Tuart, Redheart (E decipiens), Fremantle Mallee (E foecunda) Spidernet Grevillea and Parrot Bush (B sessilis)

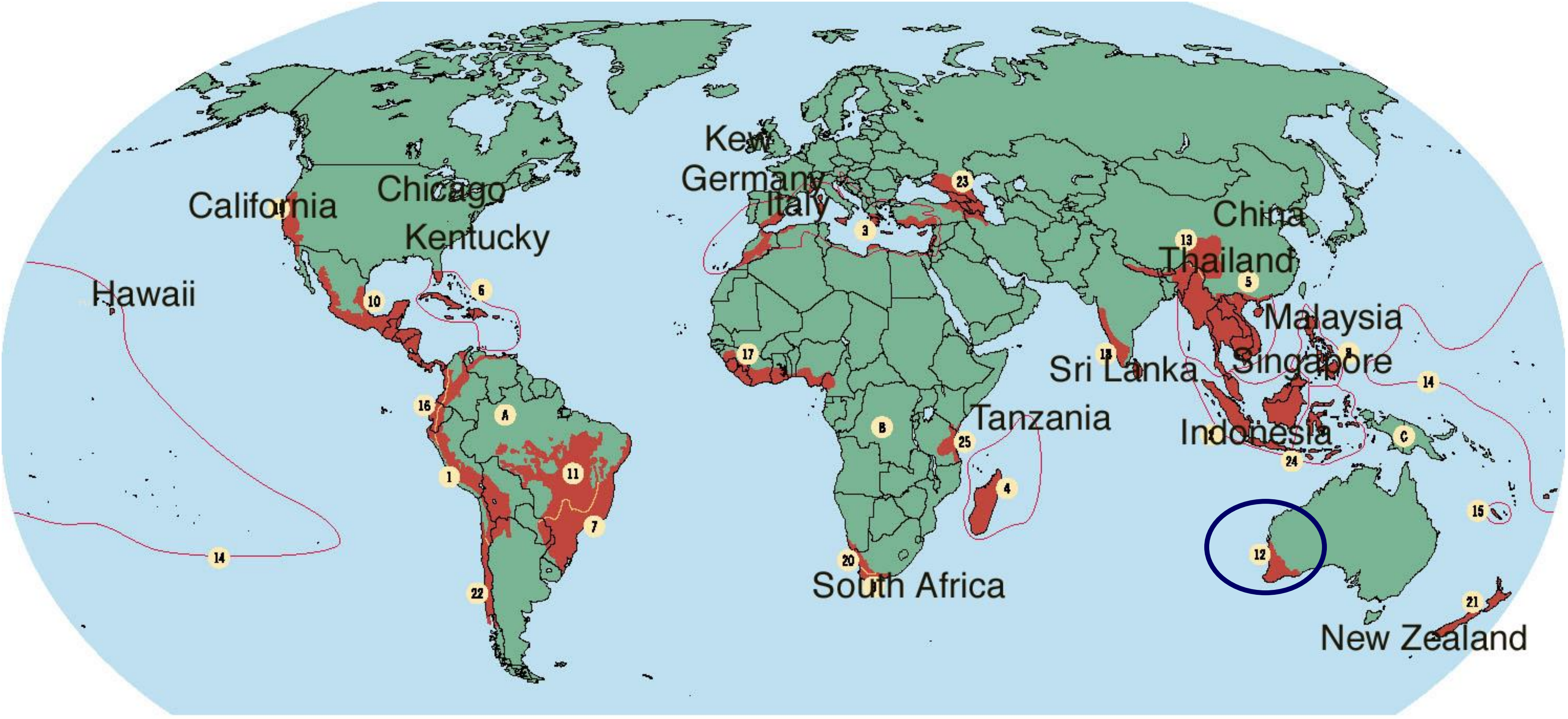
Hans Lambers

School of Biological Sciences

University of Western Australia

Eucalyptus decipi
Photo: Hans Lam

SW Australia is a global biodiversity hotspot: one of only 25 (36) in the entire world

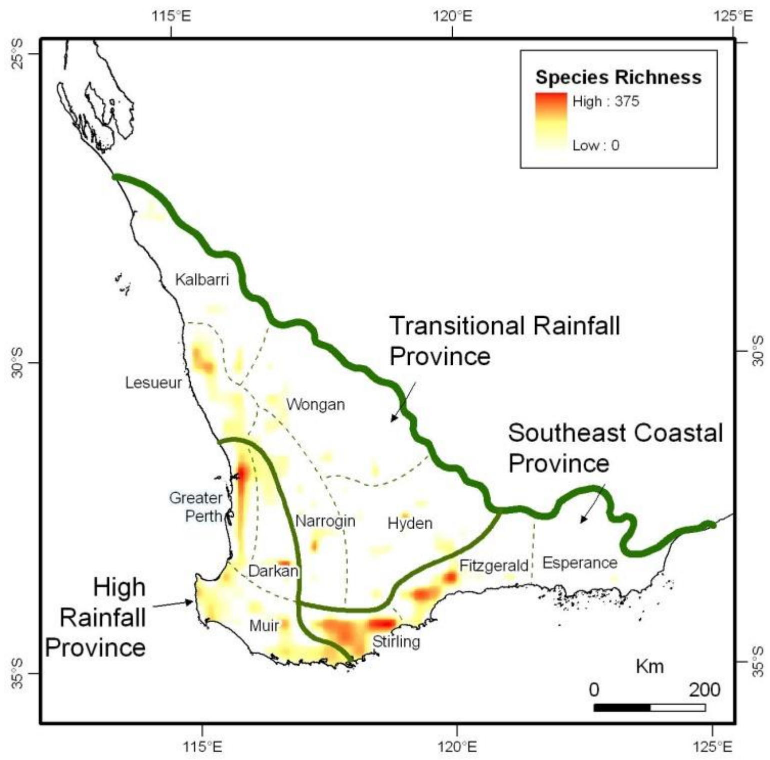


BIODIVERSITY HOTSPOTS

1 Tropical Andes
2 Sundaland
3 Mediterranean Basin
4 Madagascar & Indian Ocean Islands
5 Indo-Burma
6 Caribbean
7 Atlantic Forest Region
8 Philippines
9 Cape Floristic Region
10 Mesoamerica
11 Brazilian Cerrado
12 Southwest Australia
13 Mountains of Southwest China
14 Polynesia/Micronesia
15 New Caledonia
16 Chocó-Darién-Western Ecuador
17 Guinean Forests of West Africa
18 Western Ghats & Sri Lanka
19 California Floristic Province
20 Succulent Karoo
21 New Zealand
22 Central Chile
23 Caucasus
24 Wallacea
25 Eastern Arc Mountains & Coastal Forests of Tanzania & Kenya

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J. 2000. Biodiversity hotspots for conservation priorities. *Nature* **403:** 853-858.

‘Isoflors’ for biodiversity of the southwest of WA, home for 8,000 plant species (a third of Australia’s flora)



Hopper SD, Gioia P. 2004. The Southwest Australian Floristic Region: evolution and conservation of a global hotspot of biodiversity. *Annu. Rev. Ecol. Evol. Syst.* **35:** 623-650.

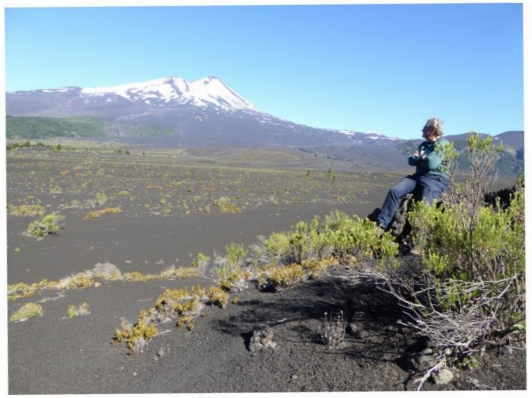
Perth is one of the most biodiverse cities in the world, and possibly even the most plant-diverse

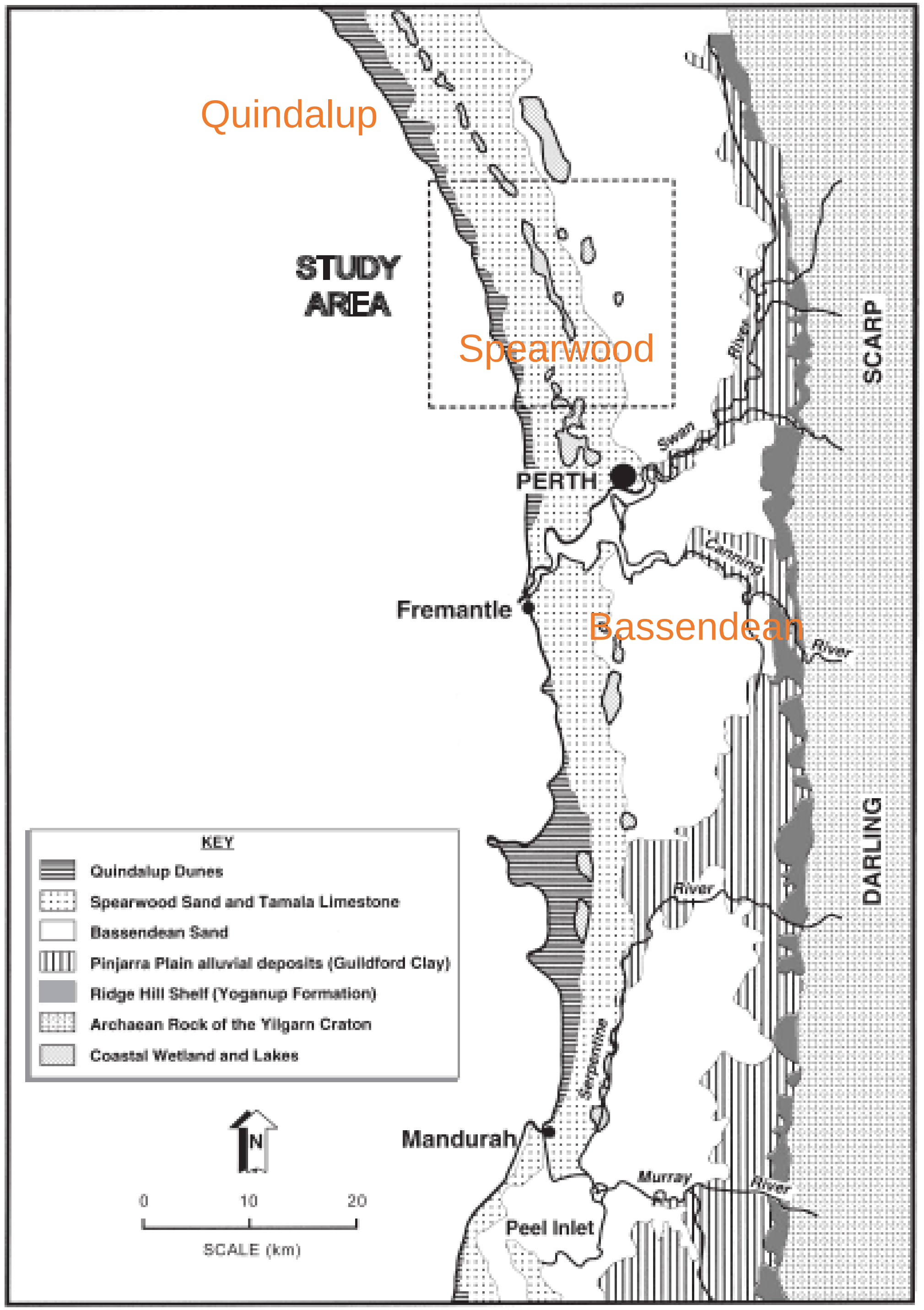
- This is accounted for by a wide range of ancient and contrasting habitats, including Manning Park
- This special feature is something to be treasured, rather than trashed

Photo: Hans Lambers

Factors determining plant species richness

- Geological stability: variation in **habitats**
- Climatic stability: no mass **extinctions**
- Soil infertility: **phosphorus**

