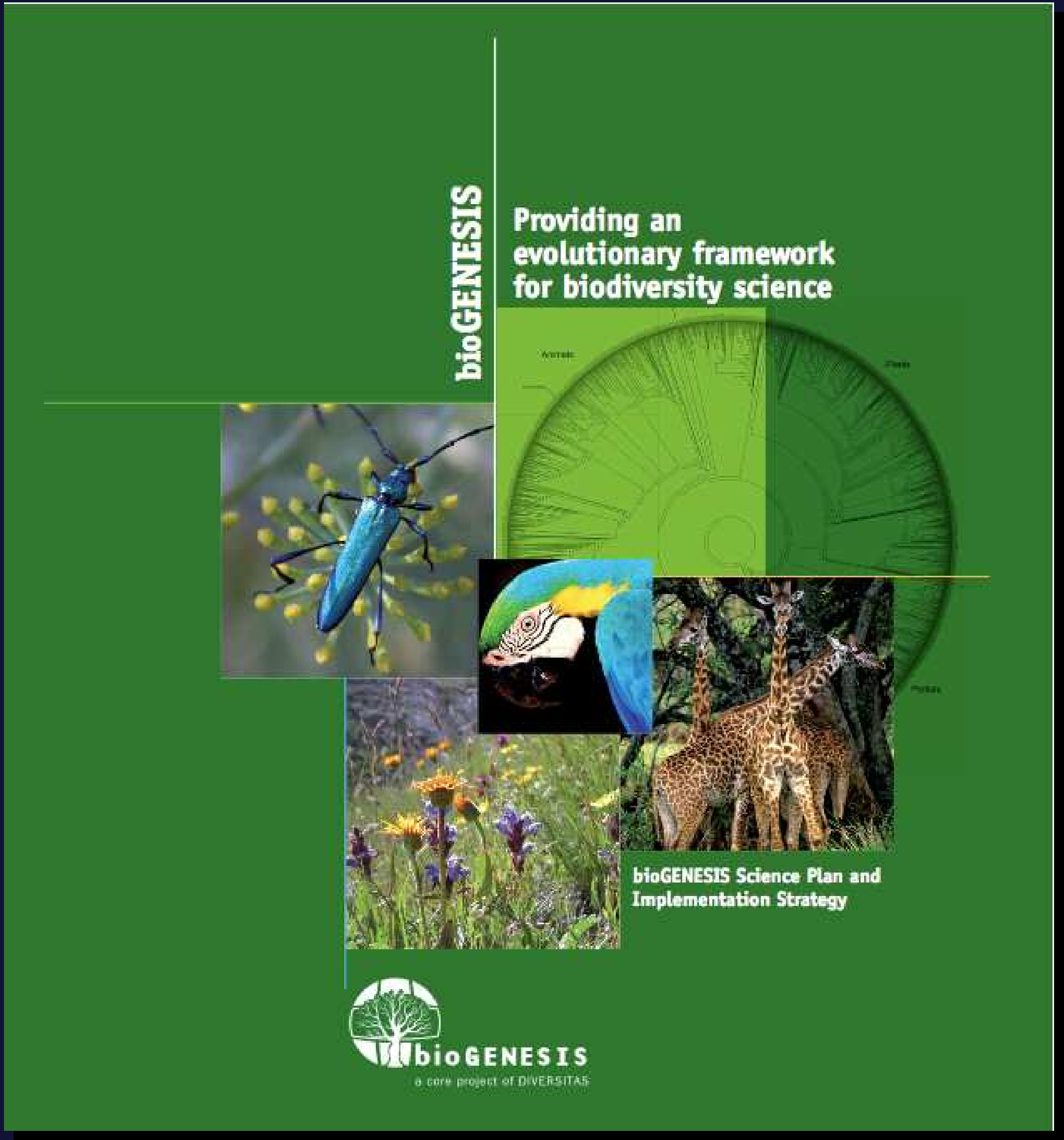
How research on phylogenetic diversity and evolution can contribute to biodiversity conservation and ecology

Daniel P. Faith
The Australian Museum

EPBRS meeting
Czech Republic,
Pruhonice, Czech Republic,
20-22 May 2009



DIVERSITAS
an international programme of biodiversity science

BioGENESIS

Integrative taxonomy,

Integrative systematics,

Integrative biodiversity science

I – DIVERSITAS

II - The bioGENESIS Science Plan

FOCUS 1. New strategies and tools for documenting biodiversity

- TASK 1.1 Discovering the unknown
- TASK 1.2 Capturing biodiversity information
- TASK 1.3 Developing phyloinformatics

FOCUS 2. The causes and consequences of diversification

- TASK 2.1 Evolutionary change in diversity
- TASK 2.2 The evolutionary history of biotic assembly
- TASK 2.3 The evolution of functional traits
- TASK 2.4 Rapid evolution and eco-evolutionary dynamics

FOCUS 3. Evolution, biodiversity, and human well-being

- TASK 3.1 Evolutionary ecosystem management
- TASK 3.2 Evolution and climatic change
- TASK 3.3 Combating disease
- TASK 3.4 Evolutionary conservation

III - Implementation Strategy

The e-conference suggested recommendations include some relating to phylogenetics

Promote the integration of phylogenetics and niche modelling to determine threats to biodiversity from climate change

Determine links between phylogenetic diversity losses and scenarios for species conservation and climate change

Phylogeny also links to these comments made in the e-conference –

Simon Tillier argued: need to make undescribed taxic diversity readily usable for ecological analysis and decision making

(“I do not believe that for sound decision-making we need to name each and every living species, whereas we do need to know that they are there”)

Integrative approaches incorporating evolution and phylogenetics can help make decisions about overall biodiversity,

even while much of biodiversity remains unknown and undescribed

a three-pronged approach to build a robust, "mobilized" taxonomy/systematics:

1. Ramping up efforts to discover and name species

2. At the same time, finding better ways to do best-possible assessments and decision-making with the taxonomic and other data that is available at any given time

   You *can* protect what you don't know...

3. Creating new pragmatic gap analyses which prioritize taxa and places, while balancing the long-term and short-term services of taxonomy

The 2010 biodiversity target calls for a significant reduction in the rate of loss of biodiversity

The 2010 biodiversity target may be achieved by effectively *measuring* biodiversity – and then protecting it through systematic conservation planning

land-use planning and other decision making that more efficiently balances conservation with other needs of society results in reduced biodiversity losses, compared to business-as-usual

Actions for the 2010 biodiversity target in Europe – how does research contribute to halting biodiversity loss? Report of an e-conference. (eds. Young, J., Ahlbeg, M., Niemelä, N., Parr, T., Pauleit, S. and Watt, A.D.),

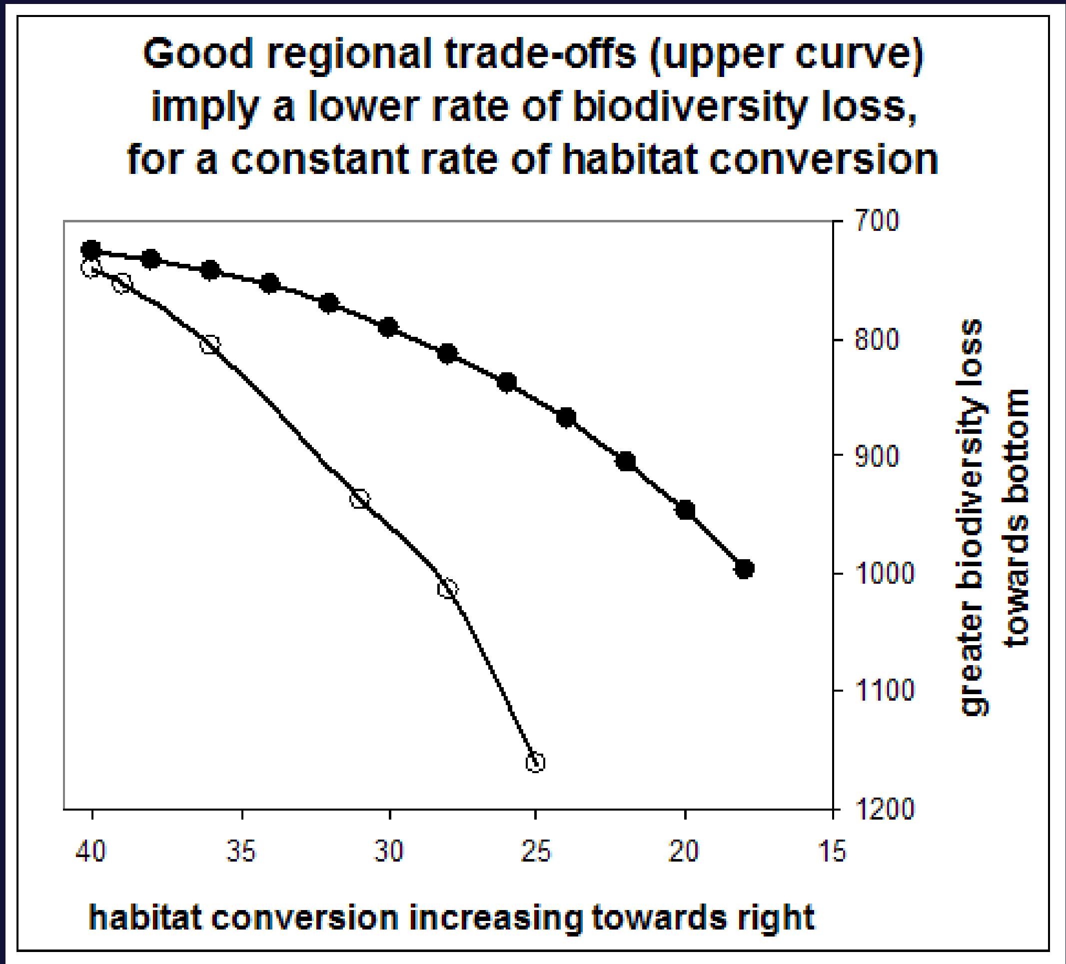
"2010 indicators for overall biodiversity"

"Taxonomic research and 2010"

"Research needs and challenges for the systematic conservation planning approach to the 2010 biodiversity target"

"The need for interdisciplinary research"

Adopting systematic conservation planning can mean a region shifts to a better trajectory



Faith, DP & Ferrier S (2005)
Good news and bad news for the 2010 biodiversity target. *Science* Online

Phylogenetic diversity - PD

PD of a set of taxa = length of spanning path of the set on the phylogeny

(if we connect up those taxa on the tree, how much of the tree has been traveled over)

- PD is about feature diversity and option values
- PD can provide different information compared to conventional species assessments
- Impacts may be clumped; need to combine with risk analyses
- A PD calculus extends many species-level indices and points to ecological and conservation applications

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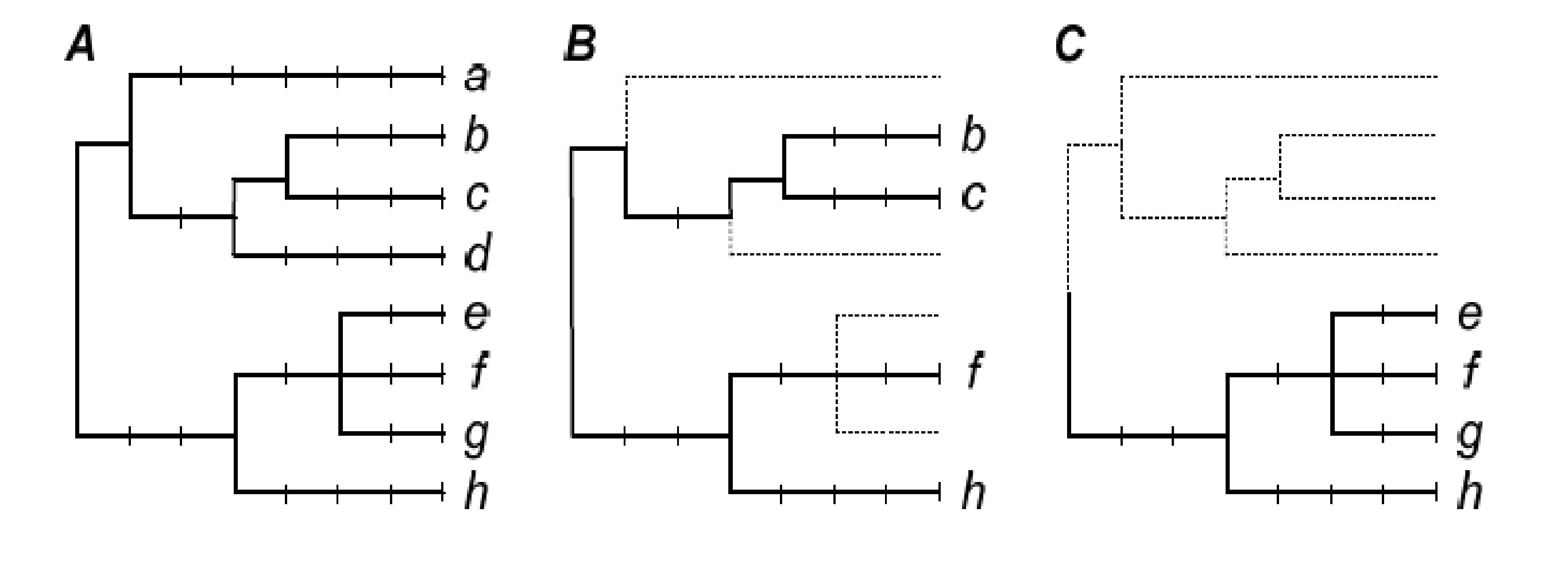
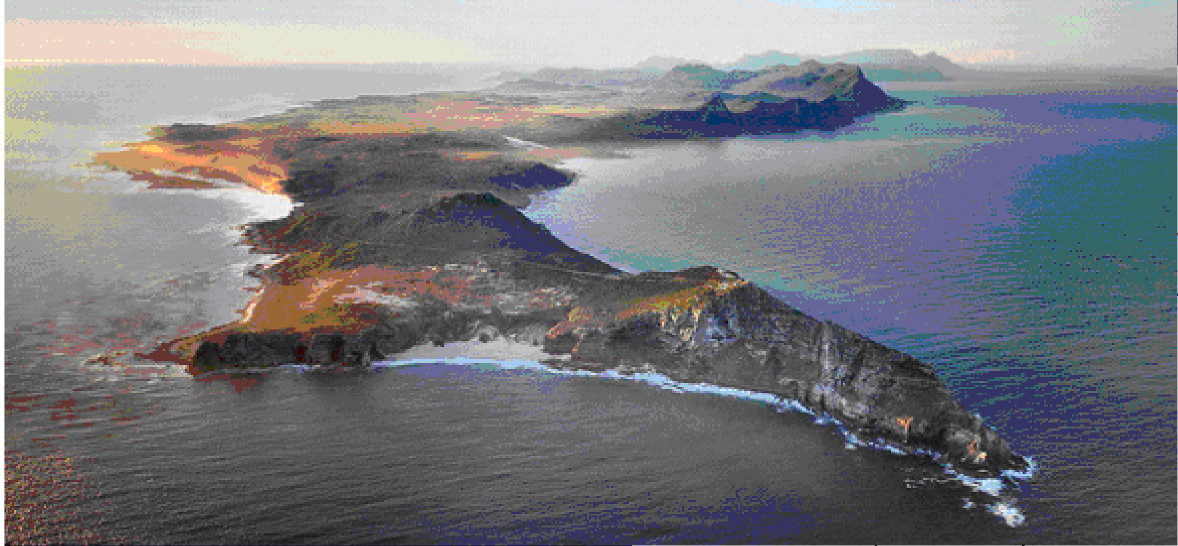
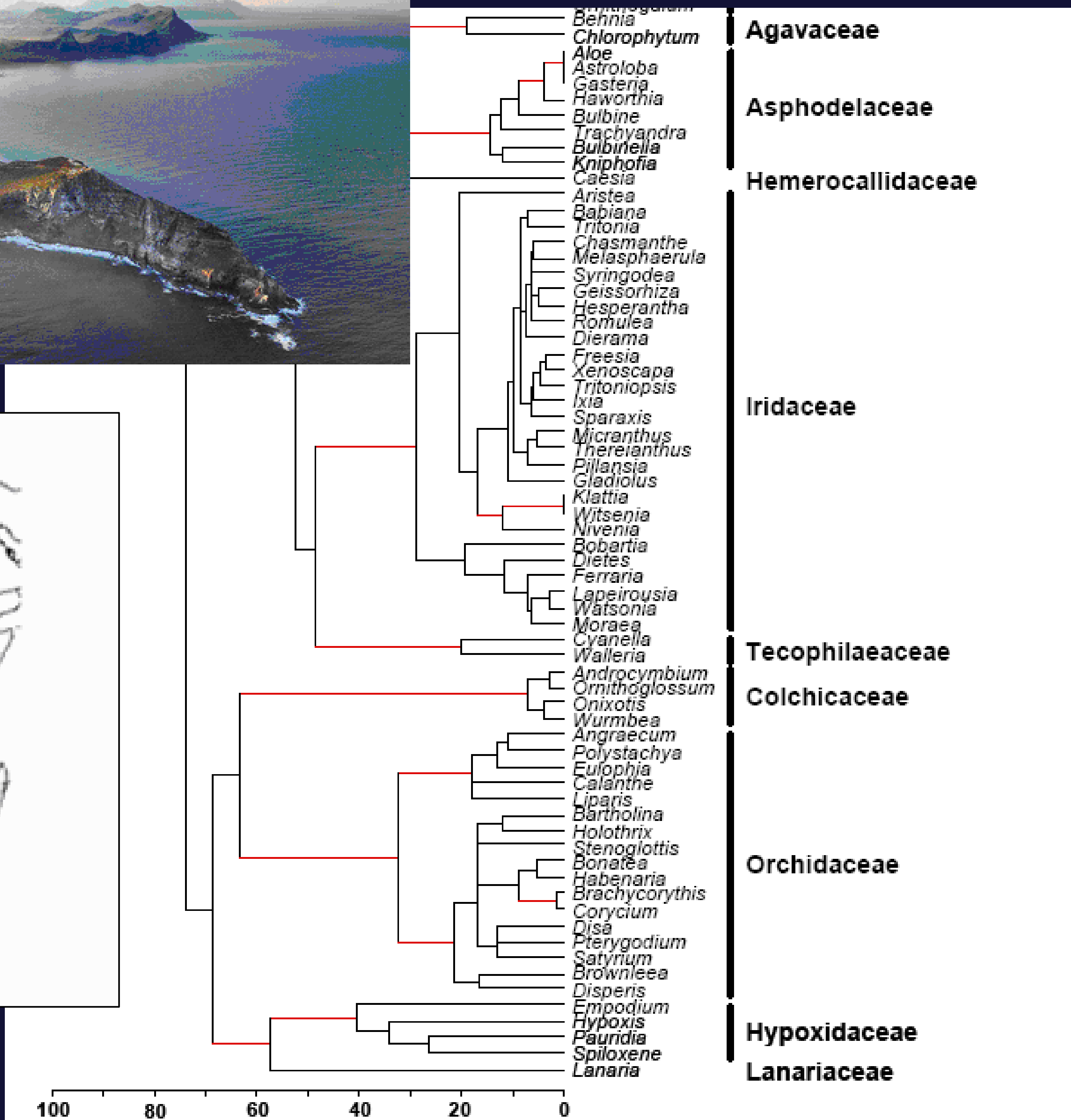
PD – phylogenetic diversity Faith 1992



Jan Schipper, et al. (2008) The Status of the World's Land and Marine Mammals: Diversity, Threat, and Knowledge *Science*

"Phylogenetic diversity is a measure that takes account of phylogenetic relationships (and hence, evolutionary history) between taxa ... It is arguably a more relevant currency of diversity..."

