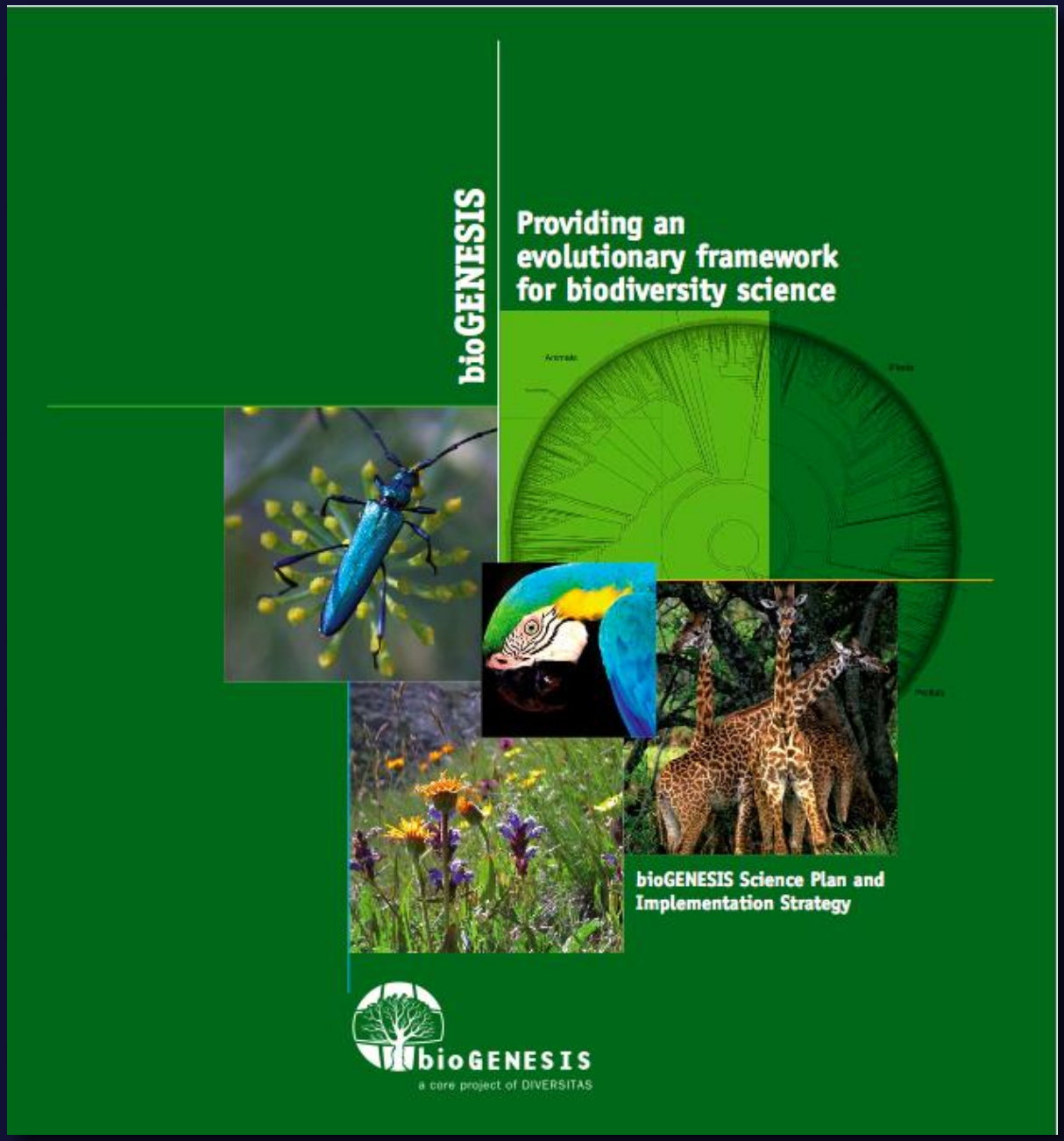
Phylogenetic diversity and conservation

Dan Faith
The Australian Museum

Applied ecology and human dimensions in biological conservation
Biota Program/ FAPESP
Nov. 9-10, 2009



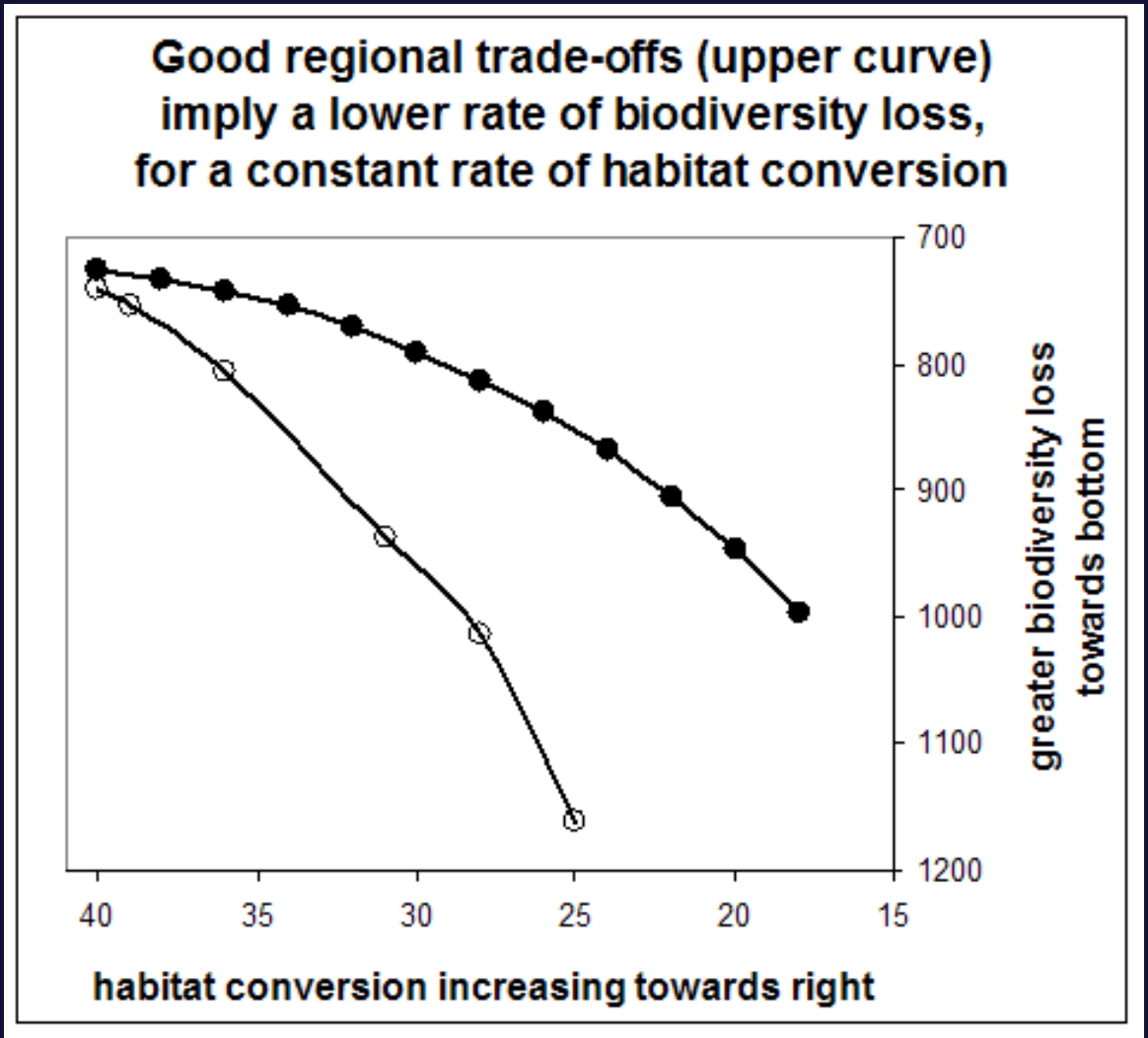
DIVERSITAS
an international programme of biodiversity science

BioGENESIS

Providing an evolutionary framework for biodiversity science

A global Biodiversity Observation Network:

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

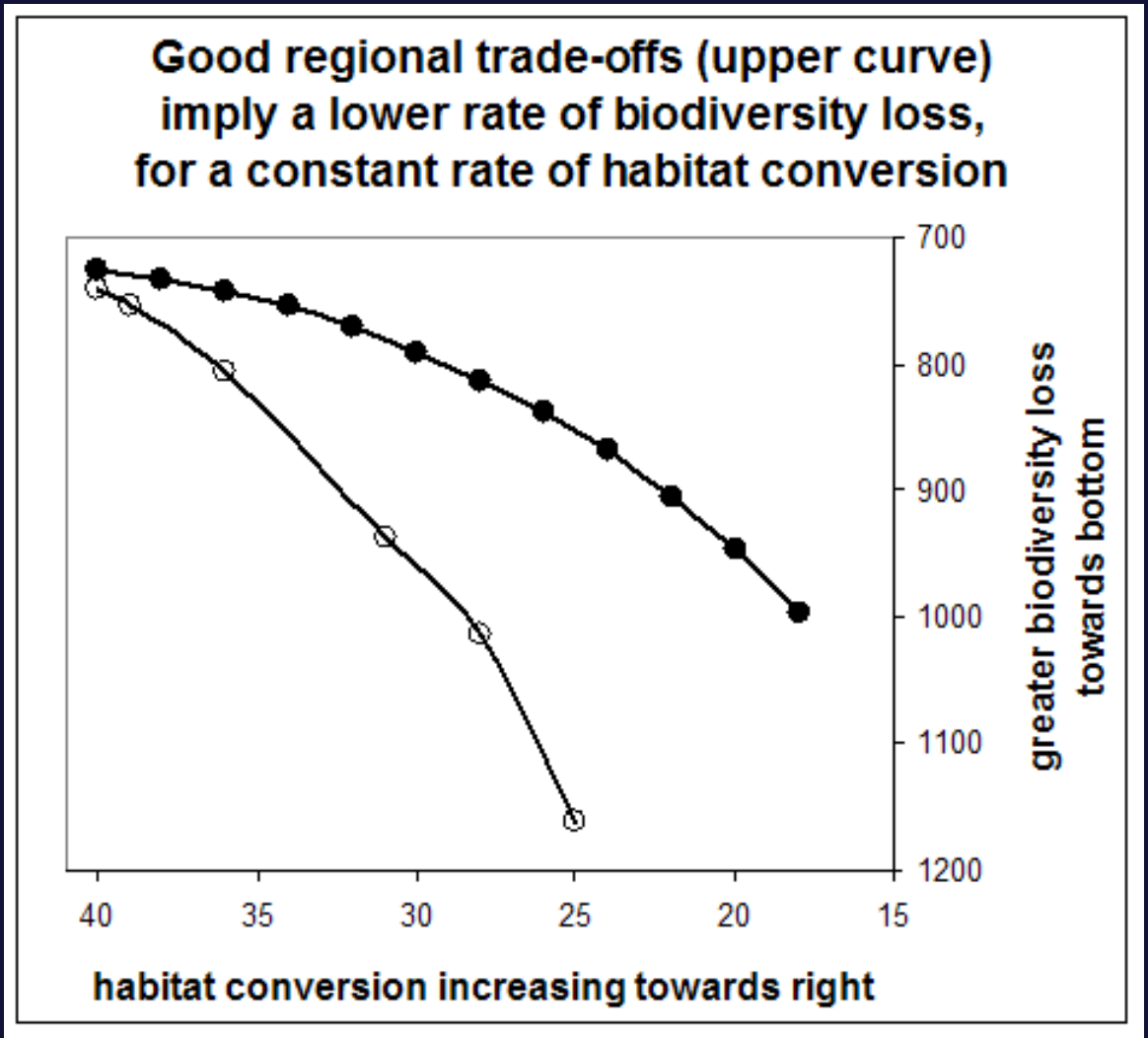
Ecosystem services

- Seems to dominate ideas on post-2010 targets
- Is this all that matters?
- Sometimes species counts are considered, as capturing ethical values, existence values etc.
  - But this misses the point.....

Evosystem services

- Consider the "evolutionary system" and its services
- This better captures "option values" or future, often unanticipated, benefits/uses
- Species counts may measure this, but another good way is to measure the evolutionary history that is preserved
  - Indicates known products and scope for finding new products not yet known
  - Also indicates capacity for producing new diversity, including in response to global changes

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



The phylogenetic diversity measure, "PD" can contribute to this strategy

Faith, DP & Ferrier S (2005)
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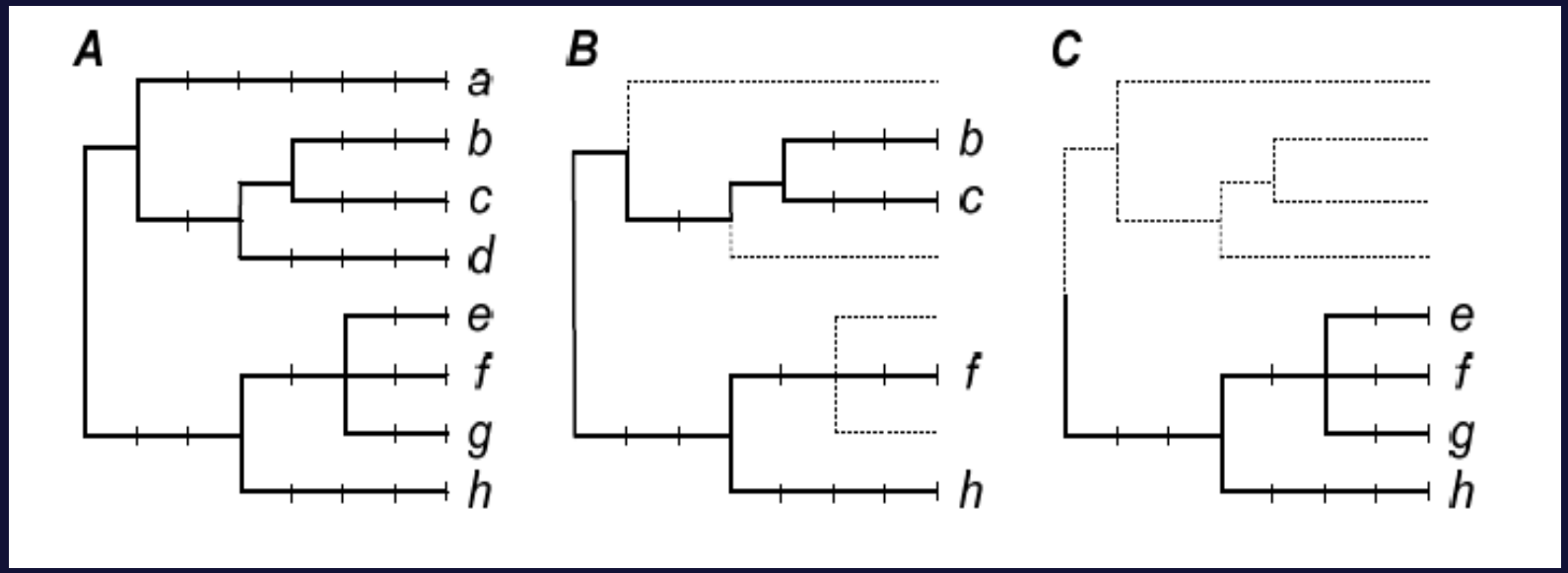
PD – phylogenetic diversity Faith 1992

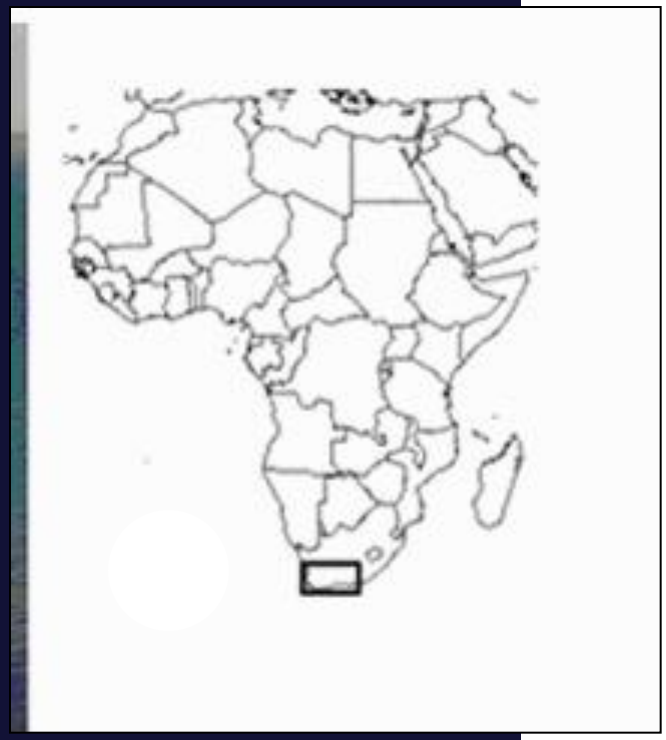
PD of a set of taxa = length of spanning path of the set on the phylogeny
(how much of the tree travelled over if connect up those taxa on the tree)



