Evolution and diversification in the biota of the arid zone

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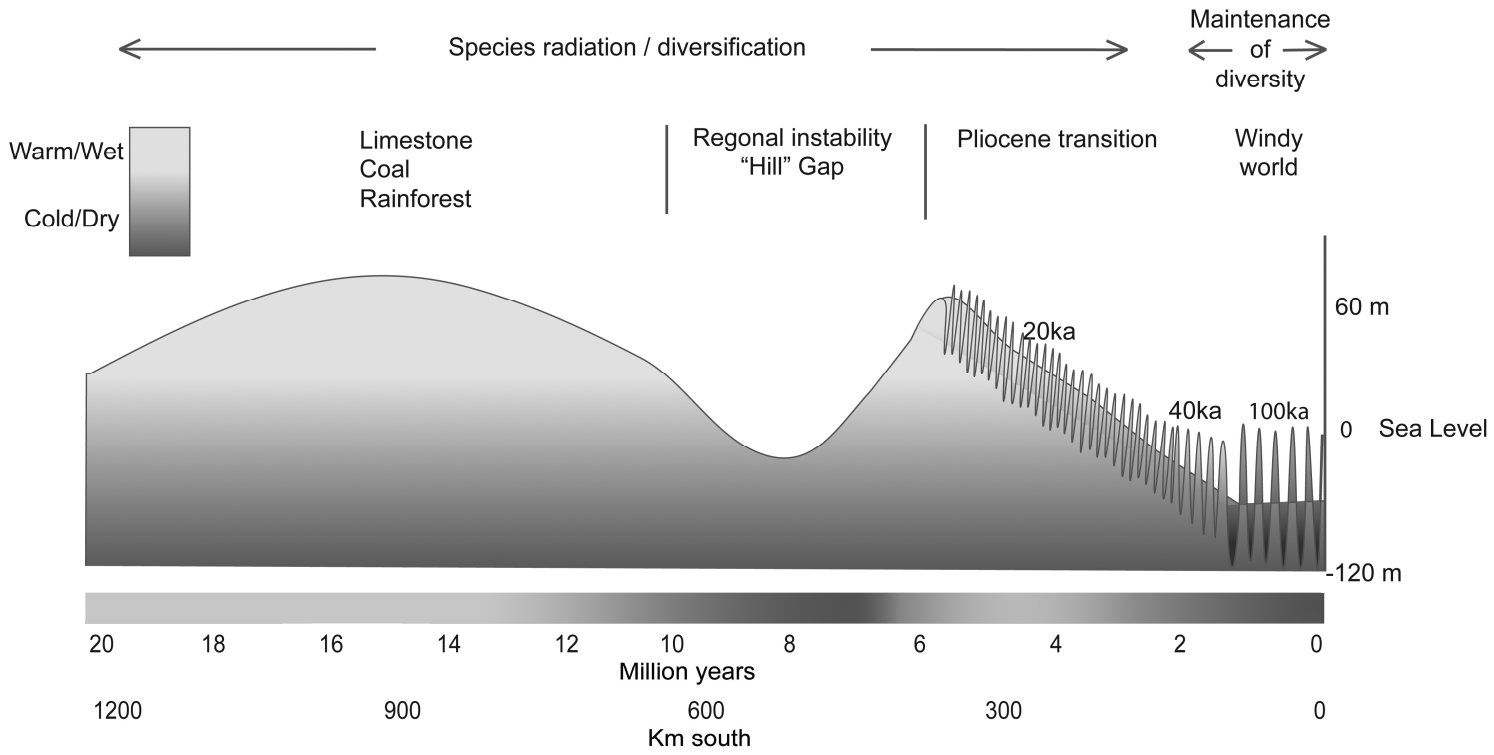
Department of
Environment and Conservation

Climatic history

Aridification since mid Miocene (20 Mya)

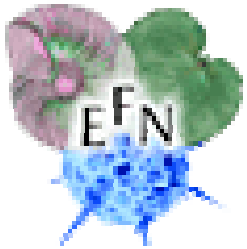
Contraction of mesic environments

Major arid/mesic cycles through Pleistocene (2.8 Mya)



Evolution and diversification

Environmental Futures Network
Evolution of the Australian Biomes Working group
- reviews of the evolutionary history of the Australian biota in arid, mesic and monsoon tropics biomes.



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INVITED REVIEW

Birth of a biome: insights into the assembly and maintenance of the Australian arid zone biota

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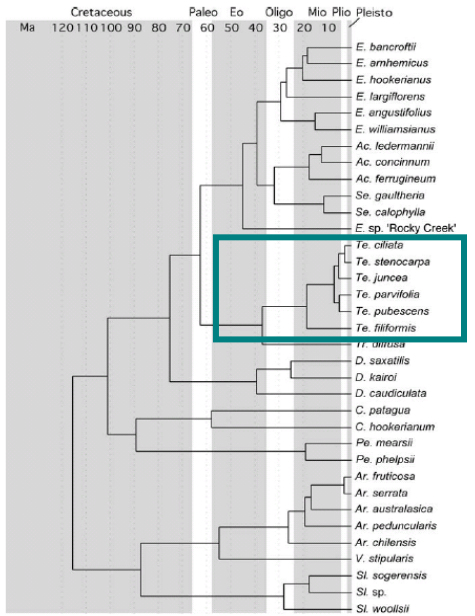
Abstract

The integration of phylogenetics, phylogeography and palaeoenvironmental studies is providing major insights into the historical forces that have shaped the Earth's biomes. Yet our present view is biased towards arctic and temperate/tropical forest regions, with very little focus on the extensive arid regions of the planet. The Australian arid zone is one of the largest desert landform systems in the world, with a unique, diverse and relatively well-studied biota. With foci on palaeoenvironmental and molecular data, we here review

Arid biome diversification

Where did the arid biota originate from?

- mesic ancestors
  - single origin
    - e.g. *Tetratheca, Halosarcia*
  - multiple independent derivation
    - e.g. *Acacia*

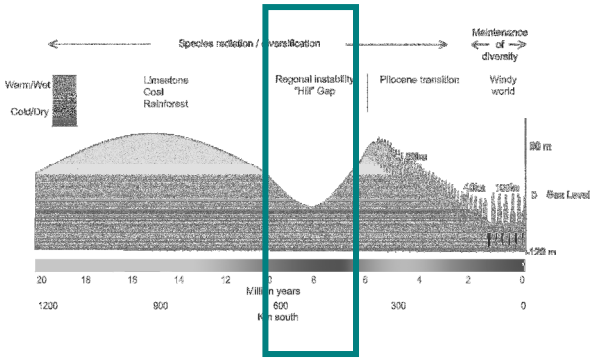


Eleaocarpaceae **Crayn et al. 2006**

Hill gap (10 – 6 Ma)

