

Biodiversity & Spatial Analysis

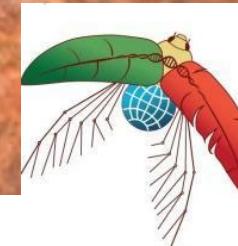
Dan Rosauer

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

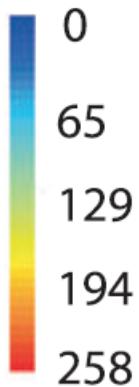
Genomes & Biodiversity Workshop 21 November 2019



Gehyra koira
Photo: Matt Summerville



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 km²

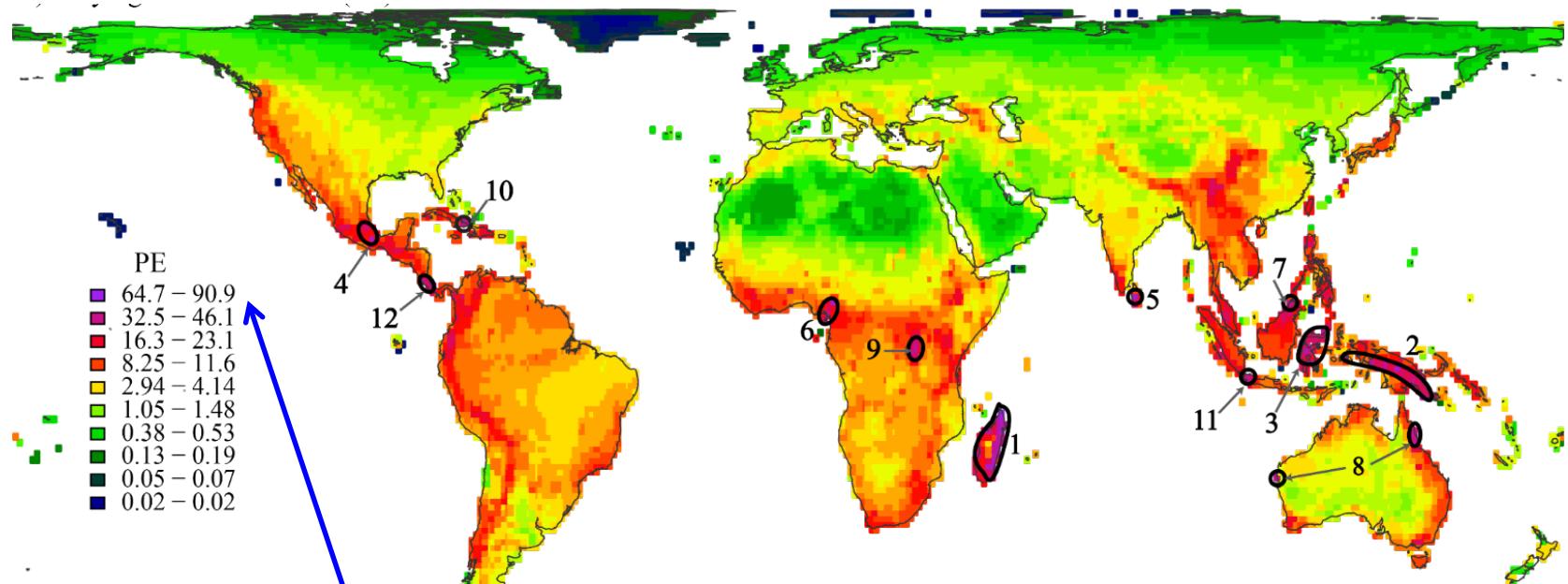


Vulpes vulpes

Extent of occurrence: ~70,000,000 km²



Phylogenetic Endemism of Terrestrial Mammals



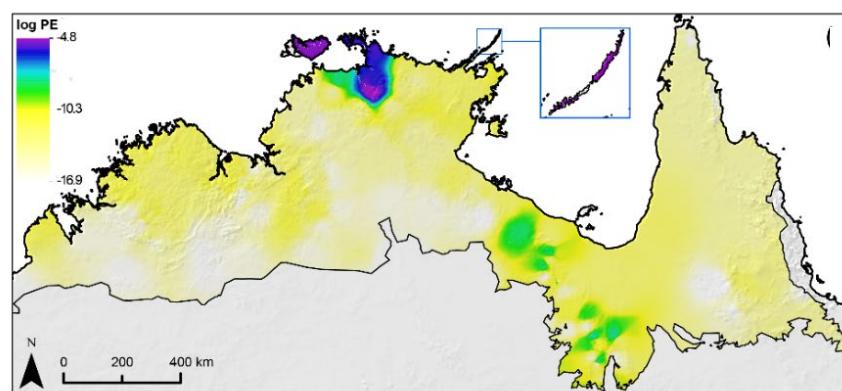
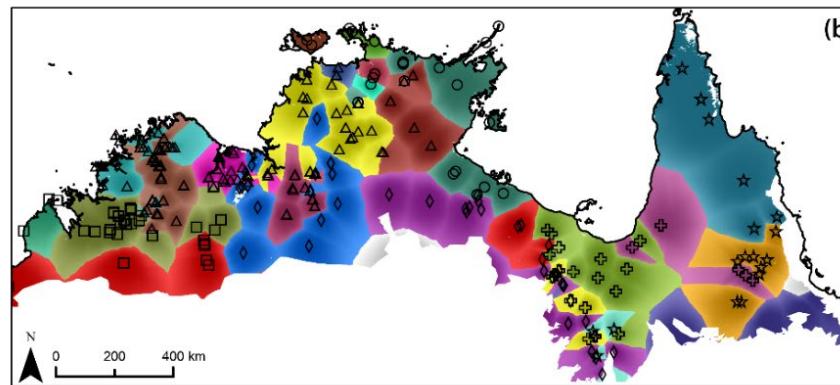
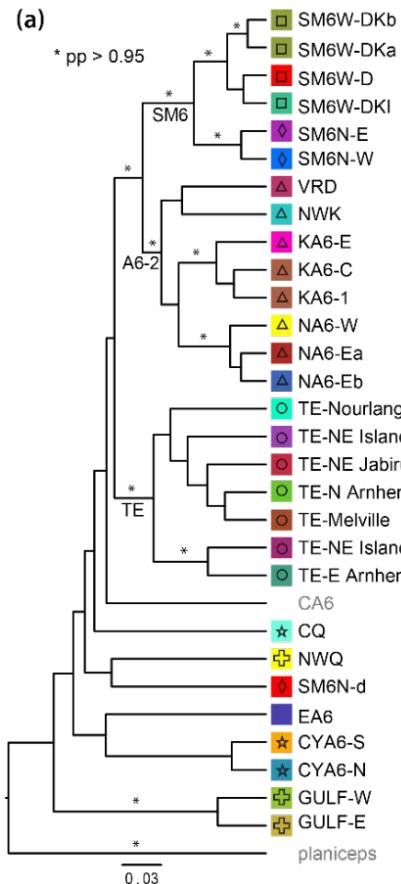
Rosauer & Jetz (2015) Global Ecology & Biogeography