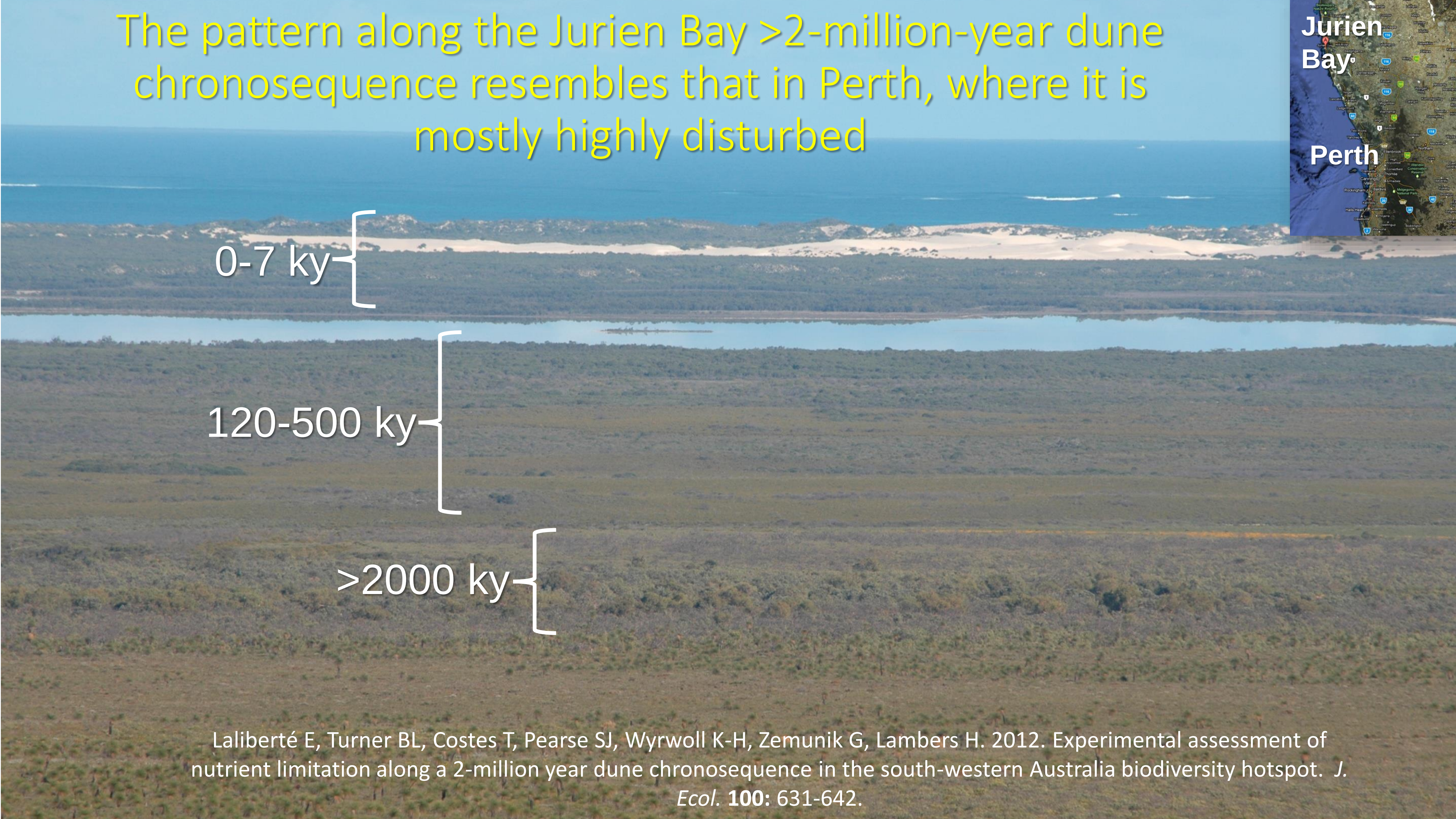



Perth is situated on the Swan Coastal Plain, a series of three dune systems of marine origin

Manning Park is situated on Spearwood dunes

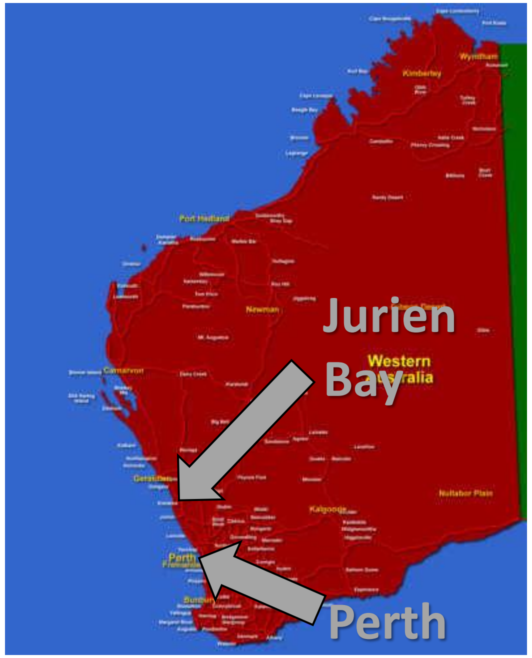
Tapsell P, Newsome D, Bastian L 2003. Origin of yellow sand from Tamala Limestone on the Swan Coastal Plain, Western Australia. *Aust. J. Earth Sci.* **50:** 331 - 342

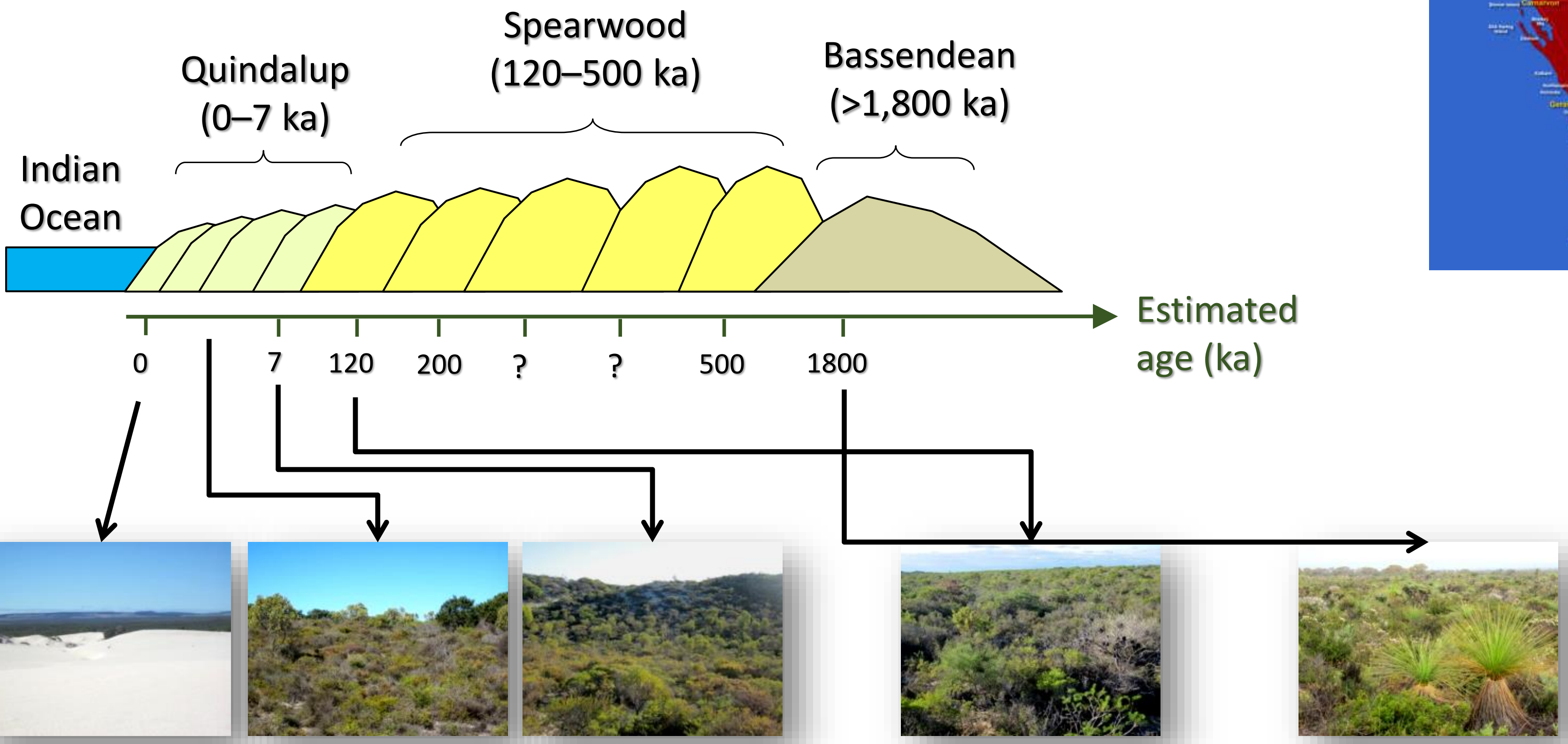
The pattern along the Jurien Bay >2-million-year dune chronosequence resembles that in Perth, where it is mostly highly disturbed



Laliberté E, Turner BL, Costes T, Pearse SJ, Wyrwoll K-H, Zemunik G, Lambers H. 2012. Experimental assessment of nutrient limitation along a 2-million year dune chronosequence in the south-western Australia biodiversity hotspot. *J. Ecol.* **100:** 631-642.

We work on the Jurien Bay and Green Head dunes on the Swan Coastal Plain, increasing in age from west to east





