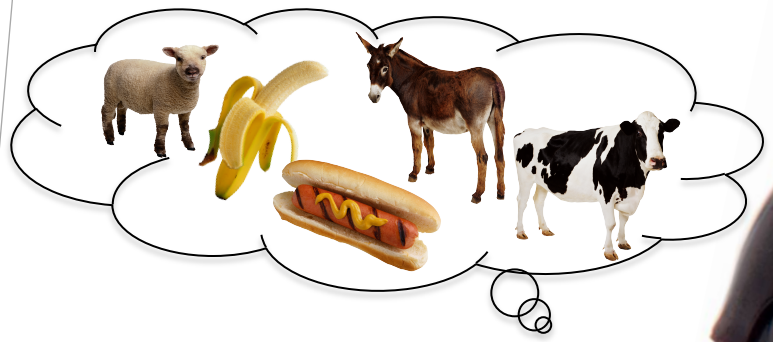


Do all dung beetles prefer dung? Tips and tricks for successful collecting

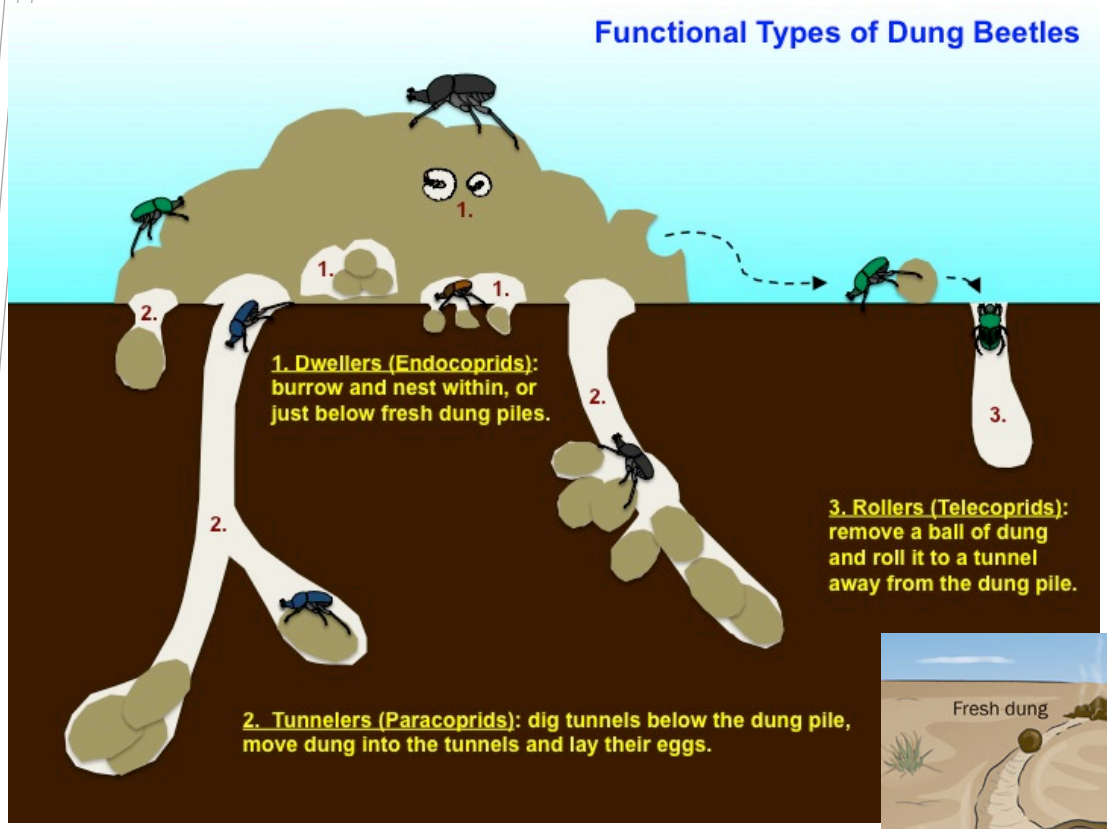
Nicole L Gunter

Cleveland Museum of Natural History

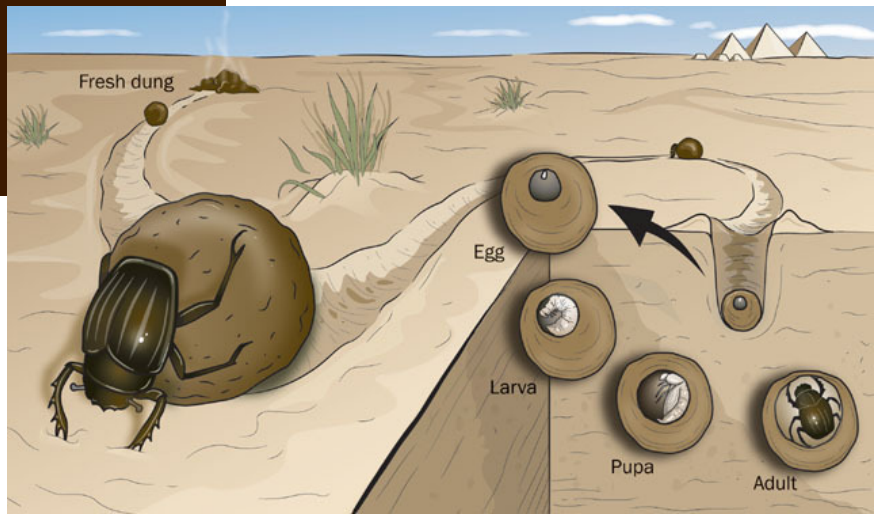
True dung beetles

- Scarabaeidae : Scarabaeinae
- ~5000 described species
- The vast majority of species feed on dung of mammals
- Show preference to dung based on host diet, dung and particle size

Basic Functional types



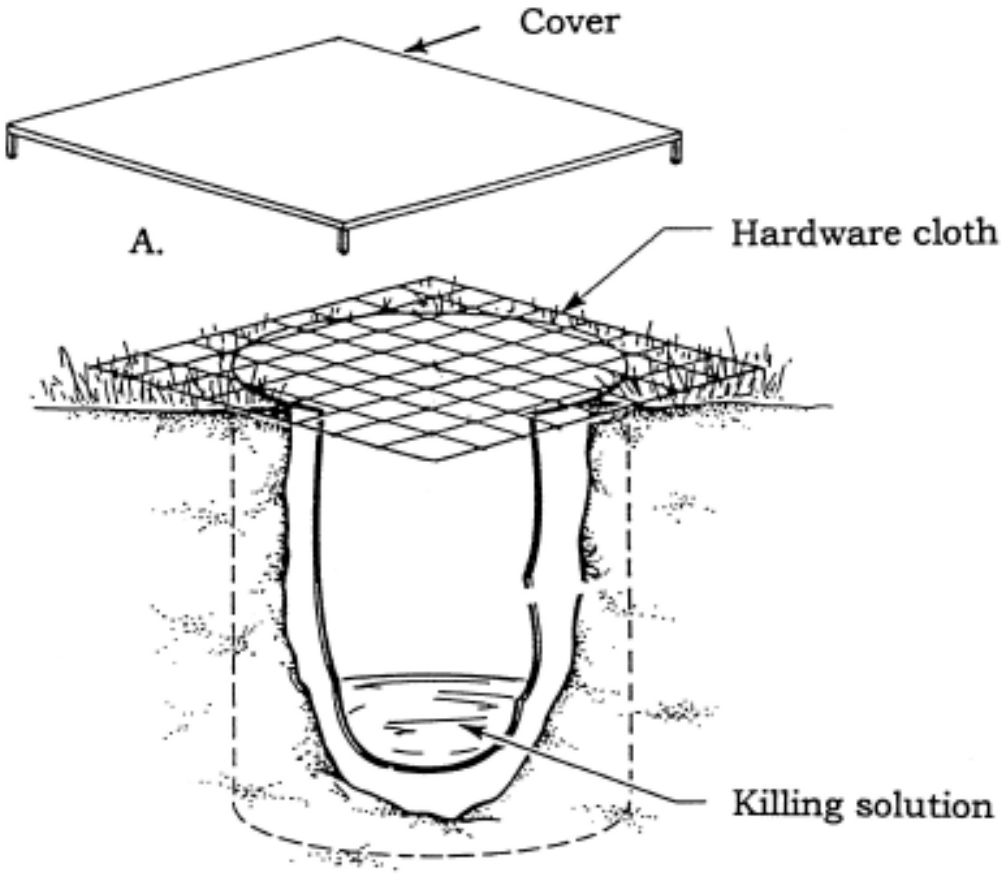
- Dwellers
- Tunnelers
- Rollers



Common collecting methods

- Pitfall traps
- Light traps
- Flight Intercept Traps
- Leaf litter sampling
  - Sifting and berlase
- Hand collecting
  - In and under dung
  - On edges
  - On and in fruit

