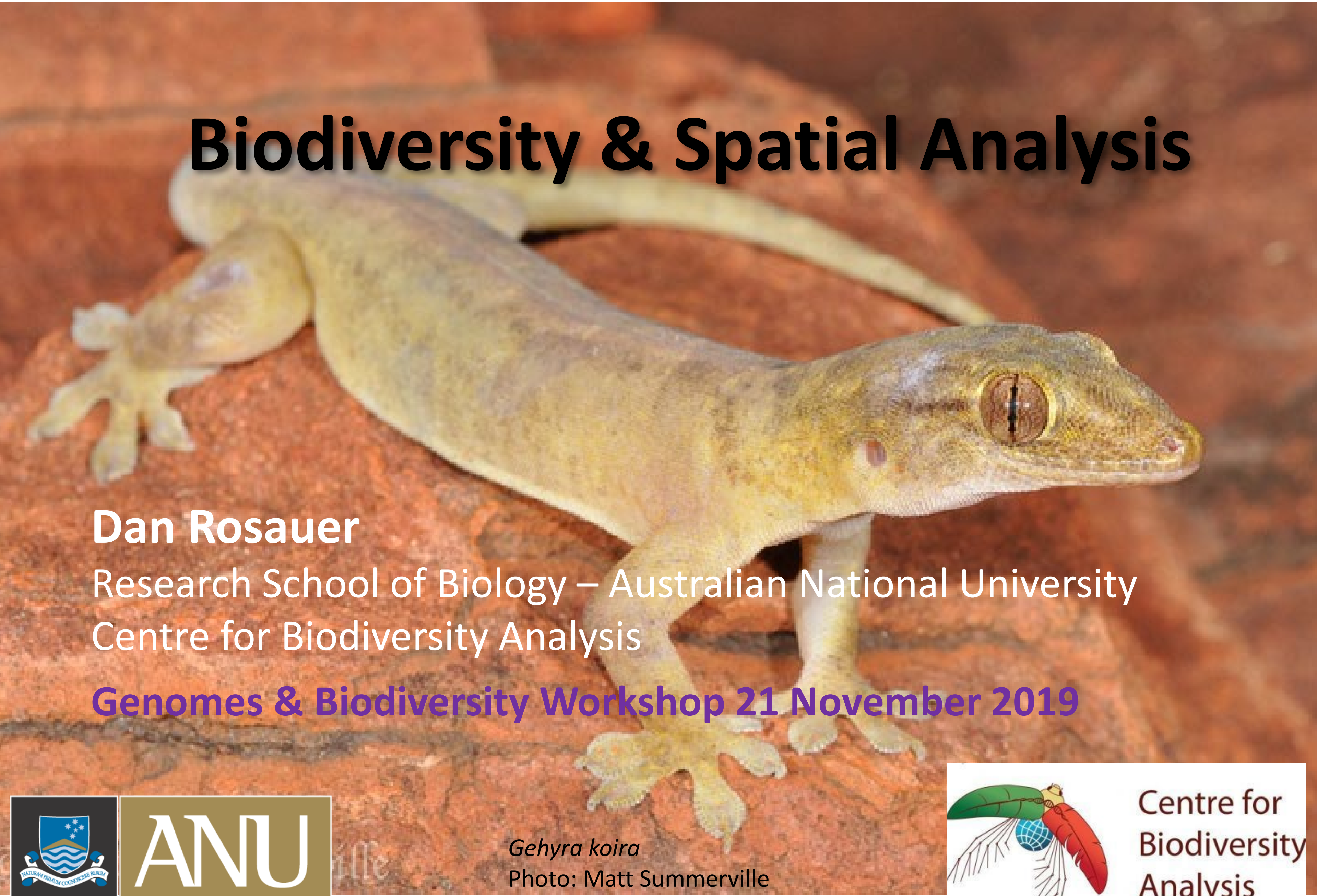


Biodiversity & Spatial Analysis

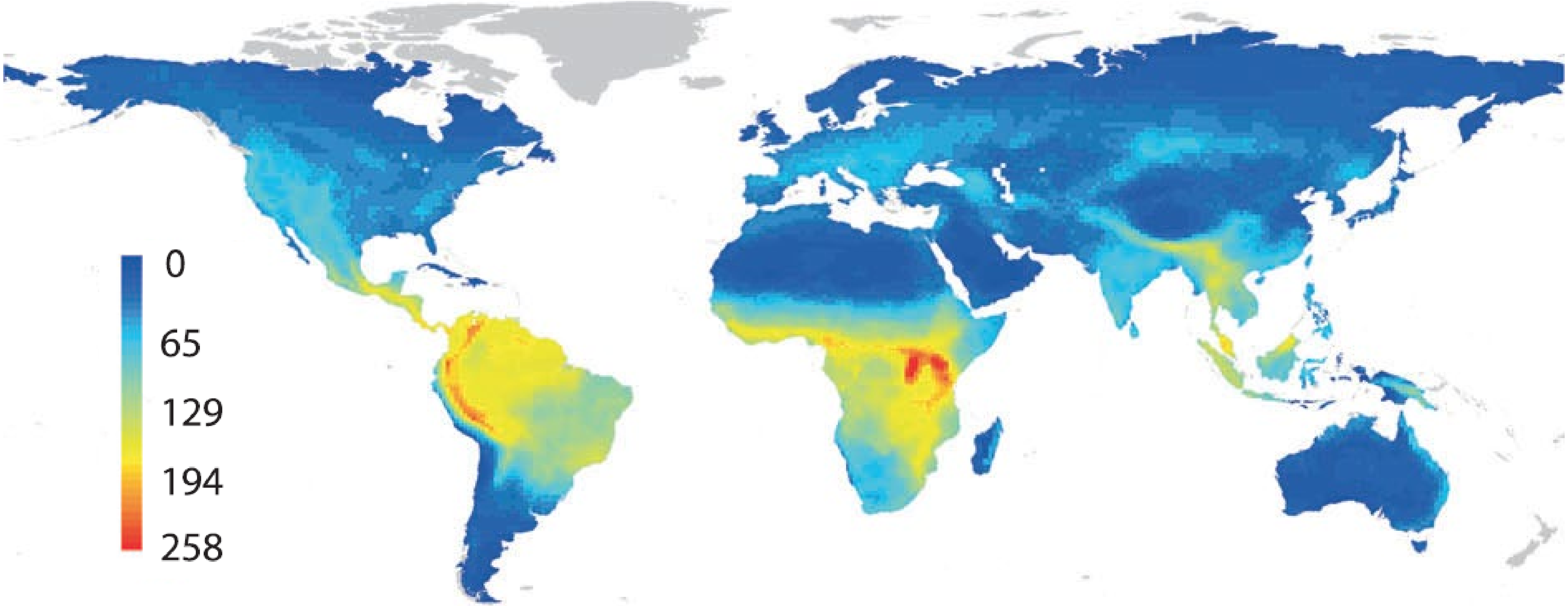
Dan Rosauer
Research School of Biology – Australian National University
Centre for Biodiversity Analysis