Stage 1
Mobile dunes
0 ka

Stage 2
Quindalup
1 ka

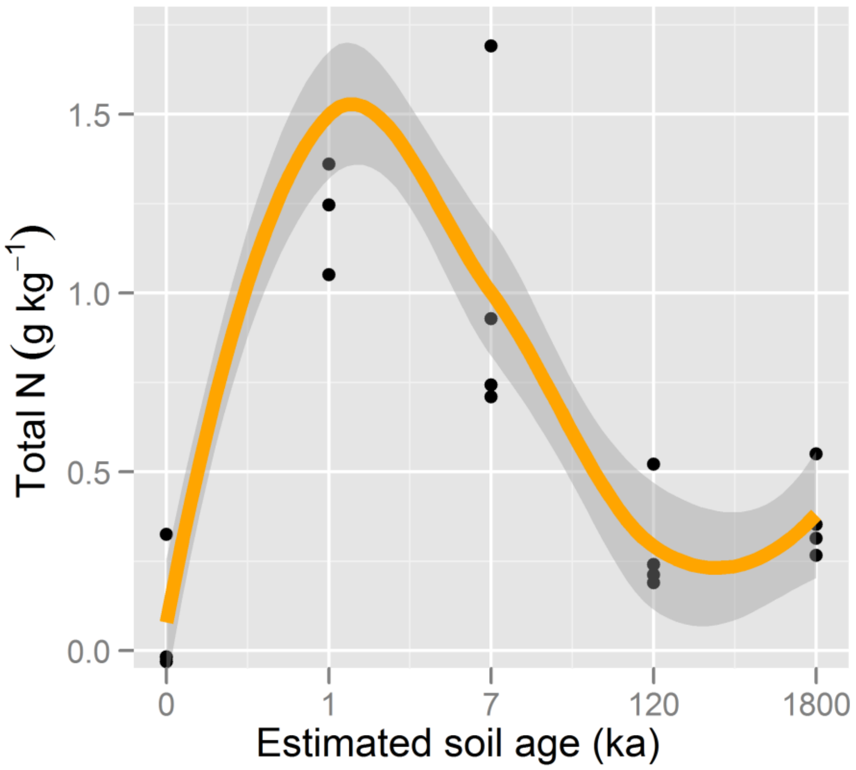
Stage 3
Quindalup
7 ka

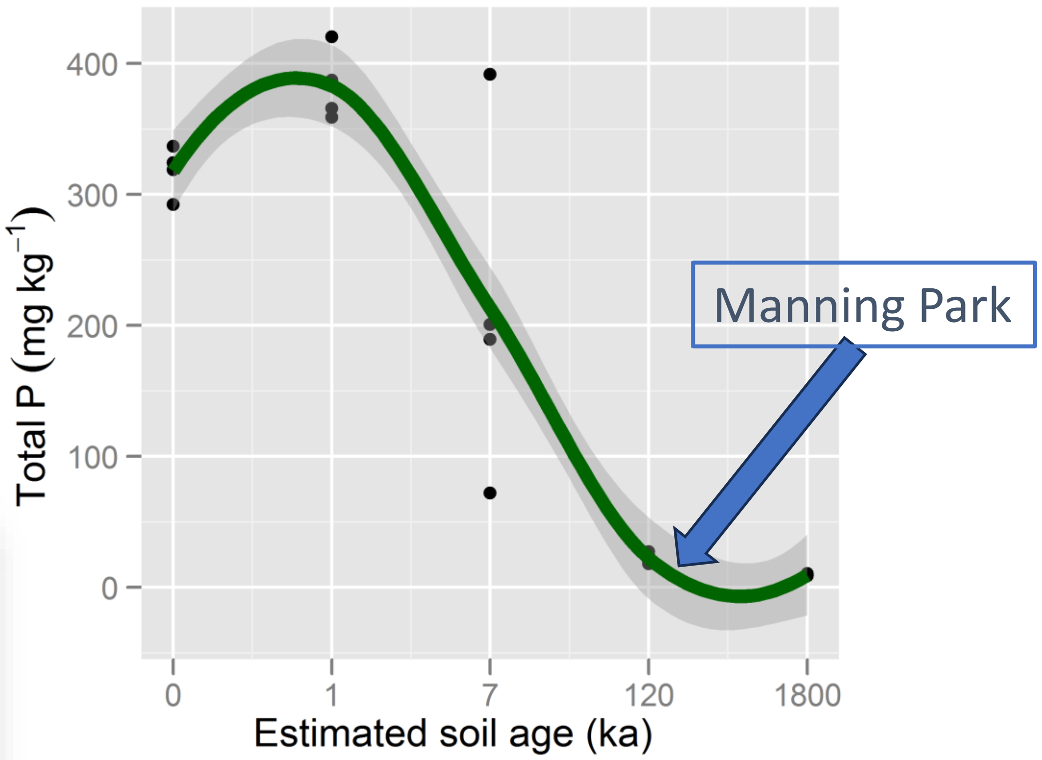
Stage 4
Spearwood
120 ka

Stage 5
Bassendean
1800 ka

Laliberté, E *et al.* 2012. *J. Ecol.* **100:** 631-642

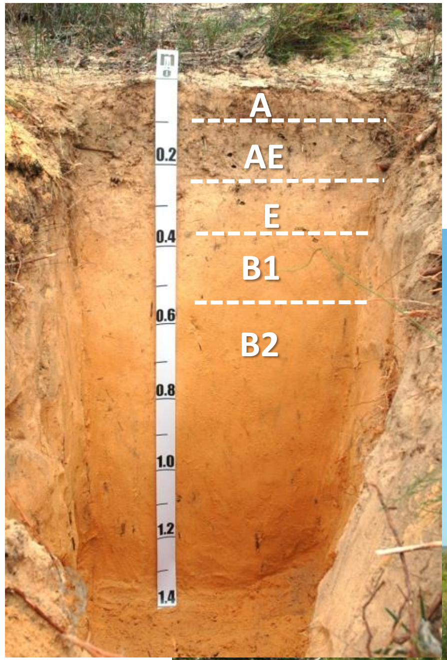
Pattern: nitrogen (N) limits plant growth on very young dunes; phosphorus (P) does on older ones



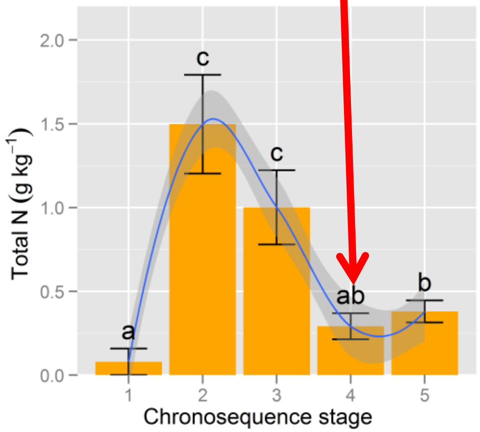


Laliberté E, Turner BL, Costes T, Pearse SJ, Wyrwoll, K-H, Zemunik G, Lambers H. 2012. Experimental assessment of nutrient limitation along a 2-million year dune chronosequence in the south-western Australia biodiversity hotspot. *J. Ecol.* **100:** 631-642.

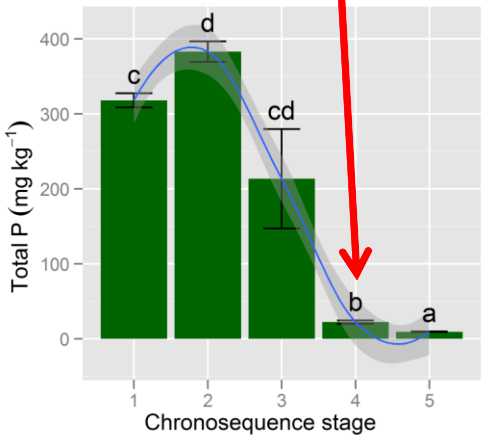
Stage 4: old dunes (~120,000 years)



Low N

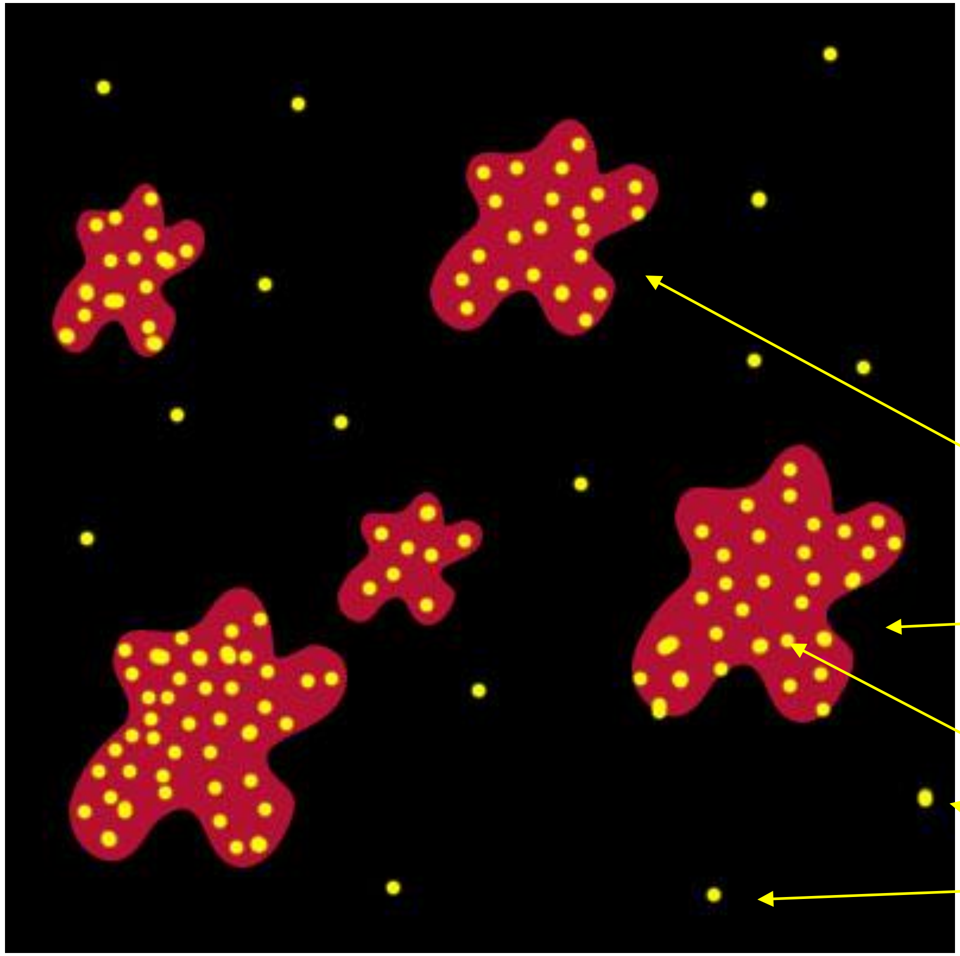


Very low P



Laliberté *et al.* 2012. *J .Ecol.* **100:** 631-642.

Soil looks a *bit* like this – with only a few phosphorus ions in solution



The "measles" are meant to represent *ad*sorbed P ions – *i.e.* on the surface

Courtesy: Dr Jim Barrow

Proteaceae, especially *Banksia* species, are very good at taking up phosphorus from severely phosphorus-impoverished soils

- They produce cluster roots
- Cluster roots release massive amounts of carboxylates
- Carboxylates mobilise phosphorus
- *Banksia sessilis* (parrot bush) can even acquire phosphorus from limestone and laterite