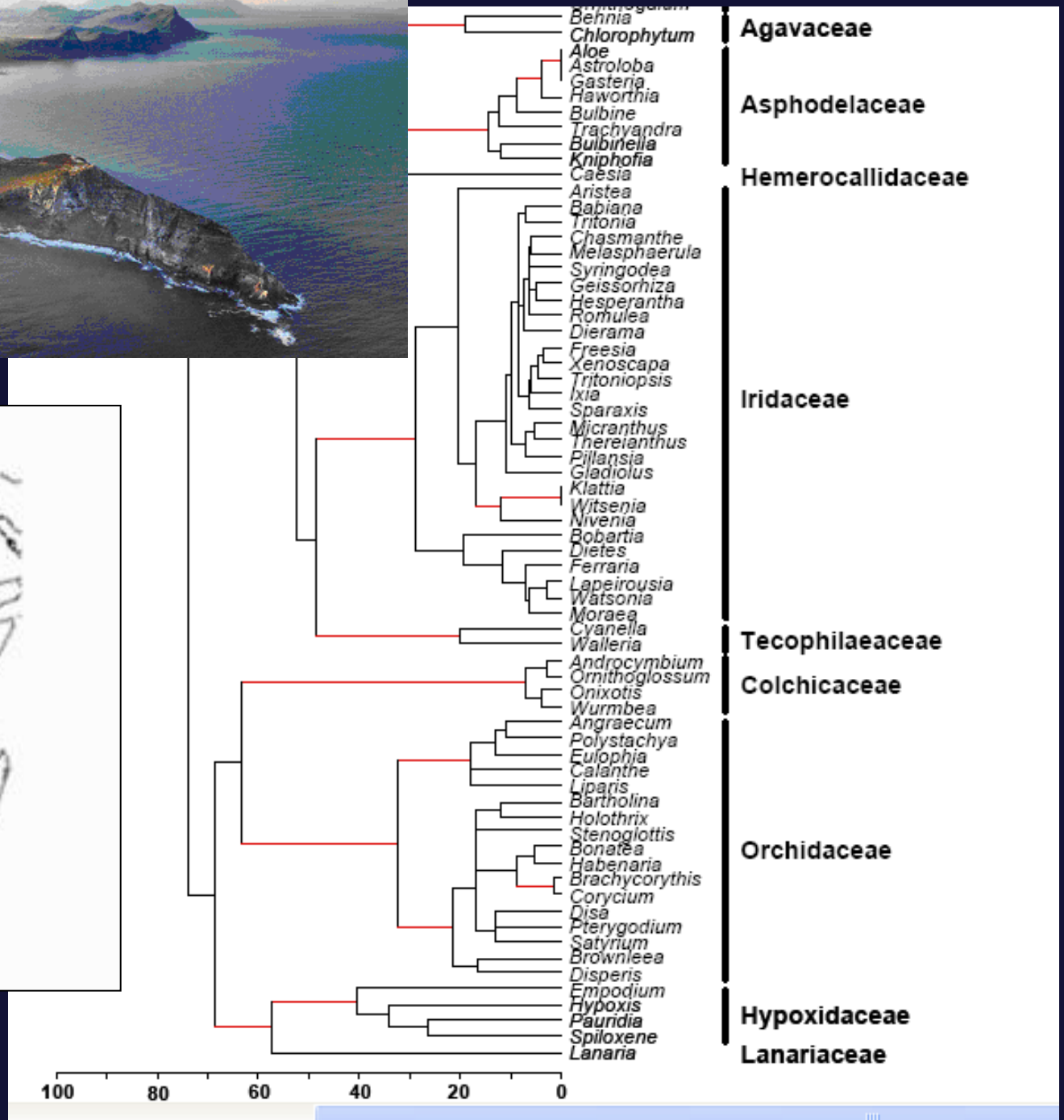
Tick marks along the branches = character changes

PD measures “feature diversity”

scenario *B* represents more feature diversity

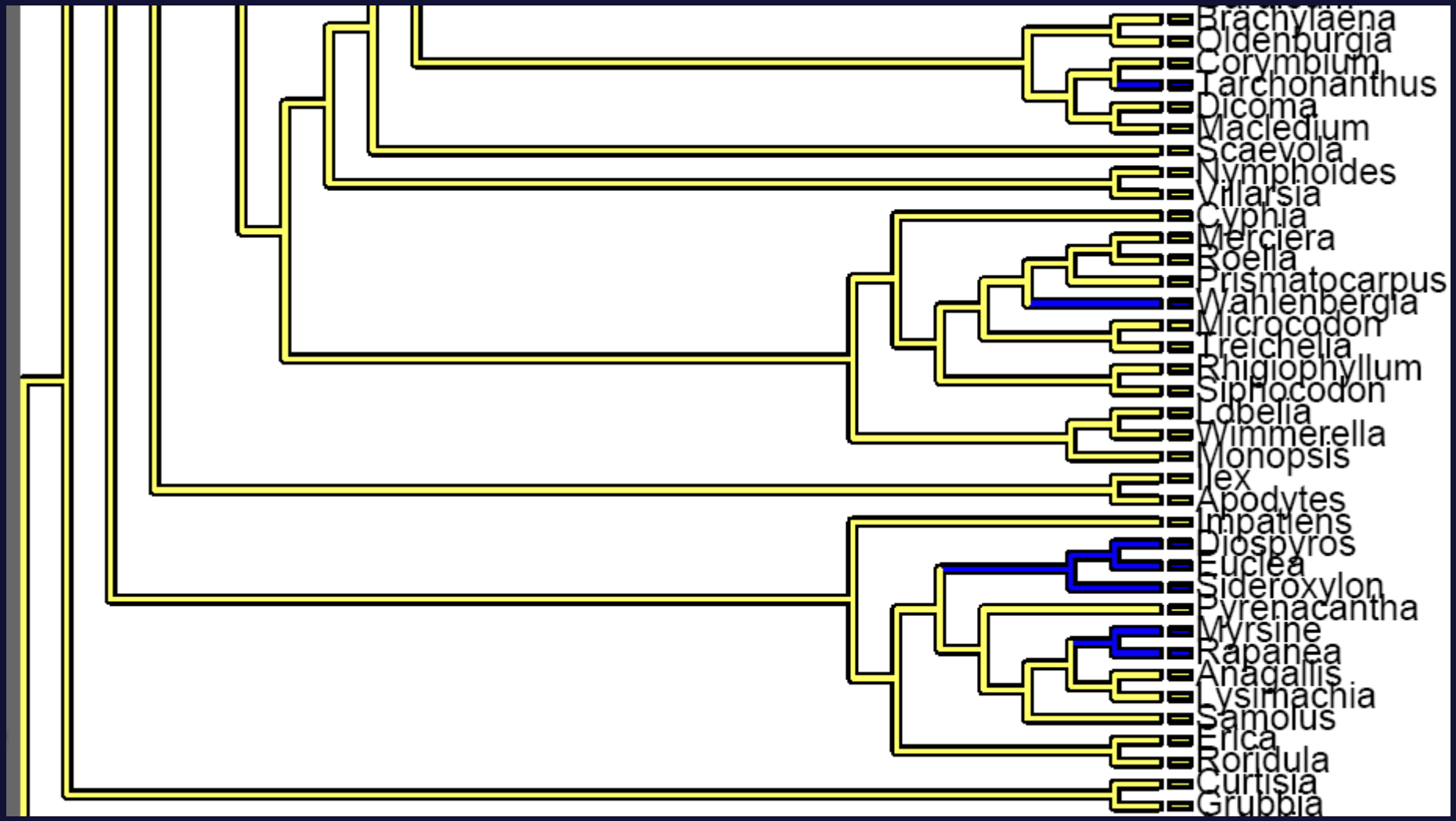


Forest et al. (2007)
Nature



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)

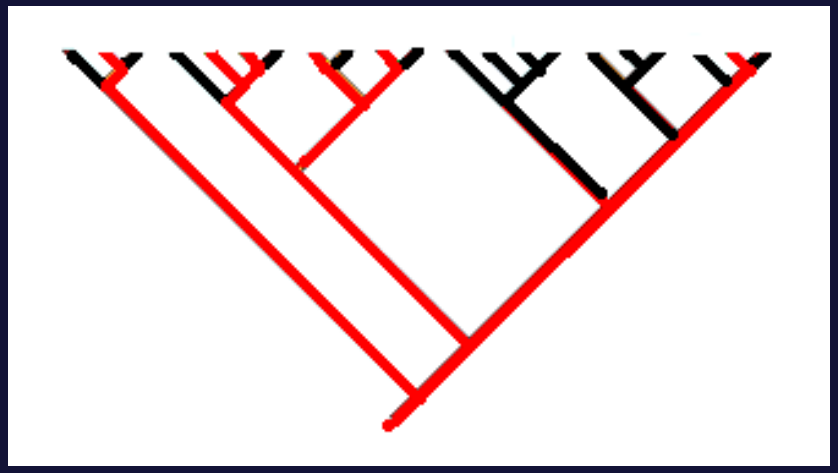


Will the impacts of climate change on PD be large or small?

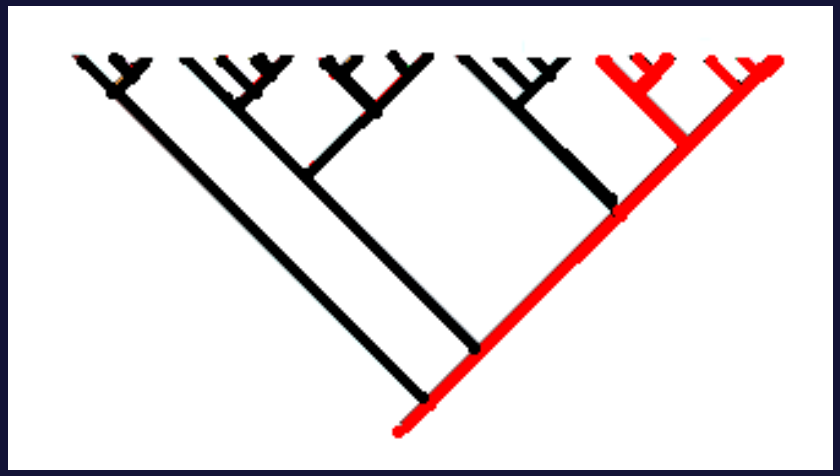
Yesson, C. and A. Culham. 2006.

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

- *large* loss of PD or evolutionary potential

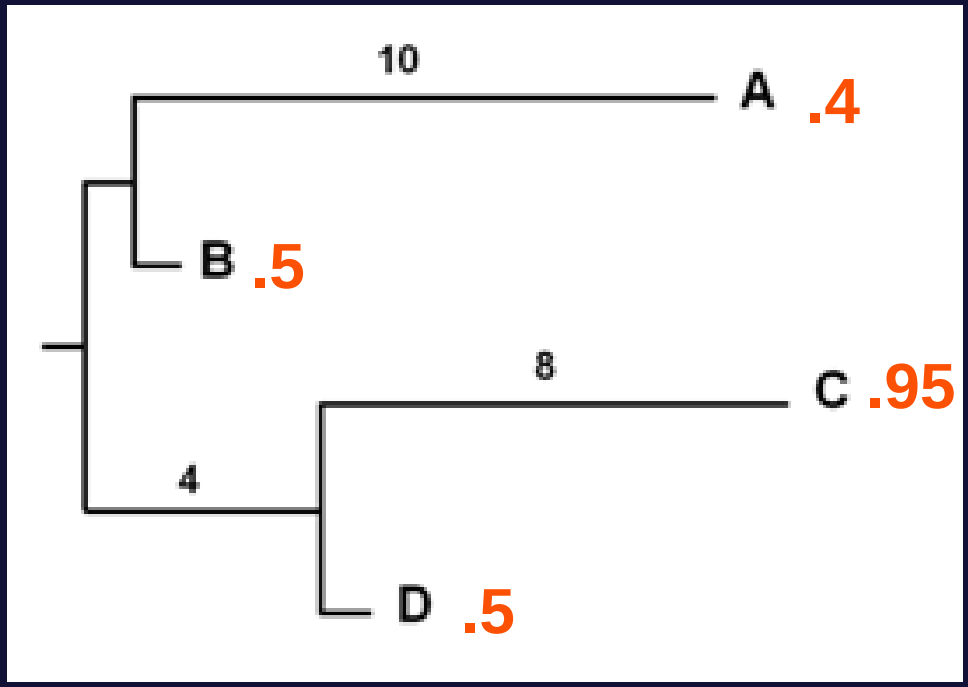


red = surviving evolutionary potential



PD and probabilities of extinction

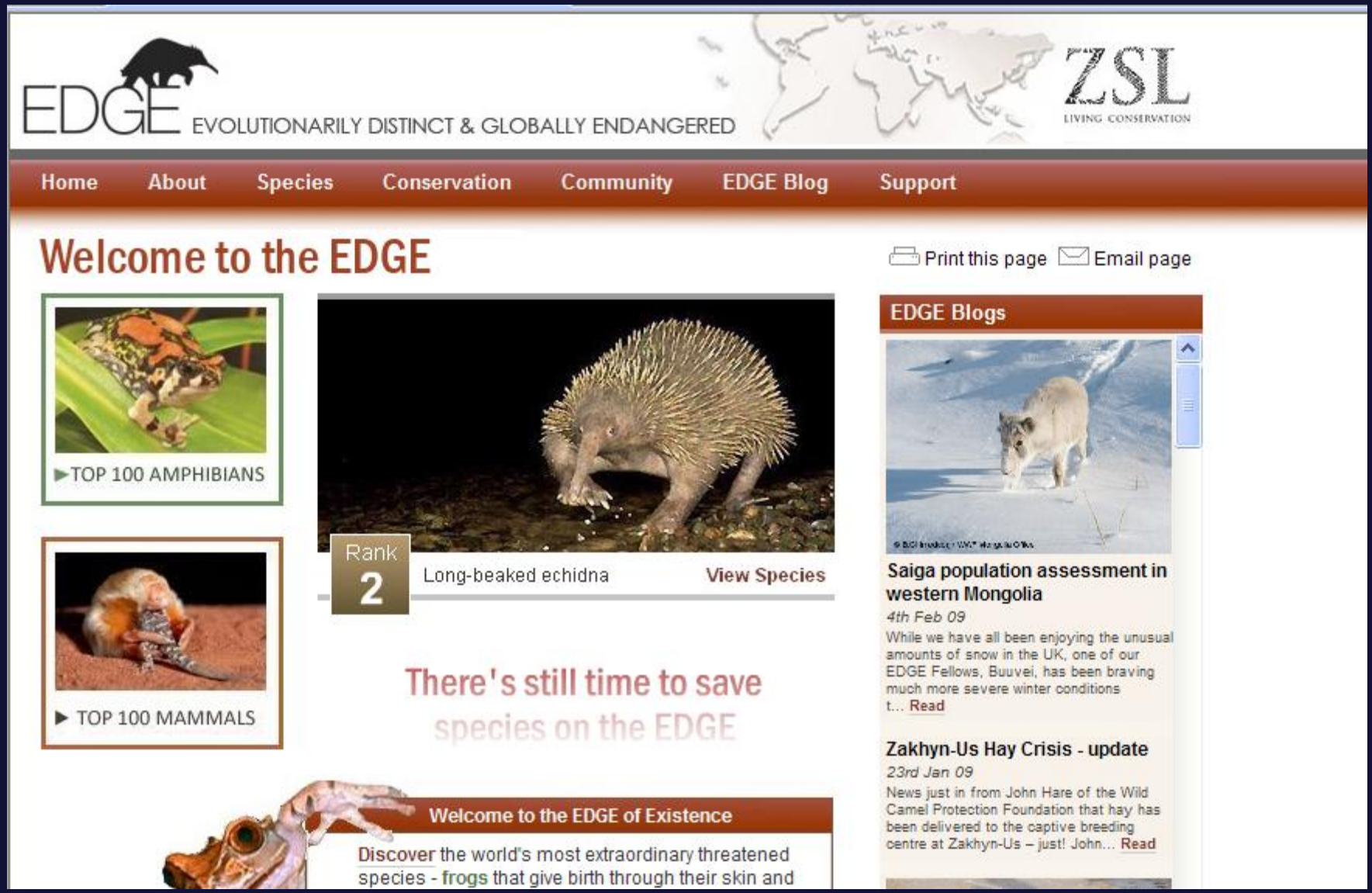
Probabilistic PD
- Red numbers are estimated probabilities of extinction