Baited pitfall traps



Biogeography and bait selection

Table 2 Summary of the diversity of naturally occurring mammals, mammal dung-types and dung beetle tribes across seven biogeographical regions (Afro = Afrotropical, Or = Oriental, Palae = Palaearctic, Neotr = Neotropical, Nearc = Nearctic, Mad = Madagascar, Aust = Australasia)

Mammal orders†	Number of genera*							Dominant dung type at present†	Divergence (Myr)
	Afro	Or	Palae	Neotr	Nearc	Mad	Aust		
Prototheria									
Monotremata	0	0	0	0	0	0	3	?	176
Metatheria									
Marsupalia	0	0	0	14	2	0	54	Pellets	176
Eutheria									
Insectivora	13	12	13	1	9	7	0	Pellets	146
Rodentia	67	65	48	65	46	1	28	Pellets	125
Macroscelidea	4	0	0	0	0	0	0	?	
Primates	17	8	0	14	0	13	0	Small odiferous	120
Scandentia	0	4	0	0	0	0	0	?	
Lagomorpha	3	2	3	1	5	0	0	Pellets	110
Xenarthra‡	0	0	0	13	2	0	0	?‡	105
Pholidota	1	1	0	0	0	0	0	?	
Tubulidentia	1	0	0	0	0	0	0	?	
Carnivora	33	27	19	17	19	2	1	small odiferous	71
Perissodactyla	3	3	1	1	0	0	0	Large fibrous	71
Artiodactyla	36	13	21	8	10	0	0	Pellets	60
tribe Bovini	1	2	2	0	1	0	0	Large soft afibrous Afro. Miocene fossils	
Hyracoidea	3	0	1	0	0	0	0	Pellets	
Proboscidea	1	1	0	0	0	0	0	Large fibrous	
Total N (genera)	182	137	105	134	93	23	86		
Total N (orders)	12	10	7	9	7	4	4		
Total dung types§	4	4	4	3	3	2	2		
Total N (scarab. tribes)	9	9	9	8	7	3	3		

Davis et al. 2002. Journal of Biogeography, 29, 1217–1256

The perfect bait!

- Particle size and diet is important determinant for dung beetles
- Studies show general preference for omnivore dung
- Carrion and fermenting fruit also are highly attractive
- Dung needs to be fresh for the volatiles to be released
  - Freezing fresh dung and then defrosting still seems to release volatiles
- Trial different baits and always record baits

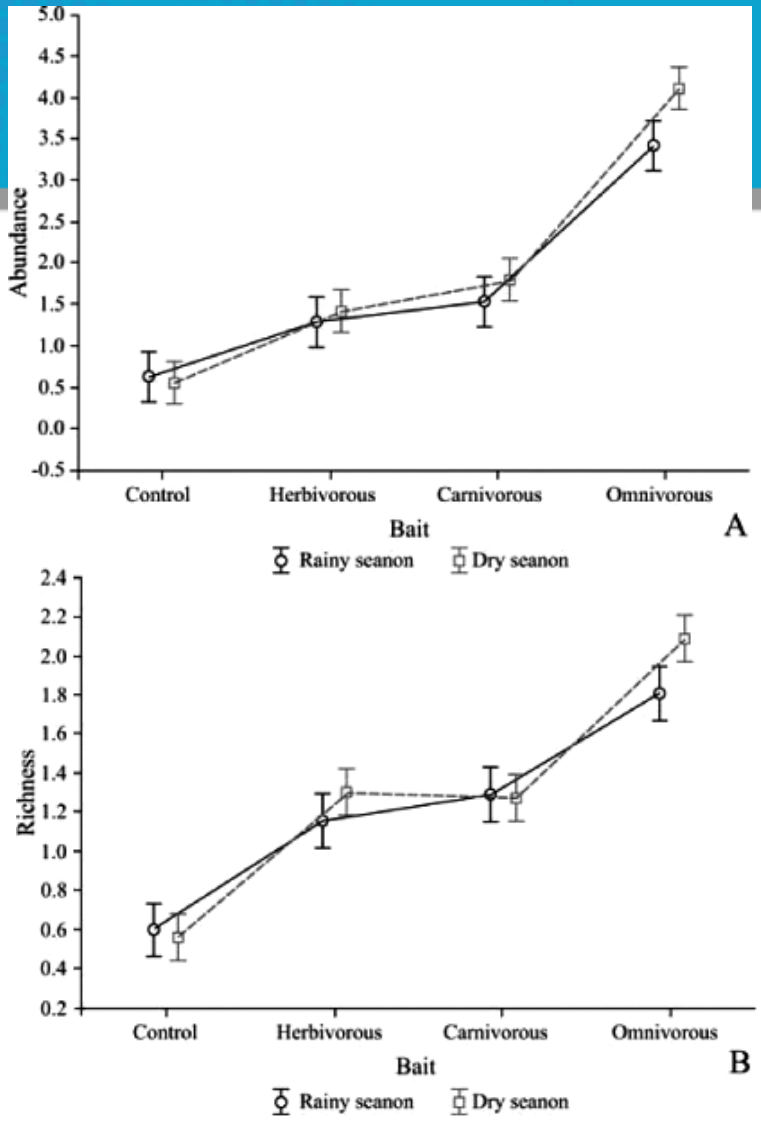


Fig. 4. ANOVA Two-Way analysis characterizing the difference between Scarabaeinae abundances and richness throughout the dry season and the rainy season, for each type of bait that was used: human (omnivorous), jaguar (carnivorous) and waterbuck (herbivorous) excrement in Parque Estadual de Dois Irmãos, Pernambuco, Brazil. (Mean ± SD).

Filgueiras etl al. 2009 Rev. Bras. entomol. vol.53

Killing solution

- Dependent on how long the traps will be left in environment

- Long-term
  - 25-50% Ethylene glycol (anti-freeze) – toxic to vertebrates
  - 25-50% Propylene glycol –less toxic but more expensive
- Short-term
  - 70% Ethanol- cheap but evaporates quickly and odorous
  - RNALater-expensive *
  - 1-5% Saline solution- cheap, neutral odor *

- *DNA quality preservation
  - I use saline solution traps left up to 1 week (usually 48hrs) and immediately transfer to 96% Ethanol

Dung beetles as environmental indicators

- Great surrogate for determining broader patterns for biodiversity
  - Multi-species communities
  - Easy to trap
  - Broad geographic distribution
  - Varying sensitivity to environmental disturbances
  - Richness can be correlated to mammal diversity

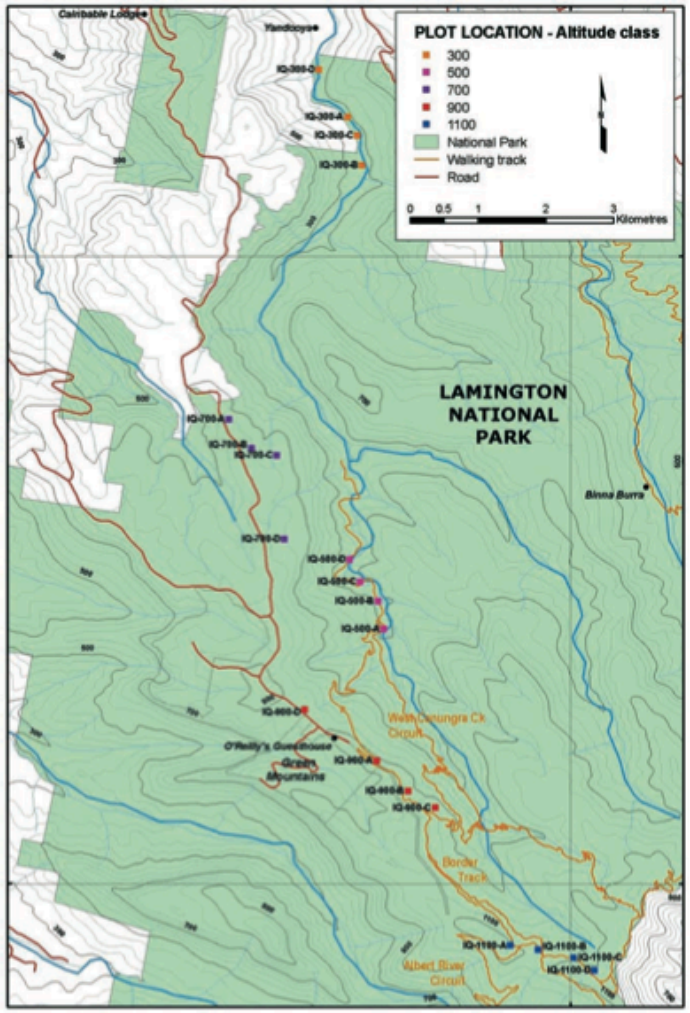
Collection protocols (Krell, 2007)

- For studying ecological assemblages using quantitative data
  - See Krell, 2007, DMNS Technical report

- 1. comparing dung beetle assemblages-without traps
  - Collect fresh bovine dung without a crust
  - Expose ~1kg dung in open habitat and put out at different times to collect either day or night active dung beetles
  - Measure environmental conditions eg. Temp, humidity etc
  - Recollect dung and soil below for tunnelers
  - Place in a bucket and fill with water, leave for at least an hour
  - Collect dung beetles with a strainer
  - Preserve beetles and ID

Collection protocols (Krell, 2007) cont.