- early arid phase
- development of lineages

pre- adapted to later aridity



Timing of diversification

Speciation and radiation of arid biota throughout Miocene & Pliocene

single origin generally earlier than multiple origins

Time	Group	Response	Reference
20 - 10 Ma	*Gossipium*	Australian clade diversified between 24.1 – 9.4 Ma.	Liu *et al.* 2001
		Divergence of arid sections *Sturtia* (C genome) and *Hibiscoidea* (G genome) around 8-15 My and tropical sect. *Grandicalyx* (K genome) 10.5 – 21My. Diversification within sect. *Sturtia* earlier (3-6 Ma) than sect. *Grandicalyx* (1.7 – 3 Ma).	Seelanan *et al.* 1999
	Acacia	Major lineages include arid and mesic-zone taxa.	Murphy *et al.* 2003
		Higher sequence divergence in arid clades (*Acacia victoriae* group) compared to mesic clades (sect. *Botrycephalae*).	Ariati *et al.* 2006 Brown *et al.* 2006 Ladiges *et al.* 2006
	Chenopods	Initial diversification of Australia clade in coastal areas 19-14 Ma.	Kadereit *et al.* 2006
	Santalum	Diversification of species between 19 – 6.3 Ma.	Harbaugh & Baldwin 2007
10 – 6 Ma	*Tetratheca*	Diversification from rainforest ancestors 6-7 Ma. Increased rate of evolution in the *Tetratheca* lineage compared to sister lineage of tropical species (*Eleocarpus* + *Aceratium* + *Sericolea*).	Crayn *et al.* 2006
	Chenopods	Rapid radiation and expansion of Salicornioideae into arid and semi-arid saline environments around 6 - 9 Ma.	Shepherd *et al.* 2004
	Acacia	Divergence of *A. lobulata* – *A. ixiophylla* 3.82 Ma. Divergence of *A. oldfieldii* – *A. acuminata* .2.87 Ma.	Byrne *et al.* 2001, 2002
6 – 2.5 Ma			
2.5 – 0.4Ma	*Lepidium*	Genus originated in Australia through hybridisation no more than 1.3Ma, species radiation 0.3 – 1.3 Ma.	Mummenhoff *et al.* 2004
	Sandalwood	Divergence of arid and semi-arid lineages of *Santalum spicatum* 0.8 Ma.	Byrne *et al.* 2003
	Acacia	Divergence of arid and semi-arid lineages of *A. acuminata* 1.0 Ma.	Byrne *et al.* 2002
		Speciation of *A. sciophanes* and *A. anfractuosa* 0.72Ma.	Byrne *et al.* 2001
	Eucalyptus series *Subulatae*	Divergence between the western, central and eastern clades at 1.25, 1.23, 0.95 Ma.	Nicolle 2008
		Divergence between western and far-western clades later at 0.49 Ma.	
	Eucalypt	Divergence of southern and northern lineages of *Eucalyptus loxophleba* 0.7 Ma.	Byrne & Hines 2004
	Eucalypt	Divergence among populations restricted to granite rocks approximately 1.1 Ma.	Byrne & Hopper 2008
0.4Ma - present			

Diversification

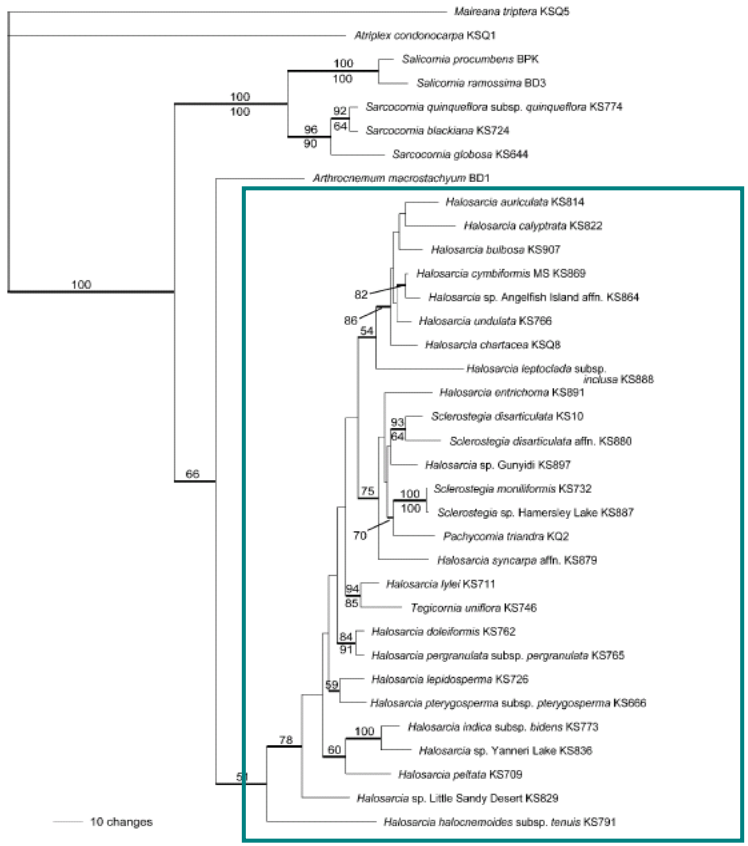
Diversification due to specific environments

saline environments

radiation of Salicornioideae in arid and

semi arid environments in late Pliocene

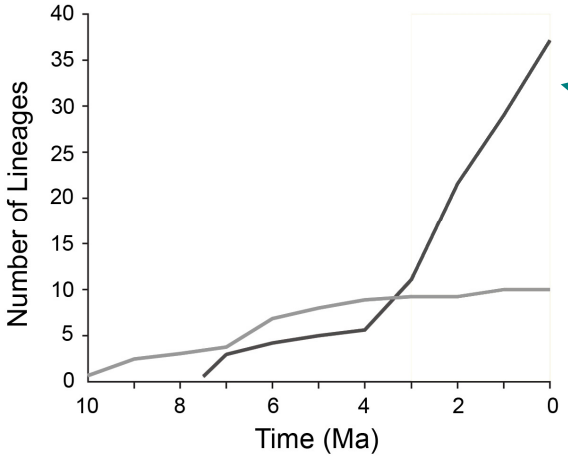
transition from surface dwelling
to groundwater dwelling
in diving beetles, amphipods and isopods
in Pliocene



Halosarcia Shepherd et al. 2004

Rate of diversification

Generally constant, some exceptions



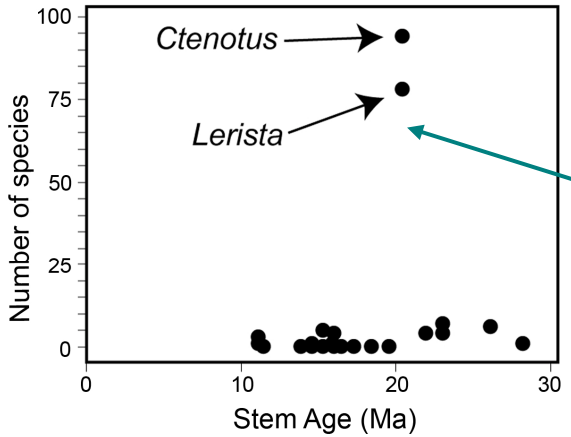
semi arid species

arid species

Gall –thrips (*Kladothrips*)