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*

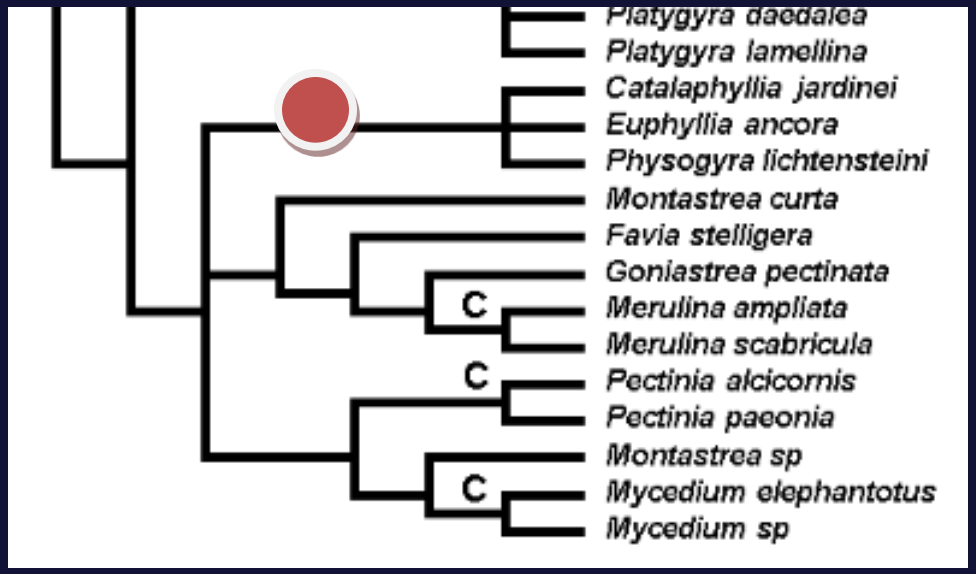
www.edgeofexistence.org



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

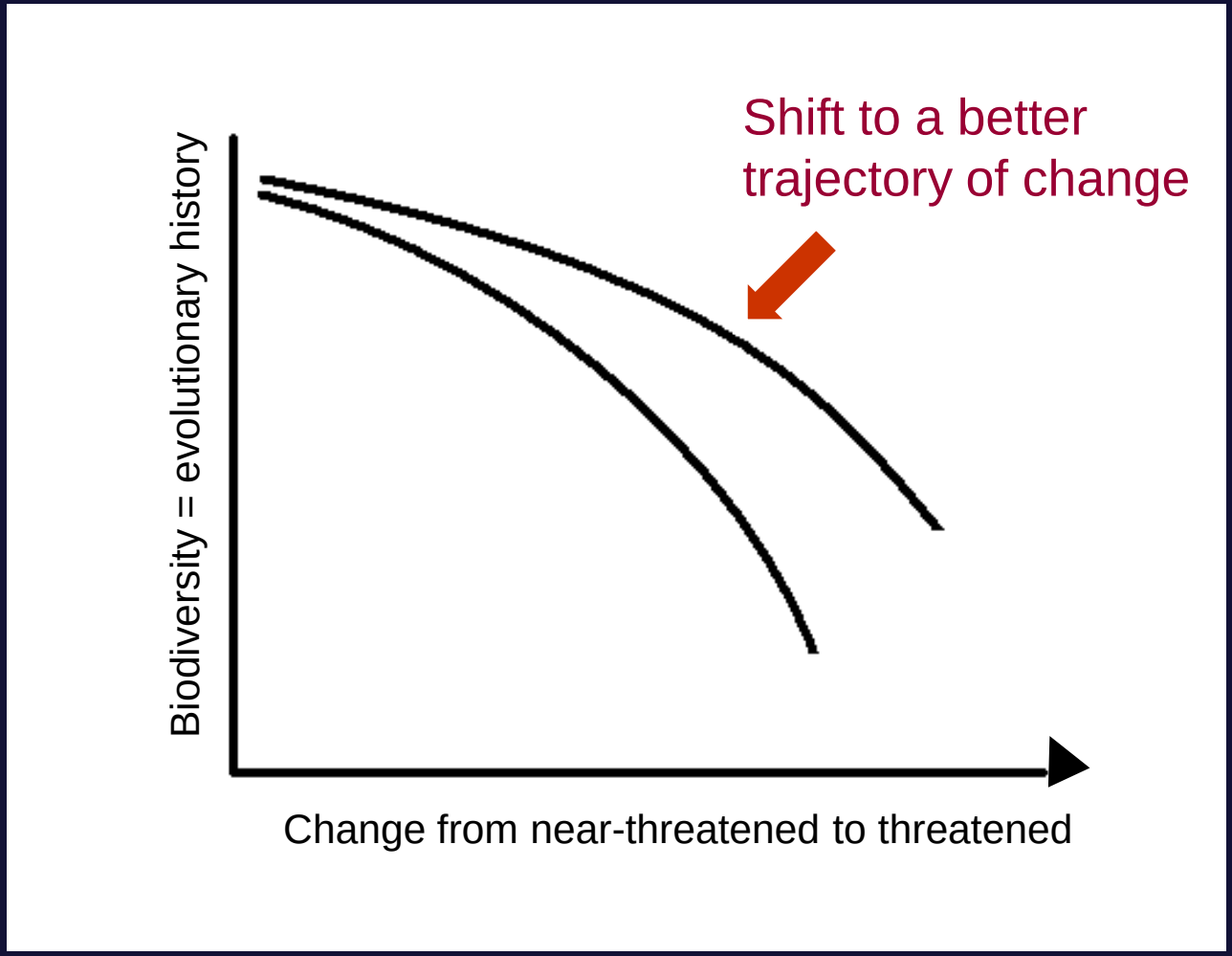
- Number of threatened species –
- "the proportion of corals (57.8%) exceeds that of all terrestrial animal groups assessed to date.."
- Carpenter et al (2008) *Science*



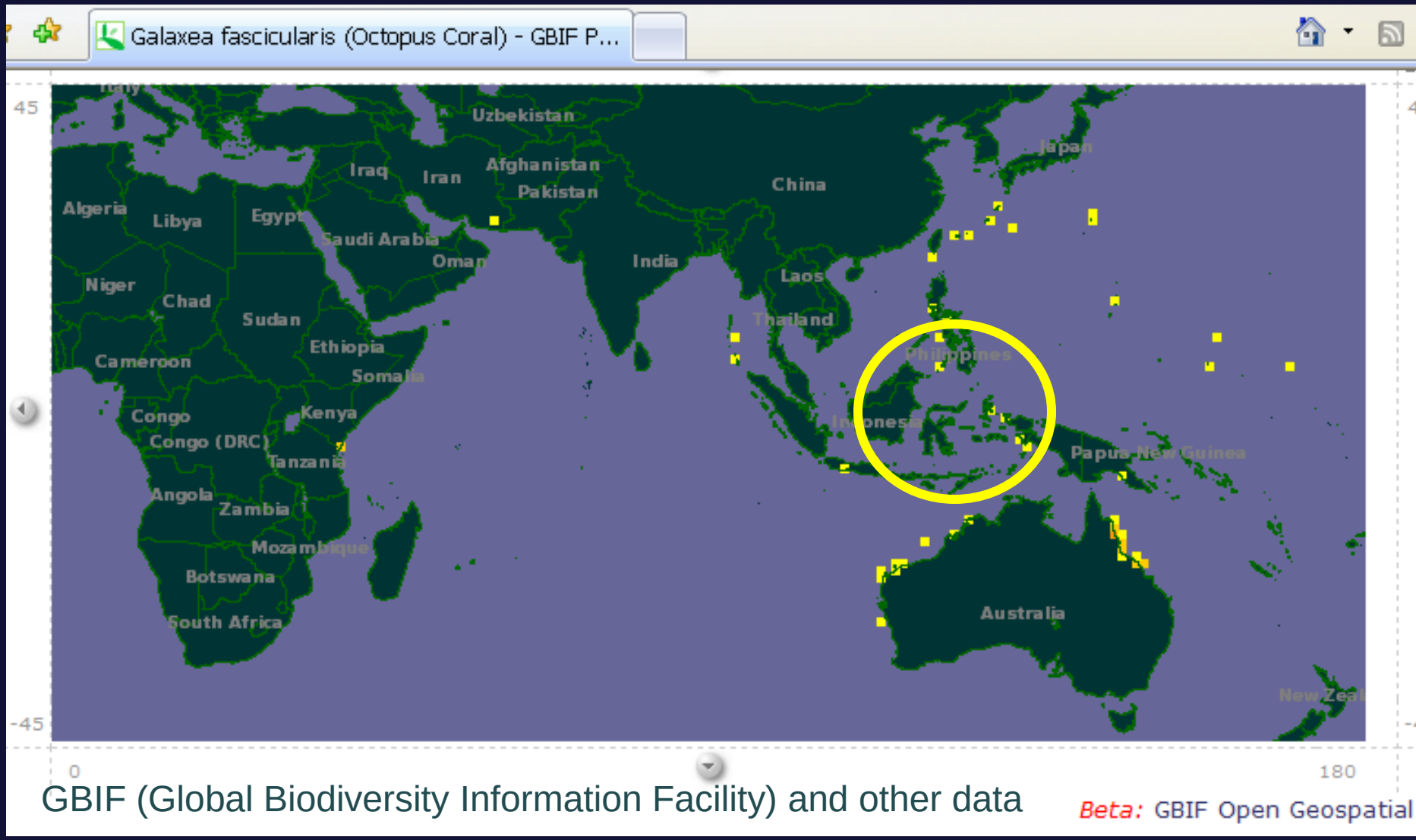
many examples where entire clades (existing families and genera) fall into IUCN threatened classes

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

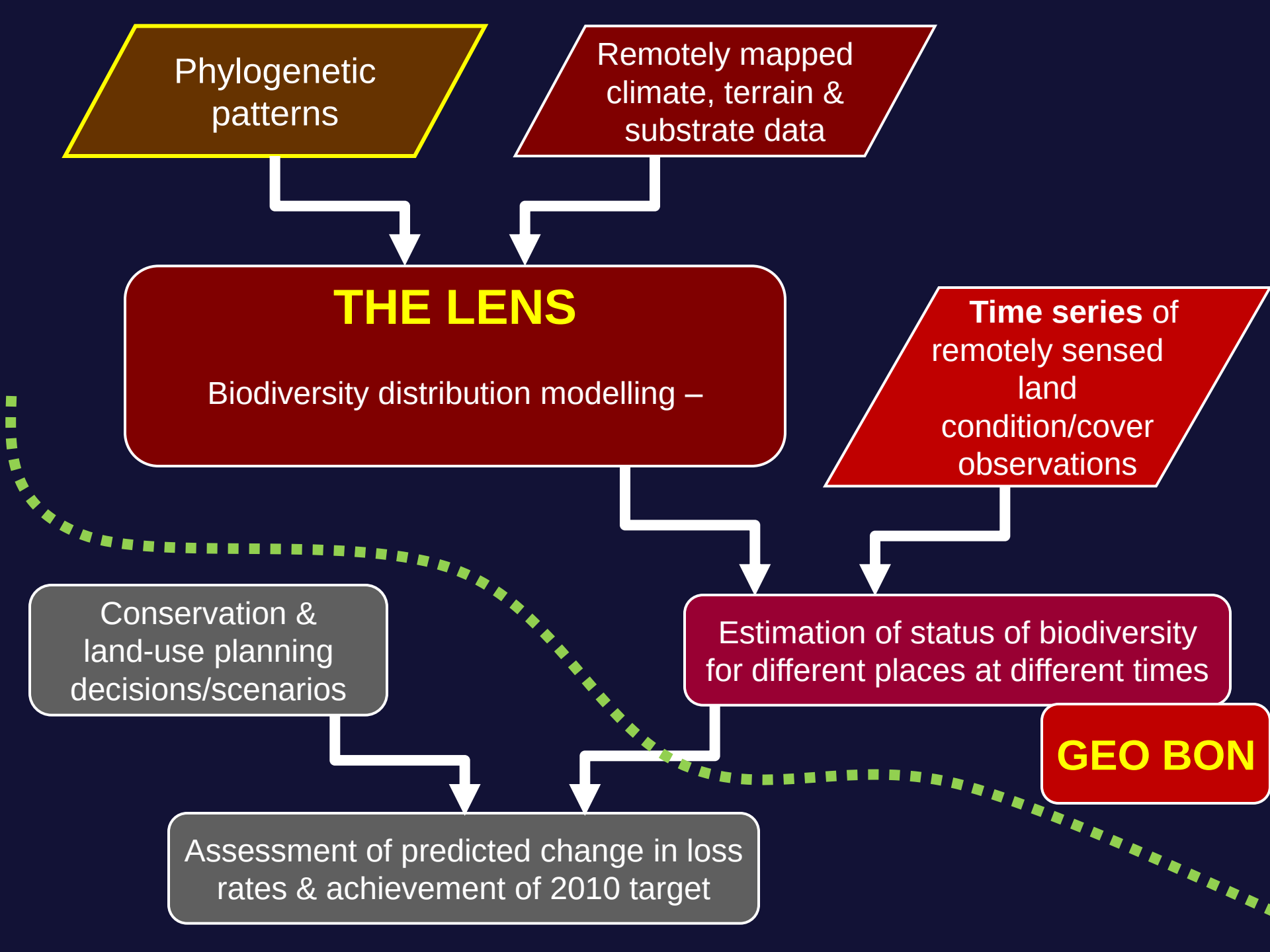
Reducing the slide from near-threatened to threatened status



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



A global Biodiversity Observation Network: how do we monitor genetic/phylogenetic diversity?


Phylogenetic patterns
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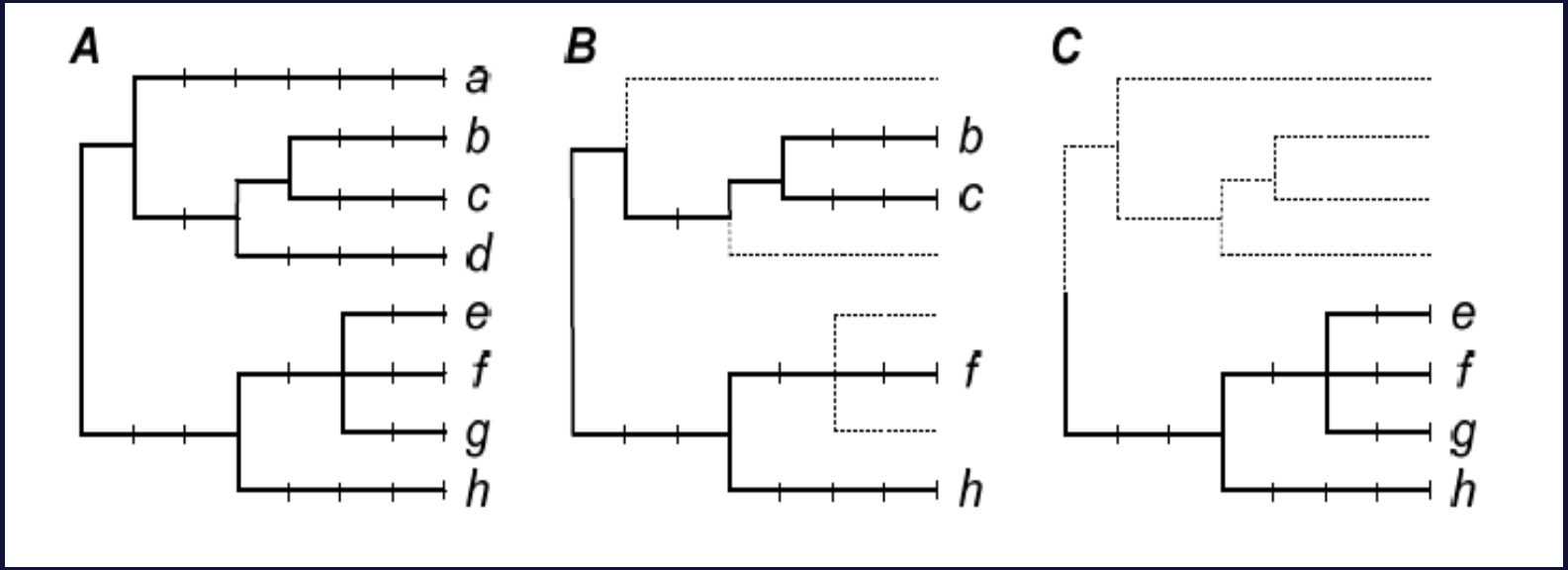
GEO BON
Assessment of predicted change in loss rates & achievement of 2010 target