Genomes & Biodiversity Workshop 21 November 2019

Gehyra koira
Photo: Matt Summerville

THE AUSTRALIAN NATIONAL UNIVERSITY

Centre for Biodiversity Analysis



Terrestrial Mammal Species Richness

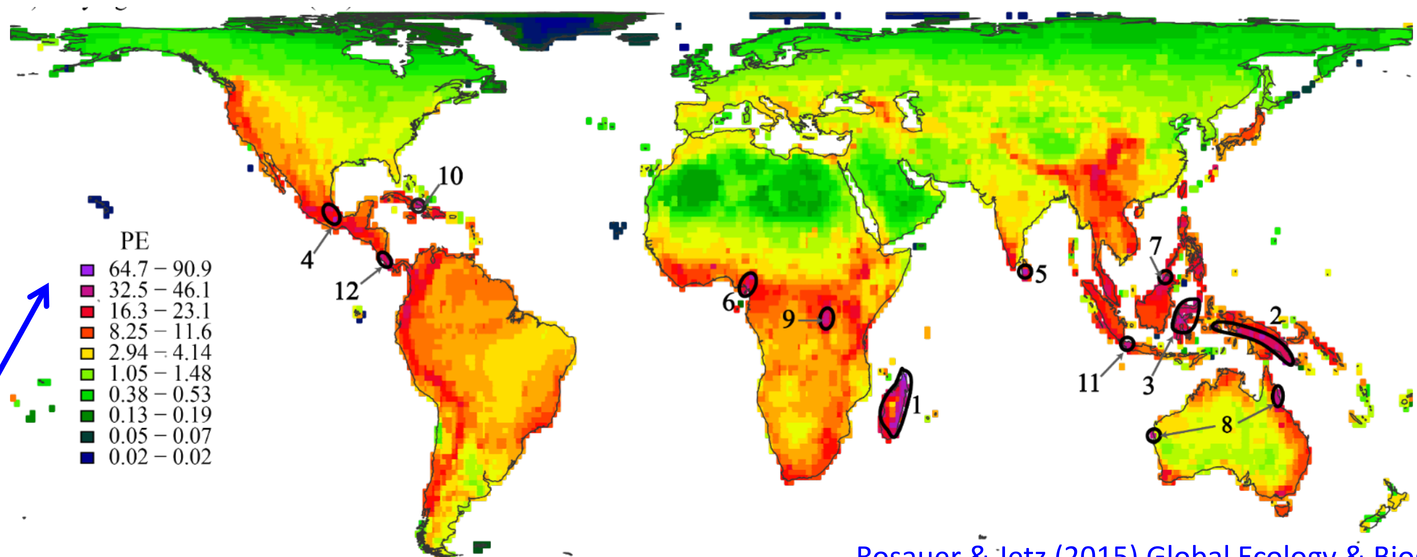
Hawkins *et al*. (2012) Journal of Biogeography

Biodiversity is distributed unequally between areas

Cavia intermedia
Extent of occurrence: 0.04 km^2

Vulpes vulpes
Extent of occurrence: ~70,000,000km^2

Phylogenetic Endemism of Terrestrial Mammals

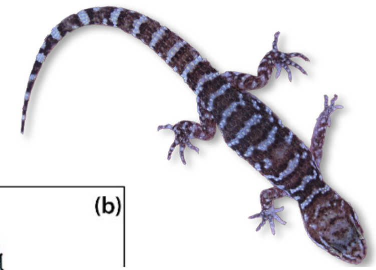


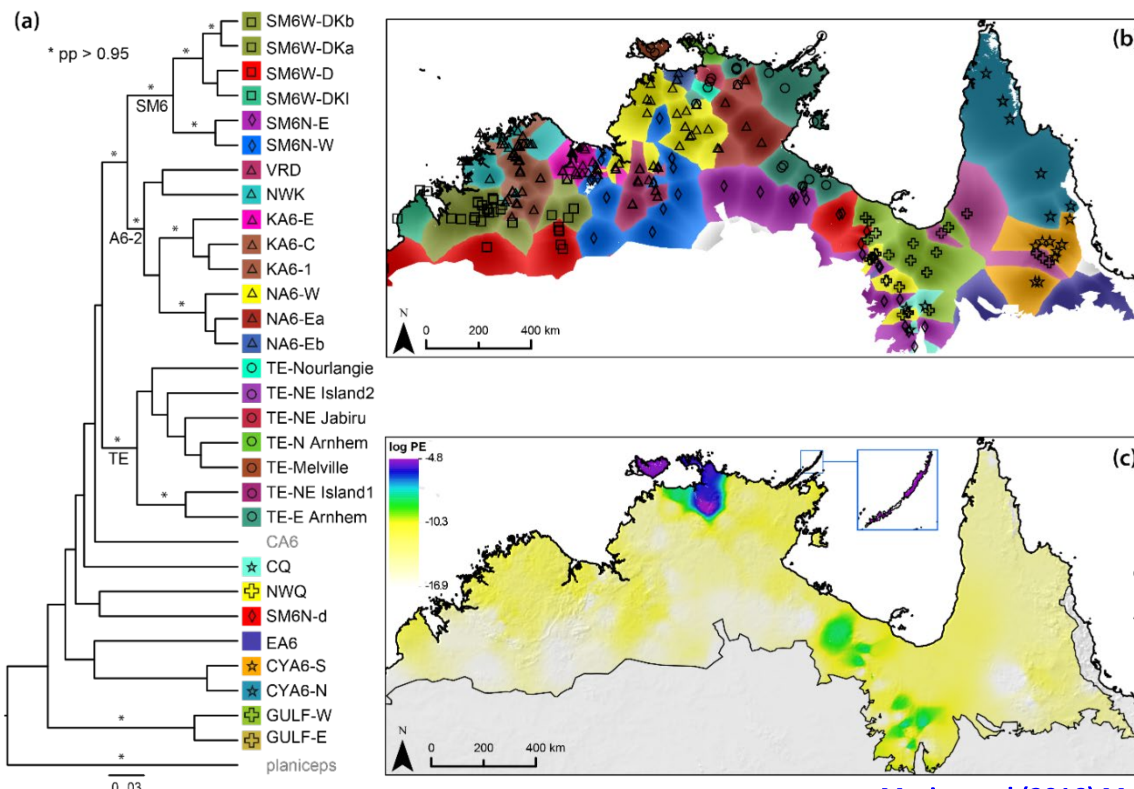
Rosauer & Jetz (2015) Global Ecology & Biogeography

A score of 90 is equivalent to:
 * 90 million years of evolutionary history restricted a single cell,
 * 180 million years spread across 2 cells…
 … or any additive combination like this