- 2. Rapid Biodiversity Assessment with traps and standard dung
  - Standard size pitfall trap, protected from rainfall
  - Closed bait cage suspended over trap
  - Standard bait type and quantity
  - Traps placed over a standard transect
  - Leave traps for 48hrs
  - Collect traps, preserve beetles and ID.



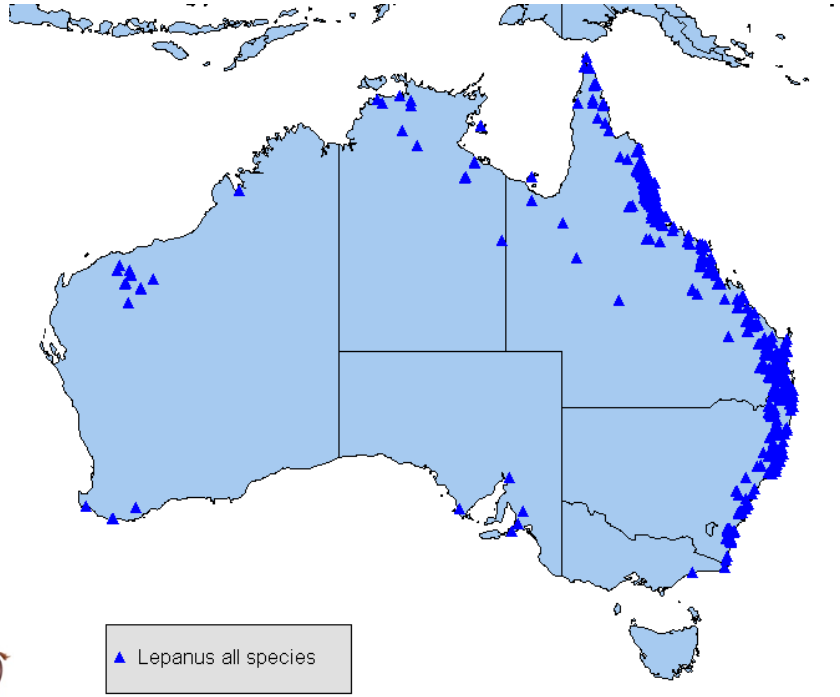
IBISCA survey. Queensland Museum

Collection protocols cont.

- 3. For studying food preference within a locality
  - Standard sized pitfall traps as above
  - Differing baits of standard size
  - Transects with traps with different baits ~2’ apart
  - Leave for 48hours
  - Collect traps, preserve beetles, ID
- Also best method to collect as much richness as possible
- Dung selection
  - Native vs introduced mammal dung (can be useful for habitat degradation studies)
  - Herbivore, omnivore, carnivore dung
  - Dung, carrion, fermenting fruit etc

My experience in Australia

- From 2009-2013 I was a postdoc at ANIC, Canberra
- Revision of dung beetle genus *Lepanus* (Canthonini)
  - 24 known species + 63 new spp.
- Many specimens already in museums but need fresh material for DNA



Australian dung beetles

- Evolved under an entirely different set of pressure to the rest of the global dung beetle fauna
  - Marsupials vs placental mammals
- Australia also went out drastic environmental changes which influenced speciation
- Australia imports European dung beetles for agriculture

African

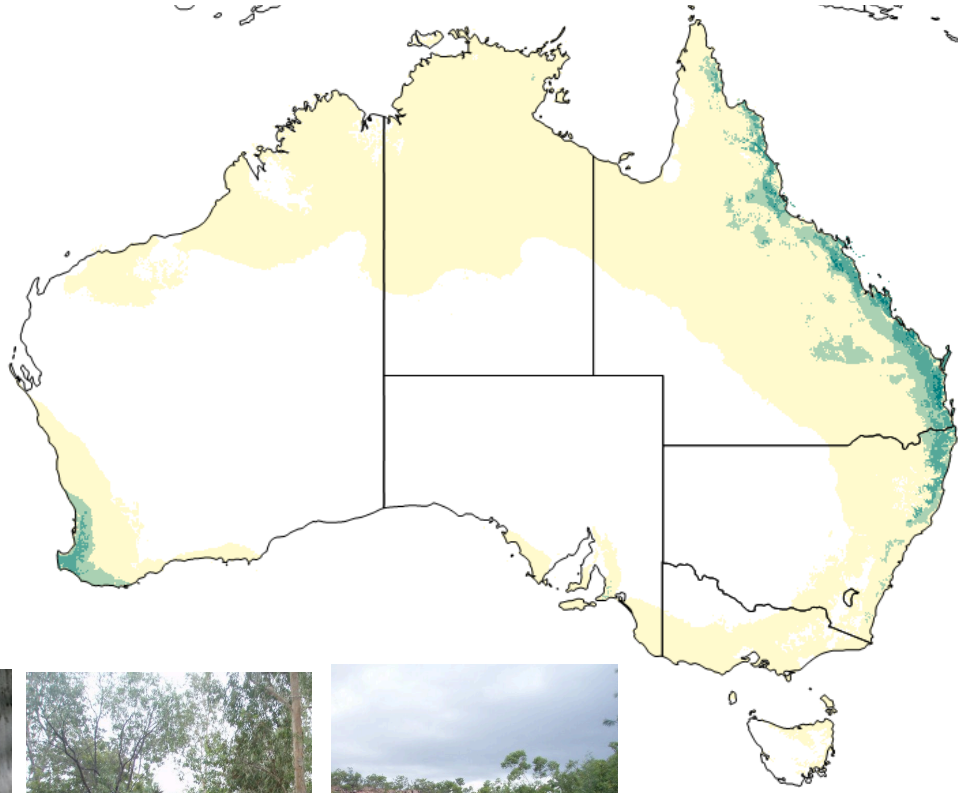
Australian

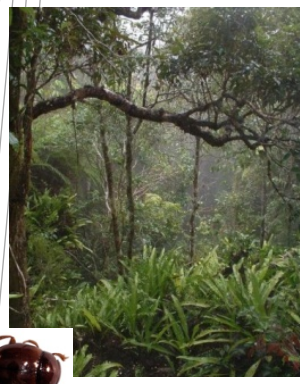
The *Lepanus* hunt…

- Baited pitfall traps
  - Kangaroo dung
  - Human dung
  - Rotting mushrooms
- Kangaroo and rotting mushroom bait most attractive
- FIT traps most successful in more open forests
- Deep moist leaf litter most successful
- Light traps- only collected *Lepanus* 1 hour before dusk to ~30mins after dark
  - Confession: I never tried collecting at dawn

Where did we go?

- Sampling in areas with known species and also previously unsampled localities
- Richness is highest in the Wet Tropics . Cape York, Central Queensland and relic rainforest patches are also species rich
- Species tightly associated with habitat.



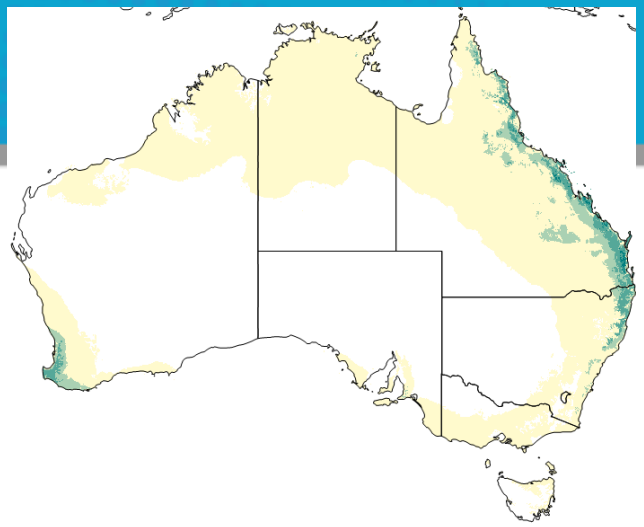




What did we collect?

- Recollected 48 of 87 spp. in 2 seasons (Sept-March)
- Most species attracted to both kangaroo and mushroom baits
- Some species only attracted to one bait type
- *Lepanus* were less common in human dung traps compared to *Onthophagus* spp.

What didn't we collect?