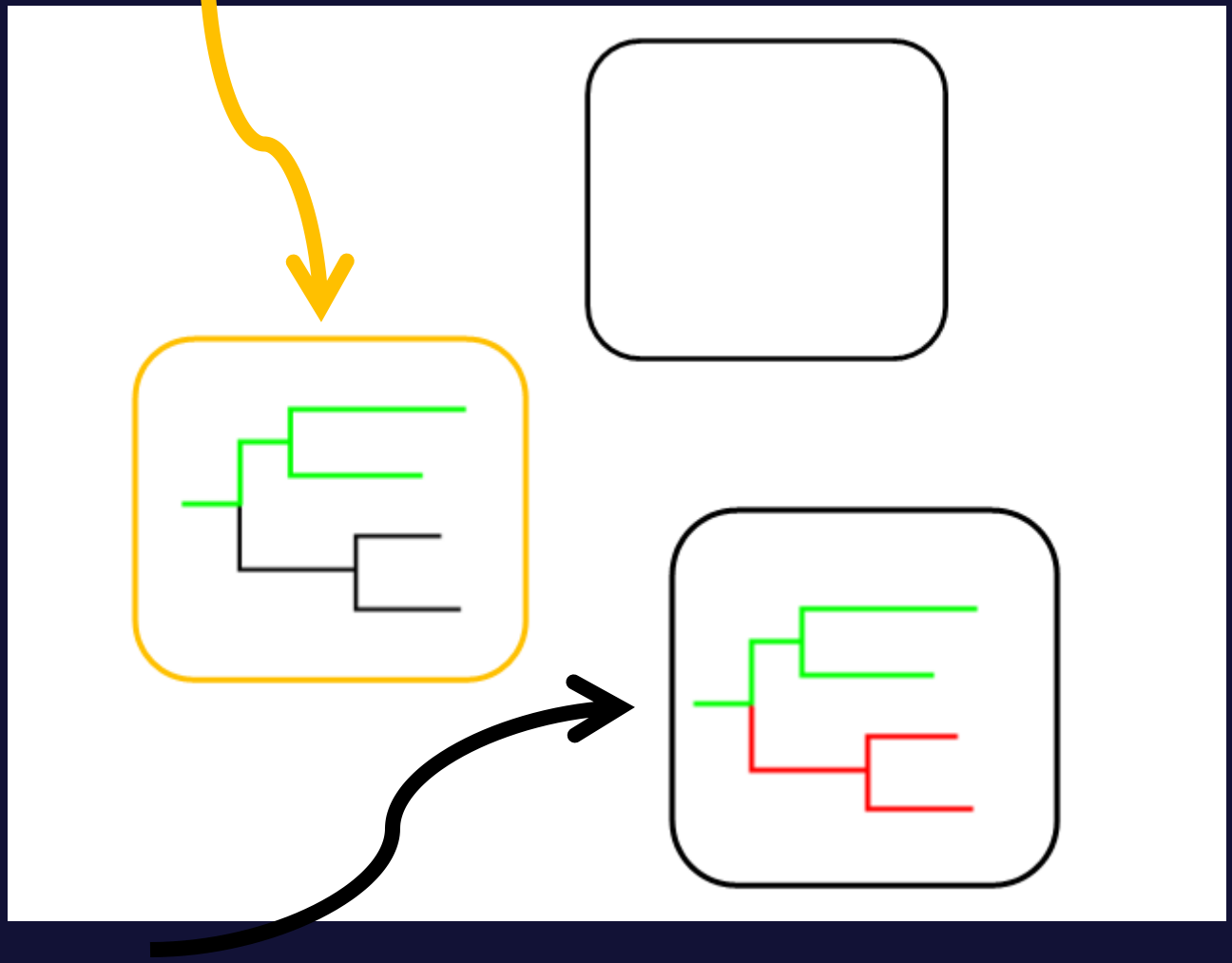
Phylogenetic ecology based on PD and feature diversity



We can take any conventional species-level index and re-express as a PD-based measure

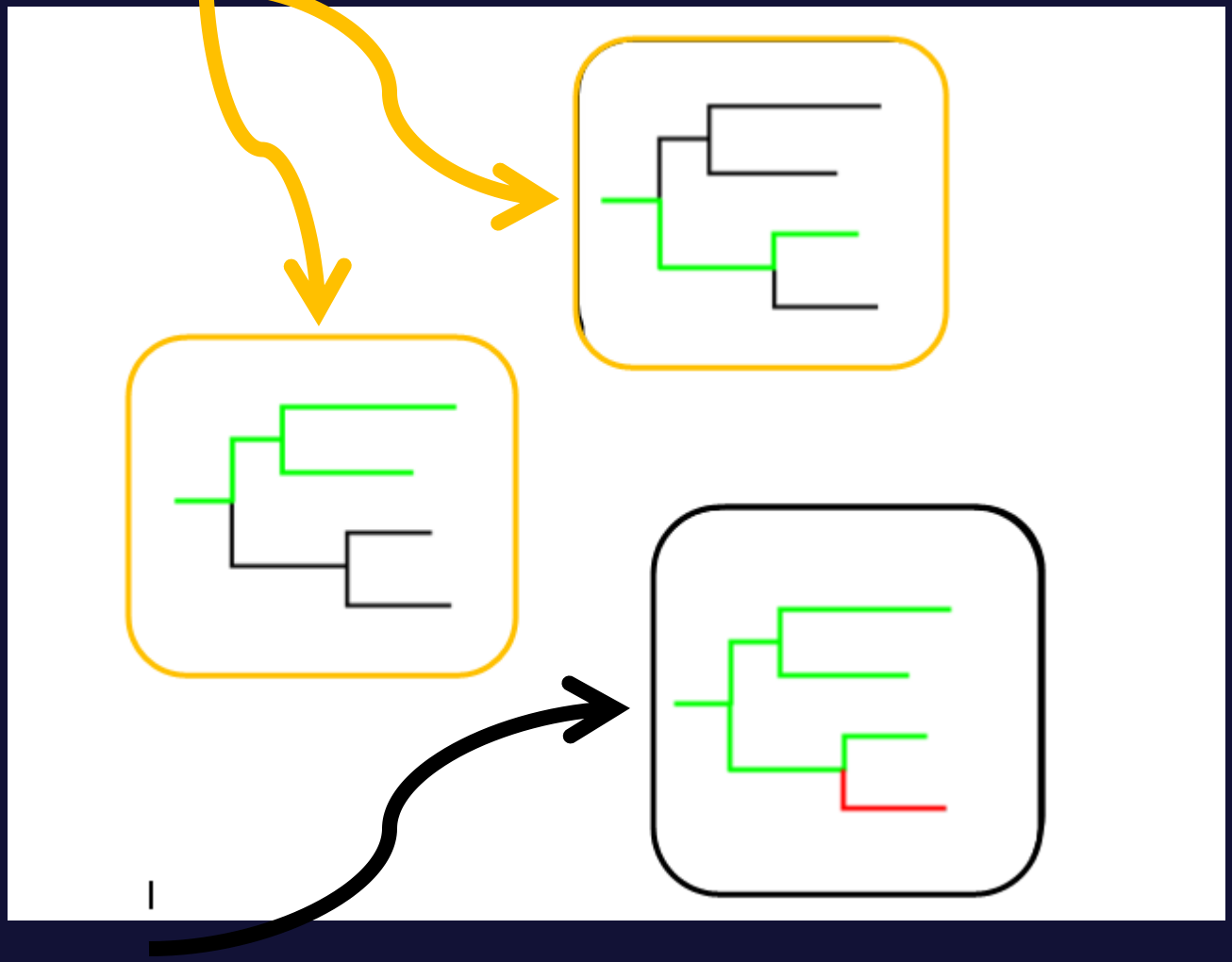
- Richness
- PD-Complementarity (gains & losses)
- PD-Endemism (e.g. Faith et al 2004)
- PD-Dissimilarity...

Orange protected area, with protected PD in green



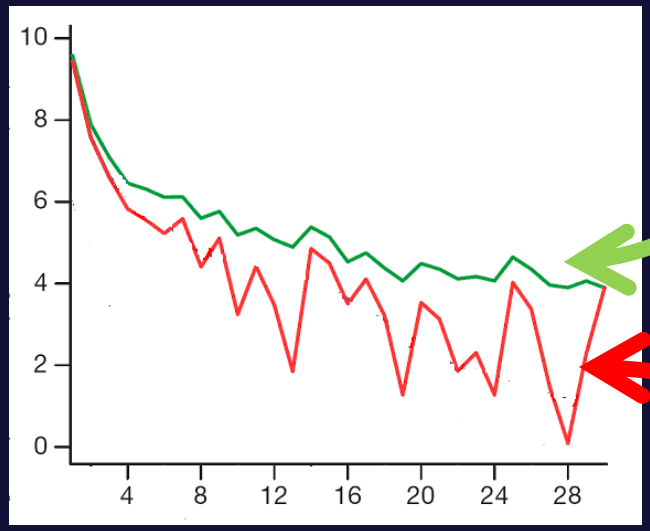
For this region, PD complementarity in red

Orange protected area, with protected PD in green



For this region, PD complementarity in red

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



the PD that you could gain

does

not

match

the PD that you do gain

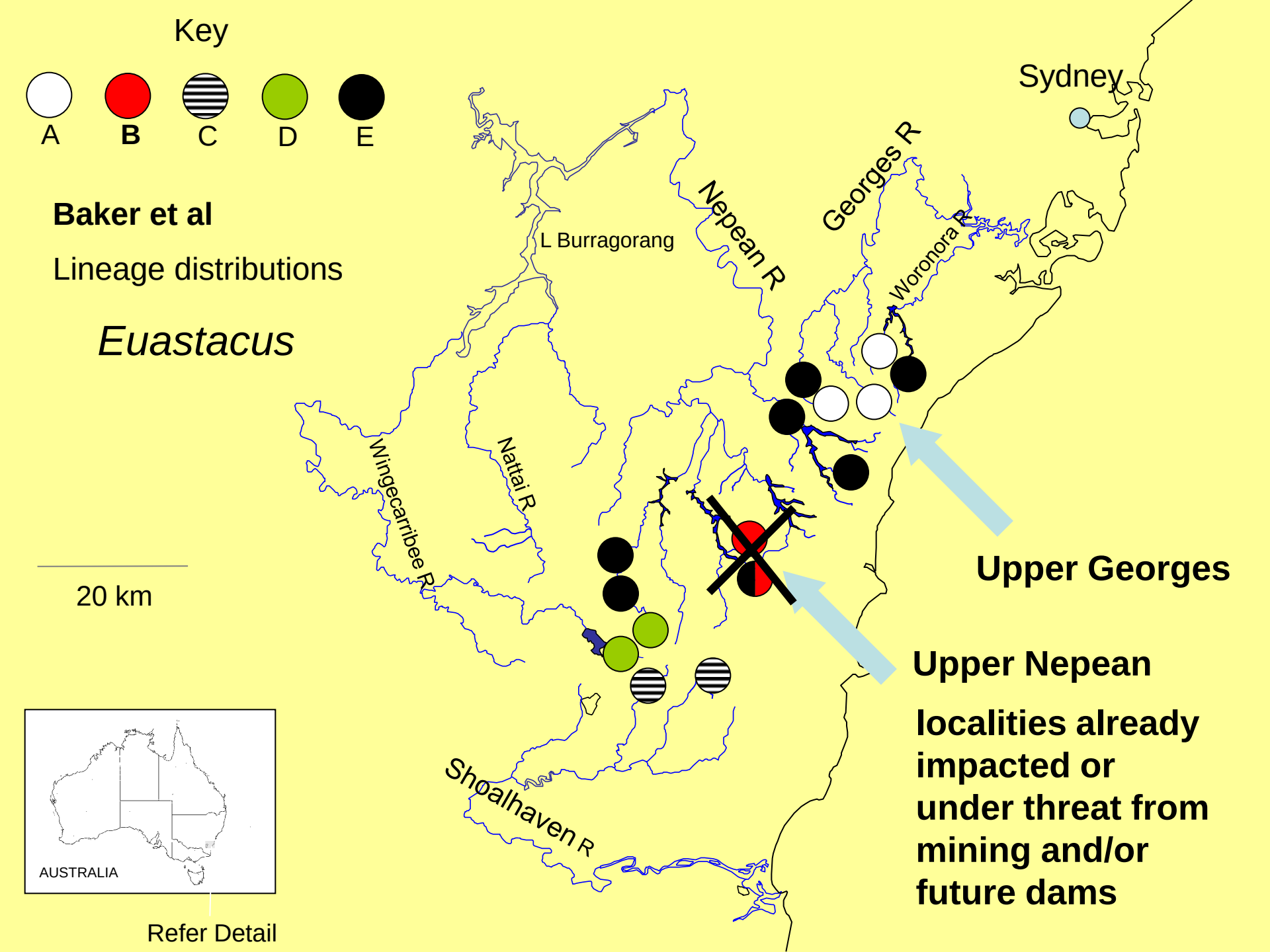
Forest et al
Nature 2007

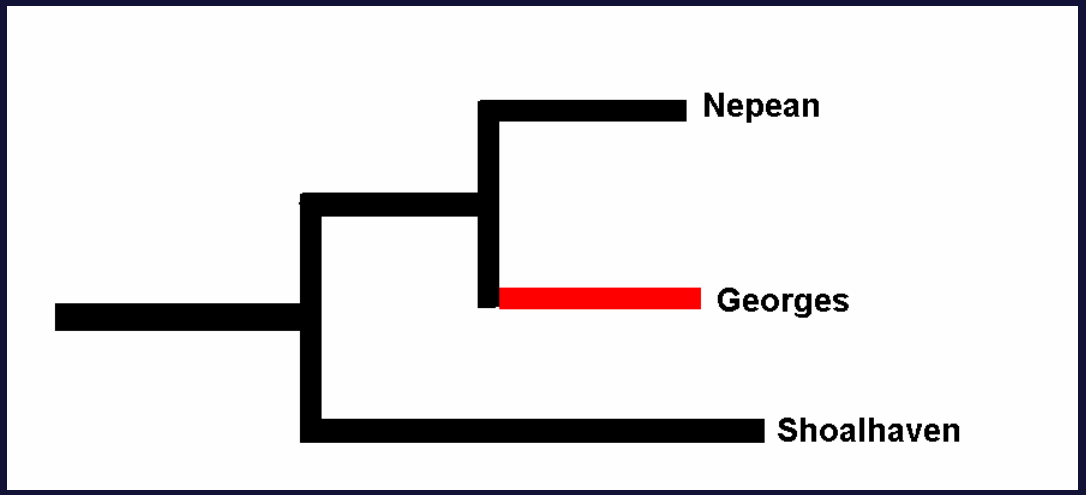
PD conservation planning example

- 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
D
E
Baker et al
Lineage distributions
Euastacus
Sydney
L Burragorang
Nepean R
Georges R
Woronora R
Wingecarribee R
Nattai R
Shoalhaven R
20 km
AUSTRALIA
Refer Detail
Upper Georges
Upper Nepean
localities already impacted or under threat from mining and/or future dams

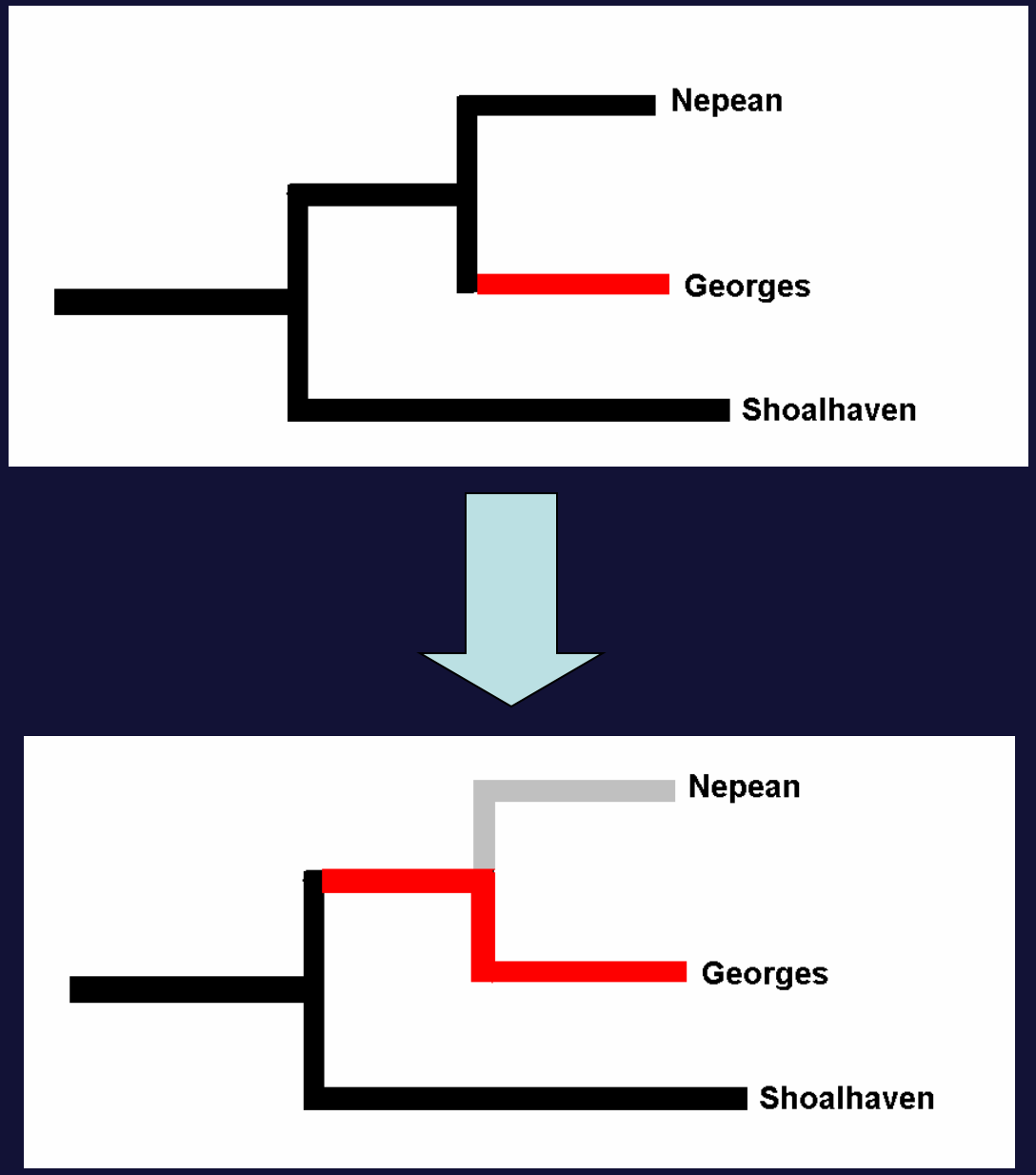


Upper Georges River's unique contribution to phylogenetic diversity is shown in red

