Transforming environmental DNA data into information and knowledge about species, communities and ecosystems

Landcare Research Link Seminar

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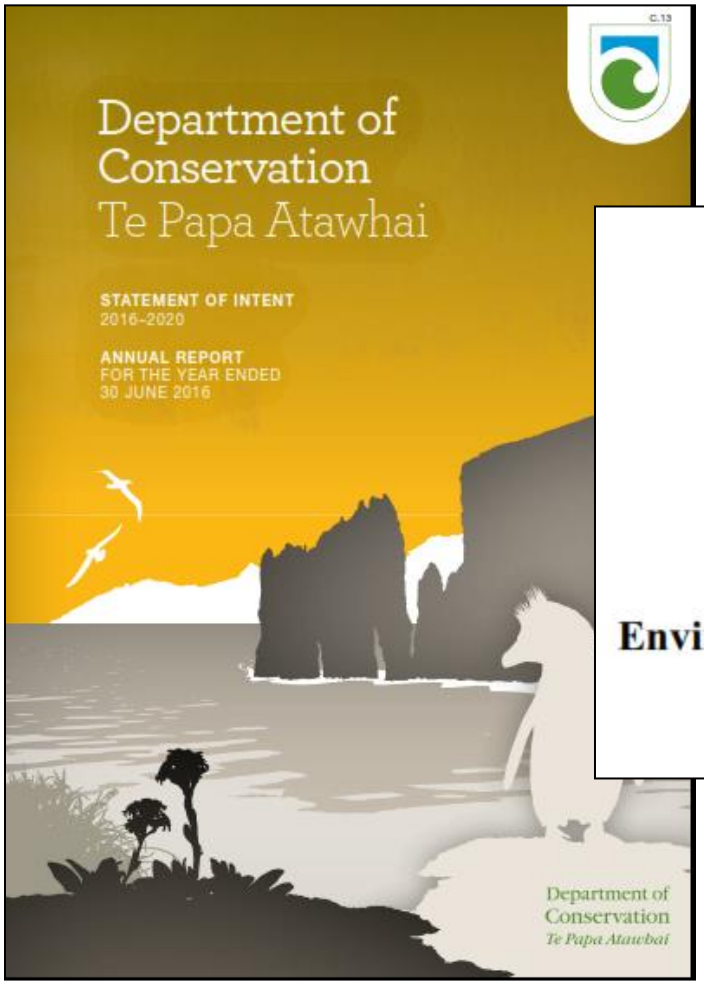
EPA, Wellington, 28 February 2017

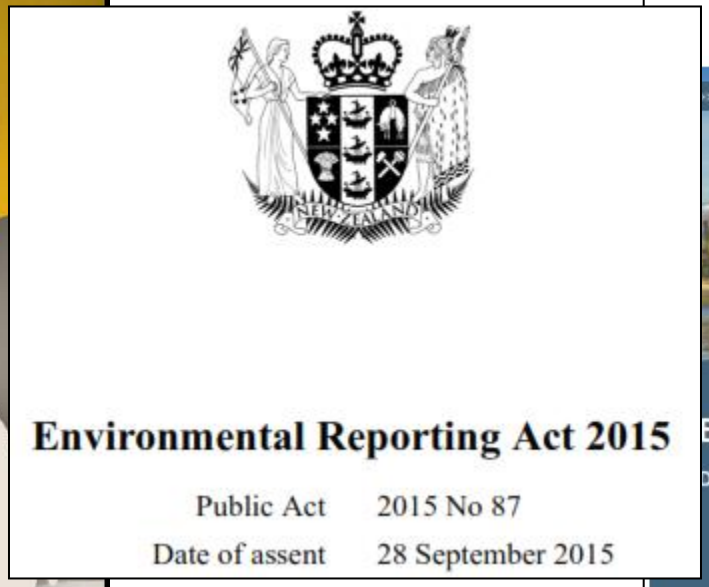
Landcare Research
Manaaki Whenua

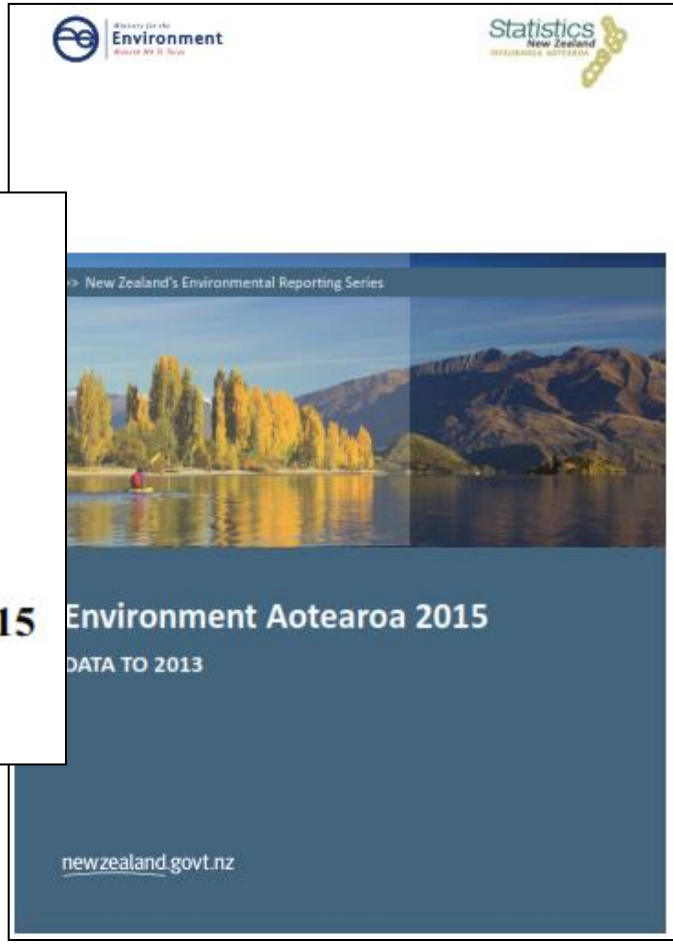
We need good data to understand the state of our environment and how it is changing, so that we can then make wise management decisions

NEW ZEALAND'S BIOLOGICAL HERITAGE

Ngā Koiora Tuku Iho



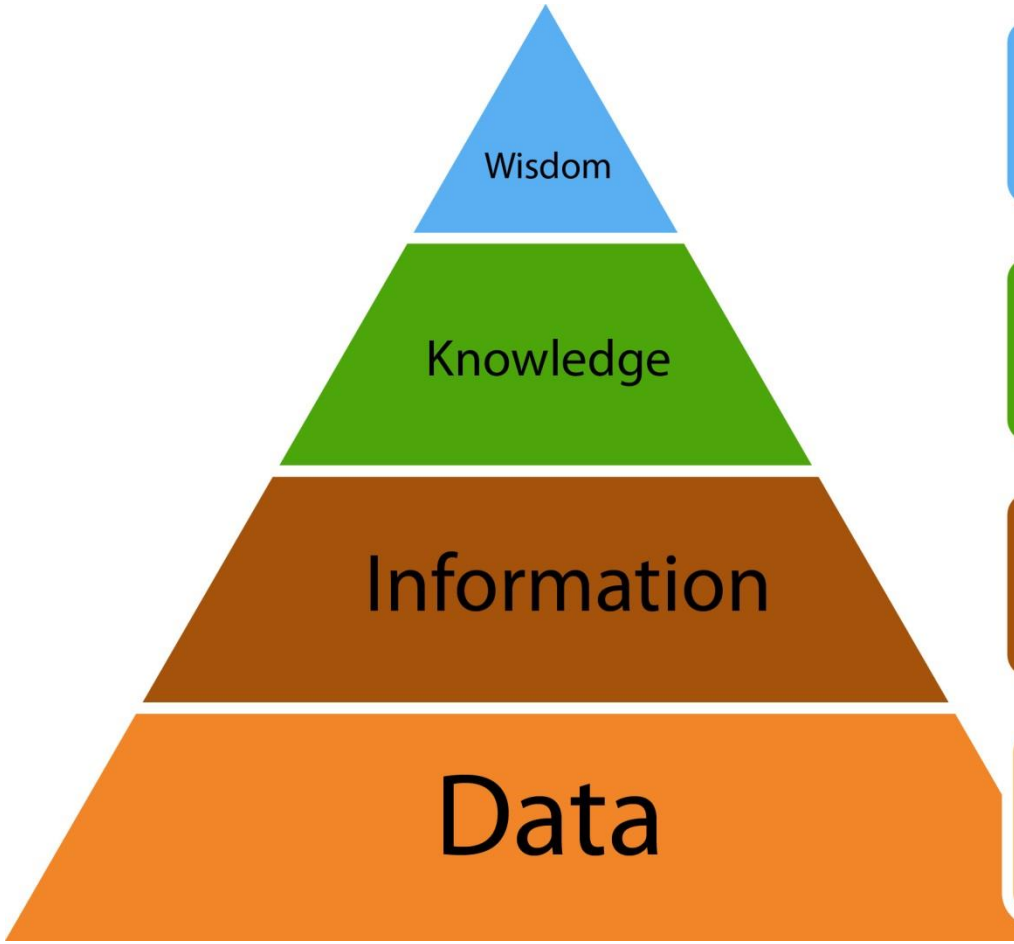




Transforming data into wisdom

NEW ZEALAND'S BIOLOGICAL HERITAGE

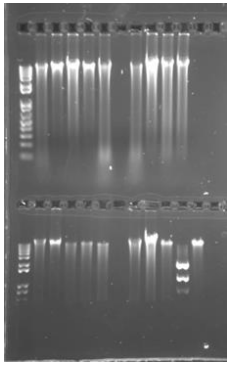
Ngā Koiora Tuku Iho



Applied	We need to activate the emergency eradication response plan!
Context	There was a stoat in Karori Wildlife Sanctuary this morning
Meaning	A stoat entered tracking tunnel ZK45 at 2am on 28th February 2017
Raw	MUSerm; TKT; ZK45; 0200.23.02.2017; 1745900; 5426370

Talk outline

1. eDNA basics
2. How does eDNA fit within Environmental Reporting?
3. Exploration of eDNA data
4. Field validation of eDNA data
5. Using eDNA to report on genetic diversity (example)
6. Key take home messages



1. eDNA basics

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What is environmental DNA (eDNA)?

= DNA extracted directly from an environmental sample

- trace DNA left behind by organisms (e.g. skin cells, faeces)
- undifferentiated micro-organism DNA (microbiomes)
- DNA samples from many pooled organisms (e.g. insects from light traps)

Biodiversity assessment using eDNA

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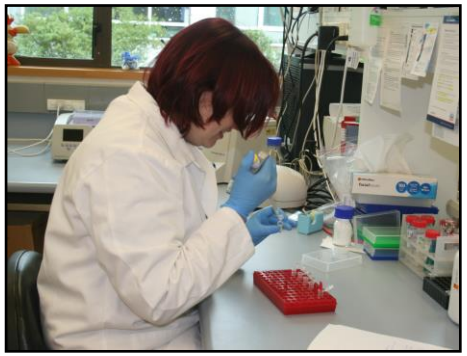
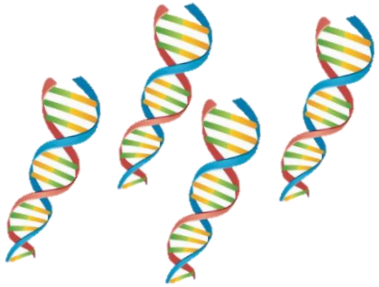
1. Collect sample

2. Extract DNA



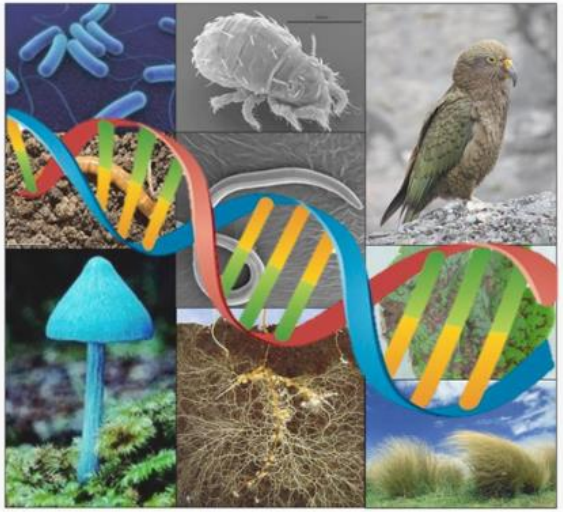
3. Amplify target DNA



4. Sequence target DNA

CGGCTAGCTGGATCGATCGTTG

5. Match DNA to species



The power of eDNA

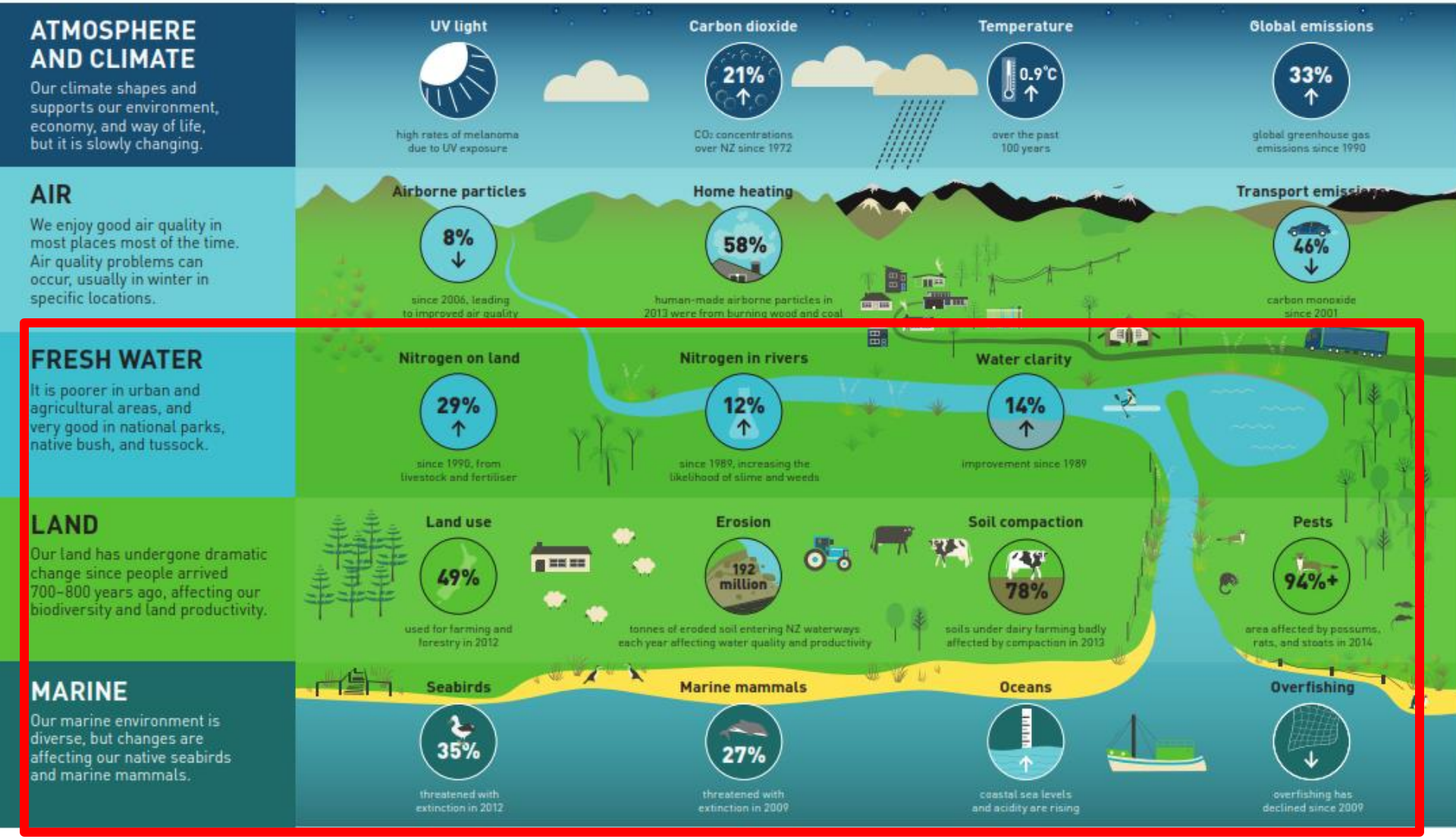
2. How does eDNA fit within environmental reporting?

New Zealand's environment at a glance

Key findings from *New Zealand's Environmental Reporting Series: Environment Aotearoa 2015*

Ministry for the Environment Manatū Mō Te Taiao

Statistics New Zealand Tatauranga Aotearoa



For more information visit www.

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Biodiversity is a cross-cutting theme

New Zealand's environment at a glance

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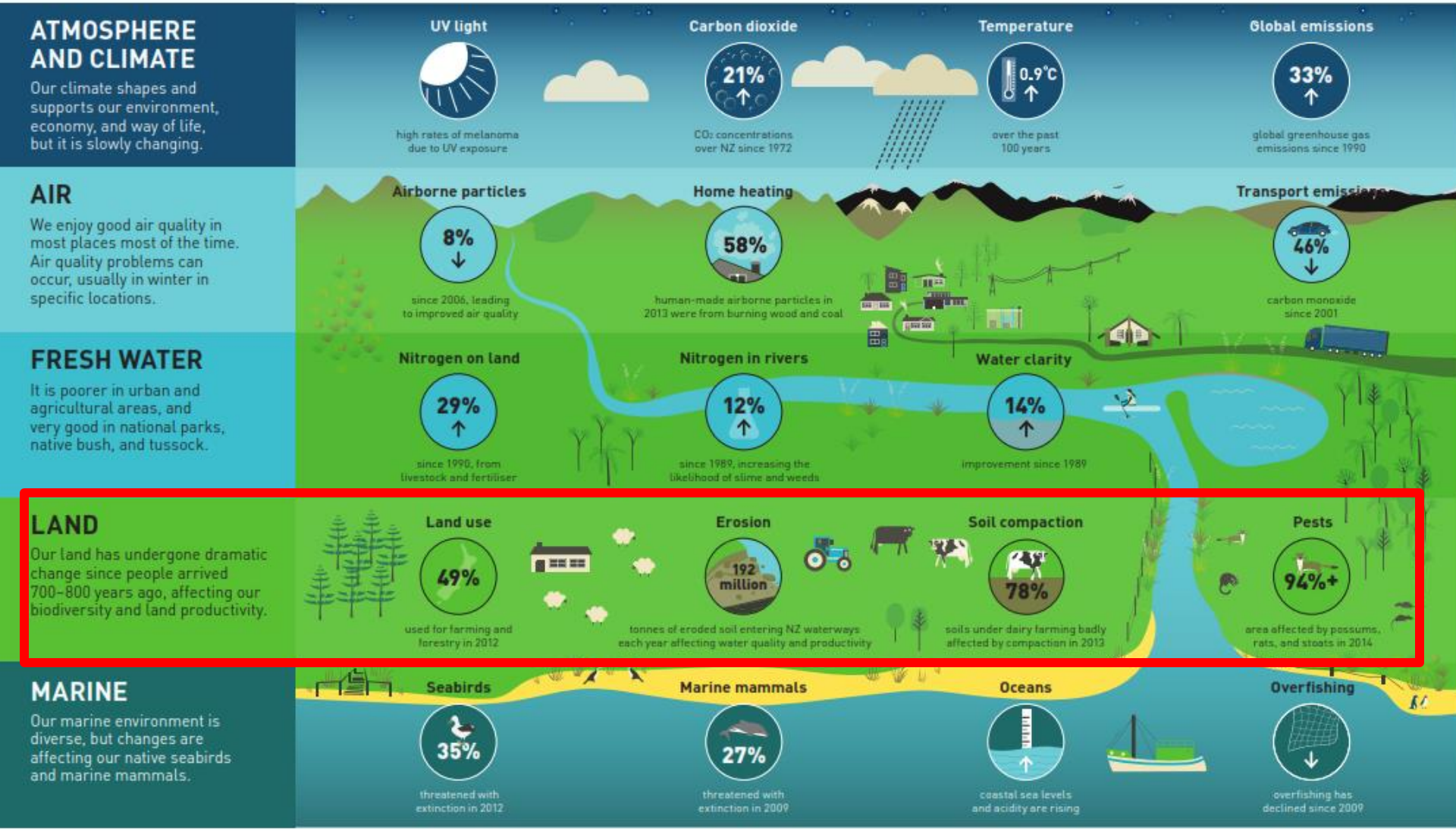