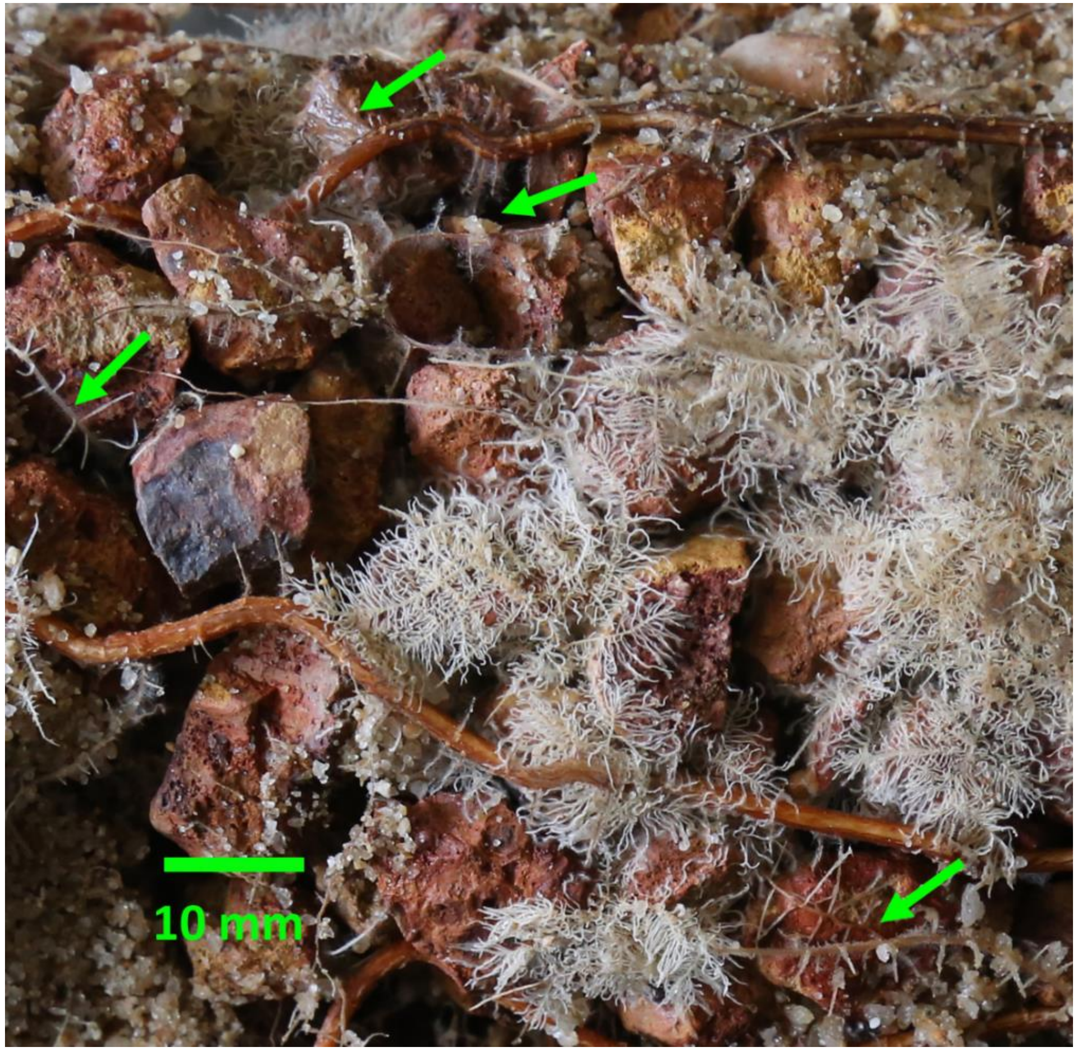
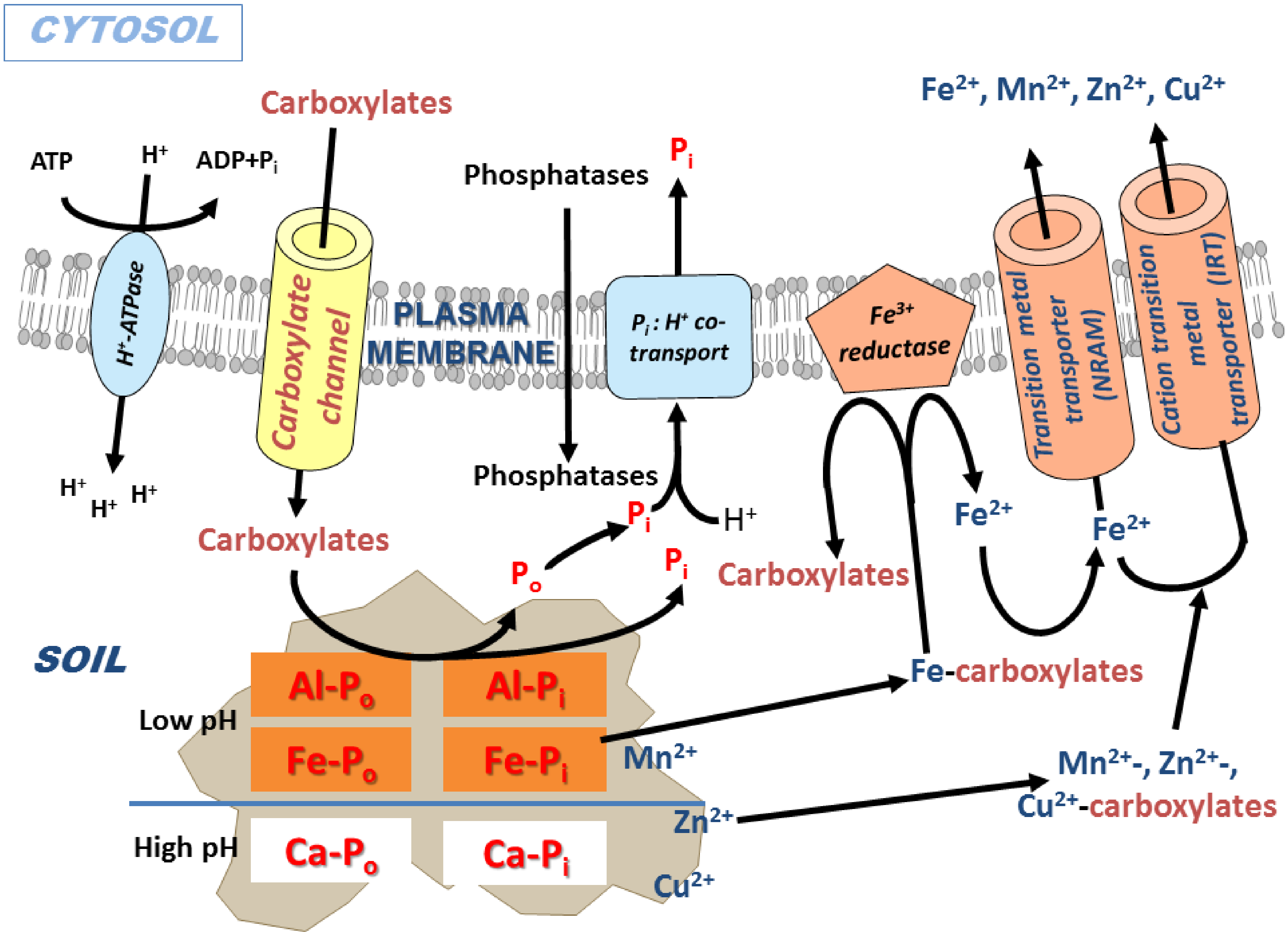


Photo: Jianmin Shi

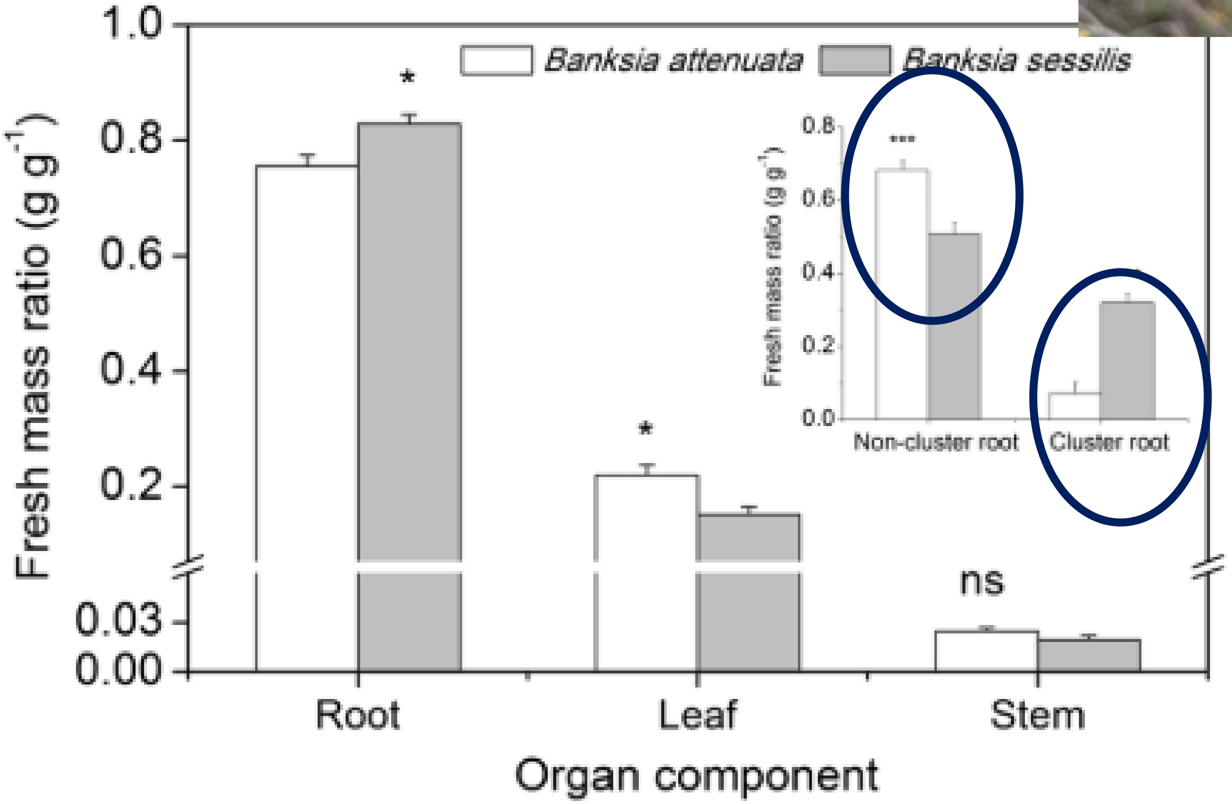
Shi, J., Strack, D., Albornoz, F., Han, Z., & Lambers, H. (2020). Differences in investment and functioning of cluster roots account for different distributions between *Banksia attenuata and B. sessilis, with contrasting life history. Plant Soil* **447:** 85–98.



Lambers, H., Hayes, P.E., Laliberté, E., Oliveira, R.S., Turner, B.L. 2014. Leaf manganese accumulation and phosphorus-acquisition efficiency. *Trends Plant Sci*. **20**: 83-90.

Spearwood sands and limestones are severely nutrient impoverished, and particularly low in phosphorus (P), an essential plant nutrient

- *Banksia sessilis* (parrot bush) is particularly good at getting phosphorus from Spearwood soil and limestone
- It produces far more cluster roots than *Banksia attenuata*
- Its cluster roots also release more carboxylates that mobilise phosphorus
- It makes fewer deep roots, and hence we often see many plants succumbing to drought at the end of summer



Shi, J., Strack, D., Albornoz, F., Han, Z., & Lambers, H. (2020). Differences in investment and functioning of cluster roots account for different distributions between *Banksia attenuata and B. sessilis, with contrasting life history. Plant Soil* **447:** 85–98.

Banksia attenuata makes deep roots, so able to survive summer.
B sessilis puts more energy into making cluster roots for phosphorus uptake rather than deep roots.
B sessilis therefore has a wider growing range than B. attenuata but it is less drought tolerant.

Another iconic Proteaceae that makes cluster roots and has a remarkable physiology: *Grevillea preissii*