Consider consequences of loss of diversity,

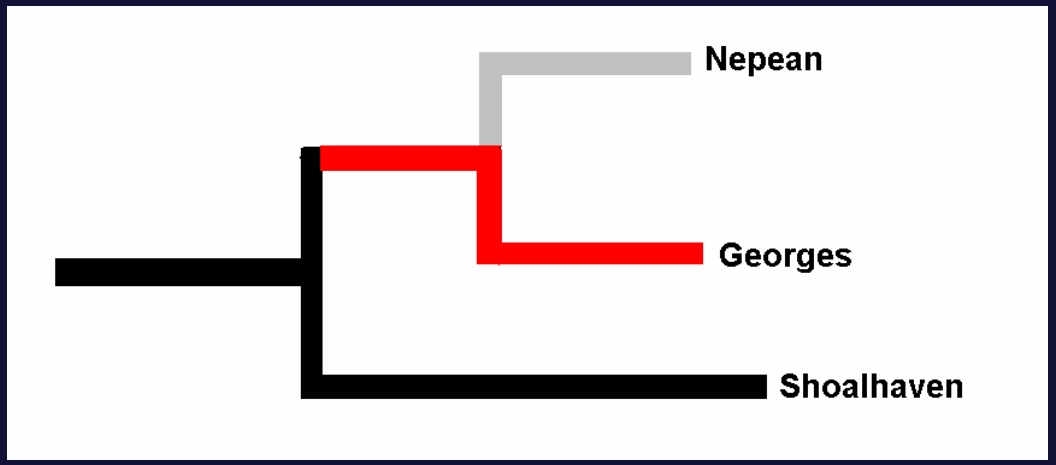
from the human impacts on Upper Nepean River

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



see also 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



New technologies such as DNA barcoding can help get more data for more taxonomic groups….

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 complementarity (marginal gains and losses)
- Not only do we by-pass species, but we may gain a boost in prediction of general biodiversity patterns

See e.g. Faith and Williams 2005; Faith and Baker 2006

the animal kingdom
Barcode of Life

example

SPECIMEN DATA -Collembola of Arctic Canada [IHCO]

Identification :	***Entomobrya comparata***
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

▲ **Collection Location [click on image to zoom]**

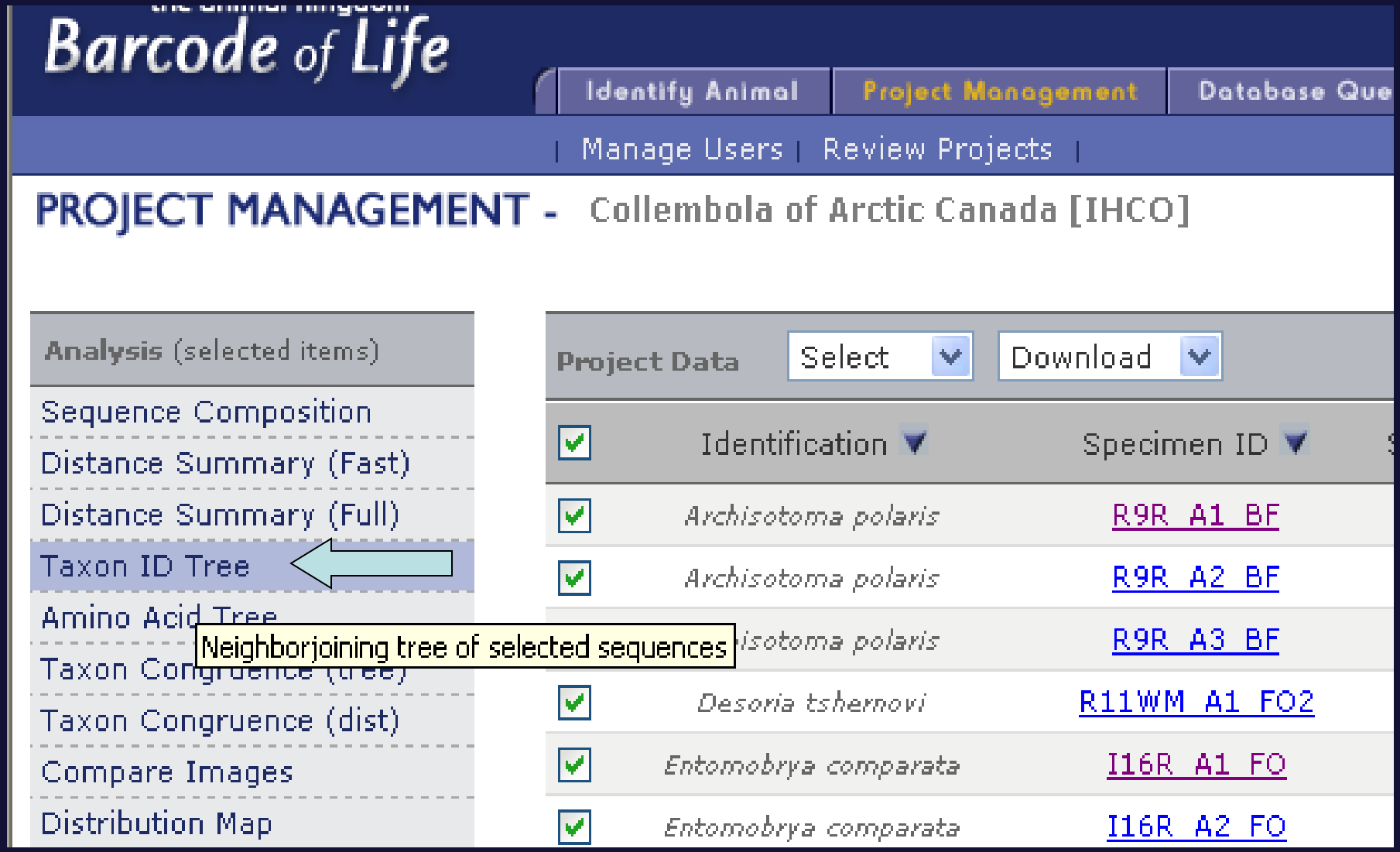
GenBank Accession :	AY665328
Museum Accession :	I16R_A1_FO
Institution Holding :	University of Waikato
Collector :	Ian Hogg
Date Collected :	2001-08-04
Identifier :	Ian Hogg
Common Name :	
Taxonomy :	phylum - Arthropoda class - Ellipura order - Collembola family - Entomobryidae genus - *Entomobrya* species - *Entomobrya comparata*

Notes :

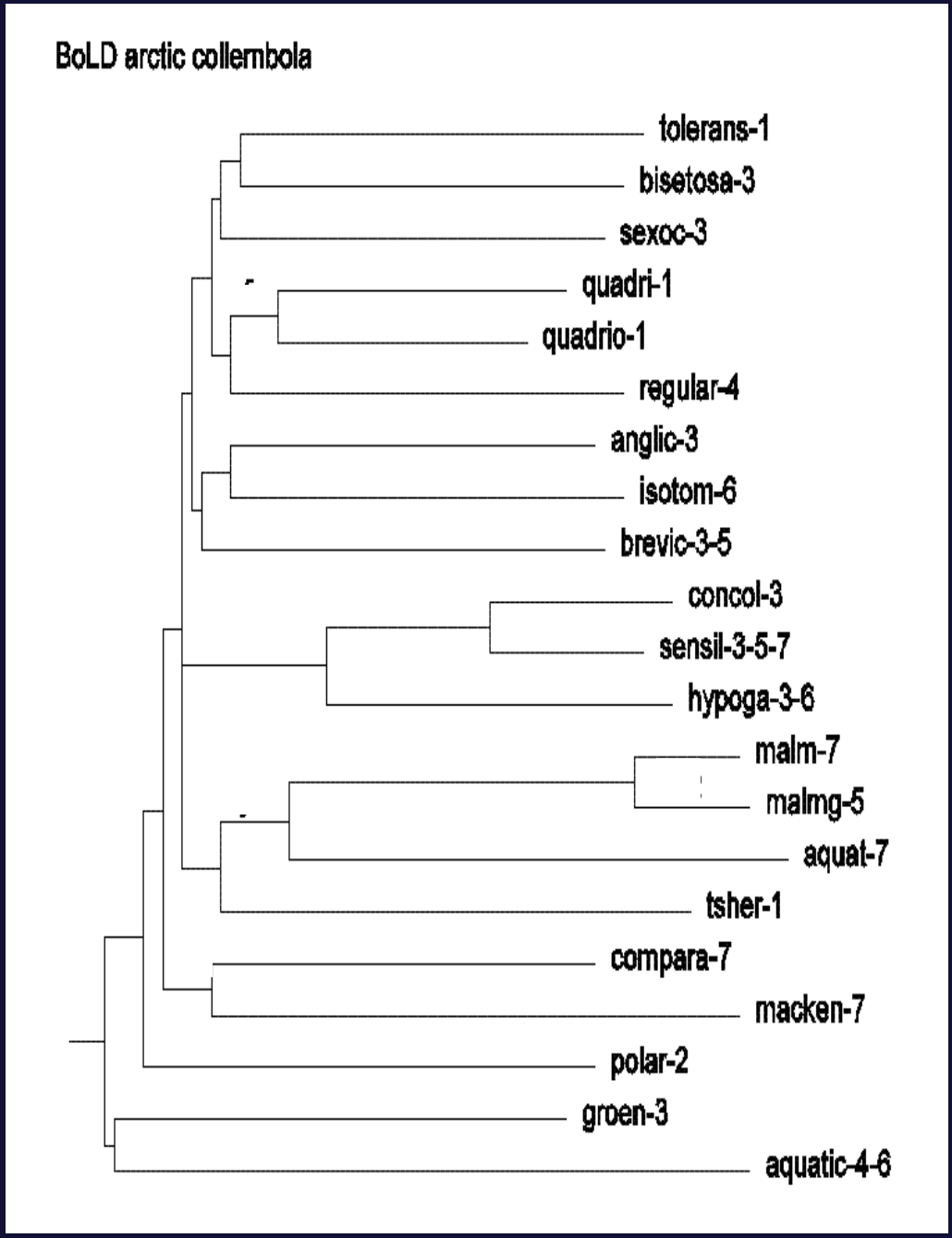
Stock image - Lateral View

Click on image to view images at larger size

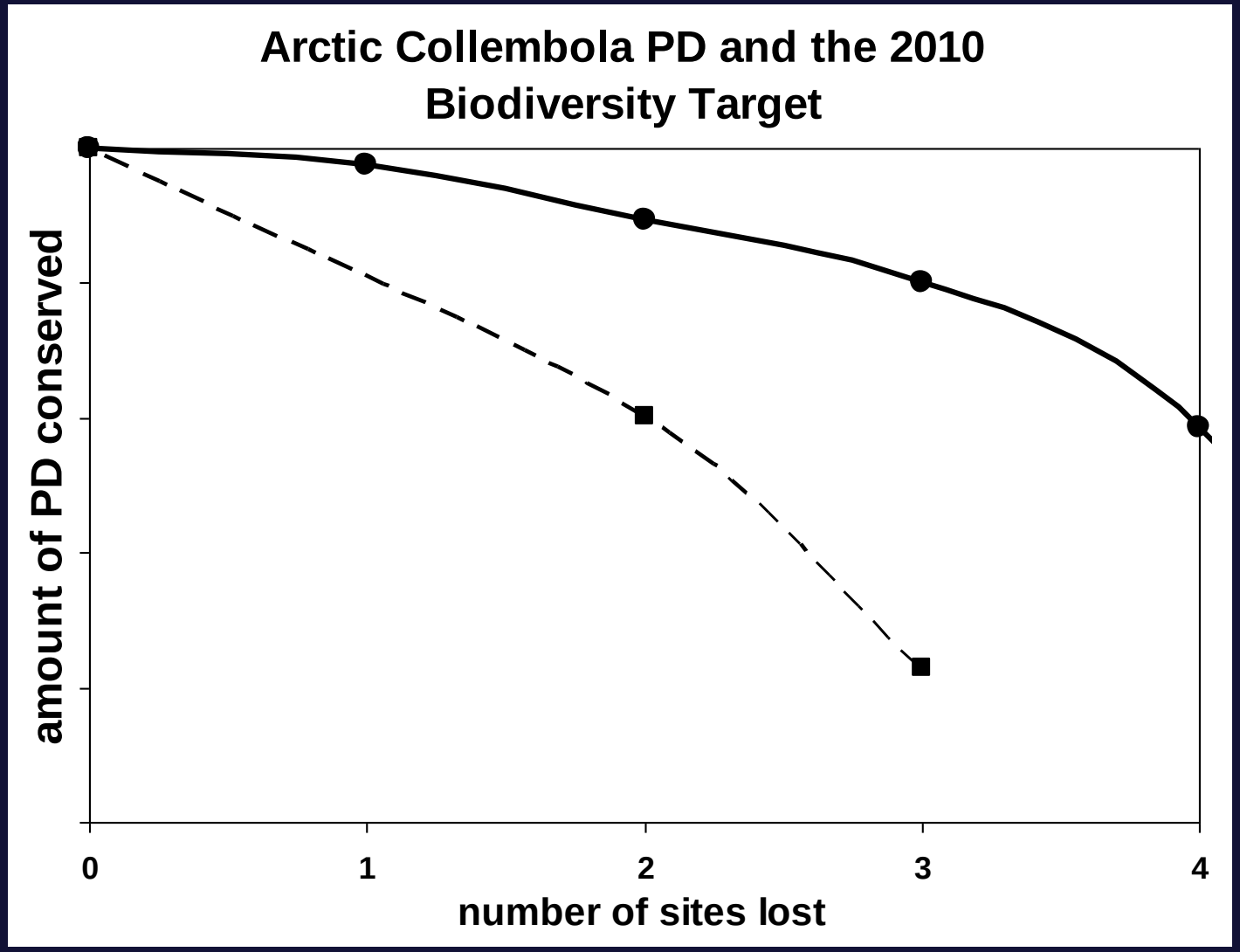
Barcoding and phylogeny estimates



Numbers are sites



Prospects: a toolbox for application to “phylogenies” from large scale DNA barcoding programs



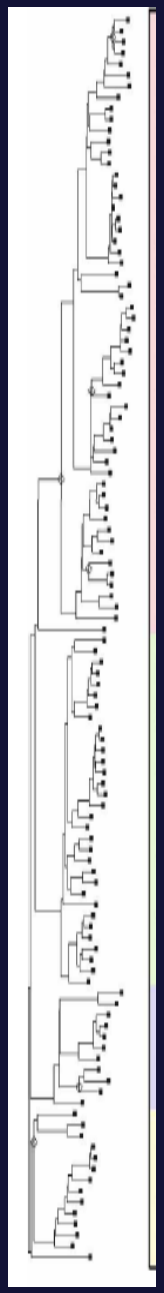
Faith, DP (2008) Phylogenetic diversity and conservation. In (eds: SP Carroll and C Fox) *Conservation Biology: Evolution in Action*. Oxford University Press.

