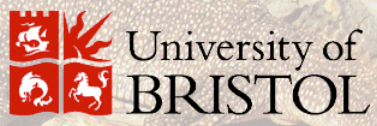
Difficulty in identifying mass extinctions amongst tetrapods (Late Permian – Early Jurassic)



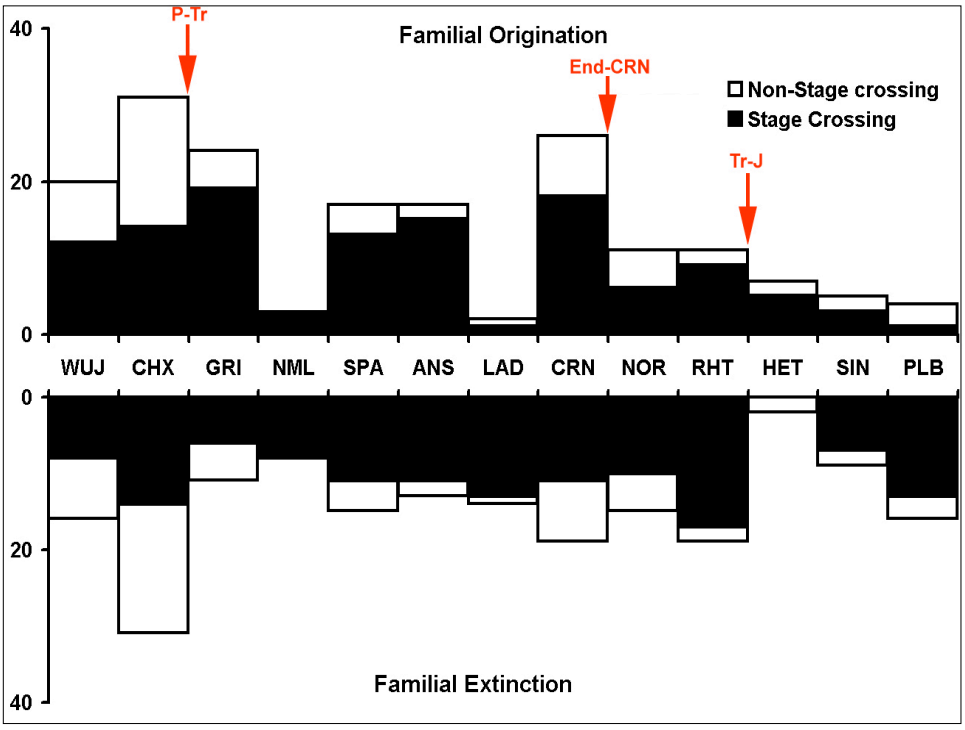
Graeme T. LLOYD &
Michael J. BENTON

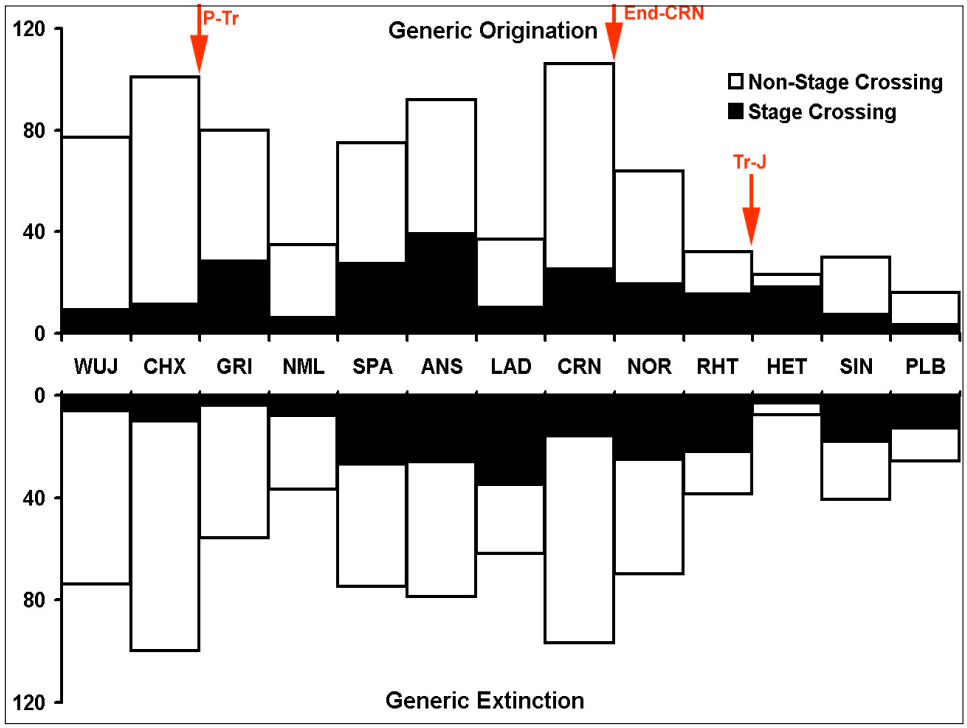
Why the Late Permian – Early Jurassic?