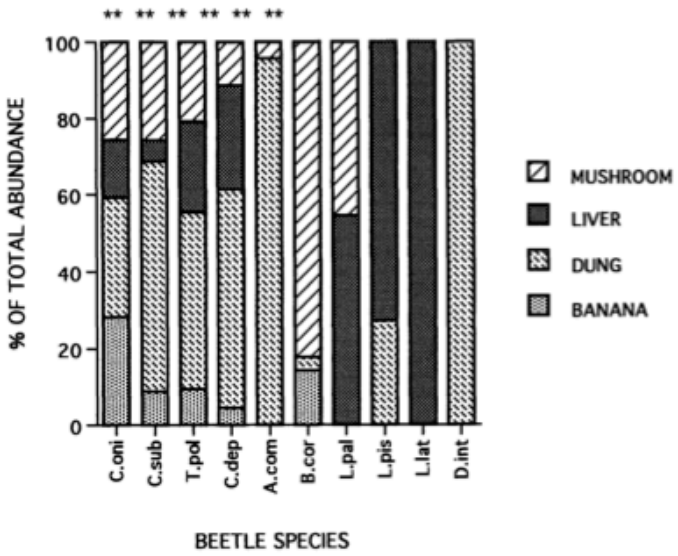


- We did not recollect 39 species
- Some from remote localities
- Interestingly it was generally the smallest species absent from out recollection.
- Inspection of label data revealed almost all of these were from either long term pitfall traps (non-baited), flight intercept traps or berlase

What are the little guys feeding on?

The genus *Lepanus* contains the smallest dung beetles in Australia. This 2-mm specimen was found in north Queensland feeding on a bird dropping. *Lepanus* is distributed along the east coast of the continent from eastern Victoria to Cape York.

- Bird dung?
  - **"A Guide to the Beetles of Australia"**
    By George Hangay, Paul Zborowski
- Other fungi?
  - Specimens in collections are often covered in fungi spores which collect on the head, tibia and pygidium
- Carrion?
  - Hill (1996) study of food preferences in tropical Australia showed L. latheticus was only collected on carrion
- Fruit?
  - *Lepanus pisionae* is named for the pisionia plant

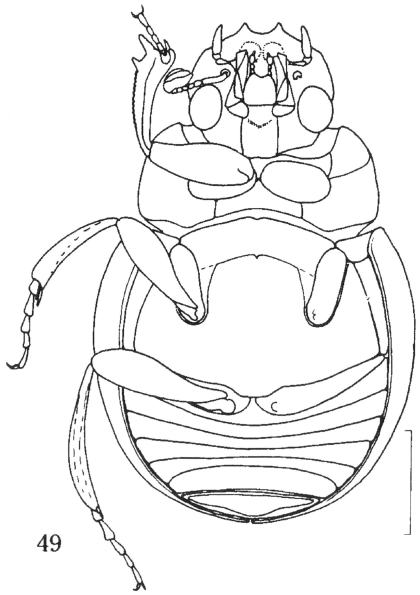


Summary

- Design your sampling for your project
  - Rapid Biodiversity Assessment vs taxonomic revision
- Think about the evolutionary environment and local mammals for bait selection
- Be creative in bait trials…
- Keep good records of what you baited your traps with. It can be as important as locality information when hunting rare dung beetles
- Refer back to museum specimen label data for hints
- Be prepared for surprises if you look in the field pack of a dung beetle specialist

Digitisation project

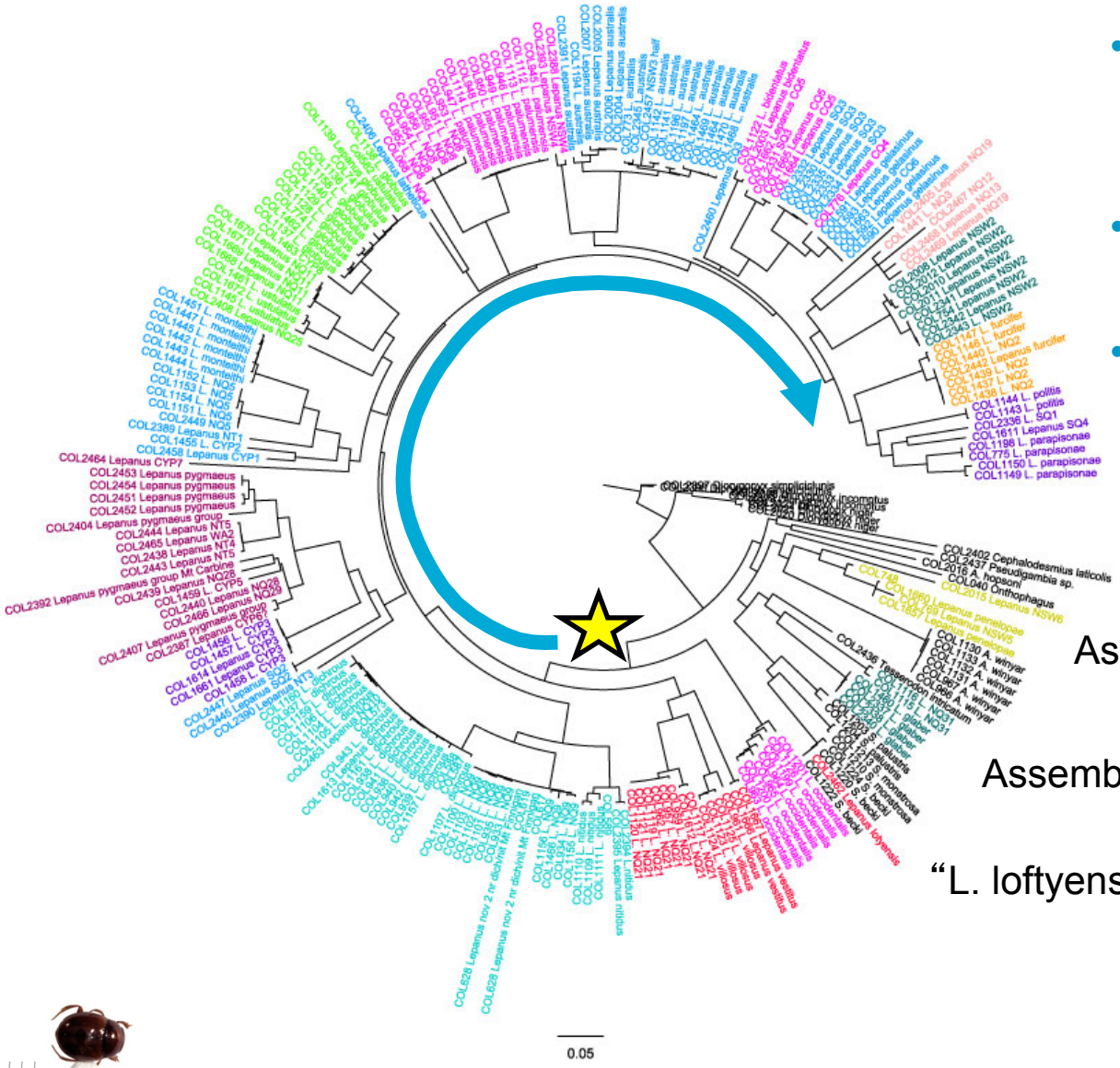
- Examination of ~13, 500 pinned specimens at ANIC, QM & AM
  - 24 described spp. + 63 undescribed spp.
  - Total= 87 spp.
- Better classification system
  - 12 Assemblages defined by pygidial characteristics



Relationships between Lepanus spp.

- What I sequenced
  - 350+ specimens
  - 64/ 87 spp.
  - 12/12 assemblages
- 3 genes
  - 28s
  - COI
  - 16s
- Phylogenetic analyses
  - Aligned genes individually
  - Concatenated the data
  - Only specimens with at least 2 genes included in analysis
  - Maximum likelihood and Bayesian analysis to generate tree

Phylogenetic tree



- Colour-coded by assemblage with outgroups in black
- Lepanus is not monophyletic!
- Confirmed species concepts and monophyly of some assemblages