PD-complementarity values

often missing information for many sites...

Lozupone and Knight 2005, Ferrier et al 2007 extend PD to produce dissimilarities between sites. These are linked to environmental variables

Microbial ecology



Big trees,

Few taxa,

Many samples

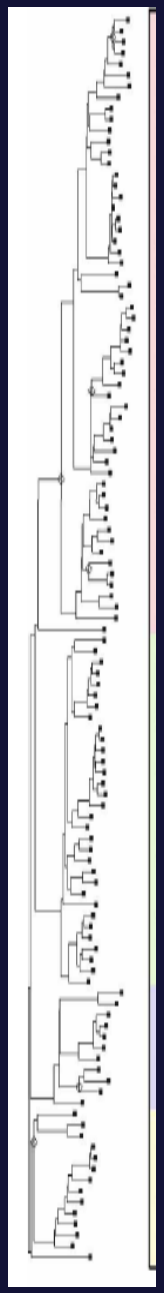
Have used PD to quantify biodiversity -

“The explosion of 16S rRNA gene sequence data in the public databases, in conjunction with new high-throughput sequencing technologies such as pyrosequencing... allows us to address a vast range of fundamental questions about microbial communities on an unprecedented scale.”

“soil, which is often described as one of the most diverse types of microbial communities based on species-based diversity measures, has below average PD in the bacteria”

(Lozupone et al., review, 2008)

Microbial ecology



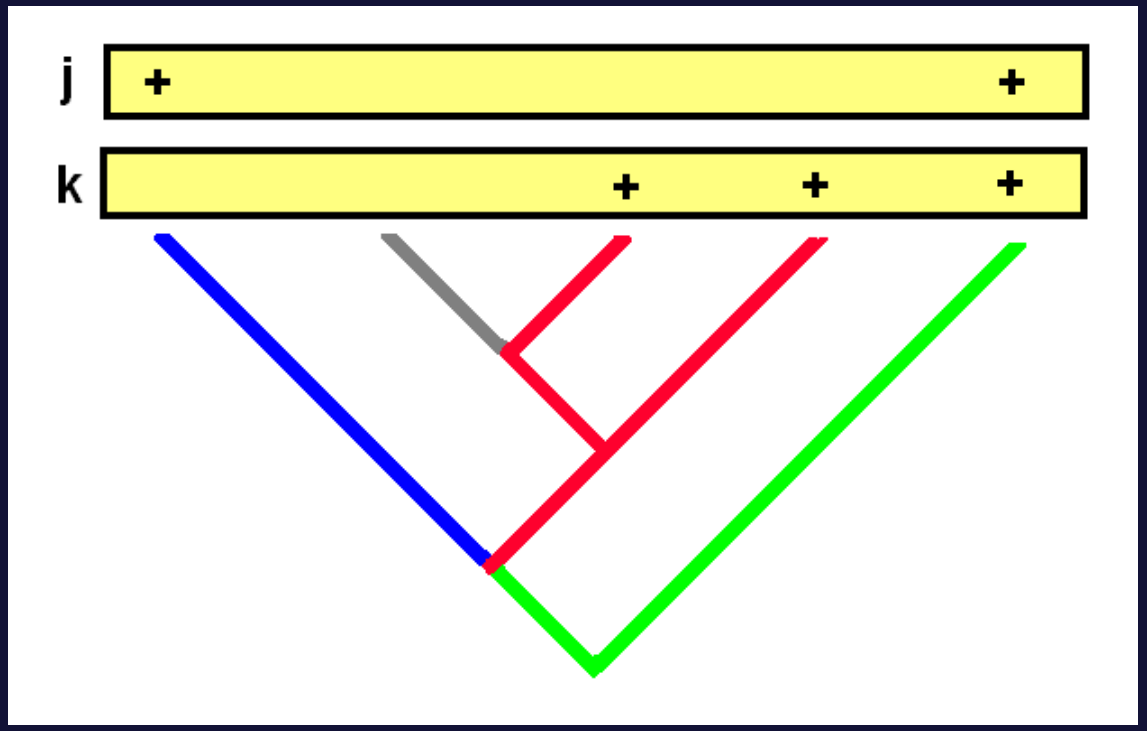
Big trees,

Few taxa,

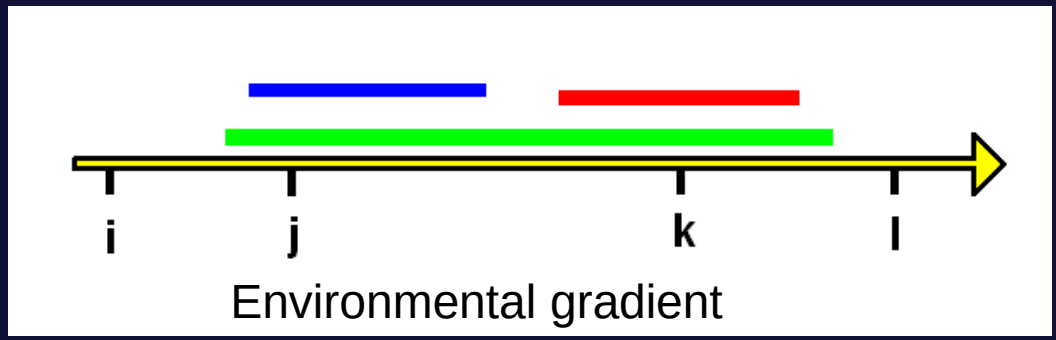
Many samples

two sample sites j and k

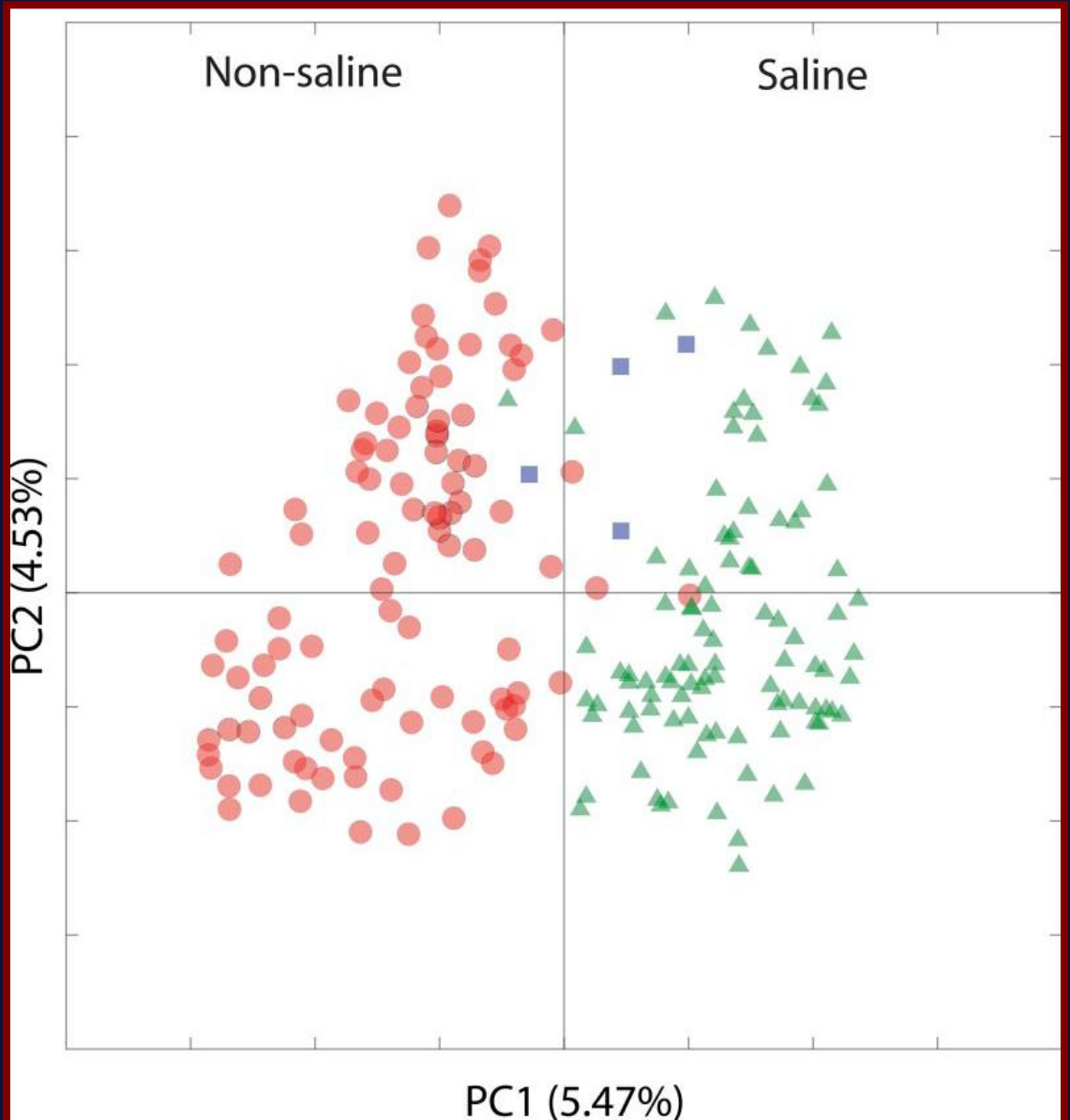
j and k dissimilar if lots of red and blue



PD-dissimilarities reflect distances along gradients

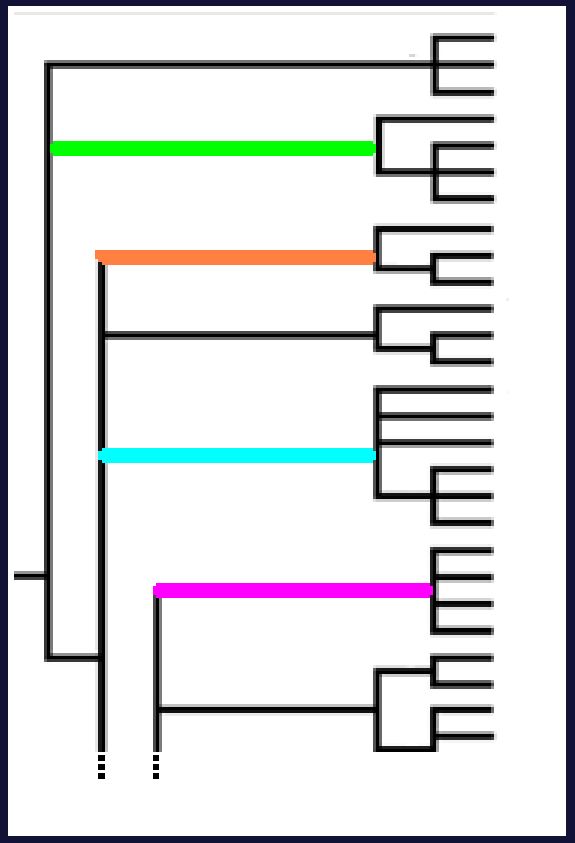


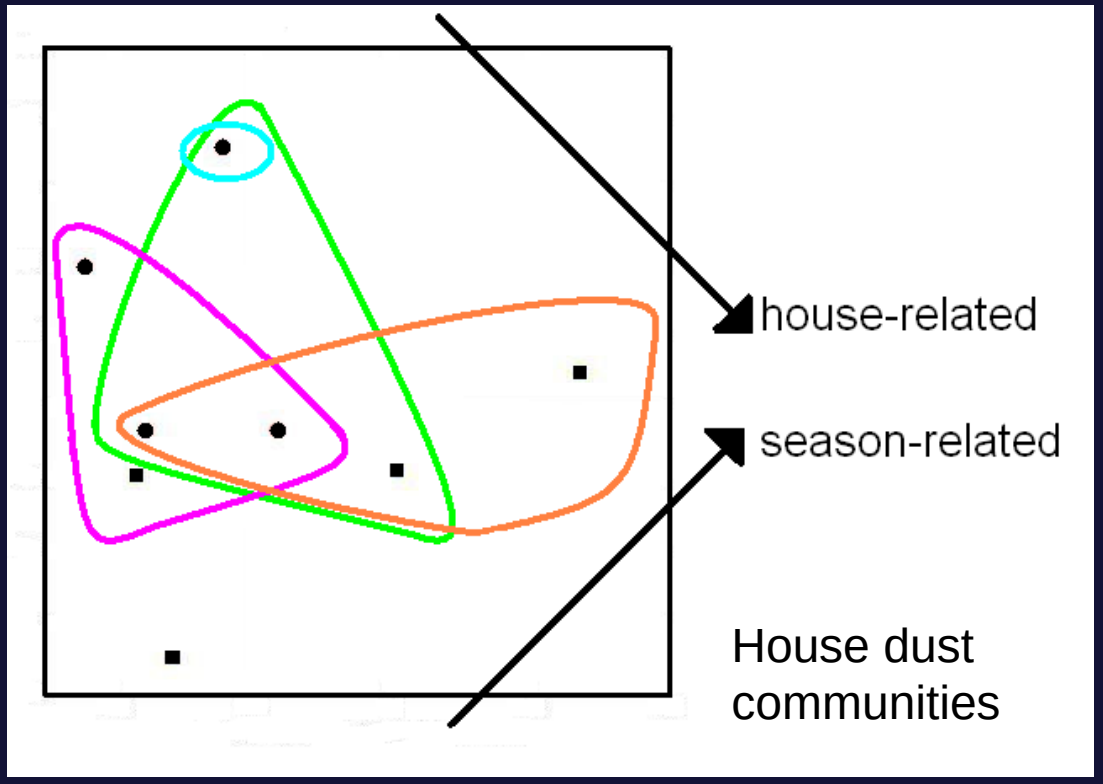
Lozupone and Knight ‘s “phylogenetic beta diversity” for global bacteria samples



- Use phylogenetic dissimilarity (“UniFrac”) among samples
- Discover that the major environmental determinant of microbial community composition is salinity

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





Faith, D. P., C. A. Lozupone, D. Nipperess, R. Knight (2009) A general model linking evolutionary features and environmental gradients supports broad applications of microbial ecology's phylogenetic beta diversity framework. *International Journal of Molecular Science*