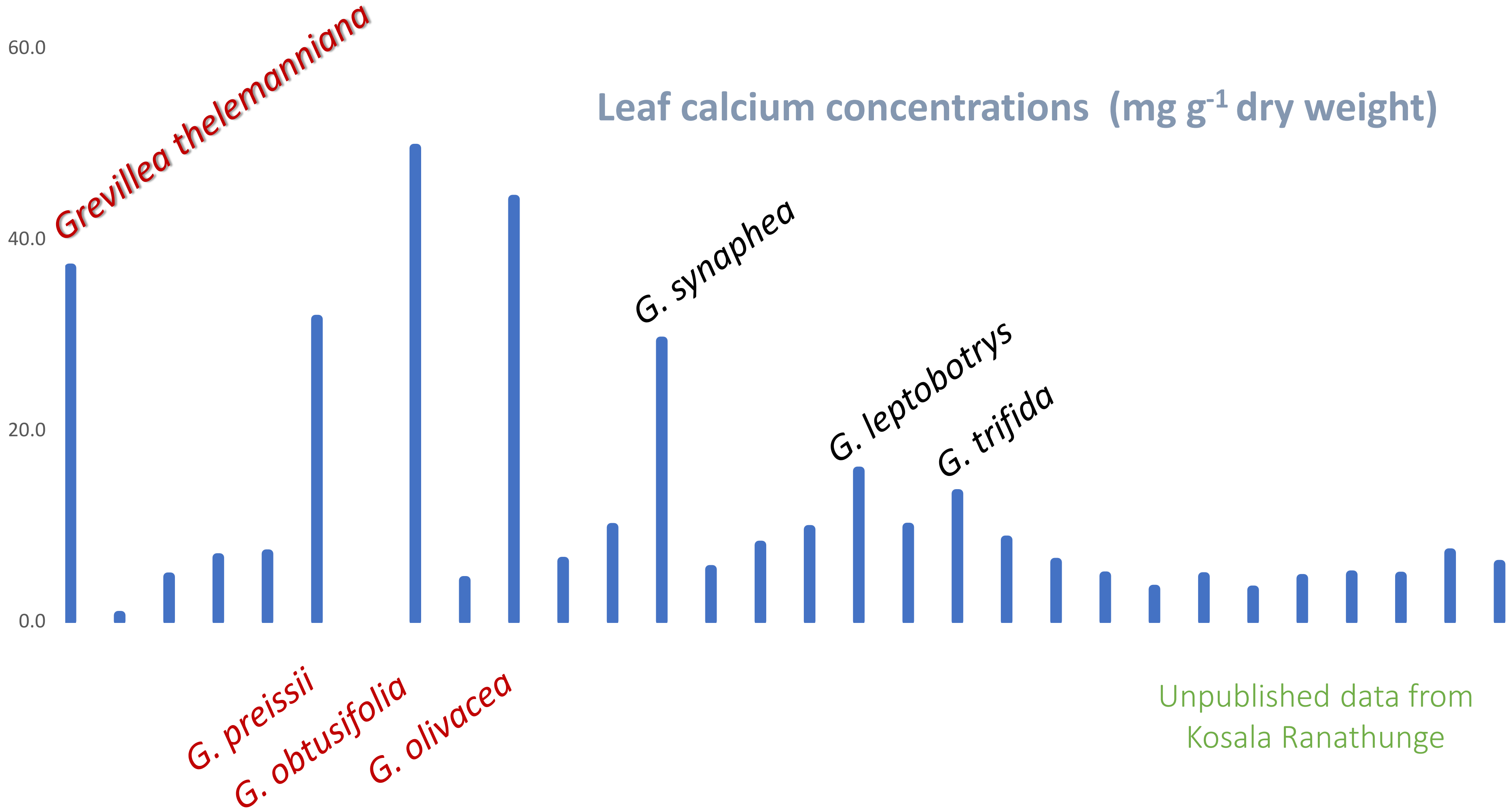
Photos: Hans Lambers

Grevillea preissii belong to the *thelemanniana* group

Johnson and Briggs (1974)	McGillivray (1993) - Group 14	Olde & Marriot (1994) - Group 14	Makinson 2000 - Thelemanniana group
			G. acropogon
	G. thelemanniana ssp. delta	G. delta	G. delta
		G. evanescens	G. evanescens
		G. exposita	G. exposita
	G. thelemanniana ssp. fililoba	G. fililoba	G. fililoba
	G. thelemanniana ssp. hirtella	G. hirtella	G. hirtella
		G. humifusa	G. humifusa
			G. mccutcheonii
G. obtusifolia	G. thelemanniana ssp. obtusifolia	G. obtusifolia	G. obtusifolia
G. olivacea	G. olivacea (Group 21)	G. olivacea	G. olivacea
G. pinaster	G. thelemanniana ssp. pinaster	G. pinaster	G. pinaster
G. preissii	**G. thelemanniana ssp. preissii**	**G. preissii**	**G. preissii**
		G. preissii ssp. preissii	G. preissii ssp. preissii
		G. preissii ssp. glabrilimba	G. preissii ssp. glabrilimba
G. ripicola	G. ripicola	G. ripicola	G. ripicola
G. stenomera	G. stenomera	G. stenomera	G. stenomera
G. thelemanniana	**G. thelemanniana ssp. thelemanniana**	**G. thelemanniana**	**G. thelemanniana**
G. variifolia	G. variifolia	G. variifolia	G. variifolia
			G. variifolia ssp. variifolia
			G. variifolia ssp. bundera

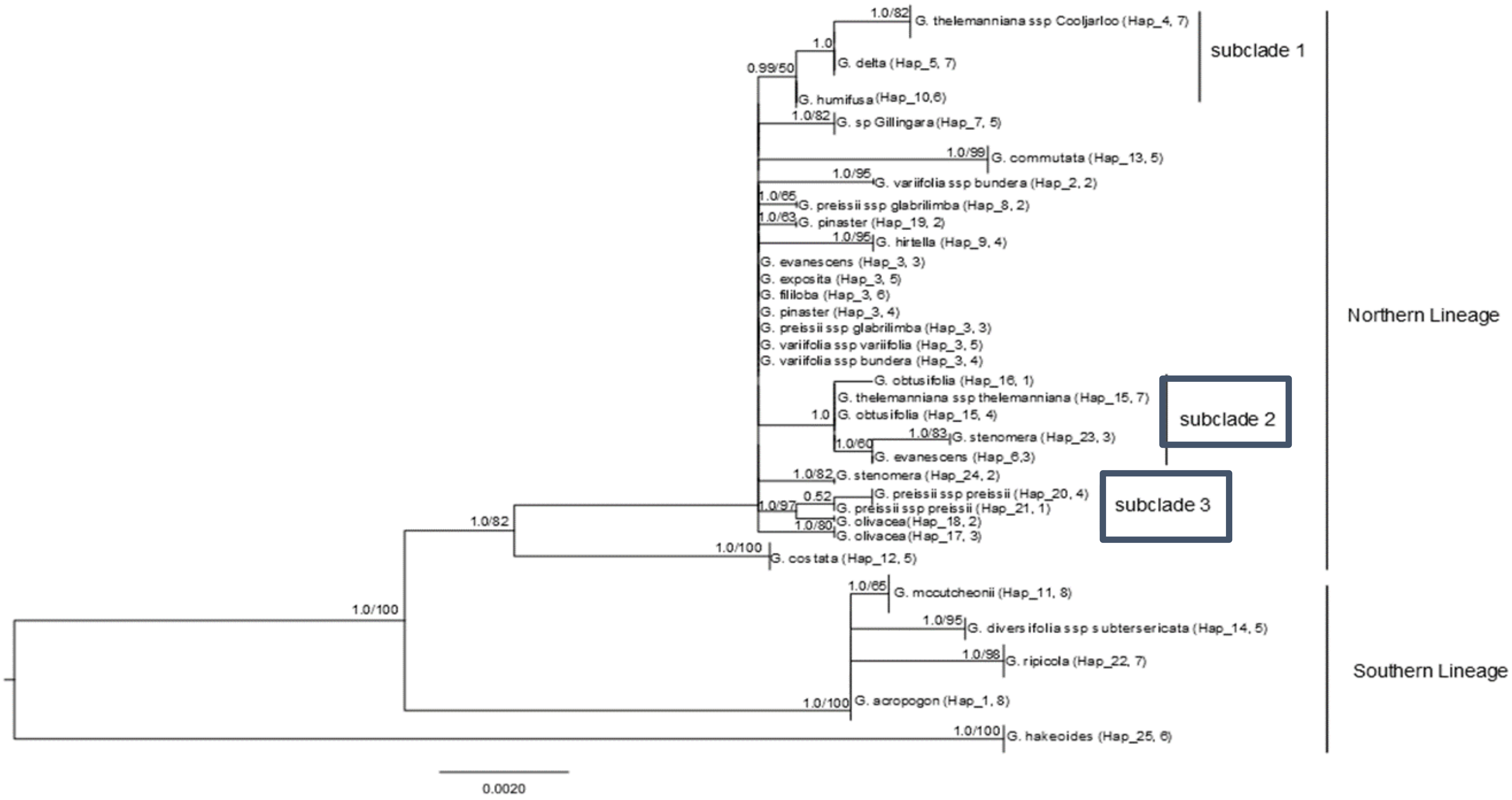
Hevroy TH. 2016. Molecular Phylogeny and Population Genetics of the *Grevillea thelemanniana* Group (Proteaceae). University of Western Australia.

Unlike most Proteaceae, *Grevillea* species belonging to the *thelemanniana* group exhibit high calcium concentrations



Unpublished data from Kosala Ranathunge

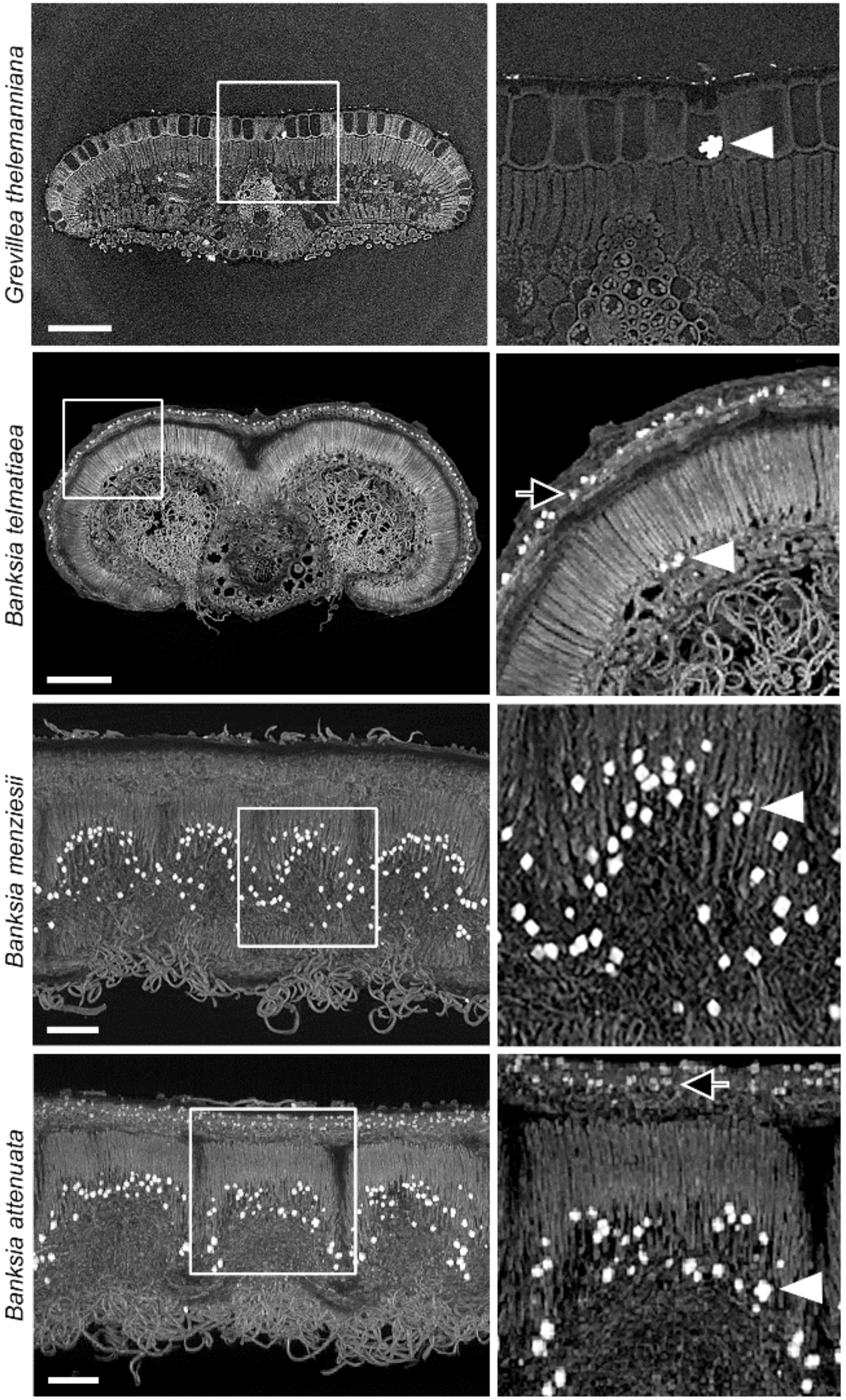
Species in subclades 2 and 3 have high leaf calcium concentrations



Hevroy TH. 2016. Molecular Phylogeny and Population Genetics of the *Grevillea thelemanniana* Group (Proteaceae). University of Western Australia.

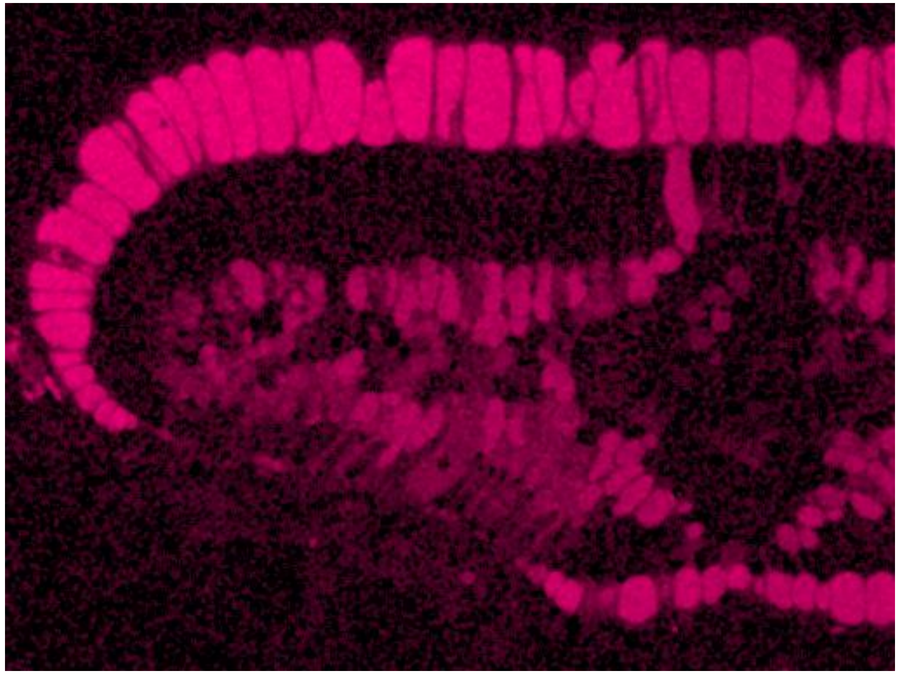
The species with the highest calcium concentration in its leaves produces the least calcium-containing crystals

Photos: Tao Zhong



Gao J, Wang F, Ranathunge K, Arruda AJ, Cawthray GR, Clode PL, He X, Leopold M, Roessner U, Rupasinghe T, Zhong H & Lambers H. 2020. Edaphic niche characterization of four Proteaceae reveals unique calcicole physiology linked to hyper-endemism of *Grevillea thelemanniana*. *New Phytol* **228:** 869-883.