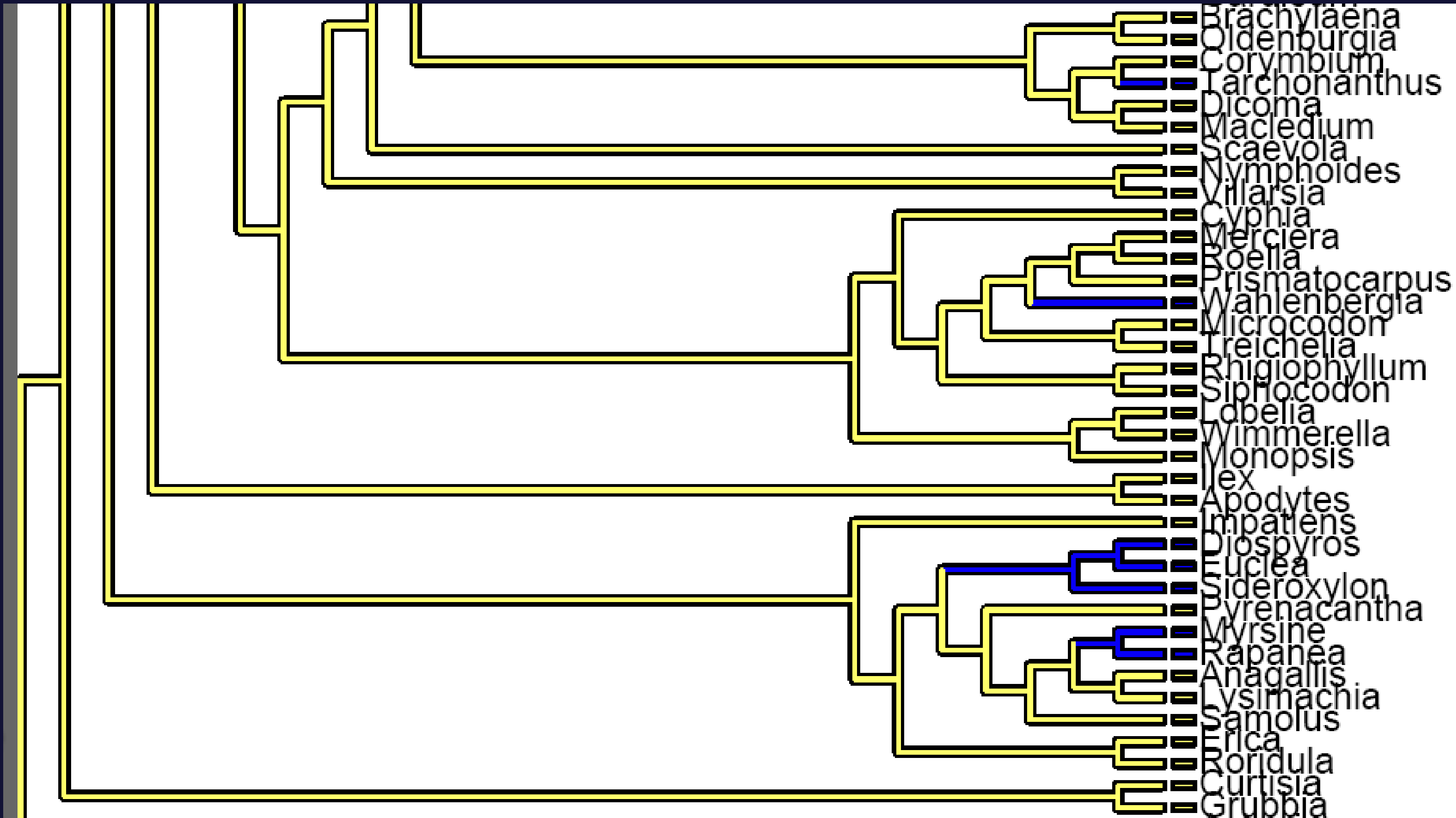




Forest et al. (2007)
Nature

blue = genera in the Cape having species of medicinal or economic importance

(as recorded in Survey of Economic Plants for Arid and Semi-Arid Lands)



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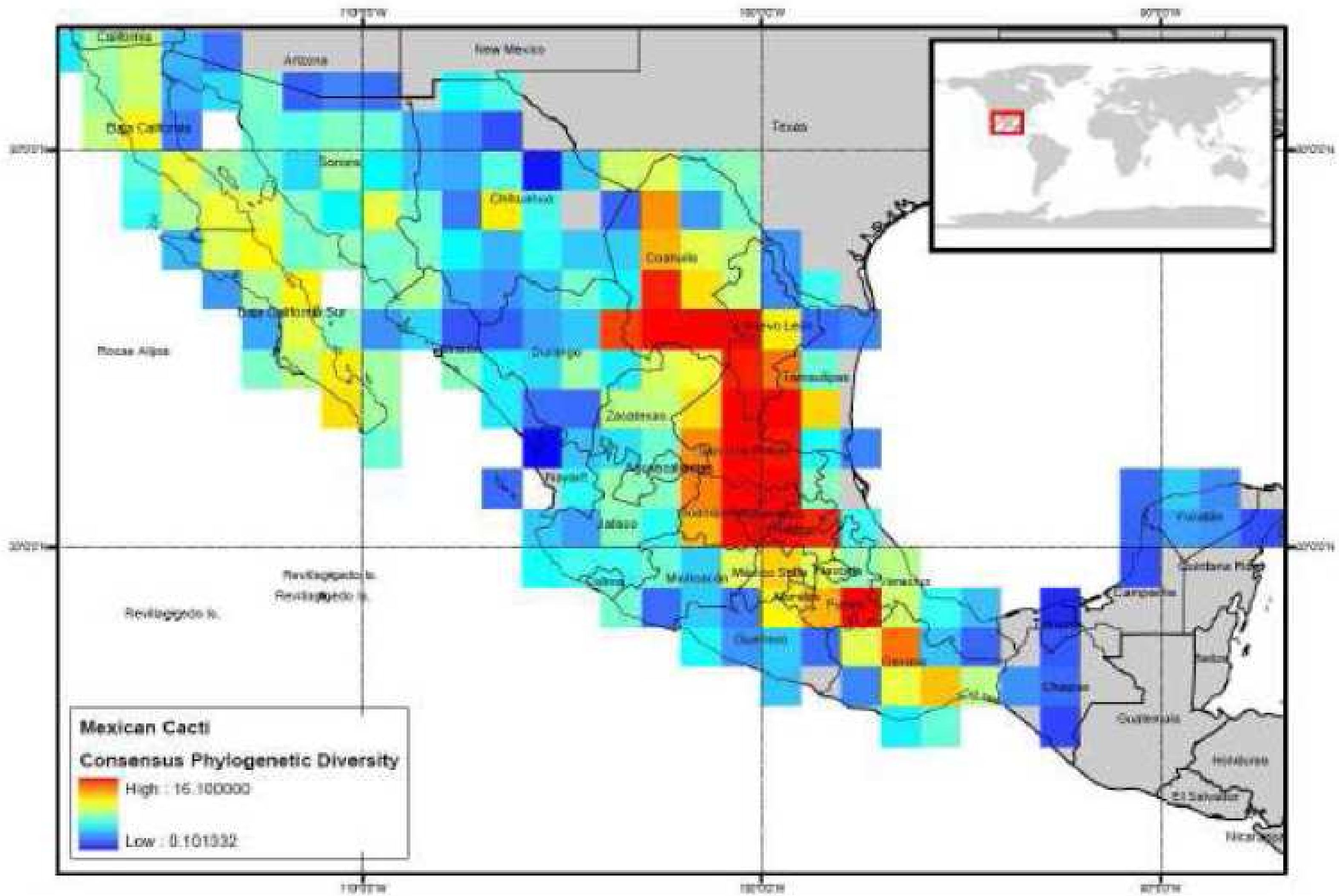
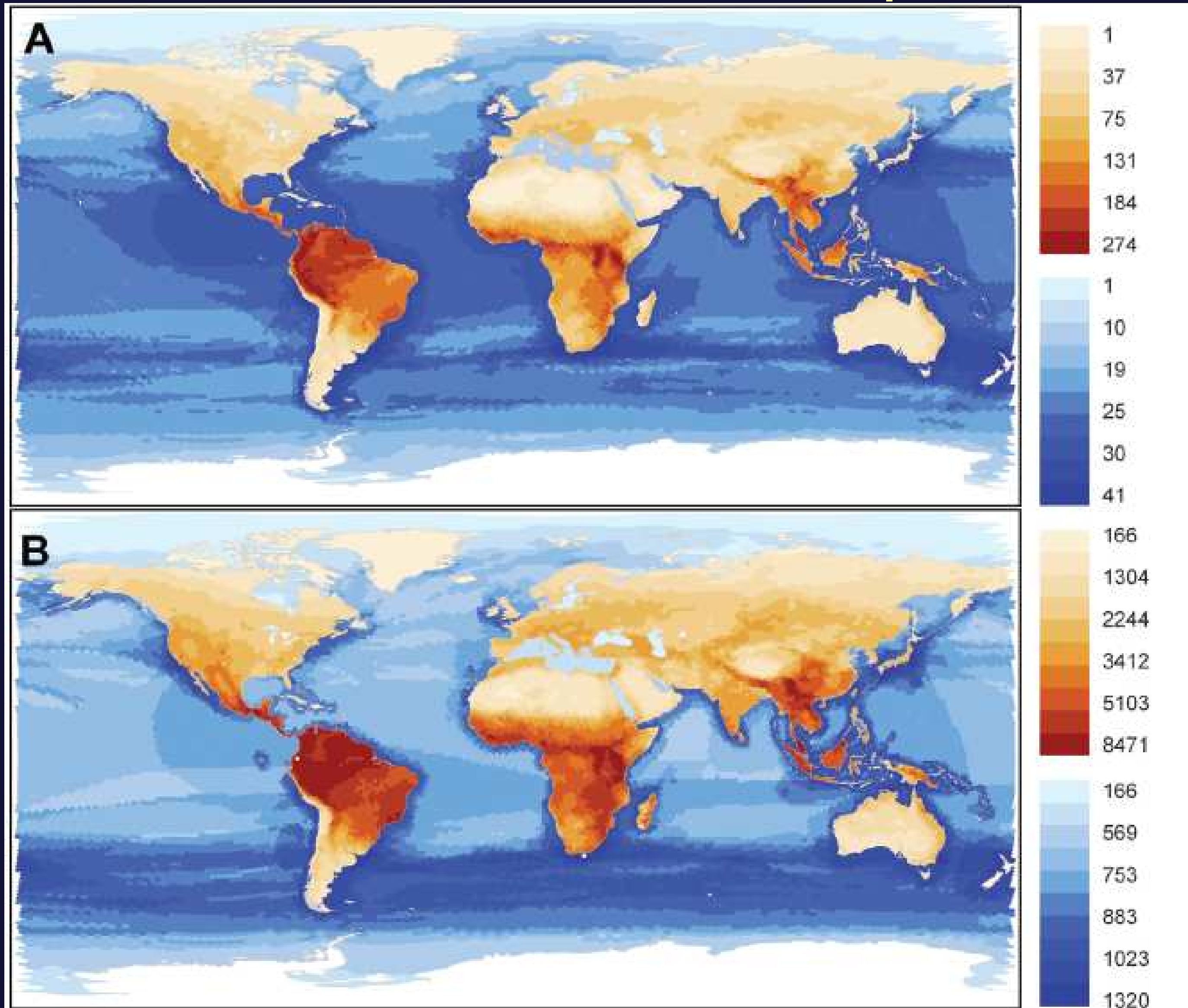
Yesson -

Figure 1. Phylogenetic diversity of Mexican Cacti (from Yesson, Bárcenas & Hawkins, In Prep). The peak of diversity is in the central scrublands rather than the large desert regions of Sonora and Chihuahua, which may impact conservation efforts (http://www.uaq.mx/ccma/)



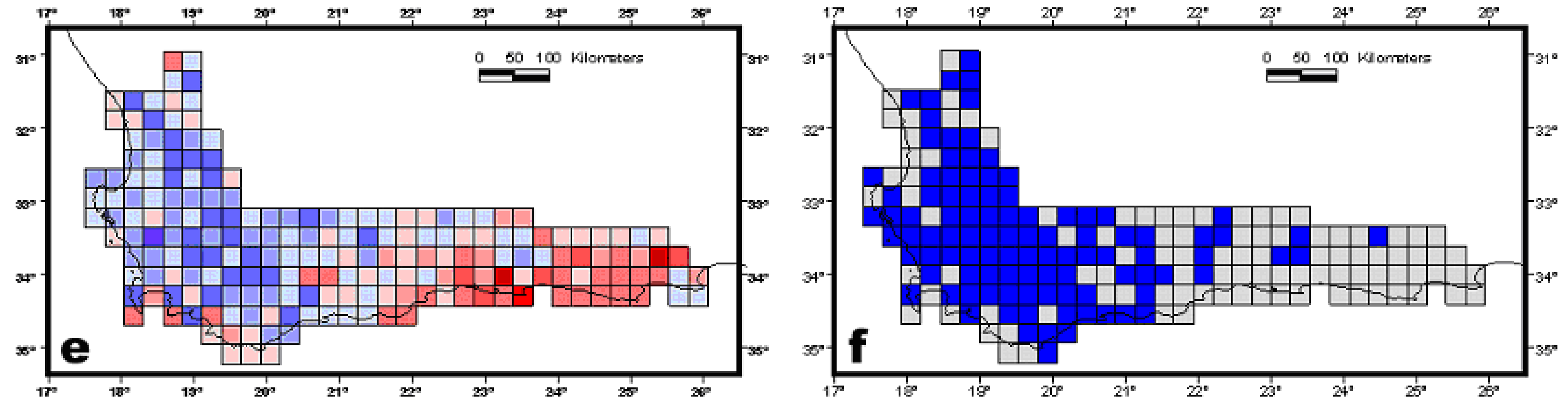
Total PD looks the same as total species diversity