Assemblage 10

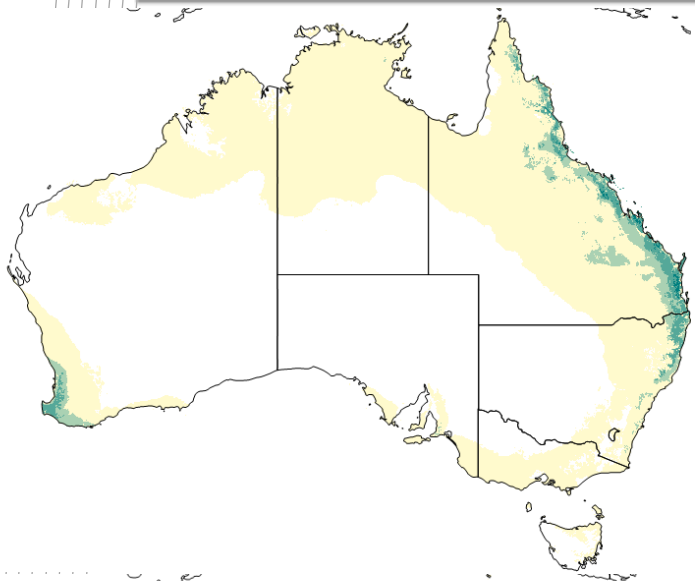
Assemblage 11

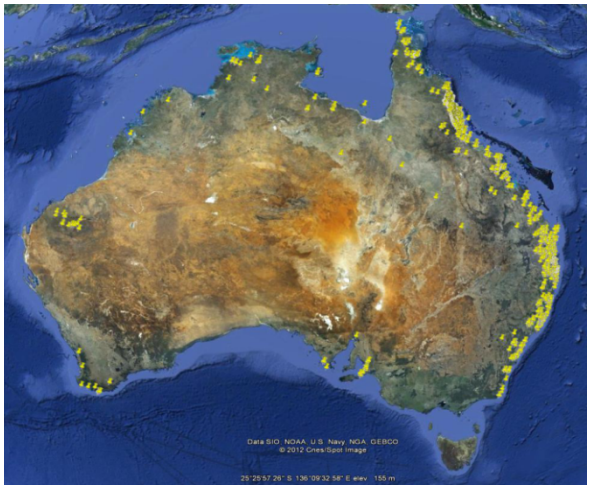
“L. loftyensis”

Extending systematics further

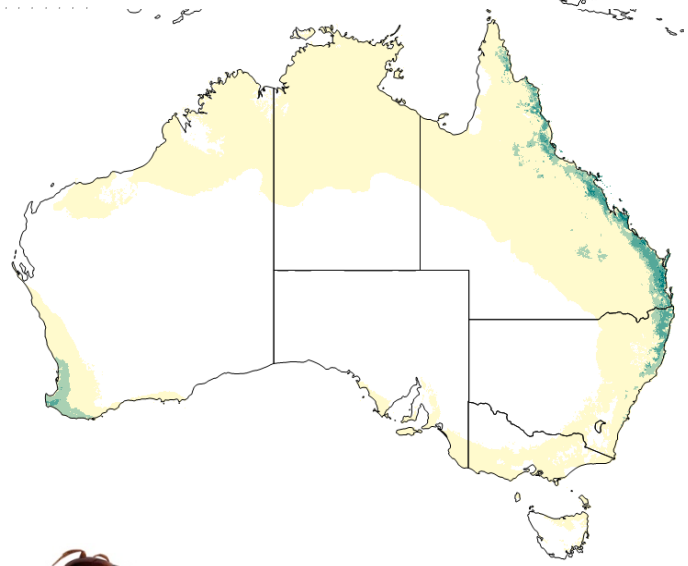
- Once confident in our taxonomy we decided to examine distributional data of species
- All specimens were databased
  - THIS IS AN AWESOME EXAMPLE OF WHY DIGITISATION IS COOL!!!
- BIOCLIM implemented in BioLink to examine predicted species distribution
  - 11 layers included temperature, rainfall and elevation data
- BIODIVERSE to examine species richness and endemism
- Examples using species complexes to examine distribution
  - *Lepanus*
  - pisioniae complex

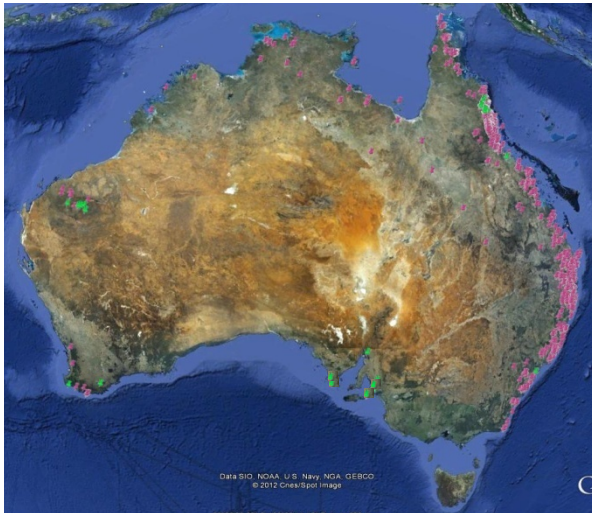
Distribution predictions "*Lepanus*"





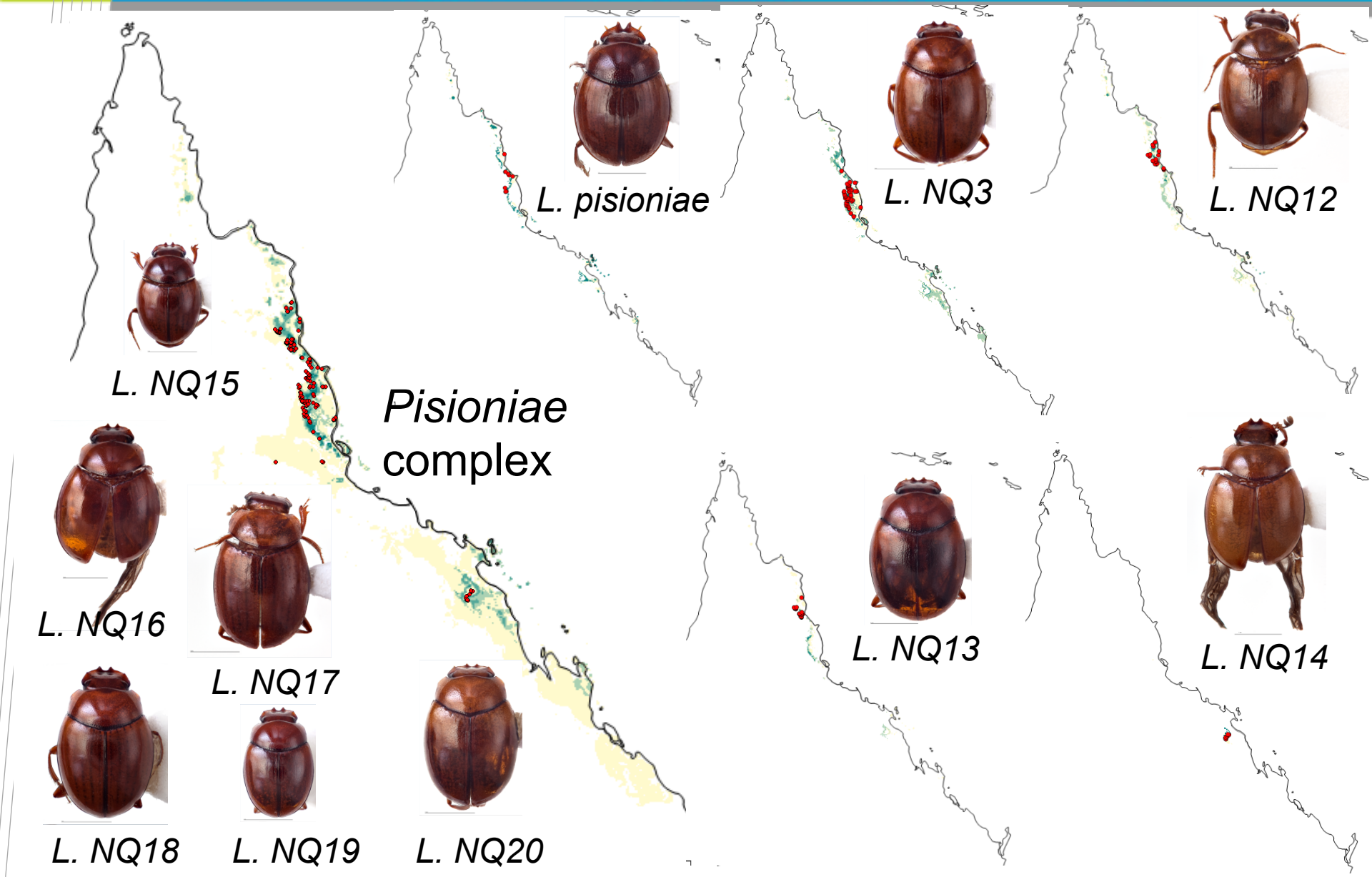
- Distribution of "*Lepanus*"
- 2242 unique species/locality data points





- Distribution of *Lepanus* minus assemblage 10,11 and *L. loftyensis*
- 2154 unique species/ locality data points

Species distribution "*L. pisioniae*" complex



Richness

- Originally 24 described species
- Additional 63 new species identified within collections
- Genetic data confirmed 13 '*Lepanus*' spp. did not belong to the genus
- TOTAL = 74 spp. of *Lepanus*