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Focus on land environment in this talk

Ecological Integrity framework for biodiversity reporting

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Ngā Koiora Tuku Iho

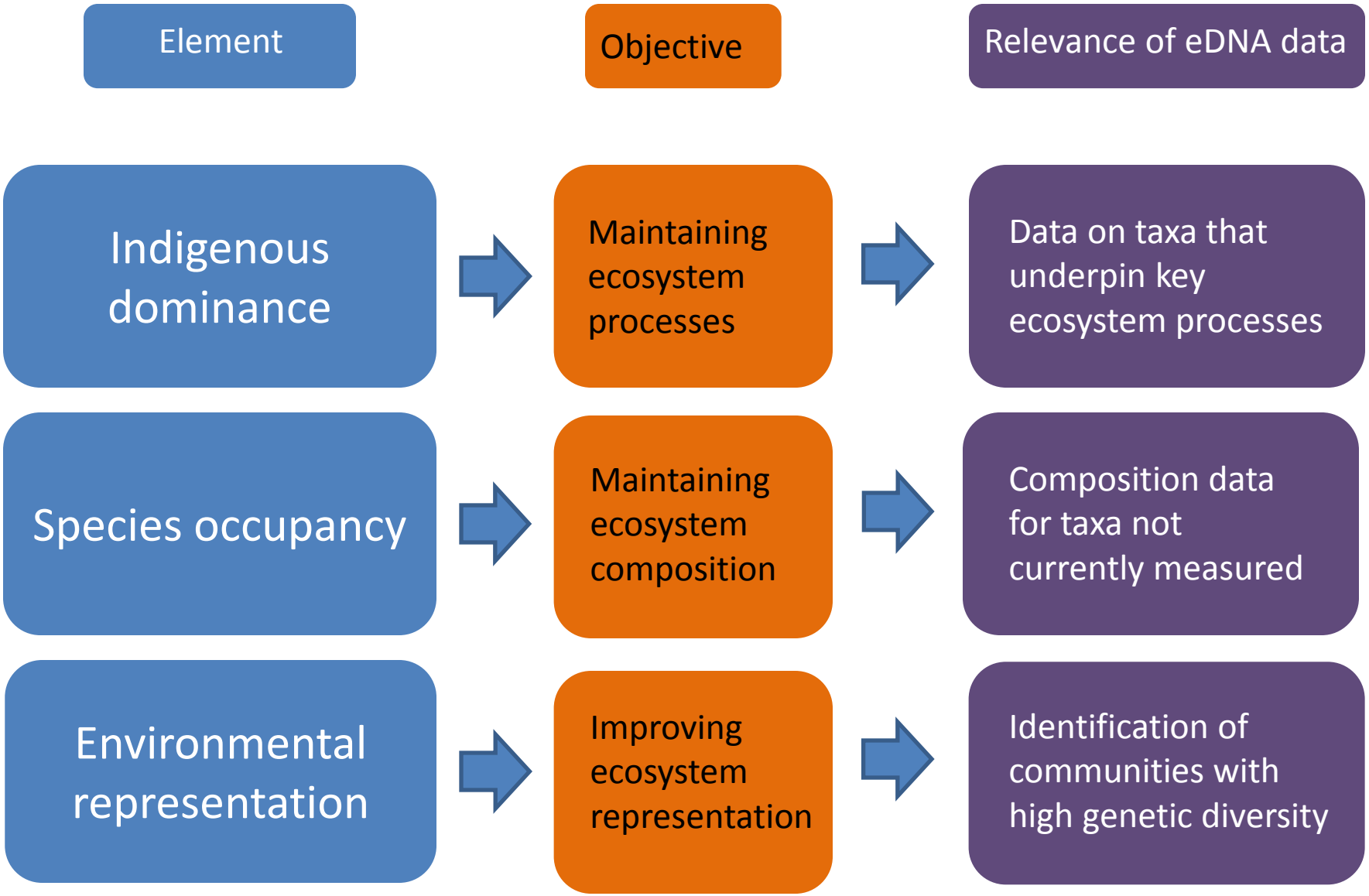
- "ecological integrity means the full potential of indigenous biotic and abiotic features and natural processes, functioning in sustainable communities, habitats, and landscapes"
  - Environmental Reporting Act 2015

Indigenous dominance

Species occupancy

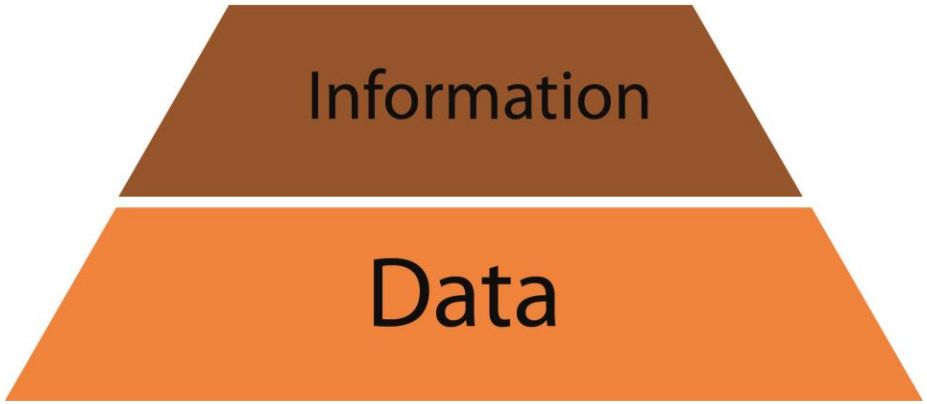
Environmental representation

How does eDNA data fit?



3. eDNA data

- what does it look like?



DOC eDNA pilot study

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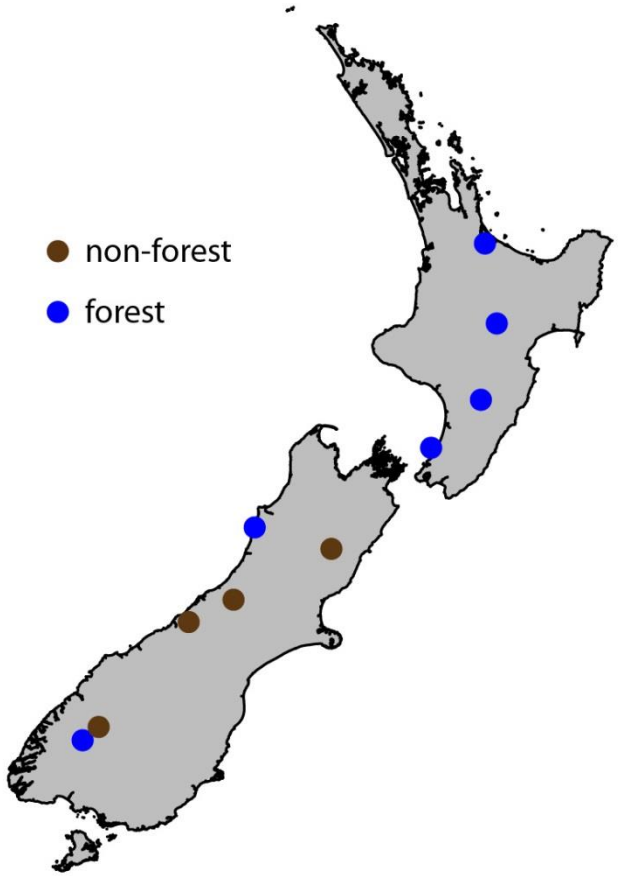
Ngā Koiora Tuku Iho

Department of Conservation
Te Papa Atawhai

Landcare Research
Manaaki Whenua

ALLAN WILSON CENTRE
FOR MOLECULAR ECOLOGY AND EVOLUTION

Bio-Protection
Bioprotection science for New Zealand



A comparison of two approaches

NEW ZEALAND'S BIOLOGICAL HERITAGE

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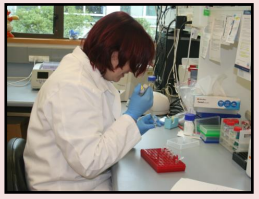
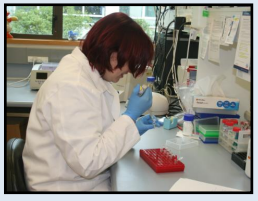
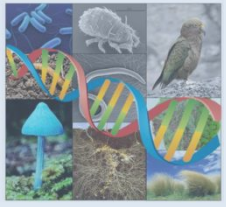
DOC & Landcare

Allan Wilson Centre

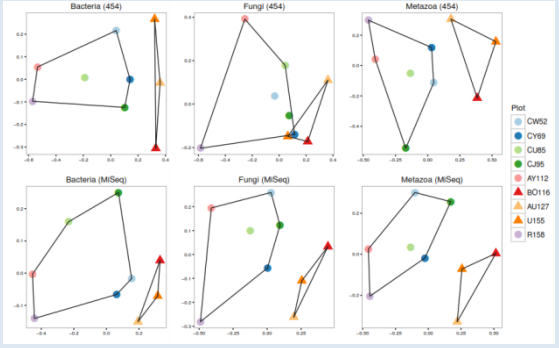


Landcare





Landcare



Our questions

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Ngā Koiora Tuku Iho

Is it practical to collect eDNA data from Tier 1 plots?

What sort of data do we get?

Are there patterns between forest and non-forest plots?

Are the results from the two very different approaches consistent?

Results (eDNA)

NEW ZEALAND'S BIOLOGICAL HERITAGE

Ngā Koiora Tuku Iho

- DNA data – Alan Wilson centre (Illumina MiSeq)
  - ~12,000 unique OTUs
  - ~ 1.2 million sequences

What is an OTU?

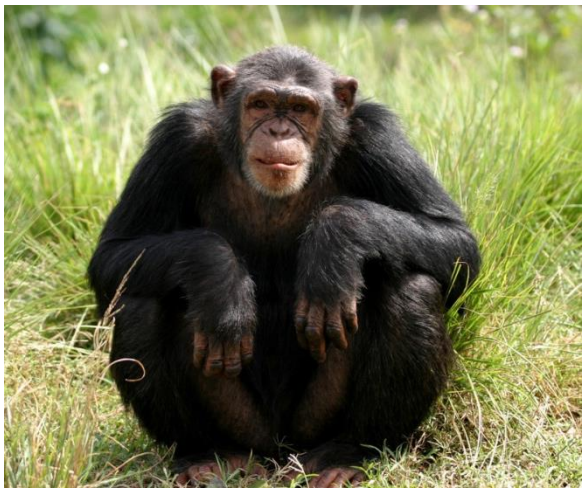
- DNA data – Landcare (454)
  - ~5,500 unique OTUs
  - ~ 0.4 million sequences

Operational Taxonomic Unit (OTU)

NEW ZEALAND'S BIOLOGICAL HERITAGE

Ngā Koiora Tuku Iho

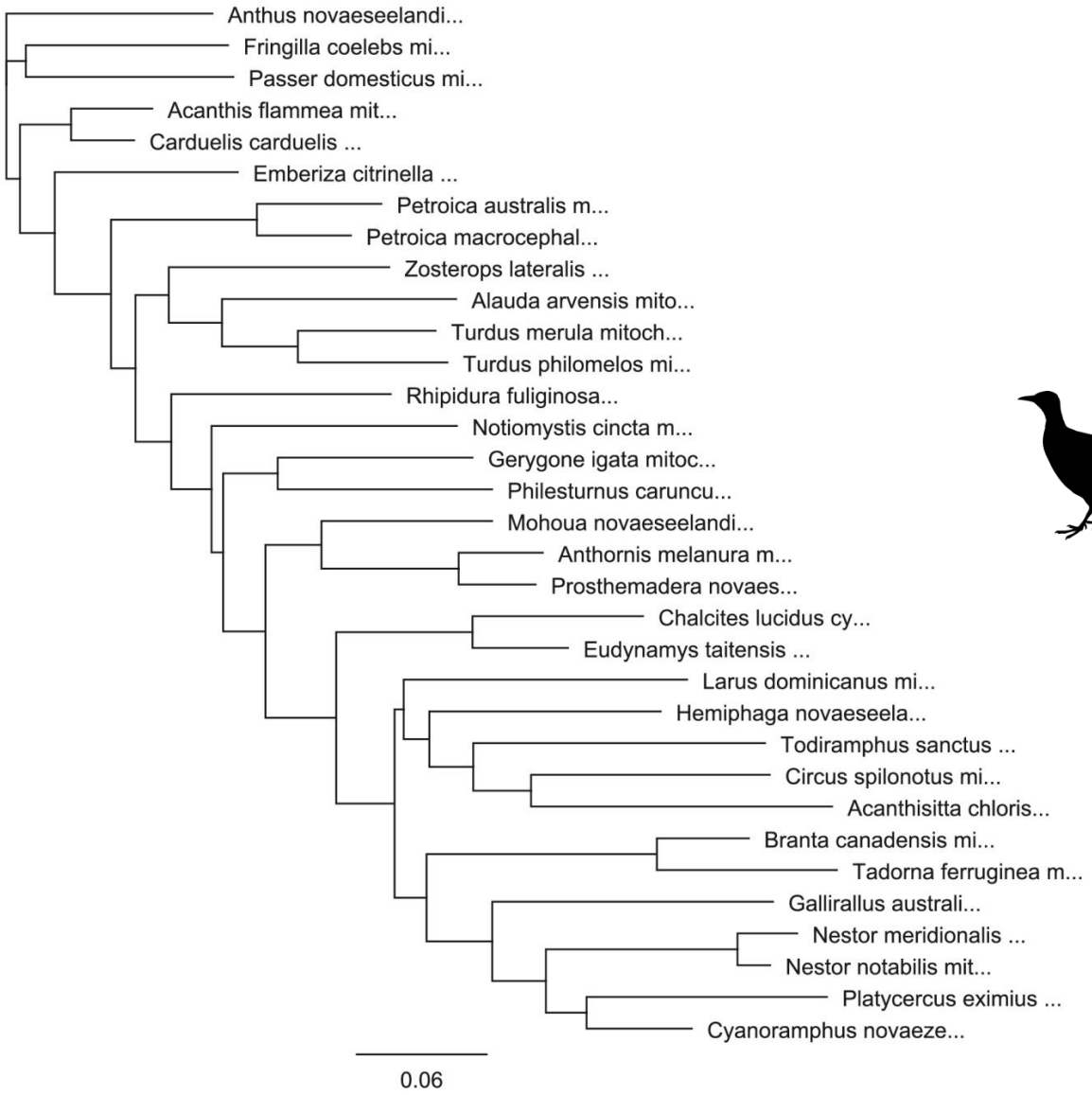
- Groups of similar sequences
- Typically clustered with 97% similarity
- ~ DNA equivalent of a species



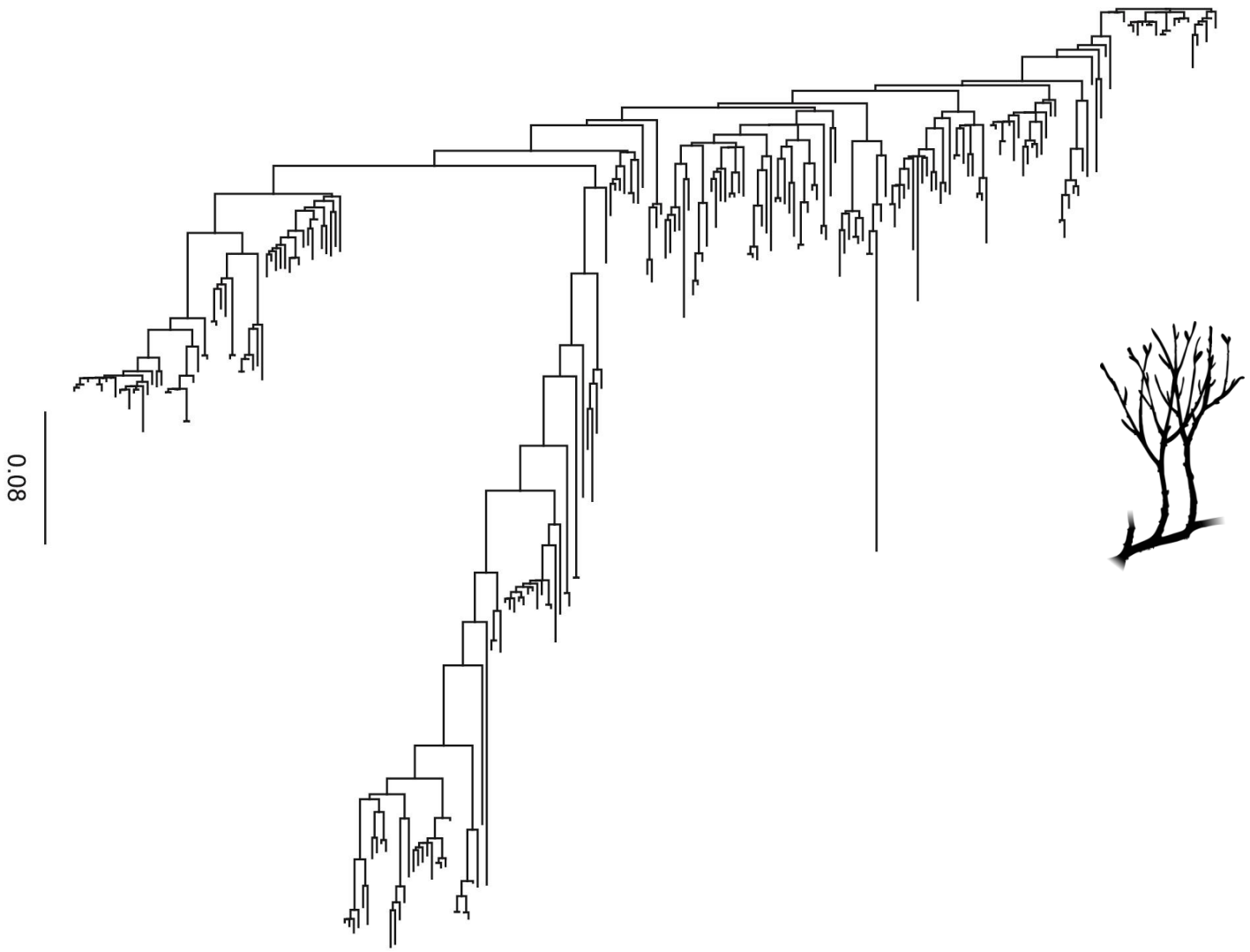
Results (Conventional data)

- Conventional field data from same plots
  - 33 bird species
  - 352 plant species in total; 311 native, 41 exotic

Taxonomic scope of the data - birds



Plants (field data)



Animals (eDNA data)