McLeish et al. 2007

Sphenomorphine skinks



arid genera

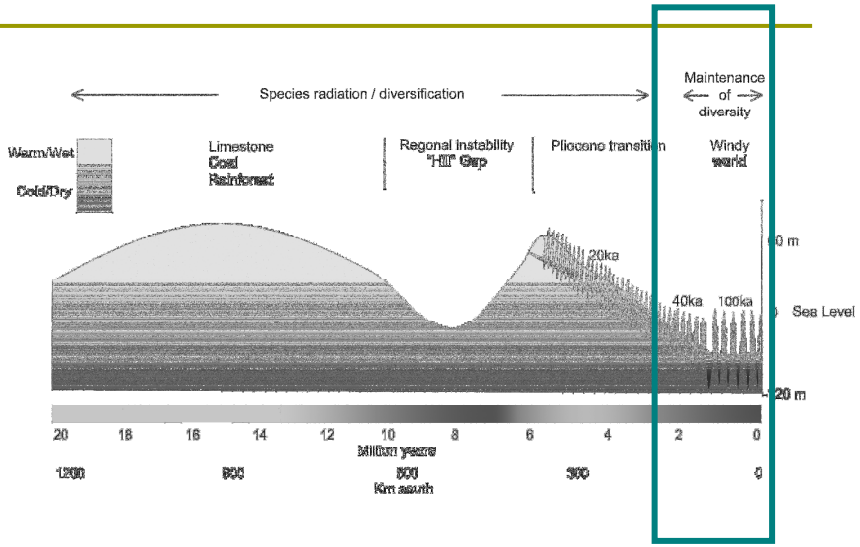
Rabosky et al. 2007

Pleistocene diversification

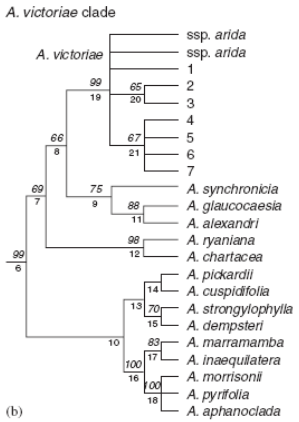
Maintenance of diversity

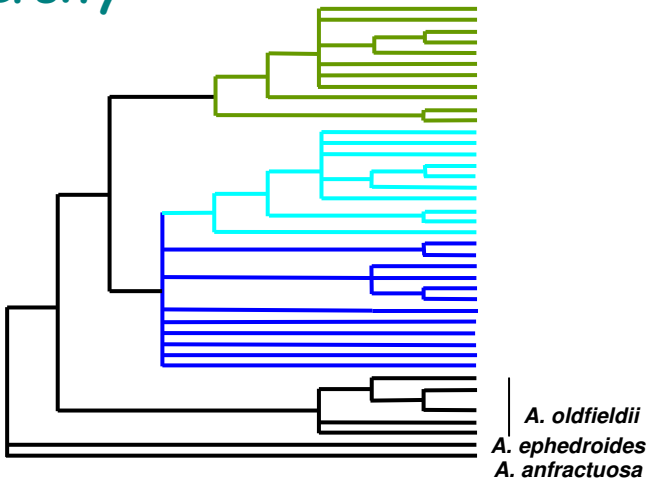
Lineage divergence

Little speciation
(*Lepidium*, *Acacia*)



Genetic diversity on a par with species diversity





Phylogeography

Phylogeography -

biotic responses to historical processes

through

spatial distribution of genealogical lineages

Genetic/spatial associations of lineages

- dispersal/gene flow
- vicariance/fragmentation
- range expansion/colonisation

Biotic response

response options to unsuitable conditions

move
track ecological niche through migration

contraction/ extinction

adapt
tolerate conditions and remain in-situ

diversification

persist
contract to patches of suitable habitat within range

diversification

Common phylogeographic pattern

Most common pattern – plants and animals

- highly structured divergent lineages
- generally mid-Pleistocene or older

→ early Pleistocene – major contraction of biota
(formation of sandy deserts dated at 1 Mya)

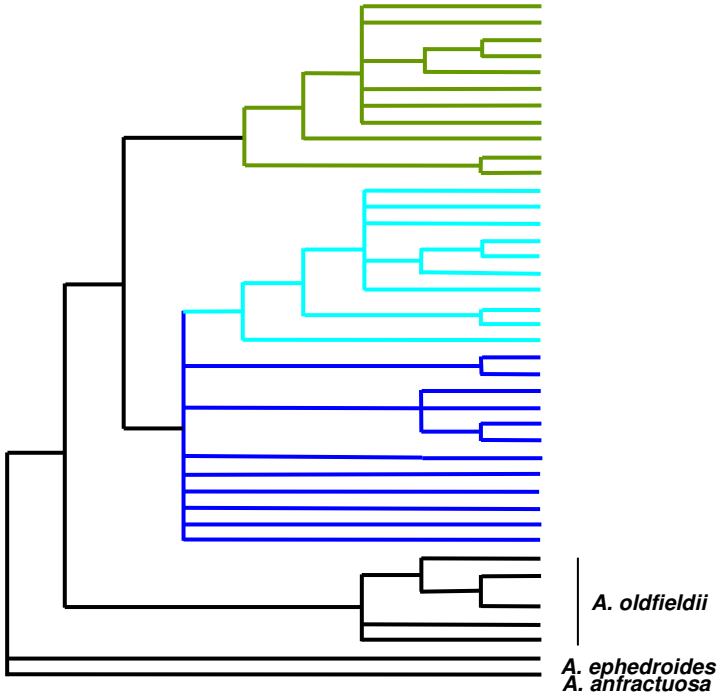
- within lineages highly diverse and localised haplotypes

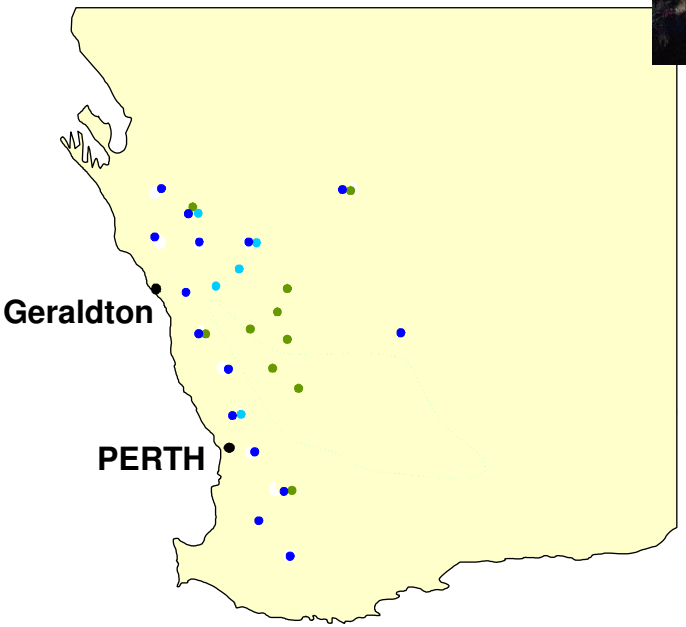
→ multiple localised refugia
persistence and resilience of biota through arid cycles