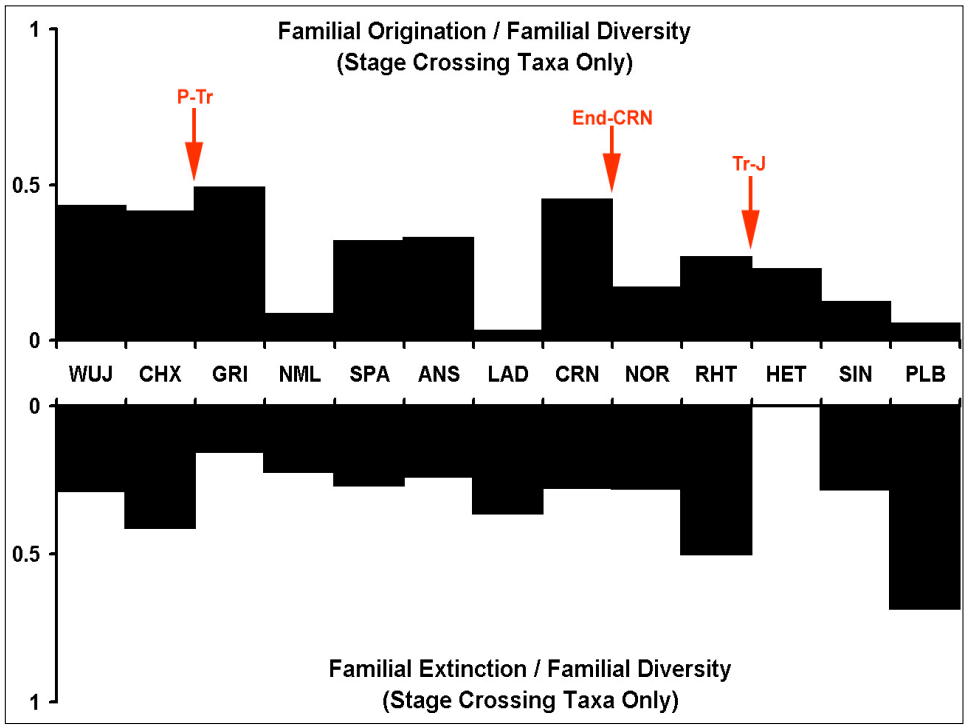
- Period of major change amongst tetrapods
- Earliest: mammals, dinosaurs, pterosaurs, ichthyopterygians, sauropterygians, turtles, crocodiles, frogs, and caecilians
- Triassic bounded by two 'Big 5' events (+ third?)
- Received relatively little study
- Lacks a thorough analysis (Weems, 1992)
- Until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