A score of 90 is equivalent to:

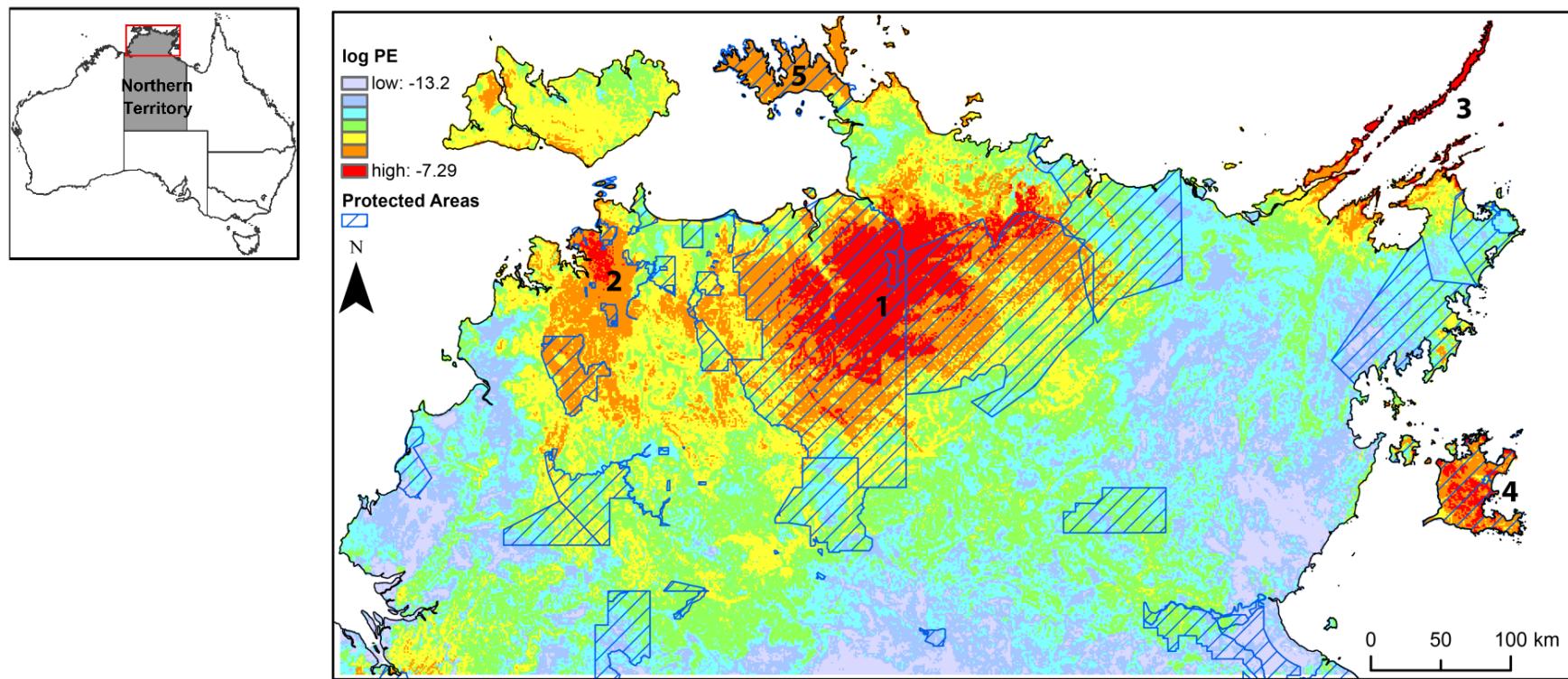
- * 90 million years of evolutionary history restricted a single cell,
- * 180 million years spread across 2 cells...
- ... or any additive combination like this

