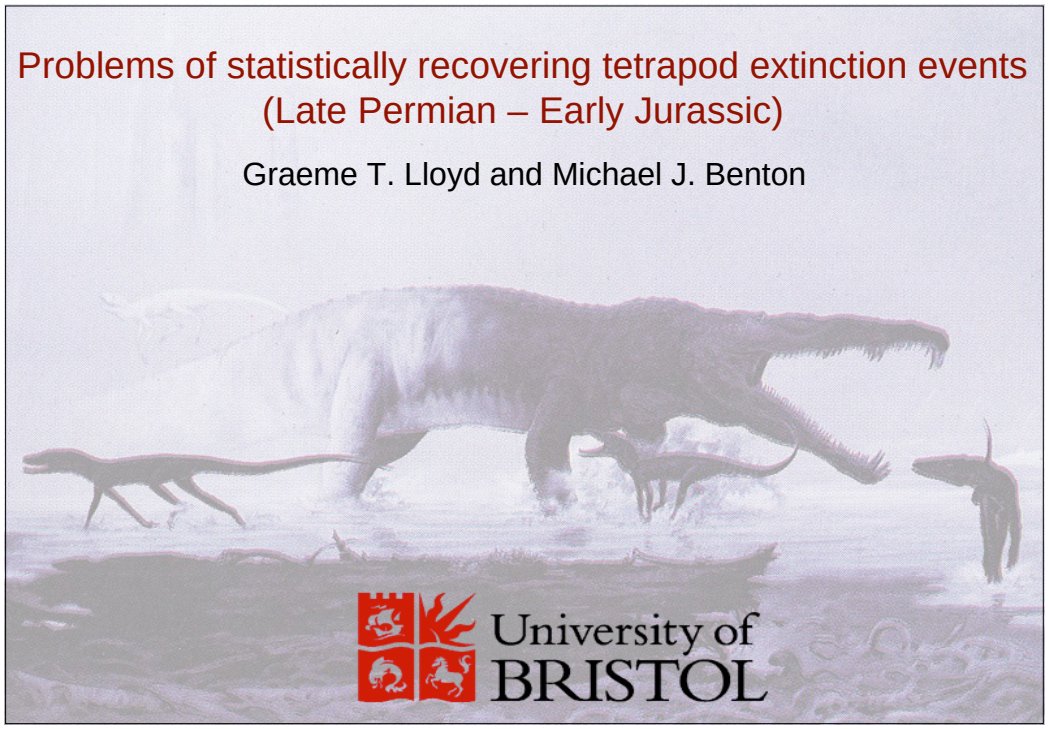
Problems of statistically recovering tetrapod extinction events (Late Permian – Early Jurassic)