Species have been around for a long time

No recent colonisation since peak aridity of LGM

Acacia acuminata



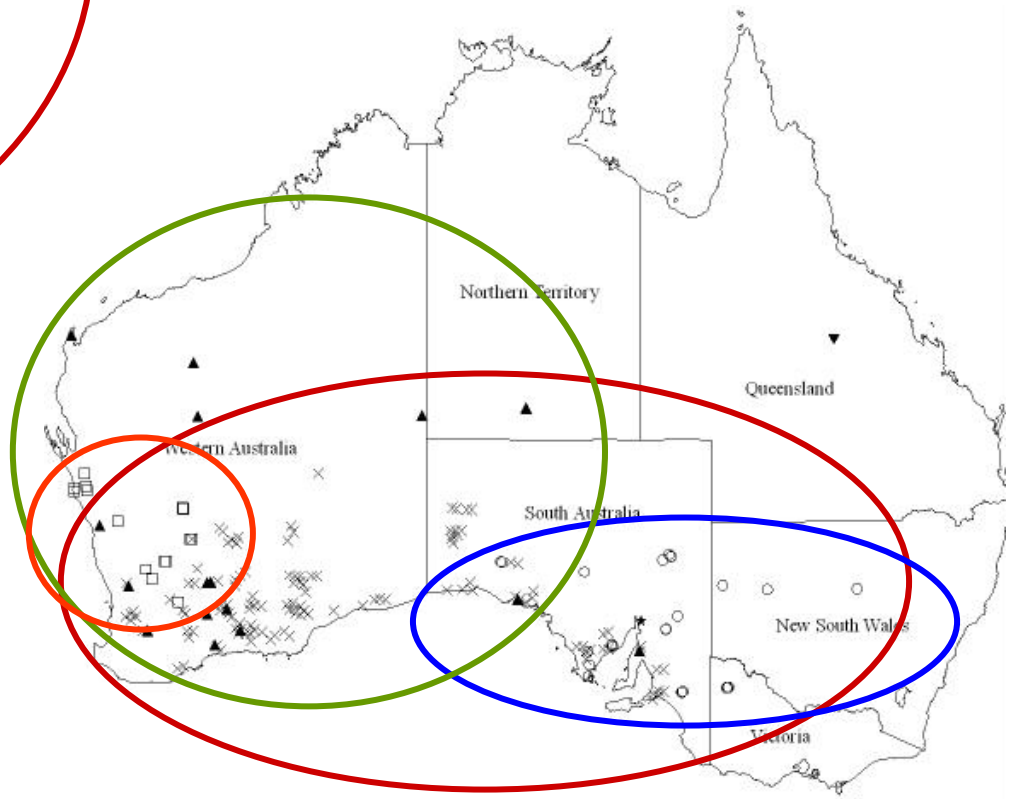


2 lineages, coastal, inland
Coastal - high diversity, structure
Inland - high diversity, structure

Byrne et al. 2002 J Evol Biol 15: 576

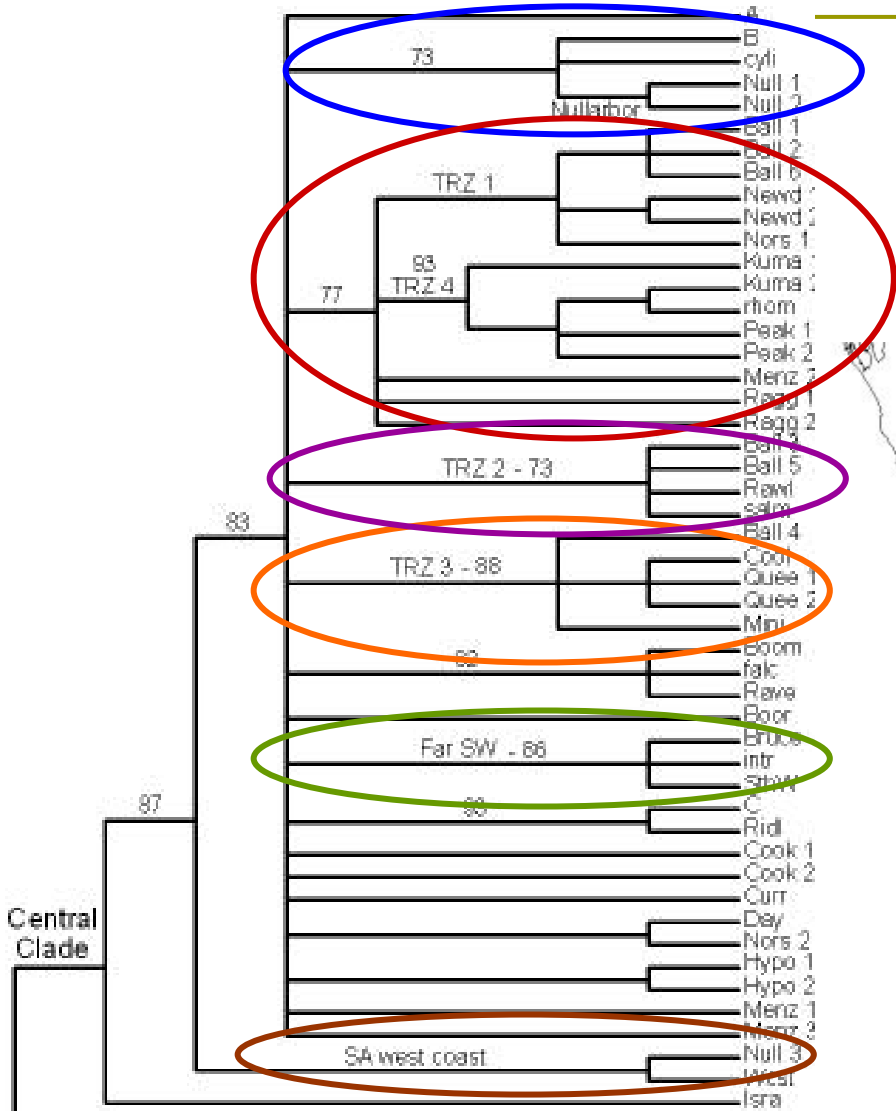
Eucalyptus series subulatae

4 lineages, central, eastern, western, far western
All - high diversity, structure