Phylogeny matters for conservation

It can detect patterns independent of named taxa



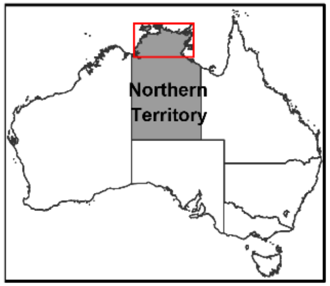


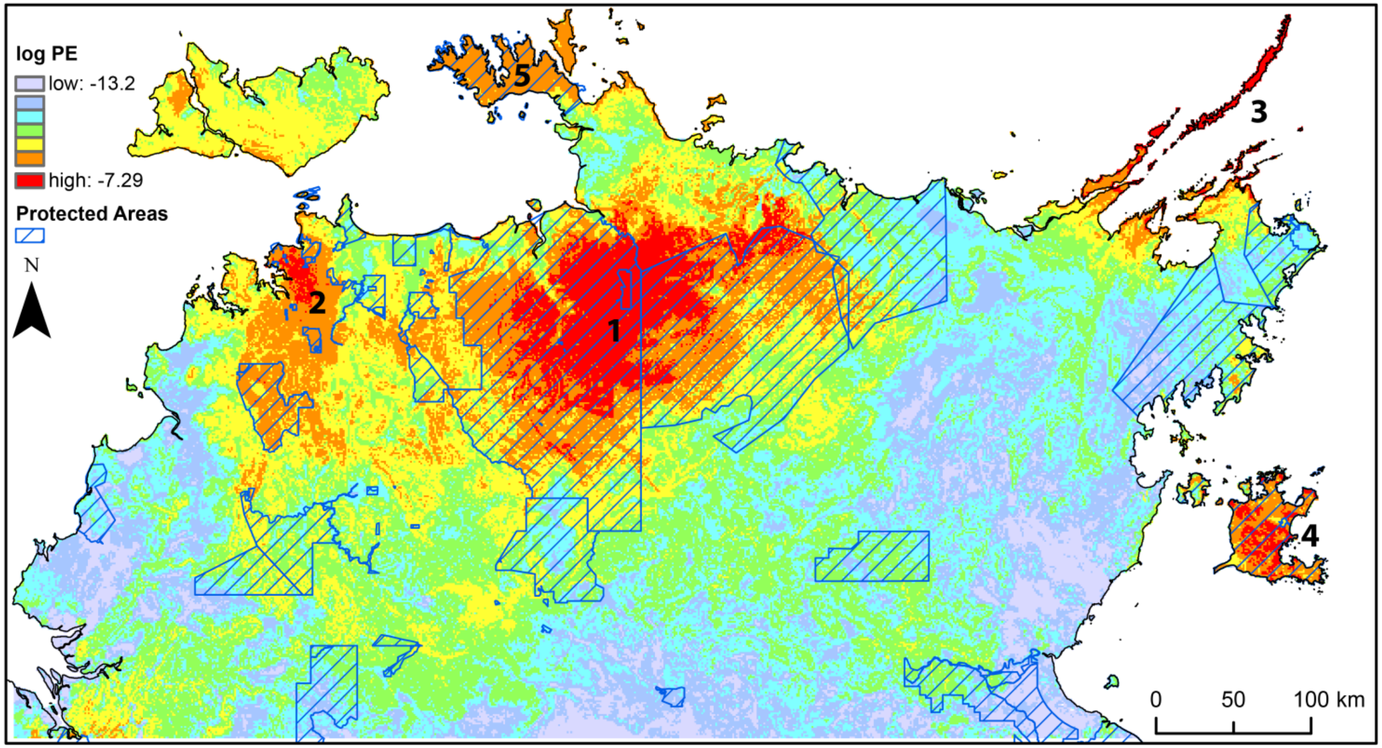
Northern lineages of *H. binoei*

Phylogenetic endemism within *H. binoei*

Moritz et al (2016) Molecular Ecology

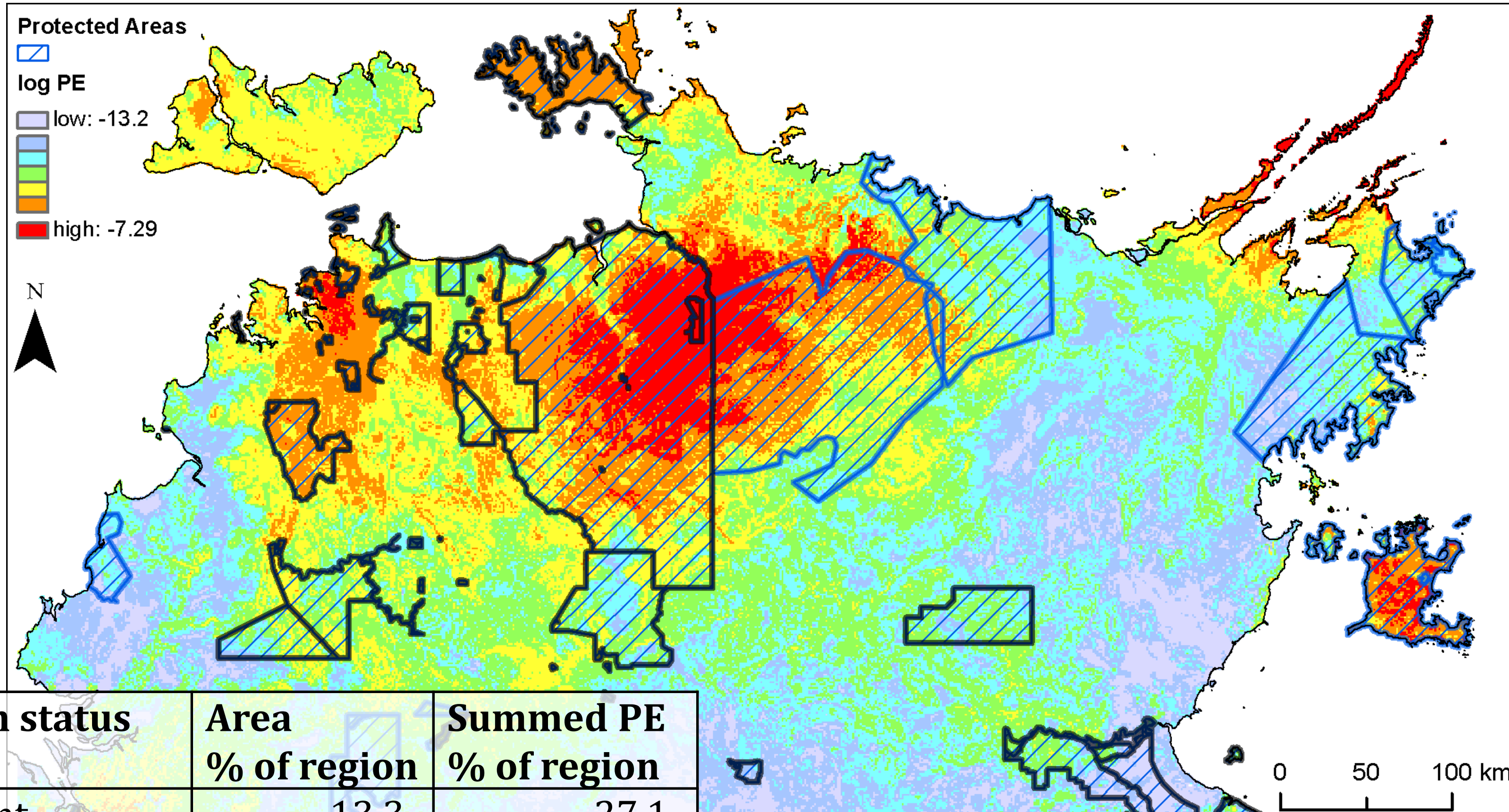
Phyloendemism in the Top End for 10 lizard genera





Rosauer *et al*. (2016) Biological Conservation

Phyloendemism in the Top End for 10 lizard genera

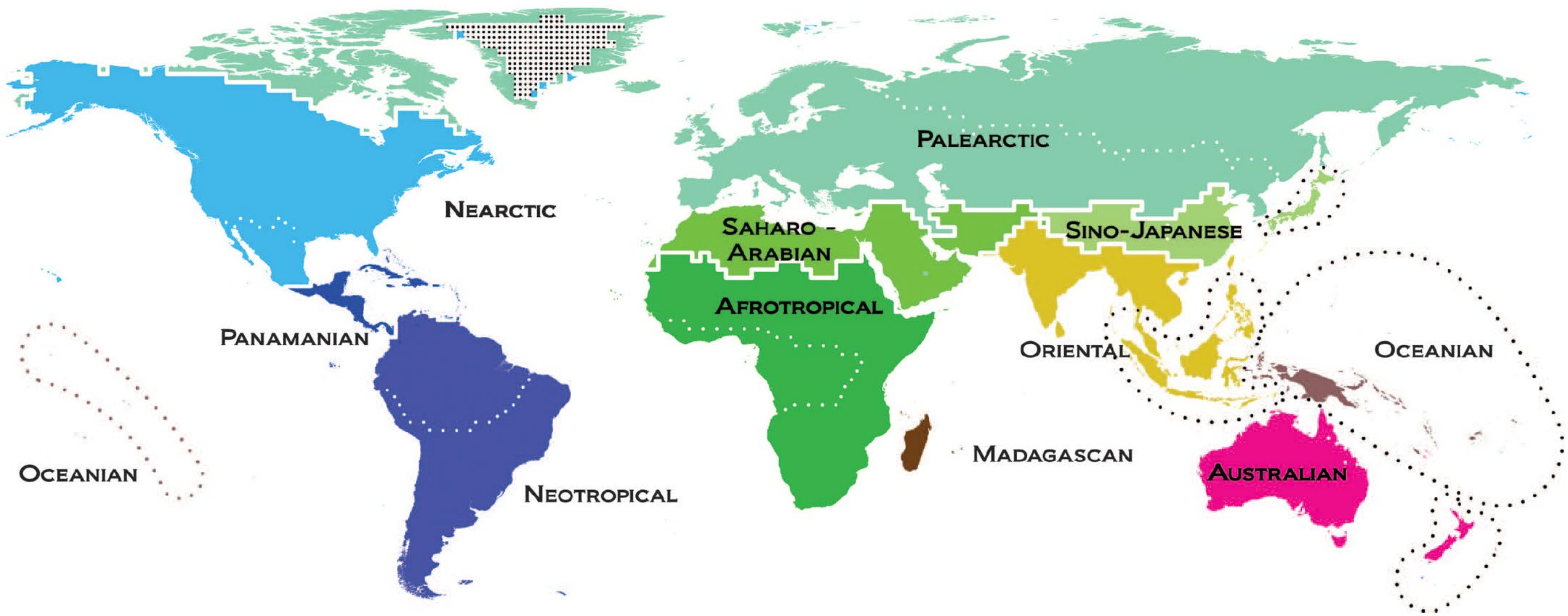


Protection status	Area % of region	Summed PE % of region
Government	13.3	27.1
Indigenous	12.8	17.9
Conservation NGO	1.5	1.1
Total	*27.6*	***46.1***

Rosauer *et al*. (2016) Biological Conservation

An Update of Wallace's Zoogeographic Regions of the World

Ben G. Holt,[1]* Jean-Philippe Lessard,[1]*† Michael K. Borregaard,[1] Susanne A. Fritz,[1,2] Miguel B. Araújo,[1,3,4] Dimitar Dimitrov,[5] Pierre-Henri Fabre,[5] Catherine H. Graham,[6] Gary R. Graves,[1,7] Knud A. Jønsson,[5] David Nogués-Bravo,[1] Zhiheng Wang,[1] Robert J. Whittaker,[1,8] Jon Fjeldså,[5] Carsten Rahbek[1]