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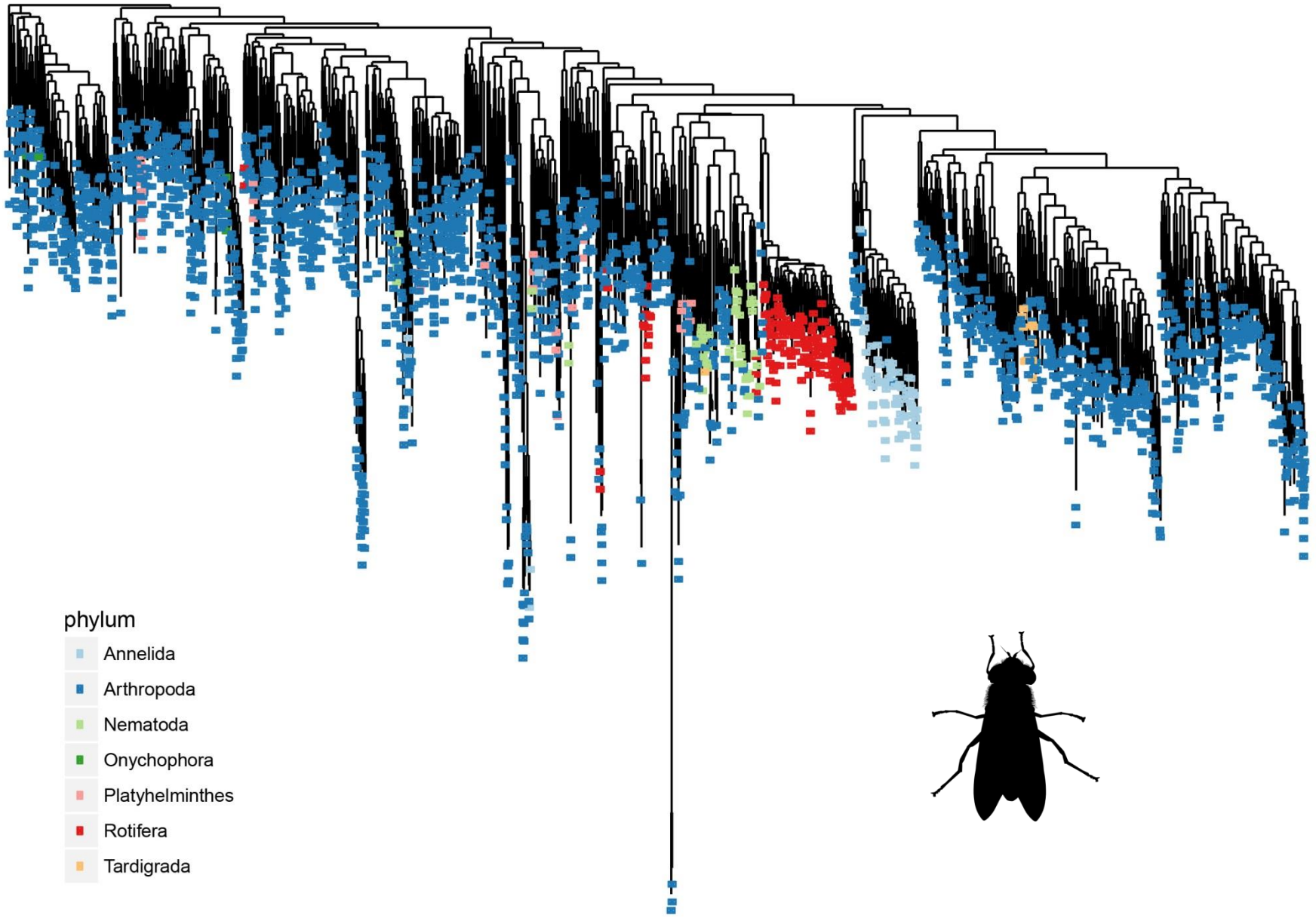
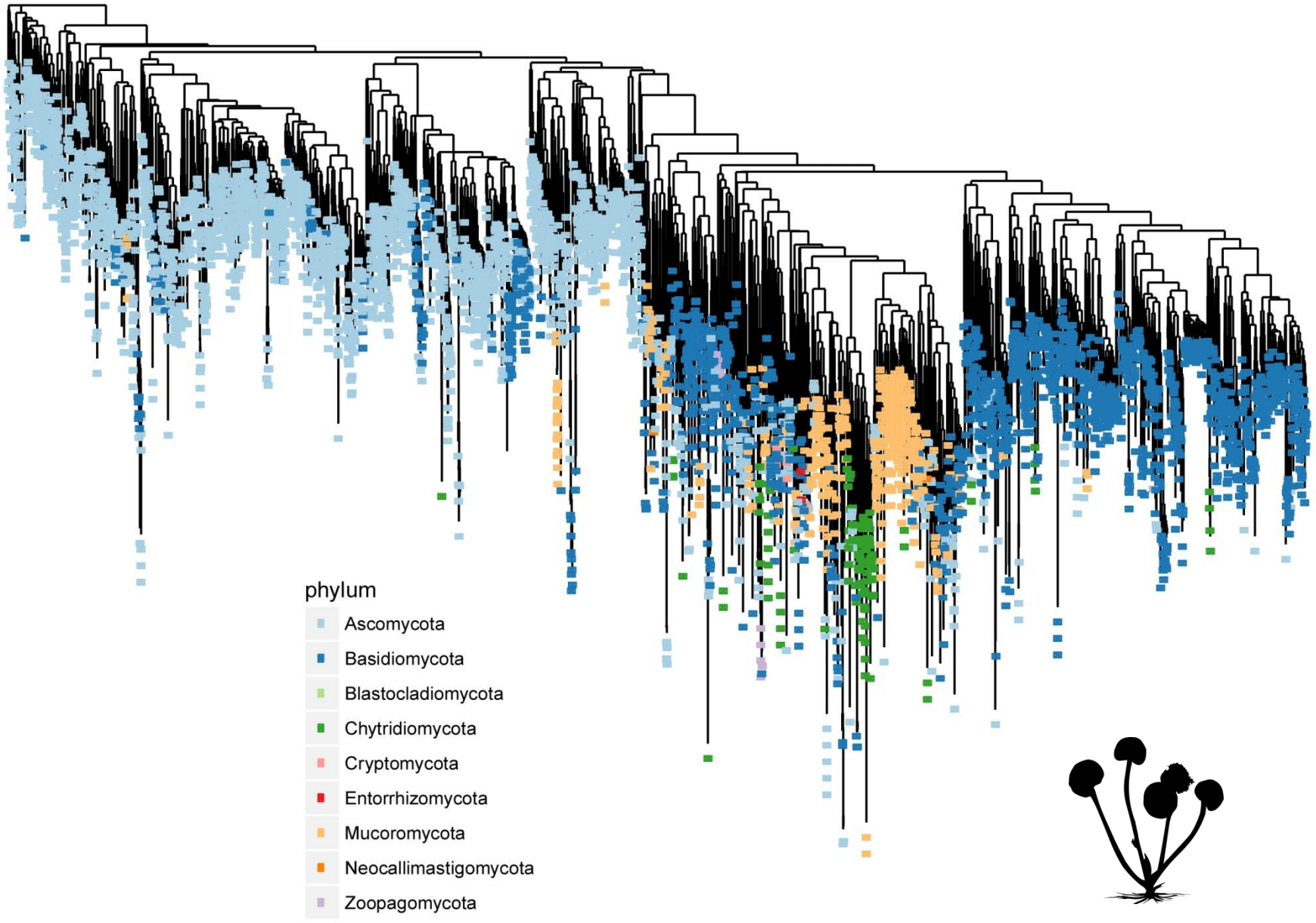


Fungi (eDNA data)



Bacteria (eDNA data)

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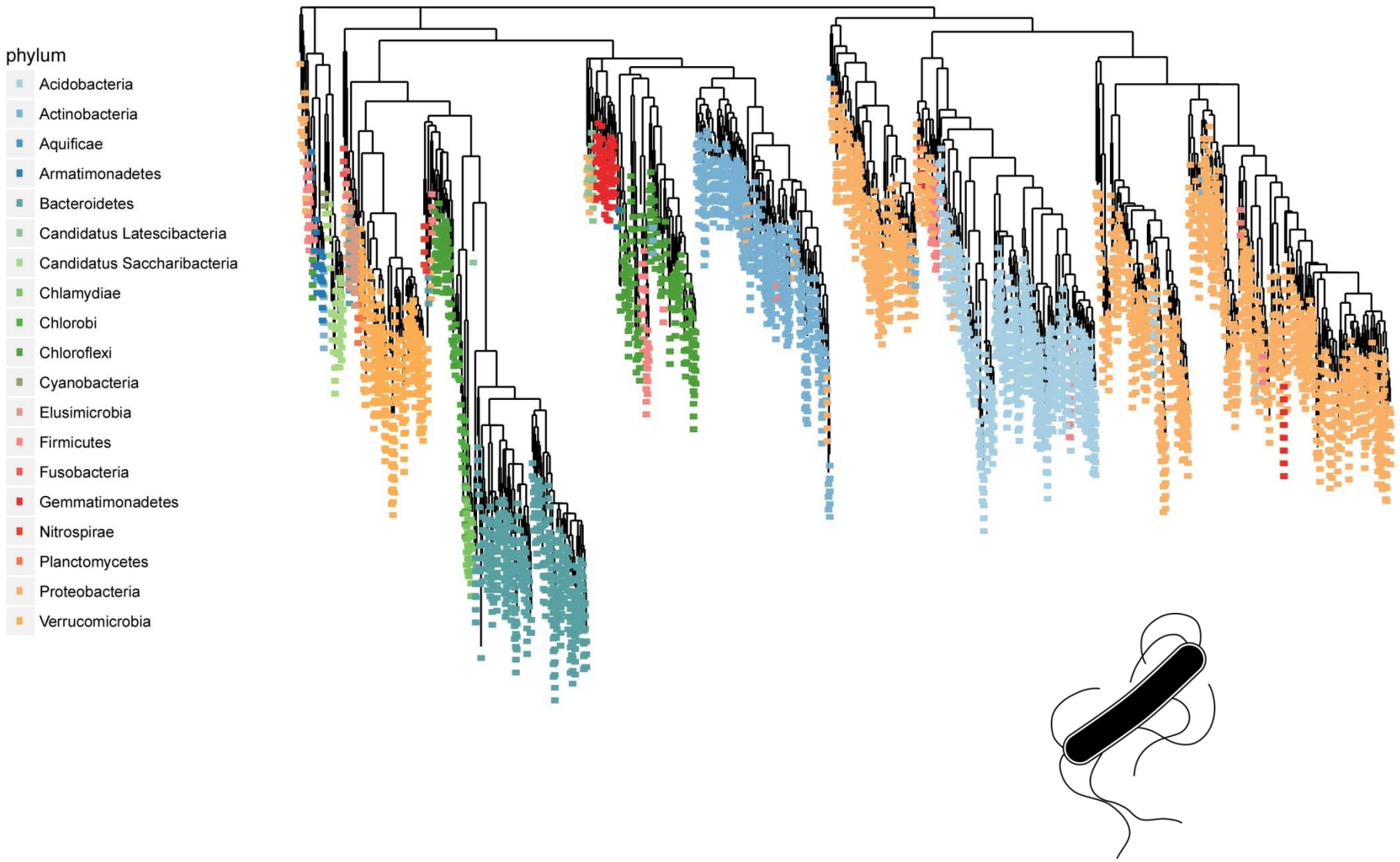
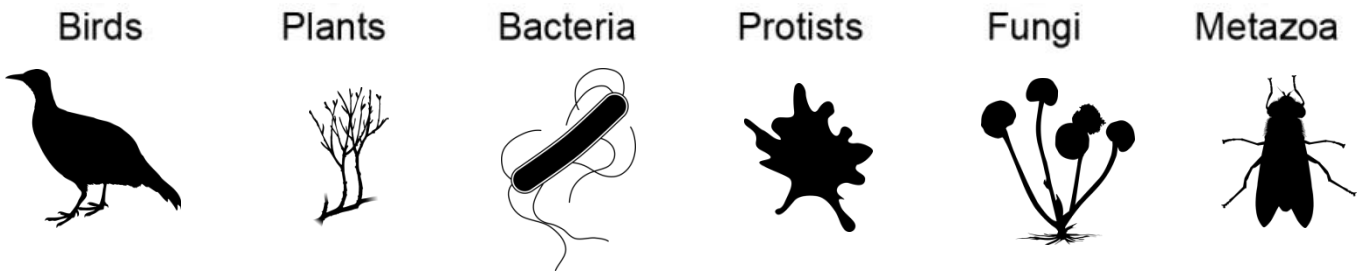


Results – relative richness



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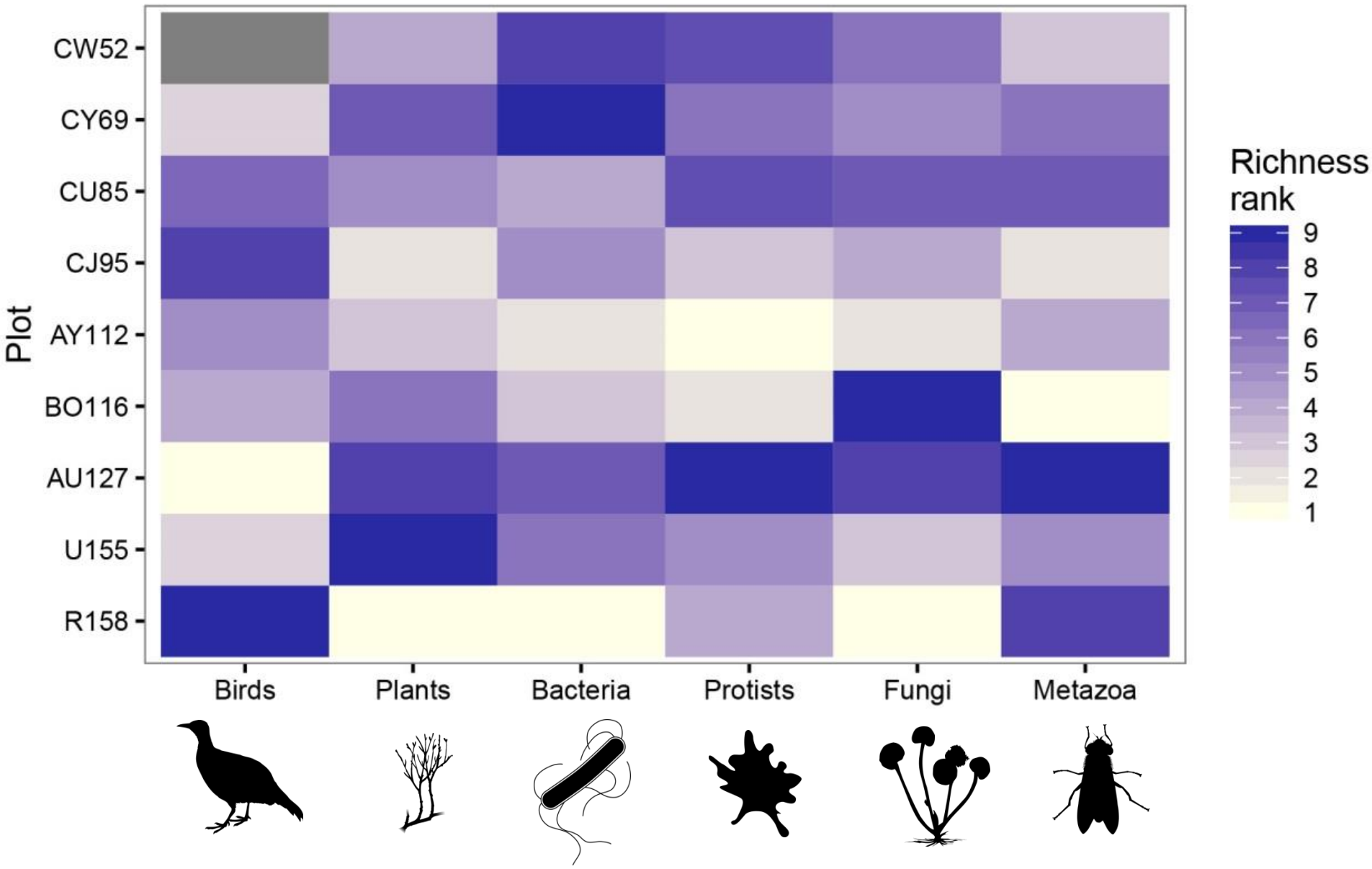

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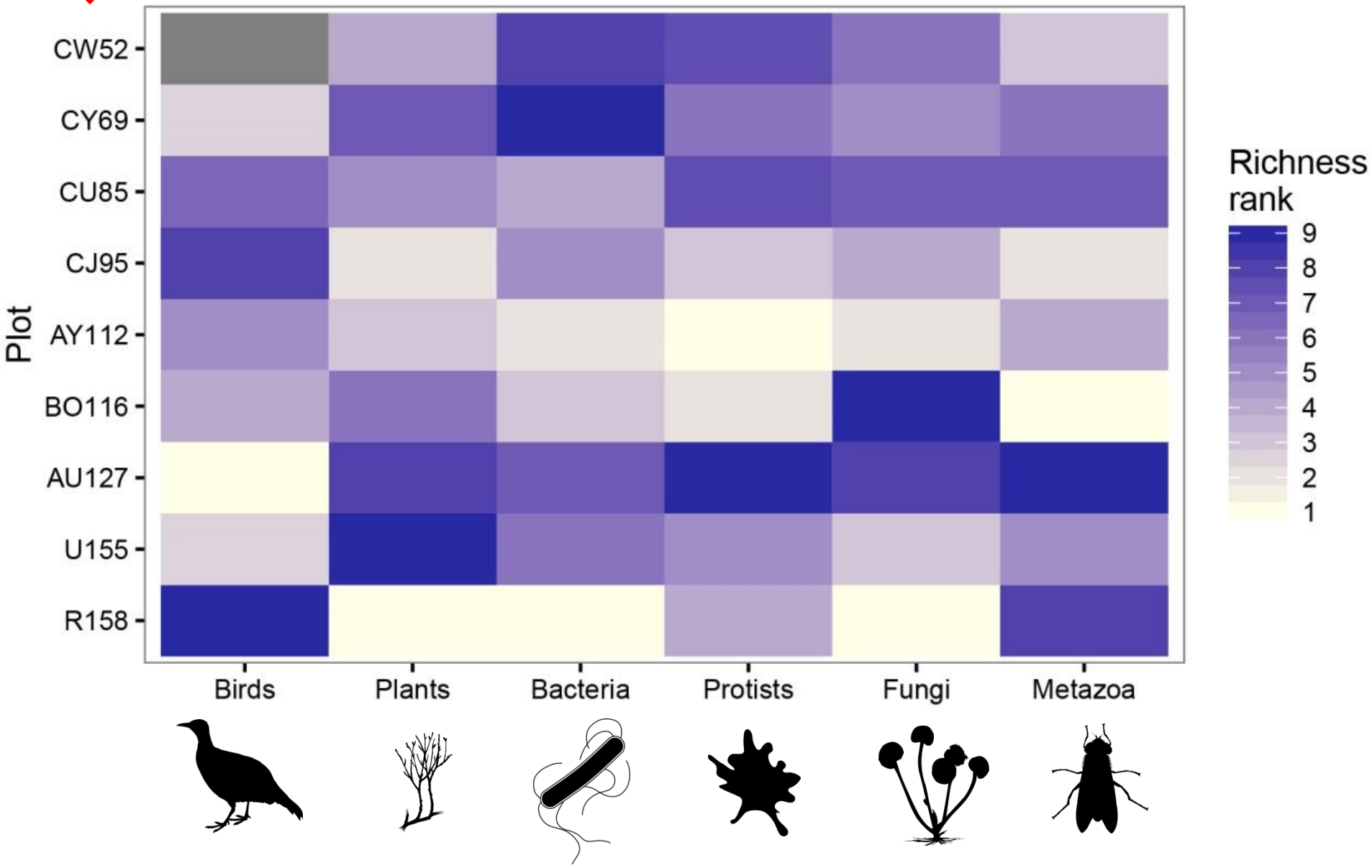

Results – relative richness

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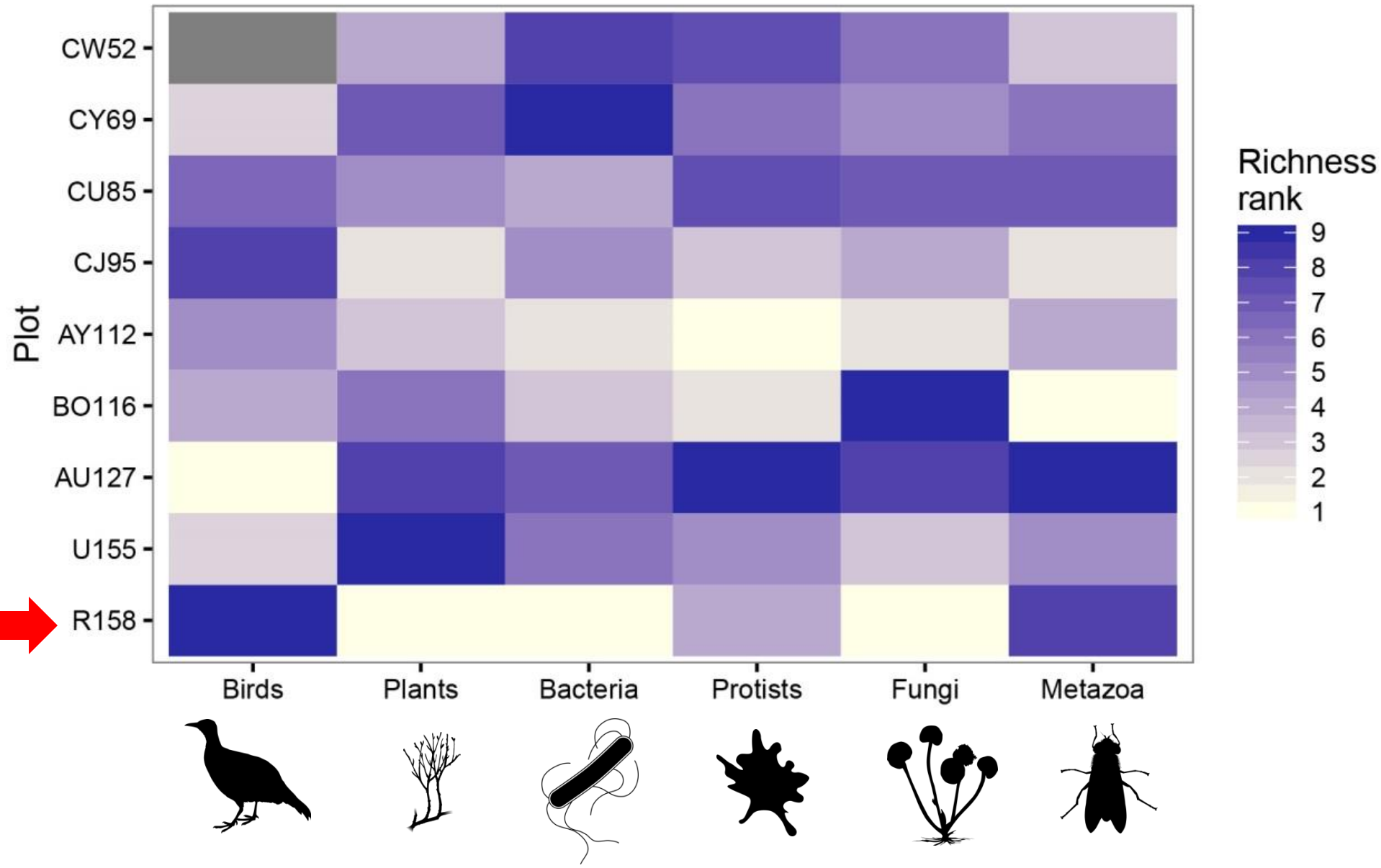