Phylogeny matters for conservation

It can detect patterns independent of named taxa

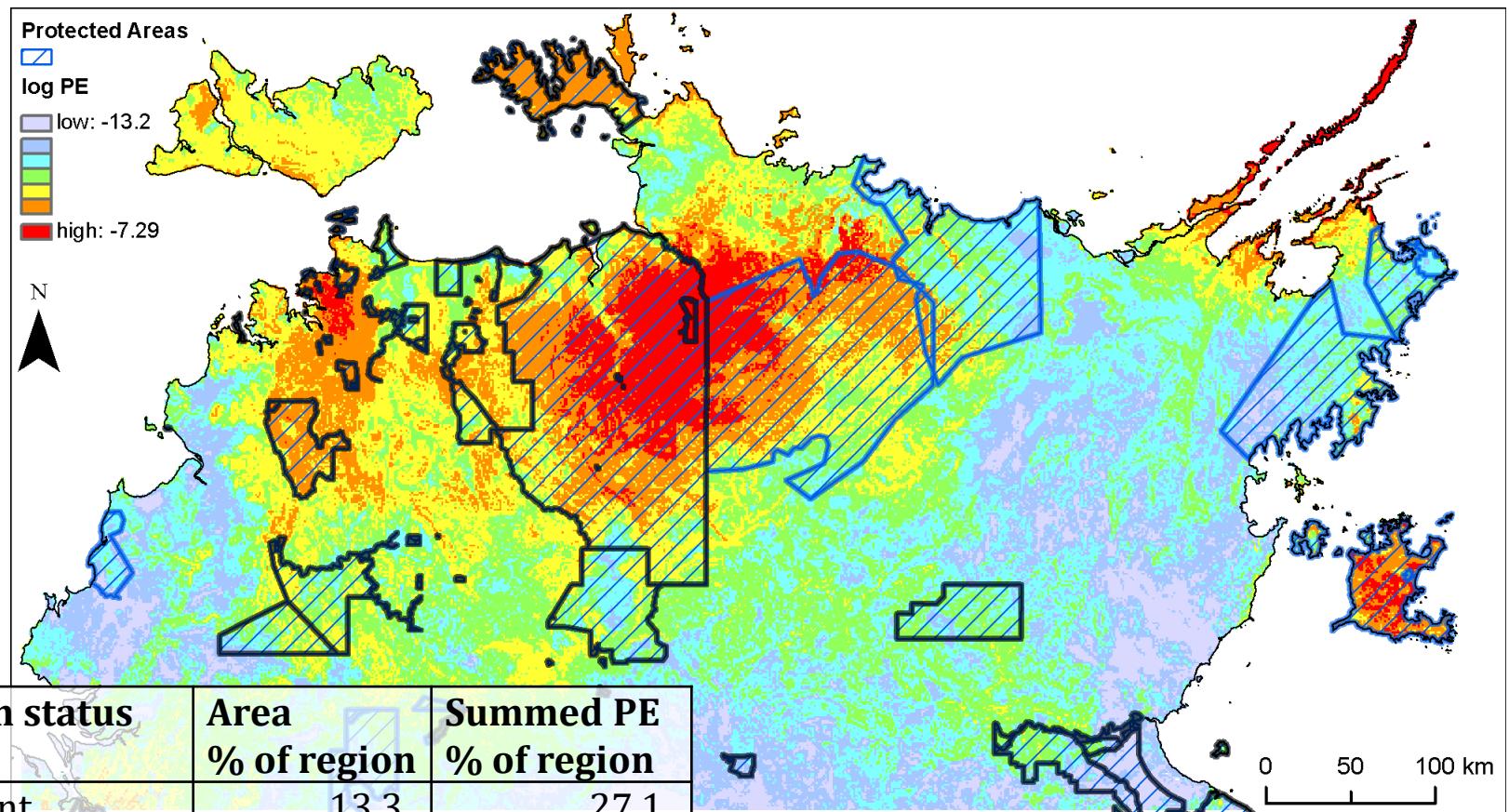


Phyloendemism in the Top End for 10 lizard genera



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 Rahbek¹



Holt *et al.* (2013) Science

Clustering areas which share the same or closely related biota:

phylogenetic beta diversity

Getting practical basics of mapping biodiversity

- Types of species location data - knowing what lives where
- Resolution (spatial units of analysis)
- Metrics

Species Richness	Phylogenetic Diversity
Species Endemism	Phylogenetic Endemism
Species beta diversity	Phylogenetic beta diversity

- Exercises

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	<i>Acrobates pygmaeus</i>
Common name	Feathertail glider
Locality	Trawalla forest reserve
Latitude	-37.45
Longitude	143.42



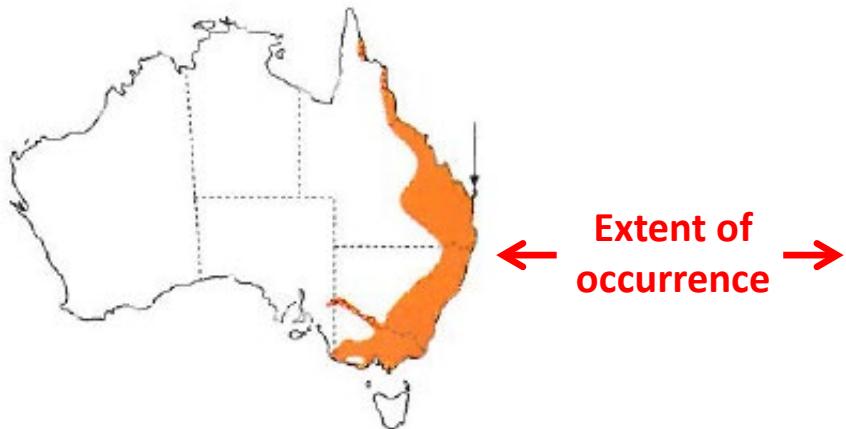
Atlas of Living Australia
ala.org.au



- 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



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



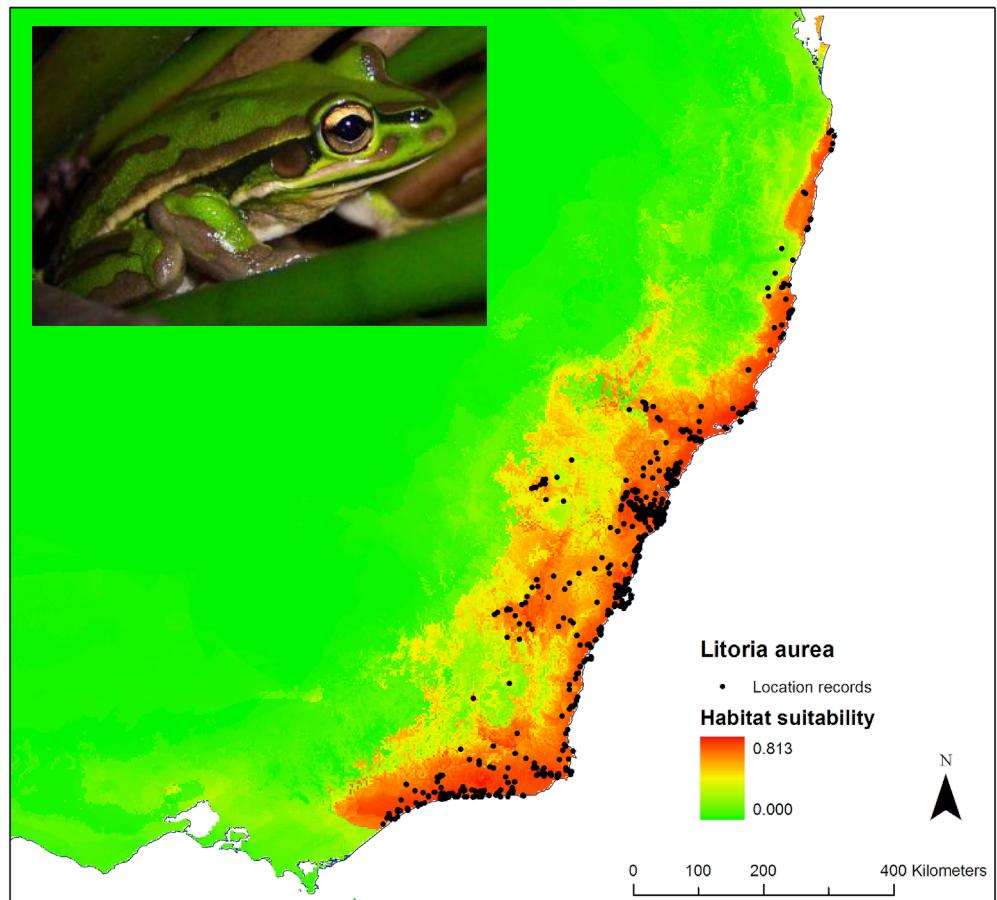
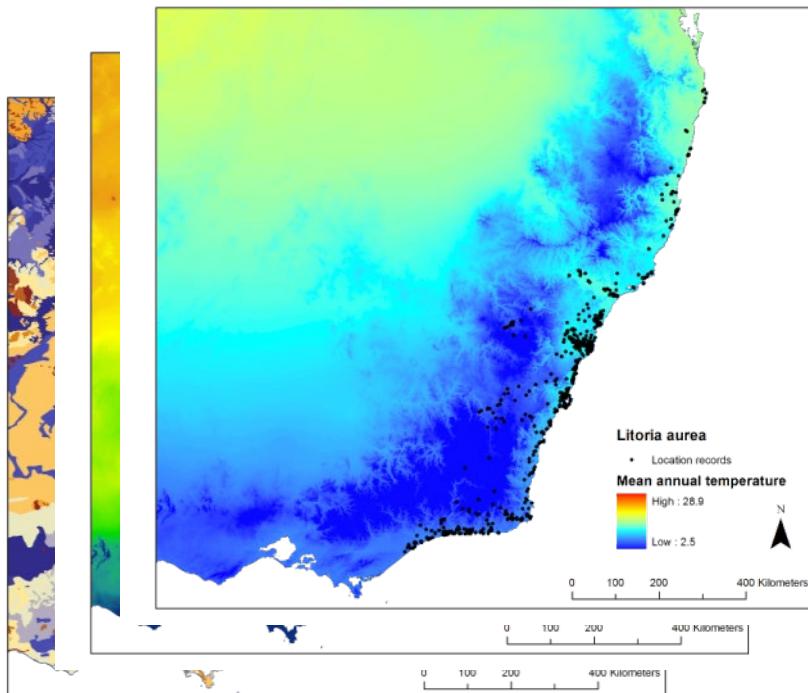
IUCN Global Mammal Assessment