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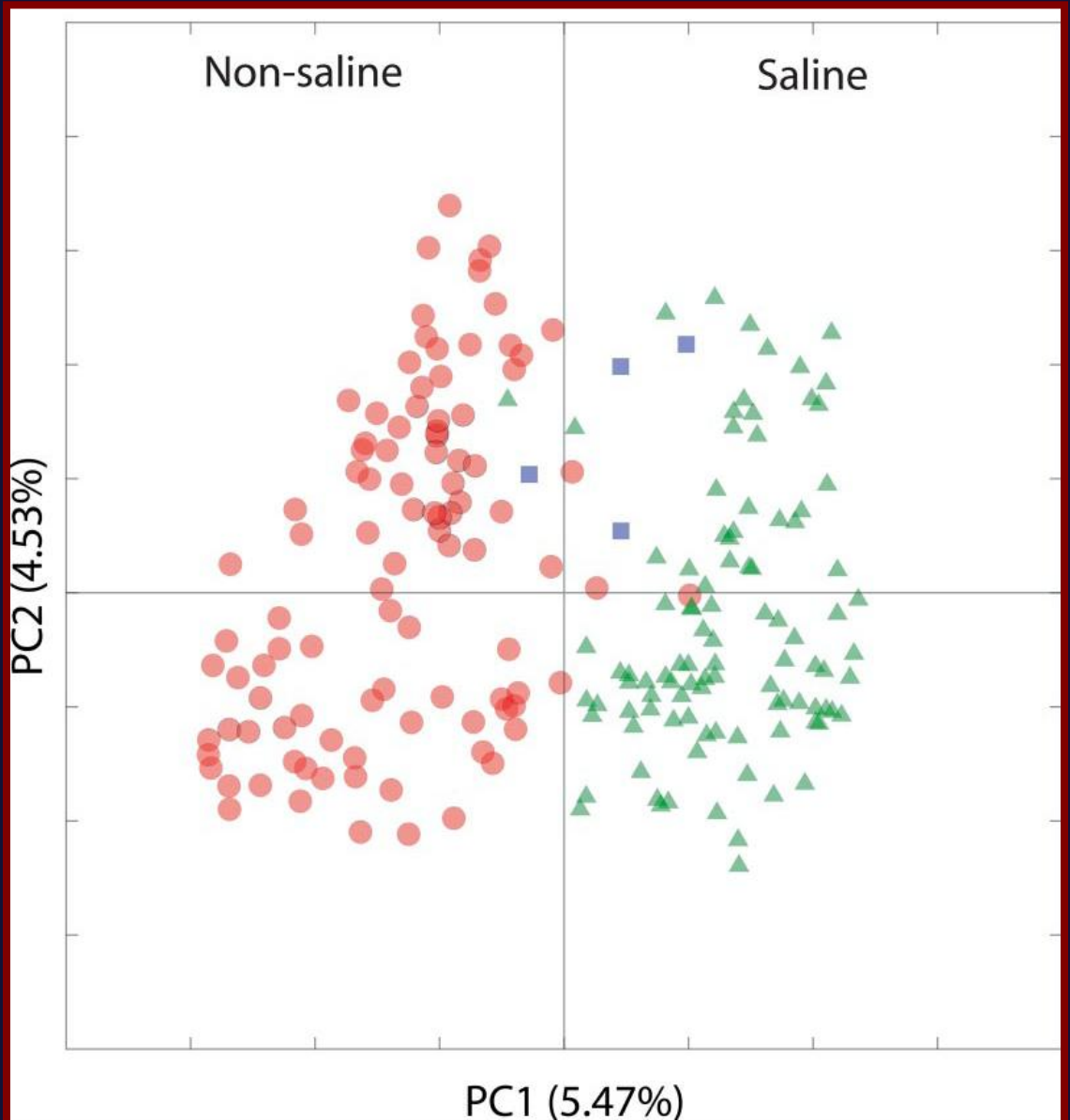
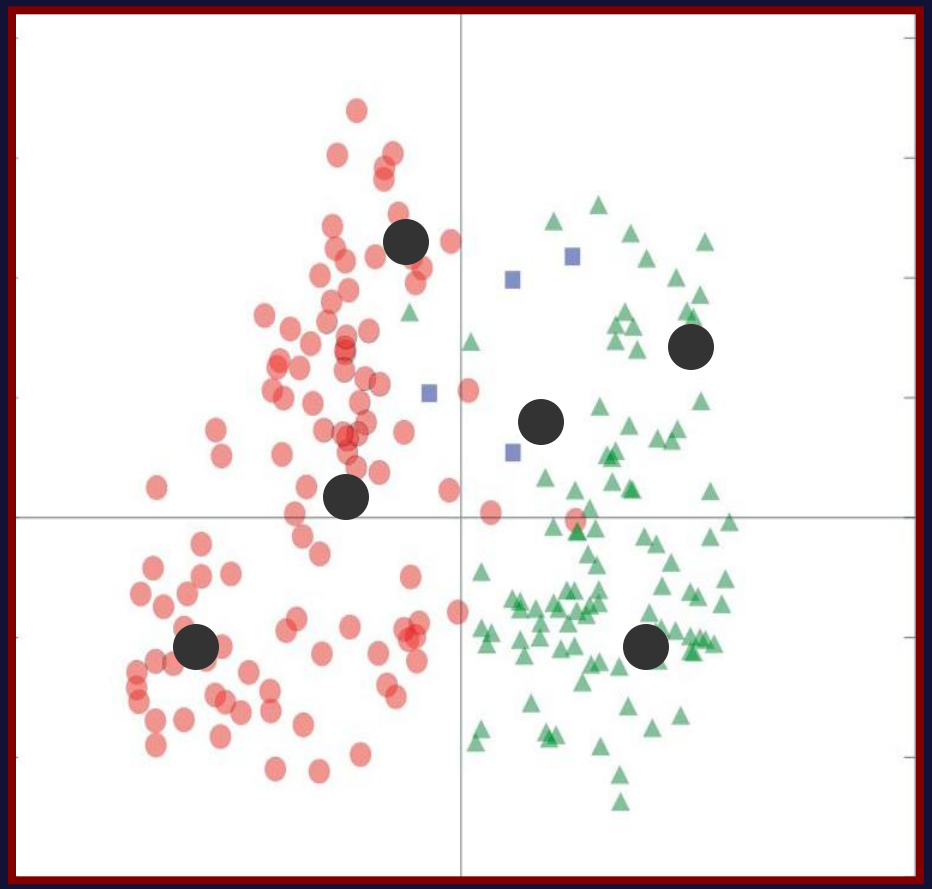
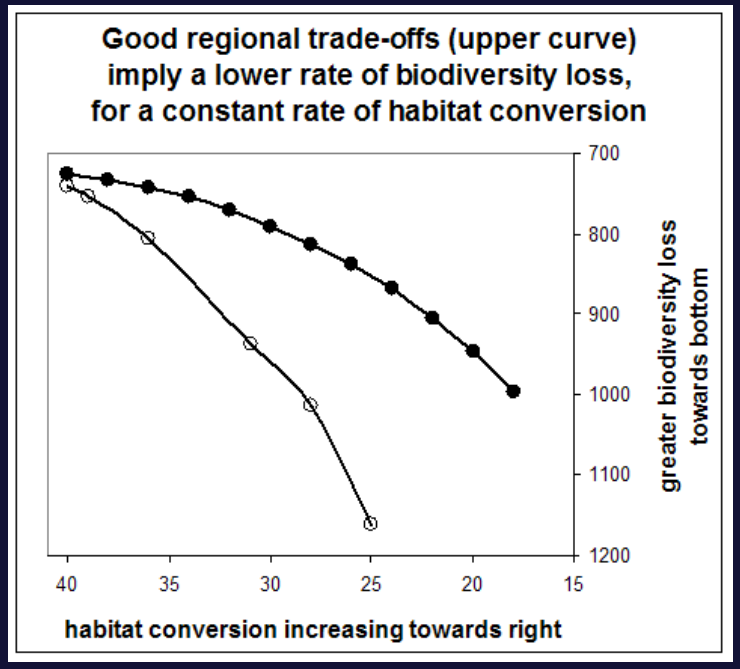


- Use phylogenetic dissimilarity among samples
- Discover that the major environmental determinant of microbial community composition is salinity

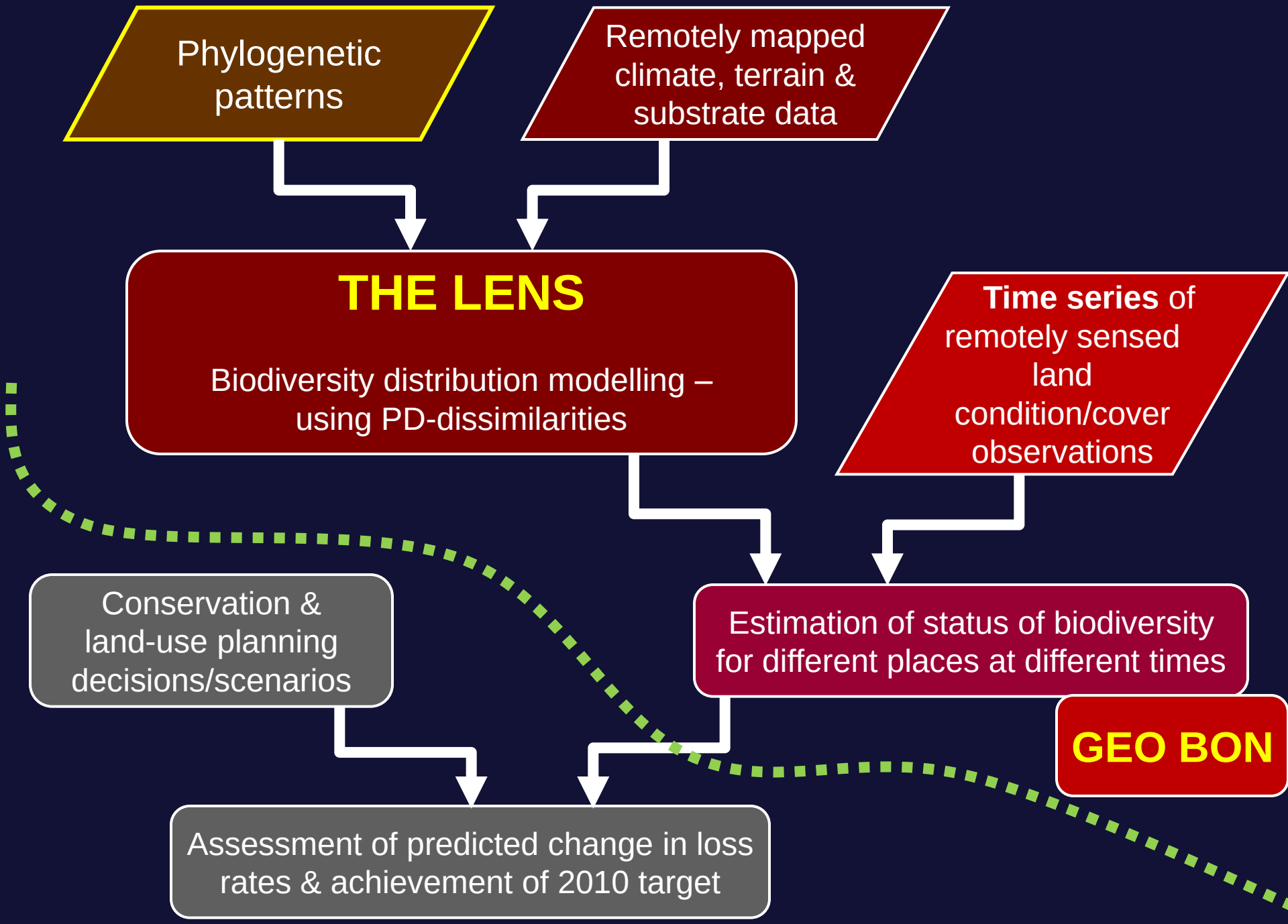
ED (environmental diversity) method “counts-up” species under evolutionary model of unimodal response to gradients.

ED estimates the biodiversity represented by any set of protected areas





phylogenetic information can be integrated into a “lens” for interpreting remotely sensed changes in land condition – useful for GEO BON....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Remotely mapped climate, terrain & substrate data
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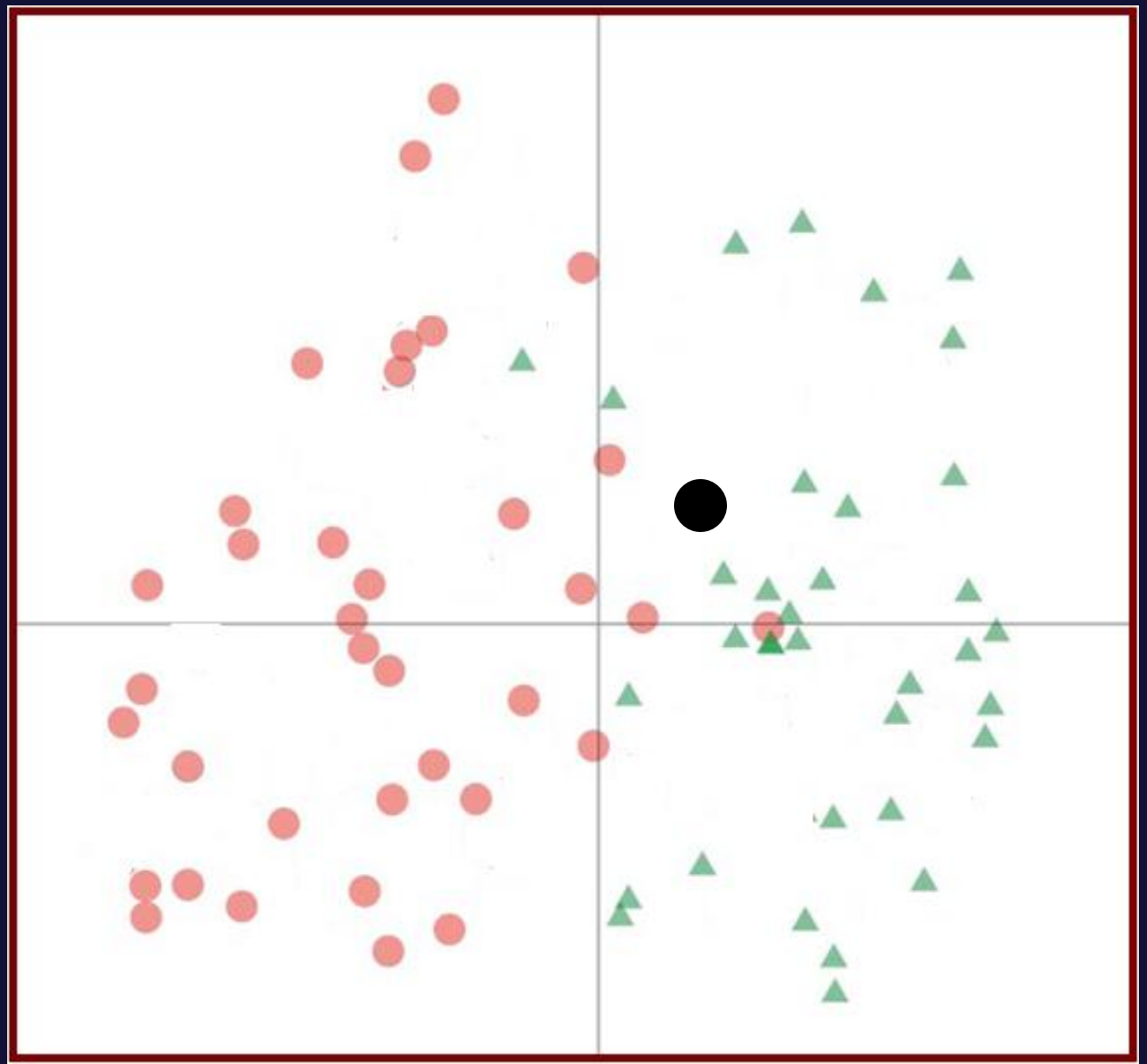
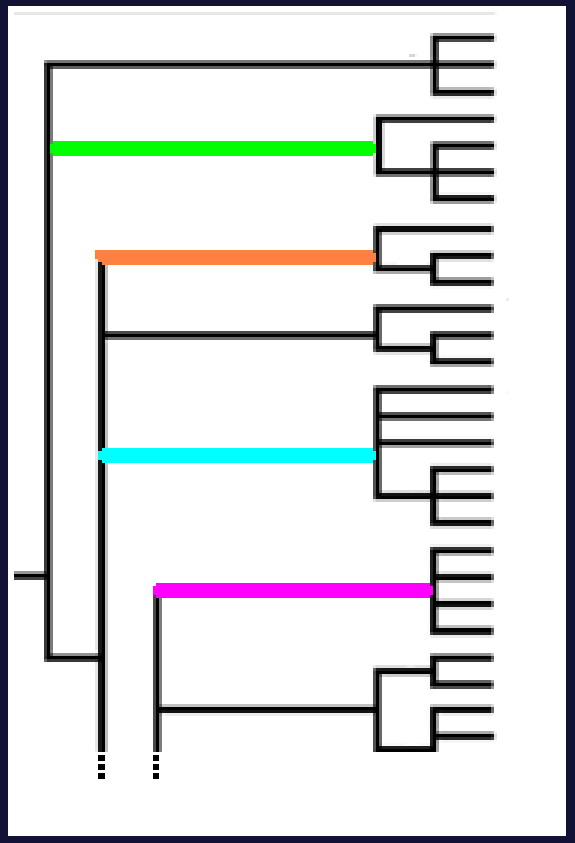
GEO BON
Assessment of predicted change in loss rates & achievement of 2010 target

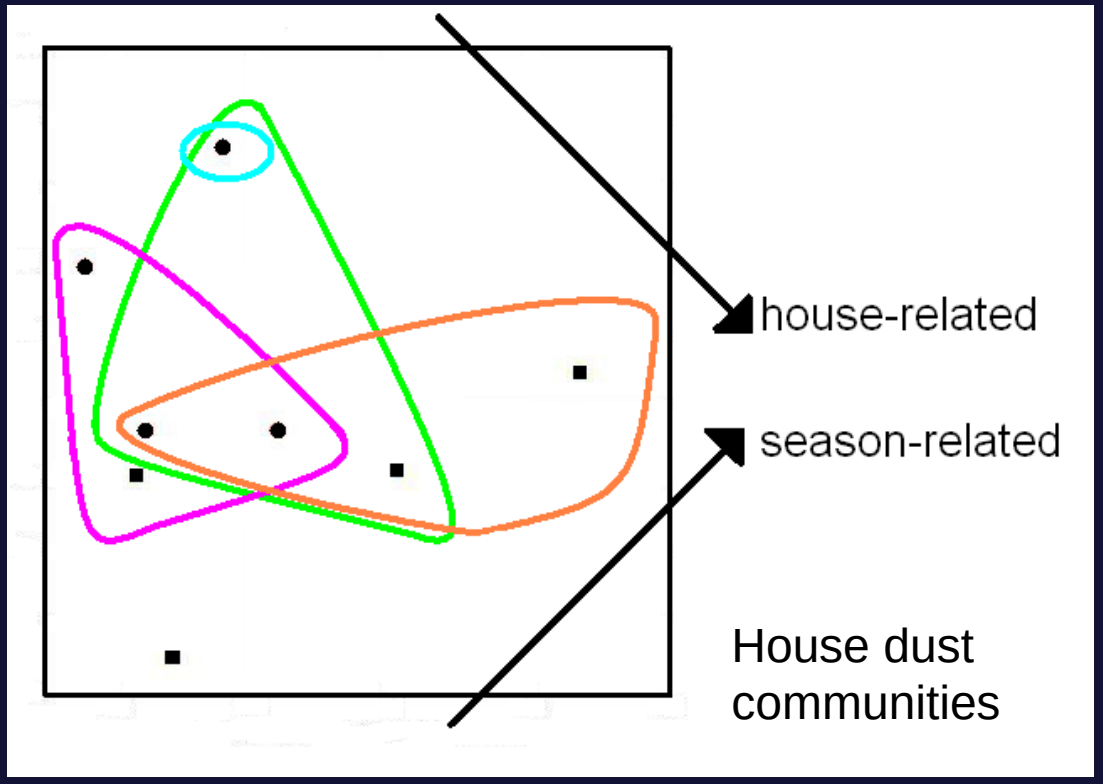
A global Biodiversity Observation Network: how do we monitor genetic/phylogenetic diversity?