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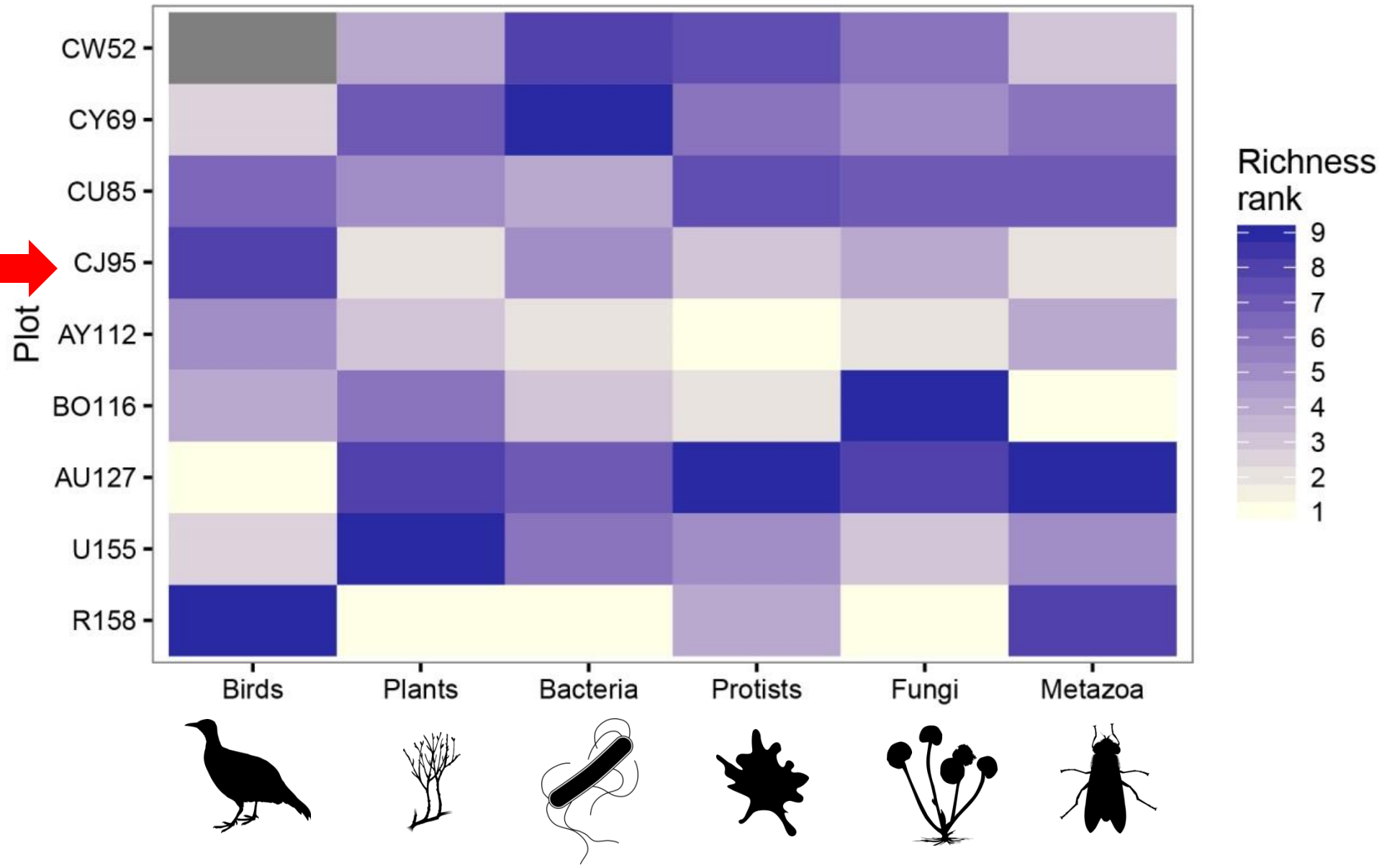
Results – relative richness



Results – relative richness

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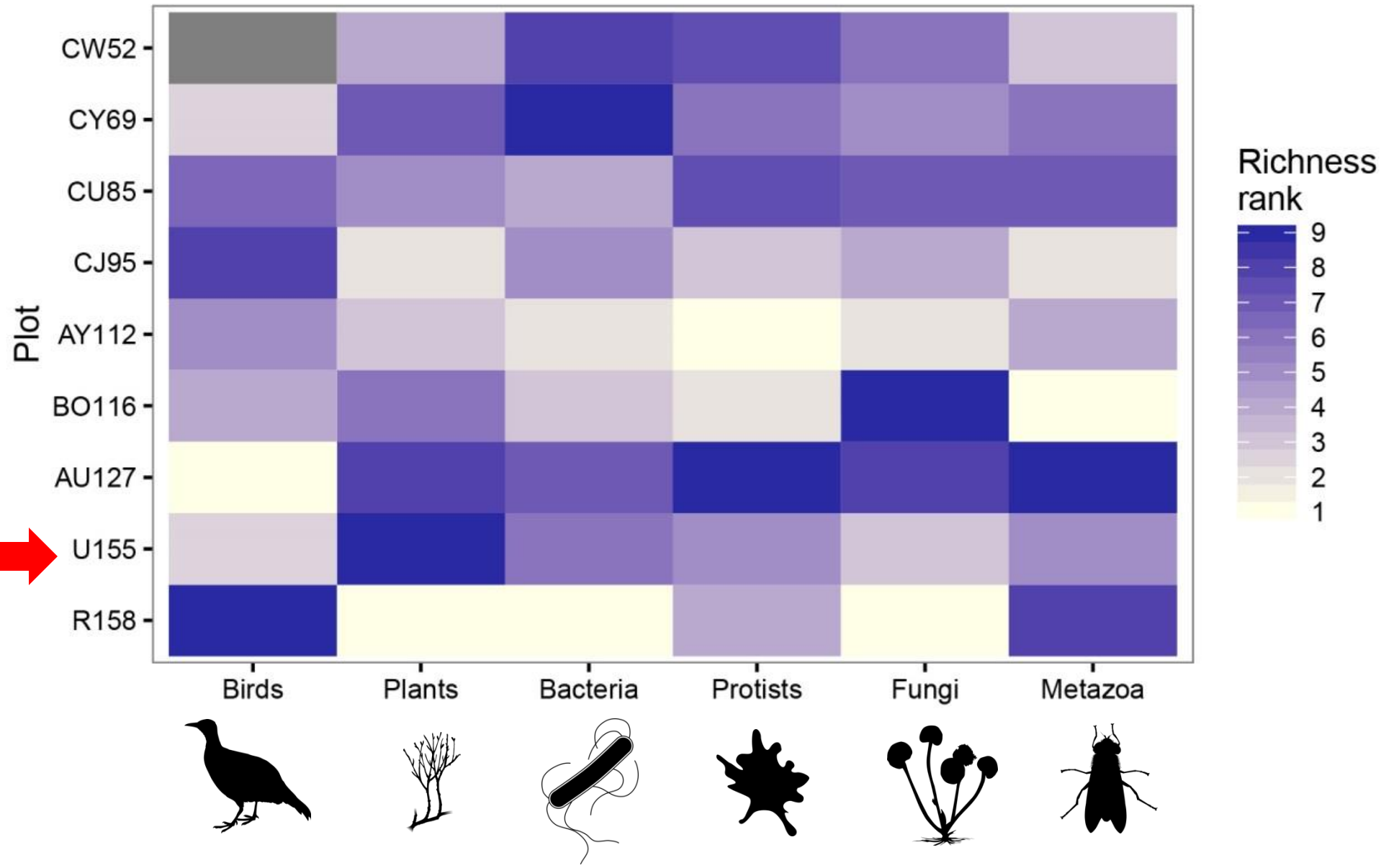

Results – relative richness

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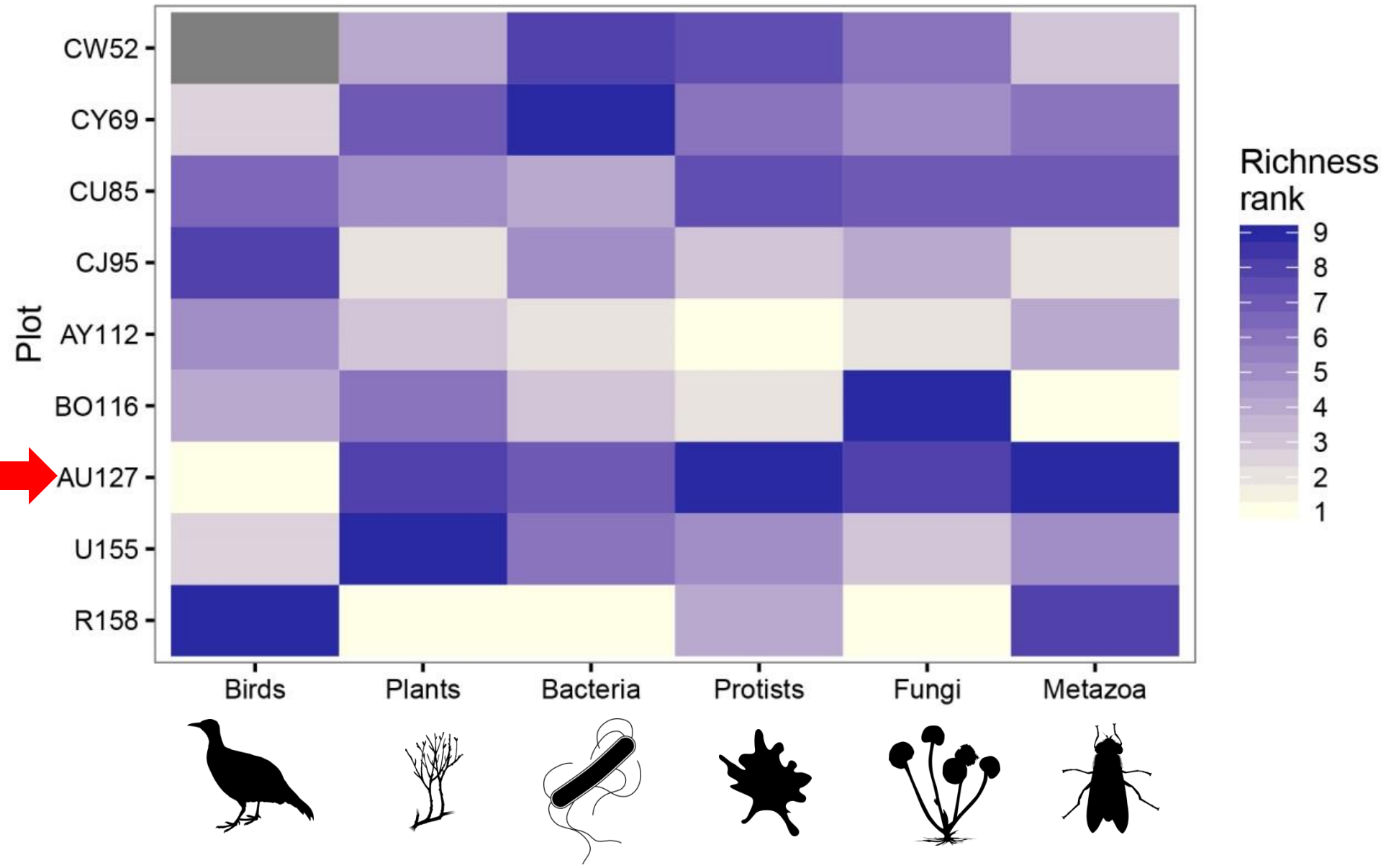
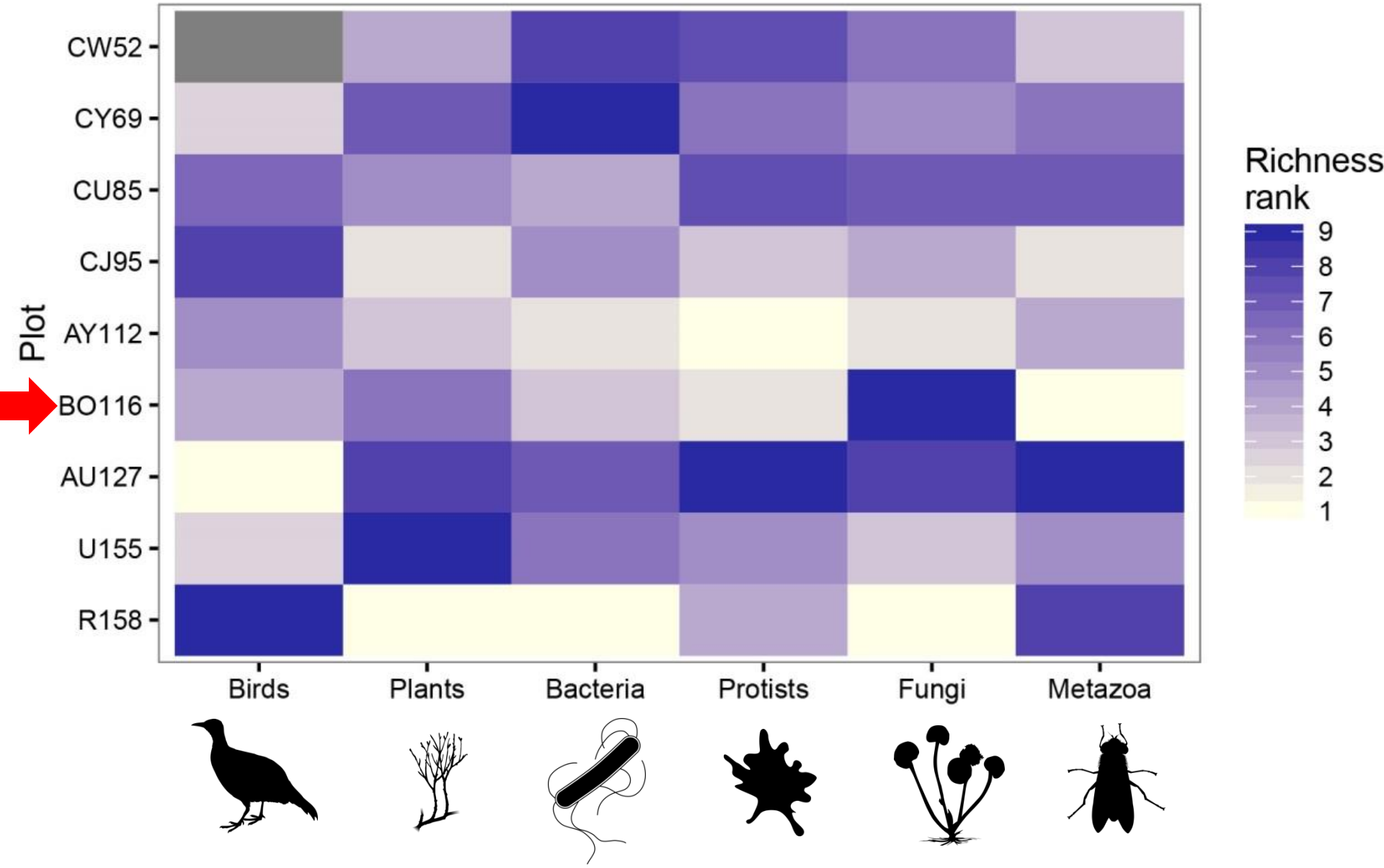
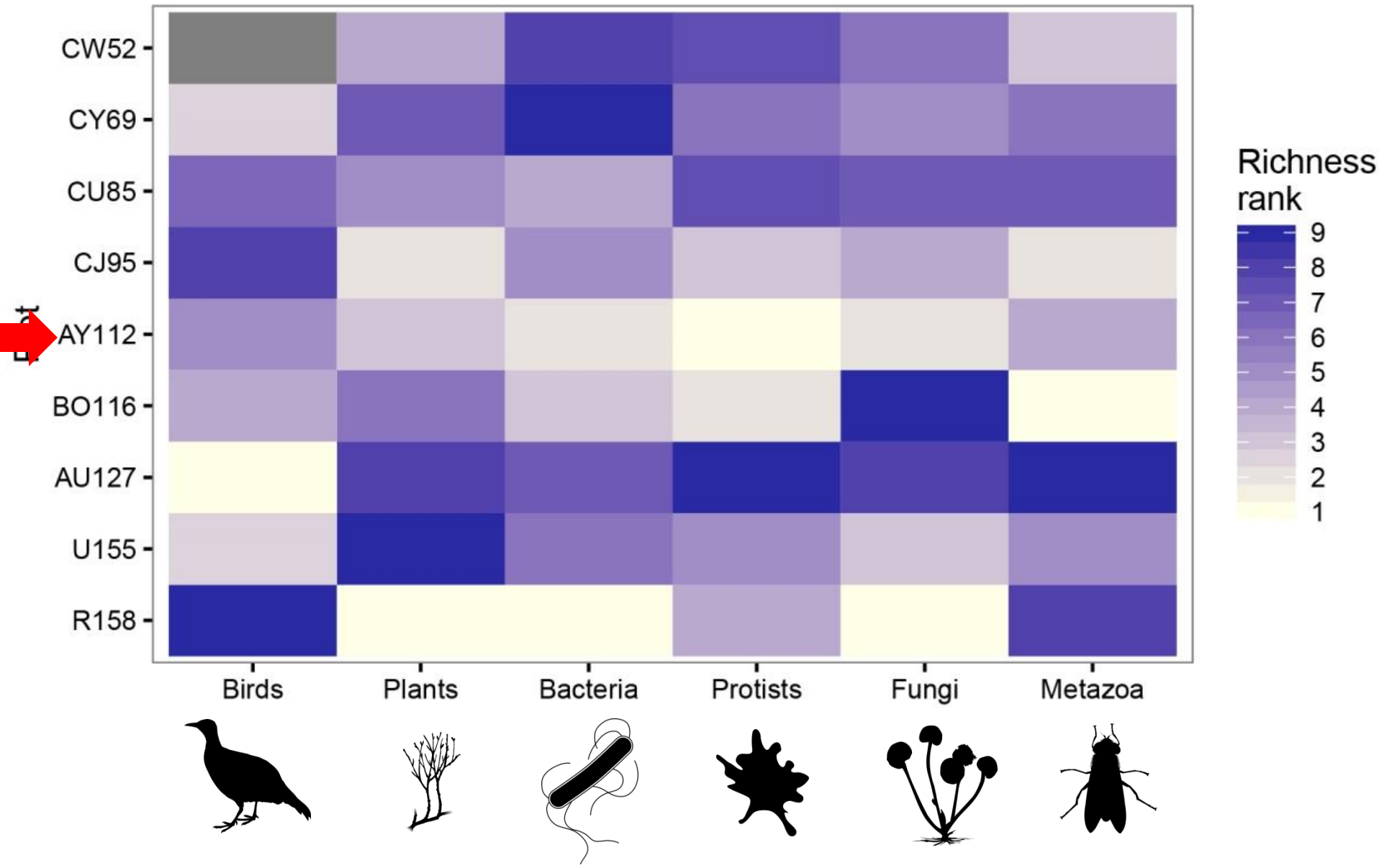