- 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

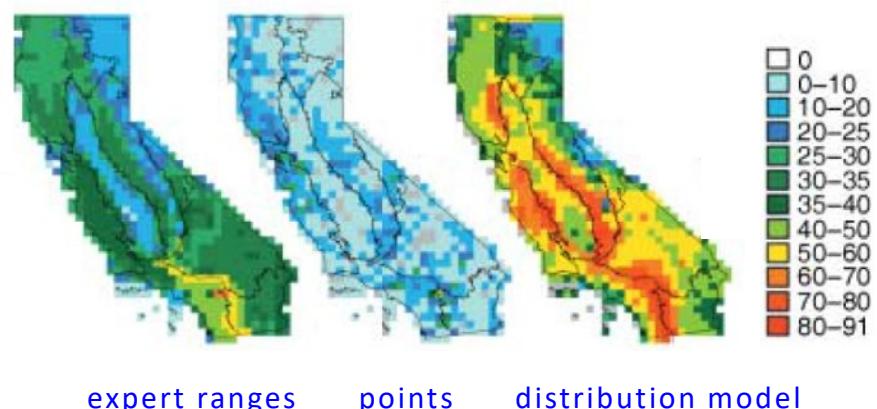
Data Type	Richness	Resolution
Survey point records	<i>lowest</i>	The richness difference between points and expert ranges is greater for fine scale analyses
Expert ranges	<i>intermediate</i>	
Modelled ranges <i>highest</i>		Herbert & Jetz (2007) PNAS

Global Ecology and Biogeography, (Global Ecol. Biogeogr.) (2006) 15, 578–587

RESEARCH
PAPER

A comparison of methods for mapping species ranges and species richness

Catherine H. Graham^{1*} and Robert J. Hijmans²



Graham & Hijmans (2006) Global Ecology & Biogeography

Measuring endemism

What defines endemism?

- **Absolute endemism** - fixed boundary
- **Relative endemism** - continuous function

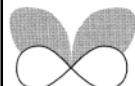


Weighted endemism (WE)

$WE = \frac{1}{\text{range}}$ (for each species)

total of endemism scores for species recorded
in the cell

Journal of Biogeography, 28, 183–198



Endemism in the Australian flora

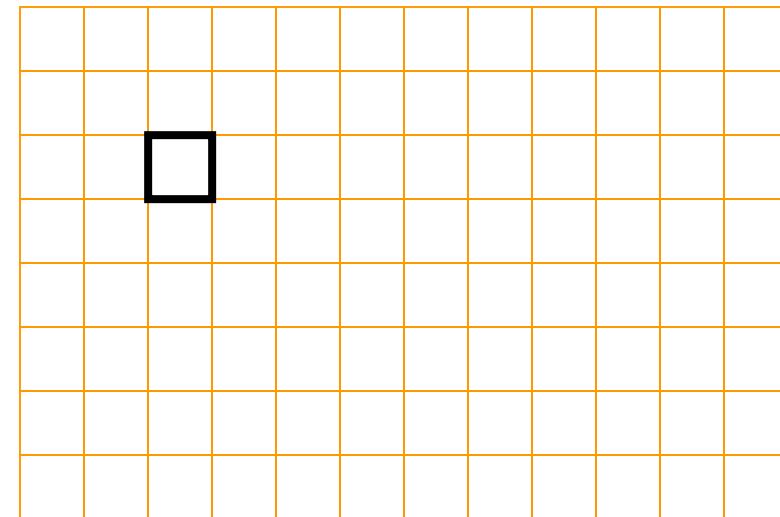
M. D. Crisp¹*, S. Laffan², H. P. Linder³ and A. Monro¹ ¹Division of Botany and Zoology,

²Department of Geography, Australian National University, Canberra ACT 0200, Australia
and ³Department 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
<i>Callionima denticulata</i>	
<i>Dirphia avia</i>	
<i>Sphinx merops</i>	

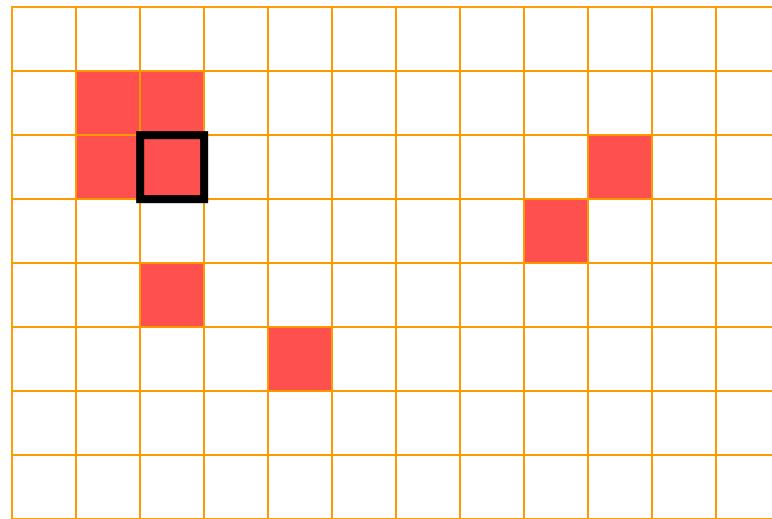


How weighted endemism is calculated?



Species	Range
<i>Callionima denticulata</i>	8
<i>Dirphia avia</i>	
<i>Sphinx merops</i>	

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

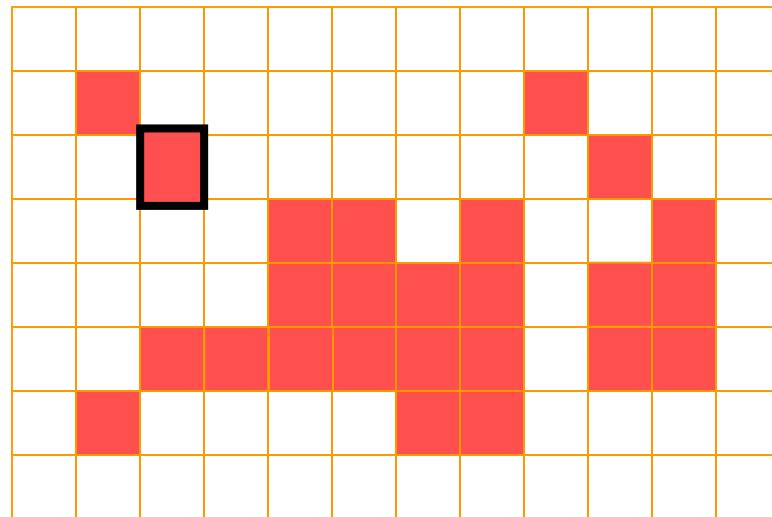


How weighted endemism is calculated?