Calcium in leaves of Proteaceae



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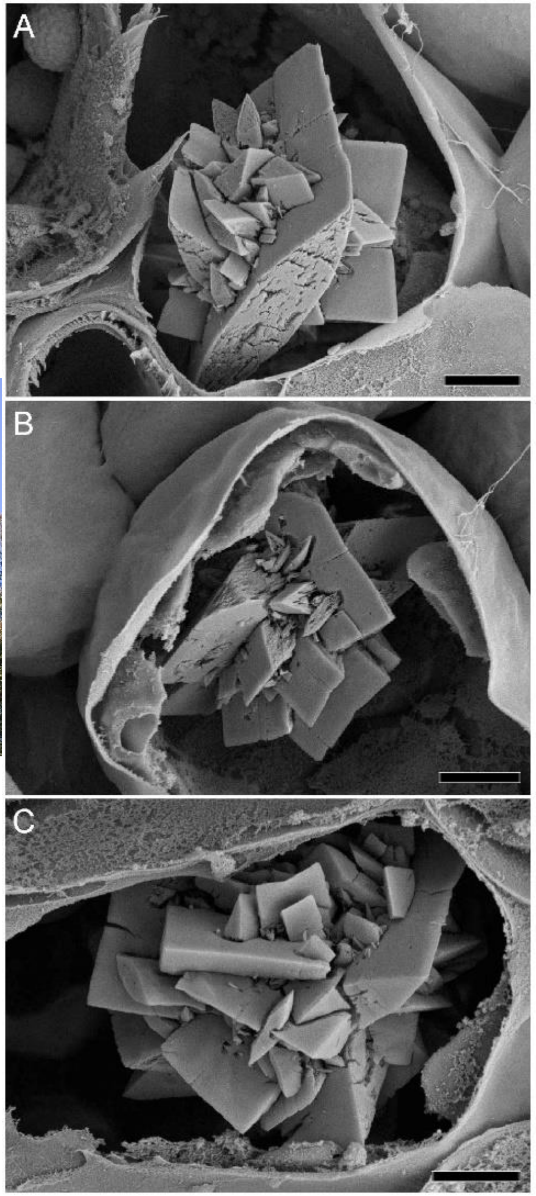
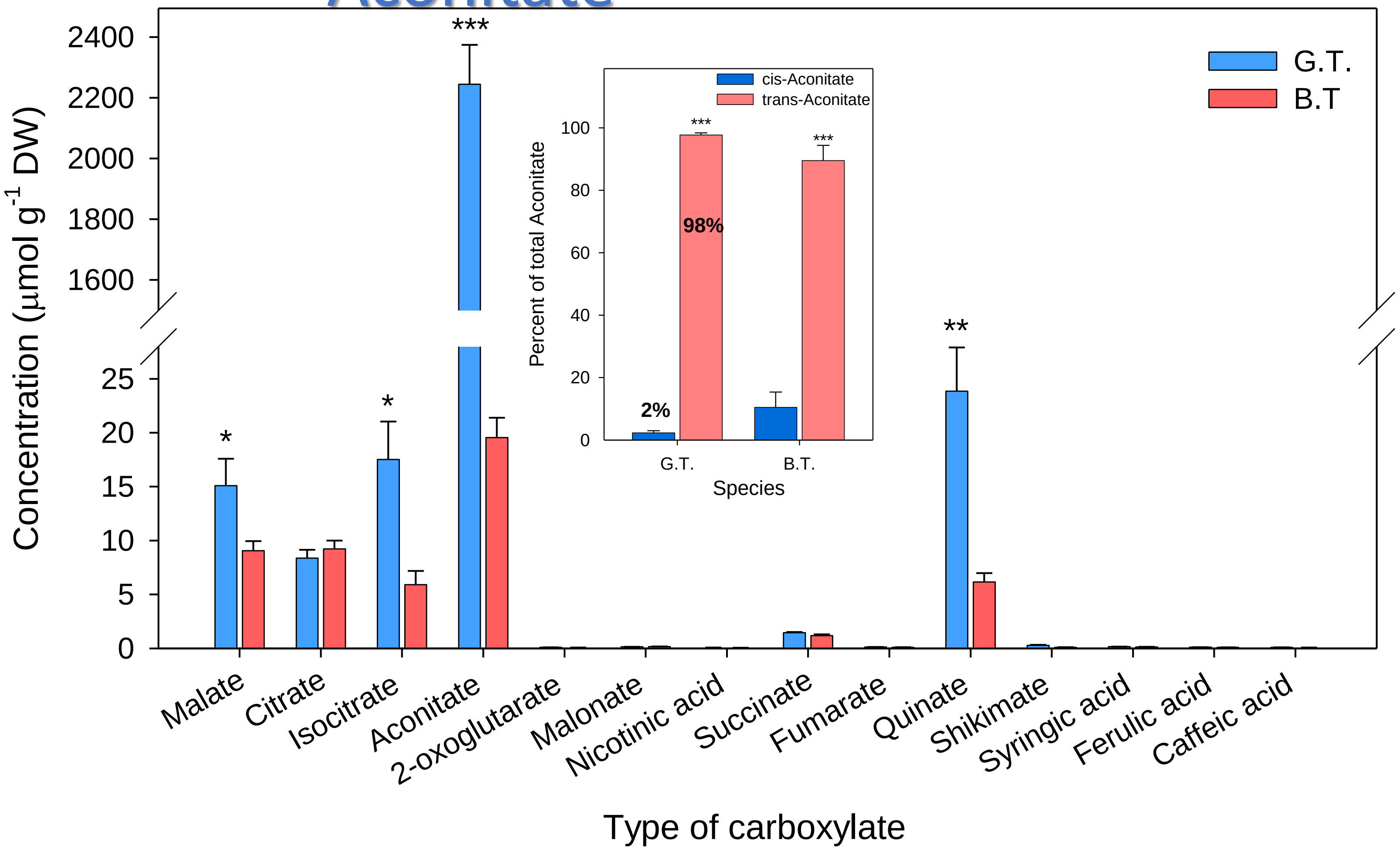


Unpublished data on *Banksia attenuata* from Nicolas Honvault and Peta Clode

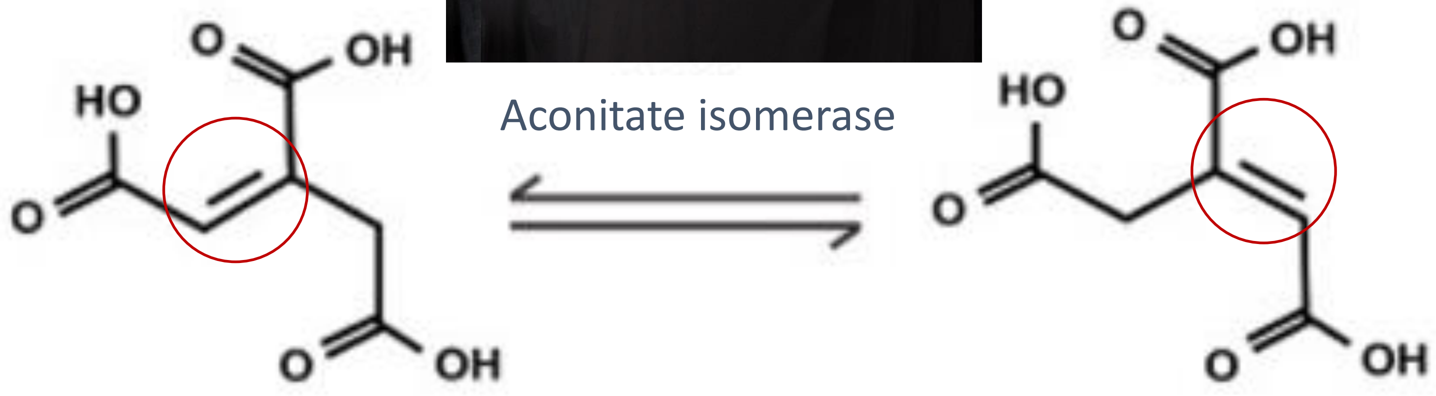
What is the negative ion to balance the positive calcium ions?

Aconitate



Gao J, Wang F, Ranathunge K, Arruda AJ, Cawthray GR, Clode PL, He X, Leopold M, Roessner U, Rupasinghe T, Zhong H & Lambers H. 2020. Edaphic niche characterization of four Proteaceae reveals unique calcicole physiology linked to hyper-endemism of *Grevillea thelemanniana*. *New Phytol* **228:** 869-883.

cis- and *trans*-aconitate are stereoisomers

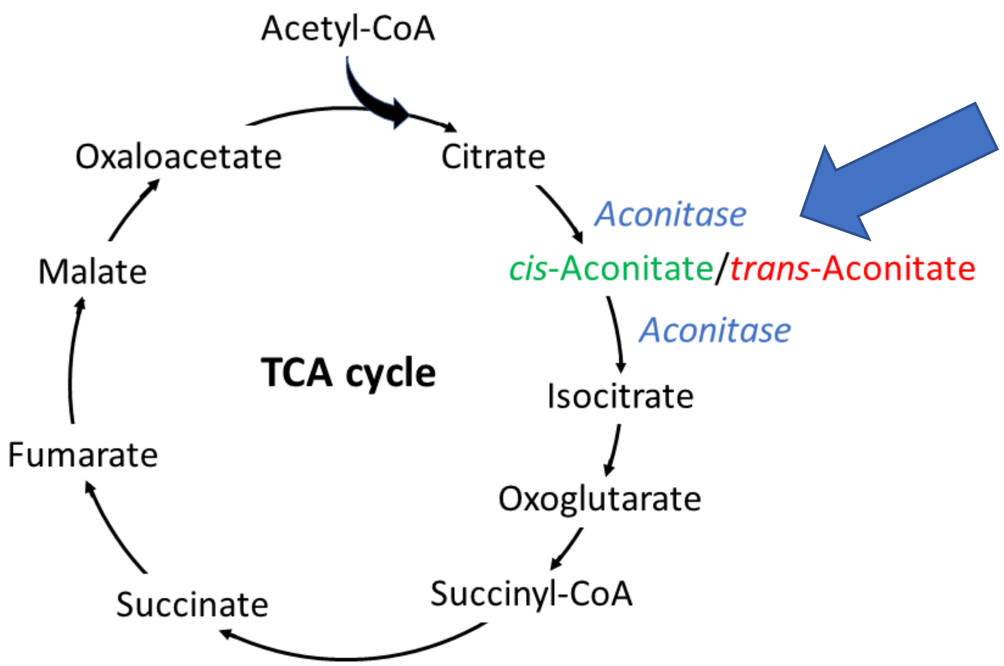


cis-aconitate

trans-aconitate

Klinman JP, Rose IA. 1971. Mechanism of the aconitate isomerase reaction. *Biochemistry* **10**: 2259-2266.

trans-aconitate is a stereoisomer of *cis*- aconitate, and an antimetabolite: a feeding deterrent



trans-Aconitate blocks the activity of aconitase, and thus inhibits respiration: calcium is needed to balance its negative charge