Results – relative richness



Results – relative richness

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Comparison of two eDNA approaches (richness)

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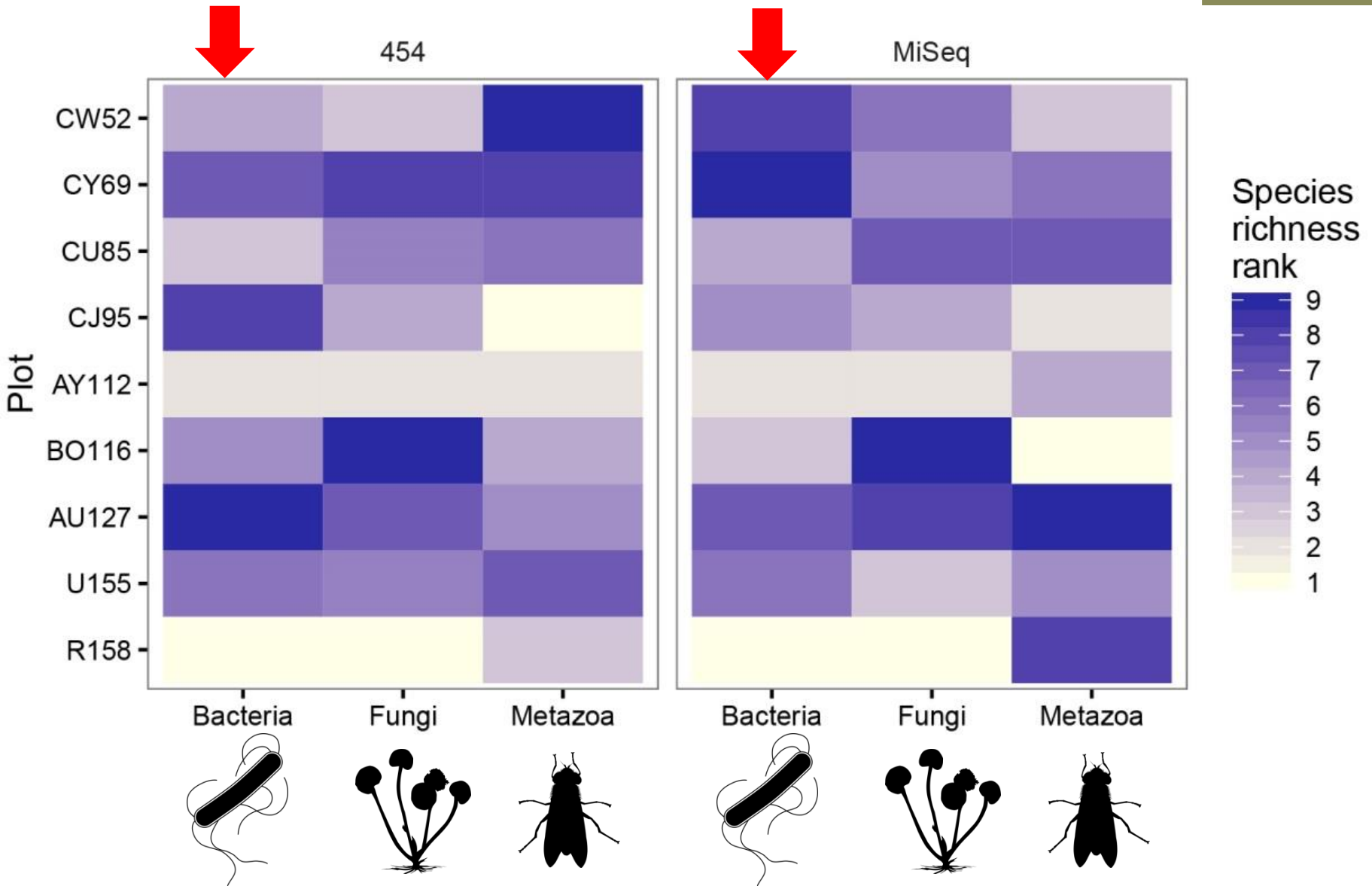

Comparison of two eDNA approaches (richness)

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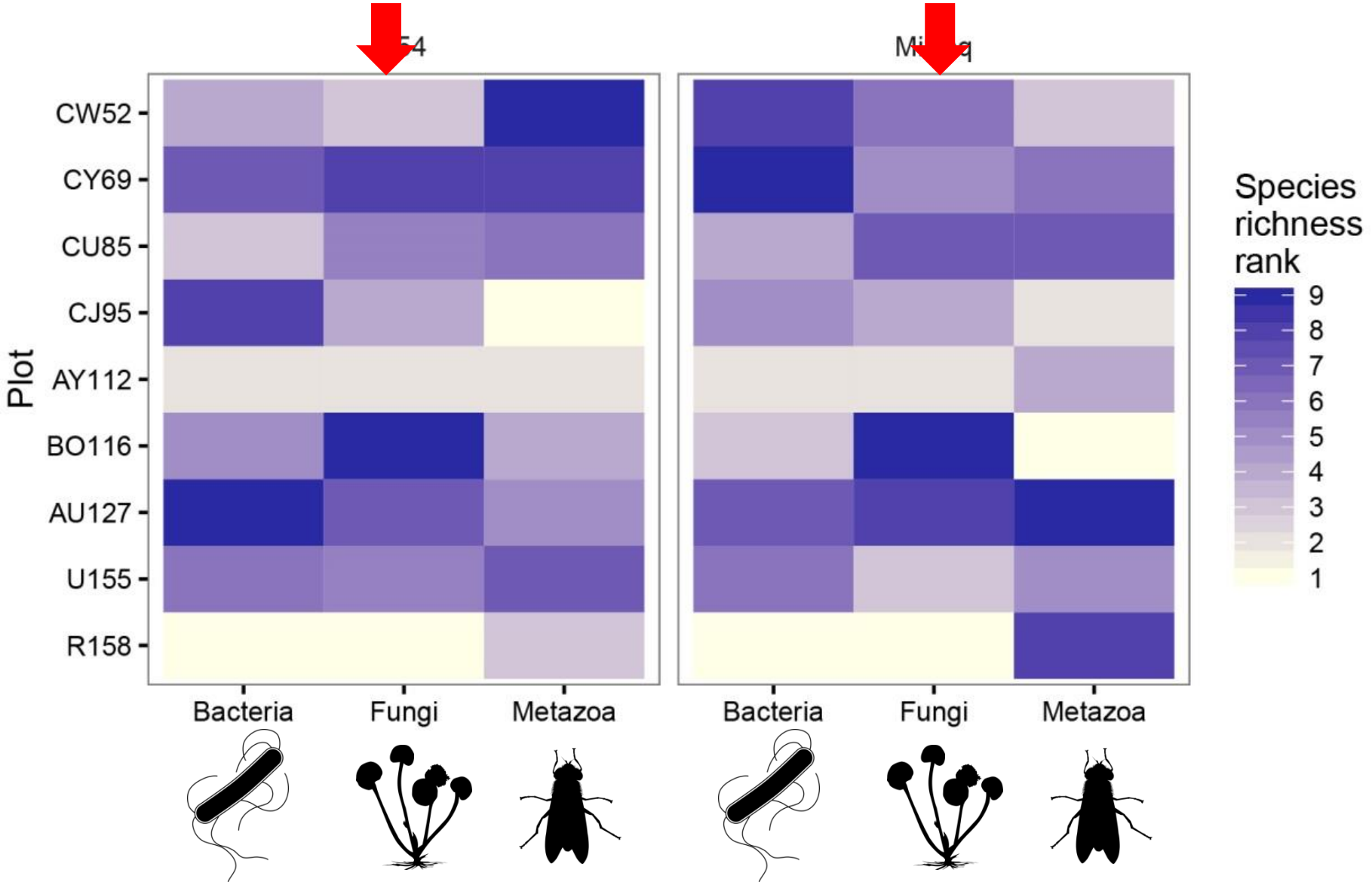

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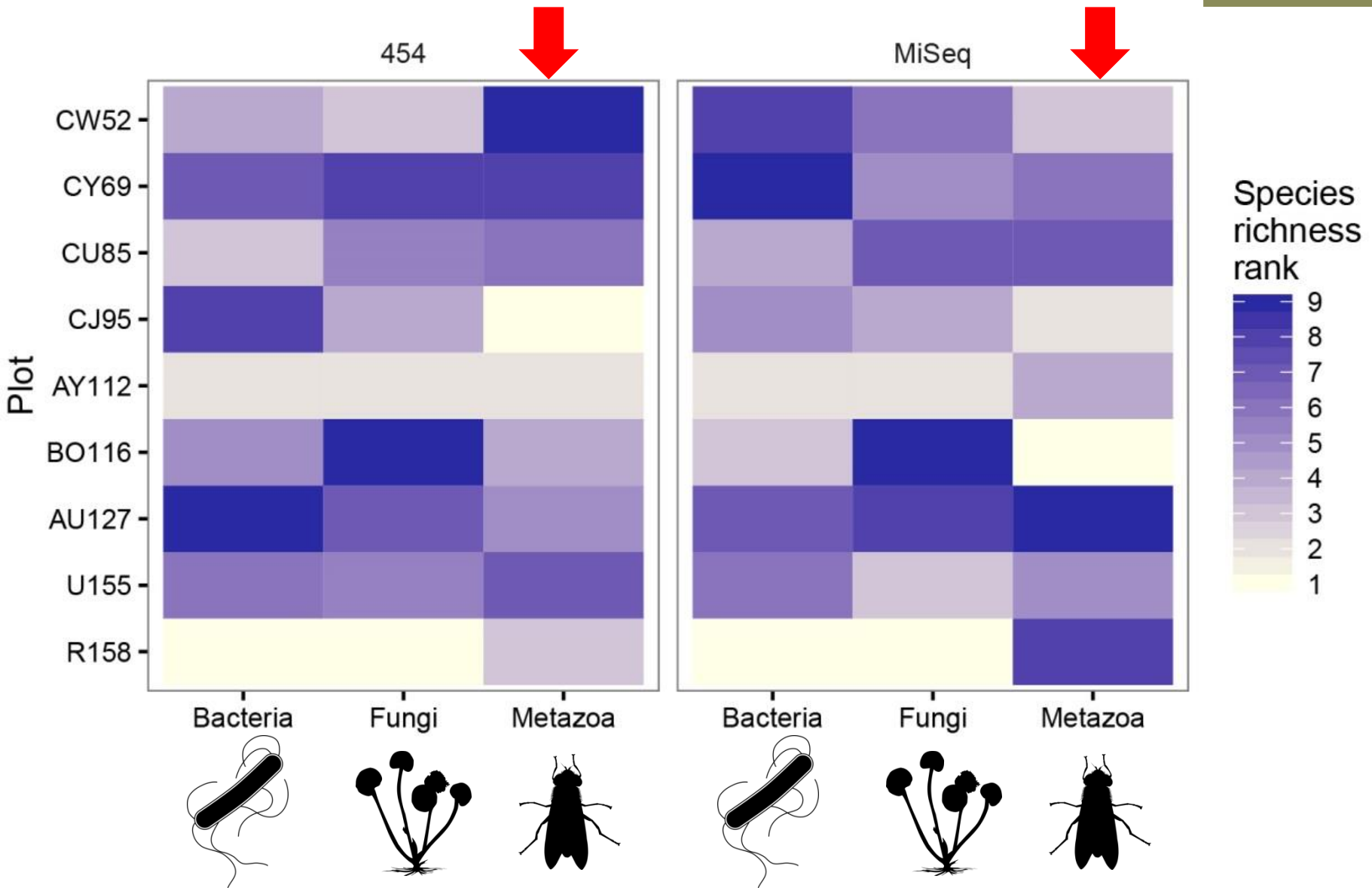
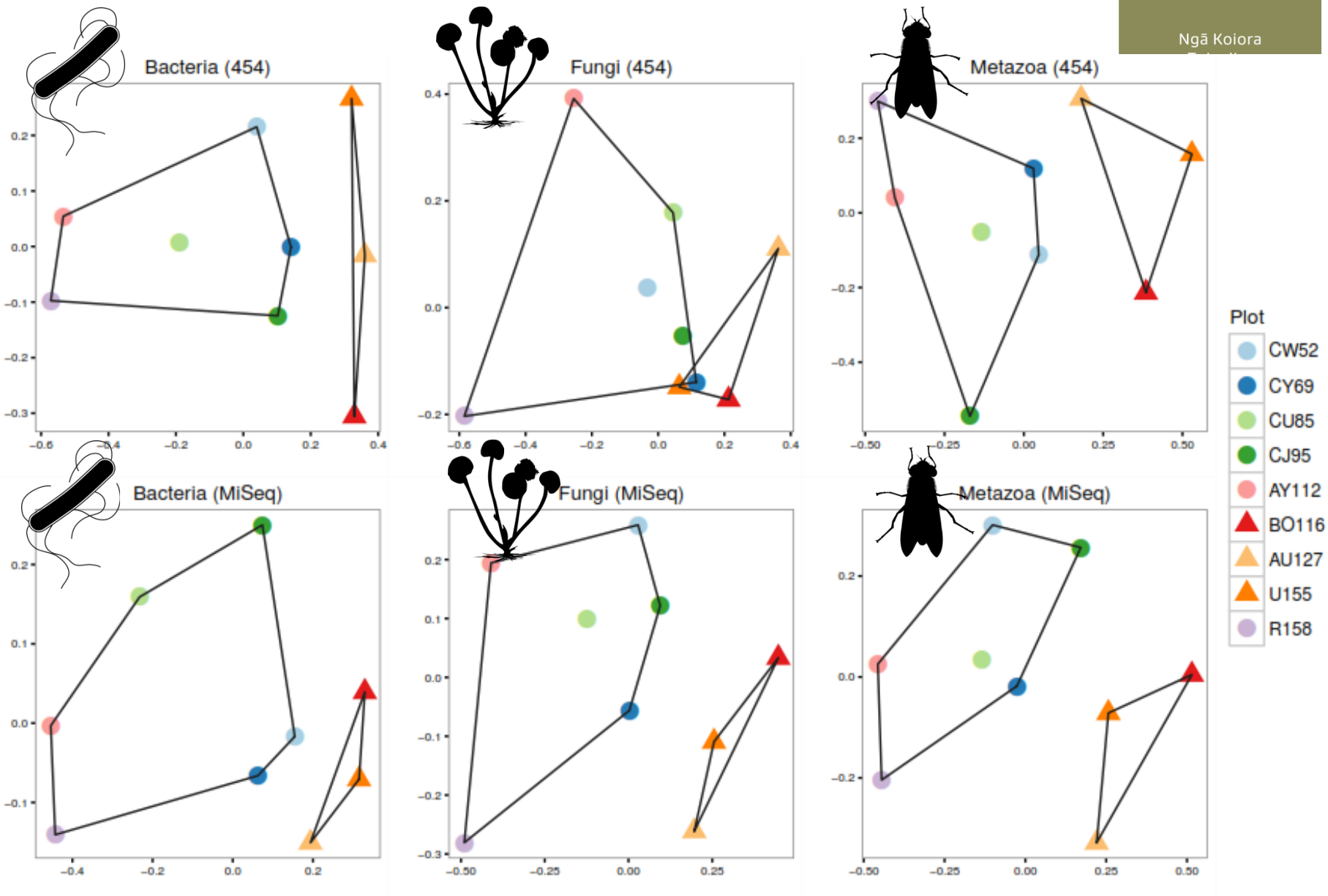


Composition comparison



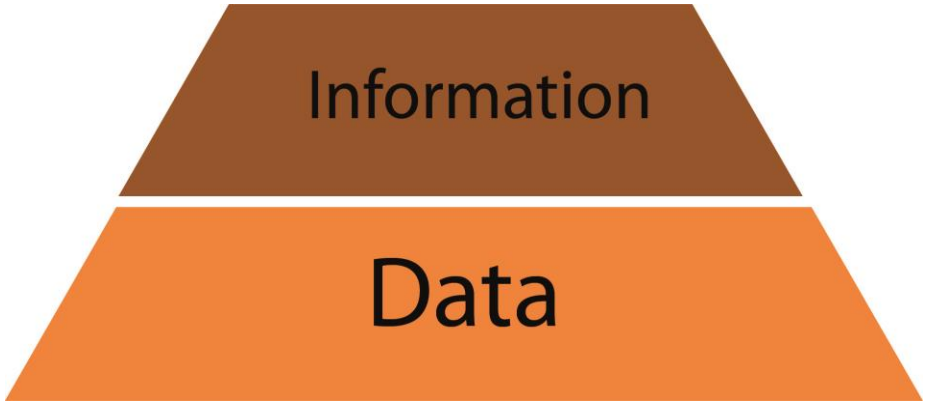
Conclusions from T1 eDNA pilot

NEW ZEALAND'S BIOLOGICAL HERITAGE

Ngā Koiora Tuku Iho

- Is it practical to collect eDNA data from Tier 1 plots? **YES**
- What sort of data does the method generate? **LOTS**
- Are there patterns between forest and non-forest plots? **YES**
- Are the results from the two very different approaches consistent? **Somewhat**

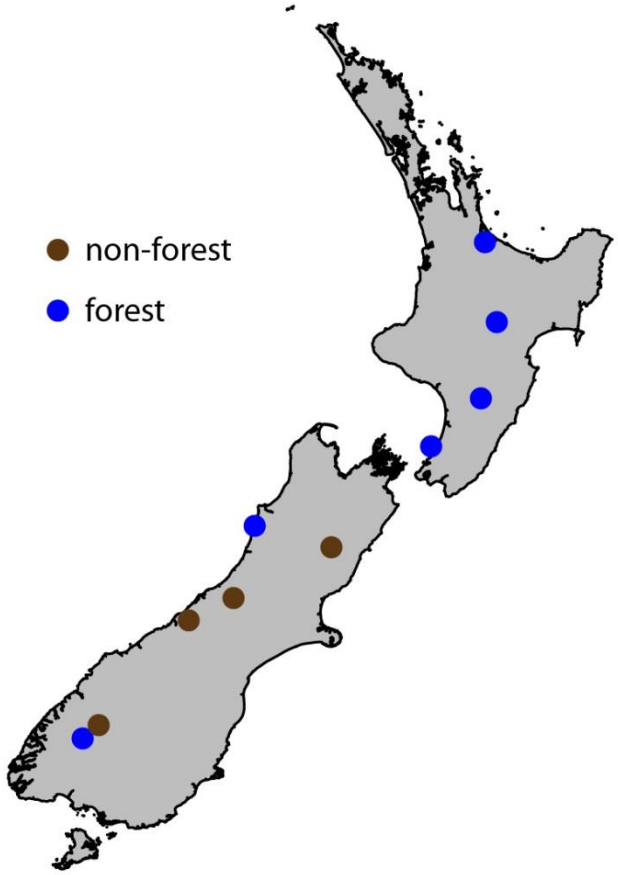
4. Field validation of eDNA data



Field data vs DNA data

- Plants as test-case

- Initially trialed sampling from soil cores but results were poor
  - Sampling not optimal for plants
  - Low sequence count
  - Poor reference data