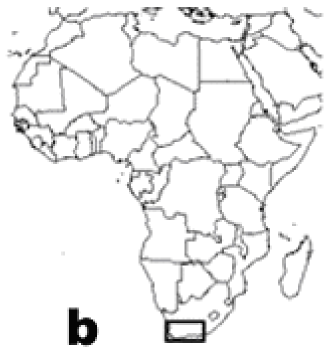


Jan Schipper, et al. *Science* 322, 225 (2008)

but see Forest et al *Nature* (2007) – marginal gains/losses matter

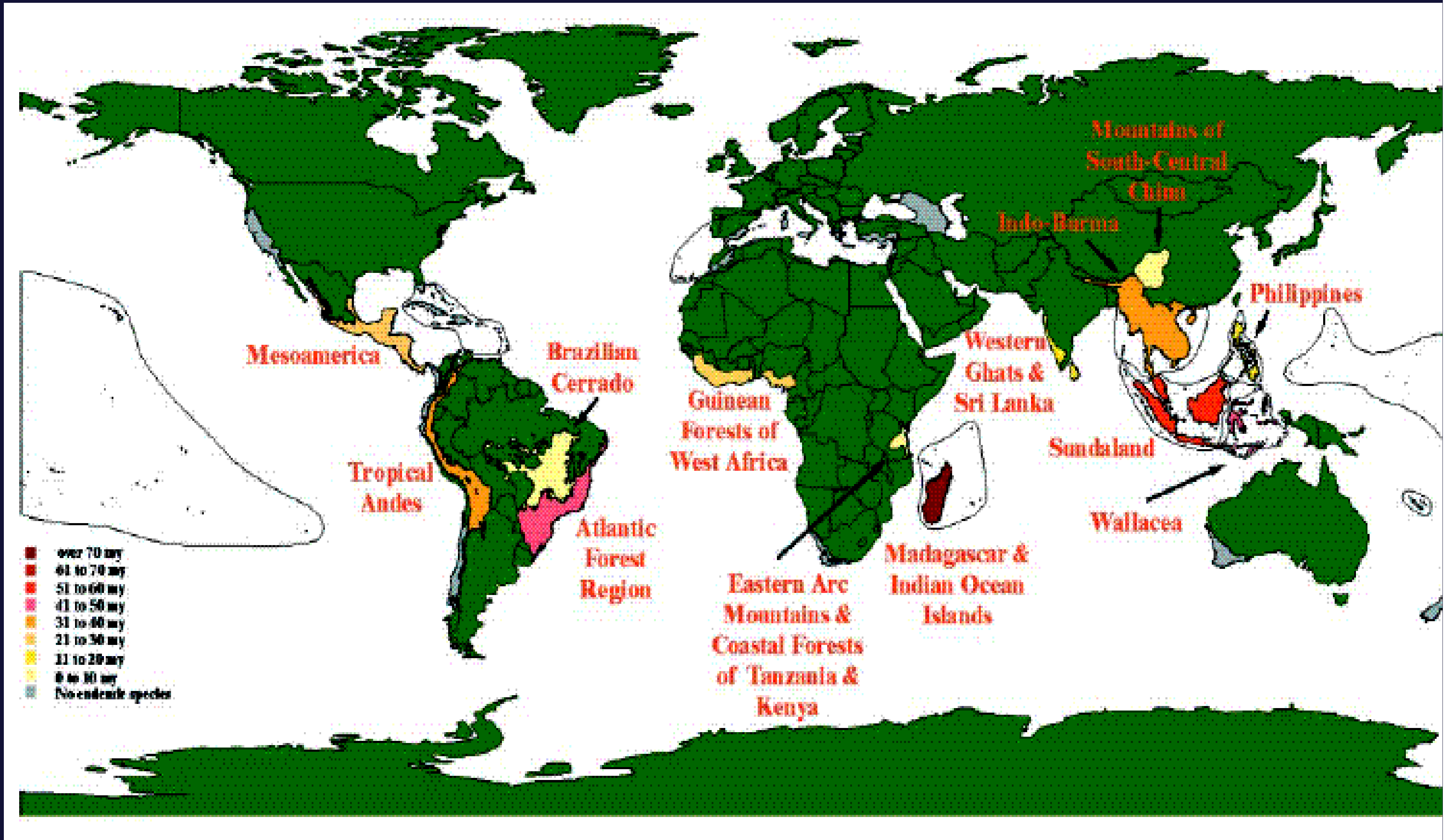
PD and the Cape hotspot: species counting highlights the western portion but PD highlights the eastern portion





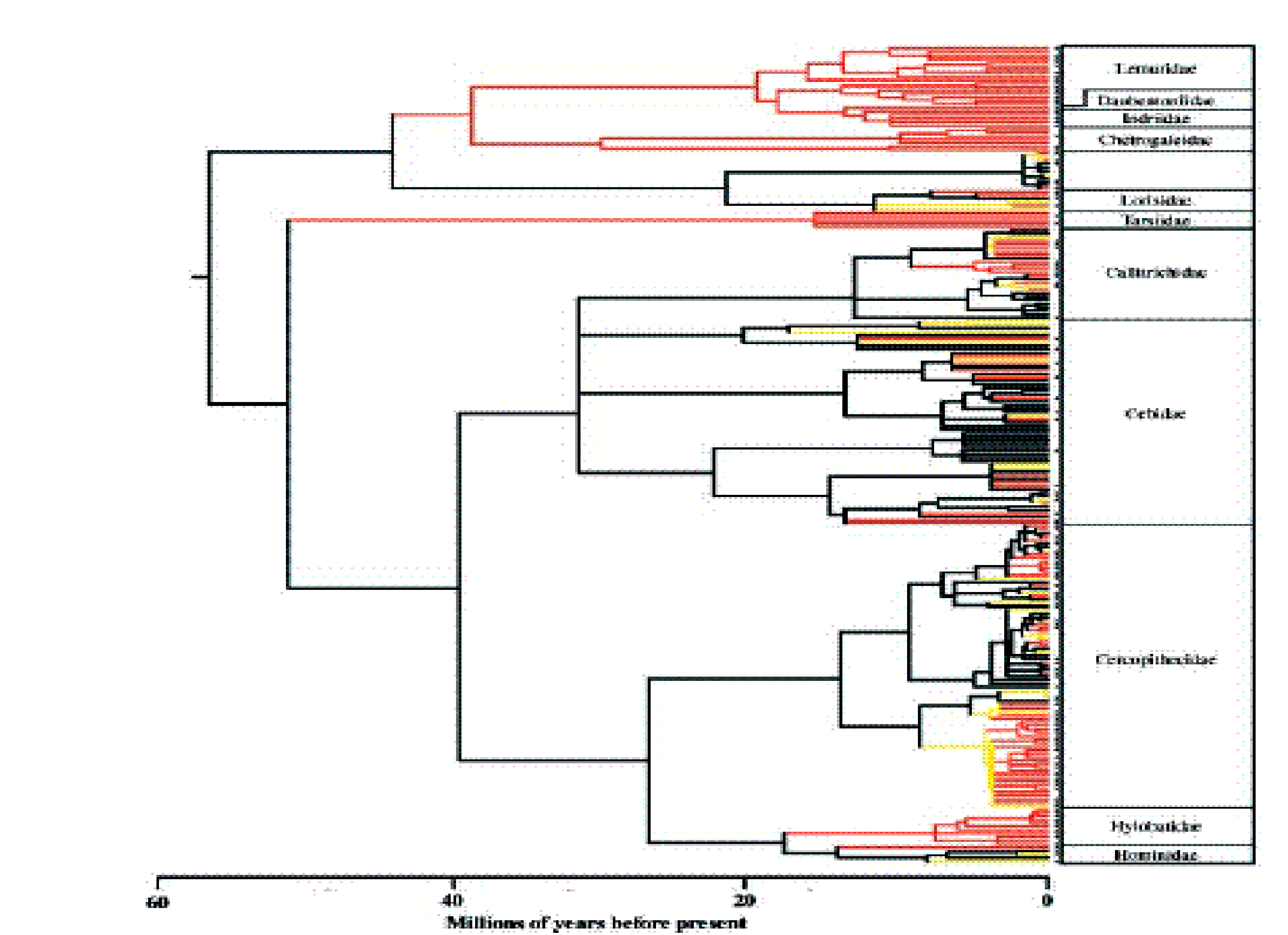
Forest et al
Nature 2007

Original 25 Global Hotspots



Sechrest et al

Hotspots and phylogenetic diversity
red branches restricted to hotspot regions



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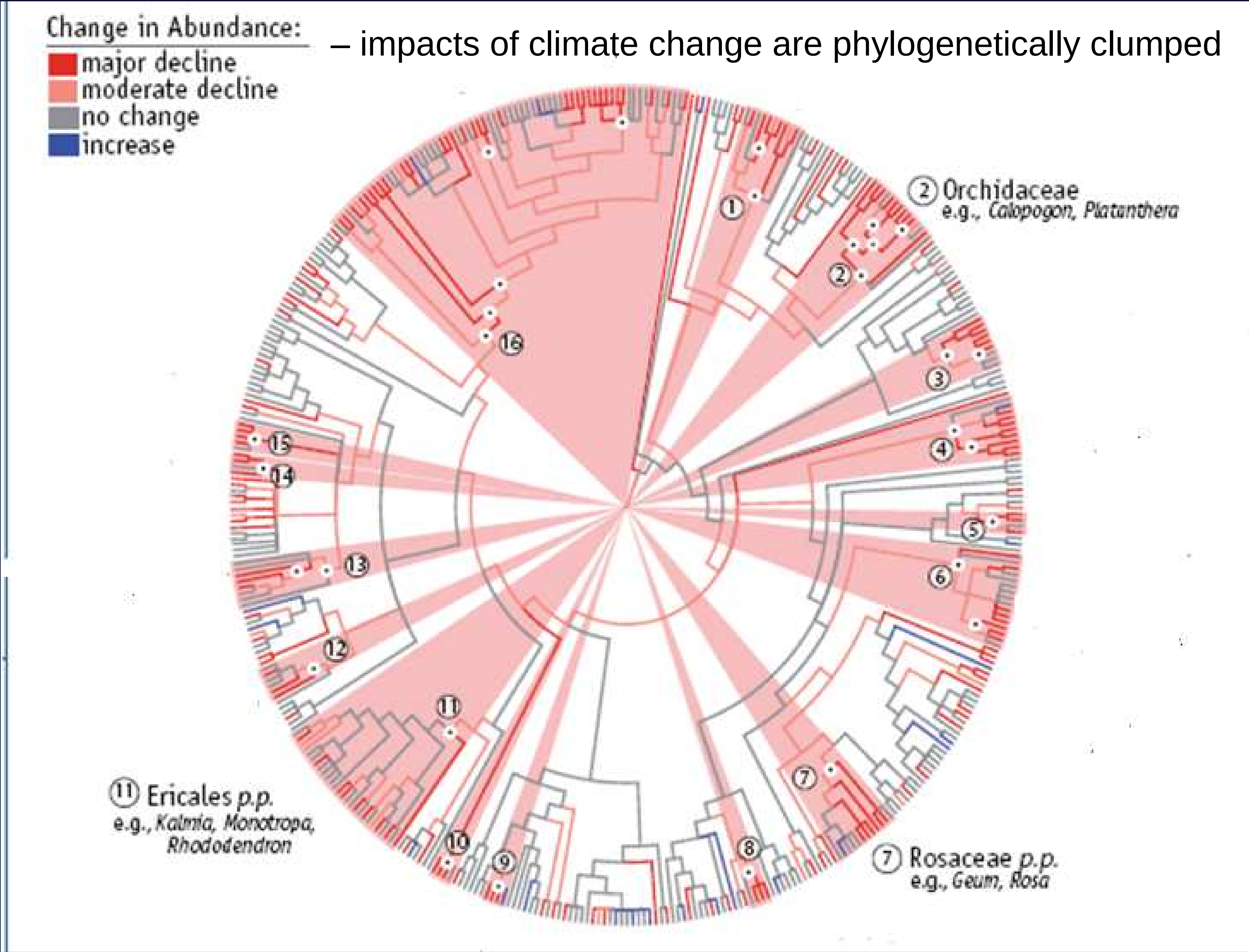
- Parts of the phylogeny provide lots of unique features
- Parts of the phylogeny have high vulnerability to impacts

flora of Walden Pond (from Willis and co.)

– impacts of climate change are phylogenetically clumped



PD and climate change impacts

Yesson, C. and A. Culham. 2006.

A phyloclimatic study of Cyclamen.

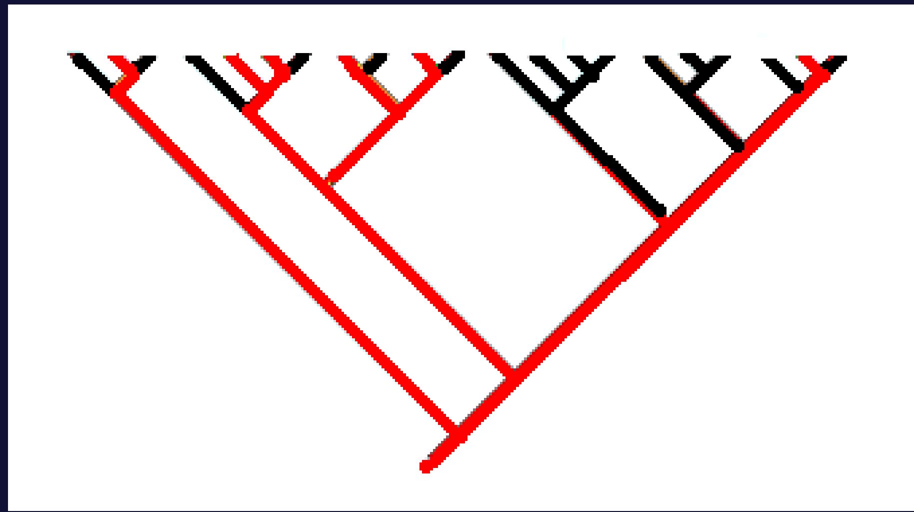
BMC Evolutionary Biology 6:72

How does climate change impact on PD and evolutionary potential?

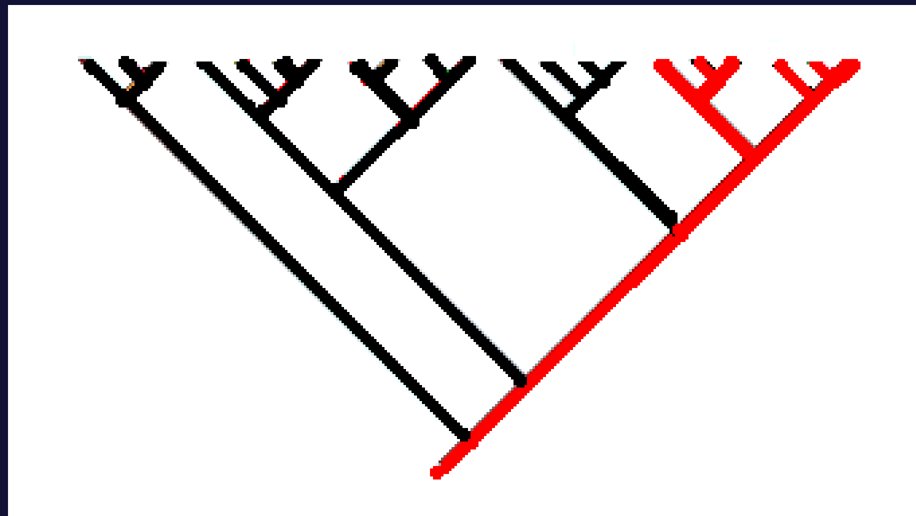
PD – phylogenetic diversity (Faith 1992)

Will the impacts of climate change on PD be large or small?