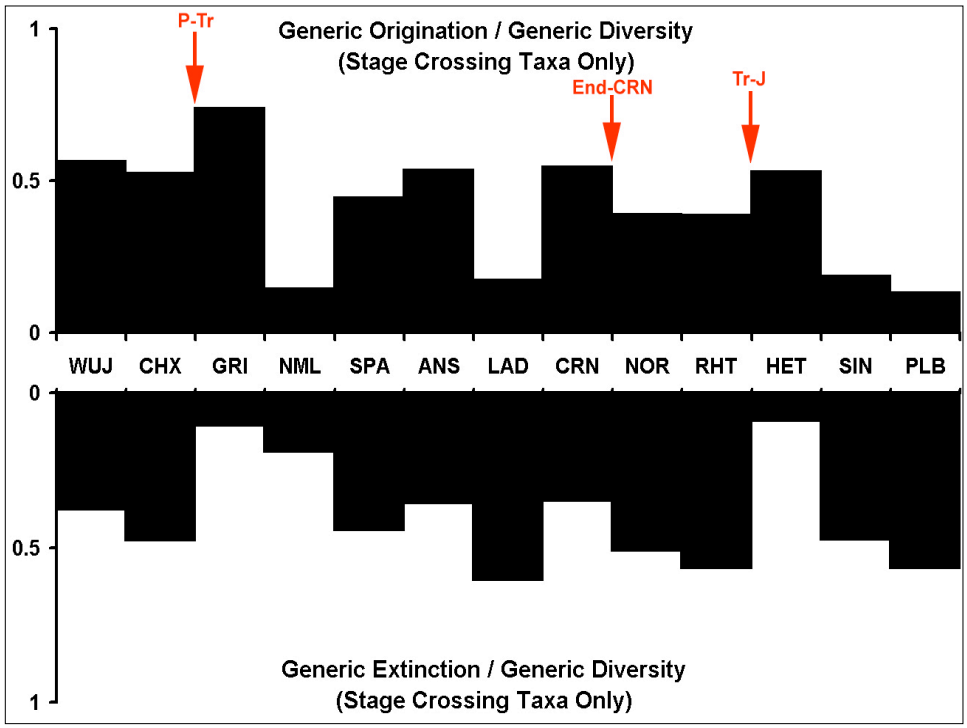
The Datasets

- 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)



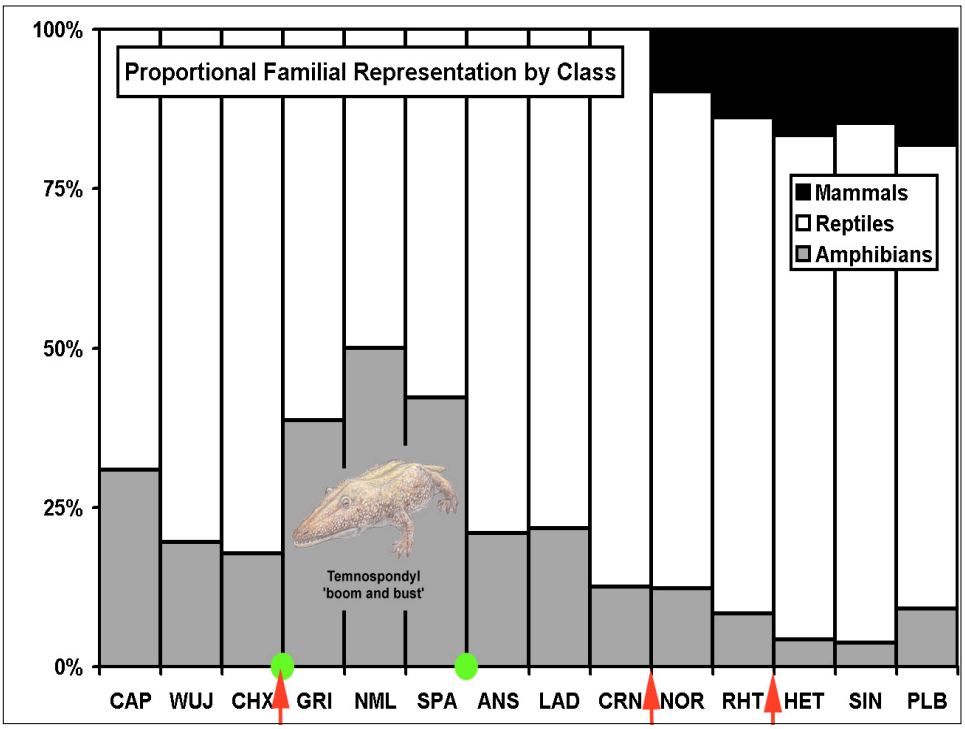

Generic Origination
P-Tr
End-CRN
Tr-J
Non-Stage Crossing
Stage Crossing
120
80
40
0
WUJ
CHX
GRI
NML
SPA
ANS
LAD
CRN
NOR
RHT
HET
SIN
PLB
0
40
80
120
Generic Extinction