Graeme T. Lloyd and Michael J. Benton



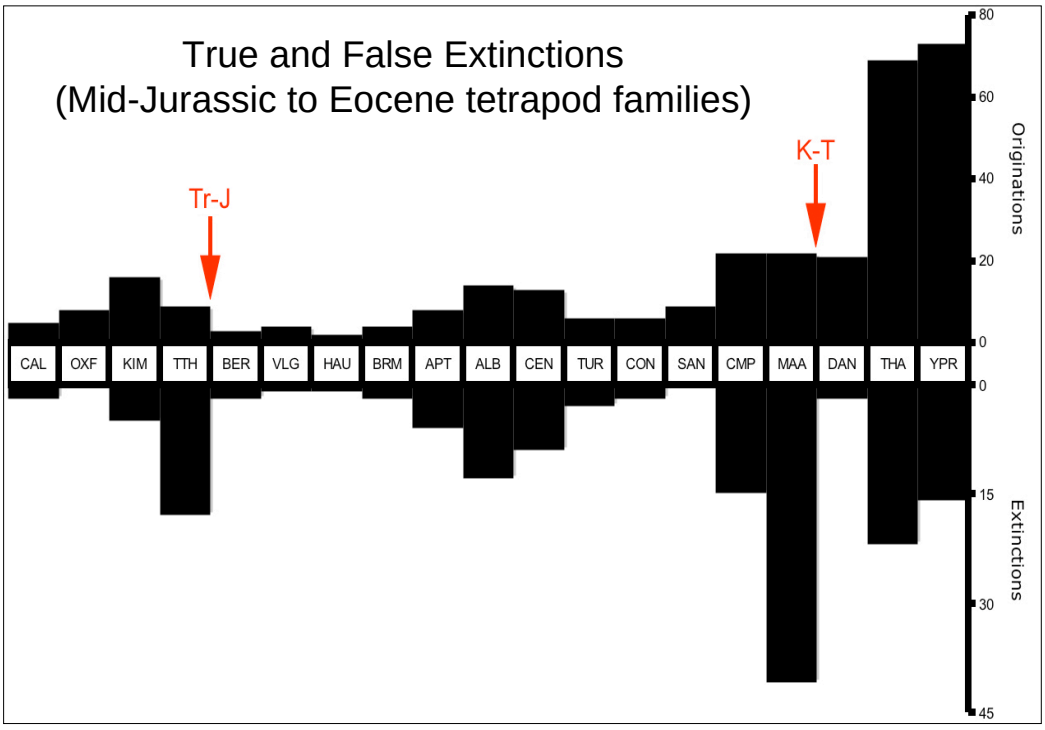
University of BRISTOL

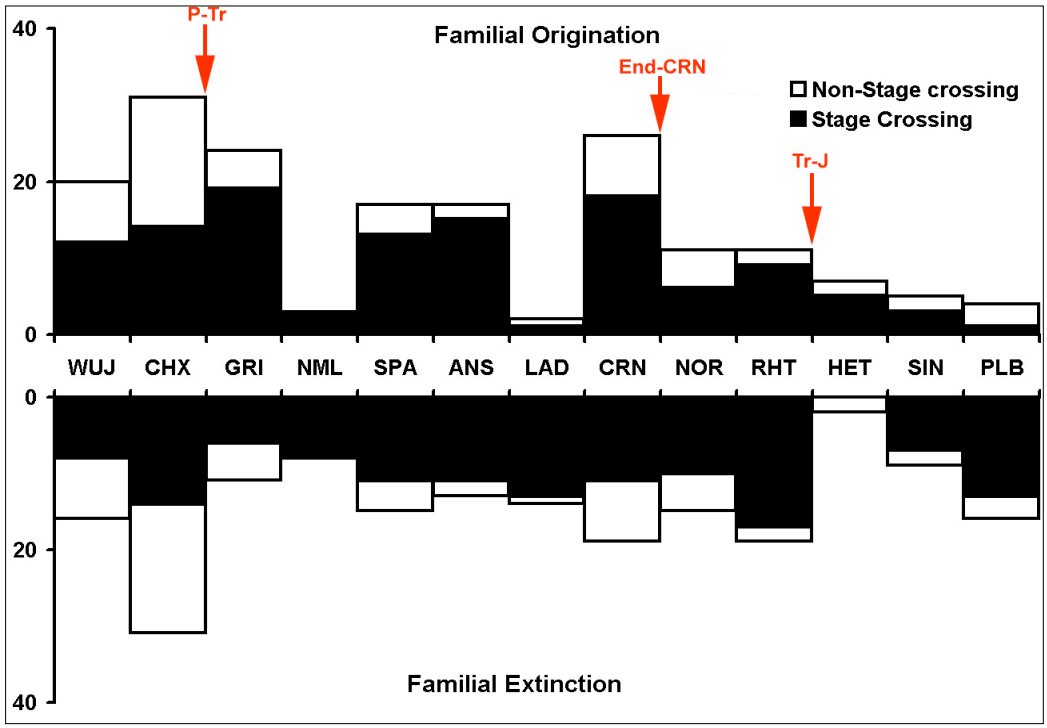
Why the Late Permian – Early Jurassic?

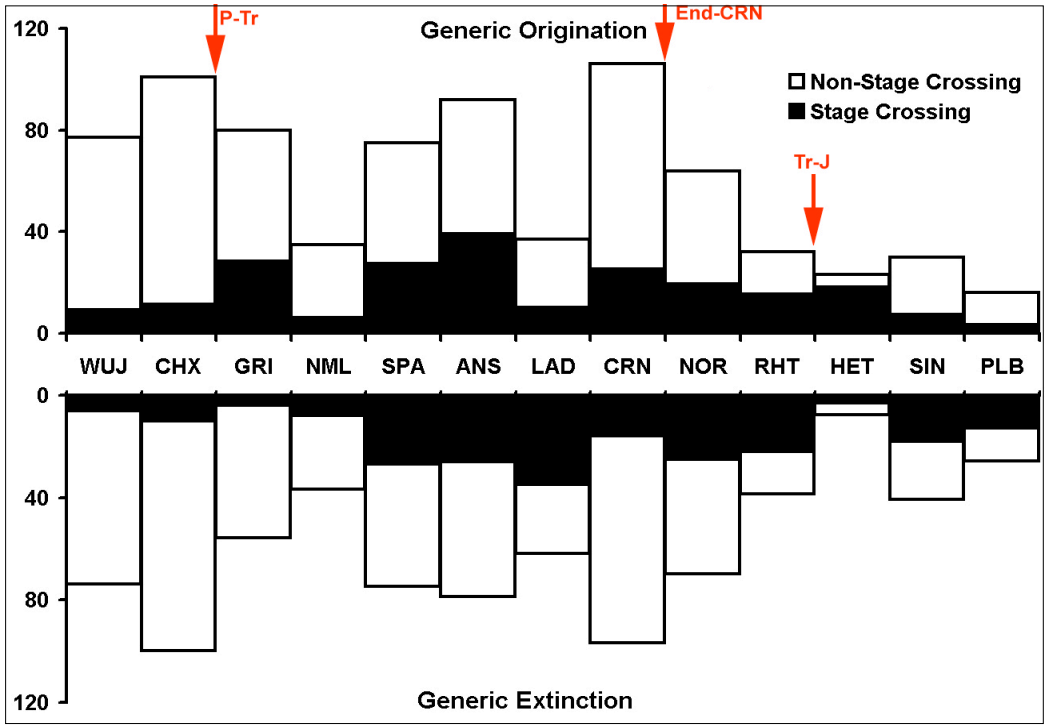
- Period of major change amongst tetrapods
- Earliest: mammals, dinosaurs, pterosaurs, ichthyopterygians, sauropterygians, turtles, crocodiles, frogs, and caecilians
- Triassic bounded by two ‘Big 5’ events (+ third?)
- Received relatively little study
- Lacks a thorough analysis (Weems, 1992)
- Until now…