NEW ZEALAND'S BIOLOGICAL HERITAGE

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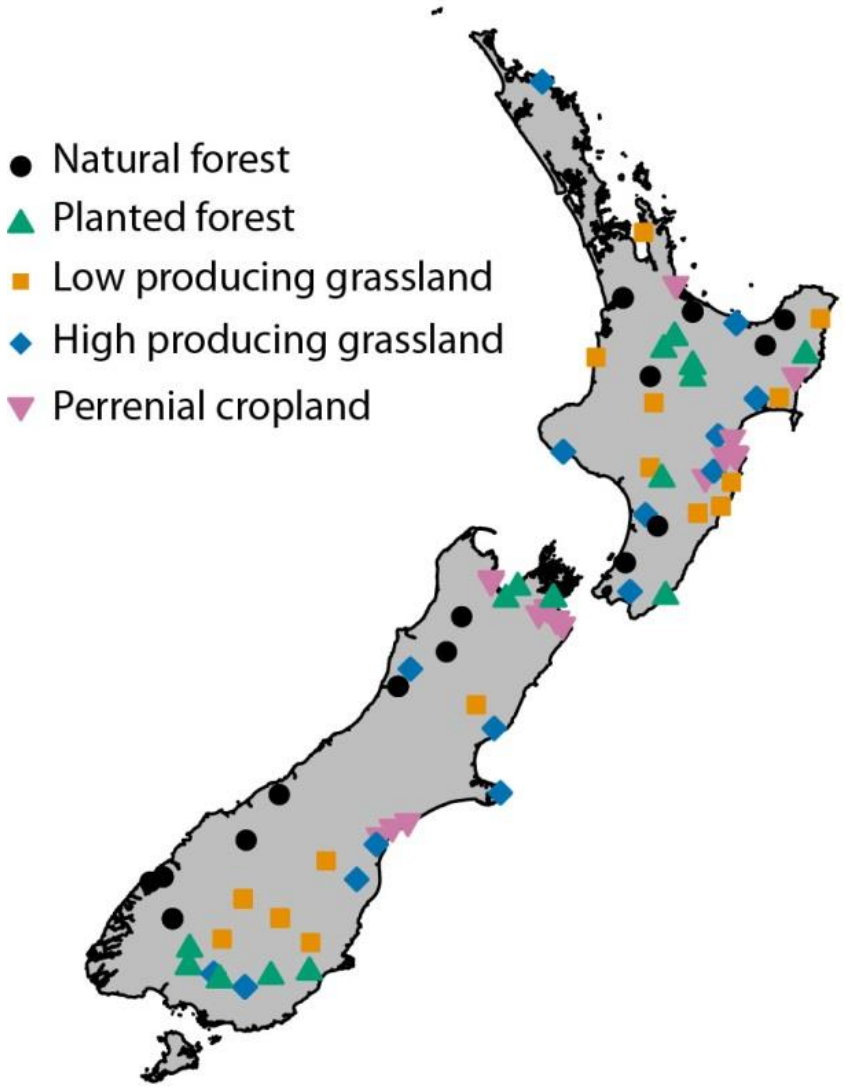
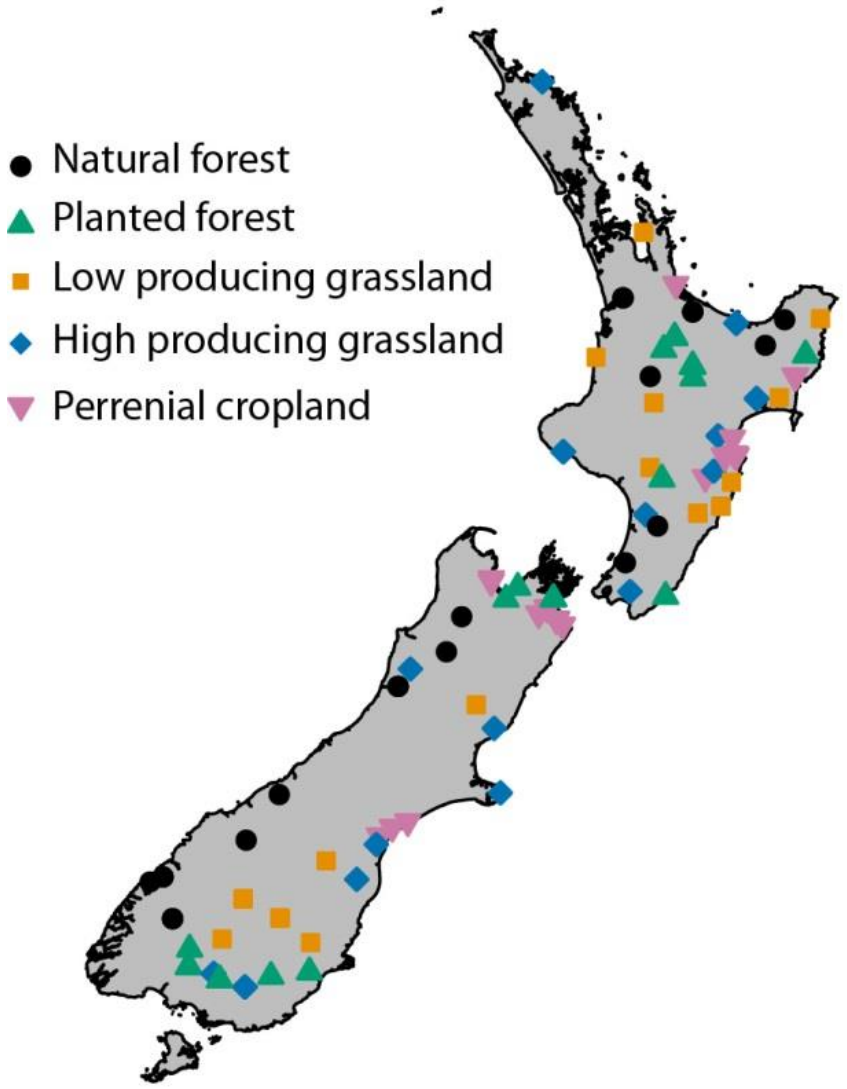
Plant field data vs DNA data
Phase 2 NGBA project

- MBIE Smart Idea
- 125 locations sampled 2015/2016
- Uses 8km grid
- 5 different land uses
- Updated primers and sampling method for plants



Plant field data vs DNA data RESULTS

- Field data
  - 671 species in total; 406 native, 265 exotic
- DNA data
  - 787 unique OTUs
  - ~ 1.8 million sequences



Community composition comparison

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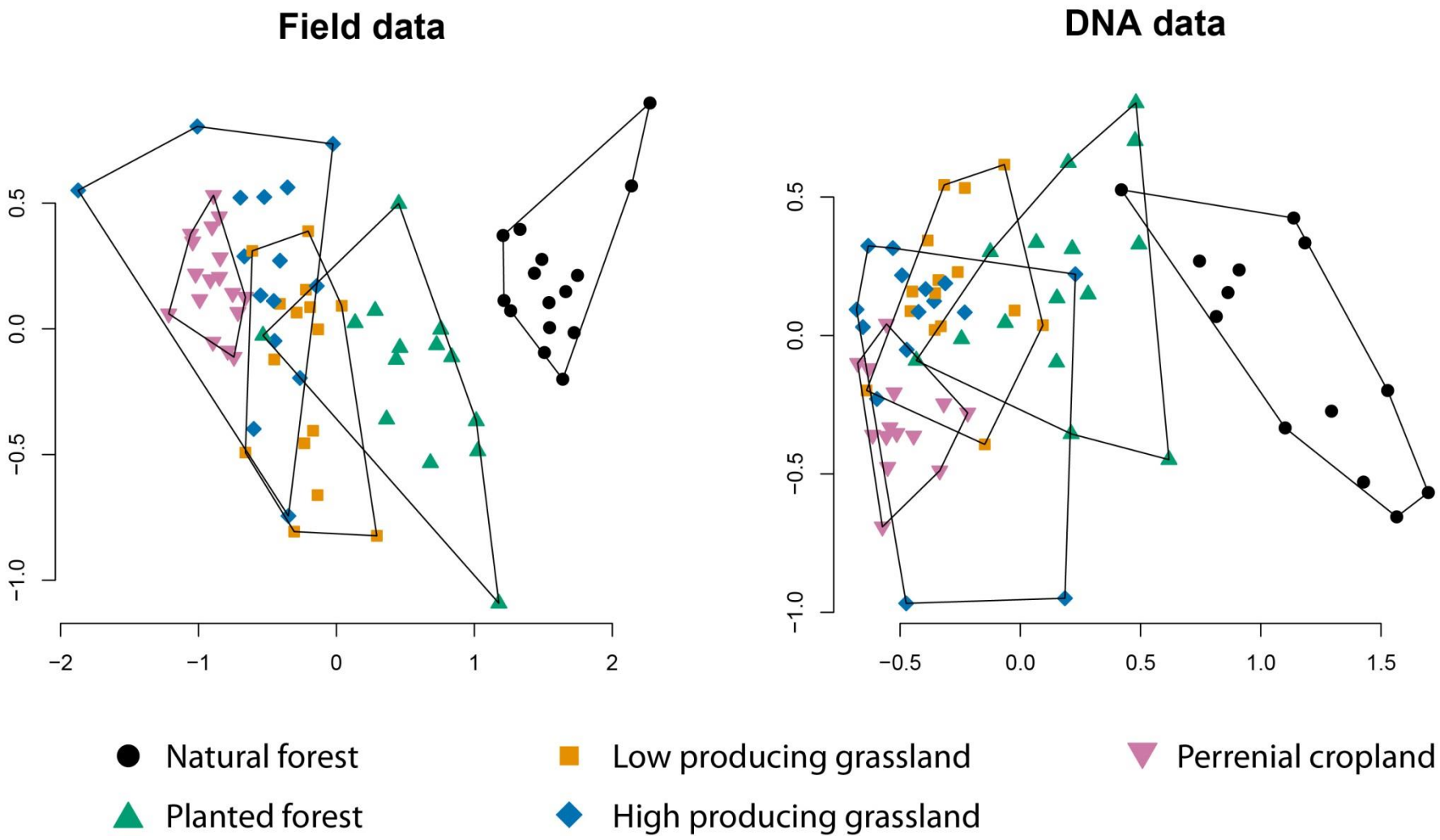

Relative richness comparison

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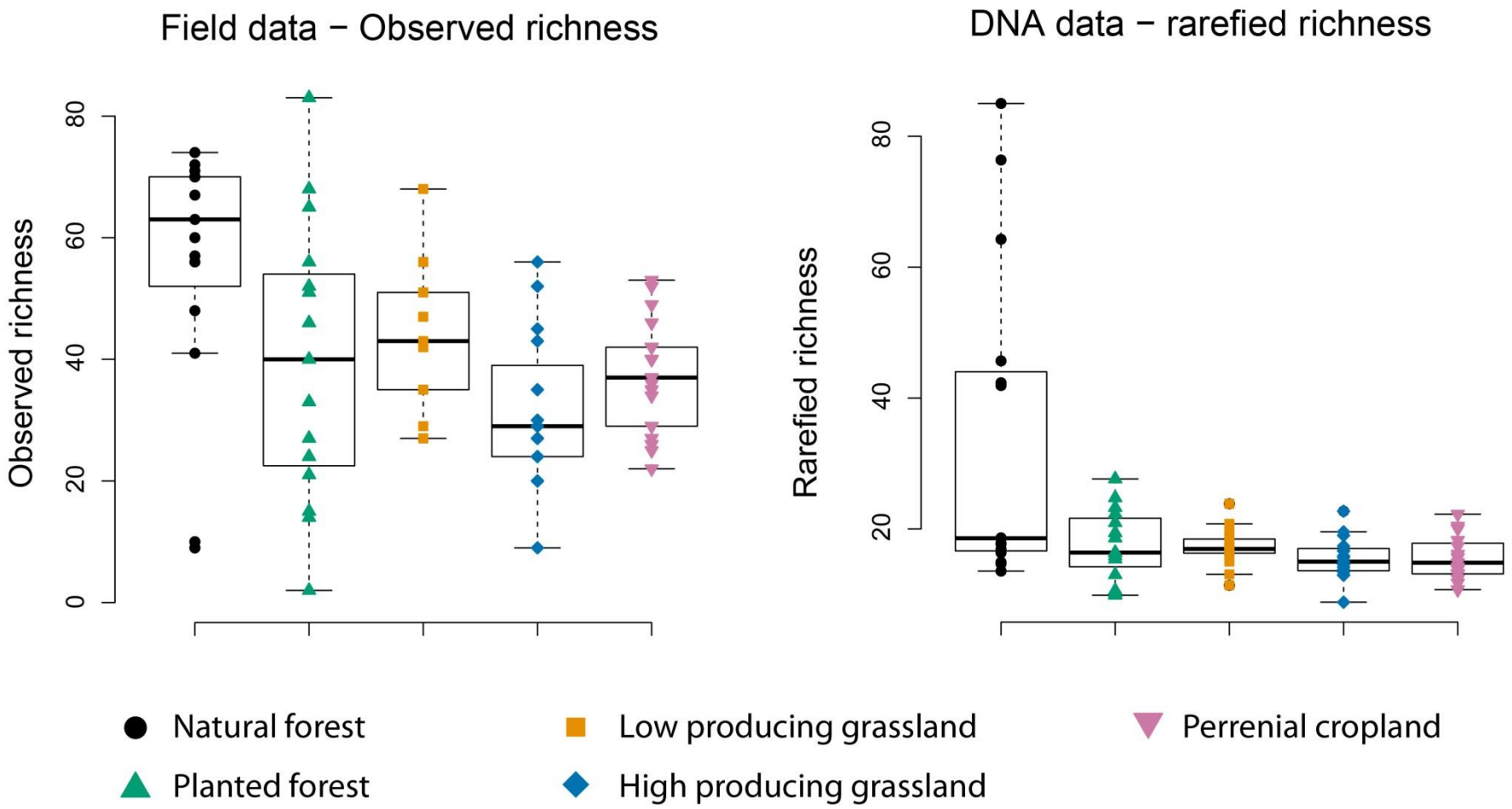

Species identification

NEW ZEALAND'S BIOLOGICAL HERITAGE

Ngā Koiora Tuku Iho

How many of the field-identified species do we detect on the same plot using eDNA?

	Species	Genus	Family
Raw match	26%	53%	62%

But how good is our reference data?

Species level

- 412 species (64%) have 1 or more sequences
- 200 species (36%) have none.

Genus level

- 279 (92%) have genus matches
- 25 genera do not

Species identification

NEW ZEALAND'S BIOLOGICAL HERITAGE

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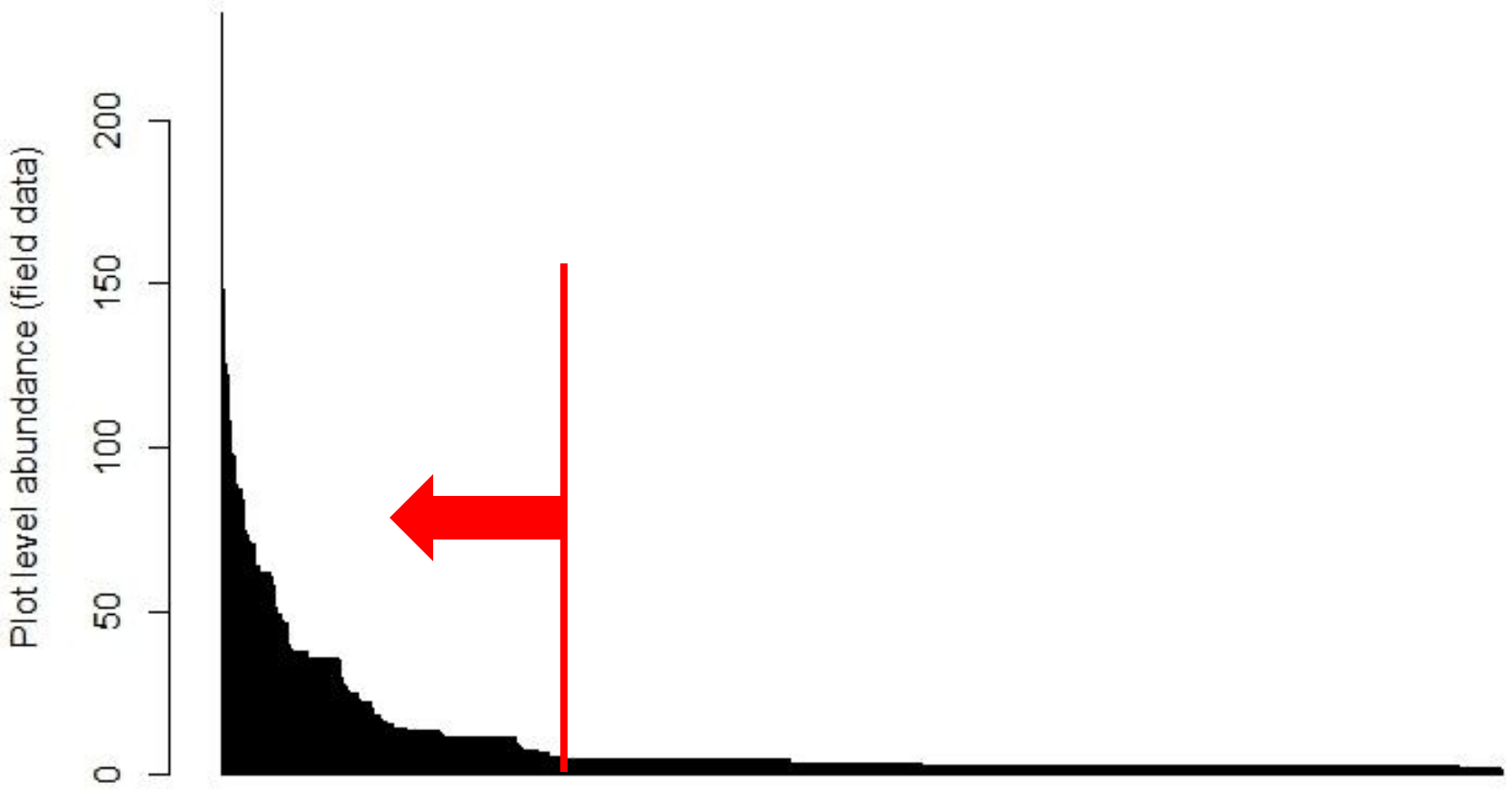
How many of the field-identified species do we detect on the same plot using eDNA?

	Species	Genus	Family
Raw match	26%	53%	62%
Species with reference data	37%	64%	77%

Detection issues? Long tail of rare species



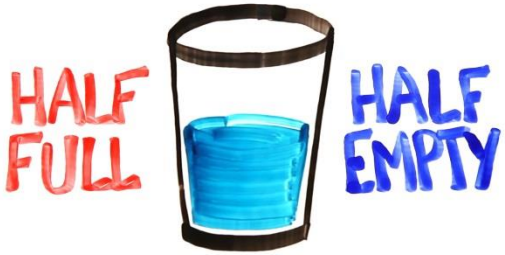
Species identification

How many of the field-identified species do we detect on the same plot using eDNA?

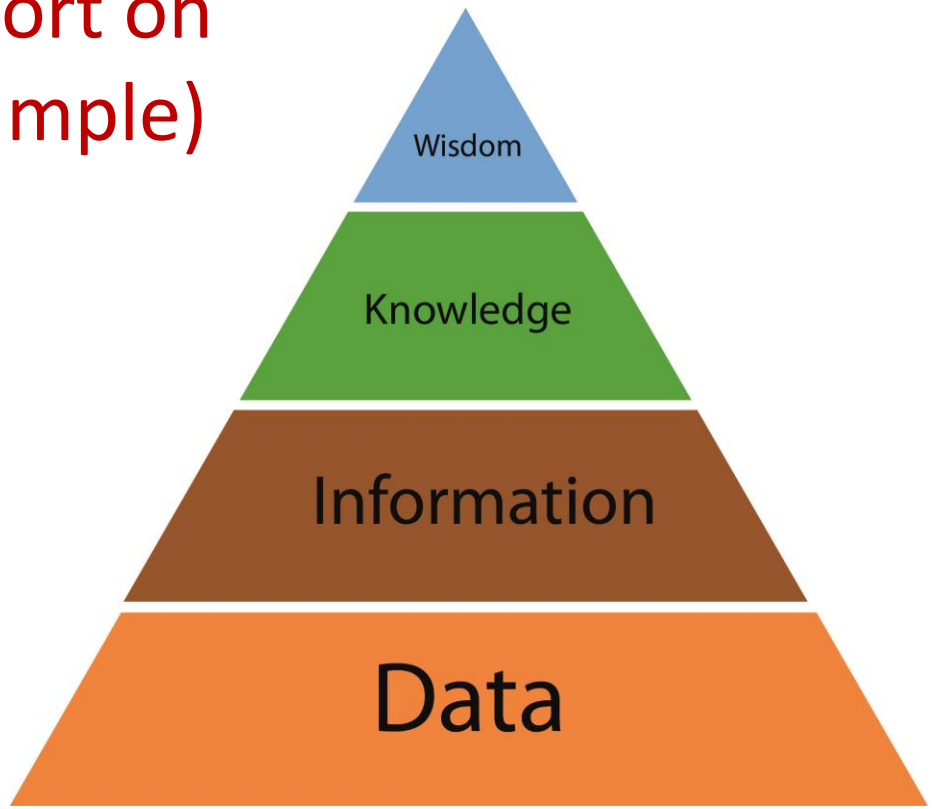
	Species	Genus	Family
Raw match	26%	53%	62%
Species with reference data	37%	64%	77%
With reference data and abundant	47%	78%	91%

What does this tell us about the data?