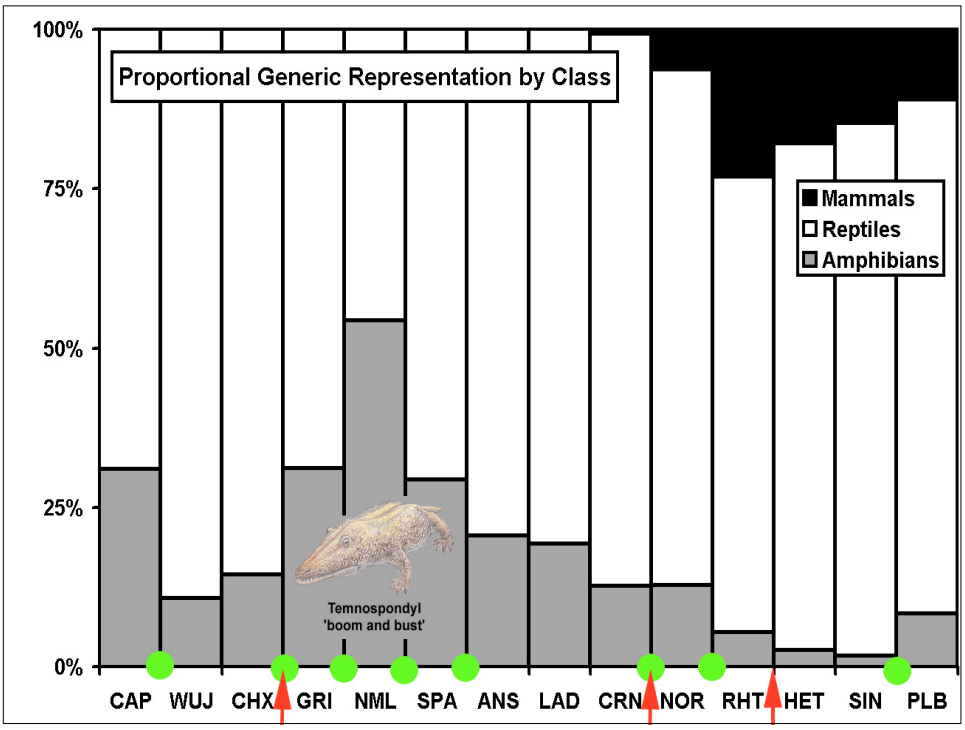

Familial Origination / Familial Diversity
(Stage Crossing Taxa Only)
P-Tr
End-CRN
Tr-J
1
0.5
0
WUJ
CHX
GRI
NML
SPA
ANS
LAD
CRN
NOR
RHT
HET
SIN
PLB
0
0.5
1
Familial Extinction / Familial Diversity
(Stage Crossing Taxa Only)



Origination and Extinction

- Origination and Extinction seem to support end-Permian and end-Triassic events
- There is no evidence to support an end-Carnian event