- *small* loss of PD or evolutionary potential for given species loss



red = surviving evolutionary potential

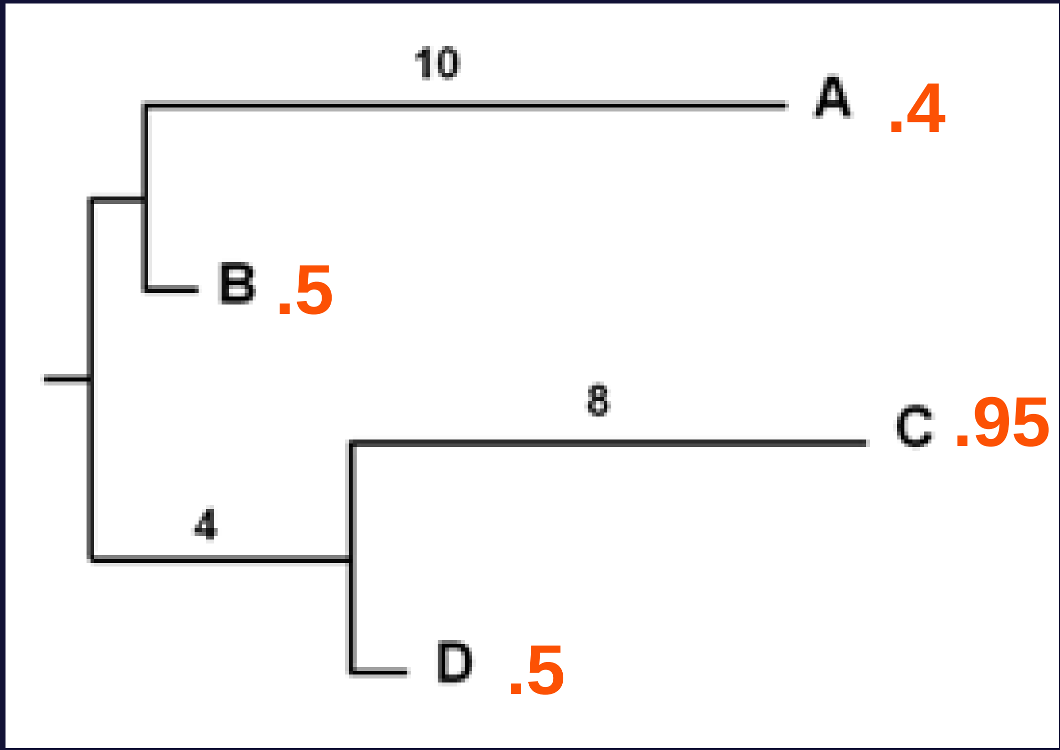


- *large* loss of PD or evolutionary potential

PD and probabilities of extinction

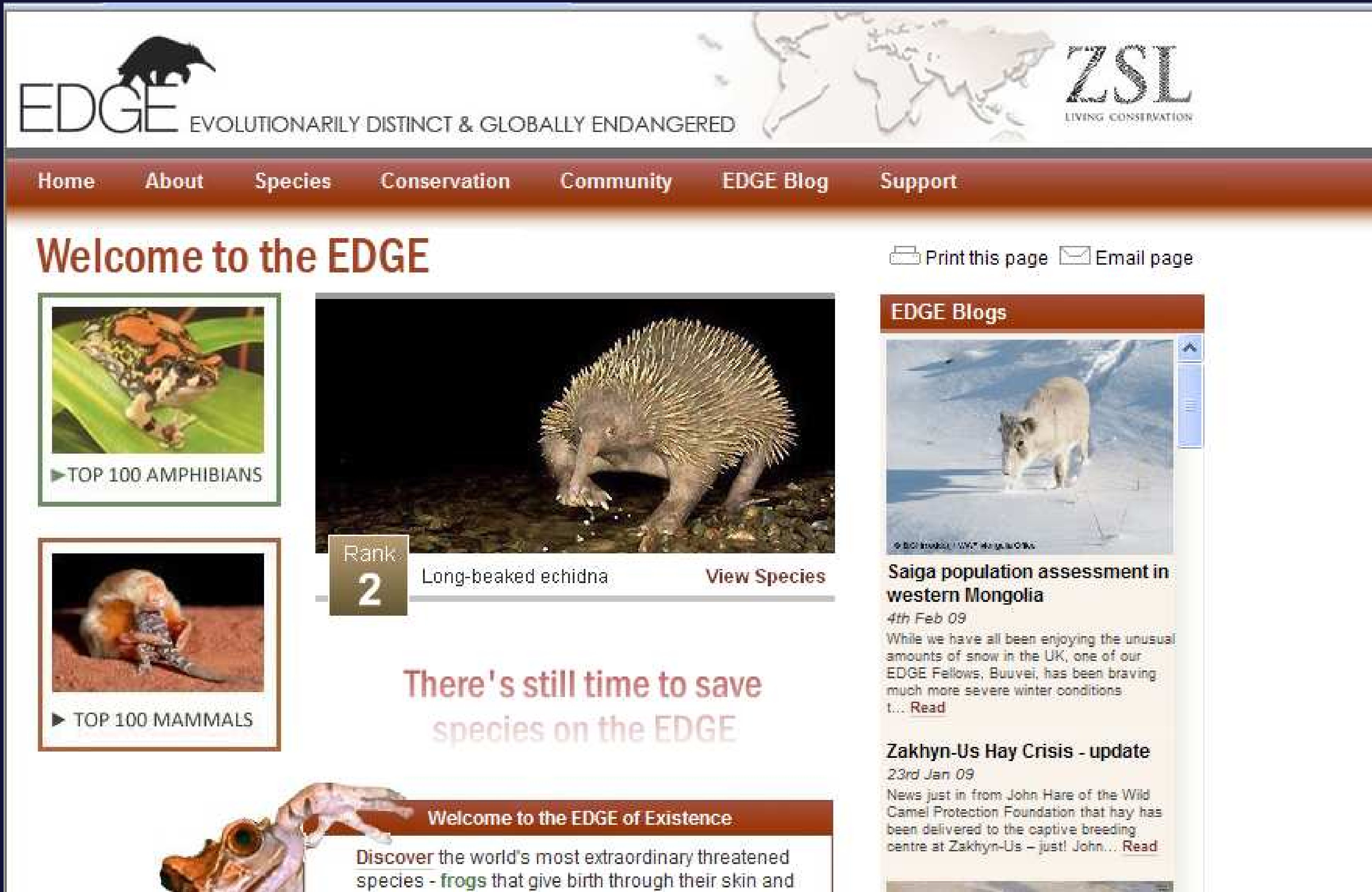
Probabilistic PD

– Red numbers are estimated probabilities of extinction



Can estimate “expected phylogenetic diversity” or do “phylogenetic risk analysis”

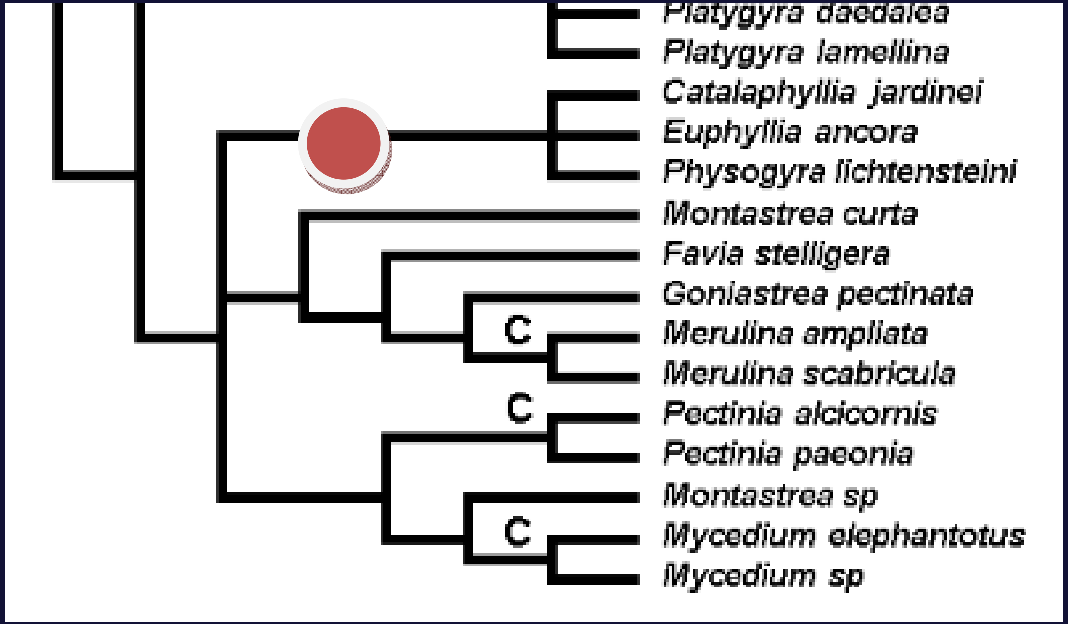
Faith DP (2008) Threatened species and the preservation of phylogenetic diversity (PD): assessments based on extinction probabilities and risk analysis. *Conservation Biology* www.edgeofexistence.org



Mooers AØ, Faith DP, Maddison WP (2008) Converting Endangered Species Categories to Probabilities of Extinction for Phylogenetic Conservation Prioritization. *PLoS ONE*

Loss of the world's corals

- Number of threatened species –
- "the proportion of corals (57.8%) exceeds that of all terrestrial animal groups assessed to date.."
- Carpenter et al (2008) *Science*

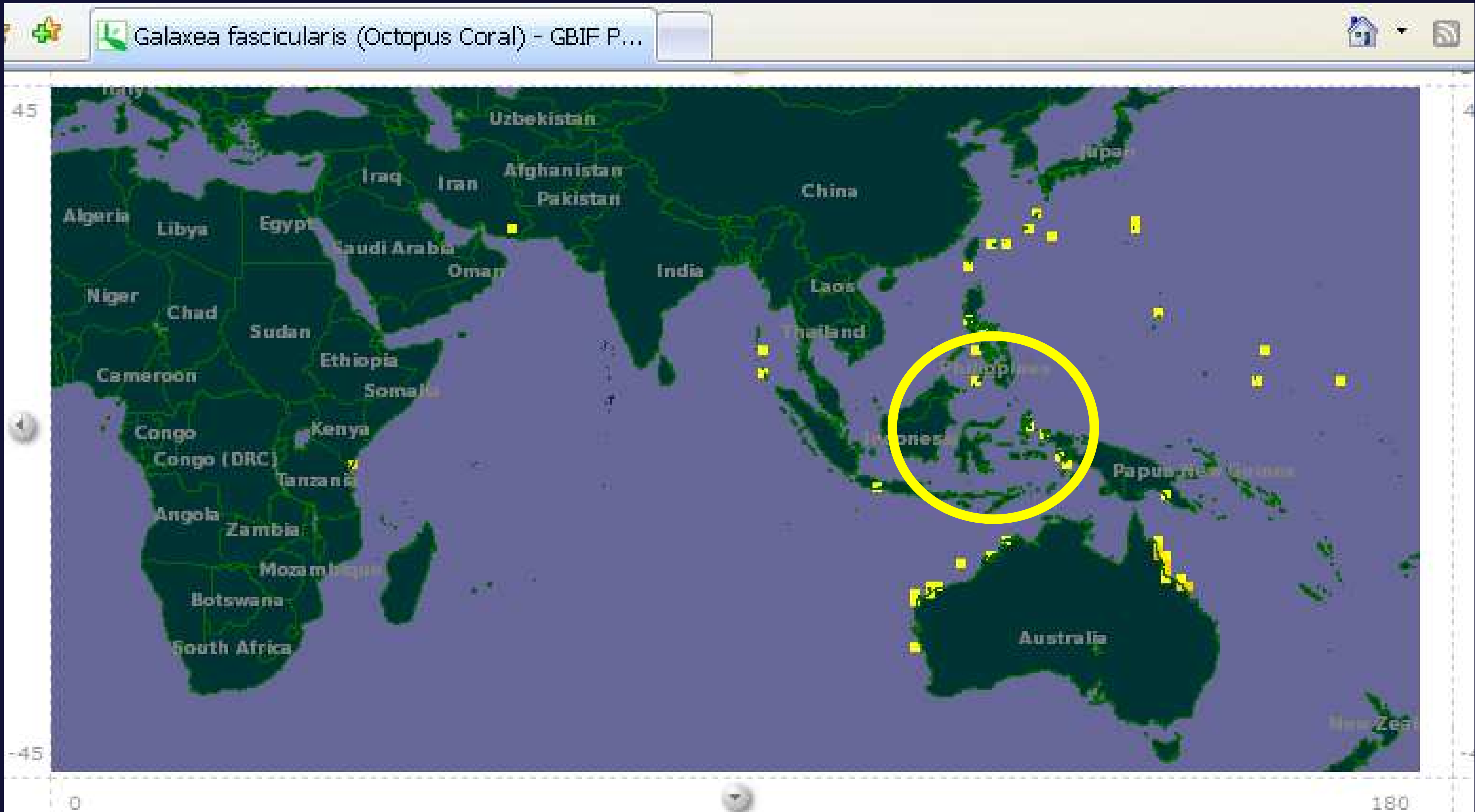


many examples where entire clades (existing families and genera) fall into IUCN threatened classes

- apply phylogenetic risk analysis to a "supertree" for corals.

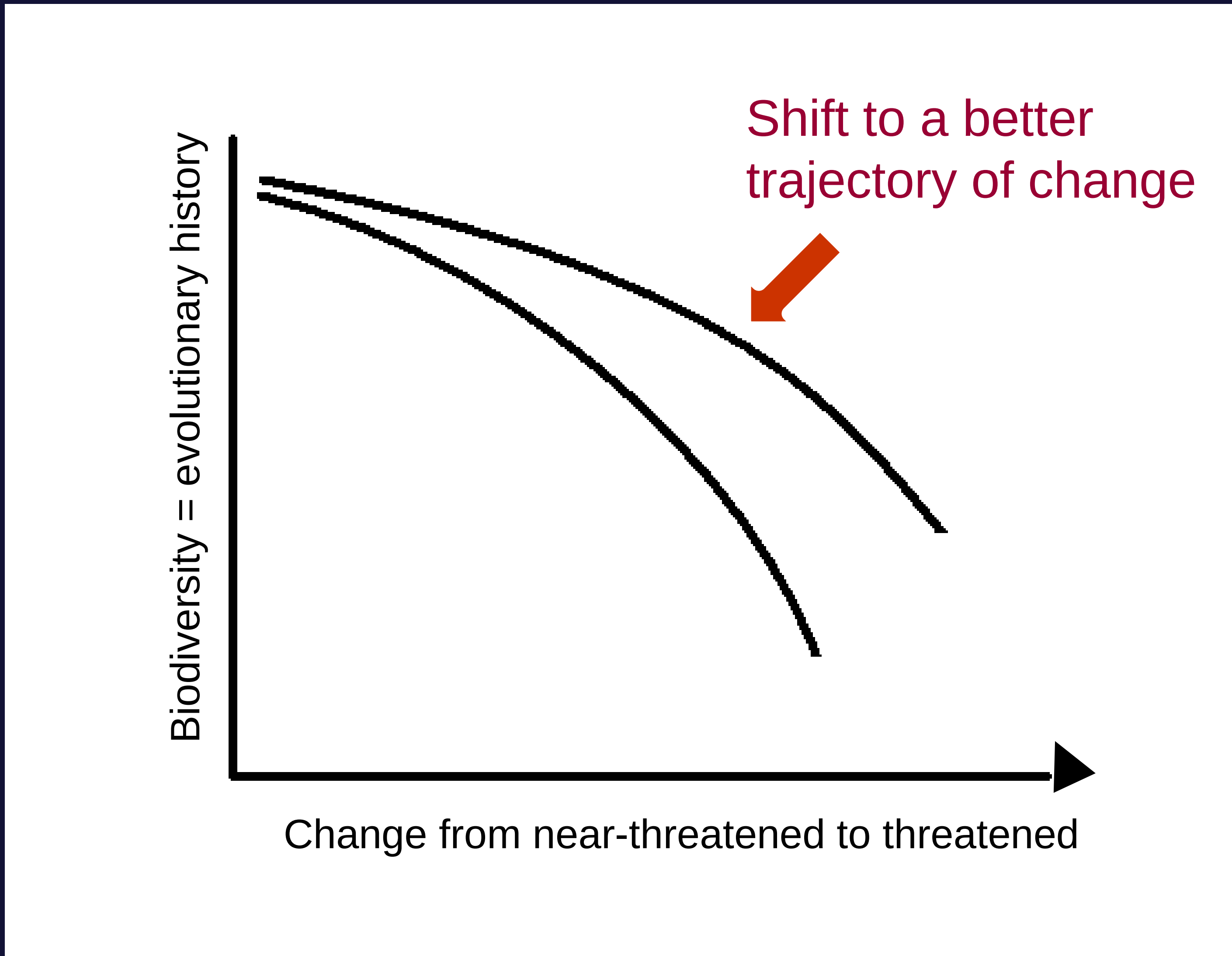
Faith DP (2009) Phylogenetic triage, efficiency, and risk aversion. *Trends in Ecology and Evolution*

Perhaps risk analysis can help identify key places to invest in coral conservation, to avoid worst-case PD losses



GBIF (Global Biodiversity Information Facility) and other data

Reducing the slide from near-threatened to threatened status



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DNA barcoding

- The use of a small, standardised, portion of DNA sequence for the purpose of species identification and discovery

- We can use PD calculations – e.g. PD versions of endemism and complementarity (marginal gains and losses)
- Not only do we by-pass species, but we may gain a boost in prediction of general biodiversity patterns

the animal kingdom
Barcode of Life

example

SPECIMEN DATA -Collembola of Arctic Canada [IHCO]

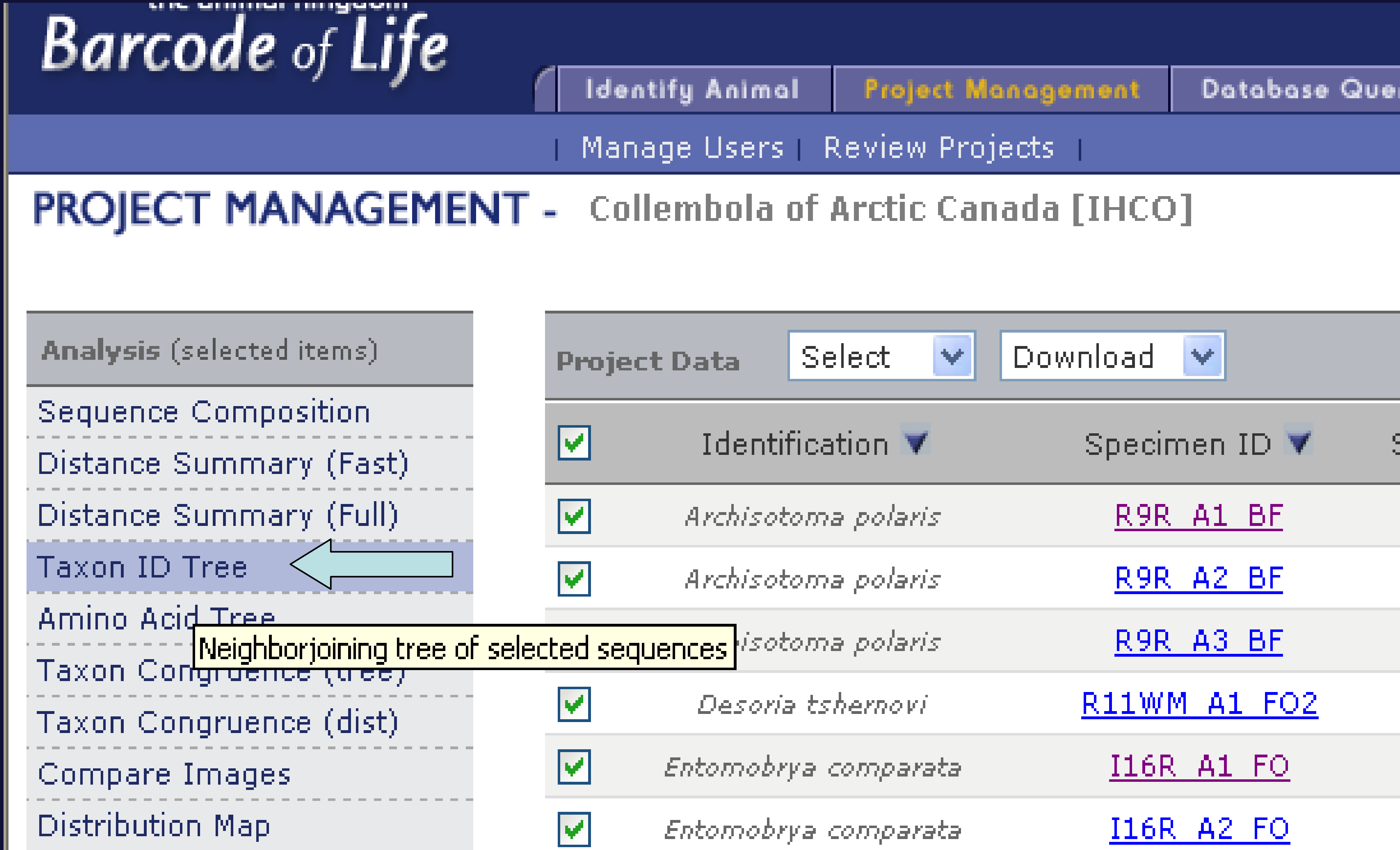
Identification :	*Entomobrya comparata*
GenBank Accession :	AY665328
Specimen Accession :	I16R_A1_FO
Specimen Label :	ecom-i16-1
Sex :	Unknown
Reproduction :	
Life Stage :	
GPS Latitude :	69.333
GPS Longitude :	-81.65
Elevation (meters) :	
Country :	Canada
State/Province :	Nunavut
Region :	Igloolik Island
Sector :	I16
Site :	rock
Museum Accession :	I16R_A1_FO
Institution Holding :	University of Waikato
Collector :	Ian Hogg
Date Collected :	2001-08-04
Identifier :	Ian Hogg
Common Name :	
Taxonomy :	phylum - Arthropoda class - Ellipura order - Collembola family - Entomobryidae genus - *Entomobrya* species - *Entomobrya comparata*
Notes :	