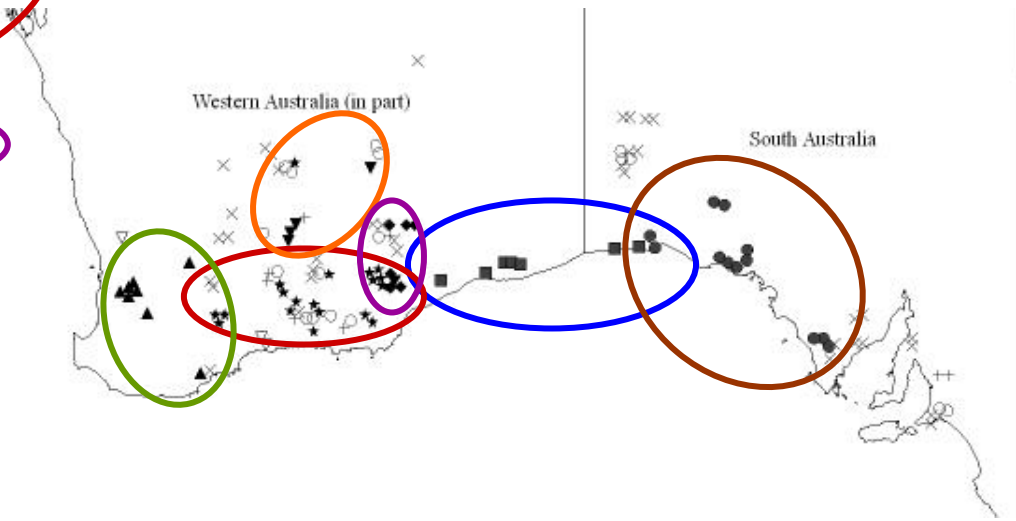


Nicolle 2008 PhD Thesis

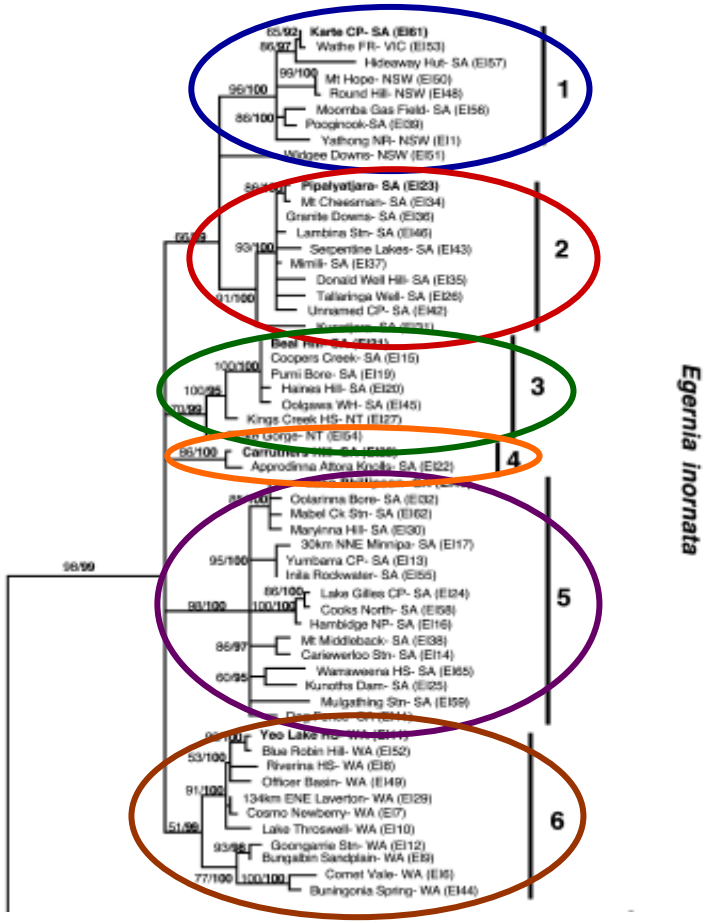
Eucalyptus series *subulatae* central clade

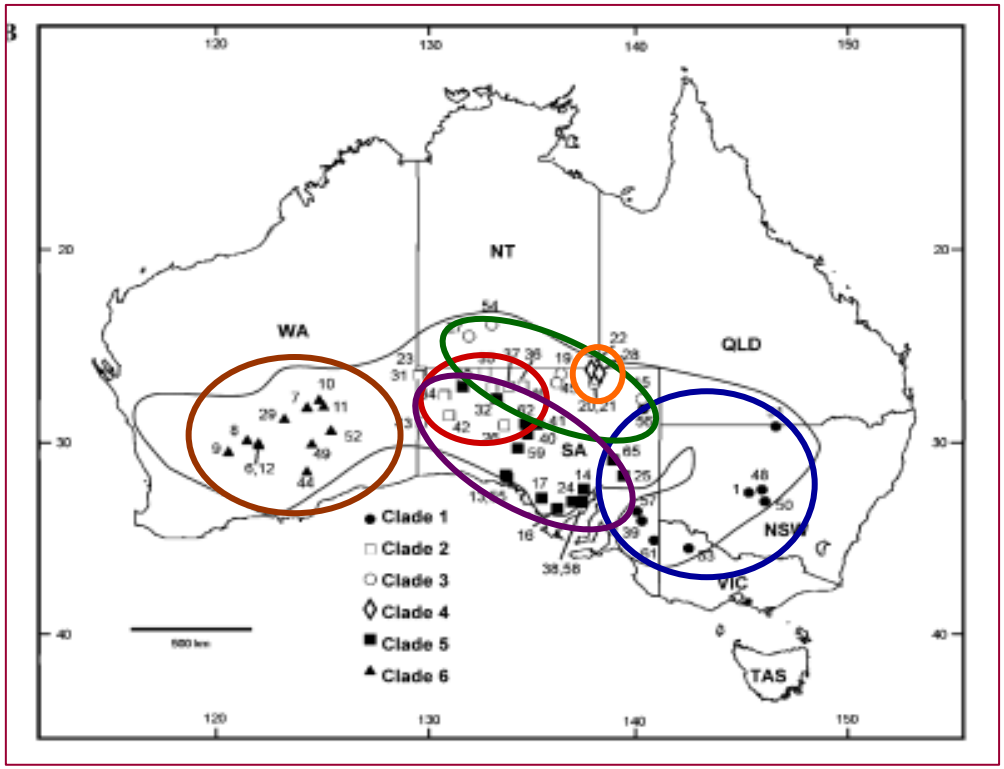


6 main sublineages
Most sublineages – some diversity
SA- low diversity



Skink





6 lineages including 3 in central Australia
High diversity, structure within lineages

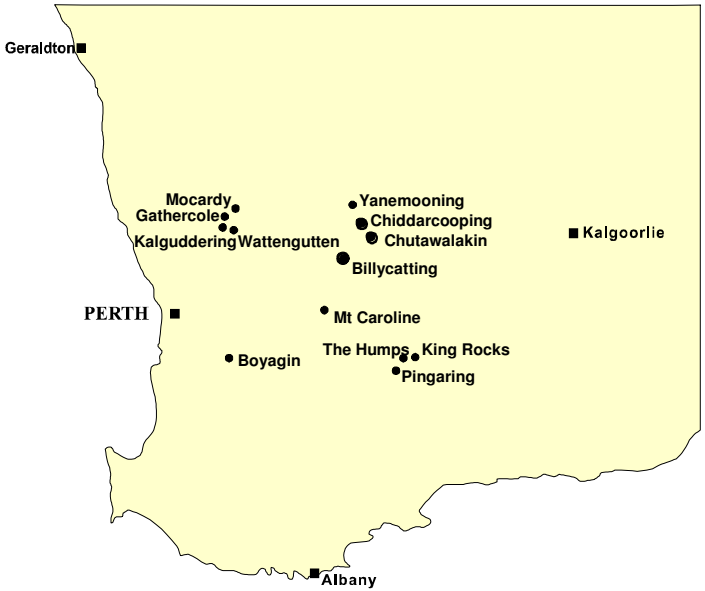
Egernia inornata
Chapple et al. 2004 Mol Phy Evol 33: 549