Holt *et al*. (2013) Science

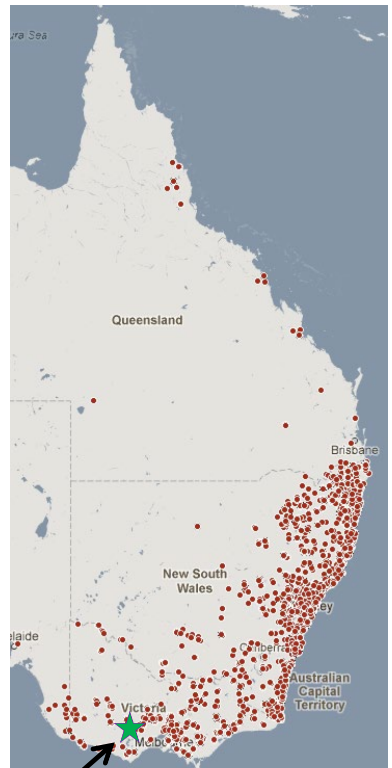
Getting practical
basics of mapping biodiversity

- Getting practical – basics of mapping biodiversity
  - Types of species location data - knowing what lives where
  - Resolution (spatial units of analysis)
  - Metrics
  - Units of biodiversity (species or phylogenetic)

Types of species distribution data

Specimen & survey records

Collection	[Museum Victoria Mammalogy Collection]()
Catalogue number	C 22667
Basis of record	Preserved Specimen
Preparations	Skeleton
Collecting date	1965-06-02
Sex	Female
Individual count	1
Scientific Name	Acrobates pygmaeus
Common name	Feathertail glider
Locality	Trawalla forest reserve
Latitude	-37.45
Longitude	143.42



Atlas of Living Australia

ala.org.au

- Specific location and date
- Does not extrapolate beyond known location
- Fine spatial resolution
- Can relate species occurrence to conditions at site
- Physical evidence
- **Underestimates species occurrence**

Types of species distribution data

Expert range maps

Extent of occurrence

IUCN Global Mammal Assessment

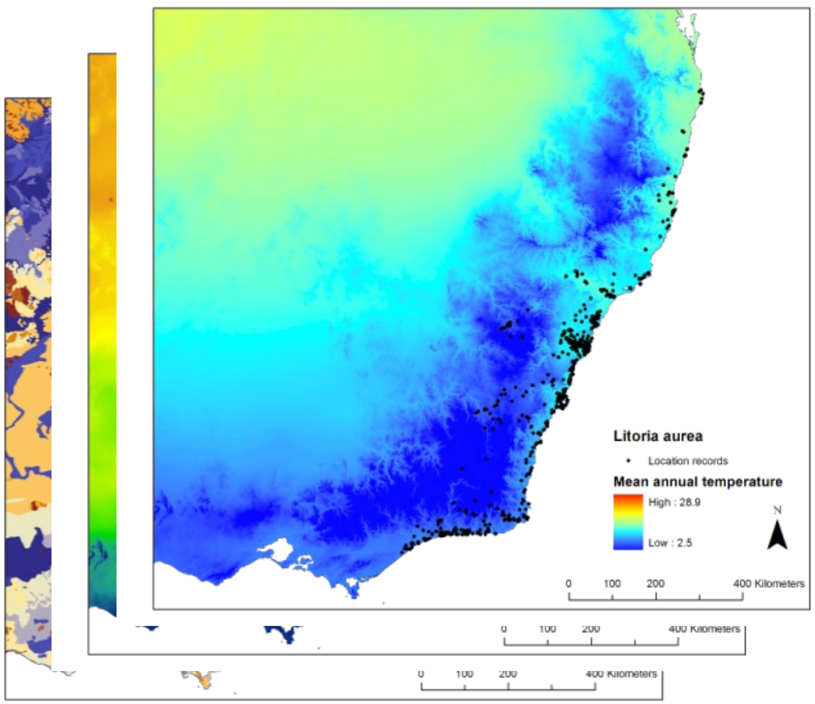
Feathertail Glider *Acrobates pygmaeus*

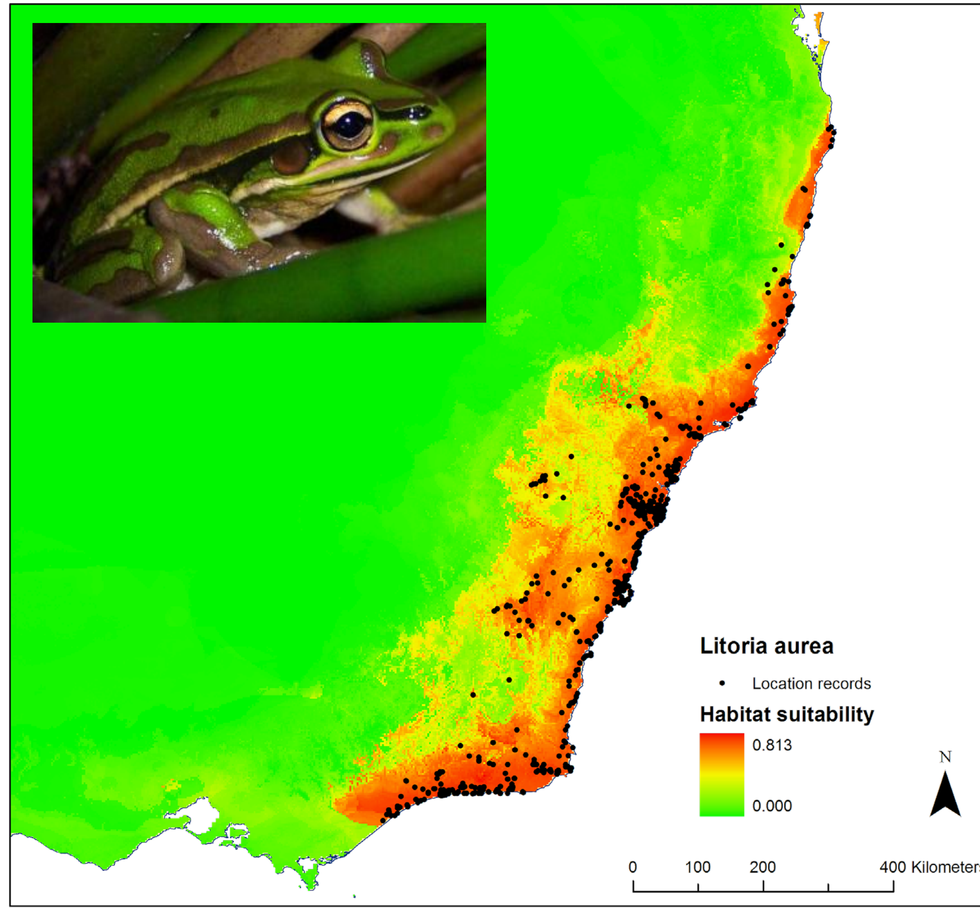
hb 65–80 mm; **t** 70–80 mm; **wt** 10–14 g
World's smallest gliding mammal—size of small mouse. Tail unique among Aust mammals—almost hairless except for fringe of long stiff hairs on either side giving feather-like appearance. Gliding membrane between elbows and knees. Upperparts uniform mid-grey; often with white patch behind ears; blackish around eyes. Underparts whitish, including face below eyes. **Distribution, habitat and status** Widespread in cool-temperate and tropical eucalypt forests of e. Aust to se. SA. Needs high diversity of trees and shrubs to provide year-round nectar. More common in wet and old-growth forest than dry or regenerating

Menkhorst & Knight (2001) A Field Guide to Mammals of Australia

- Less affected by sample bias
- Can benefit from expert knowledge as well as data
- No fine scale information about where the species occurs within its range
- **Overestimates species occurrence**

Species Distribution Models use environmental data to estimate areas of suitable habitat





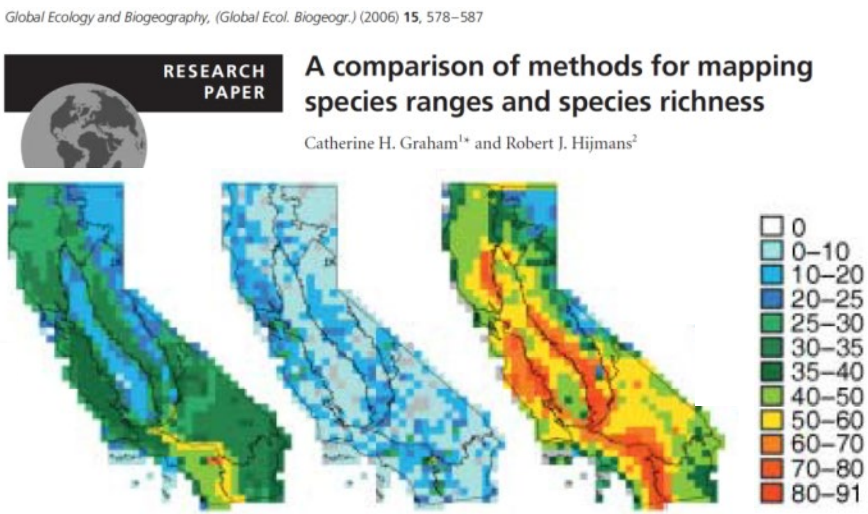
Measuring richness: effect of data type and resolution

Data Type	**Richness**
Survey point records	*lowest*
Expert ranges	*intermediate*
Modelled ranges	*highest*

Resolution

The richness difference between points and expert ranges is greater for fine scale analyses

Hurbert & Jetz (2007) PNAS



expert ranges points distribution model

Graham & Hijmans (2006) Global Ecology & Biogeography

Measuring endemism

What defines endemism?