▲ Collection Location [click on image to zoom]

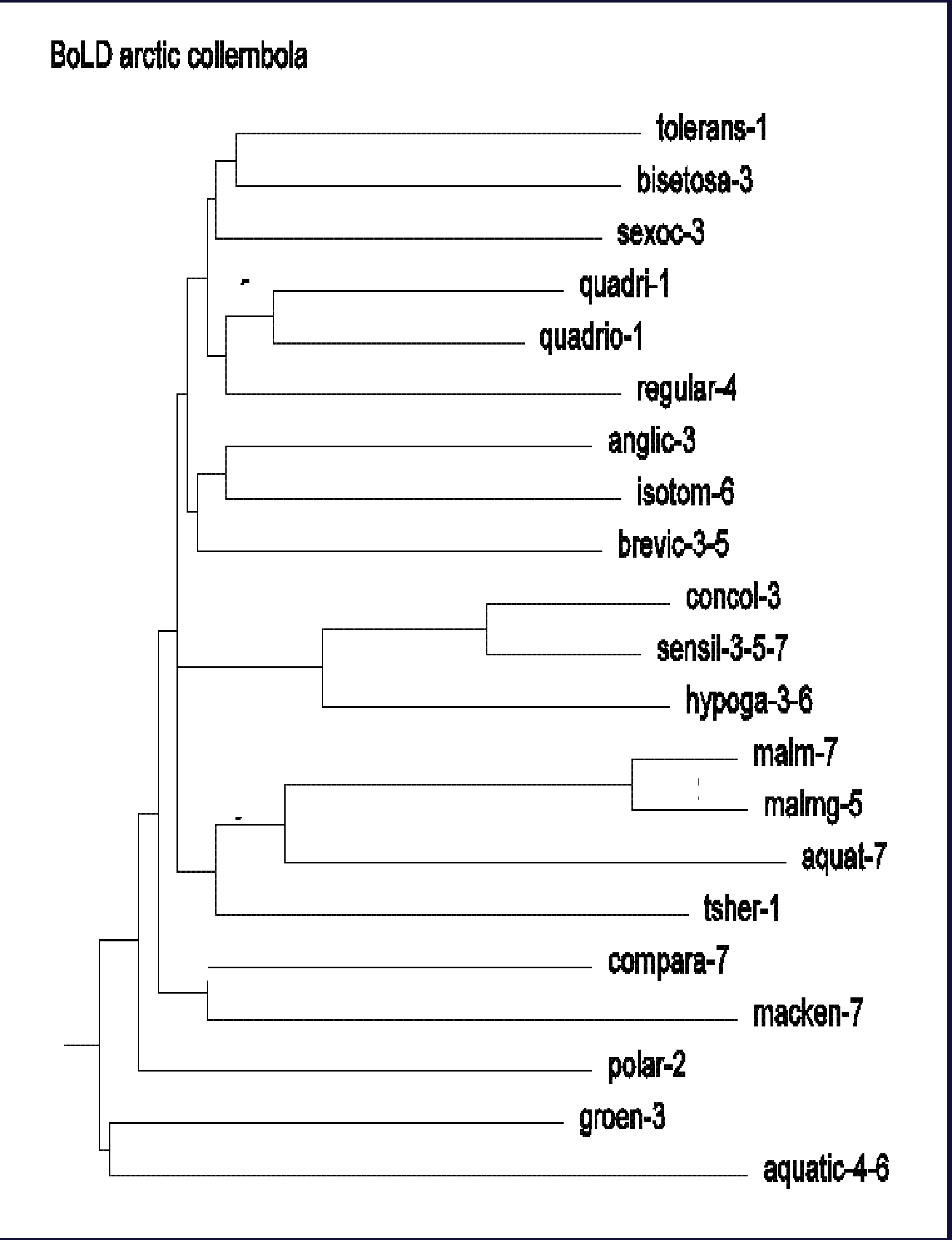
Stock image - Lateral View

Click on image to view images at larger size

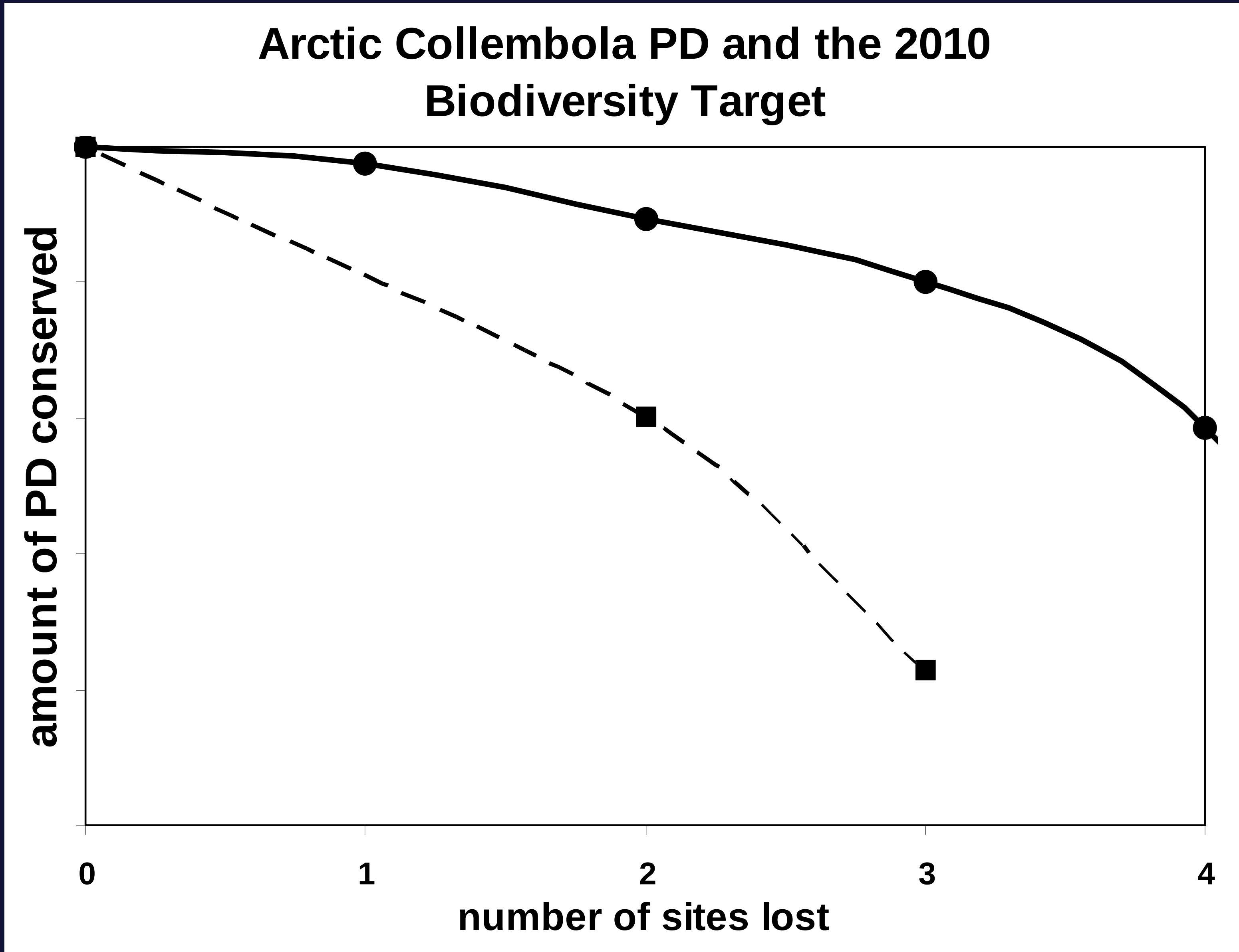
Barcoding and phylogeny estimates



Numbers are sites



Prospects:
Application to “phylogenies” from large scale DNA barcoding programs



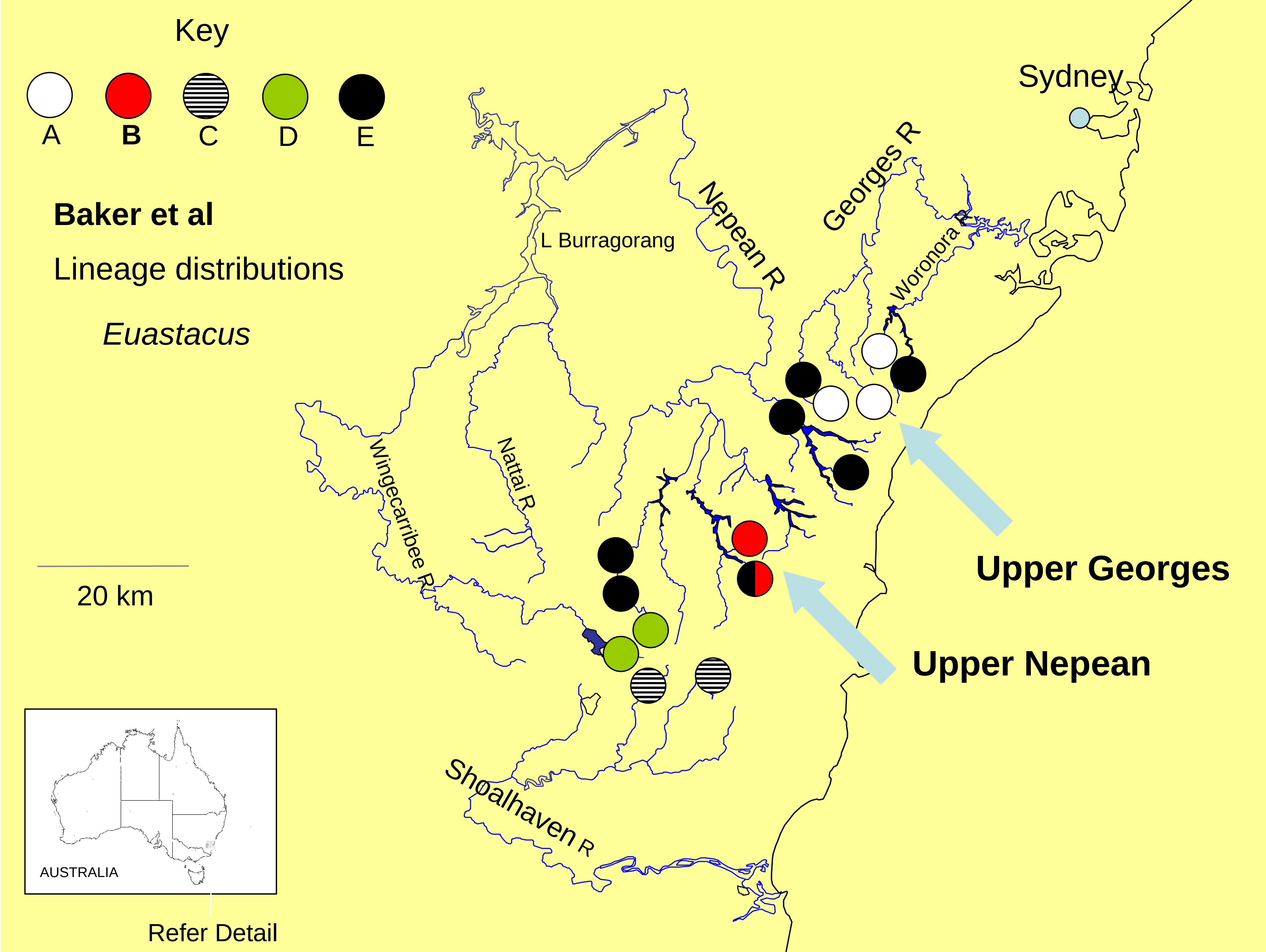
Faith, DP (2008) Phylogenetic diversity and conservation. In (eds: SP Carroll and C Fox) *Conservation Biology: Evolution in Action*. Oxford University Press.

PD conservation planning example

- Sydney water supply catchment region
- Threats from mining, new dams
- Baker et al studies, using DNA barcoding type methods, reveal