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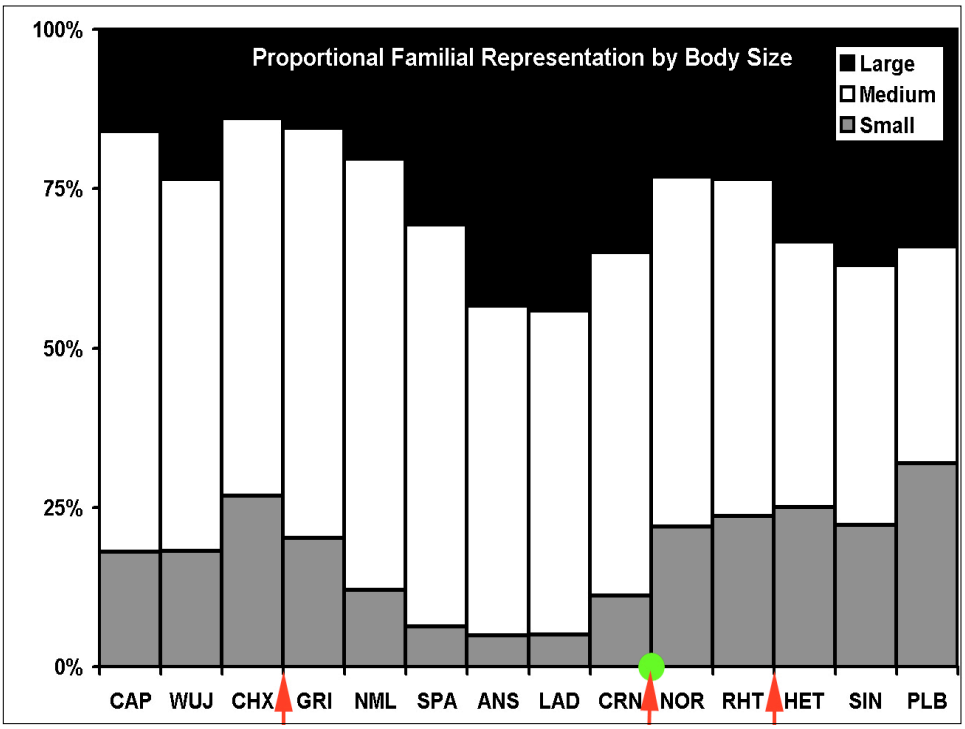
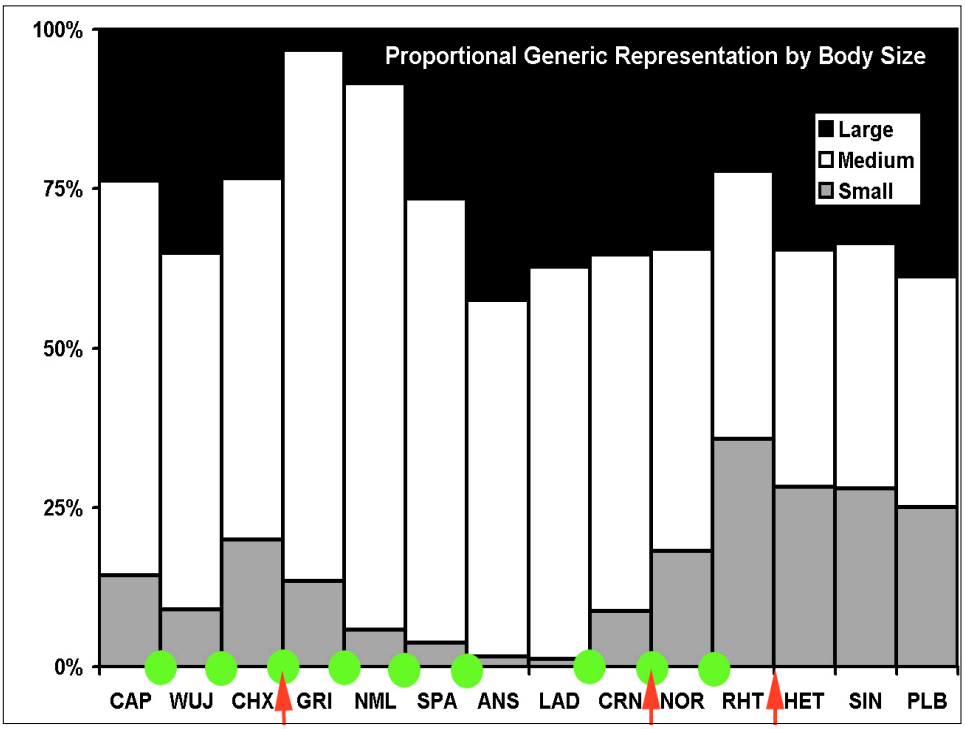
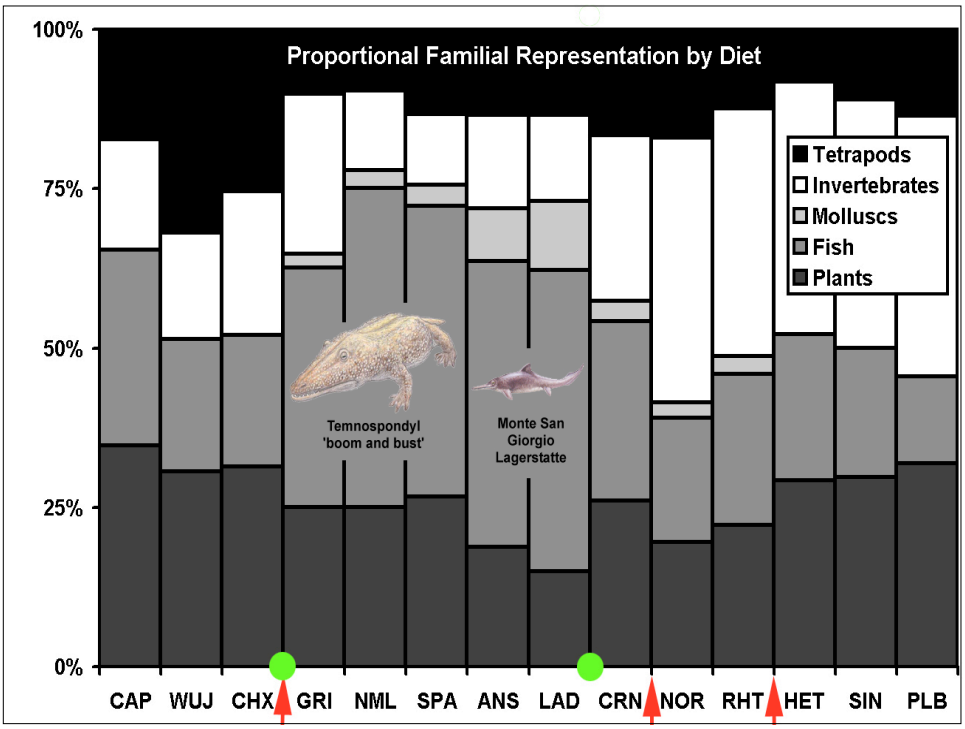