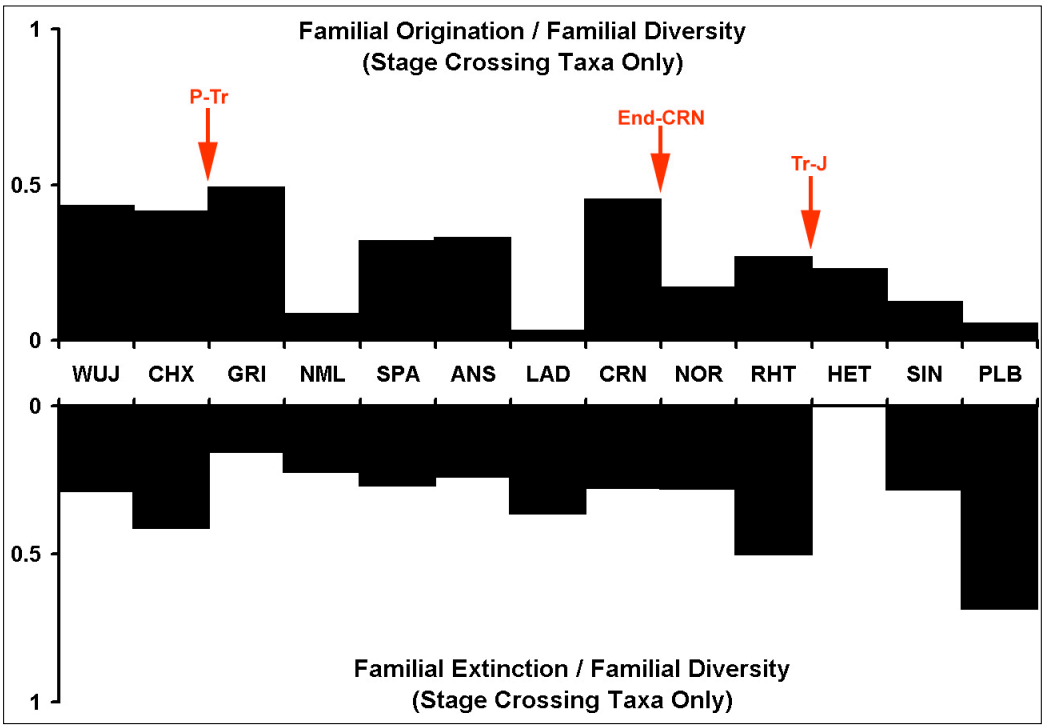
The Datasets

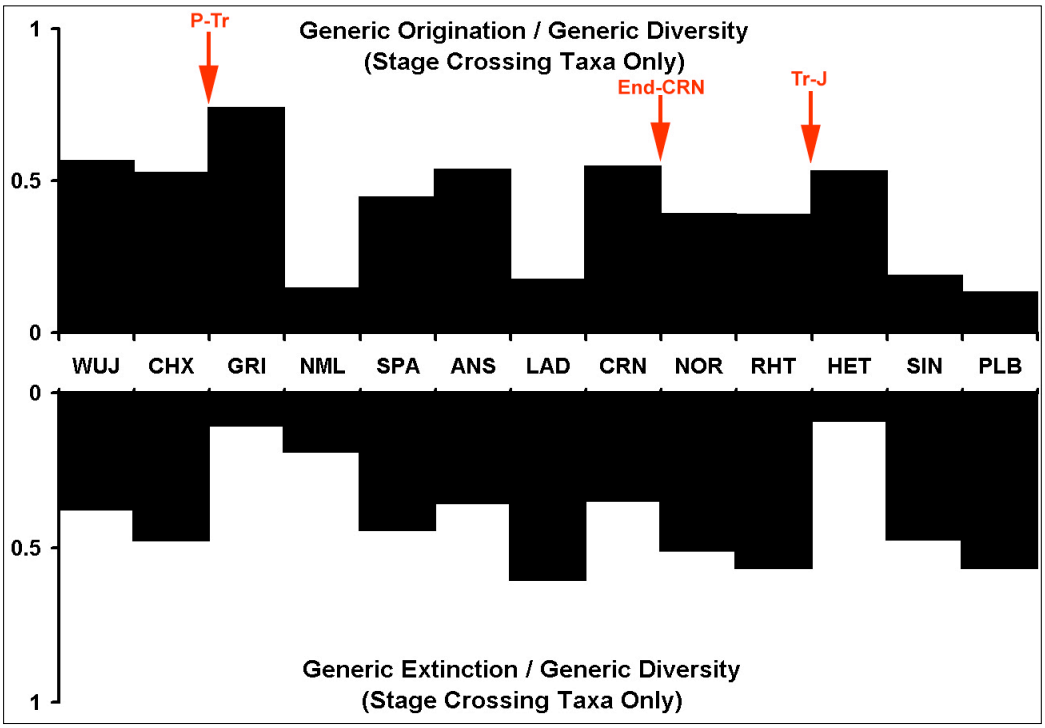
- 204 families and 810 genera
  - Stratigraphic range (stage)
  - Geographic range (continent)
  - Taxonomic class (amphibians/reptiles/ mammals)
  - Body size (small/medium/large)
  - Diet (invertebrates/tetrapods/browser/ fish/molluscs)
  - Habitat (marine/freshwater/terrestrial/ aerial/arboreal)