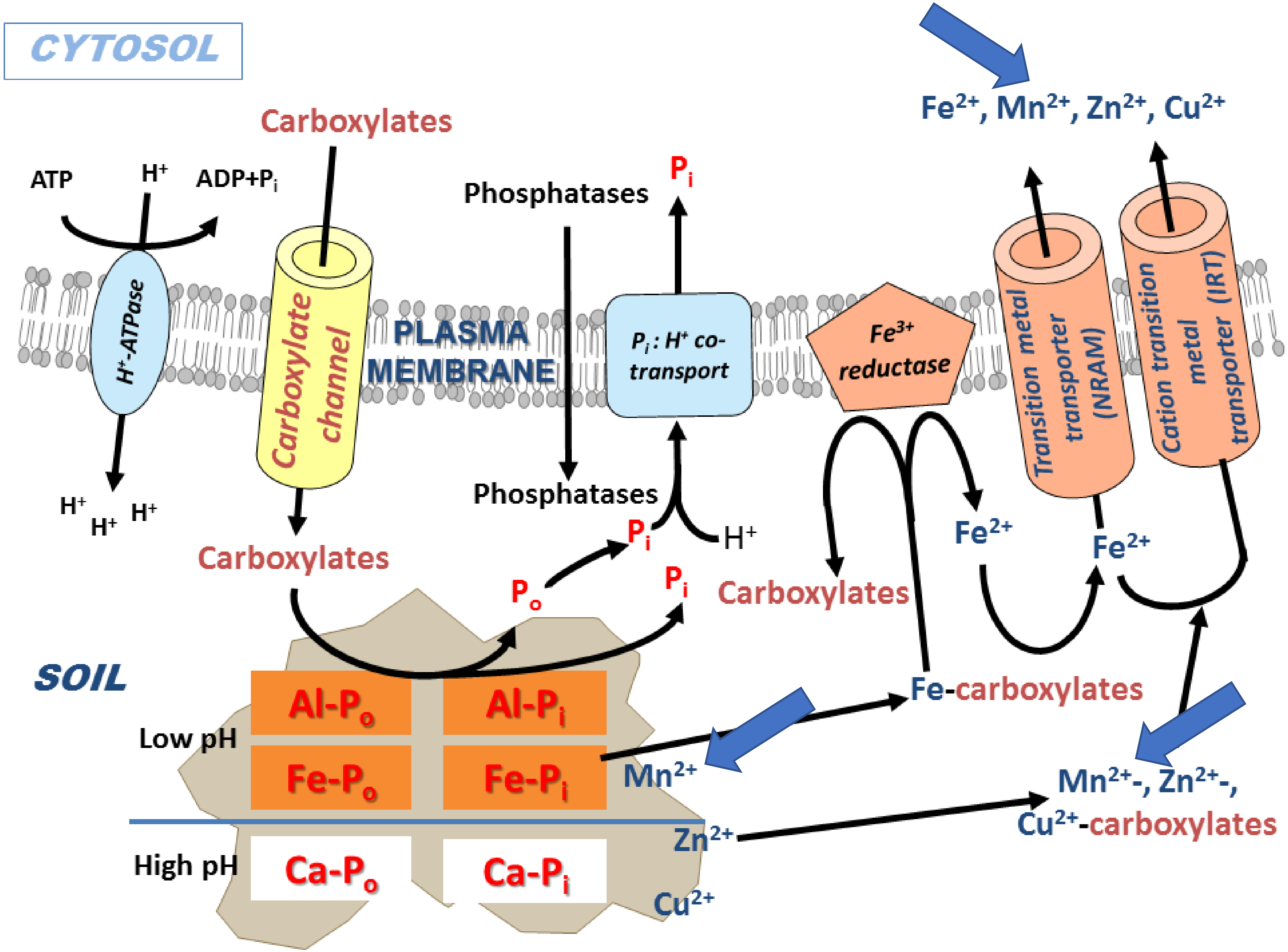
Saffran M, Prado JL. 1949. Inhibition of aconitase by *trans*-aconitate. *J Biol Chem* **180**: 1301-1309.
Lambers H. 2022. Chapter 17: Nutrient-use efficiency. In: Marschner's Mineral Nutrition of Plants, Fourth Edition, Rengel, Z., Cakmak, I. & White, P.J. (eds). Academic Press, London, in press.

Eeyore:
Why do all plants which an animal likes, have the wrong sort of swallow or too many spikes?

Milne AA. 1928. The House at Pooh Corner. Dutton, New York.

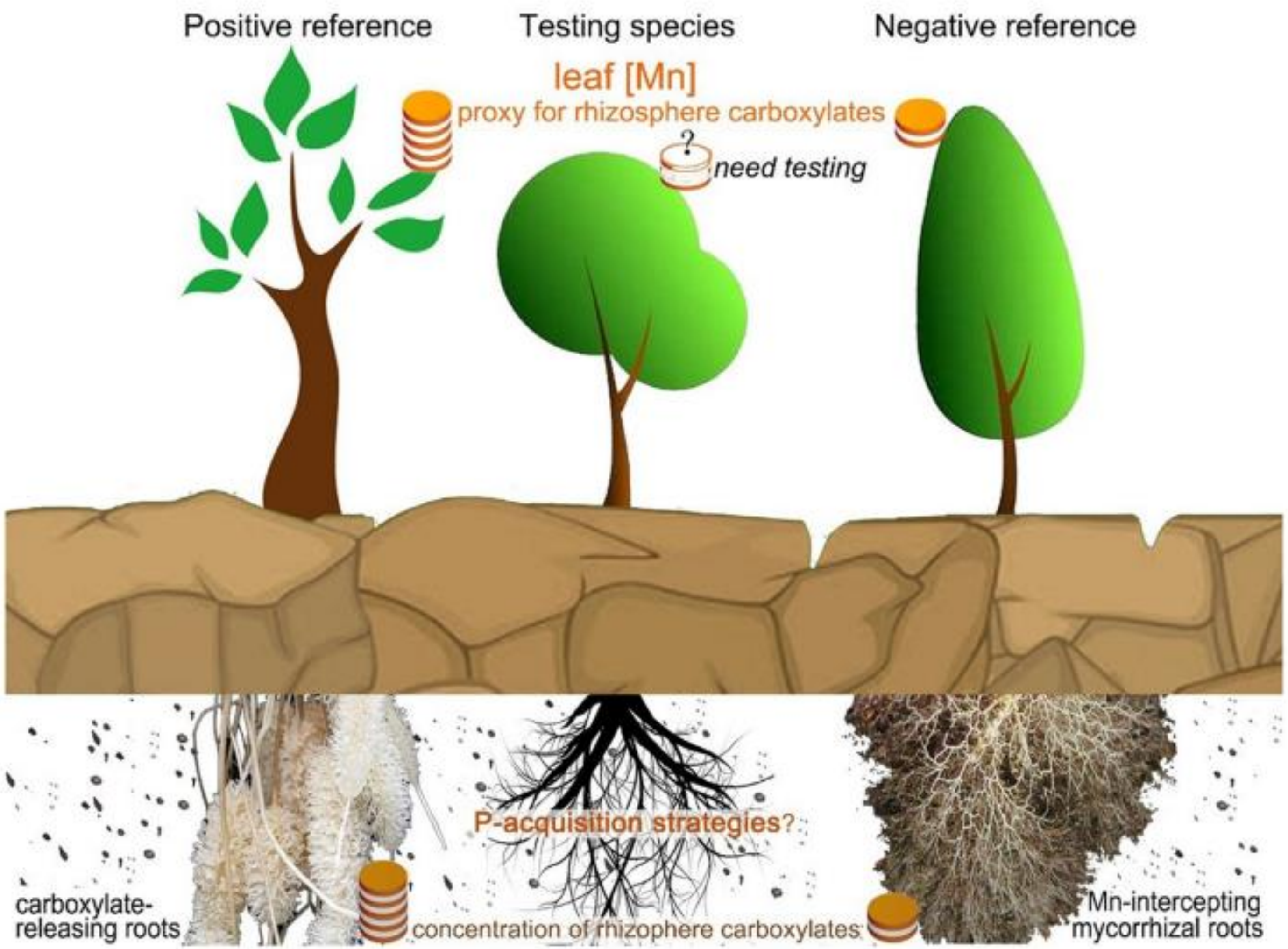
But what about the eucalypts in Manning Park, *e.g.*, *Eucalyptus decipiens* (redheart), *Eucalyptus foecunda* (Fremantle mallee) and *Eucalyptus gomphocephala* (tuart)?

Photos: Hans Lambers



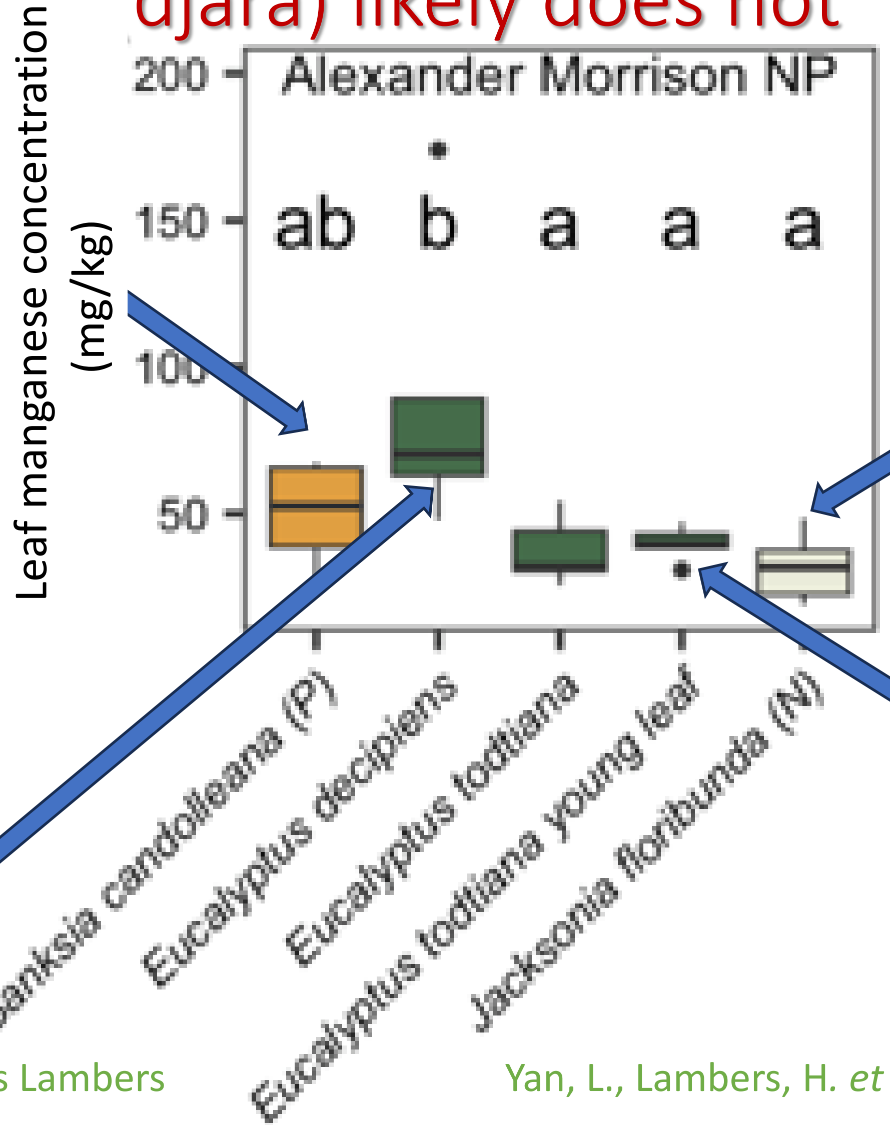
Lambers, H., Hayes, P.E., Laliberté, E., Oliveira, R.S., Turner, B.L. 2014. Leaf manganese accumulation and phosphorus-acquisition efficiency. *Trends Plant Sci*. **20:** 83-90.

Experimental design to assess if a species whose phosphorus-acquisition strategy is unknown (middle) uses a carboxylate-releasing phosphorus-mobilising strategy



Lambers, H. 2023. Chapter 17 - Nutrient-use efficiency.' in Z. Rengel, I. Cakmak and P.J. White (eds.), Marschner's Mineral Nutrition of Plants (Fourth Edition), Academic Press, San Diego.