– **Absolute endemism** - fixed boundary

– **Relative endemism** - continuous function

Weighted endemism (WE)

$WE = {}^{1}/_{range}$ (for each species)

total of endemism scores for species recorded in the cell

Journal of Biogeography, **28**, 183–198

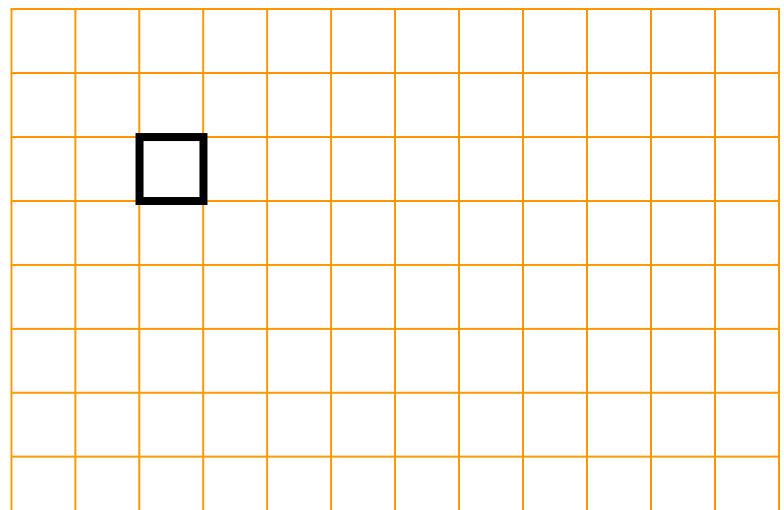
Endemism in the Australian flora

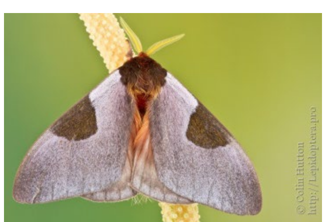
M. D. Crisp[1]*, S. Laffan[2], H. P. Linder[3] and A. Monro[1] [1]*Division of Botany and Zoology,* [2]*Department of Geography, Australian National University, Canberra ACT 0200, Australia and* [3]*Department of Botany, University of Cape Town, Rondebosch 7700, South Africa*

How weighted endemism is calculated?

Consider an area where 3 species are found:

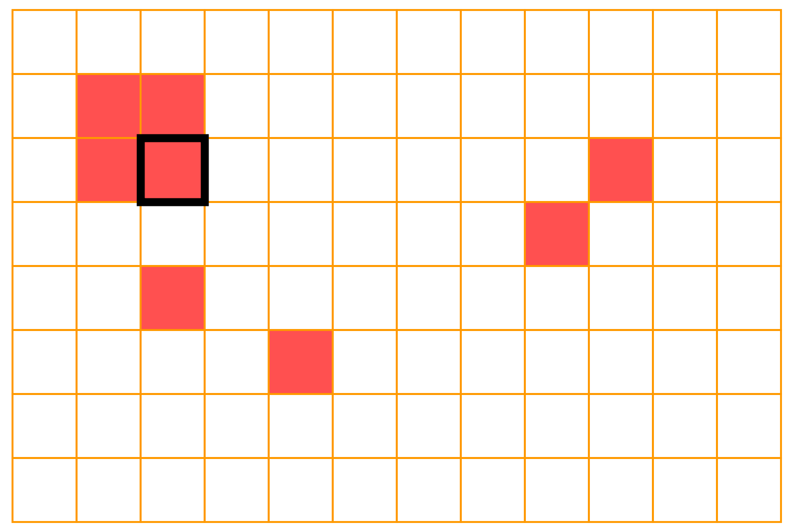
Species	**Range**
Callionima denticulata	
Dirphia avia	
Sphinx merops	



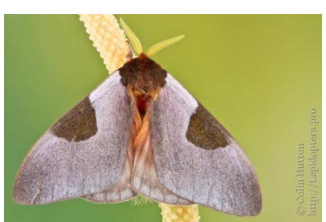


How weighted endemism is calculated?

Species	**Range**
Callionima denticulata	8
Dirphia avia	
Sphinx merops	



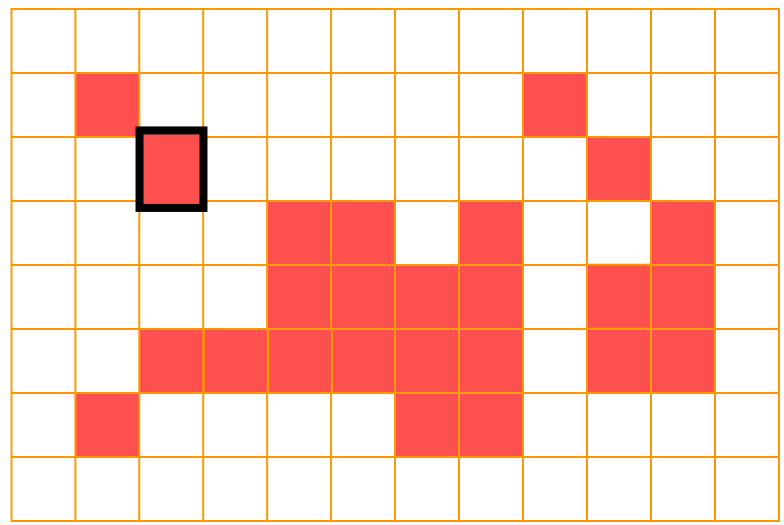
$$\frac{1}{8}$$

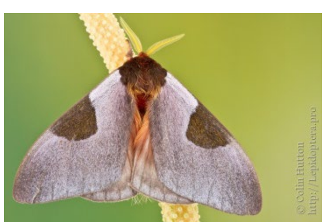


How weighted endemism is calculated?

Species	Range
Callionima denticulata	8
Dirphia avia	25
Sphinx merops	

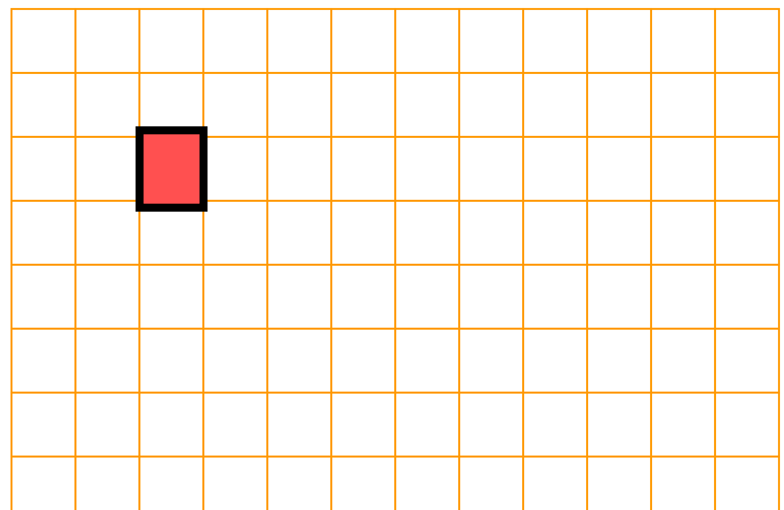
$$\frac{1}{8} + \frac{1}{25}$$



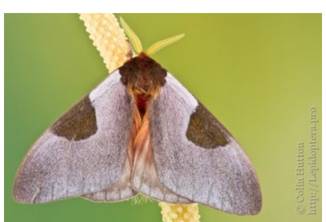


How weighted endemism is calculated?