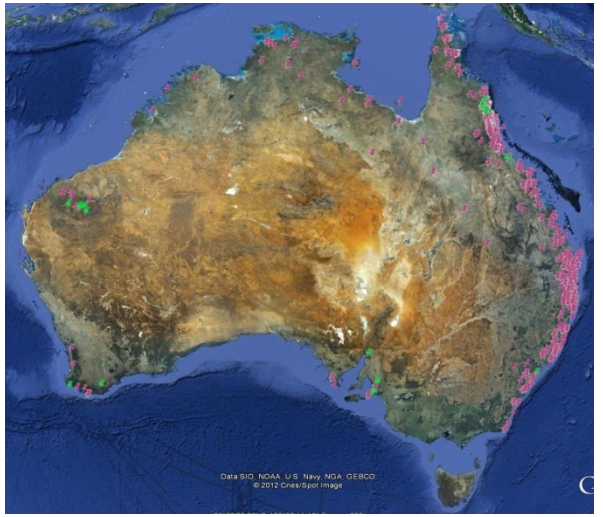
- If we had databased the collections as "identified" many short range endemics would have been lumped together

- Knowing the species boundaries is important

- Taxonomy should be extended to be more informative than just naming species

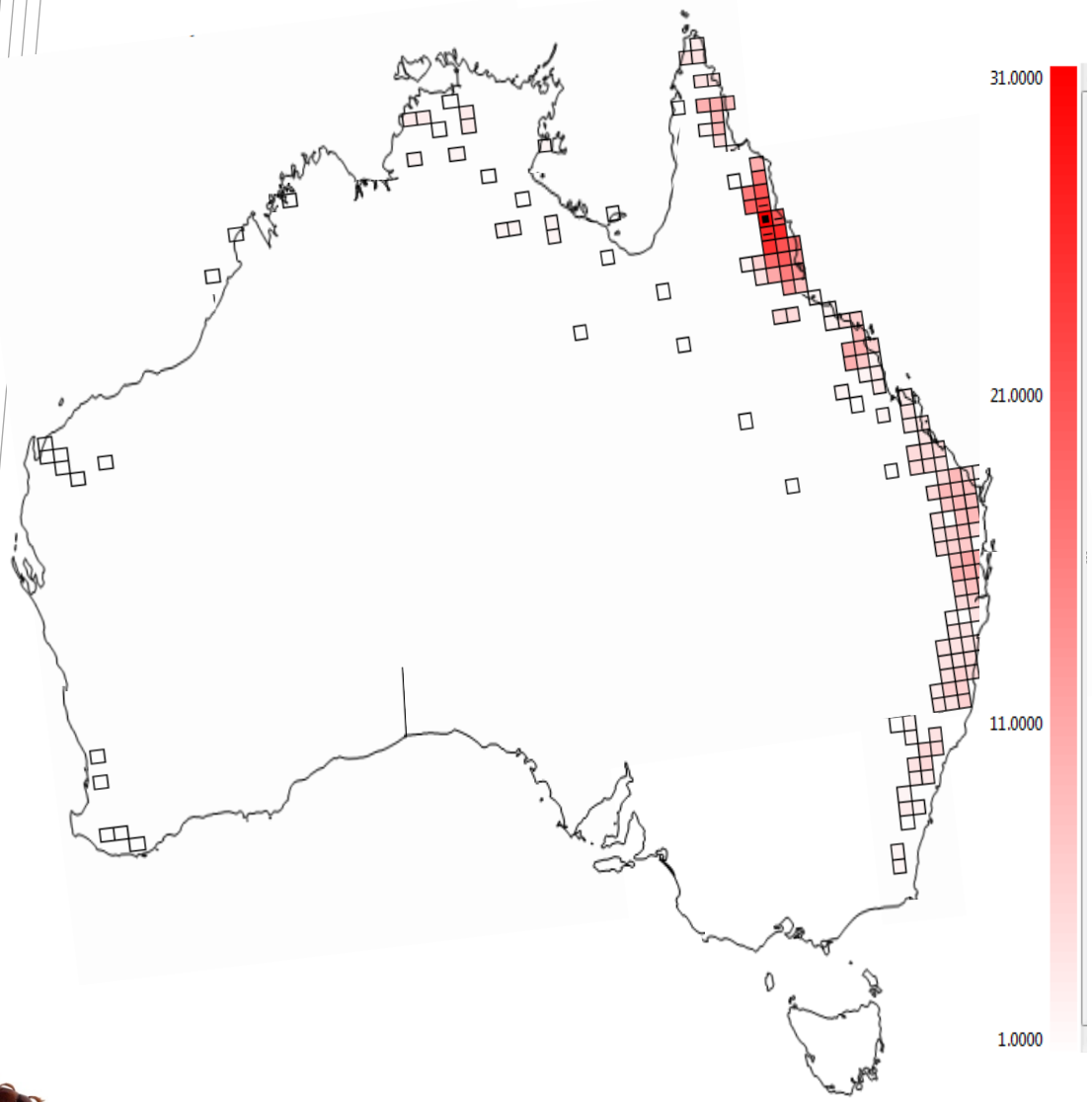
Systematics for conservation planning

- Is it better to conserve species richness or species diversity?
- The distributional data from digitised specimens can be used to answer this question
- Where is the highest diversity and are current protected areas sufficient?
- True richness and endemism examined using program BIODVERSE

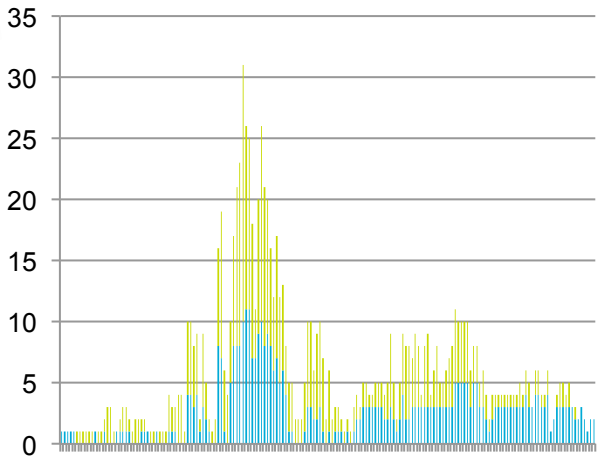


- Distribution of *Lepanus (*minus assemblage 10,11 and *L. loftyensis)*
- 2154 unique species/ locality data points

Richness (number of species)