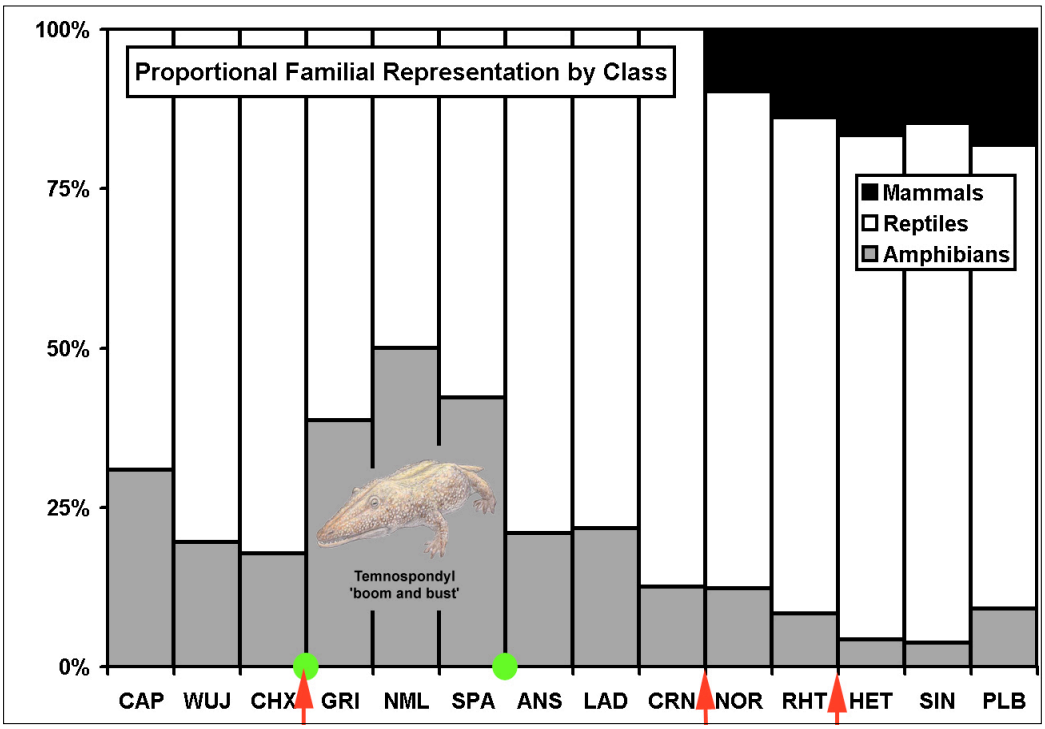


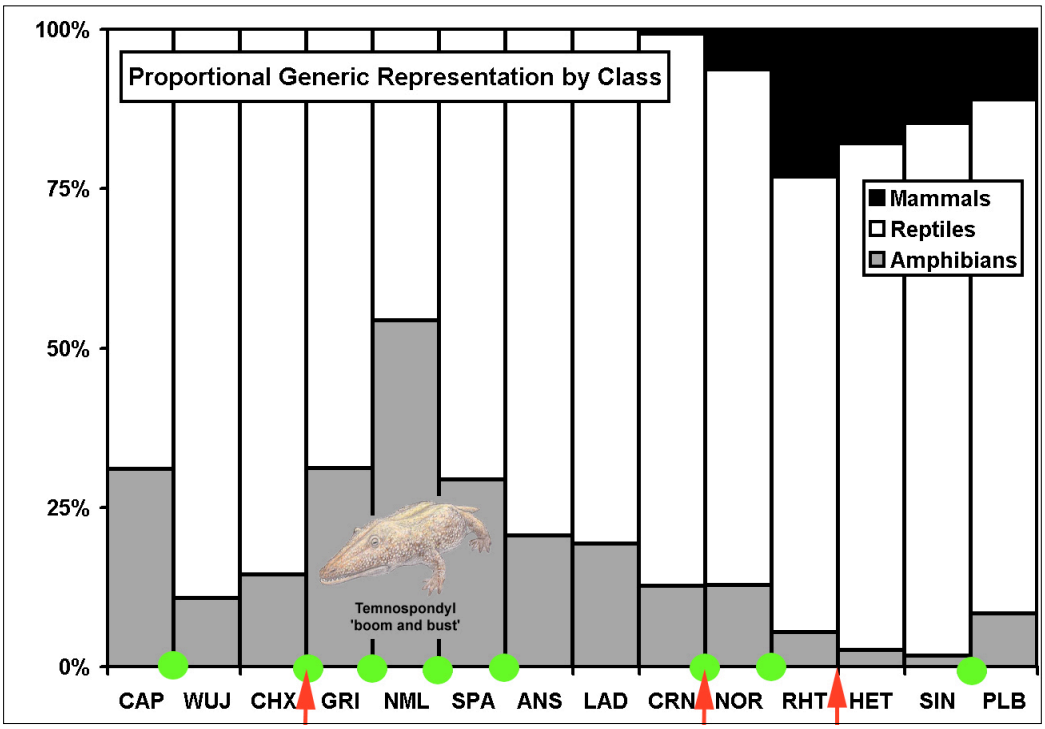

Familial Origination
P-Tr
End-CRN
Tr-J
Non-Stage crossing
Stage Crossing
40
20
0
WUJ
CHX
GRI
NML
SPA
ANS
LAD
CRN
NOR
RHT
HET
SIN
PLB
0
20
40
Familial Extinction


Generic Origination
P-Tr
End-CRN
Tr-J
Non-Stage Crossing
Stage Crossing
120
80
40
0
WUJ
CHX
GRI
NML
SPA
ANS
LAD
CRN
NOR
RHT
HET
SIN
PLB
0
40
80
120
Generic Extinction


Familial Origination / Familial Diversity
(Stage Crossing Taxa Only)
P-Tr
End-CRN
Tr-J
1
0.5
0
WUJ
CHX
GRI
NML
SPA
ANS
LAD
CRN
NOR
RHT
HET
SIN
PLB
0
0.5
1
Familial Extinction / Familial Diversity
(Stage Crossing Taxa Only)


Generic Origination / Generic Diversity
(Stage Crossing Taxa Only)
P-Tr
End-CRN
Tr-J
1
0.5
0
WUJ
CHX
GRI
NML
SPA
ANS
LAD
CRN
NOR
RHT
HET
SIN
PLB
0
0.5
1
Generic Extinction / Generic Diversity
(Stage Crossing Taxa Only)


Proportional Familial Representation by Class
100%
75%
50%
25%
0%
Mammals
Reptiles
Amphibians
Temnospondyl
'boom and bust'
CAP
WUJ
CHX
GRI
NML
SPA
ANS
LAD
CRN
NOR
RHT
HET
SIN
PLB