Species	Range
<i>Callionima denticulata</i>	8
<i>Dirphia avia</i>	25
<i>Sphinx merops</i>	

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

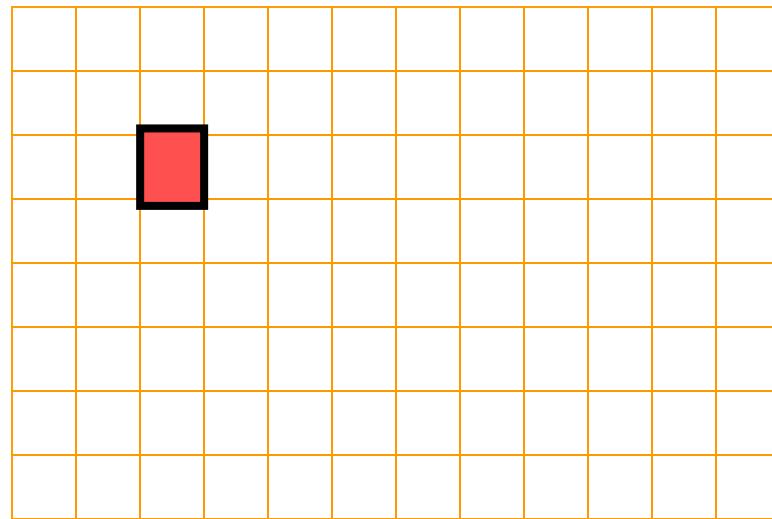


How weighted endemism is calculated?

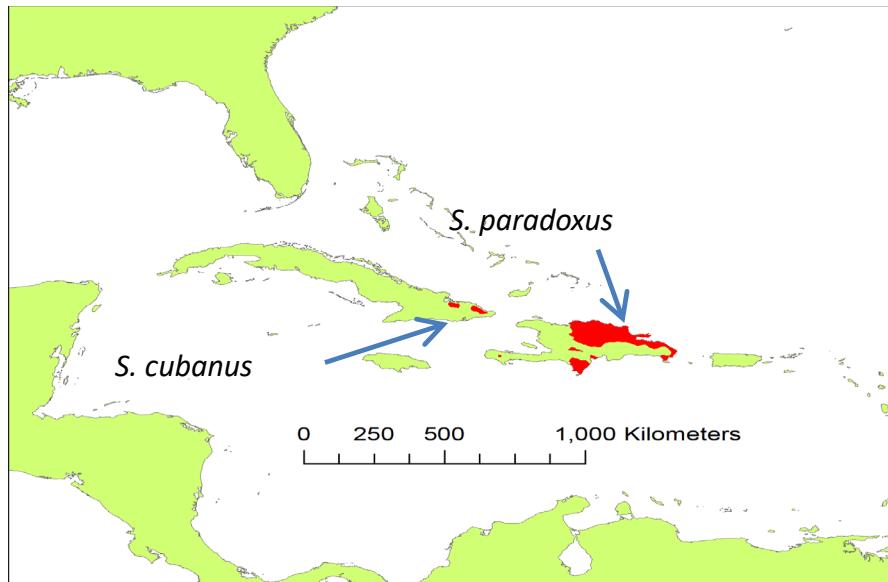


Species	Range
<i>Callionima denticulata</i>	8
<i>Dirphia avia</i>	25
<i>Sphinx merops</i>	1

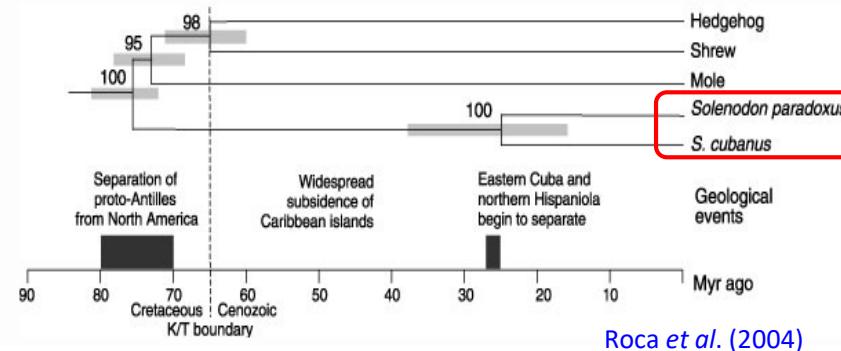
$$\frac{1}{8} + \frac{1}{25} + \frac{1}{1} = 1.16$$



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



Solenodon paradoxus

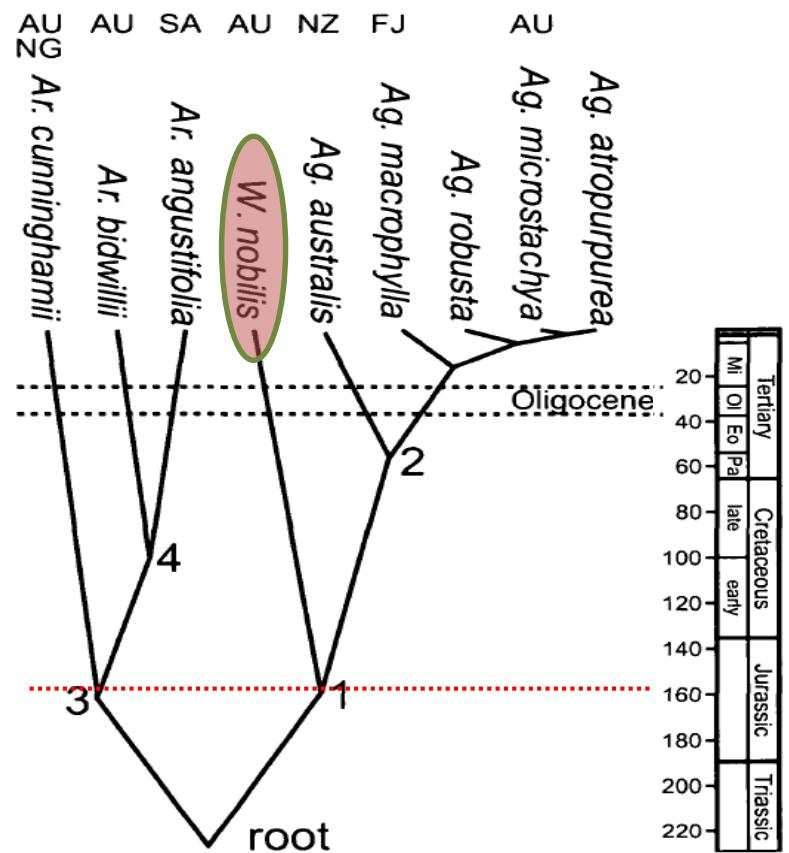
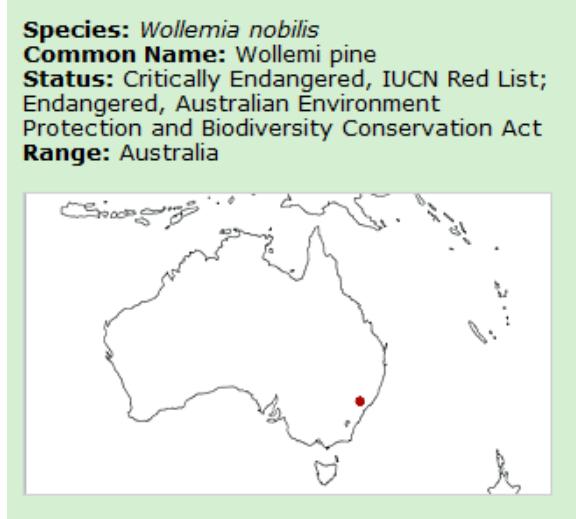