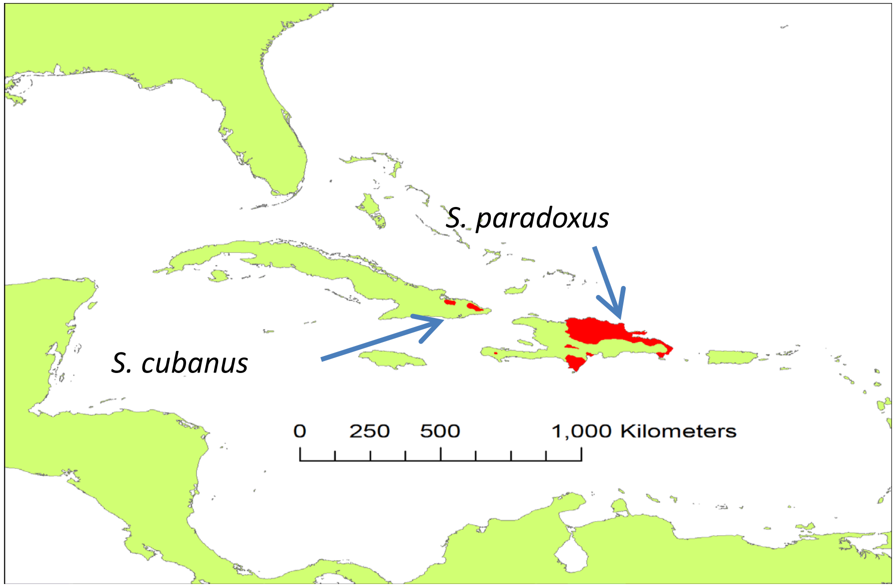
Species	**Range**
Callionima denticulata	8
Dirphia avia	25
Sphinx merops	1



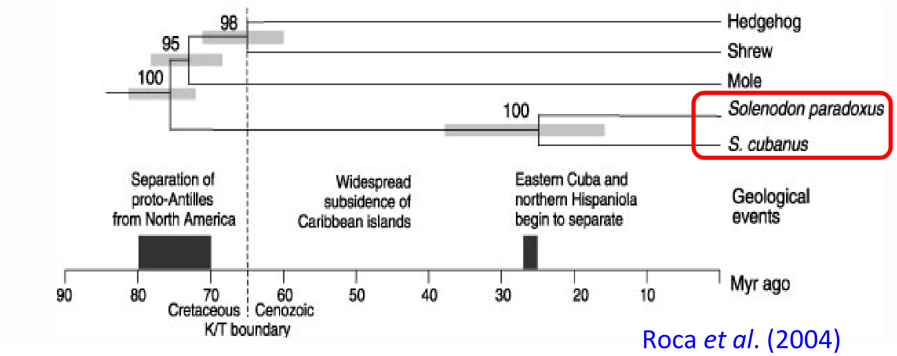
$$\frac{1}{8} + \frac{1}{25} + \frac{1}{1} = 1.16$$



Biological diversity is distributed unequally between species as well as between areas



Solenodon paradoxus

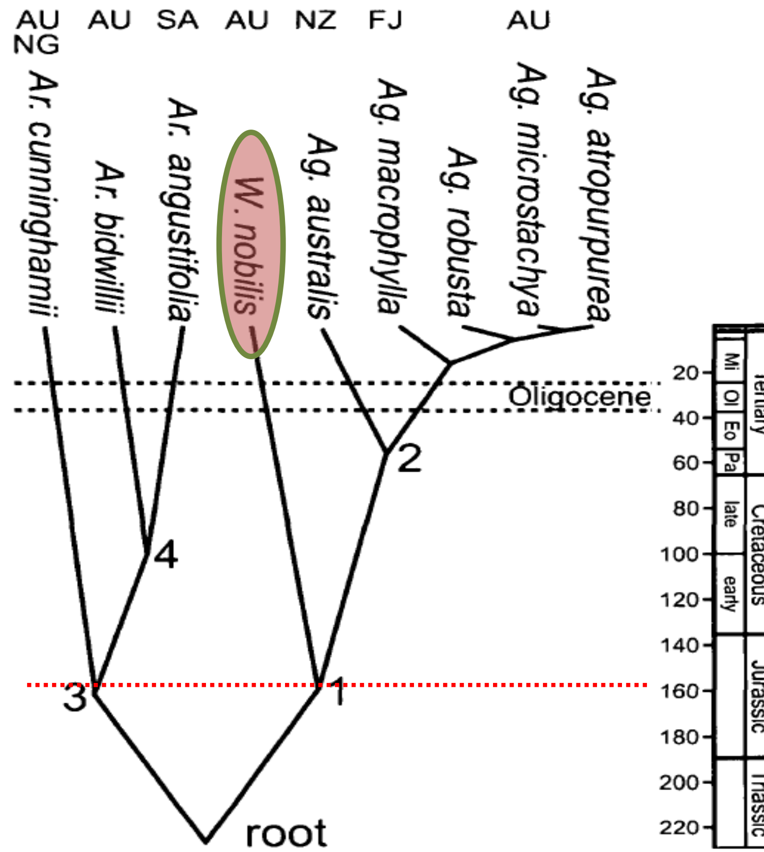


Roca *et al*. (2004)

Biological diversity is distributed unequally between species as well as between areas

The Wollemi Pine

Species: *Wollemia nobilis*
Common Name: Wollemi pine
Status: Critically Endangered, IUCN Red List; Endangered, Australian Environment Protection and Biodiversity Conservation Act
Range: Australia



Knapp *et al*. 2007 Sys. Biol.

Improving conservation decisions

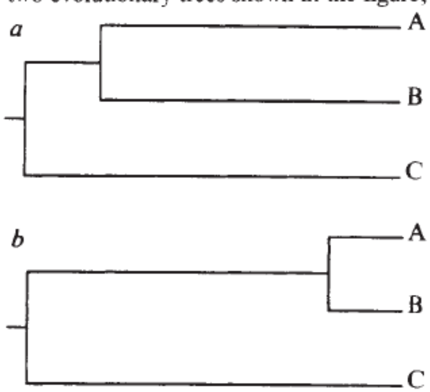
NATURE · VOL 348 · 6 DECEMBER 1990

STEPHEN F. ALTSCHUL
DAVID J. LIPMAN

Equal animals

SIR—May in News and Views[1] discusses the question of whether all species should be equally valued from the perspective of conservation biology. He and others have concluded that some animals must be considered more equal than others[4] when assigning spaces in a shrinking — if not sinking — ark.

But how can one assess the relative worth of, for example, two different species of lemur? If diversity is the goal the key seems to lie in taxonomy, with species for which no close relatives exist receiving greater weight. May described several weighting schemes based on the branching order, or topology, of an evolutionary tree relating the species in question. The length of the branches of such a tree, corresponding to degrees of change between evolutionary diversions, should also be taken into account. The two evolutionary trees shown in the figure,



for example, are topologically identical. Yet the three species in tree *a*, having diverged at nearly the same time, should

...xonomy as destiny

M. May

Econometrica, Vol. 66, No. 6 (November, 1998), 1279–1298

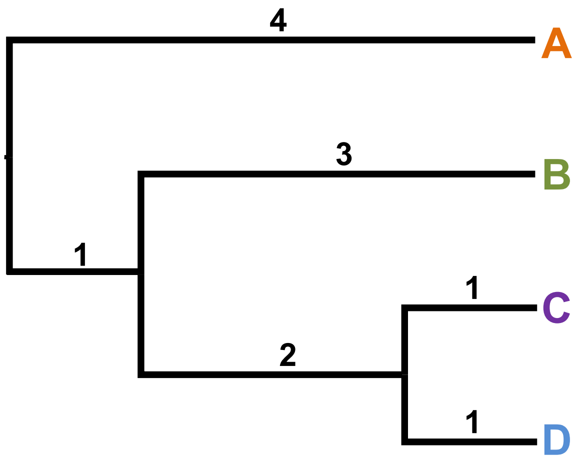
THE NOAH'S ARK PROBLEM

BY MARTIN L. WEITZMAN

This paper is about the economic theory of biodiversity preservation. A cost-effectiveness methodology is constructed, which results in a particular formula that can be used as a criterion to rank projects. The ranking criterion is sufficiently operational to be useful in suggesting what to look at when determining actual conservation priorities among endangered species. At the same time, the formula is firmly rooted in a mathematically rigorous optimization framework, so that its theoretical underpinnings are clear. The underlying model, called the "Noah's Ark Problem," is intended to be a kind of canonical form that hones down to its analytical essence the problem of best preserving diversity under a limited budget constraint.