Proportional Generic Representation by Class
100%
75%
50%
25%
0%
Mammals
Reptiles
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'boom and bust'
CAP
WUJ
CHX
GRI
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LAD
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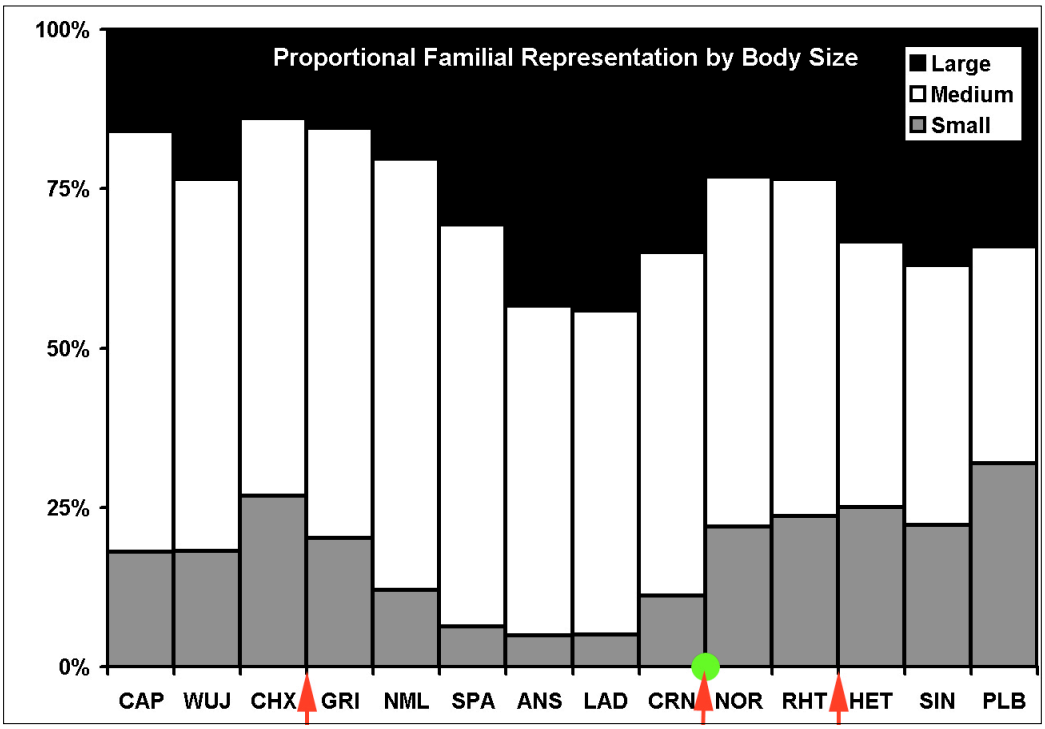
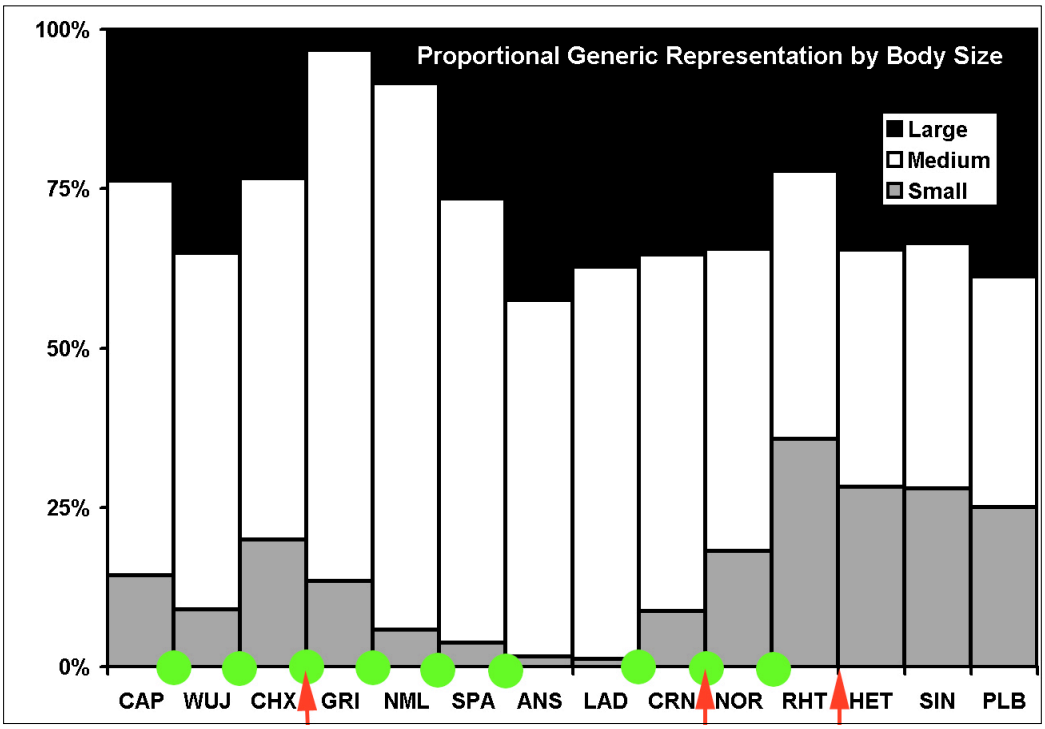
PLB


Proportional Familial Representation by Body Size
Large
Medium
Small
100%
75%
50%
25%
0%
CAP
WUJ
CHX
GRI
NML
SPA
ANS
LAD
CRN
NOR
RHT
HET
SIN
PLB