Roca et al. (2004)

Miguel A. Lundestoy T.

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

The Wollemi Pine



Knapp et al. 2007 Sys. Biol.

Improving conservation decisions

NATURE · VOL 348 · 6 DECEMBER 1990

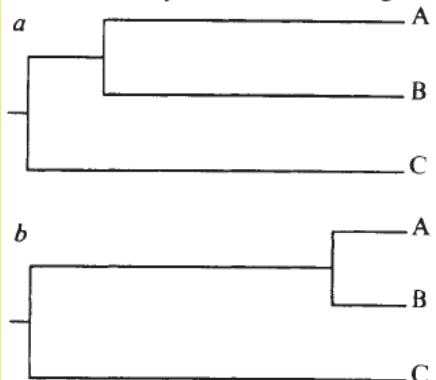
STEPHEN F. ALTSCHUL

DAVID J. LIPMAN

Equal animals

SIR—May in News and Views¹ 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 others² 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

Economy as destiny

M. May

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

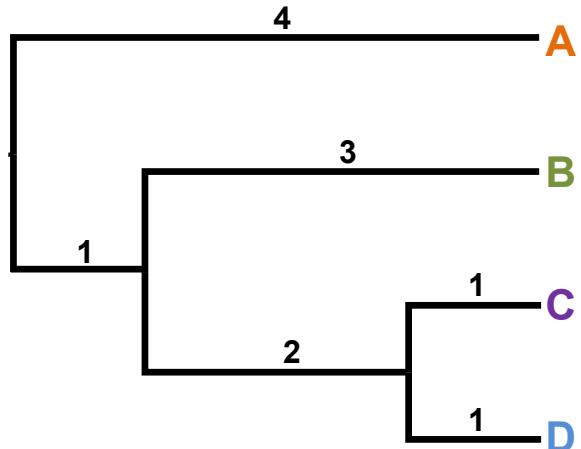
THE NOAH'S ARK PROBLEM

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.

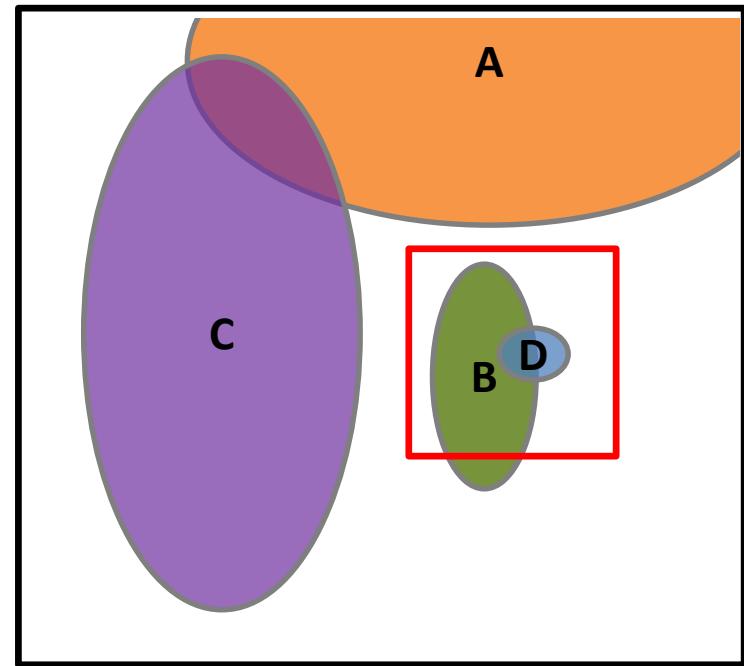
Calculating phylogenetic diversity and endemism



Phylogenetic Diversity (PD)

Faith (1992)

$$PD = 1 + 3 + 2 + 1 = 7$$

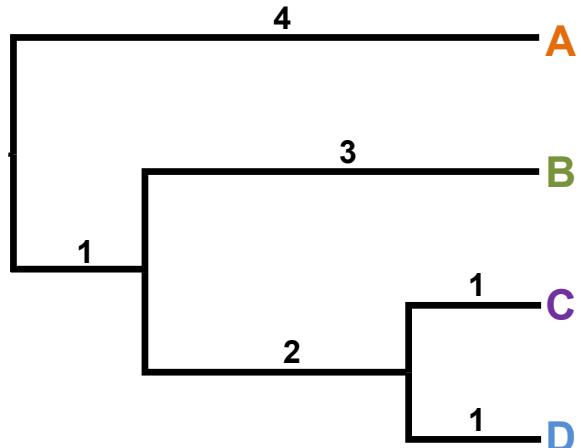


Advantages of PD

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

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

Calculating phylogenetic diversity and endemism



Phylogenetic Diversity (PD)