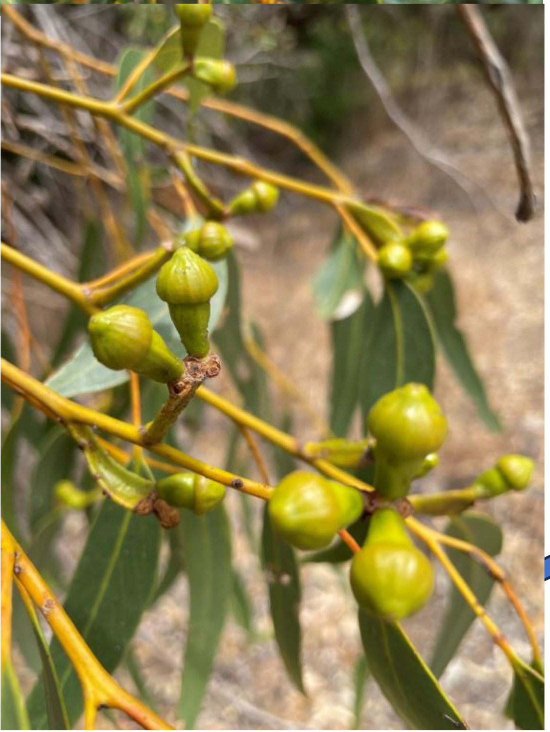
Eucalyptus decipiens (redheart) likely releases carboxylates, like *Banksia candolleana* does, but *Eucalyptus todtiana* djara) likely does not

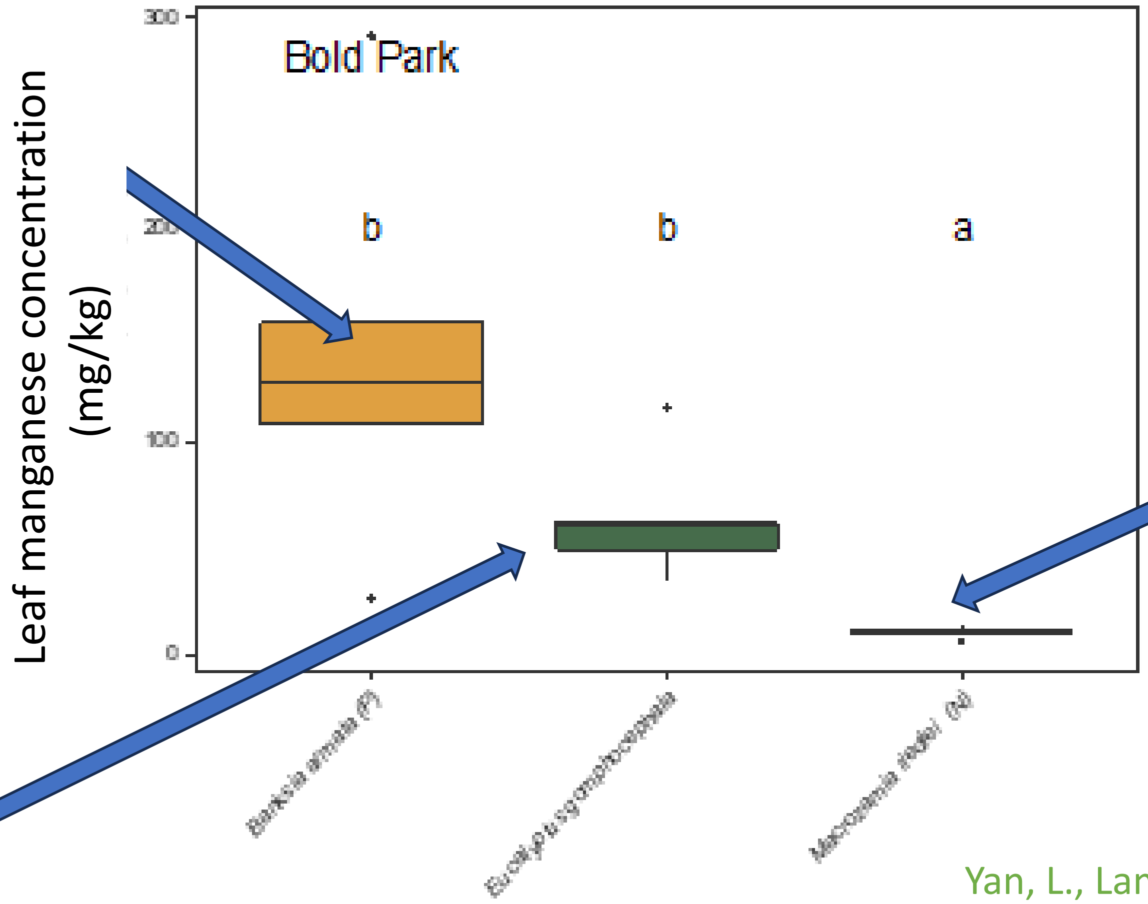


Photos: Hans Lambers

Yan, L., Lambers, H. *et al*., unpublished

Eucalyptus gomphocepahala (tuart) likely releases carboxylates, like *Banksia armata* does

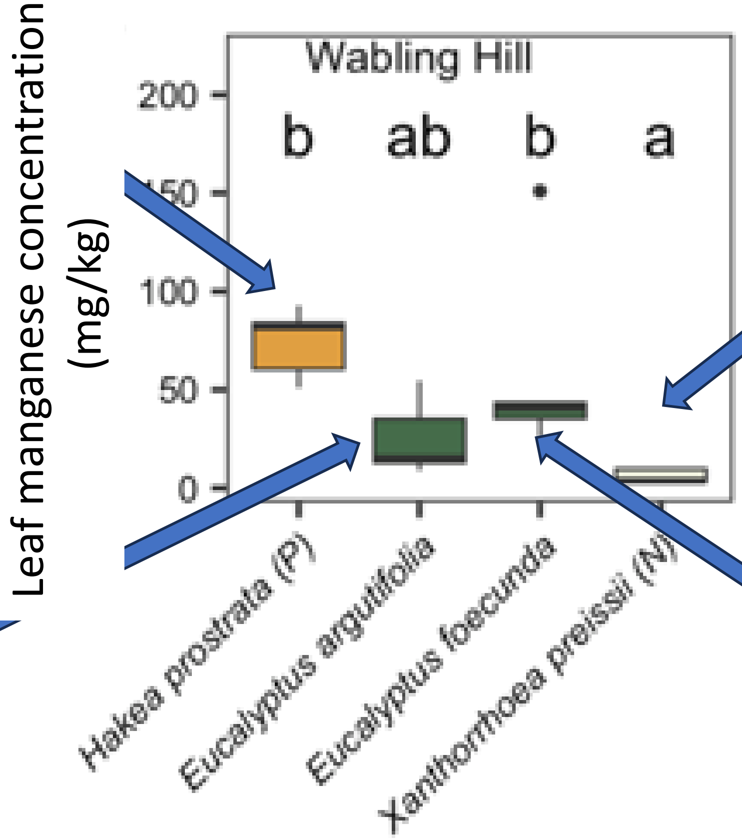




Yan, L., Lambers, H. *et al*., unpublished

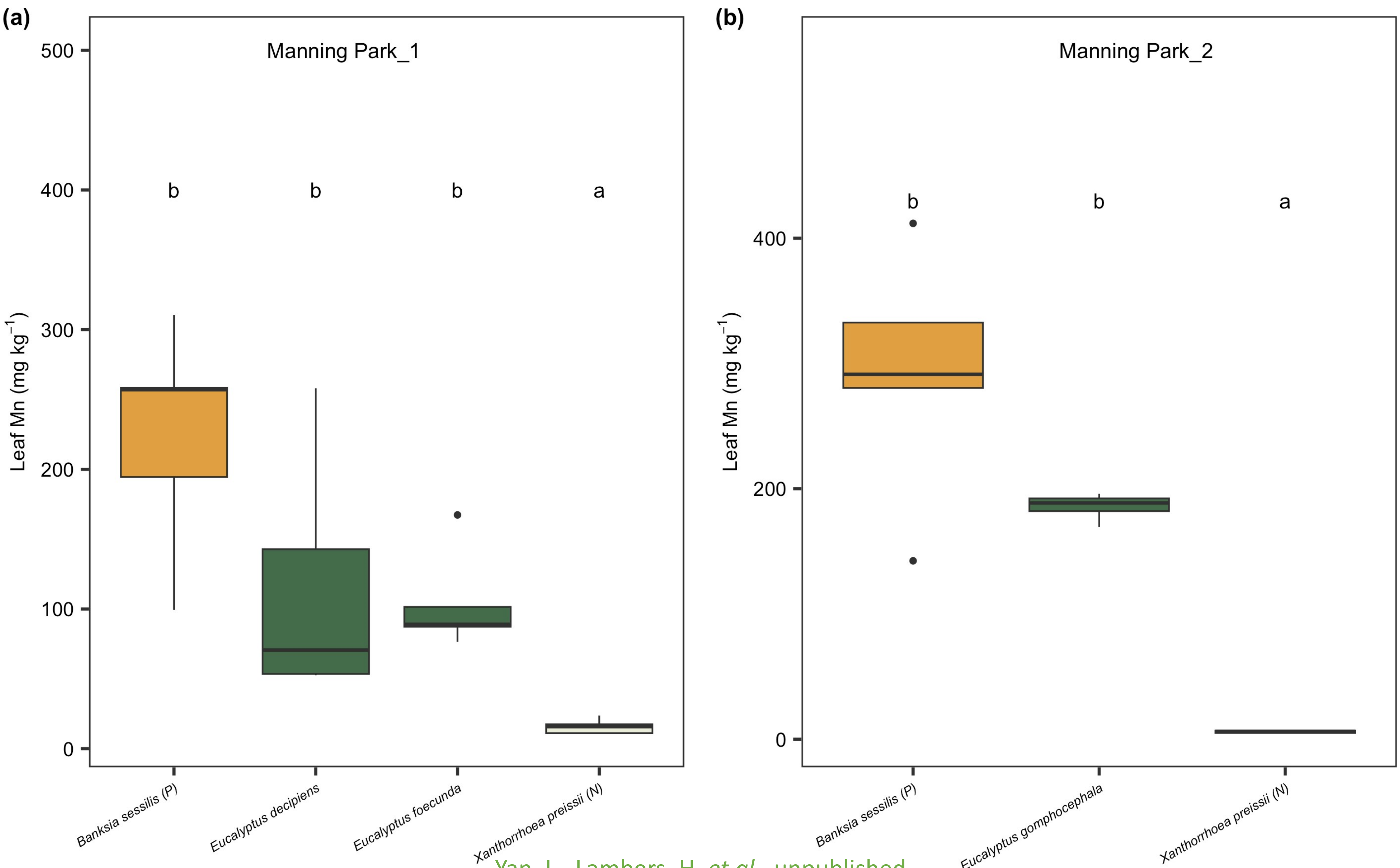
Photos: Hans Lambers

Eucalyptus foecunda (Fremantle mallee) likely releases carboxylates, like *Hakea prostrata* does, but the threatened *Eucalyptus argutifolia* (Wabling Hill mallee) likely does not



Photos: Hans Lambers

Yan, L., Lambers, H. *et al*., unpublished



Yan, L., Lambers, H. *et al.*, unpublished

Eucalyptus gomphocephala (tuart)
Photo: Hans Lambers

Concluding remarks

- Both ***Banksia*** and ***Eucalyptus*** species in Manning Park are very well adapted to phosphorus-impoverished soils
- All ***Eucalyptus*** species in Manning Park release carboxylates, but not all *Eucalyptus* in WA species do
- What about ***Melaleuca*** species there?
- Nobody knows (yet)!
- Habitats like Manning Park contribute enormously to Perth' reputation as one of the most plant-diverse cities in the world
- Management strategies should underpin maintenance of that plant diversity
- Showcase the biodiversity to ecotourists

Maintain the whole Catena!

Acknowledgements

- Marion Cambridge, Greg Cawthray, Patrick Finnegan, Sashima Funayama-Noguchi, Matthias Leopold, Shutong Liu, Jiayin Pang, Kosala Ranathunge, Michael Shane, Hongtao Zhong (UWA)
- Anna Abrahão, Felipe Albornoz, Daniel Beeck, Toby Bird, Clément Gille, Caio Guilherme Pereira, Patrick Hayes, Ana Luíza Muler, Shutong Liu, Francis Nge, Qi Shen, Graham Zemunik (past and present students)
- Kingsley Dixon, Steve Hopper, Etienne Laliberté, John Raven, Sally Smith, Christiana Staudinger, Cate Tauss, Ben Turner, Jun Wasaki (Australian and international collaborators)
- Australian Research Council
- City of Cockburn