Proportional Generic Representation by Body Size
Large
Medium
Small
100%
75%
50%
25%
0%
CAP
WUJ
CHX
GRI
NML
SPA
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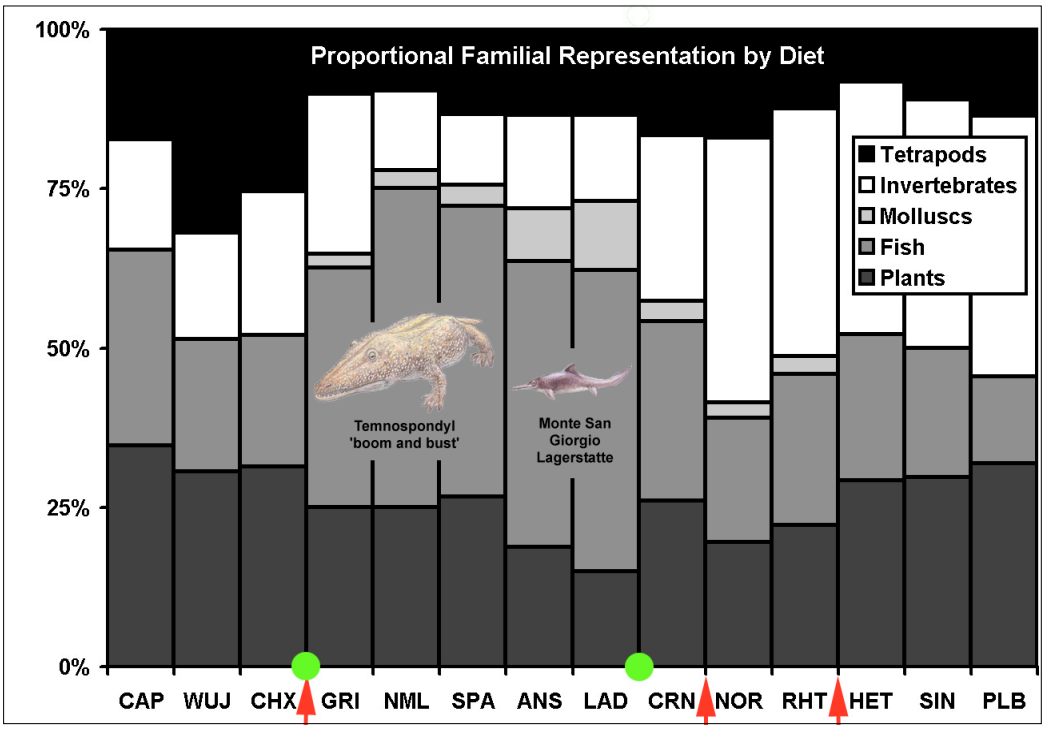
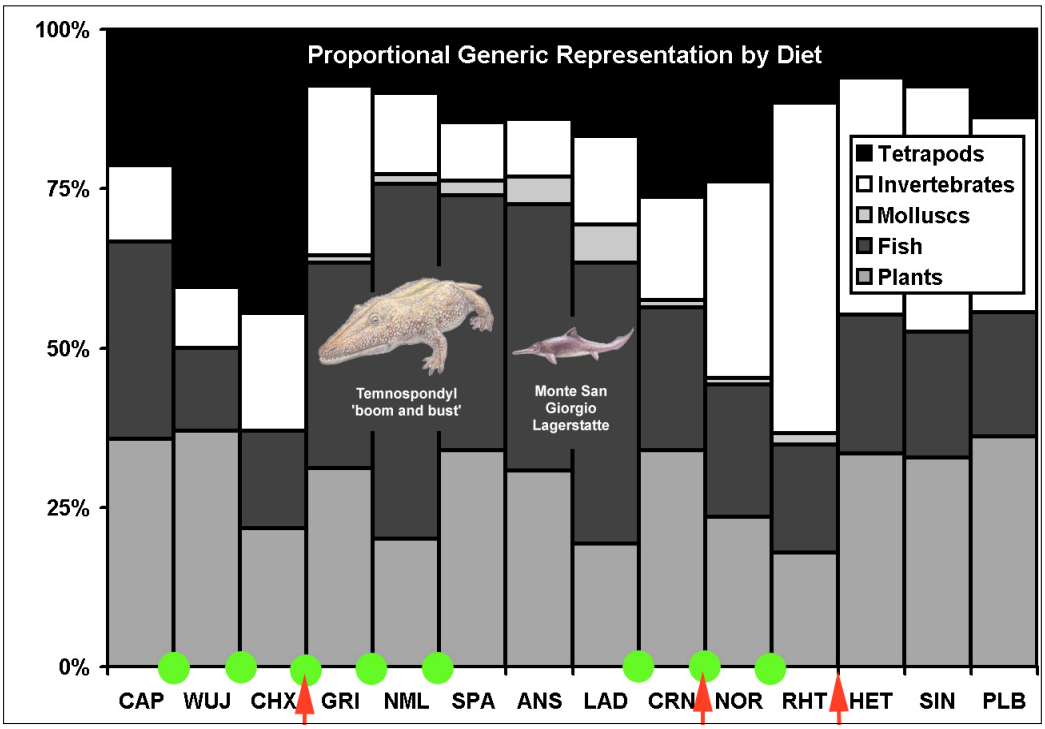
LAD
CRN
NOR
RHT
HET
SIN
PLB


Proportional Familial Representation by Diet
100%
75%
50%
25%
0%
Tetrapods
Invertebrates
Molluscs
Fish
Plants
Temnospondyl 'boom and bust'
Monte San Giorgio Lagerstatte
CAP
WUJ
CHX
GRI
NML
SPA
ANS
LAD
CRN
NOR
RHT
HET
SIN
PLB