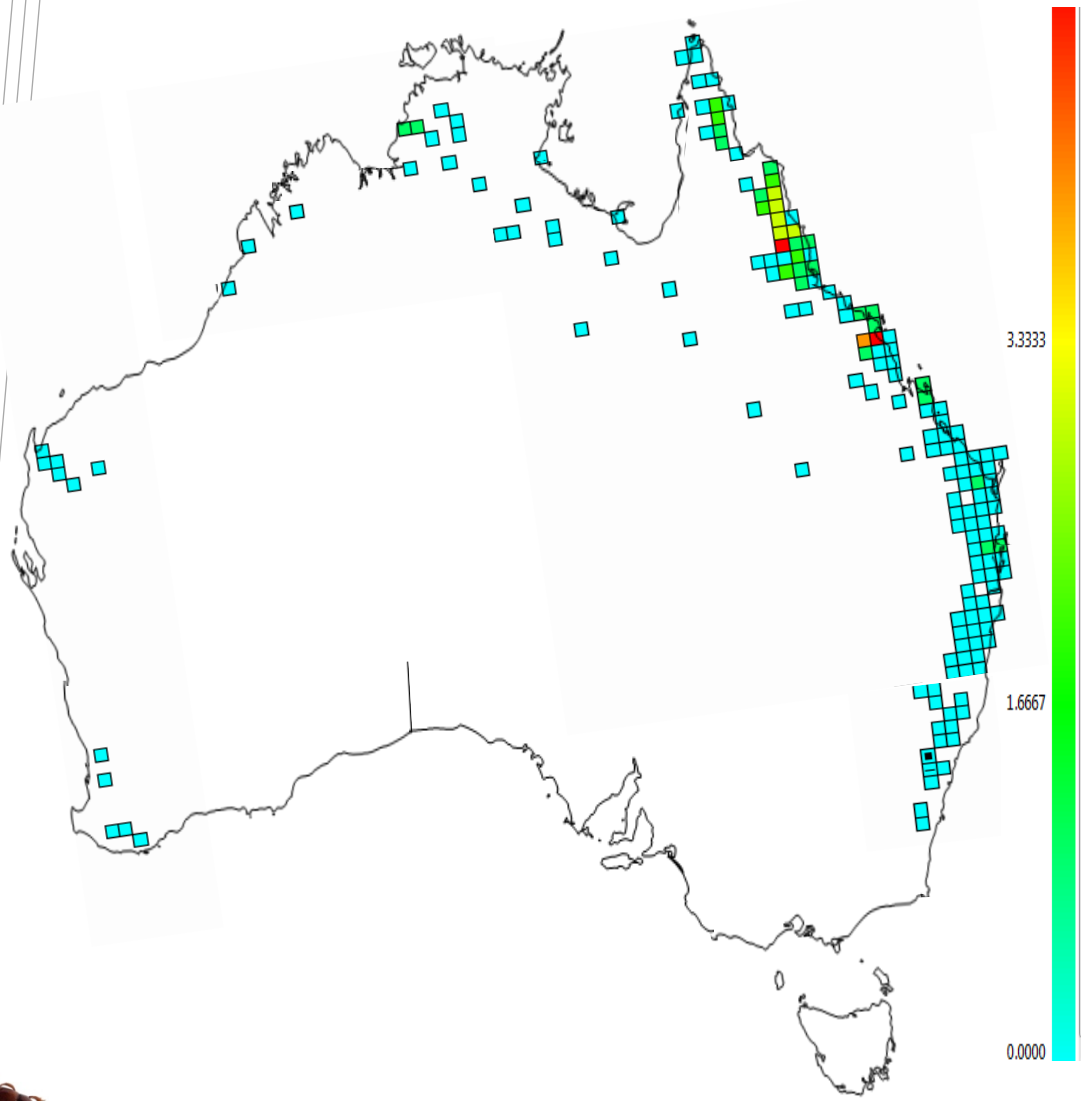


	total	max/grid
• NQ	43 spp.	31 spp.
• CYP	12 spp.	10 spp.
• CQ	15 spp.	10 spp.
• SQ	16 spp.	11 spp.
• NSW	8 spp.	6 spp.
• NT	8 spp.	3 spp.
• WA	4 spp.	1 sp.



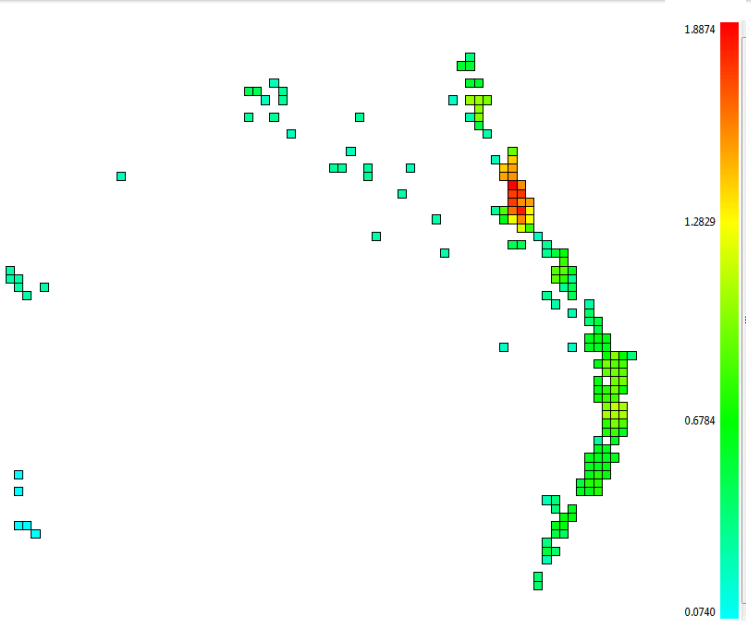
grids described vs undescribed diversity

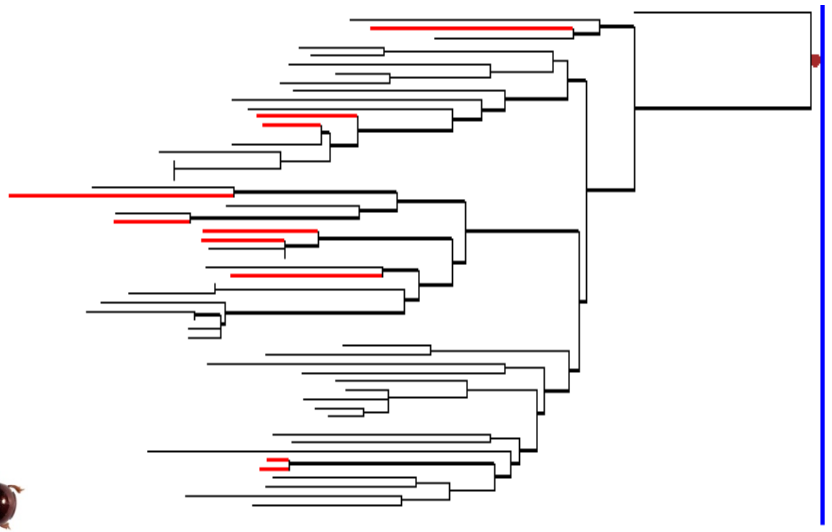
Endemism (no. species with restricted distribution)



- Counts species only recorded in grid or directly neighbouring grids
- In total 25 spp. were short range endemics
- NQ- 12 of 43 spp.
- CQ- 7 of 15 spp
- CYP- 3 of 12 spp.
- SQ- 2 of 16 spp.
- NT- 1 of 8 spp.

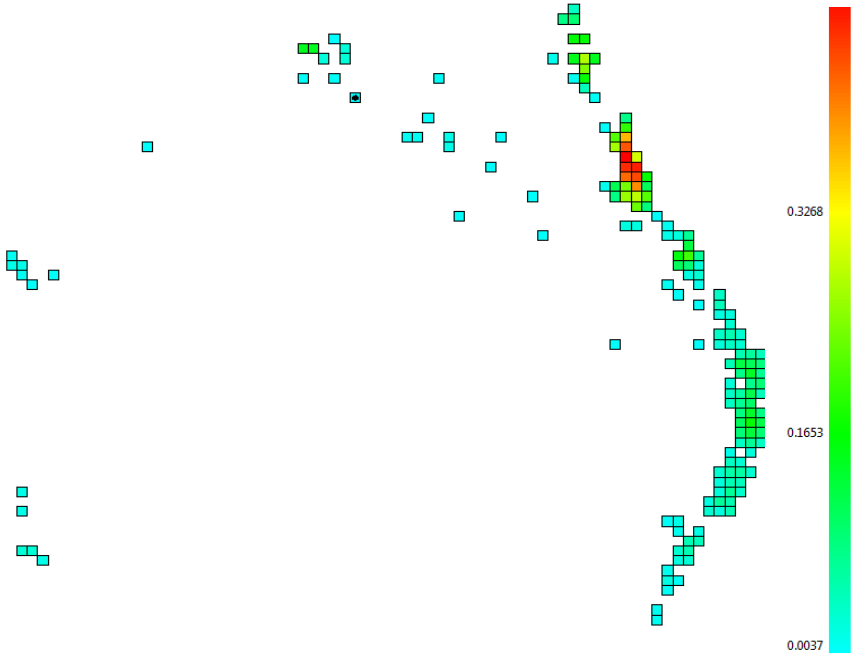
Phylogenetic diversity



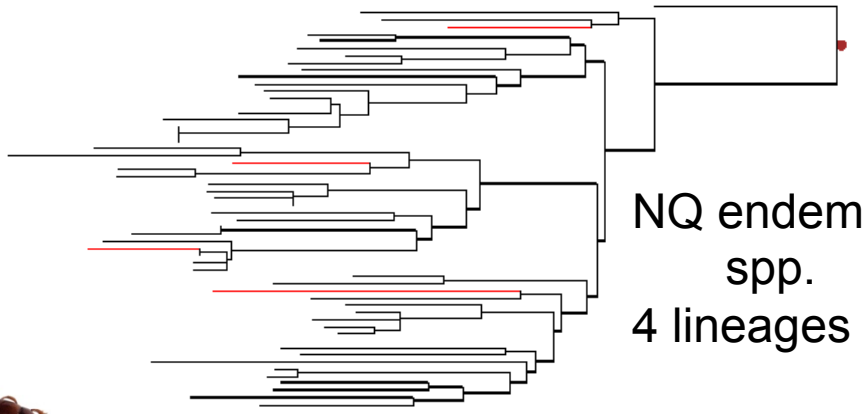


- Considered genetic relatedness in analyses
- Only 57 of 74 *Lepanus* with sequences
- Phylogenetic diversity highest in the North Queensland Wet Tropics