  lots of cryptic variation over several freshwater invertebrate groups

  + lots of “phylogeographic” structure


Key
A
B
C
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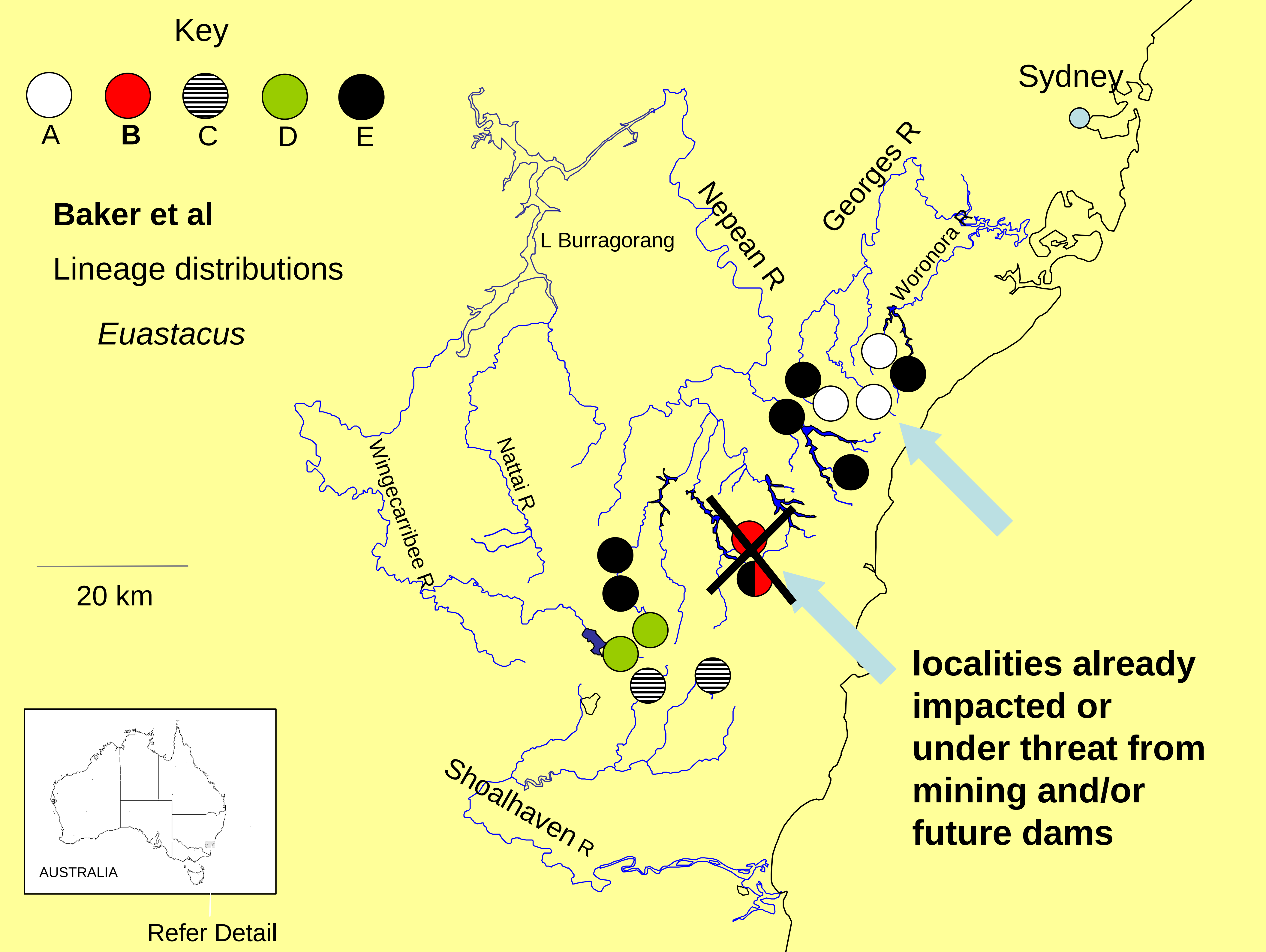
E
Baker et al
Lineage distributions
Euastacus
20 km
AUSTRALIA
Refer Detail
Sydney
L Burragorang
Nepean R
Georges R
Woronora R
Wingecarribee R
Nattai R
Shoalhaven R
Upper Georges
Upper Nepean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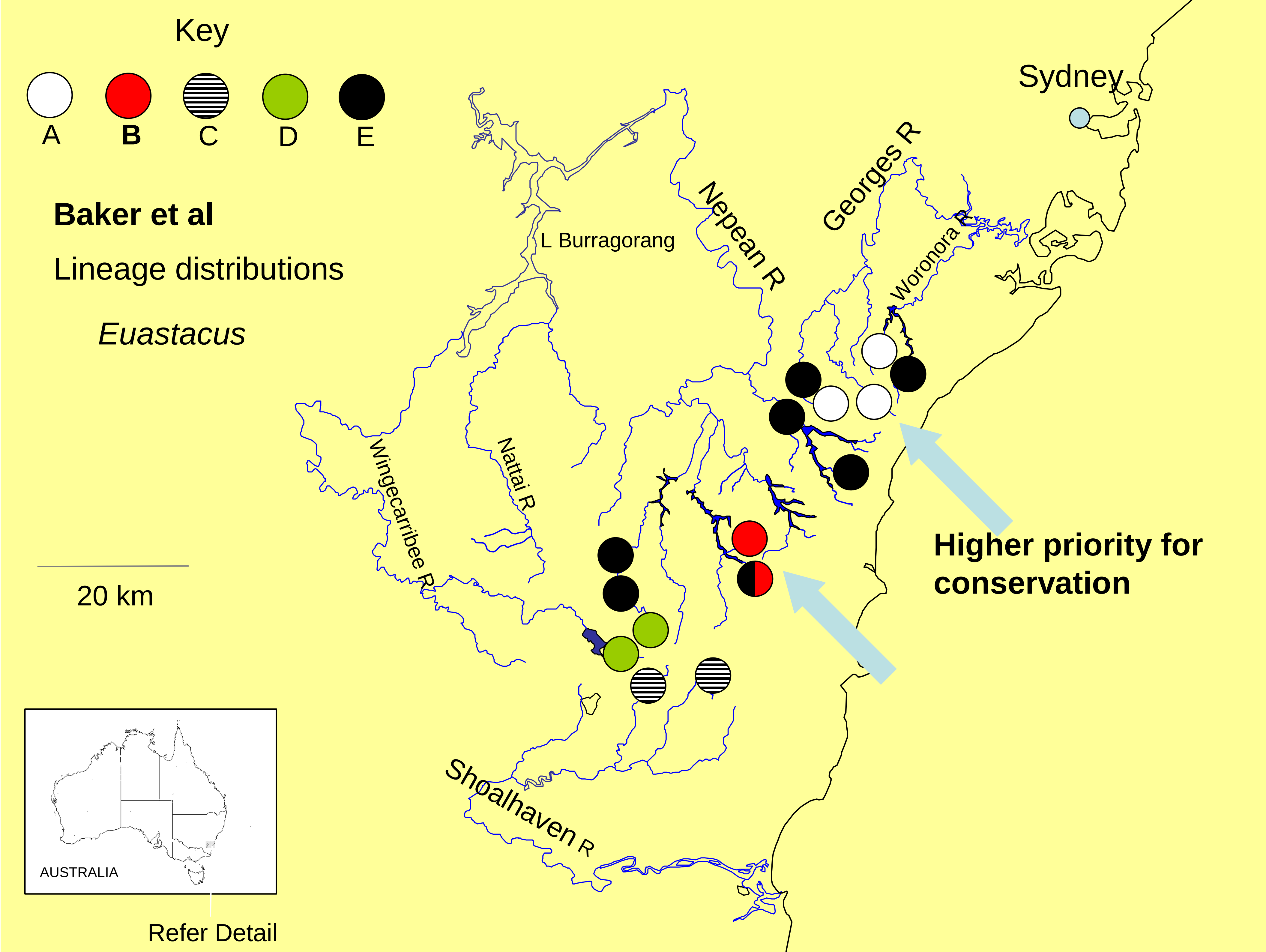
Nattai R
Wingecarribee R
Shoalhaven R
localities already impacted or under threat from mining and/or future dams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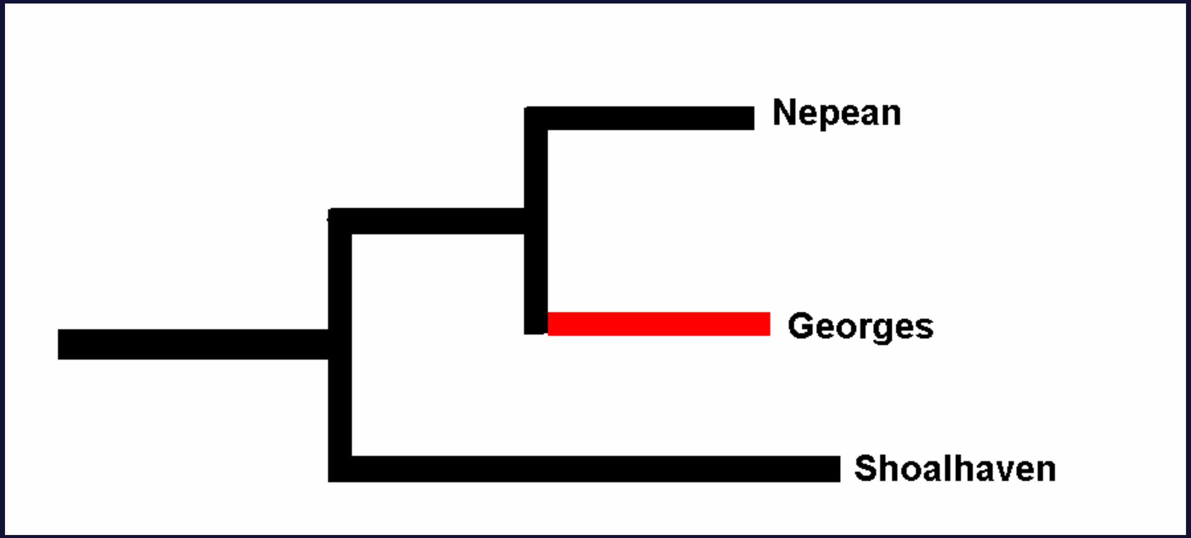
Higher priority for conservation

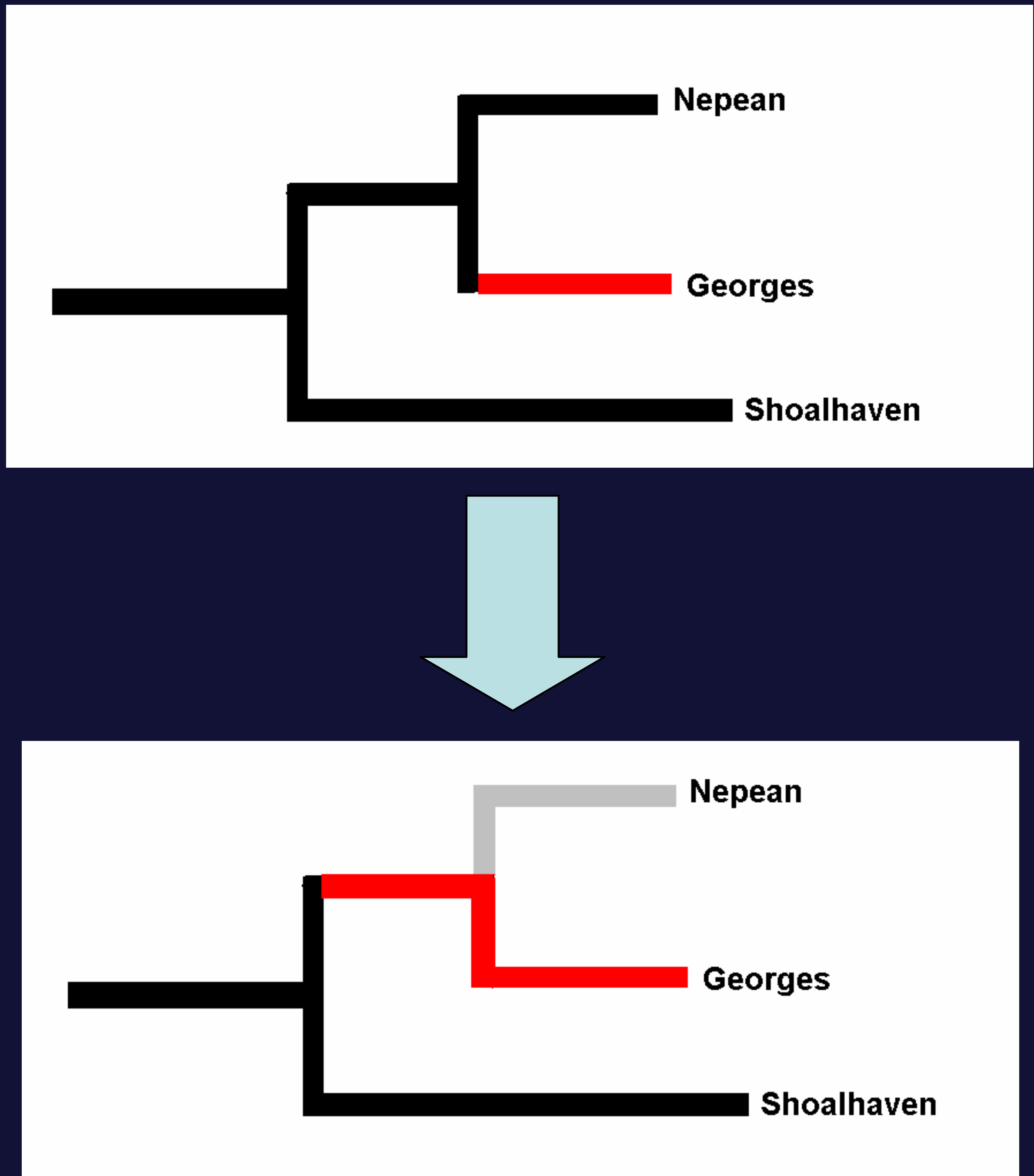


Upper Georges River’s unique contribution to phylogenetic diversity is shown in red

Consider consequences of loss of diversity,

from the human impacts on Upper Nepean River

Faith, D. P and A. Baker, 2006. Phylogenetic diversity (PD) and biodiversity conservation: some bioinformatics challenges” *Evolutionary Bioinformatics Online* 2



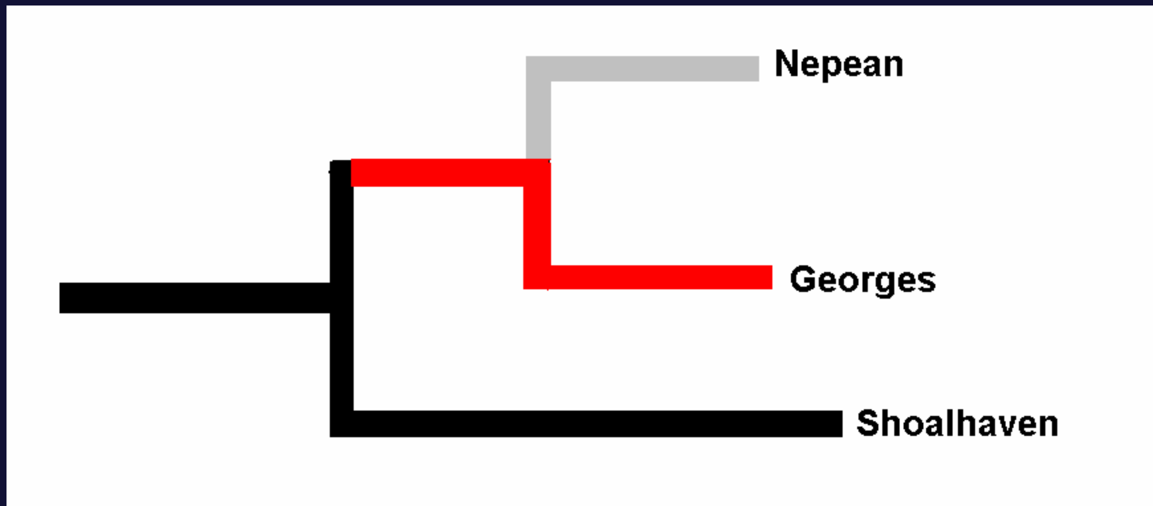
Faith, D. P. 2008. Phylogenetic diversity and conservation. In (eds: SP Carroll and C Fox) *Conservation Biology: Evolution in Action*. Oxford University Press.

For conservation planning

congruence in PD complementarity values (the red bits)

gives confidence that these values

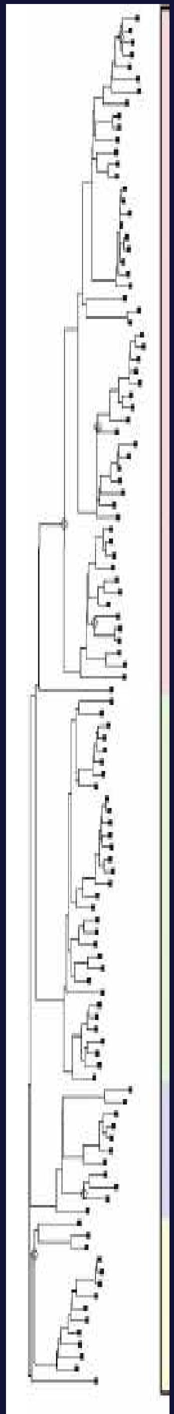
may reflect more general values



Now, let’s extend the PD calculus....

two sample sites j and k

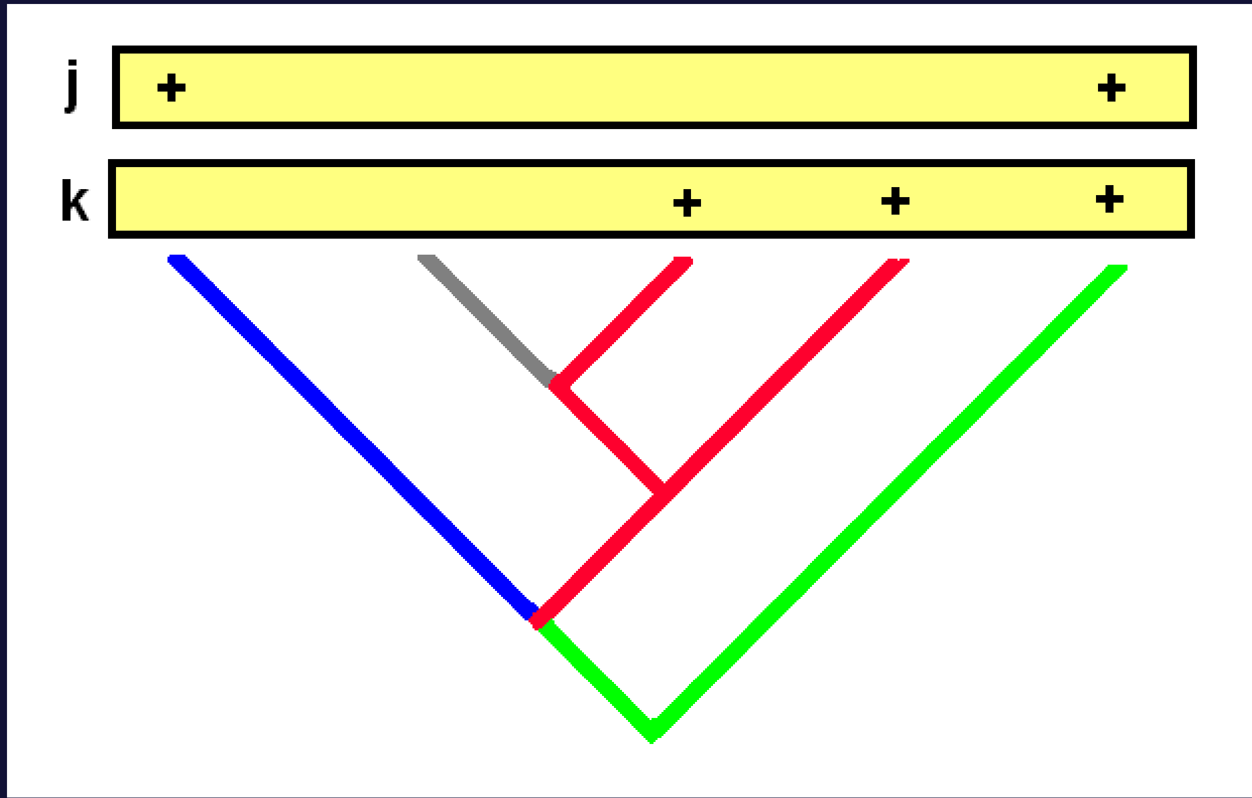
j and k dissimilar if lots of red and blue