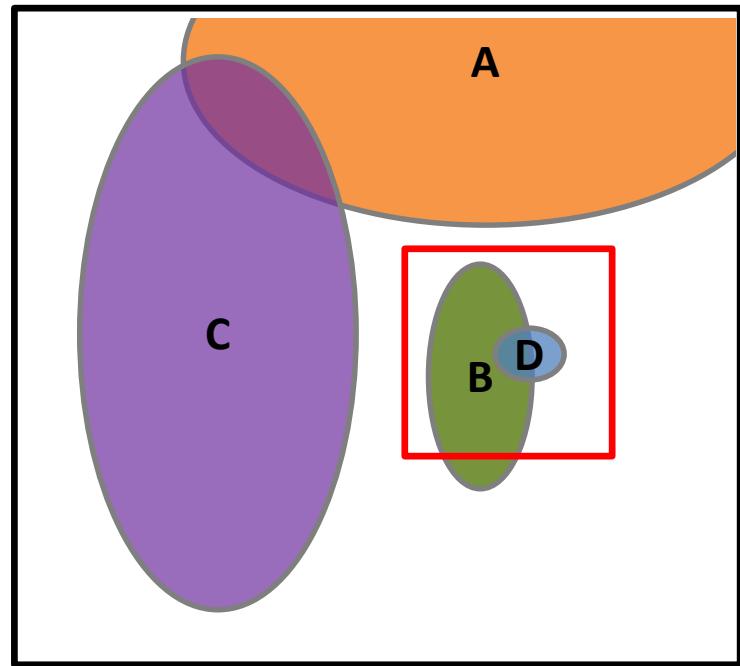
Faith (1992)

$$PD = 1 + 3 + 2 + 1 = 7$$

Phylogenetic Endemism (PE)

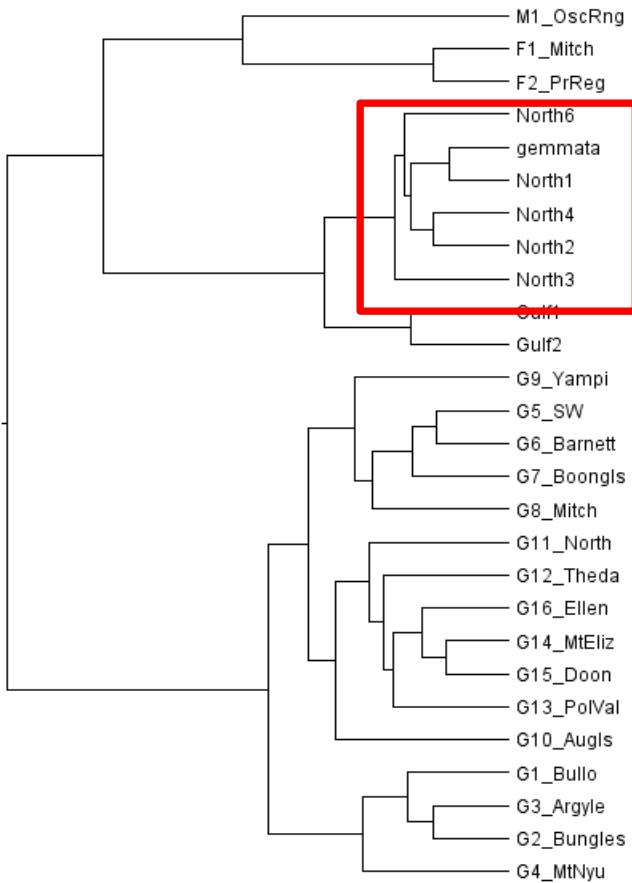
Rosauer et al (2009)

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

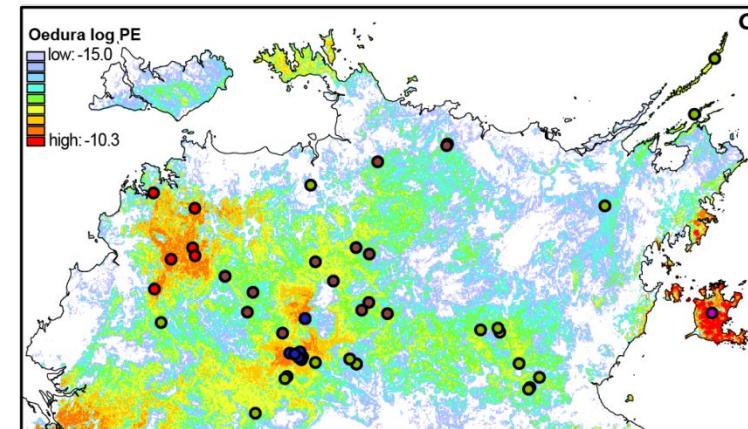
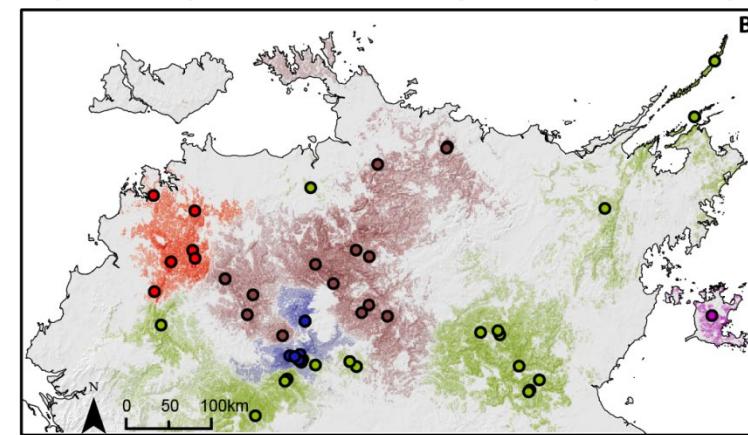
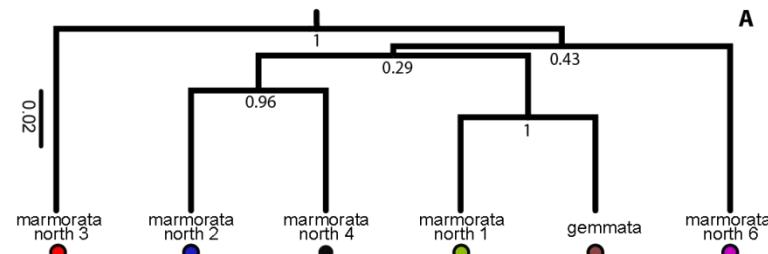


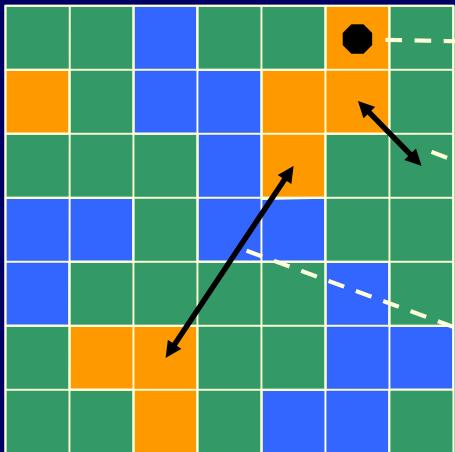
$$PE = \sum_{\{c \in C\}} \frac{L_c}{R_c}$$

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



Oedura





-- alpha diversity (local richness)

beta diversity

gamma diversity

'dissimilarity'

'turnover'

'complementarity'



Compositional dissimilarity between locations:

Sørensen distance:

between composition of 2 sites

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



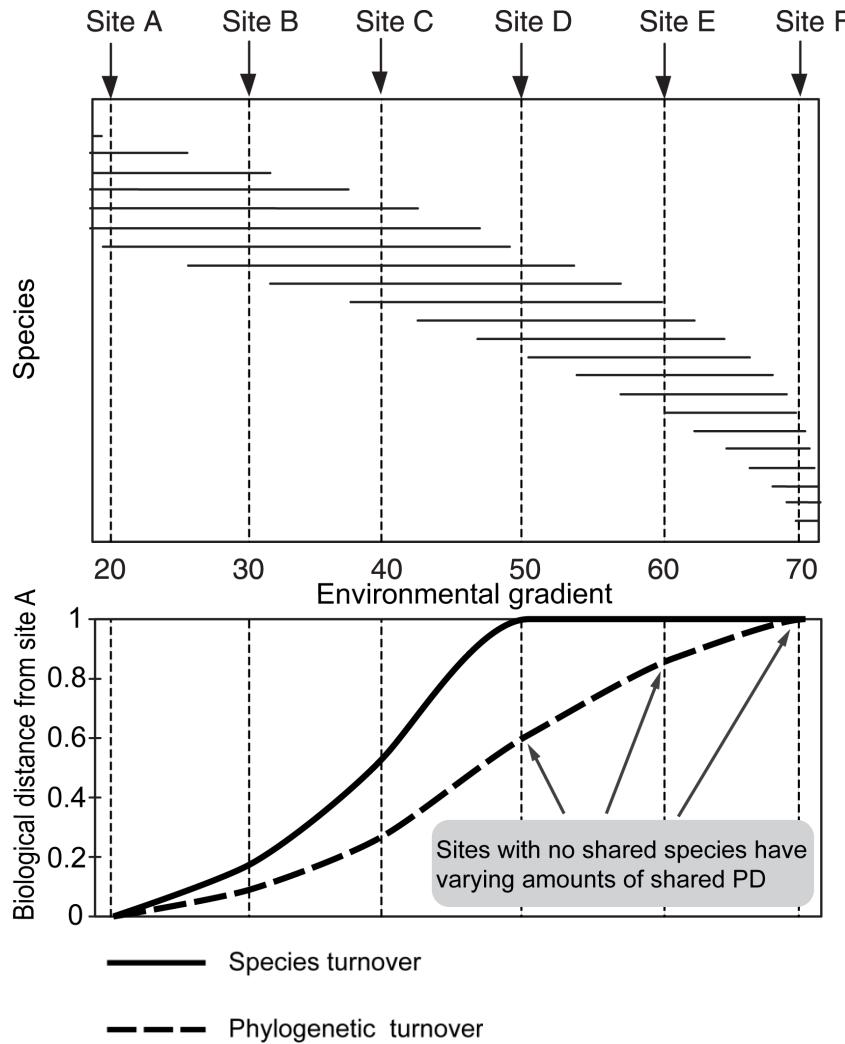
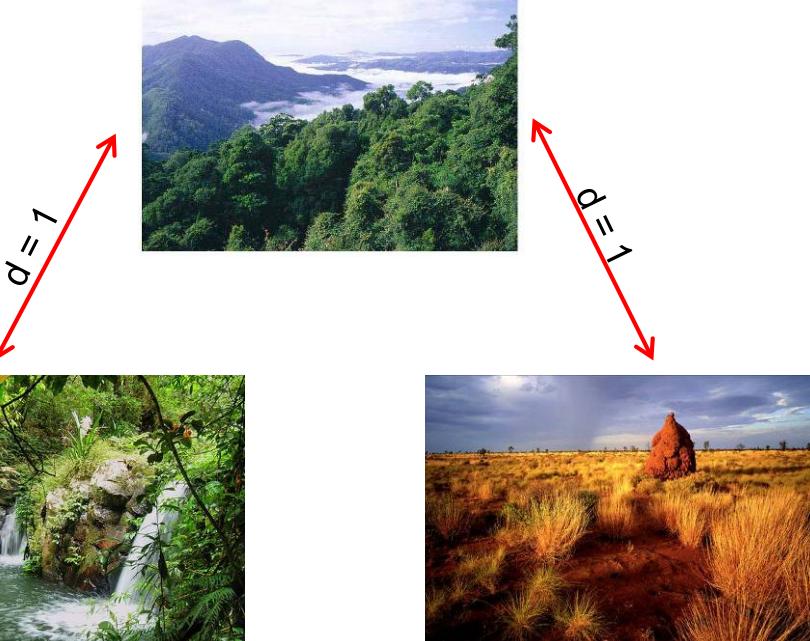
0 => complete overlap - identical composition

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.

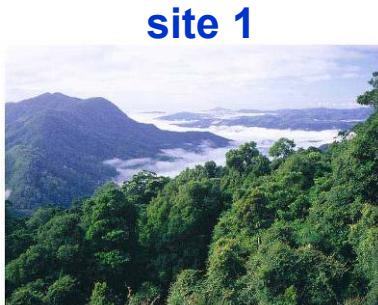


Rosauer *et al.* (2014)

Phylogenetic beta diversity is more informative

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

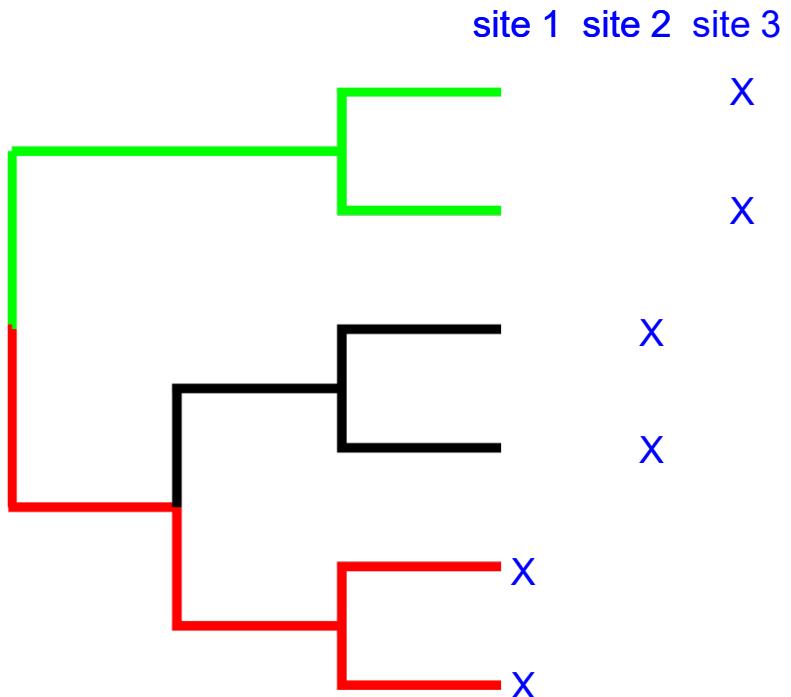
Sites may have closely related species or, have nothing in common, but if no species are shared, dissimilarity is the same.



site 2



site 3



A = shared branches = 0

B = only at site 1 = 4

C = only at site 2 = 4

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