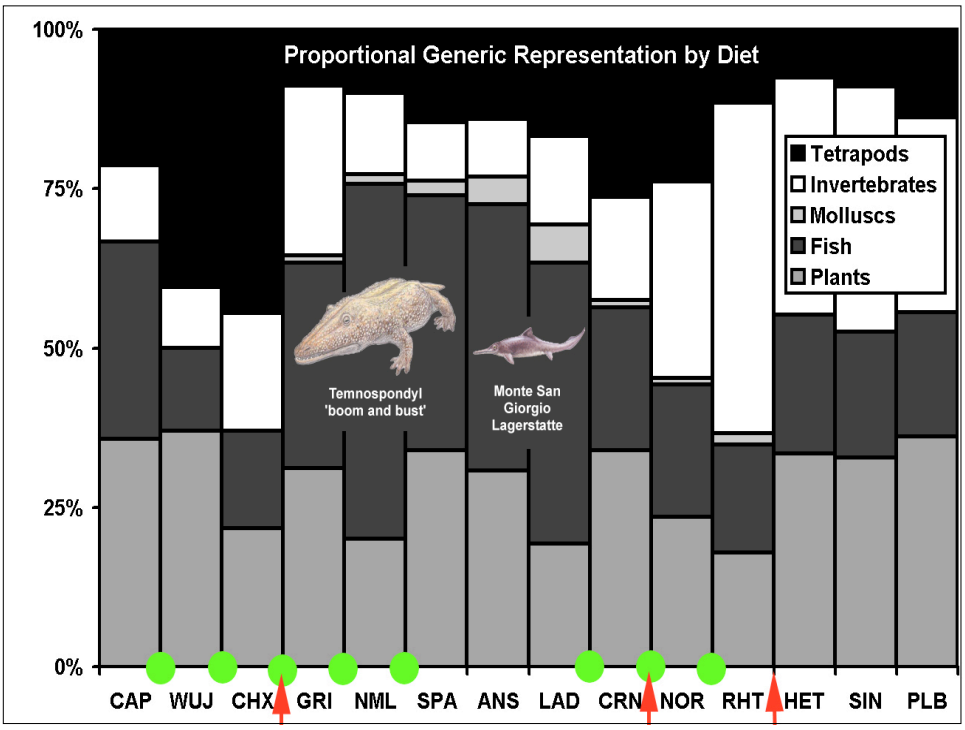
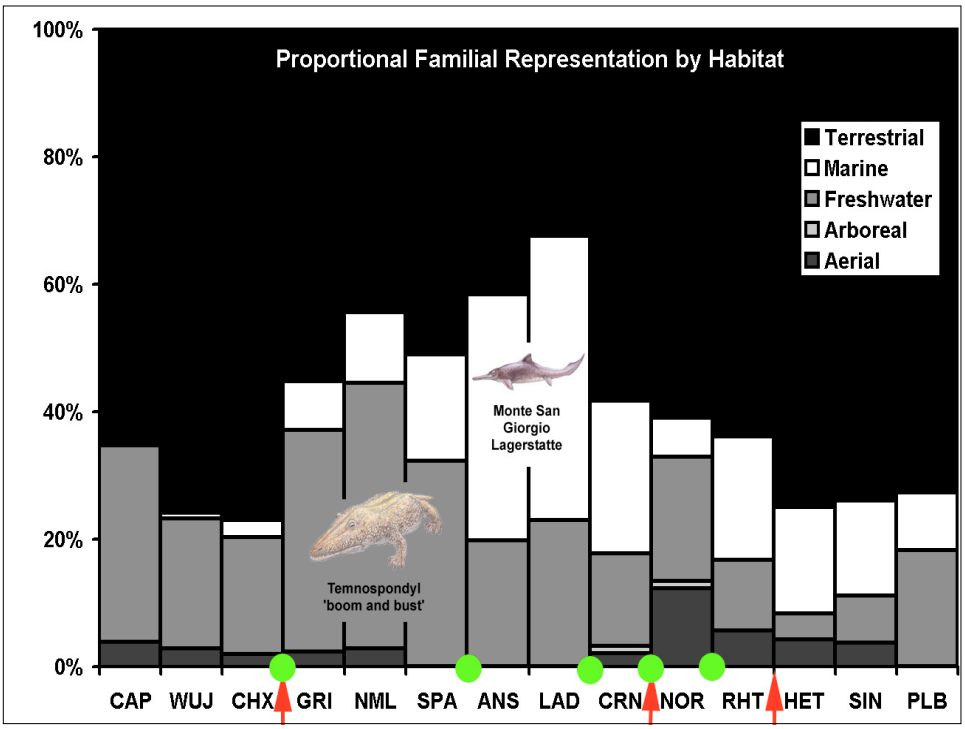
100%
75%
50%
25%
0%
Mammals
Reptiles
Amphibians
Temnospondyl
'boom and bust'
CAP WUJ CHX GRI NML SPA ANS LAD CRN NOR RHT HET SIN PLB