Proportional Generic Representation by Diet
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50%
25%
0%
Tetrapods
Invertebrates
Molluscs
Fish
Plants
Temnospondyl 'boom and bust'
Monte San Giorgio Lagerstatte
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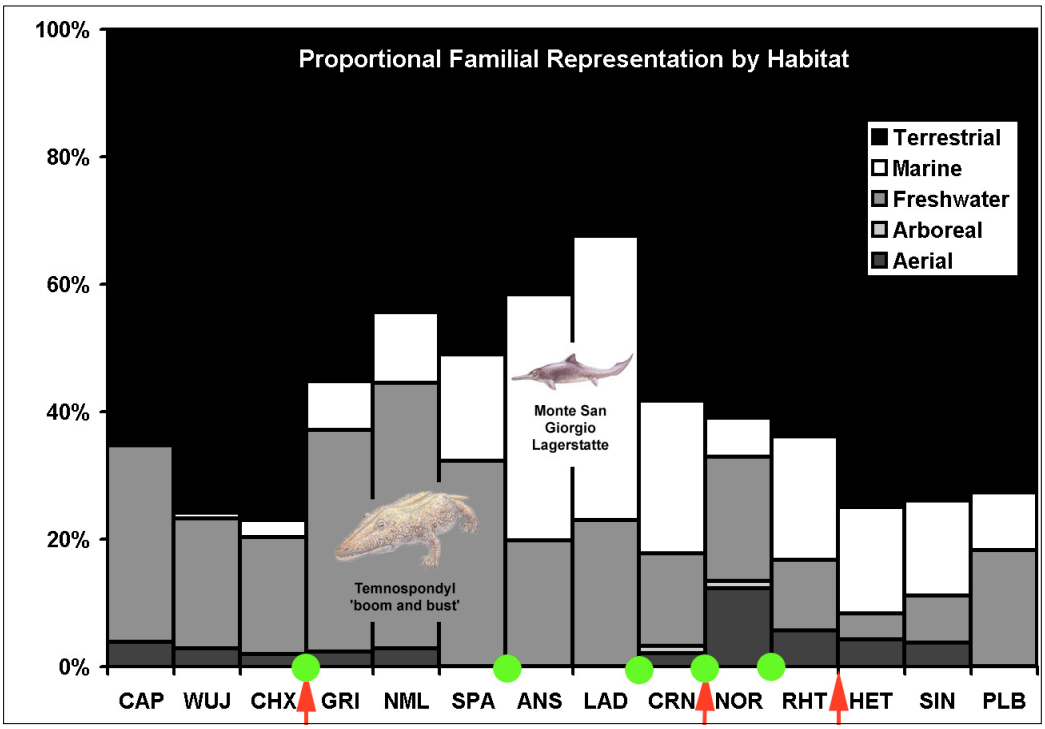
Proportional Familial Representation by Habitat
Terrestrial
Marine
Freshwater
Arboreal
Aerial
100%
80%
60%
40%
20%
0%
Monte San Giorgio Lagerstatte
Temnospondyl 'boom and bust'
CAP
WUJ
CHX
GRI
NML
SPA
ANS
LAD
CRN
NOR
RHT
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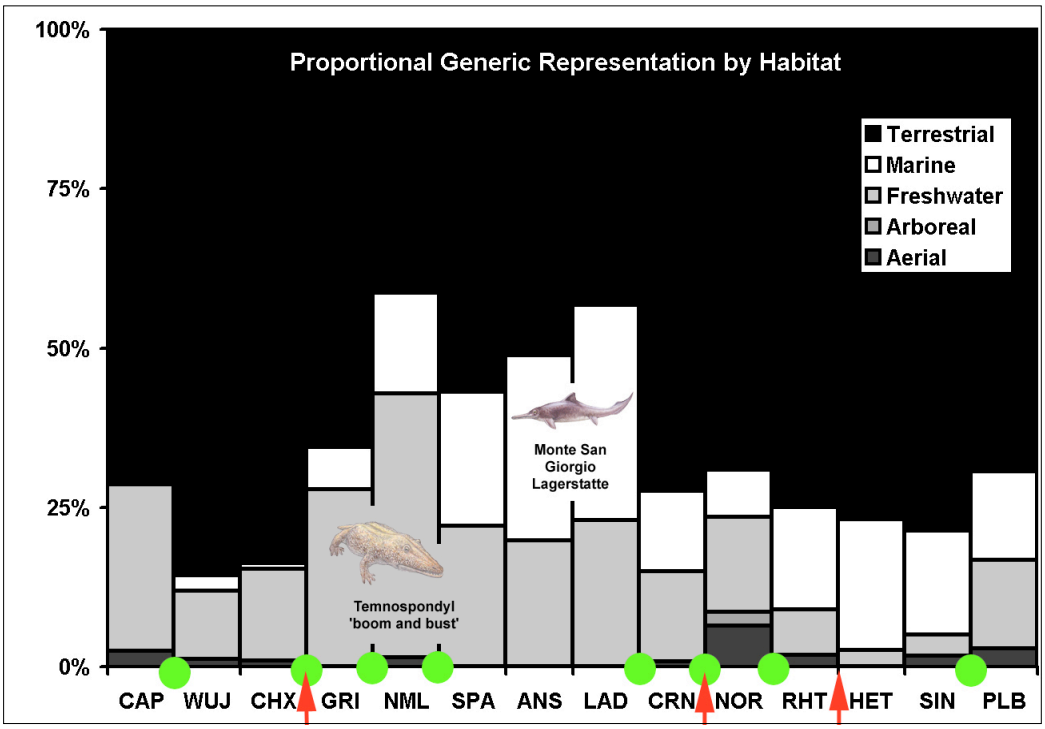
PLB


