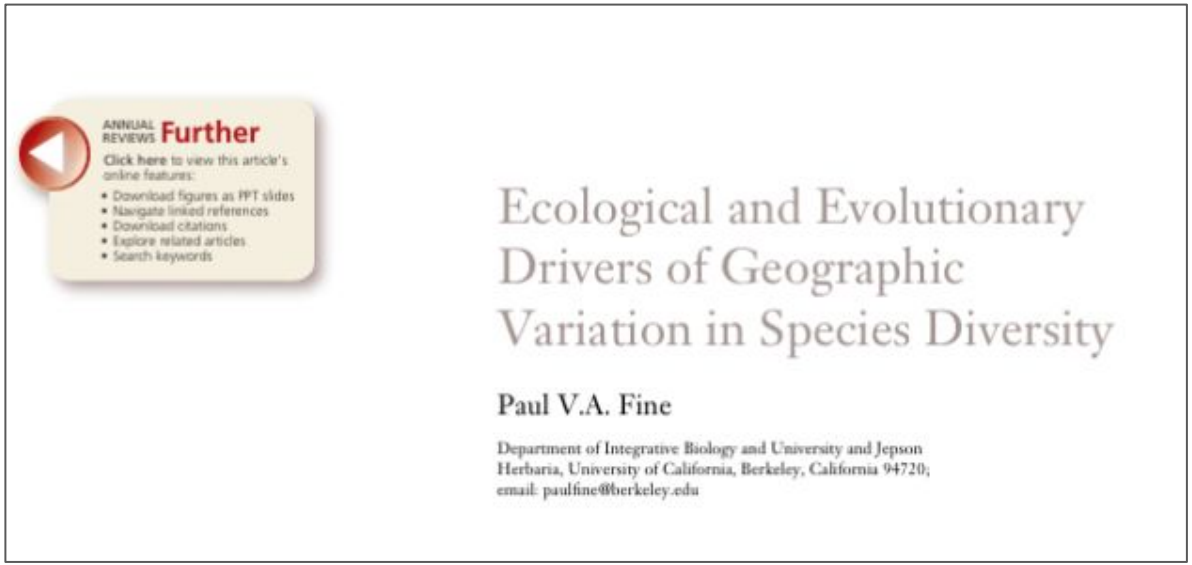


Further reading



These hypotheses apply beyond latitudinal patterns

Examples:

- Older vs. younger habitat types and resources
- Older vs. younger islands
- Productivity variation in aquatic environments
- Niche conservatism of other traits

Next class: Student presentations!