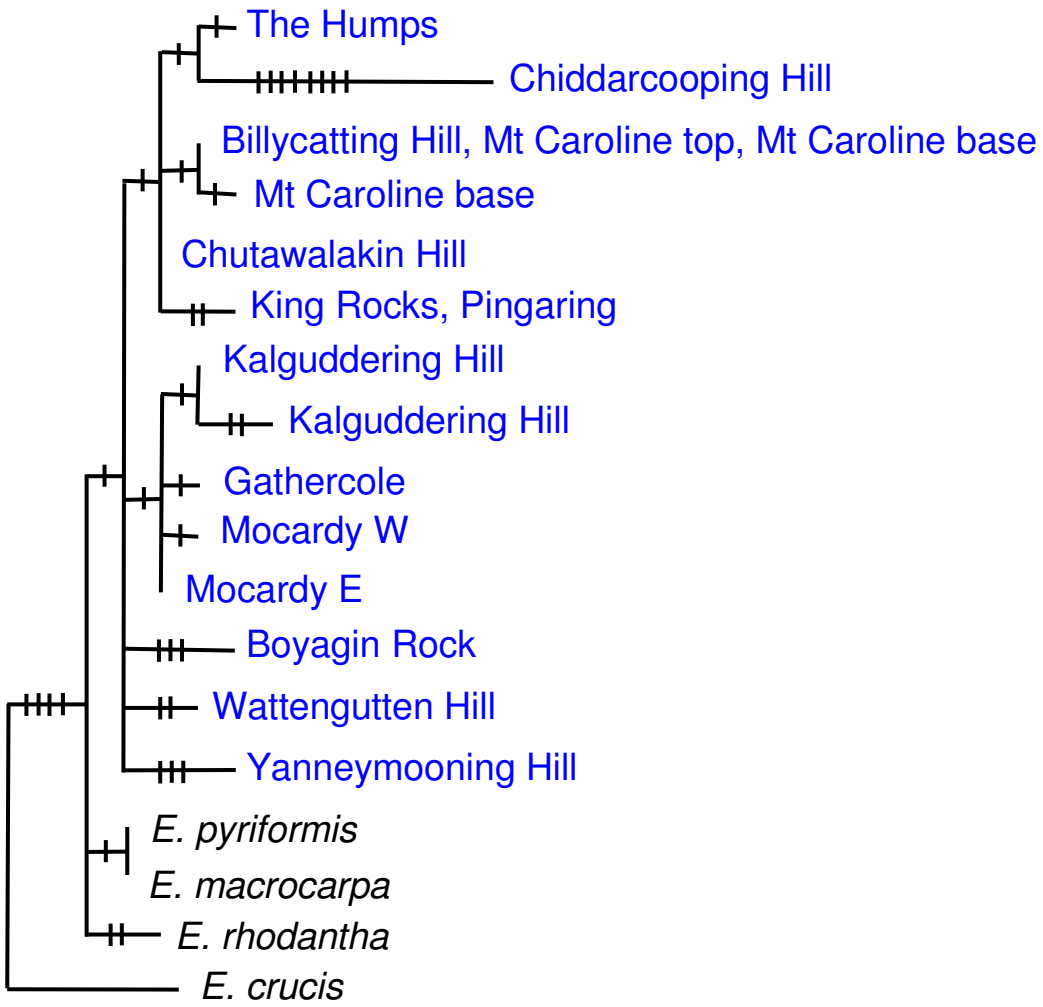
Specialised habitats

Granite outcrops

Mound springs

Eucalyptus caesia





Byrne & Hopper 2008 Biol J Linn Soc 93: 177

Hydrobiid snails

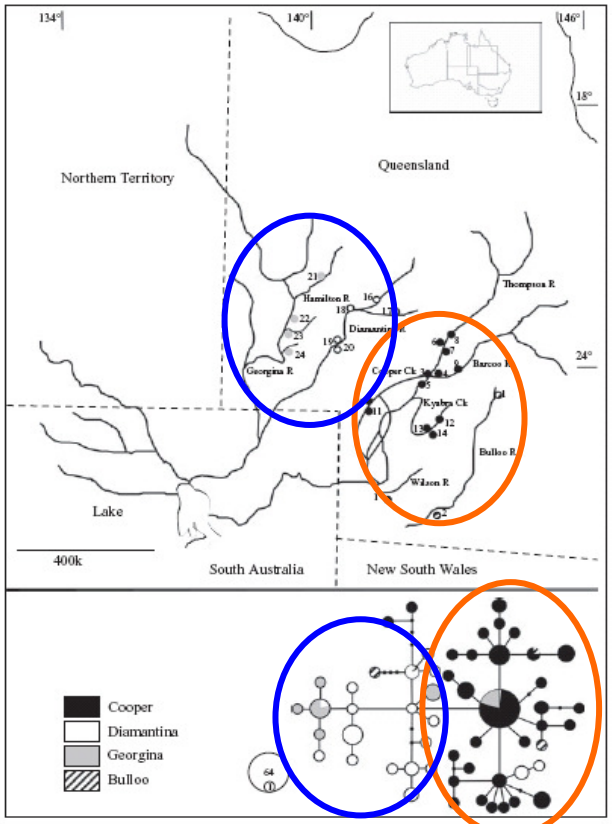


Figure 1. Map of the north-eastern section of the Lake Eyre Basin, illustrating the four major catchments: Bulloo, Cooper, Diamantina and Georgina. A total of 24 waterholes, indicated by circles, were sampled from these catchments. The shading of the circles represents different catchments as shown in the genealogy network. Bulloo catchment: 1, Quilpie. 2, Thargomondah. Cooper catchment: 3, Murken. 4, Currareva. 5, Shedh. 6, Top. 7, Pelican. 8, Waterloo. 9, Retreat. 10, Tanbar. 11, Yalungah. 12, Homestead. 13, One Mile. 14, Warranee. 15, Noccundra. Diamantina catchment: 16, Wockingham. 17, Combo. 18, Fish. 19, Stock route. 20, Middle. Georgina catchment: 21, Bulla Bulla. 22, Four Mile. 23, King. 24, Cuttaburra. The genealogy network shows catchment distributions for each haplotype; the circle size of each haplotype is