KEYWORDS: Biodiversity, endangered species, diversity theory.

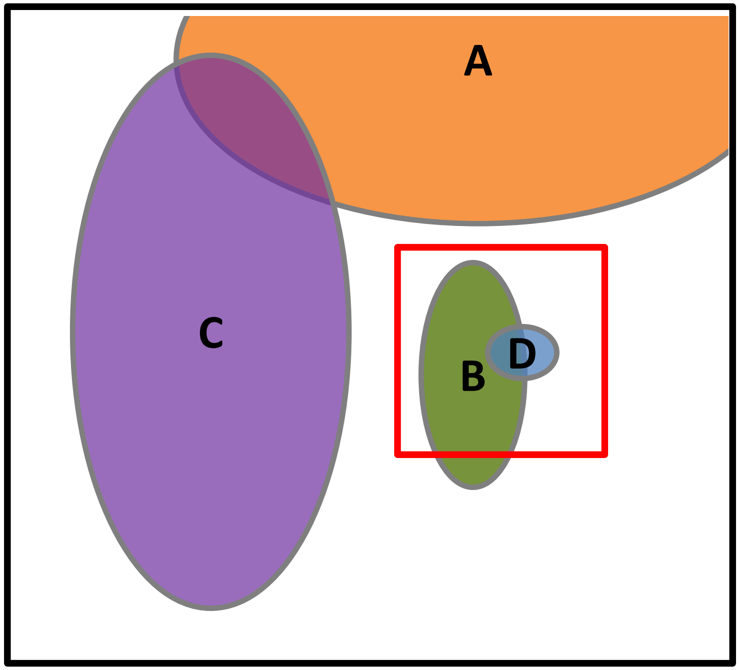
Calculating phylogenetic diversity and endemism



Phylogenetic Diversity (PD)

Faith (1992)

PD = 1 + 3 + 2 + 1 = 7

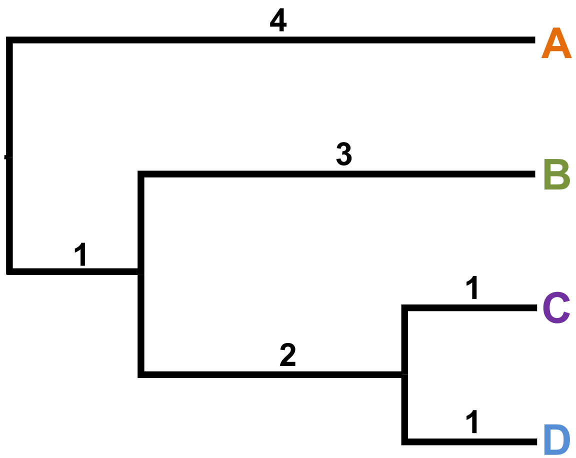


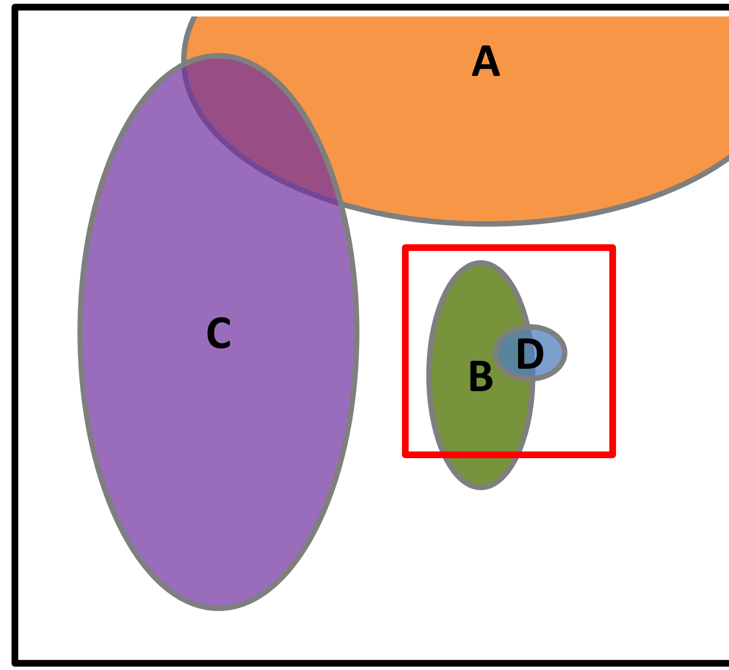
$$PD = \sum_{\{c \in C\}} L_c$$

Advantages of PD

- captures more information on diversity
- robust to taxonomic uncertainty
- doesn’t even require taxonomy

Calculating phylogenetic diversity and endemism





Phylogenetic Diversity (PD)

Faith (1992)

PD = 1 + 3 + 2 + 1 = 7

Phylogenetic Endemism (PE)

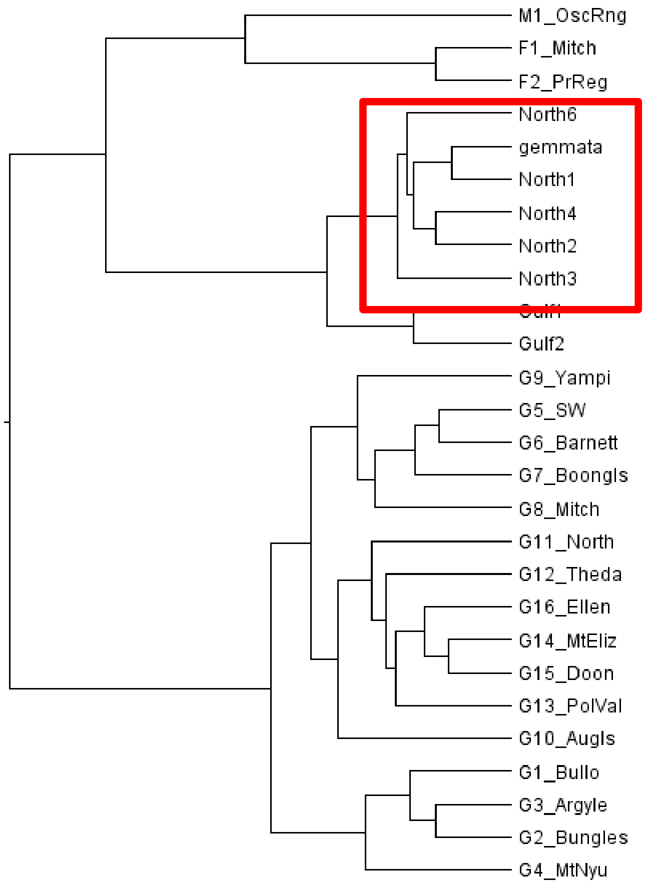
Rosauer et al (2009)

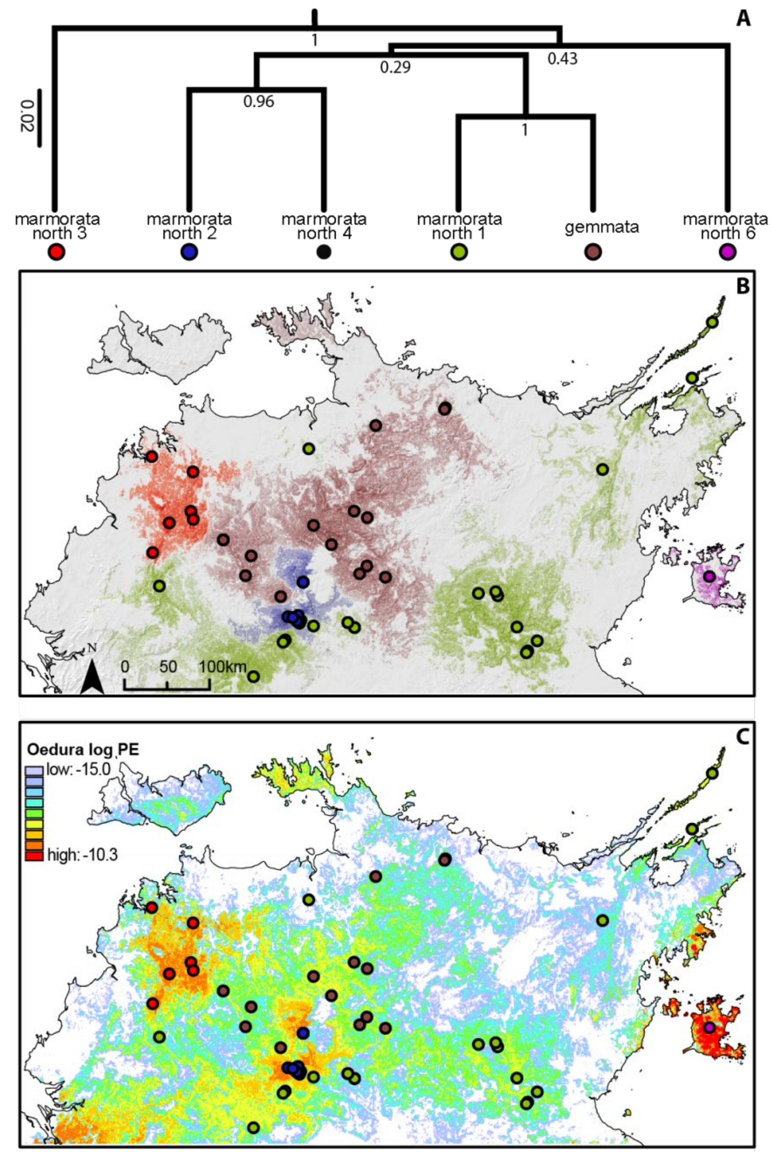
PE = (1*1) + (3*0.8) + (2*0.2) + (1*0.25) = 4.05