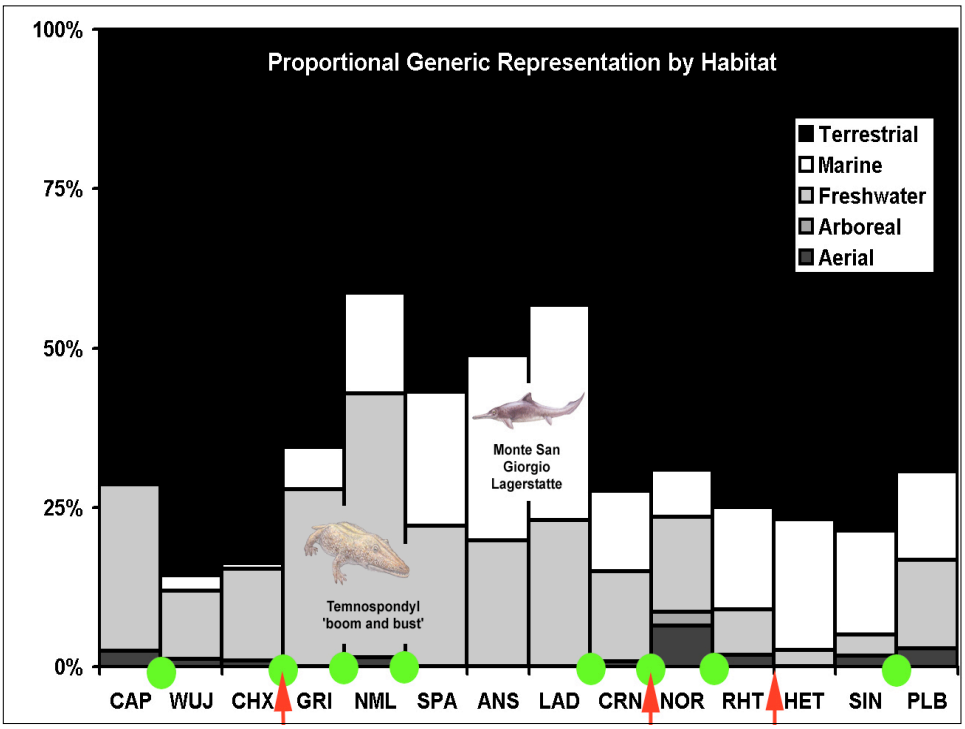

Proportional Familial Representation by Body Size
Large
Medium
Small
100%
75%
50%
25%
0%
CAP
WUJ
CHX
GRI
NML
SPA
ANS
LAD
CRN
NOR
RHT
HET
SIN
PLB


Proportional Generic Representation by Body Size
Large
Medium
Small
100%
75%
50%
25%
0%
CAP
WUJ
CHX
GRI
NML
SPA
ANS
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

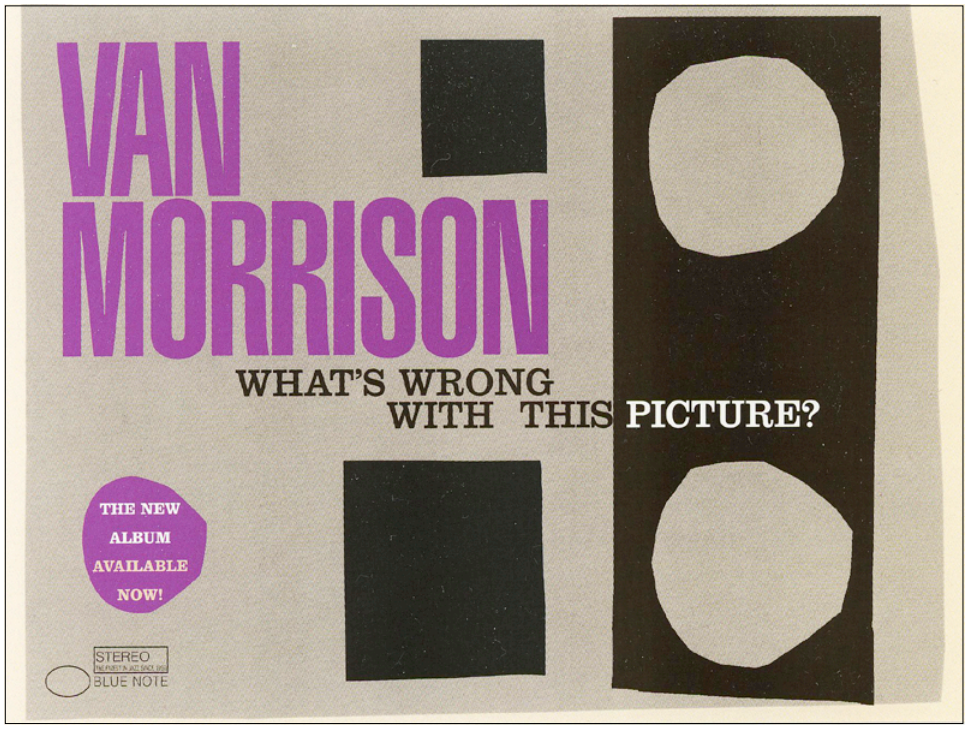

Proportional Generic Representation by Diet
100%
75%
50%
25%
0%
Tetrapods
Invertebrates
Molluscs
Fish
Plants
Temnospondyl 'boom and bust'
Monte San Giorgio Lagerstatte
CAP WUJ CHX GRI NML SPA ANS LAD CRN NOR RHT HET SIN PLB