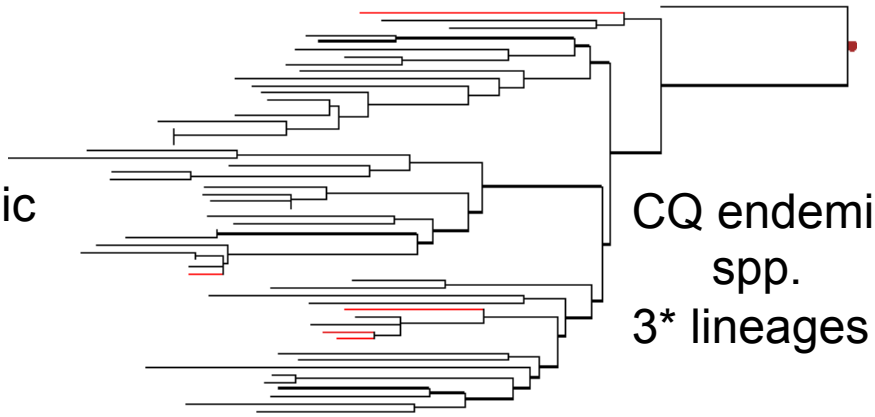
Phylogenetic endemism



- Due to the nature of sampling fewer short range endemics were sequenced
- Results should be interpreted cautiously
- PE was also highest in the wet tropics

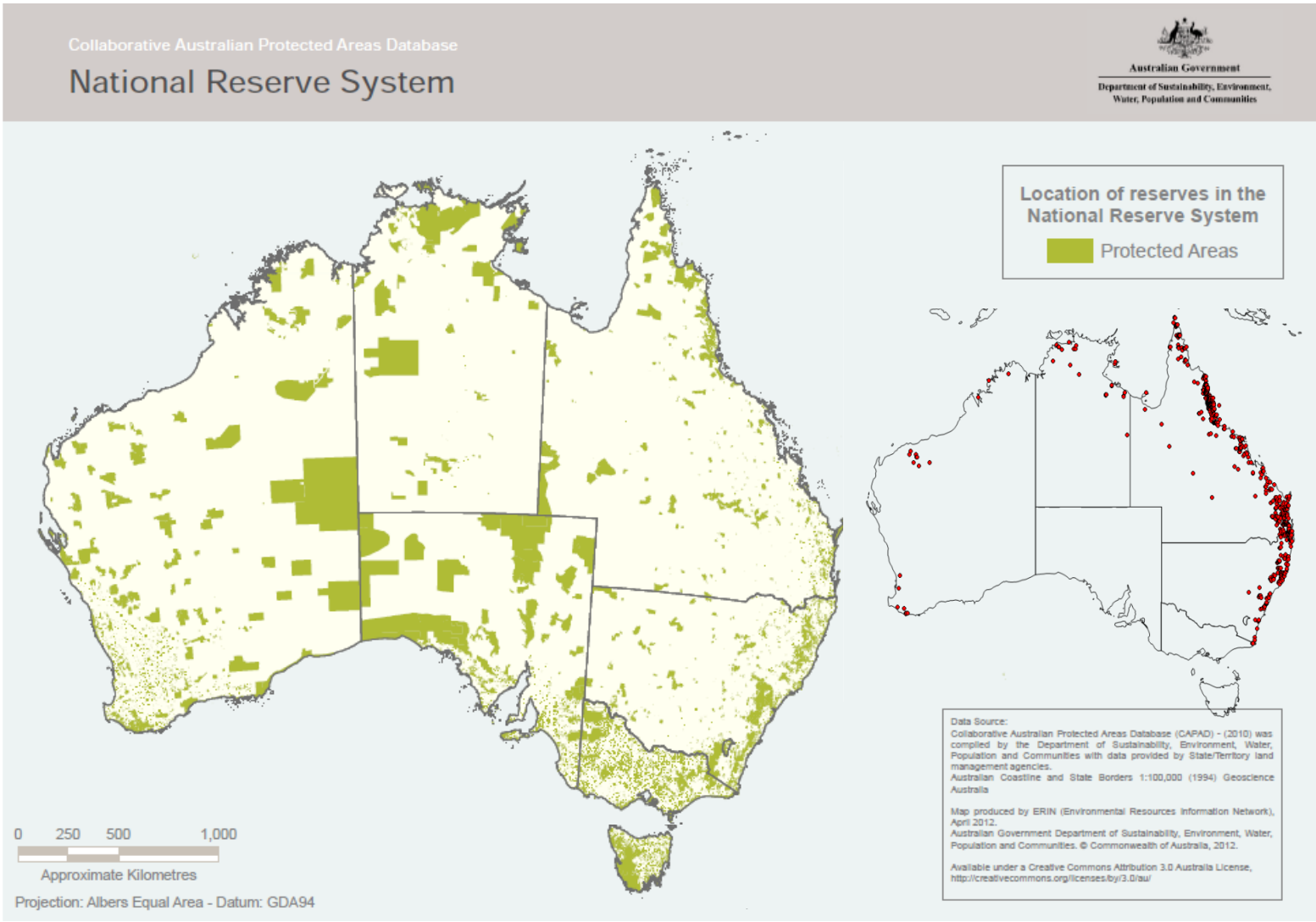


NQ endemic spp.
4 lineages

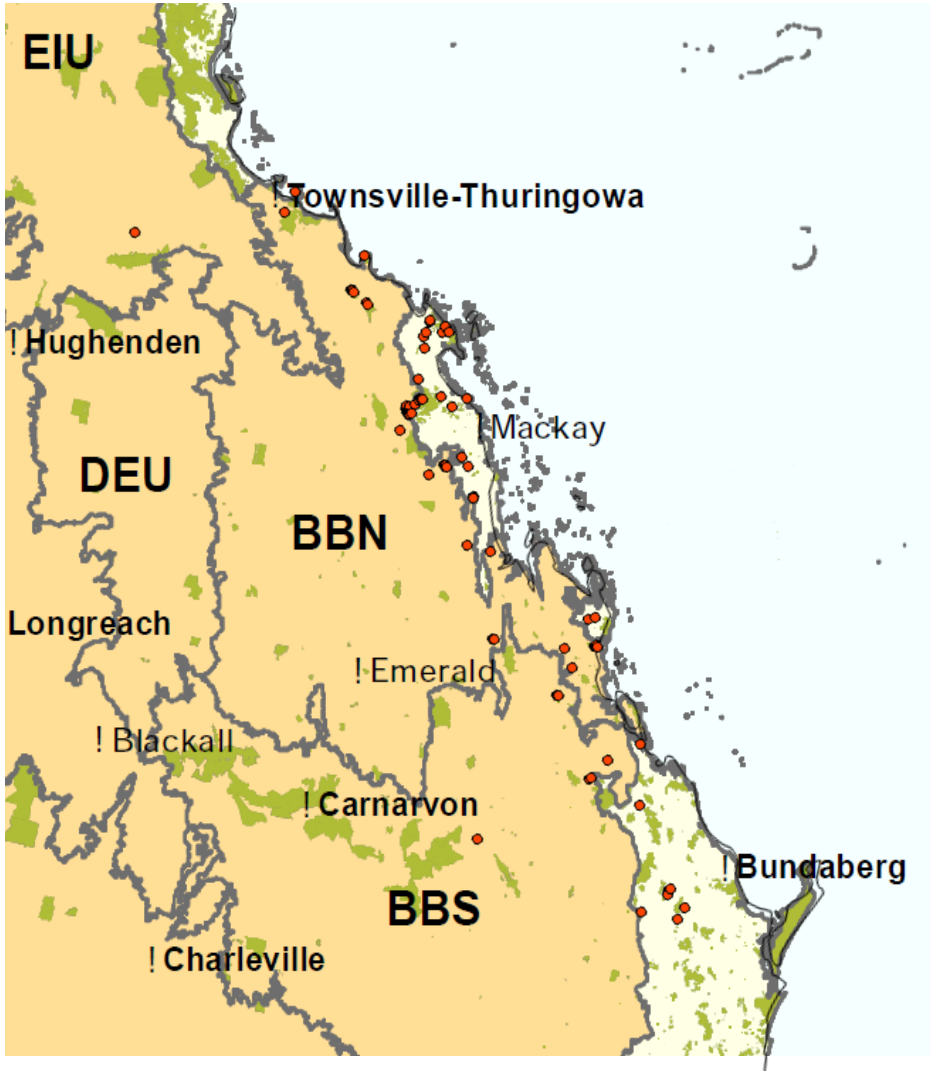


CQ endemic spp.
3* lineages

Is the NRS adequate for conservation?



CQ short range endemics ?!?



- 7 of 15 spp. that occur in CQ are short range endemics
- Most species seem to be collected from reserves
- Given the high number of short range endemics relative to total species richness CQ should be highlighted as an area of potential conservation concern

Why it matters

- Many evolutionary and conservation based questions have a systematic frame work
- If we assume we have our classification correct we have the potential to getting our predictions very wrong.
- *Lepanus* is not a unique example. We know less a quarter of invertebrate species are described, many of which are already likely to exist in Museum collections
- The occurrence of species complexes within the collections highlights the importance of investing in taxonomy to compliment digitisation

Thank you for listening

A dung beetle walks into a bar. “Pardon me,” he says to the bartender. “Is this stool taken?”