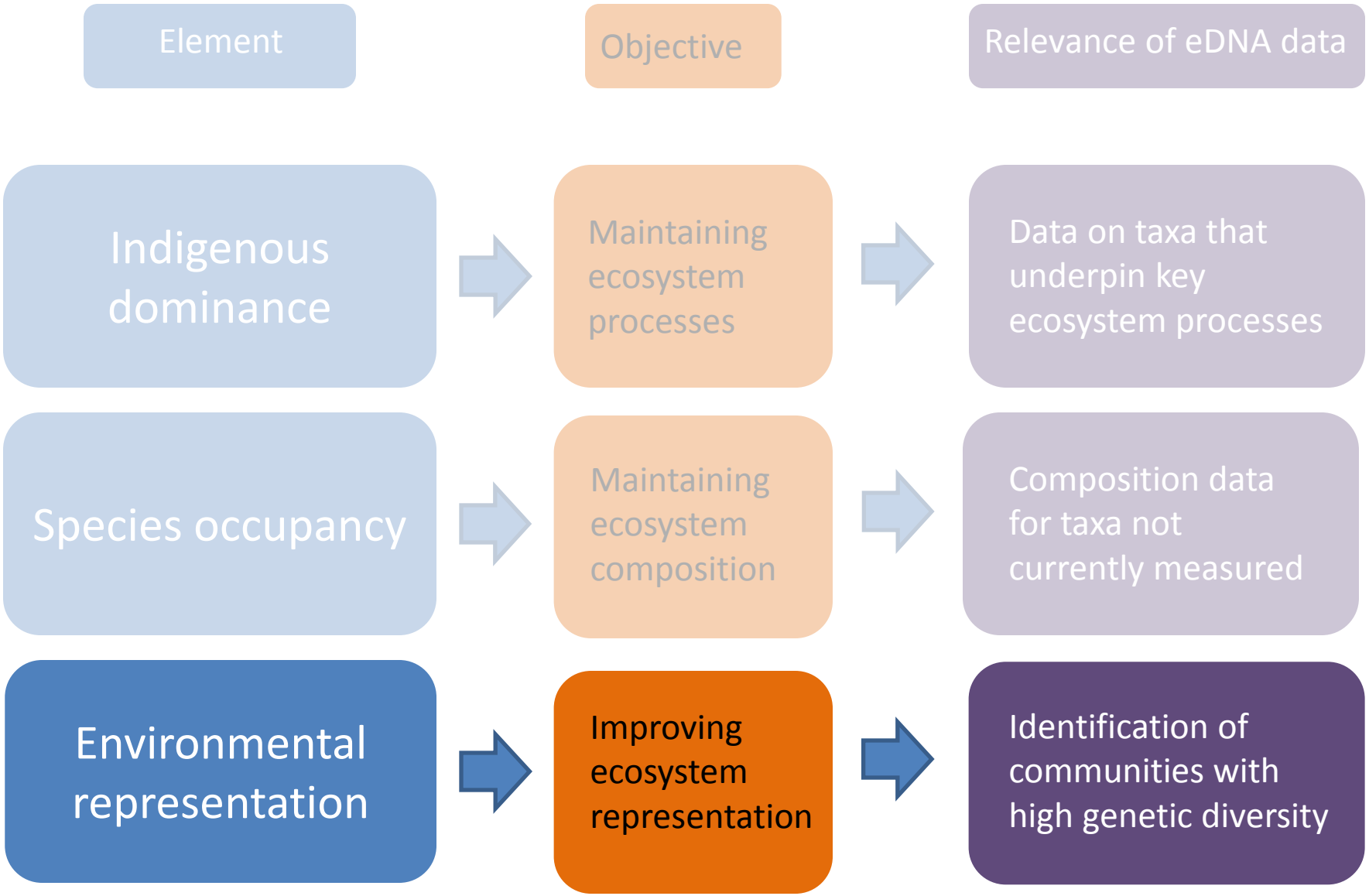
- eDNA identifies similar compositional patterns but richness not so well
- Species level matches can occur but are not the norm
  - Treat name assignments with caution!
- Plant data are a difficult test-case
  - High field data standards
  - Funky genomes
- More accurate matches at higher taxonomic levels
  - these are more meaningful for other diverse taxa



5. Using eDNA to report on genetic diversity (example)



Genetic diversity in a reporting context



(Phylo)genetic diversity as a potential indicator

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A measure of evolutionary relatedness

Community A

Community B

Community (B) has higher genetic diversity compared with community (A)

Community (B) has greater evolutionary potential

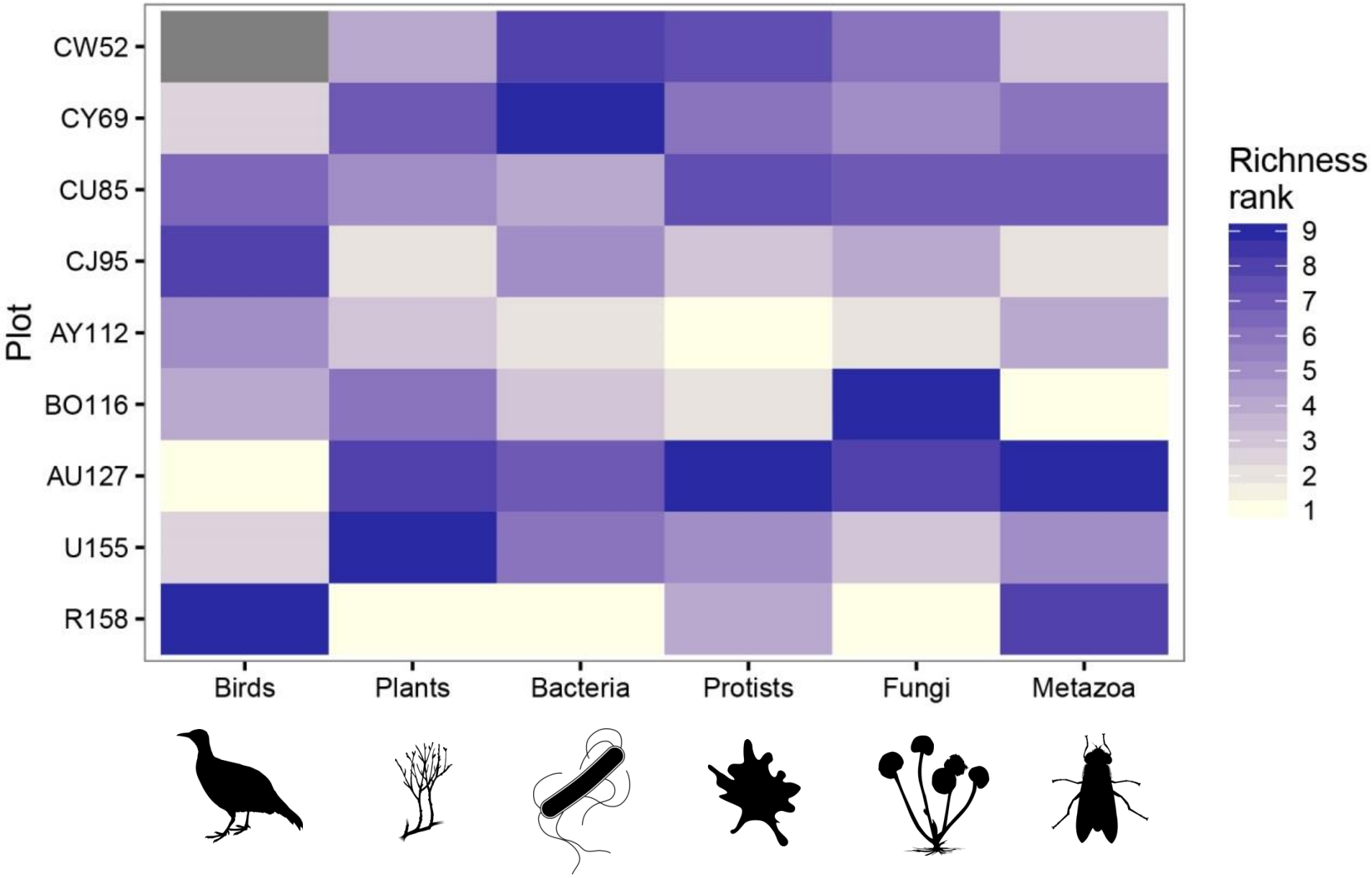
Anthus novaeseelandi...
Fringilla coelebs mi...
Passer domesticus mi...
Acanthis flammea mit...
Carduelis carduelis ...
Emberiza citrinella ...
Petroica australis m...
Petroica macrocephal...
Zosterops lateralis ...
Alauda arvensis mito...
Turdus merula mitoch...
Turdus philomelos mi...
Rhipidura fuliginosa...
Notiomystis cincta m...
Gerygone igata mitoc...
Philesturnus caruncu...
Mohoua novaeseelandi...
Anthornis melanura m...
Prosthemadera novaes...
Chalcites lucidus cy...
Eudynamys taitensis ...
Larus dominicanus mi...
Hemiphaga novaeseela...
Todiramphus sanctus ...
Circus spilonotus mi...
Acanthisitta chloris...
Branta canadensis mi...
Tadorna ferruginea m...
Gallirallus australi...
Nestor meridionalis ...
Nestor notabilis mit...
Platycercus eximius ...
Cyanoramphus novaeze...

0.06

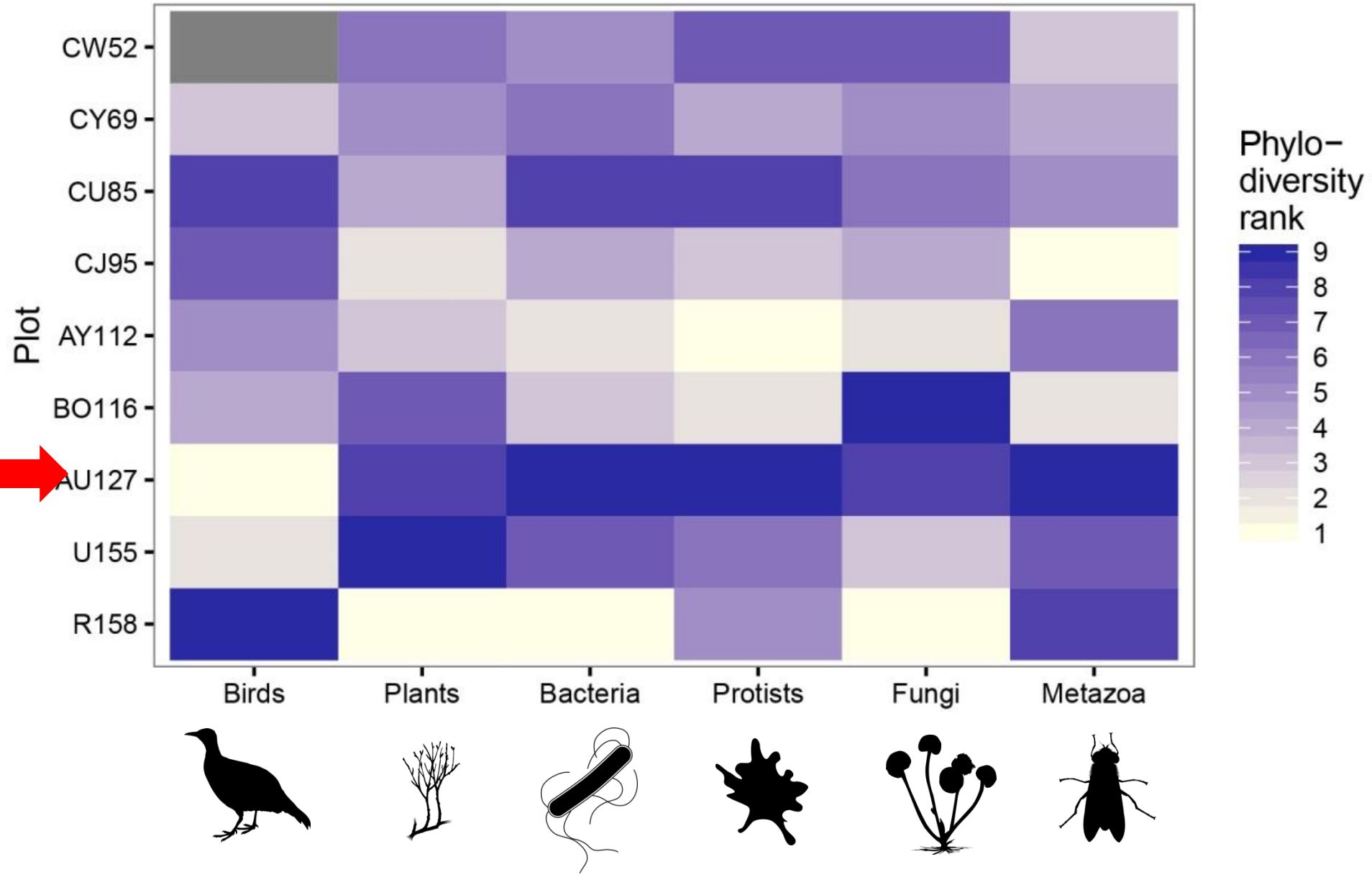
Strengths of phylogenetic indicators

- Robust to taxonomic (name) uncertainty and change
- Capture information about the entire community
- Can be calculated directly from eDNA data

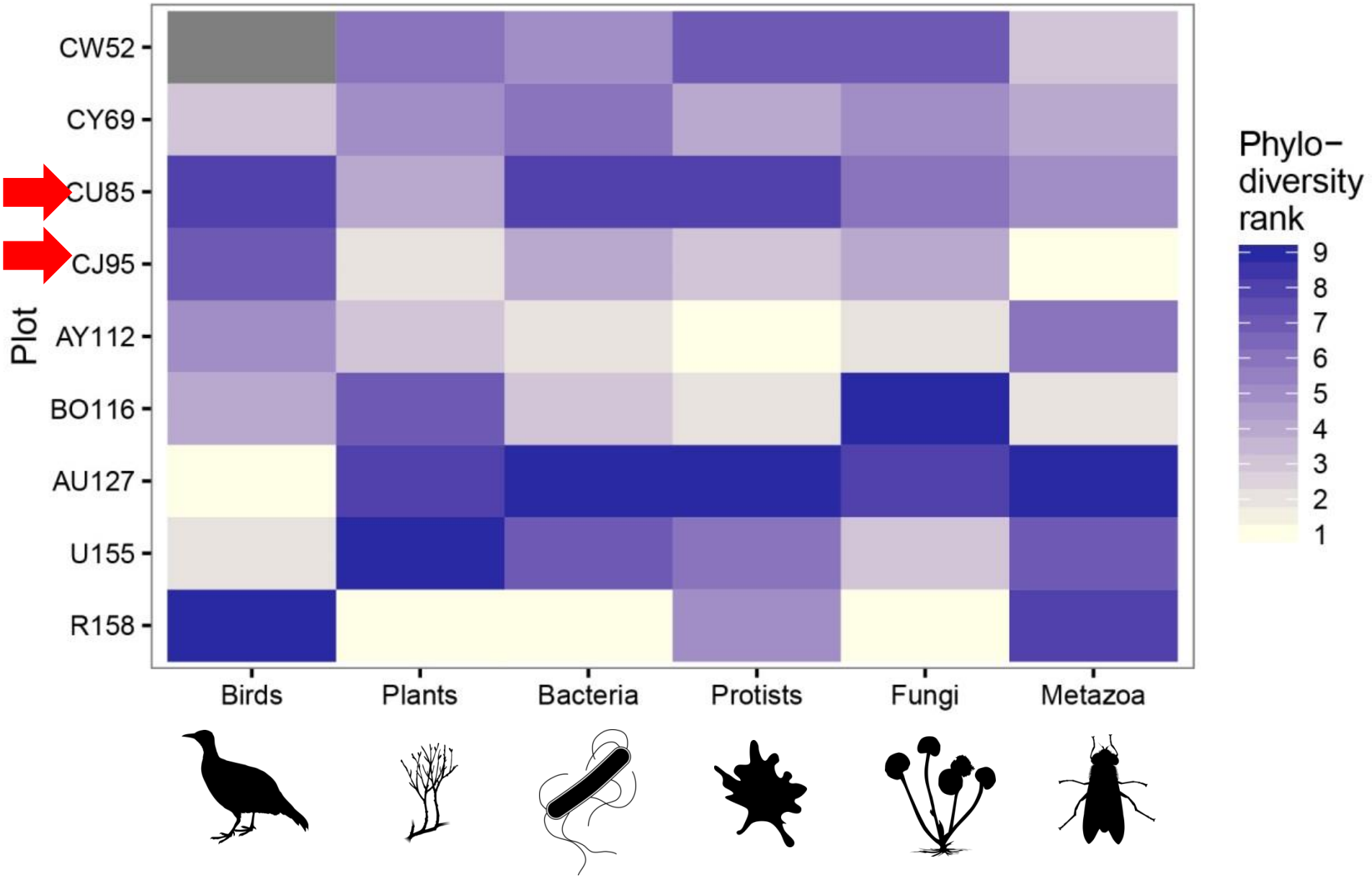
Results – relative richness



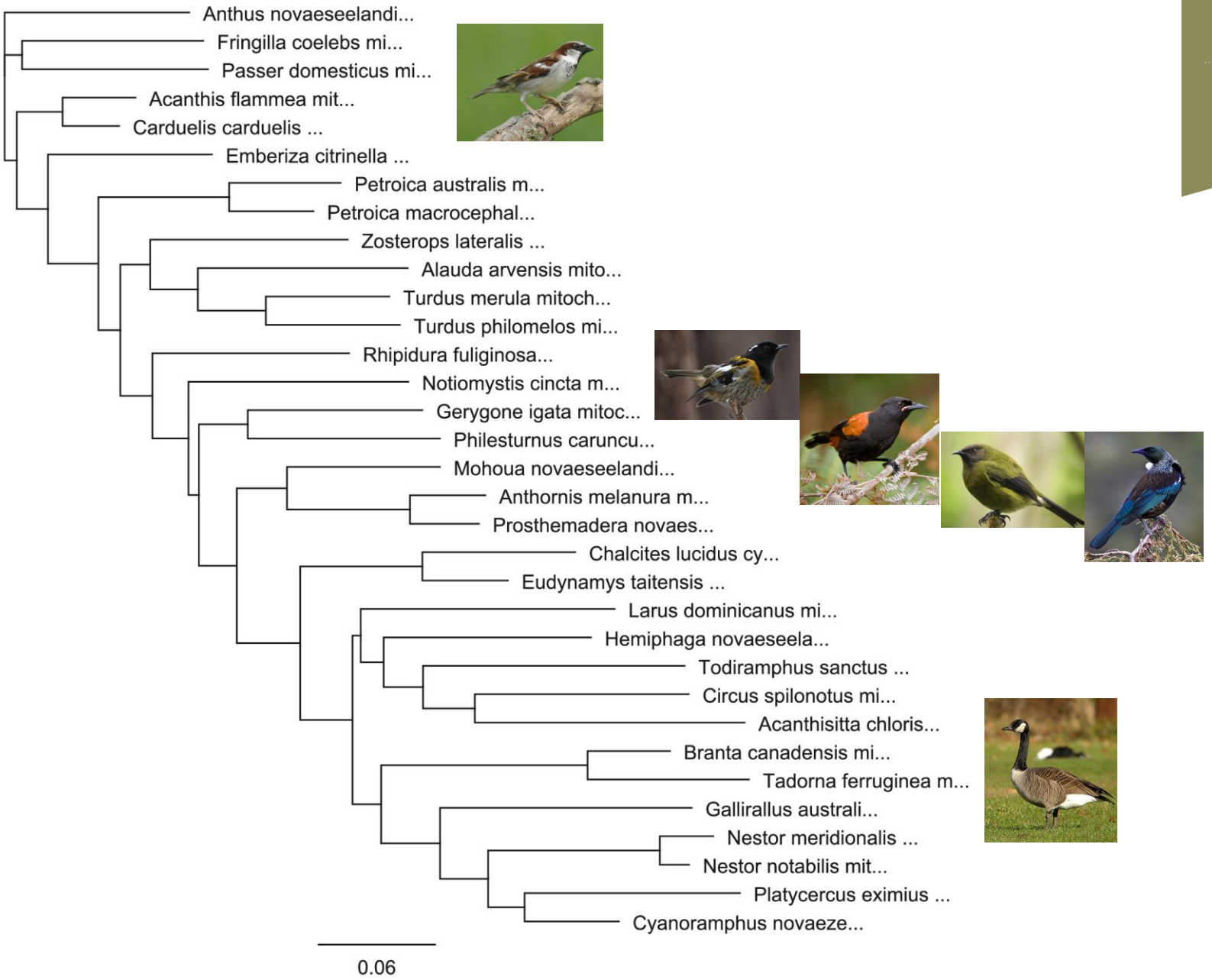
Results – Phylogenetic diversity



Results – Phylogenetic diversity



Which has the highest Phylogenetic diversity?