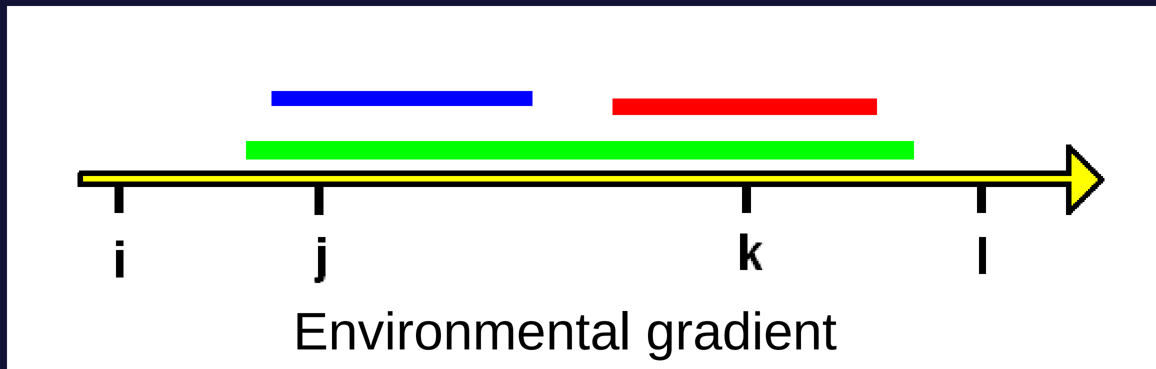
Big trees,

Few taxa,

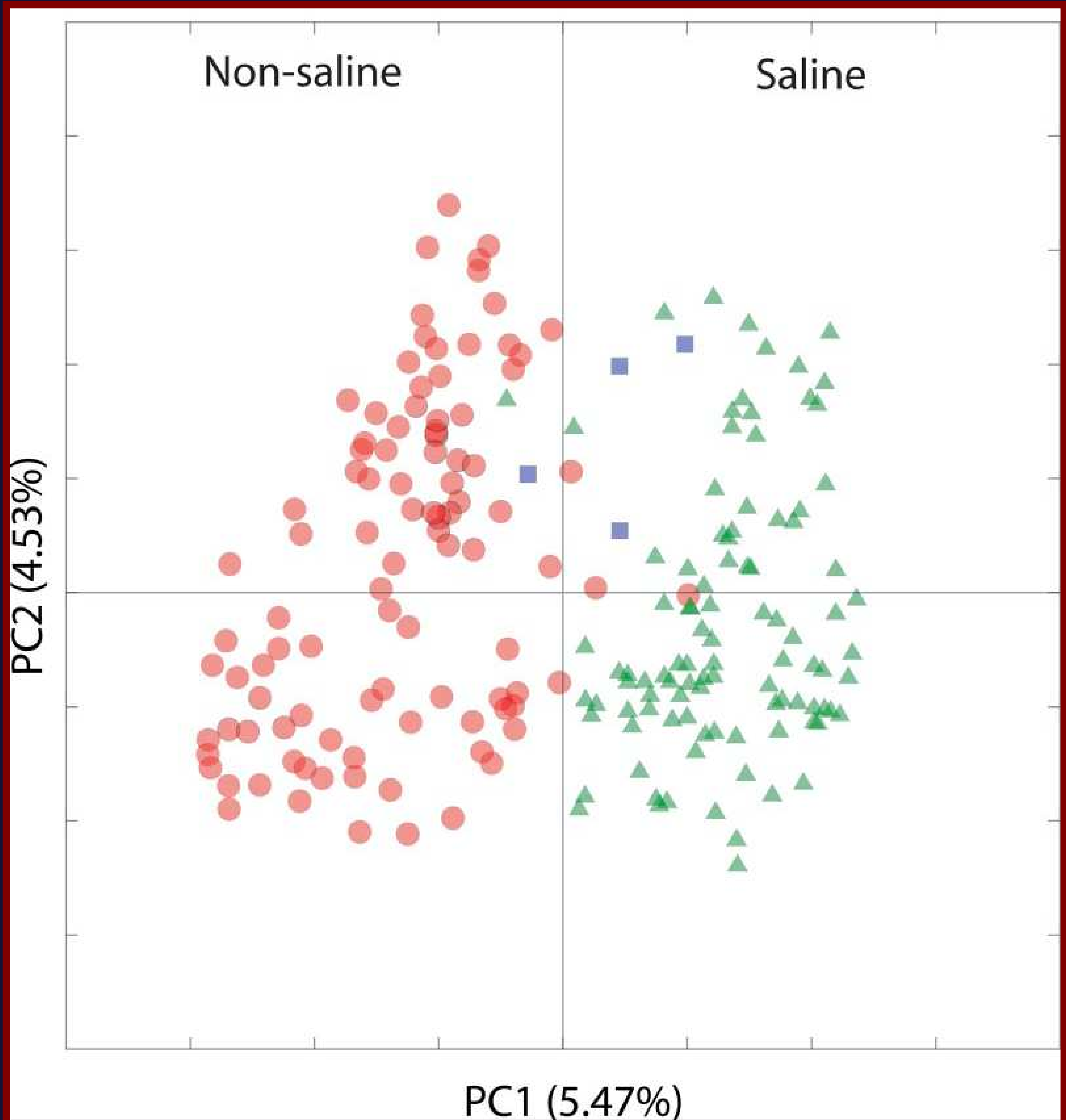
Many samples



PD-dissimilarities reflect distances along gradients

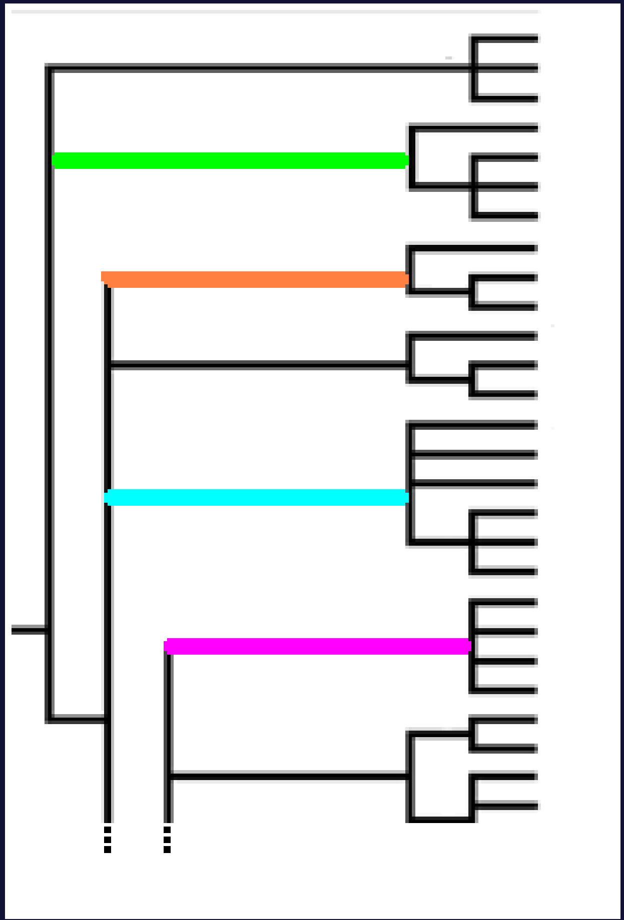


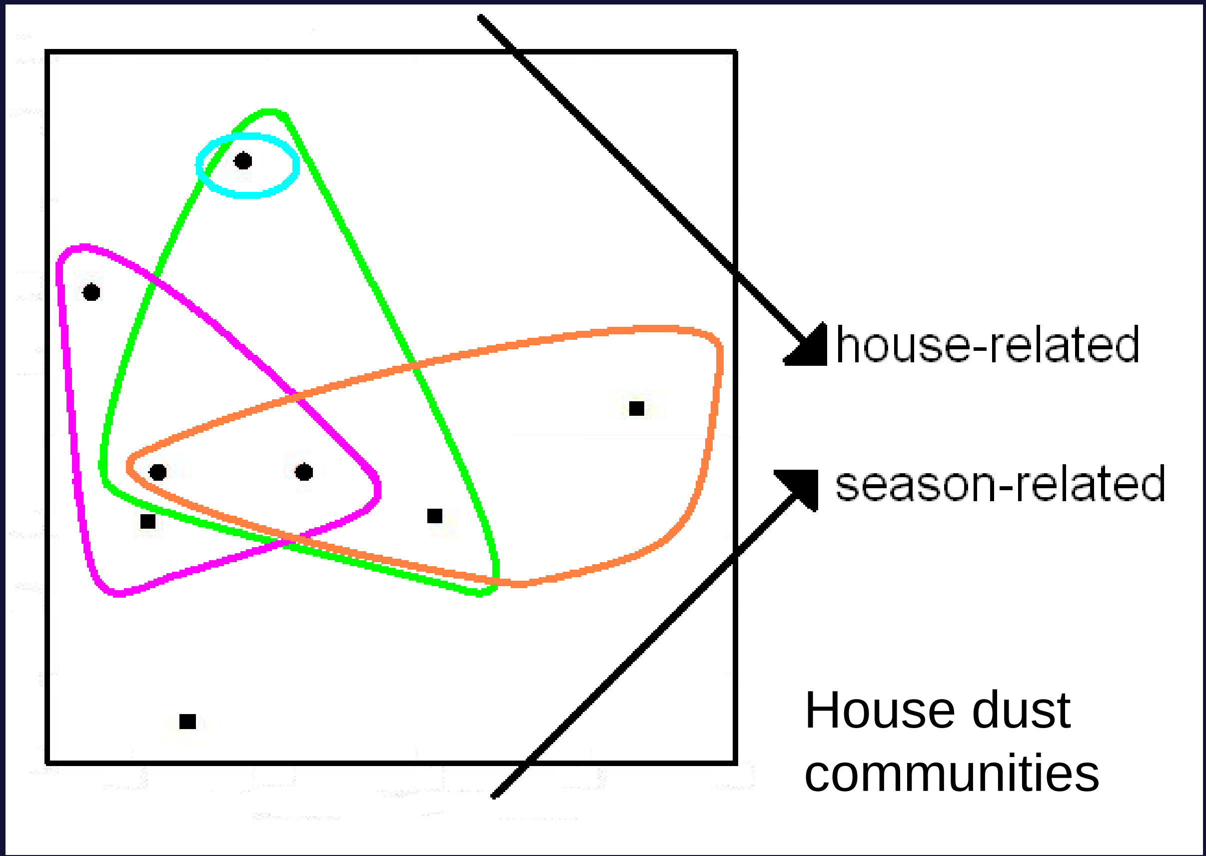
Lozupone and Knight 's work on global bacteria samples



- Use phylogenetic similarity among samples
- Discover that the major environmental determinant of microbial community composition is <u>salinity</u>

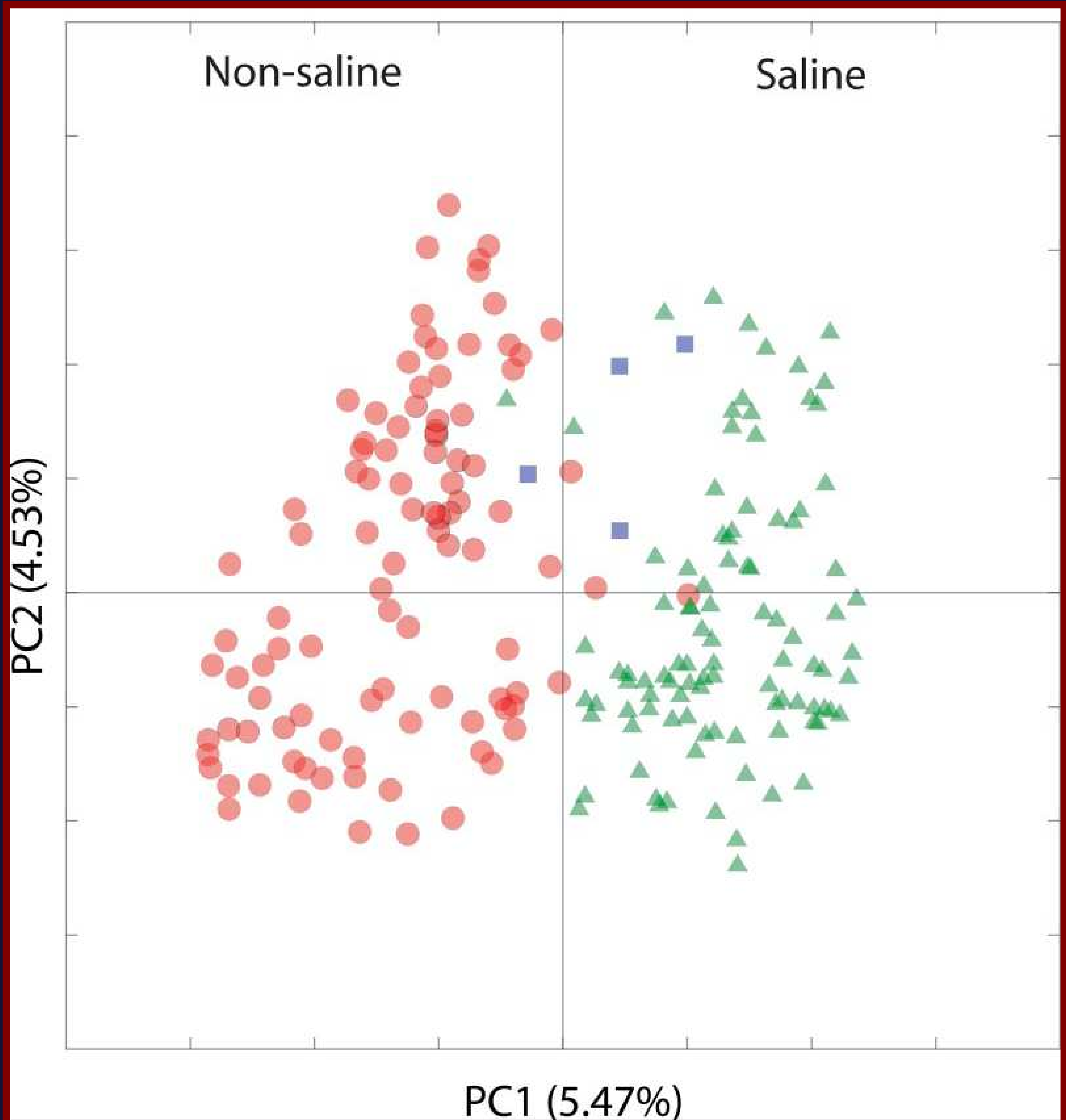
Phylogeny helps find important gradients, because even deeper branches have unimodal response to gradients





Faith, D. P., C. A. Lozupone, D. Nipperess, R. Knight (in review),
A general model linking evolutionary features and environmental gradients supports broad applications of microbial ecology's phylogenetic beta diversity framework

Lozupone and Knight 's work on global bacteria samples



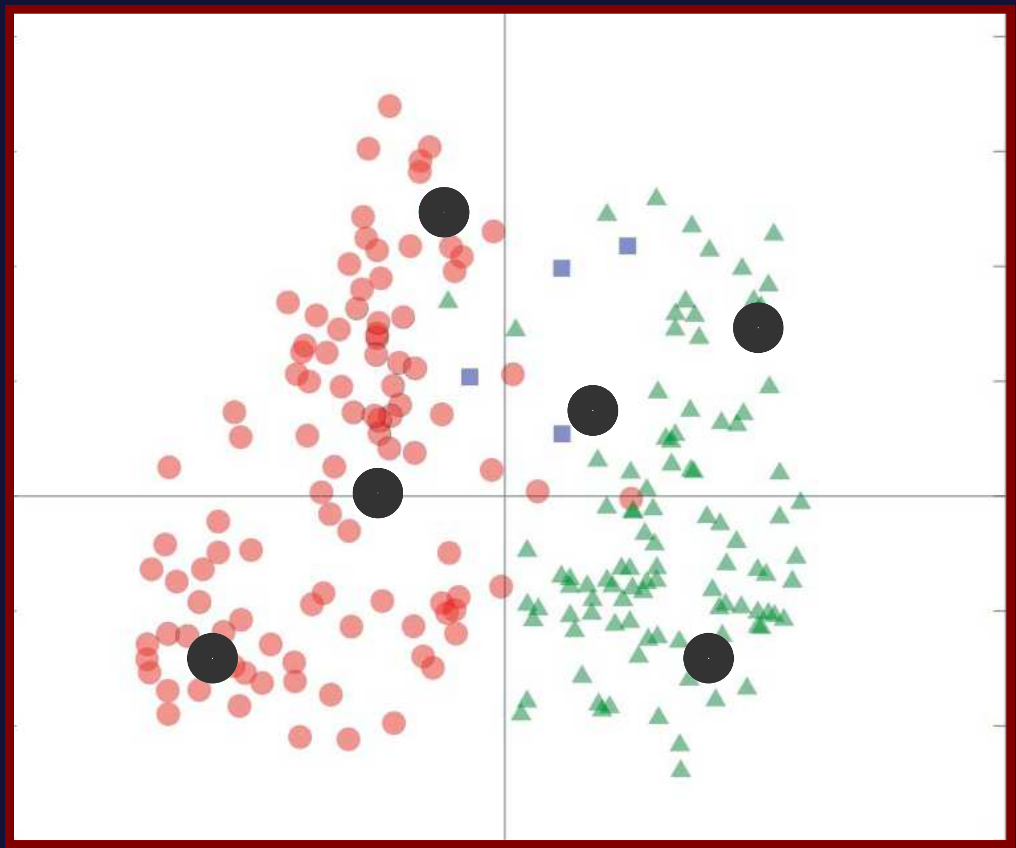
- Use
  phylogenetic similarity
  among samples

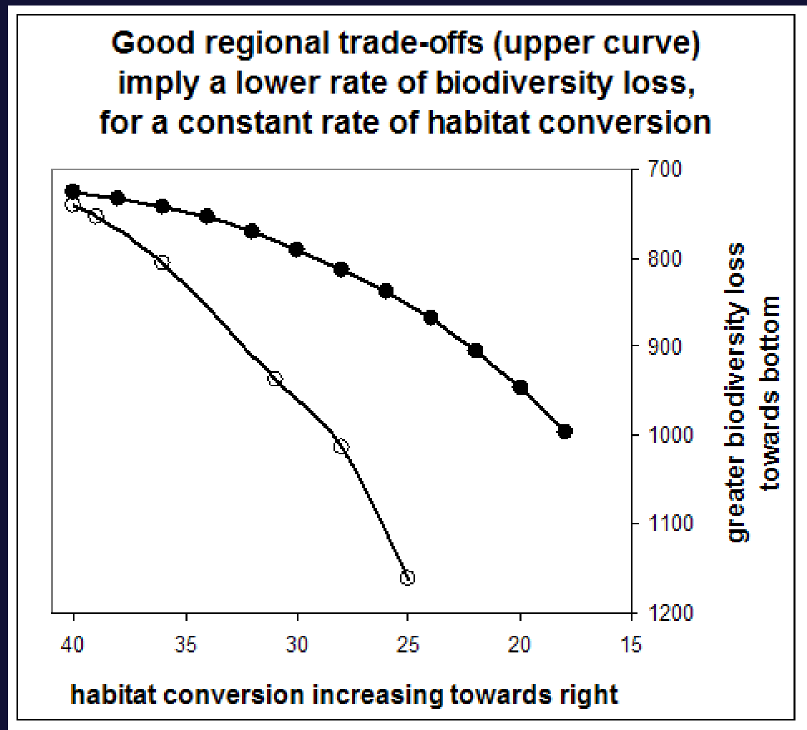
- Discover that the major environmental determinant of microbial community composition is salinity

ED (environmental diversity) method "counts-up" species under evolutionary model of unimodal response of features to gradients.