Proportional Generic Representation by Habitat
Terrestrial
Marine
Freshwater
Arboreal
Aerial
100%
75%
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25%
0%
Monte San Giorgio Lagerstatte
Temnospondyl 'boom and bust'
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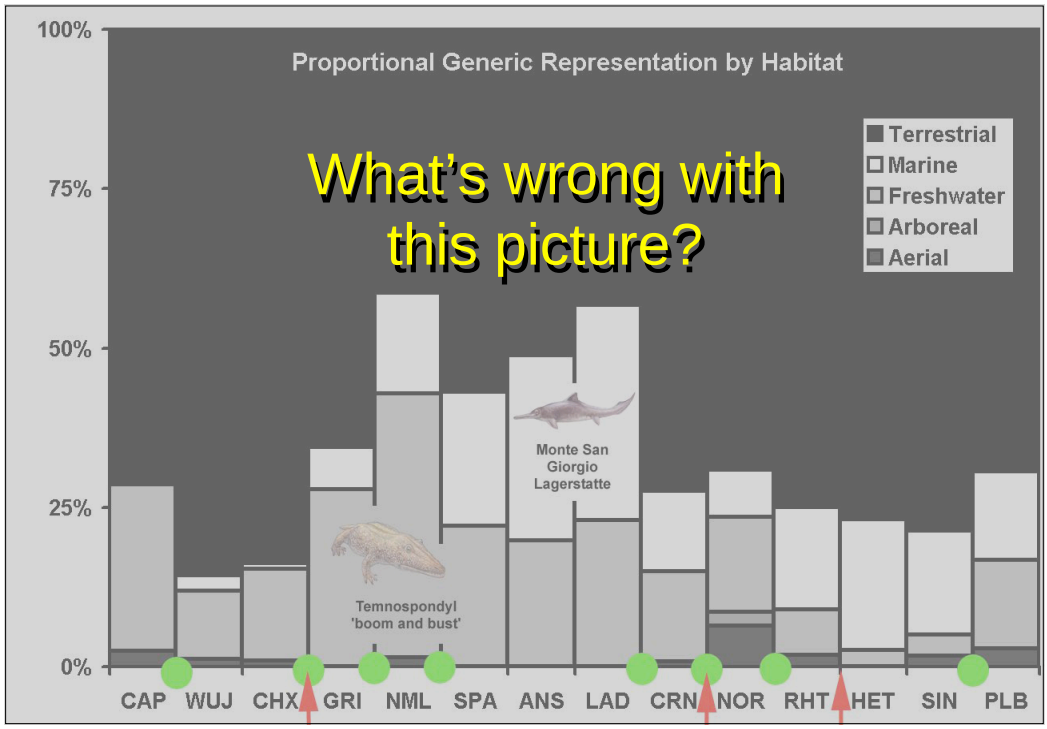
Proportional Generic Representation by Habitat
What's wrong with this picture?
Terrestrial
Marine
Freshwater
Arboreal
Aerial
100%
75%
50%
25%
0%
Monte San Giorgio Lagerstatte
Temnospondyl 'boom and bust'
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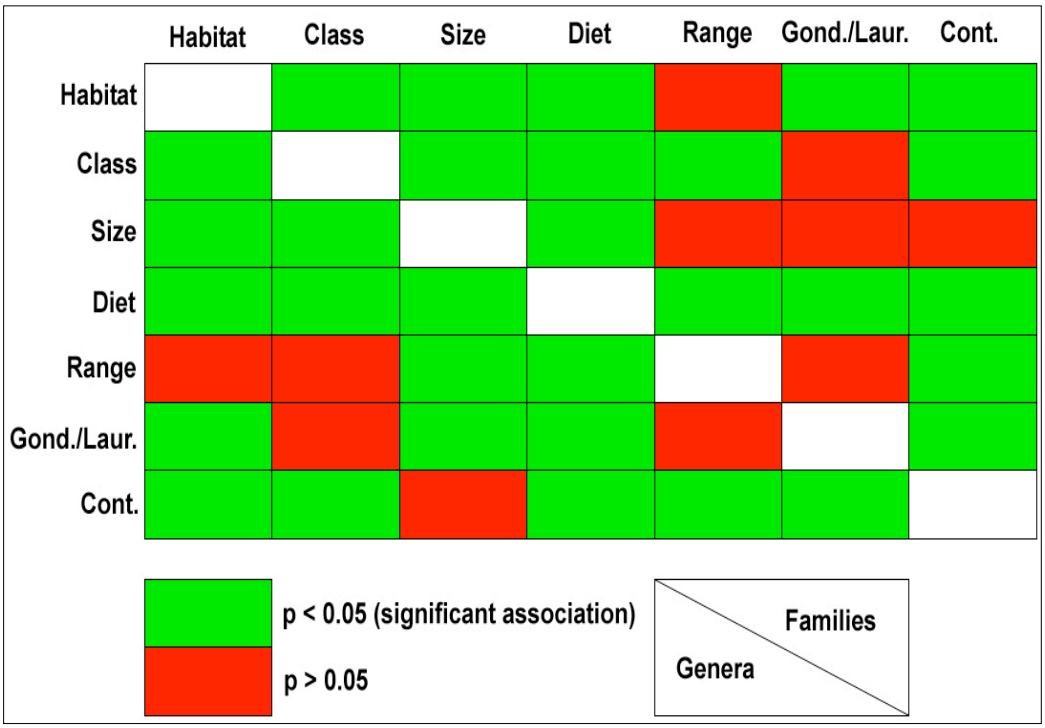
Habitat
Class
Size
Diet
Range
Gond./Laur.
Cont.
p < 0.05 (significant association)
p > 0.05
Families
Genera

Pairwise Association: What does it mean?

- Selection for one variable = selection for many (difficult to separate cause from artefact)
- Taxonomic selectivity may imply non-preservable traits
- Tetrapods are evolutionarily conservative (constrained)
- Family and genus equally biased
- Could different variables be used?

Known-Knowns and Known-Unknowns

- P-Tr event associated with extinction and ecological change Why not as pronounced as K-T?
- End-Carnian event associated with rise of mammals Why no extinction signature?
- Tr-J has apparent extinction signature Why no ecological change?
- Difficult to determine root of ecological changes
- There is hope!

An old problem

"[We] continually over-rate the perfection of the geological record, and falsely infer, because certain genera or families have not been found beneath a certain stage, that they did not exist before that stage."

Ghost ranges the answer?

Many advantages:

- We know they exist! (higher taxonomy)
- More stage-crossing taxa (affecting survivorship, e.g. Modesto *et al.*, 2003)
- Corrects collection biases (affecting biogeography, e.g. Rauhut, 2003)
- Corrects preservation biases (affecting taxonomic representation, e.g. ghost diversity in pterosaurs +253% vs. sauropterygians +22%)
- Ghost range plots ≤ MPTs
- Tetrapods are phylogenetically well understood

But…

- Requires massive trees
- Range extension is asymmetric

Acknowledgements

Mark Buckingham supplied the initial data on Late Permian tetrapods as well as helpful comments and suggestions. The Palaeontology Discussion Group (PDG) at the University of Bristol were subjected to 2 (two!) earlier versions of this presentation and are thanked for their constructive criticism. I am particularly indebted to Pam Gill and Phil Donoghue for their advice.