Carini & Hughes 2006 Biol J Linn Soc 88: 1

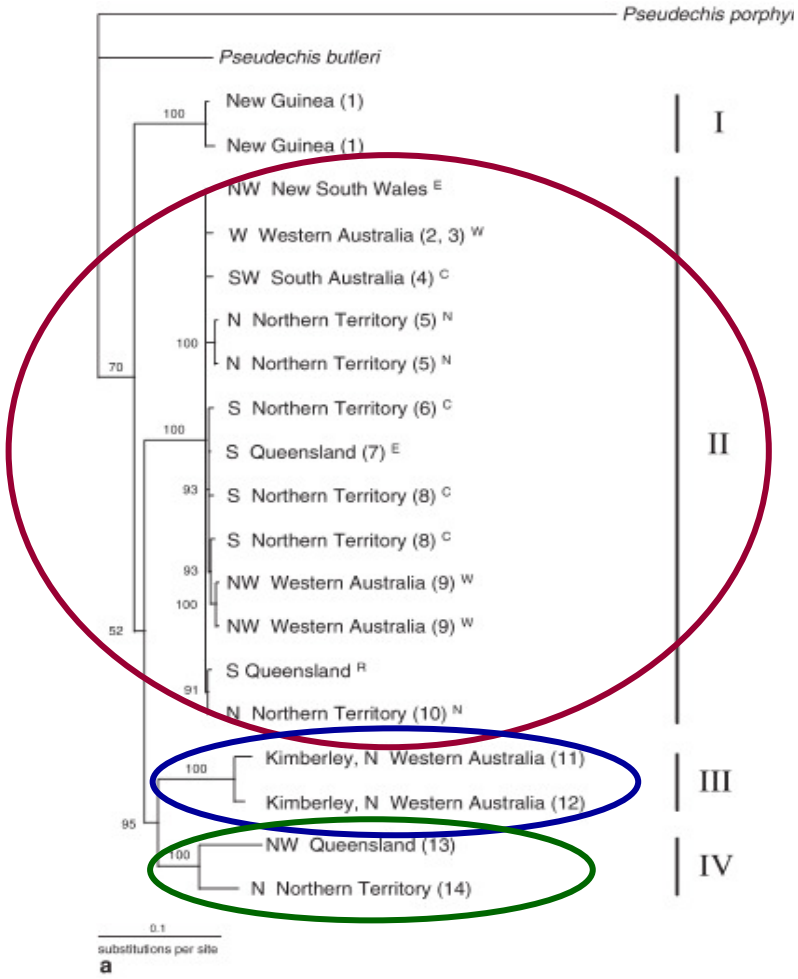
Other phylogeographic pattern

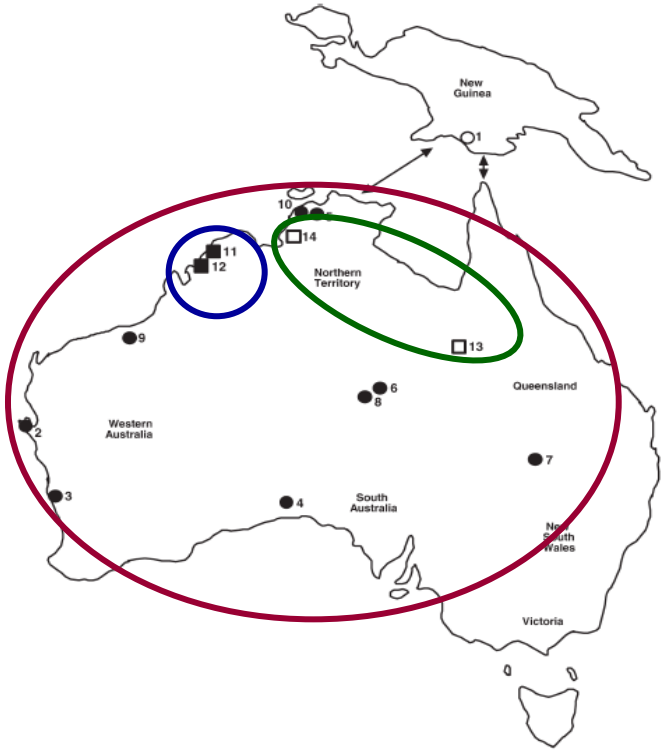
other pattern – highly mobile animals eg. birds, snake

- low diversity
- common haplotype(s) across large areas

→ recent large scale expansion and colonisation

King Brown Snake

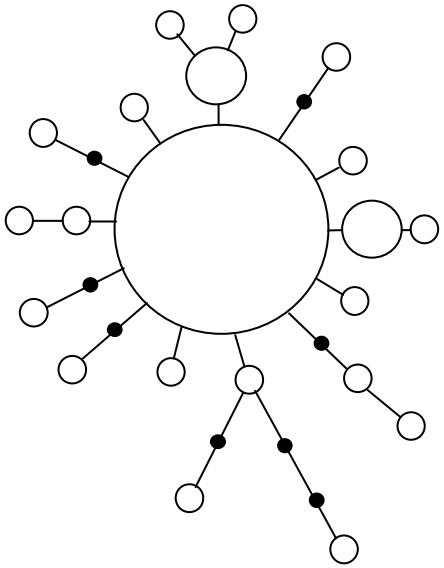




3 lineages, 2 restricted, one extensive (central)
Central lineage, low diversity little structure