$$PE = \sum_{\{c \in C\}} \frac{L_c}{R_c}$$

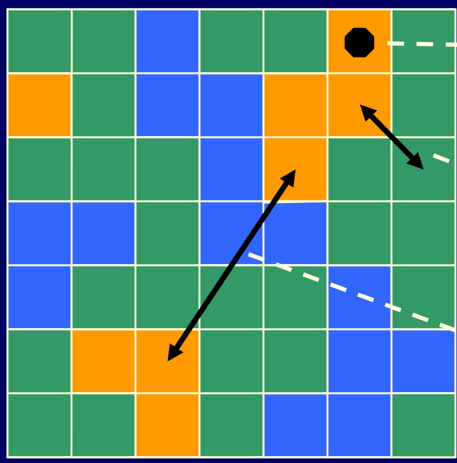
PE is the proportion of the range of each unit of diversity, that is found in a given area.

Oedura





Oedura marmorata



alpha diversity (local richness)

beta diversity

gamma diversity

‘dissimilarity’
‘turnover’
‘complementarity’

Compositional dissimilarity between locations:

Sørensen distance:
between composition of 2 sites

$$1-\frac{2A}{2A+B+C}$$

0 => complete overlap - identical composition
1 => no overlap

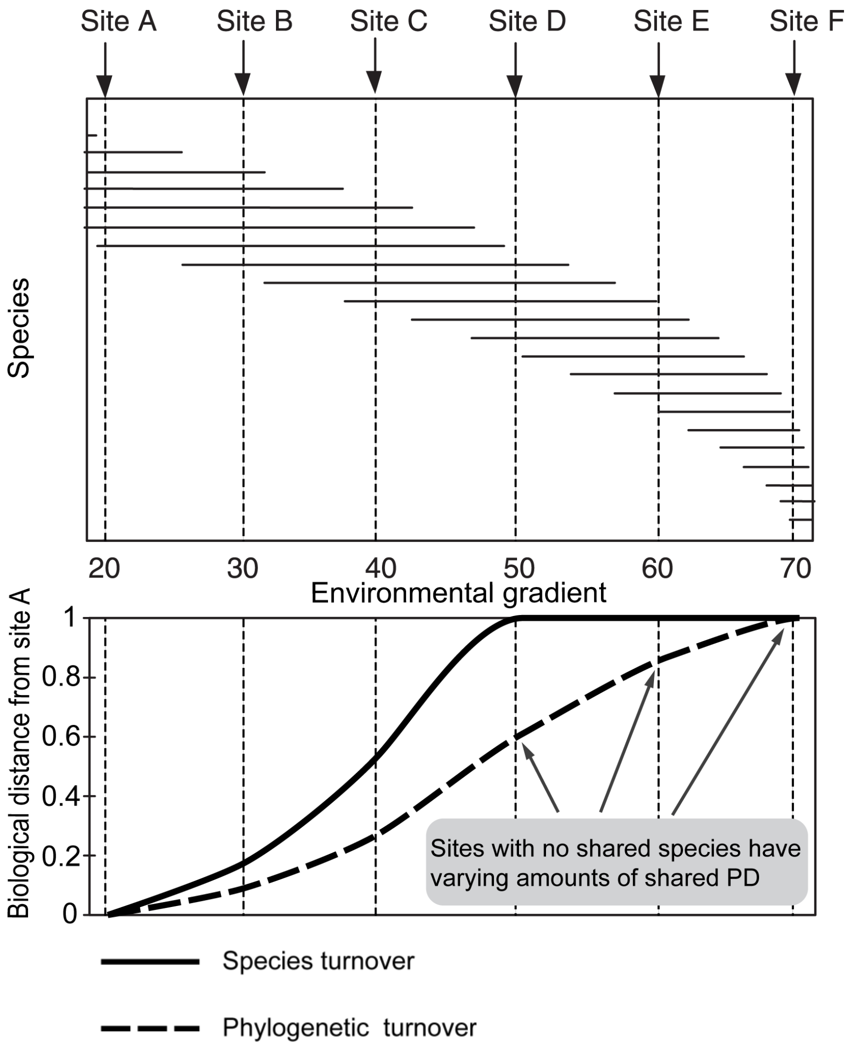
A limitation of species dissimilarity

$$d = 1 - \frac{2A}{2A + B + C}$$

Sites may have closely related species or, have nothing in common, but if no species are shared, dissimilarity is the same.

d = 1

d = 1

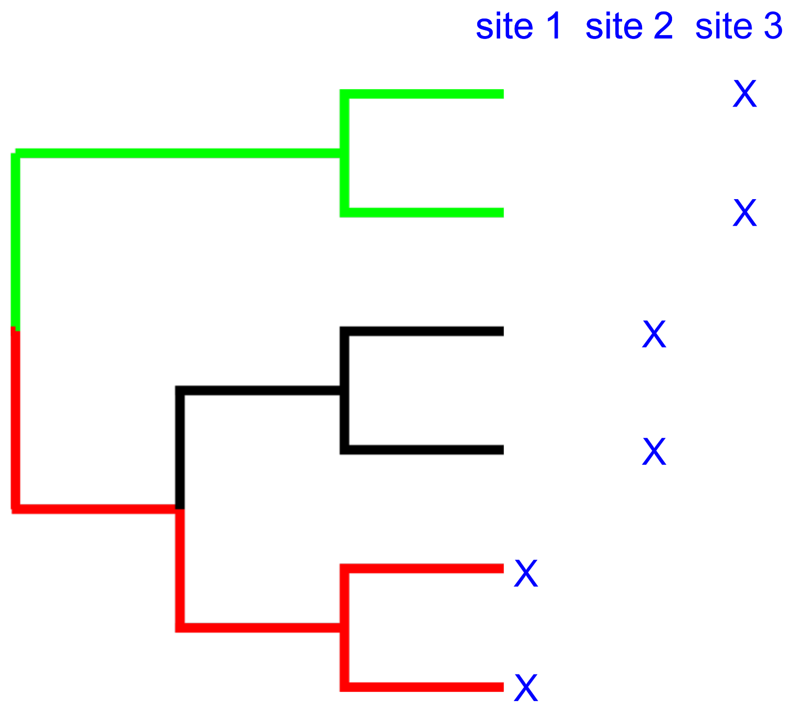


Rosauer *et al.* (2014)

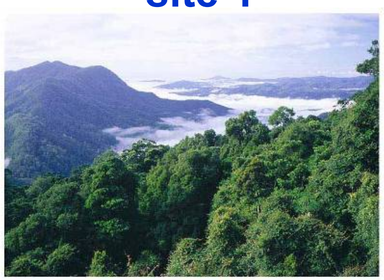
Phylogenetic beta diversity is more informative

$$d = 1 - \frac{2A}{2A + B + C}$$

Sites may have closely related species or, have nothing in common, but if no species are shared, dissimilarity is the same.



site 1



site 2

site 3

A = shared branches = 0

B = only at site 1 = 4

C = only at site 2 = 4

$$\boxed{1 - \frac{2A}{2A + B + C}} = 1.00$$