Proportional Familial Representation by Habitat
100%
80%
60%
40%
20%
0%
Terrestrial
Marine
Freshwater
Arboreal
Aerial
Monte San Giorgio Lagerstatte
Temnospondyl 'boom and bust'
CAP
WUJ
CHX
GRI
NML
SPA
ANS
LAD
CRN
NOR
RHT
HET
SIN
PLB


Proportional Generic Representation by Habitat
100%
75%
50%
25%
0%
Terrestrial
Marine
Freshwater
Arboreal
Aerial
Monte San Giorgio Lagerstatte
Temnospondyl 'boom and bust'
CAP
WUJ
CHX
GRI
NML
SPA
ANS
LAD
CRN
NOR
RHT
HET
SIN
PLB

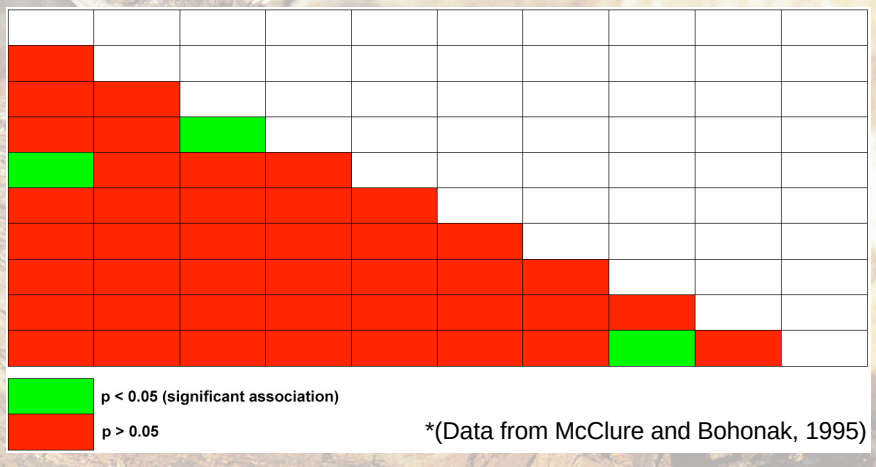
Summary of Ecological Change

- End-Permian event consistently associated with ecological change
- Marine taxa suffer a major extinction at the end-Carnian whilst mammals radiate
- End-Triassic significant only in ecological conservation



Pairwise Association I:
Late Permian – Early Jurassic tetrapods

Pairwise Association II:
K-T bivalves*



*(Data from McClure and Bohonak, 1995)

Pairwise Association III: Conclusions

- Cause and effect impossible to discern
- Taxonomic selectivity may imply non-preservable traits
- Great constraints on tetrapod evolution
- Could different variables be used?
- Geological signals are pervading the data
- New methodology required

Phylogeny to the rescue? I:

Darwin identifies the problem

"[W]e 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."

The Origin of Species (1859)

Phylogeny to the rescue? II:

Virtues of ghost range over stratigraphic range usage

- Boosts sample size - more stage-crossing taxa
- Corrects collection biases (e.g. Rauhut, 2003: Gondwanan vs. Laurasian theropods)
- Corrects preservation biases (e.g. pterosaurs vs. sauropterygians)
- Ghost range variations ≤ MPTs
- Fills ‘certain’ gaps (e.g. E. Cretaceous choristoderes, M. Jurassic pterosaurs etc.)
- Tetrapods are phylogenetically well understood
- But, requires massive trees and range extension asymmetric
- Effects every analysis undertaken here

Conclusions

- End-Permian extinction important event in tetrapod evolution
- Important ecological changes also occur at end-Carnian; lack of an extinction signature possibly a timing issue
- Interpreting end-Triassic problematic due to poor Early Jurassic record
- High pairwise association of variables prevents determination of causation (selectivity)
- Genus is a valid species proxy in tetrapod macroevolution

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 gave constructive feedback on an early version of this presentation, I am particularly indebted to Pam Gill and Phil Donoghue for their advice.