ED estimates the biodiversity represented by any set of protected areas

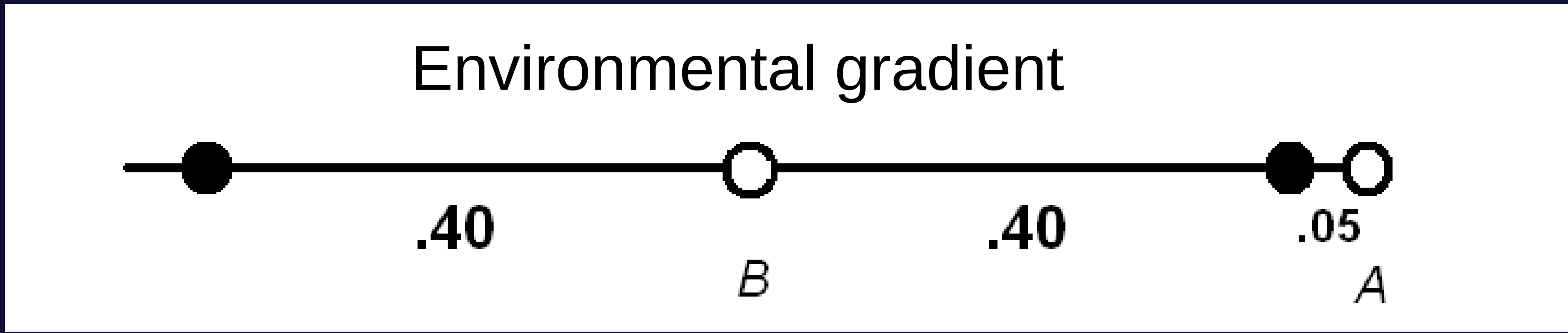
Using ED provides efficient allocation of conservation resources and a shift to the upper curve – implying achievement of the 2010 biodiversity target





ED background: Faith and Walker 1996 *Biodiversity and Conservation*

ED predicts that site B adds many more species than site A.



environmental gradient with selected sites (solid circles),

two candidate sites for selection, A and B (hollow circles).

numbers along gradient are distances between sites.

Arponen, Moilanen, et al. proposed “maximization of complementary richness” (MCR) method, which resembles ED.

However, MCR does not reliably count-up species.

In above example MCR would wrongly select site A!

MCR could increase the rate of biodiversity loss if used in systematic conservation planning for the 2010 biodiversity target

ED (environmental diversity) method "counts-up" species under evolutionary model of unimodal response to gradients.

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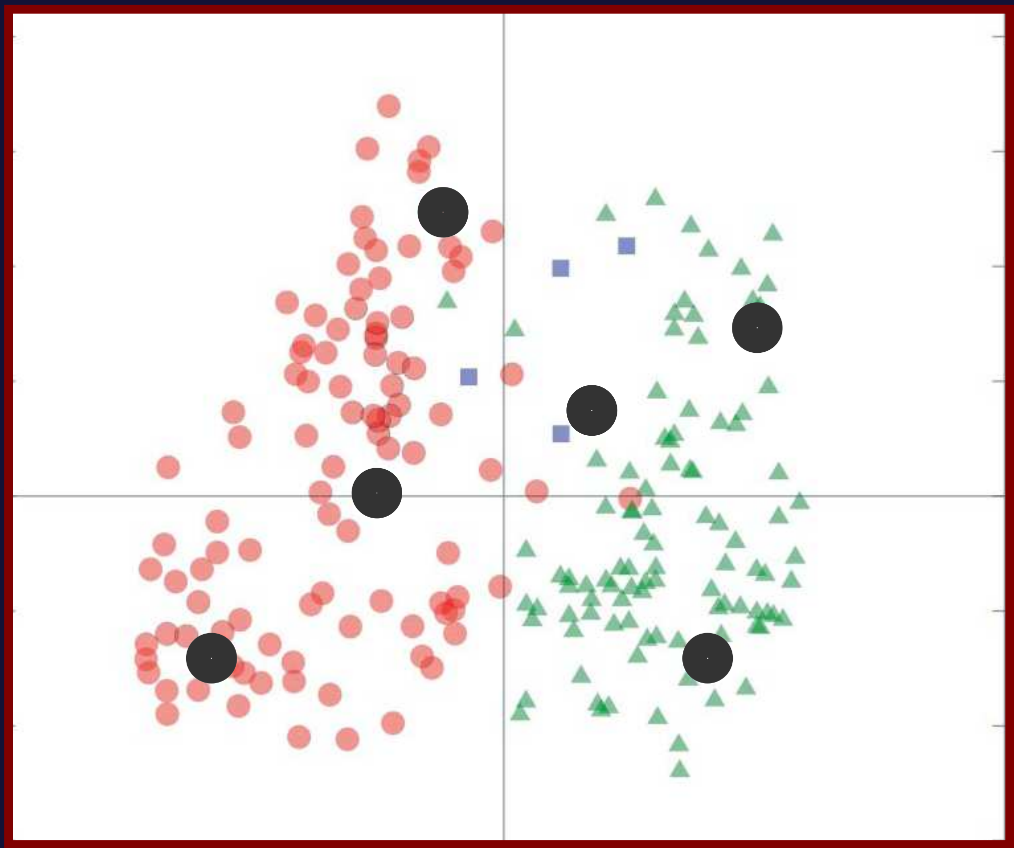
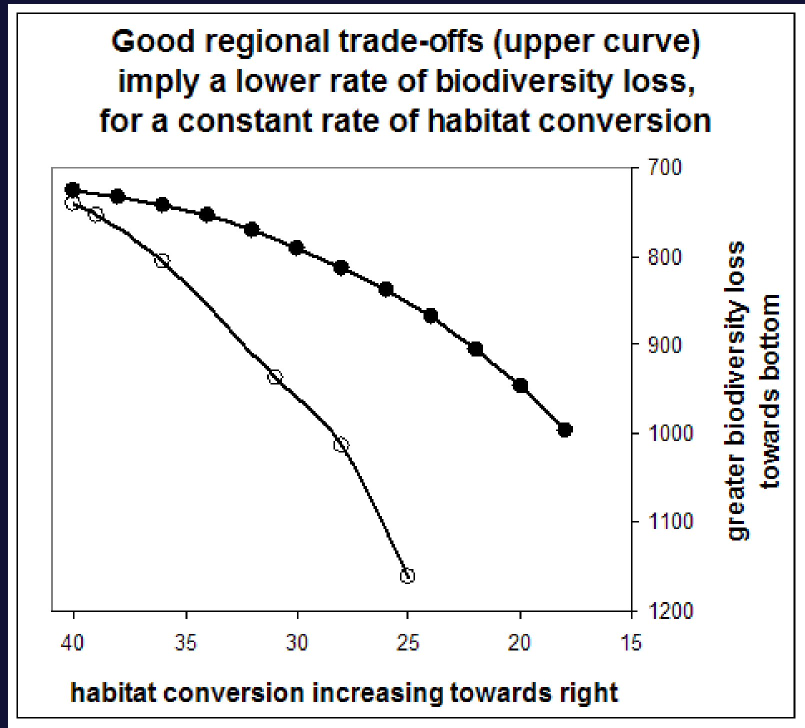
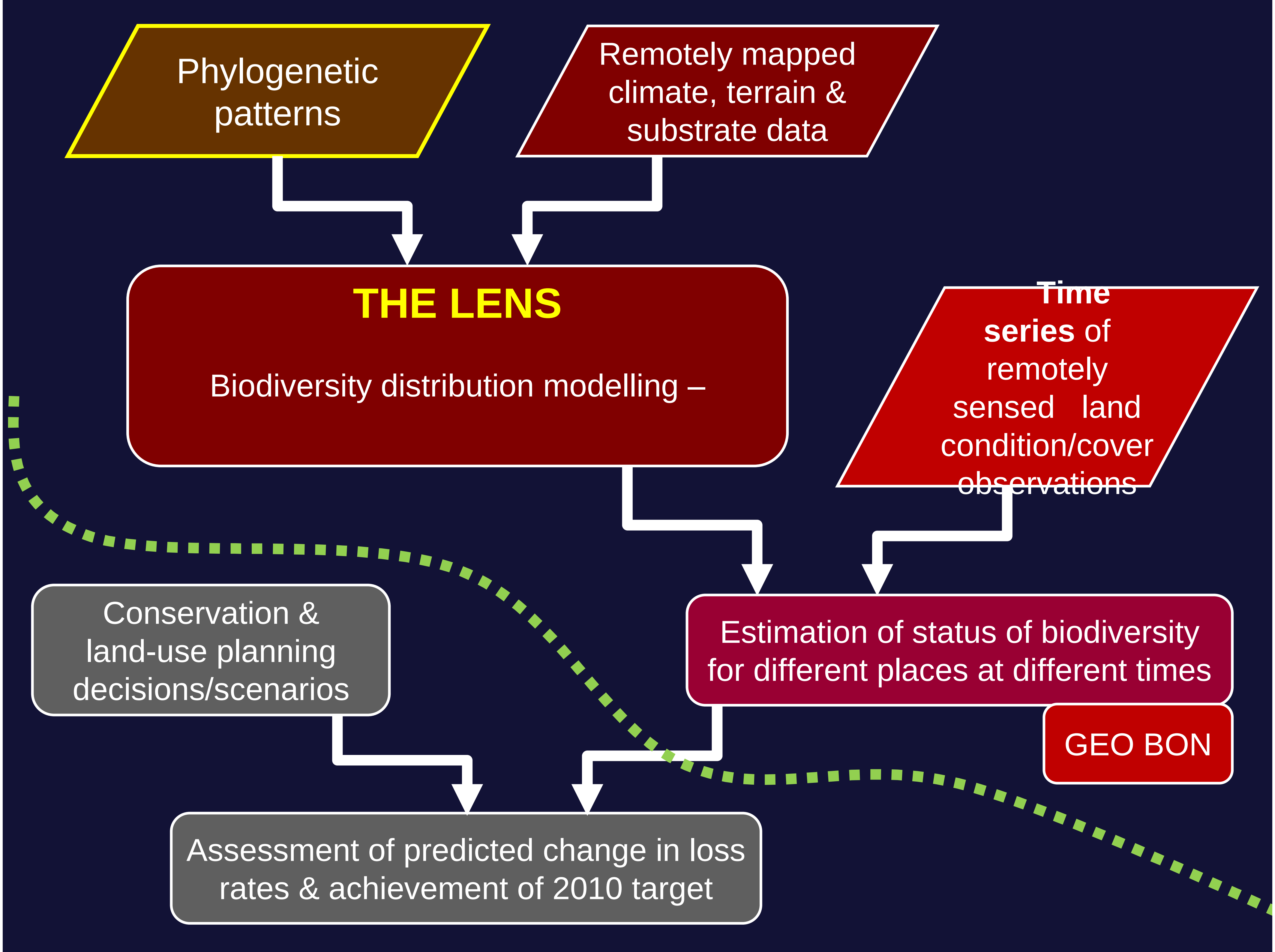


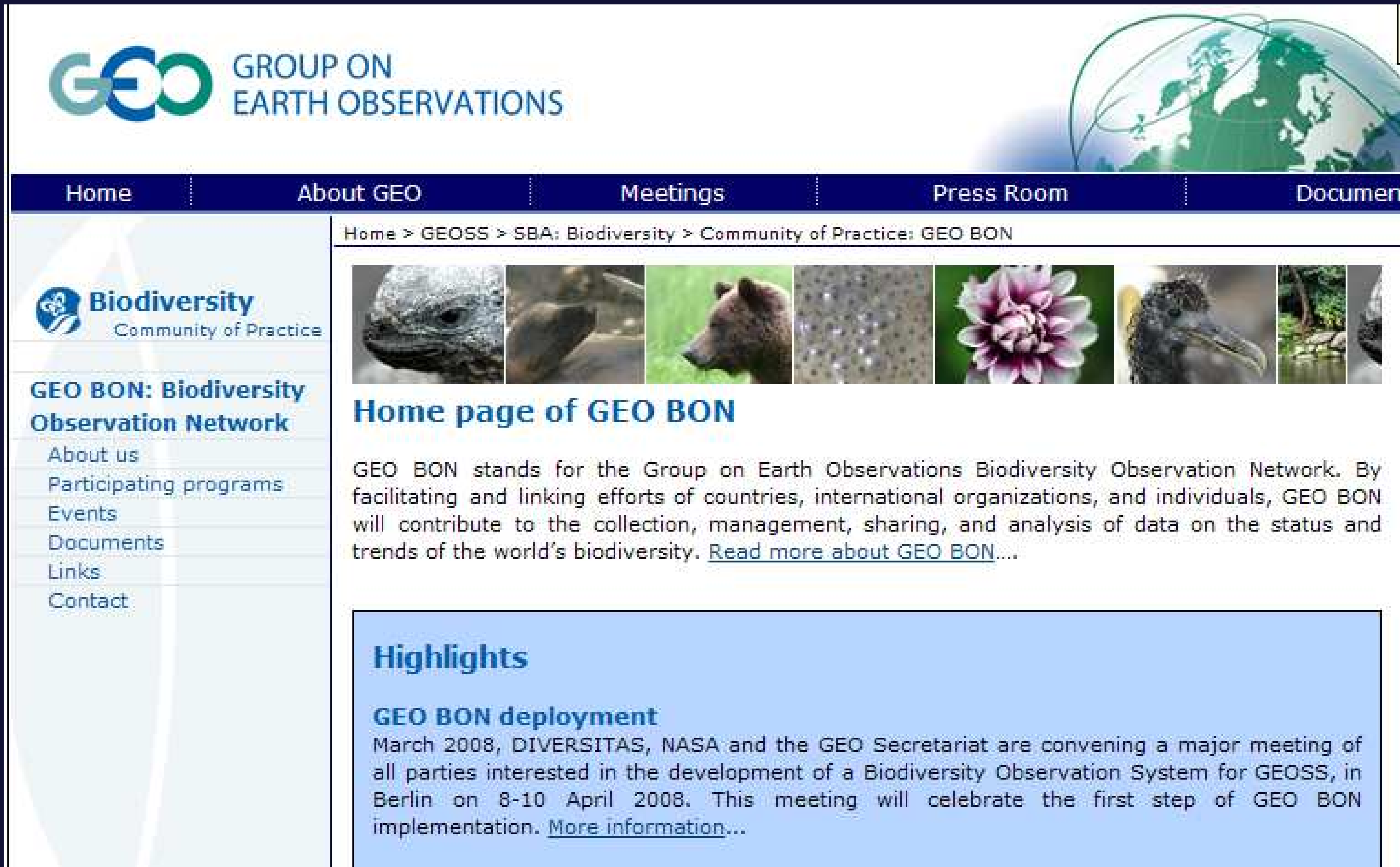


phylogenetic information can be integrated into a "lens" for interpreting remotely sensed changes in land condition – useful for GEO BON....



Phylogenetic patterns
Remotely mapped climate, terrain & substrate data
THE LENS
Biodiversity distribution modelling –
Time series of remotely sensed land condition/cover observations
Conservation & land-use planning decisions/scenarios
Estimation of status of biodiversity for different places at different times
GEO BON
Assessment of predicted change in loss rates & achievement of 2010 target

A global
Biodiversity Observation Network



Three strategies for monitoring genetic / phylogenetic diversity

Repeated observations, over time, of:

1) specific genetic / phylogenetic components of interest, in selected target species.

2) other biodiversity components (e.g. range extents for a representative set of species), integrated with models that link these observations to genetic diversity.

3) changes in land/water condition (e.g. using remote sensing), integrated with spatial genetic variation models as the “lens” to infer corresponding changes at the genetic/phylogenetic levels.

Some research issues raised in my talk

- The three-pronged approach – what are "best-possible" methods; how do we define the gaps and priorities?
- How do we monitor genetic and phylogenetic diversity at broad scales?
- What are the expected impacts of climate and land use change for overall biodiversity?
- Can phylogenetic pattern improve predictions for overall biodiversity
- How do communities change and how does this affect delivery of ecosystem services?
- How do we incorporate risk analyses?

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bioGENESIS

Providing an evolutionary framework for biodiversity science

bioGENESIS Science Plan and Implementation Strategy

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Approved by the Scientific Committee of DIVERSITAS

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