Anthus novaeseelandi...
Fringilla coelebs mi...
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Gallirallus australi...
Nestor meridionalis ...
Nestor notabilis mit...
Platycercus eximius ...
Cyanoramphus novaeze...
0.06

But what about endemism?

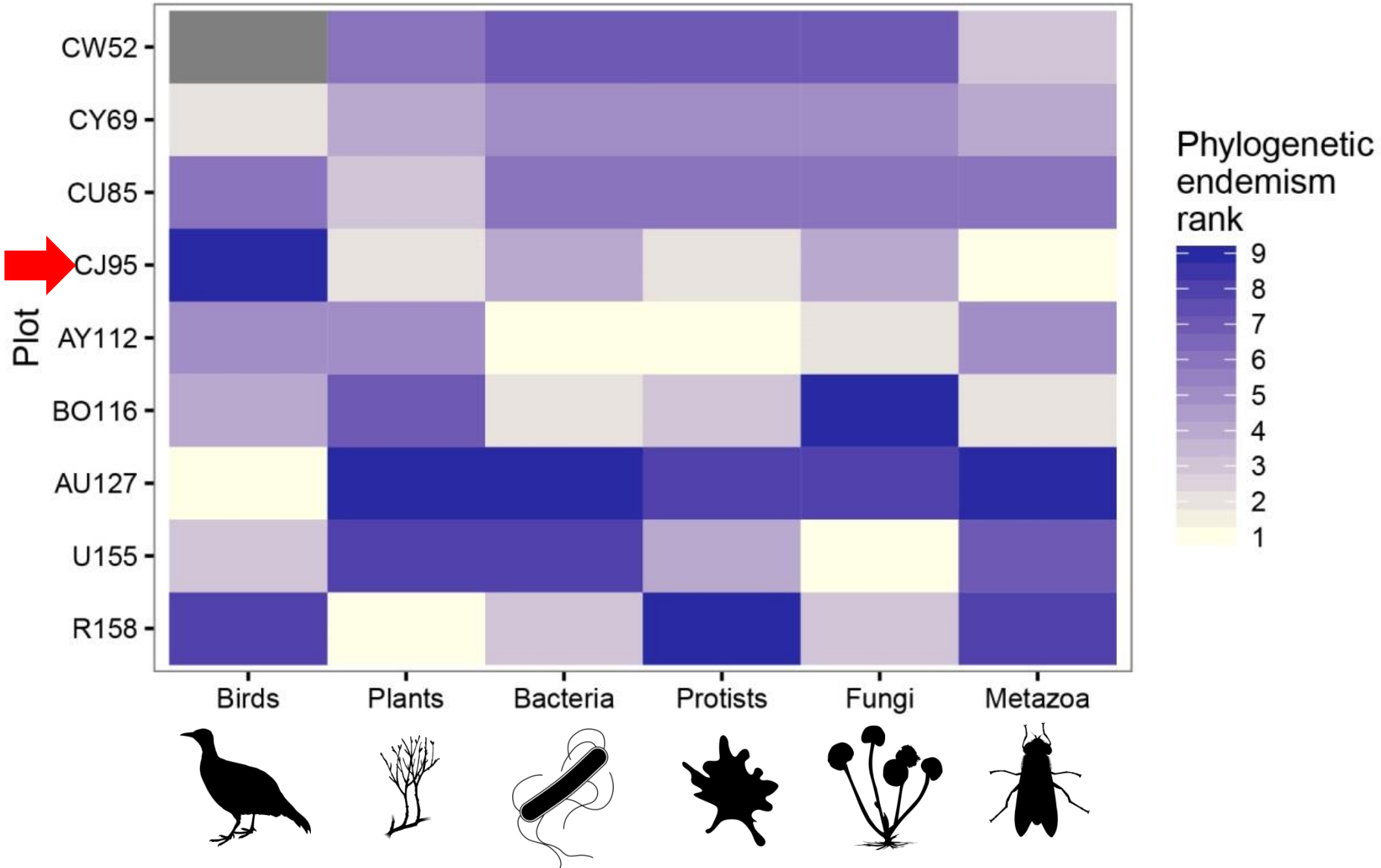
- Species found in a small number of locations are a greater conservation priority than widespread species
- Areas of endemism are where components of biodiversity with restricted ranges are concentrated
- Can quantify this within our dataset using **phylogenetic endemism** - Rosauer et al. 2009
- Calculation combines presence/absence (range size) data with data on phylogenetic relatedness
- Can be calculated using OTUs – you do not need to have a name or know if a species is native or exotic



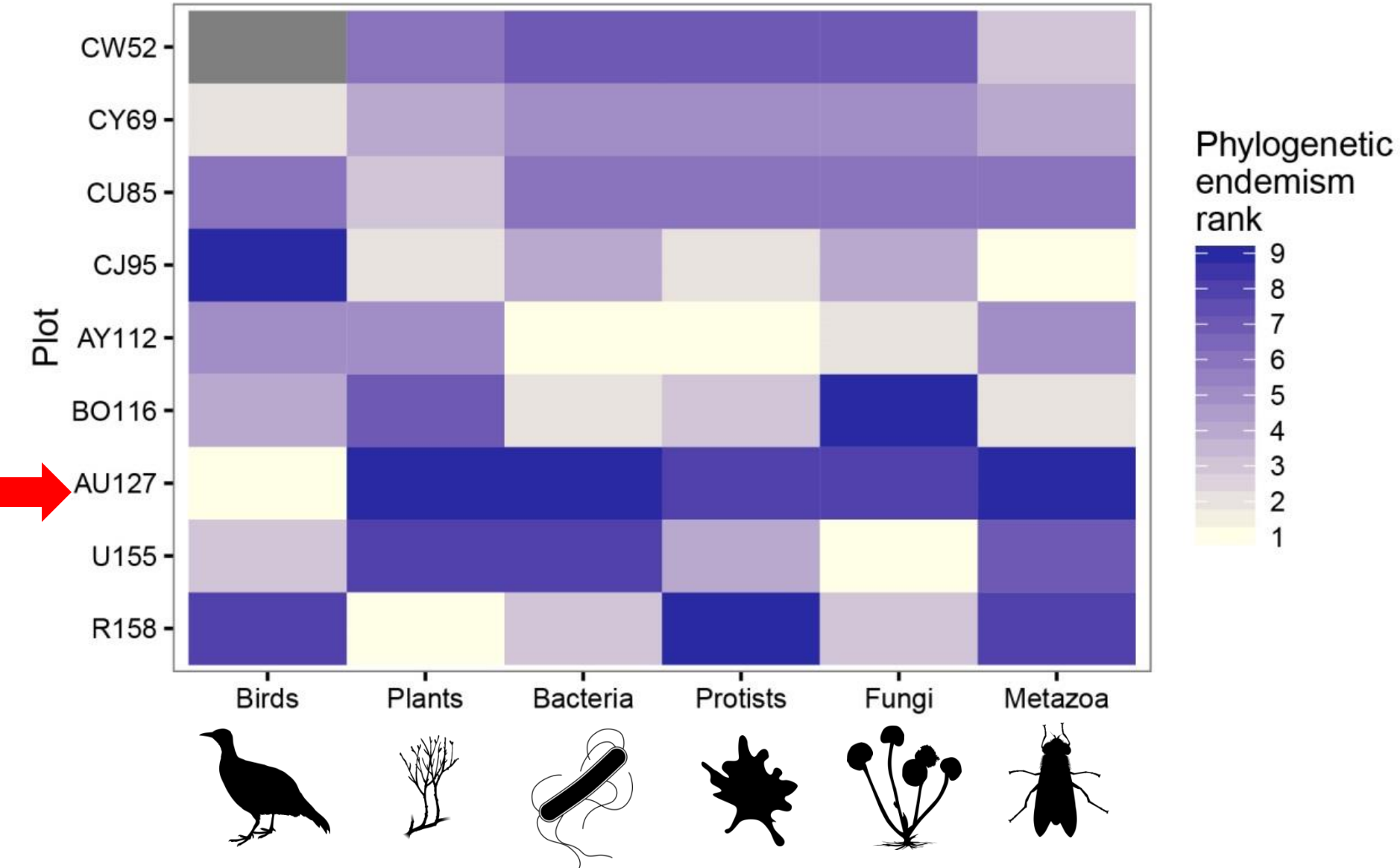
Which has the highest phylogenetic endemism?



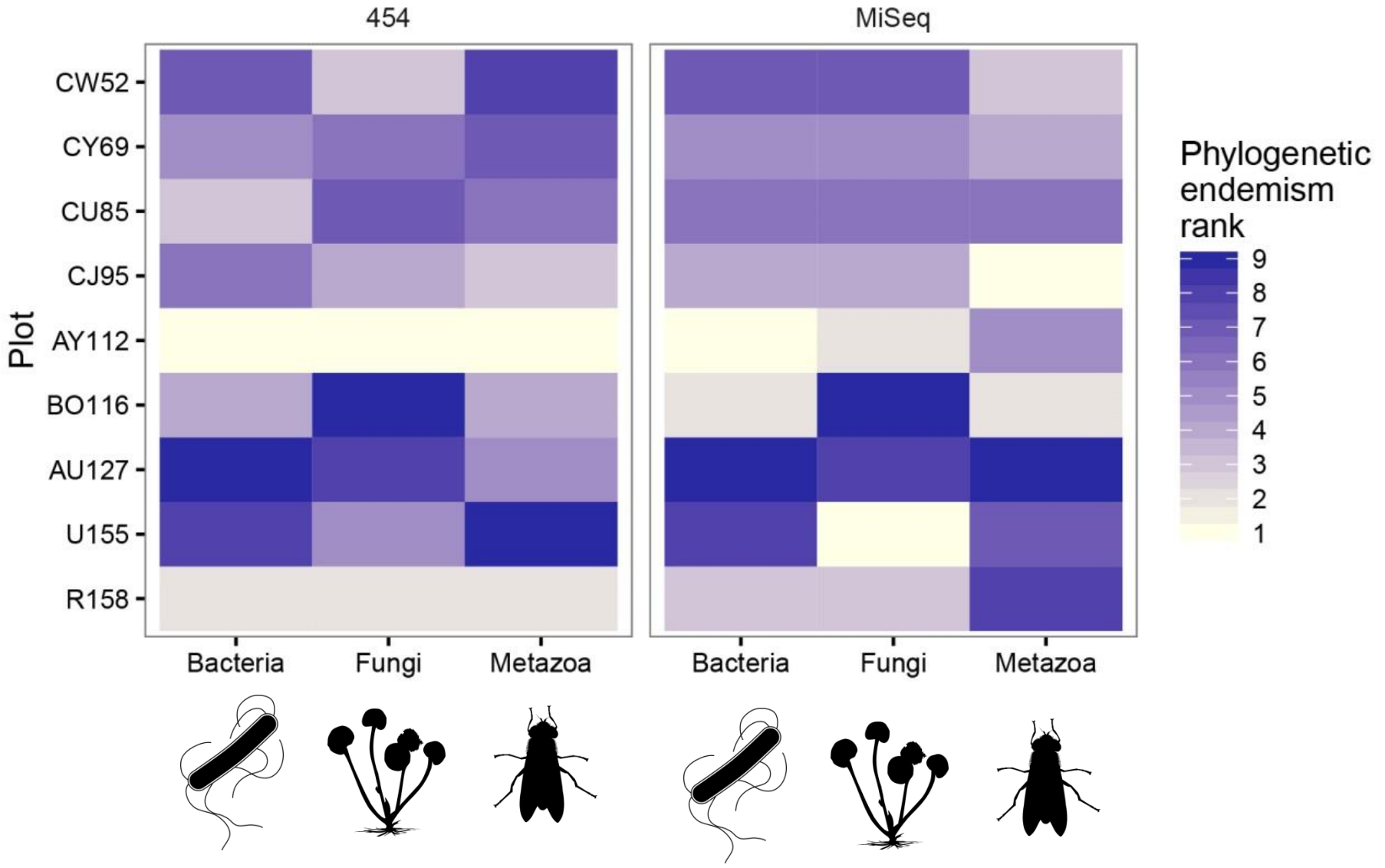

Results – Phylogenetic endemism



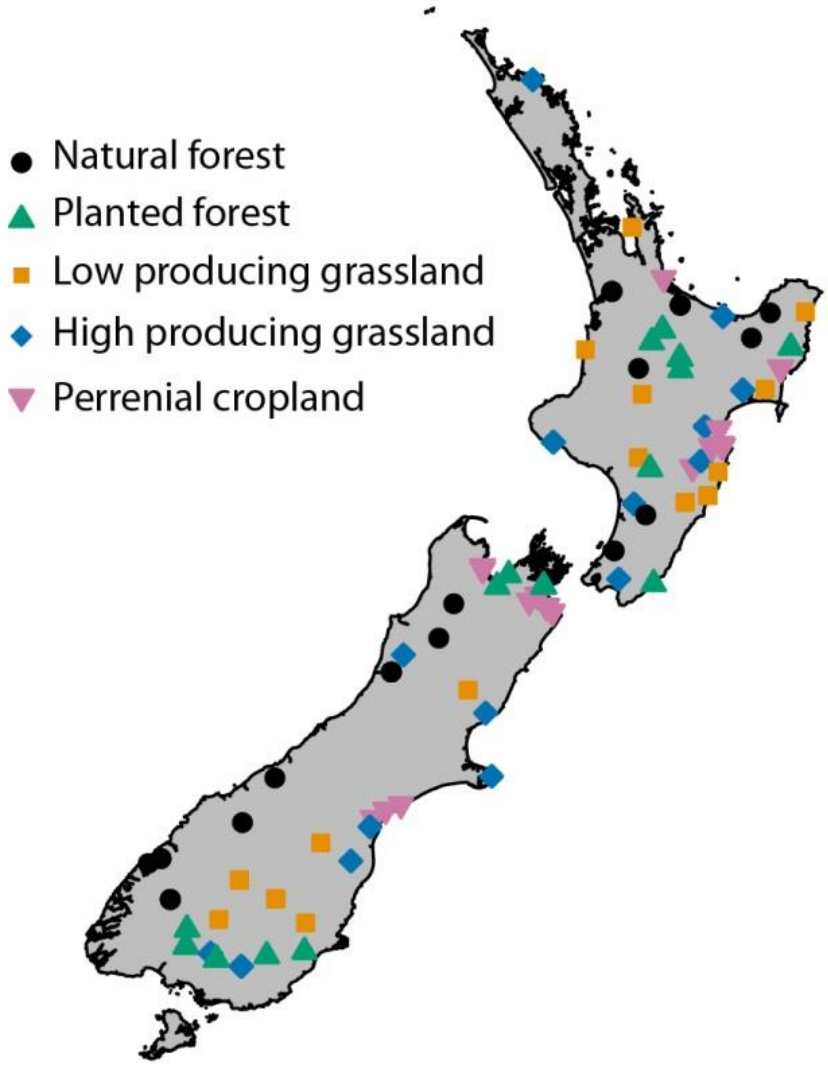
Results – Phylogenetic endemism



How reliable is phylogenetic endemism as an indicator?



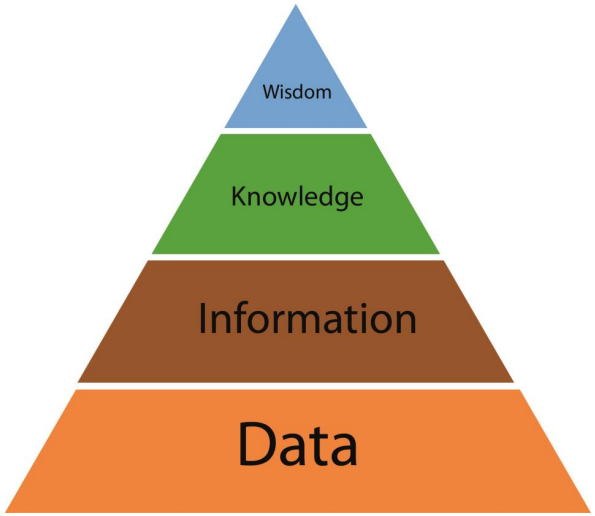
How is land use impacting genetic diversity?



We have the data to tell a national story

….. But that's for another day ☺

6. Key take home messages



Key take home messages

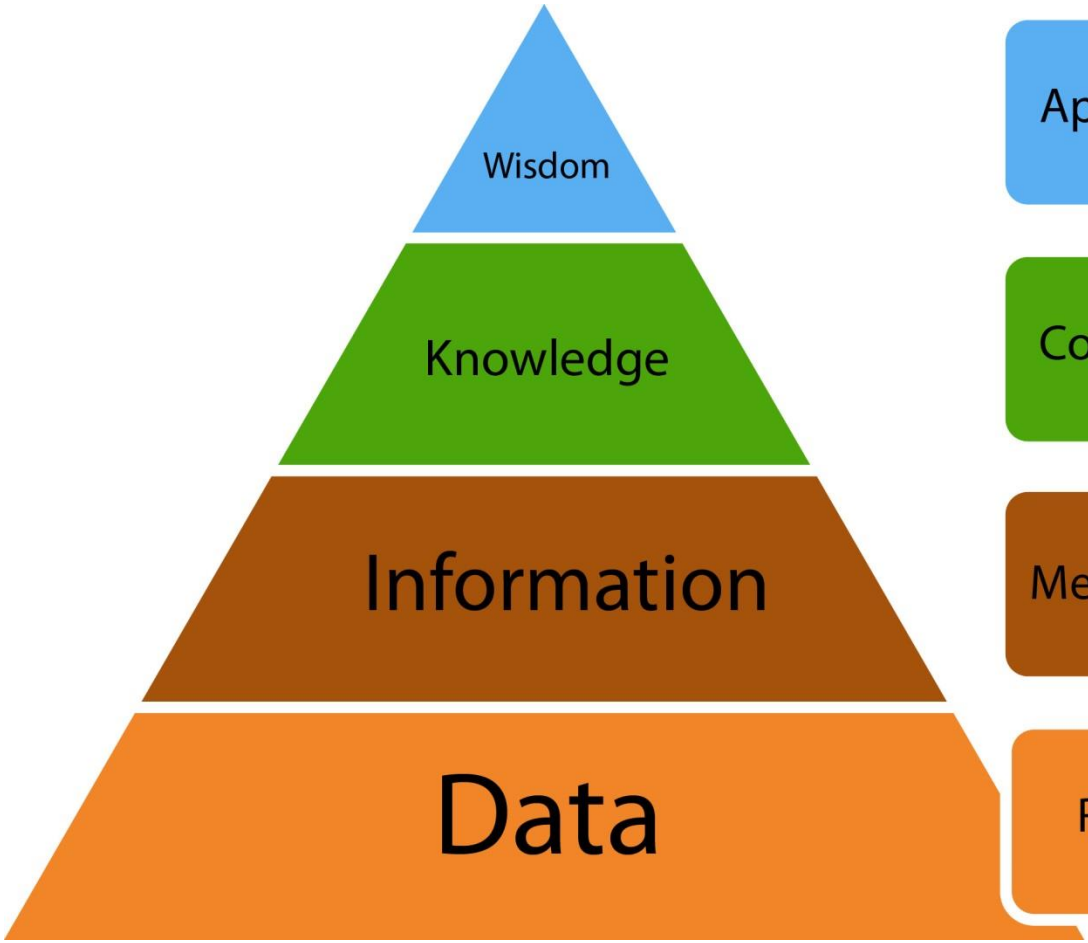
1. eDNA studies generate deep, complex datasets with many potential uses but they also have limitations

2. Analysis and interpretation is very much a work in progress – and is by no means straightforward or well developed, yet.

3. We need to properly understand the information content of eDNA data so that we are confident in its application

4. Genetic diversity indicators calculated using eDNA data show promise for environmental reporting

From Data to Wisdom (or policy)?



Applied	Protect evolutionary hotspots and promote diverse land use to enhance evoltuionary potential
Context	Identification of environments that support high genetic diversity of different taxa
Meaning	Phylogenetic endemism of community A, B, C etc.
Raw	IWPDZI08JK90Q xy=5711_1045 GTCTACAATCATAAGATATGGGTCC CTGATTGCAAGGCGCACAAAGGAT

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Acknowledgements

Projects

- Next Generation Biodiversity Assessment Project (MBIE Smart Idea)
- Department of Conservation Tier 1 eDNA pilot study (DOC, LCR, BioProtection, AWC)

People

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Landcare Research Manaaki Whenua

Bio-Protection
Bioprotection science for New Zealand

Department of Conservation
Te Papa Atawhai

Ministry of Business, Innovation & Employment

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