Pseudechis australis
Kuch et al. 2005 Naturwissenschaften 93: 121

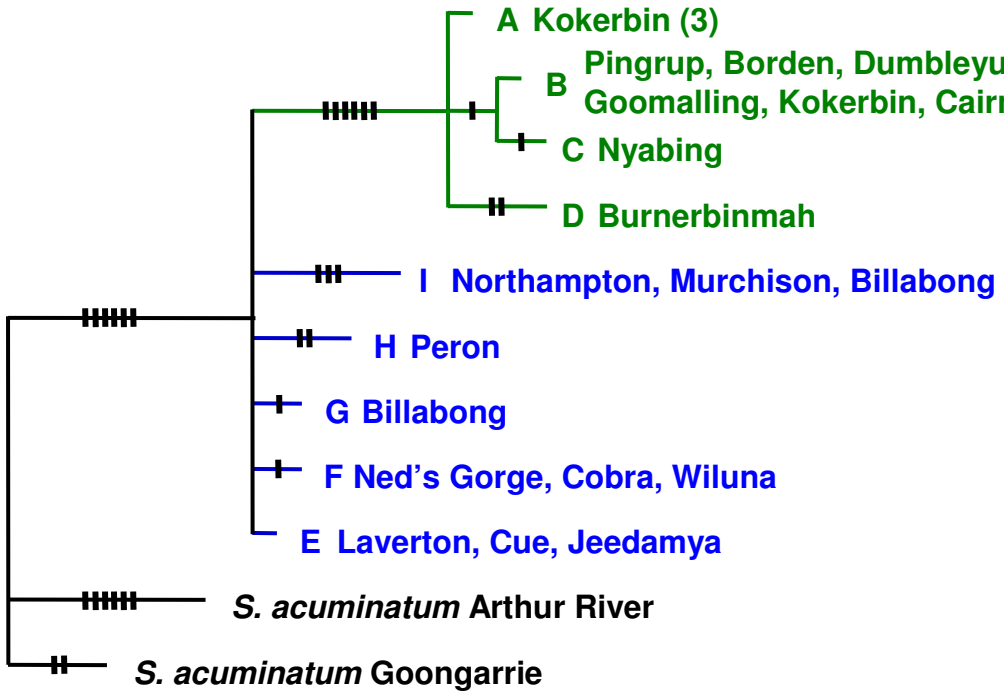
Spiny cheeked honeyeater

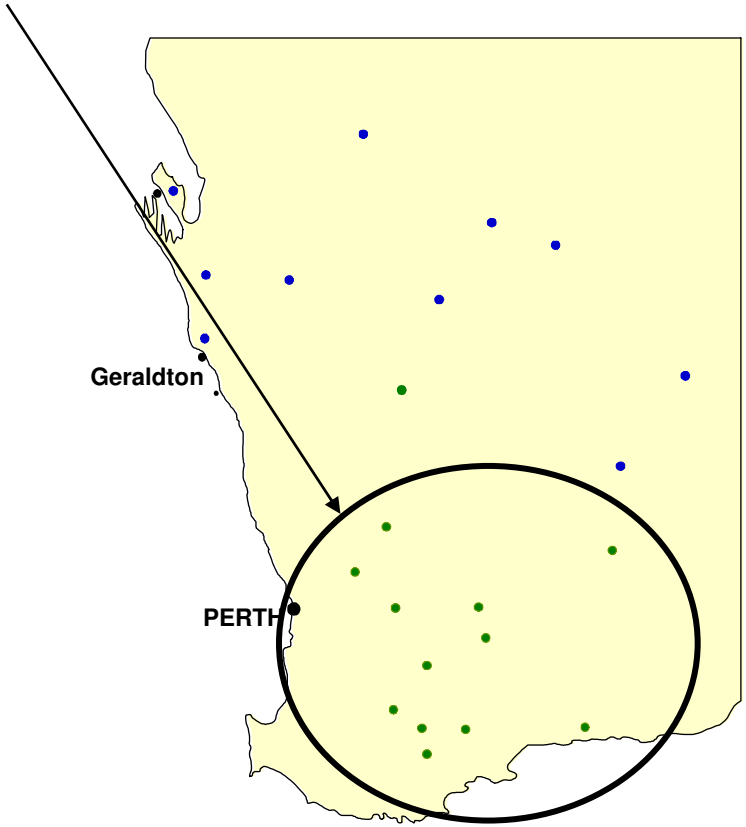


Little structure
Common haplotype occurs across Australia

Acanthogenys rufogularis
Joseph & Wilke, 2007 J Biogeo 34: 612-624

Santalum spicatum





Widespread haplotype in southern lineage – recent expansion

Byrne et al. 2003 Heredity 91: 389

Australian Phylogeography

Predominant pattern is persistence in micro refugia through the late Pleistocene – plants and animals

- highly diverse but localised haplotype distributions
- little signature of recent expansion

Exceptions –

birds (6 species),

King Brown Snake

- recent expansion

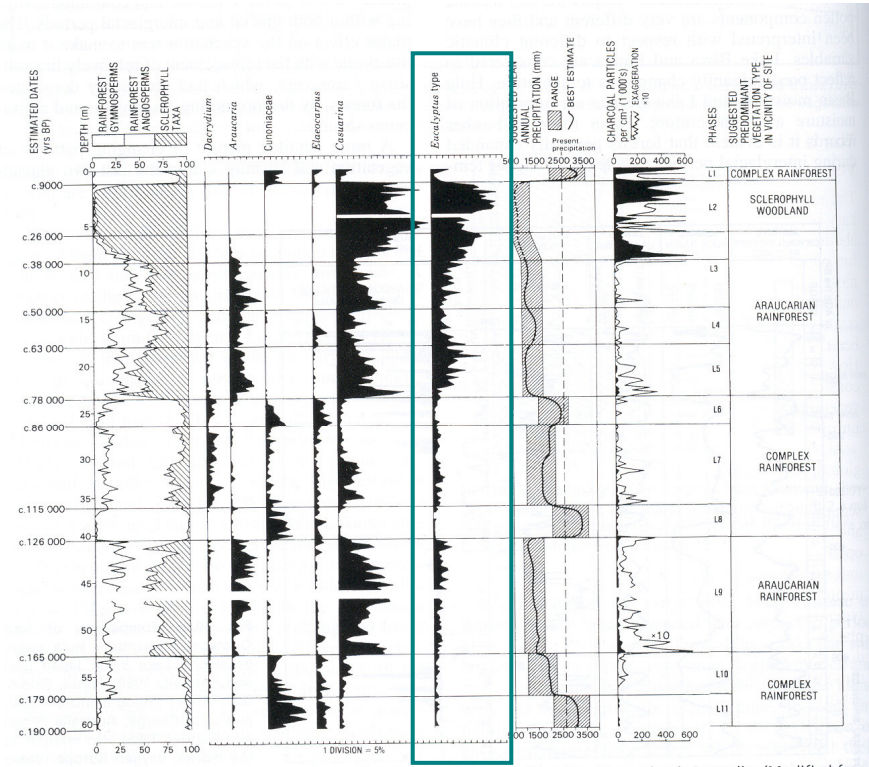


Fig. 10.27 Major features of the pollen diagram from Lynch's Crater, northeastern Queensland, Australia. (Modified from Kershaw 1986)

Phylogenetic diversity

- Historical context – understanding the impacts of historical factors on species distributions
- Identification of common patterns and evolutionary lineages
- Phylogenetic diversity – lineage richness (similar concept to species richness)
- Identification of relictual species
- Identification of evolutionary significant units / management units – at species and community level
- Genetic component of biodiversity value for priority setting

Management implications

- Landscape scale management – preservation of genetic diversity to maintain evolutionary potential of species
- Identification of evolutionary significant communities for reserve design and management
- Identification and protection of refugia
- Climate change adaptation – major range change vs persistence
- Germplasm collection strategies
- Recovery and translocation of threatened taxa
- Planning habitat restoration (provenance variation)
- Commercial utilisation of local native species

Acknowledgements

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Dr Michael Kearney	University of Melbourne	Animal phylogeography
Dr Scott Keogh	Australian National University	Vertebrate phylogeography
Dr Remko Leys	South Australian Museum	Invertebrate phylogeny
Dr Jane Melville	Museum of Victoria	Reptile phylogeography
Dr Dan Murphy	University of Melbourne	Acacia phylogeny
Dr Nic Porch	Monash University	Palaeontology
Dr Martin Williams	University of Adelaide	Quaternary geomorphology
Dr Karl-Heinz Wyrwoll	The University of WA	Palaeoenvironments
Dr David Yeates	CSIRO Entomology	Invertebrate systematics

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