Extending the lens approach to monitor impacts at new sites (no need to have all sites in the space)



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





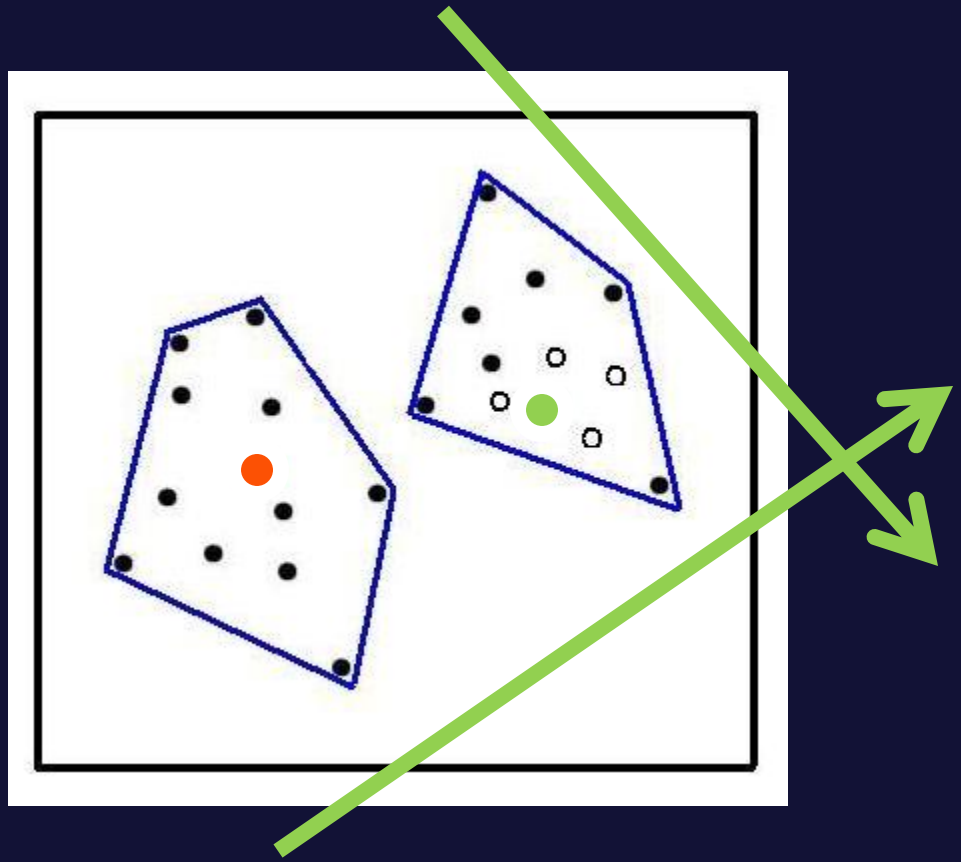
Faith, D. P., C. A. Lozupone, D. Nipperess, R. Knight
A general model linking evolutionary features and environmental gradients supports broad applications of microbial ecology's phylogenetic beta diversity framework. *International Journal of Molecular Science*

Phylogenetic monitoring to detect impacts

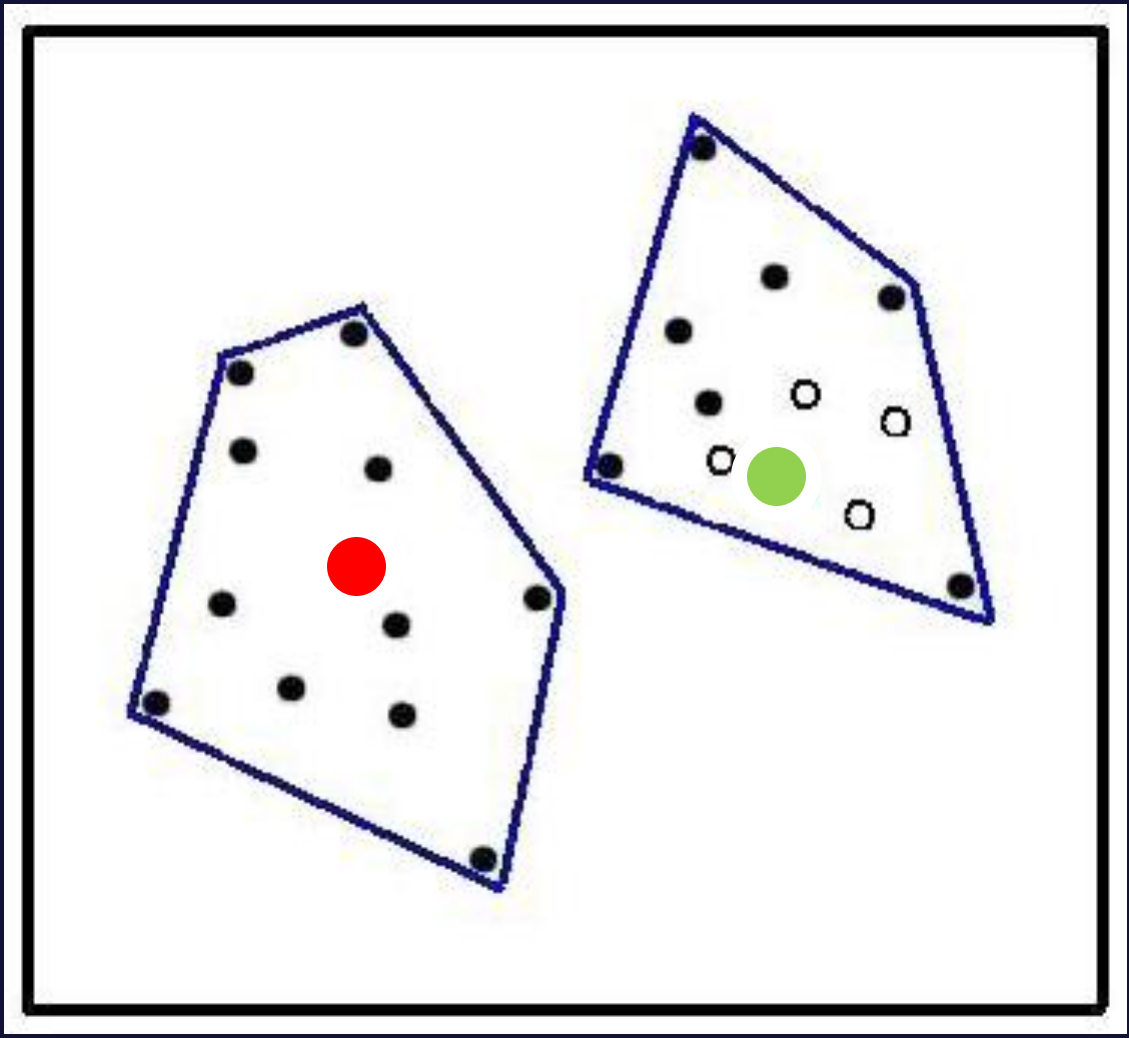
two dimensional gradient space with reference sample sites = solid and hollow dots

We can use the special regression (GDM) to predict PD-dissimilarities from environmental distances

Test site (red dot, green dot) positioned in the space based on environmental values.

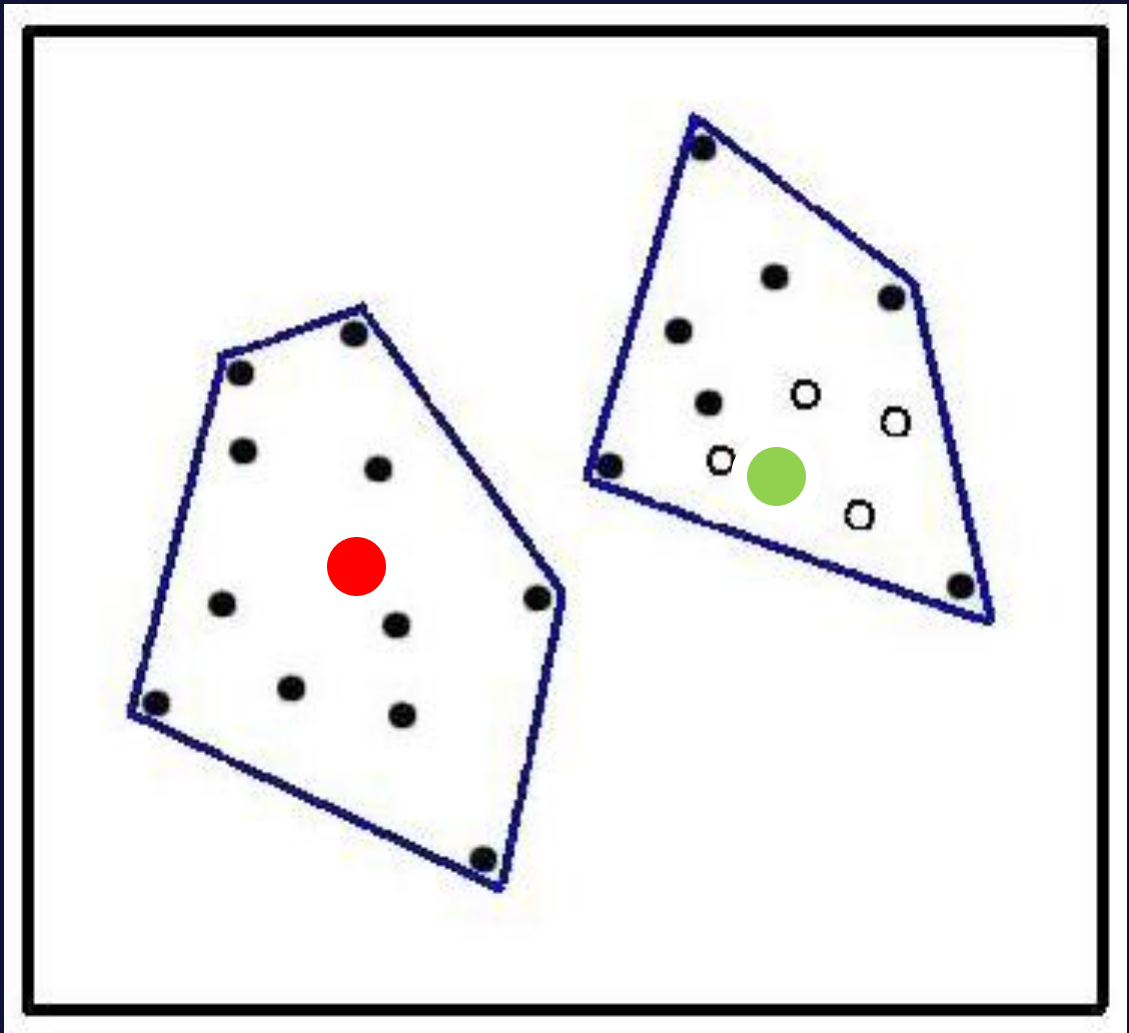


Monitoring for impacts on biodiversity - placing new sites into the environmental space

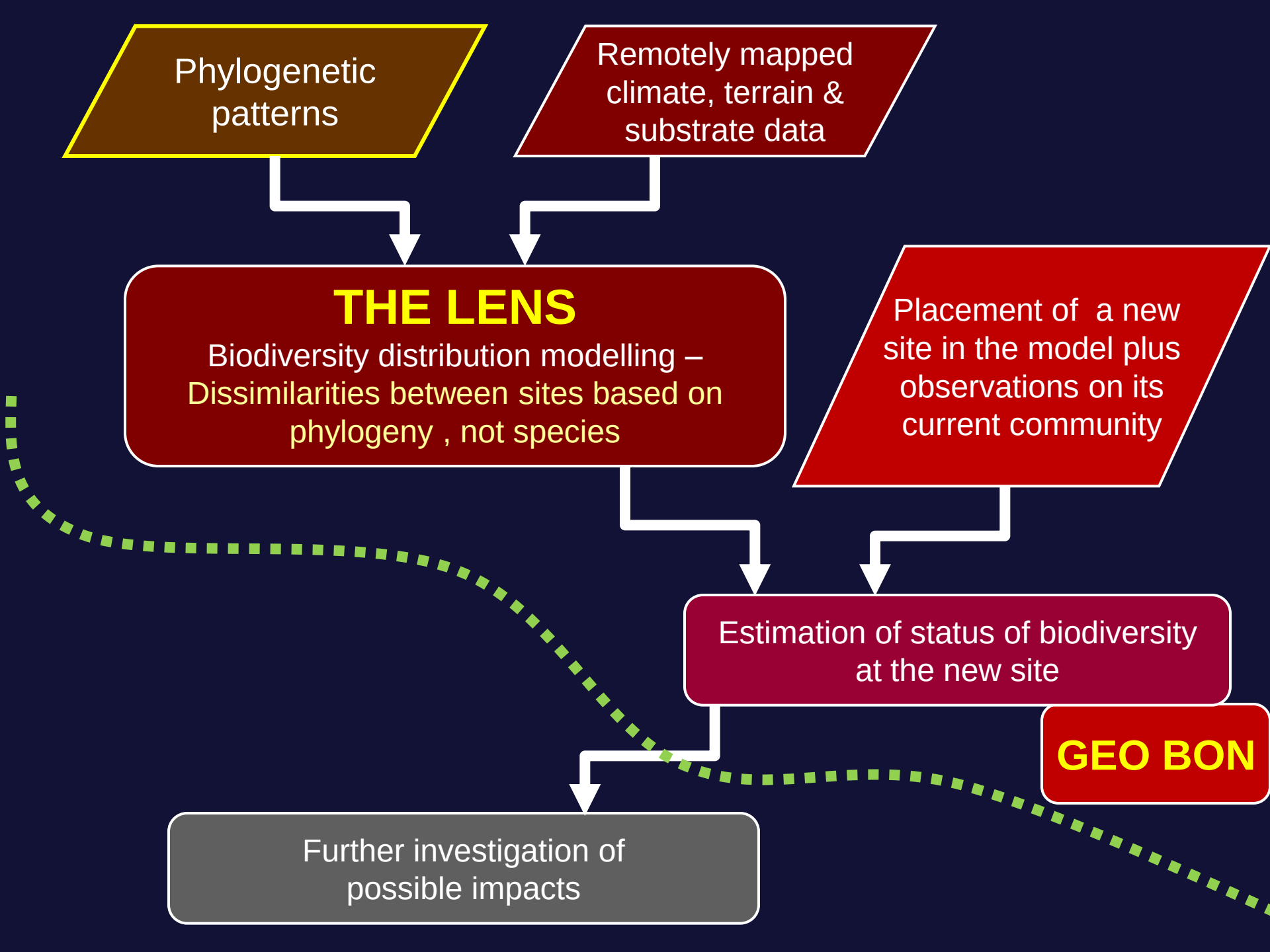


- Convex shapes are two different deep branches, solid dot = branch present in site

Monitoring for impacts on biodiversity - placing new sites into the environmental space



- on the left, absence of that lineage in the red-dot site is improbable
- - all reference sites in the convex hull had the lineage.
- on the right, absence of that lineage in the green-dot site is probable
- - the lineage is absent in some reference sites within the convex hull


Phylogenetic patterns
Remotely mapped climate, terrain & substrate data
THE LENS
Biodiversity distribution modelling – Dissimilarities between sites based on phylogeny , not species
Placement of a new site in the model plus observations on its current community
Estimation of status of biodiversity at the new site
GEO BON
Further investigation of possible impacts

Conclusions

- “evosystem services” helps better capture “option values” = future, often unanticipated, benefits/uses
- a good measure is the evolutionary history (PD) that is preserved
- we can make effective use of phylogeny and new and old survey data to create models of biodiversity that act as a “lens” to interpret time series of changes in land condition
- the same lens models may also allow impact detection at new sites
- new technologies – DNA barcoding and advanced sequencing can provide the needed data