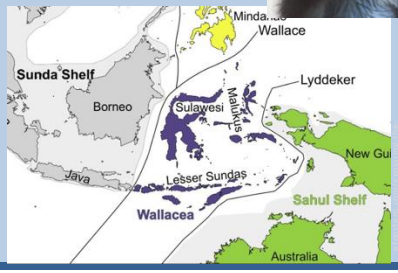
Long-distance dispersal: why study it?

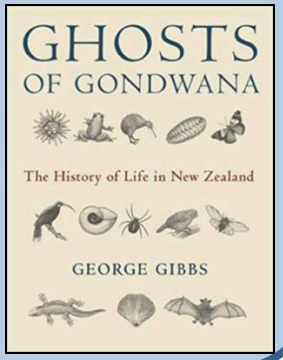
It's just interesting!

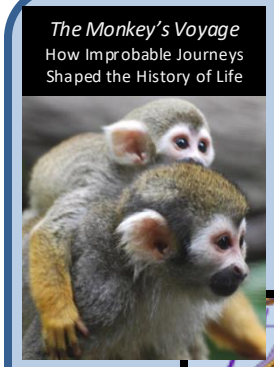
Big puzzles

No primates crossed to Australia (before humans)



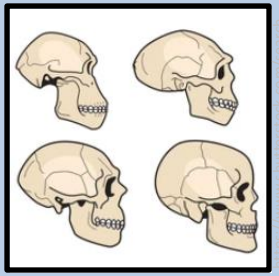
It's fundamental to understanding the biota of Aotearoa New Zealand

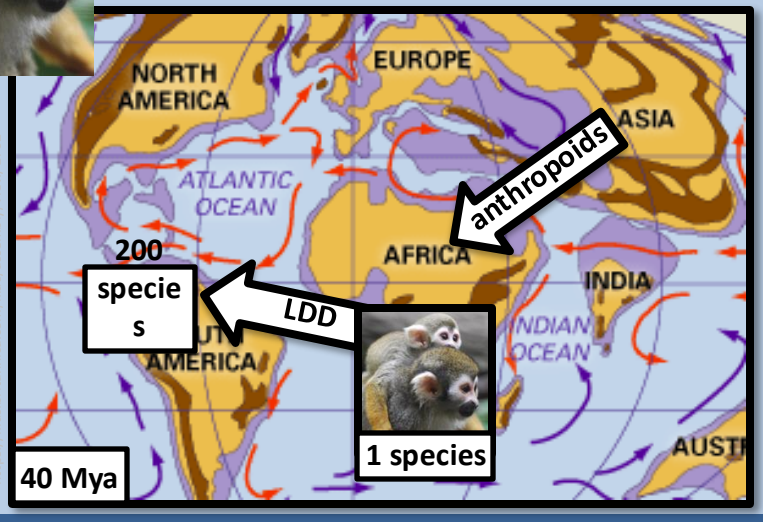




Fundamental to evolution…

…perhaps even human evolution



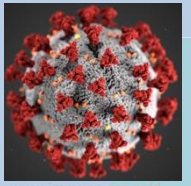


Biogeographical methods apply to:

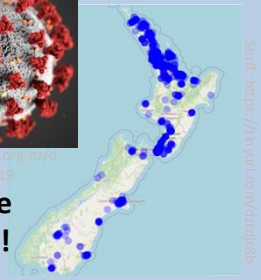
Invasive species,

Climate change,

Extinction



Disease spread!



Technical science problems

Biogeographical methods: 1000s of papers/year

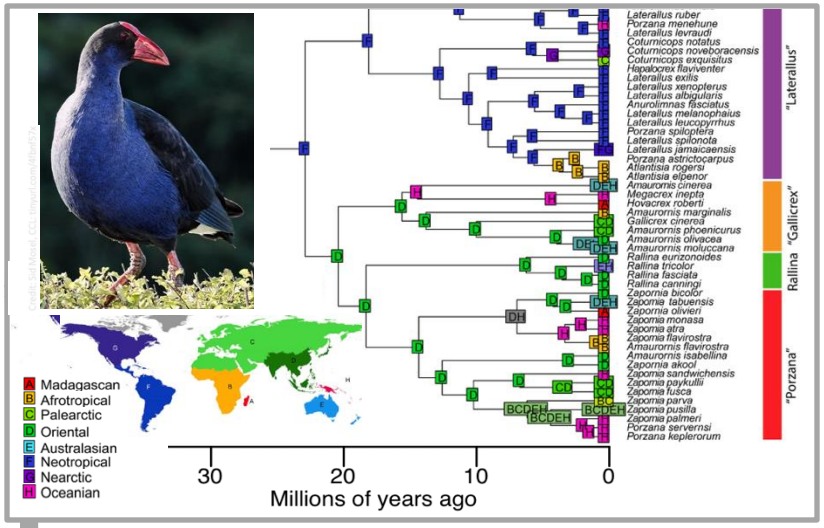
Available computational methods ignore many important processes

From miracle to mechanism in biogeography

Nicholas J. Matzke, Senior Lecturer, SBS, U. Auckland

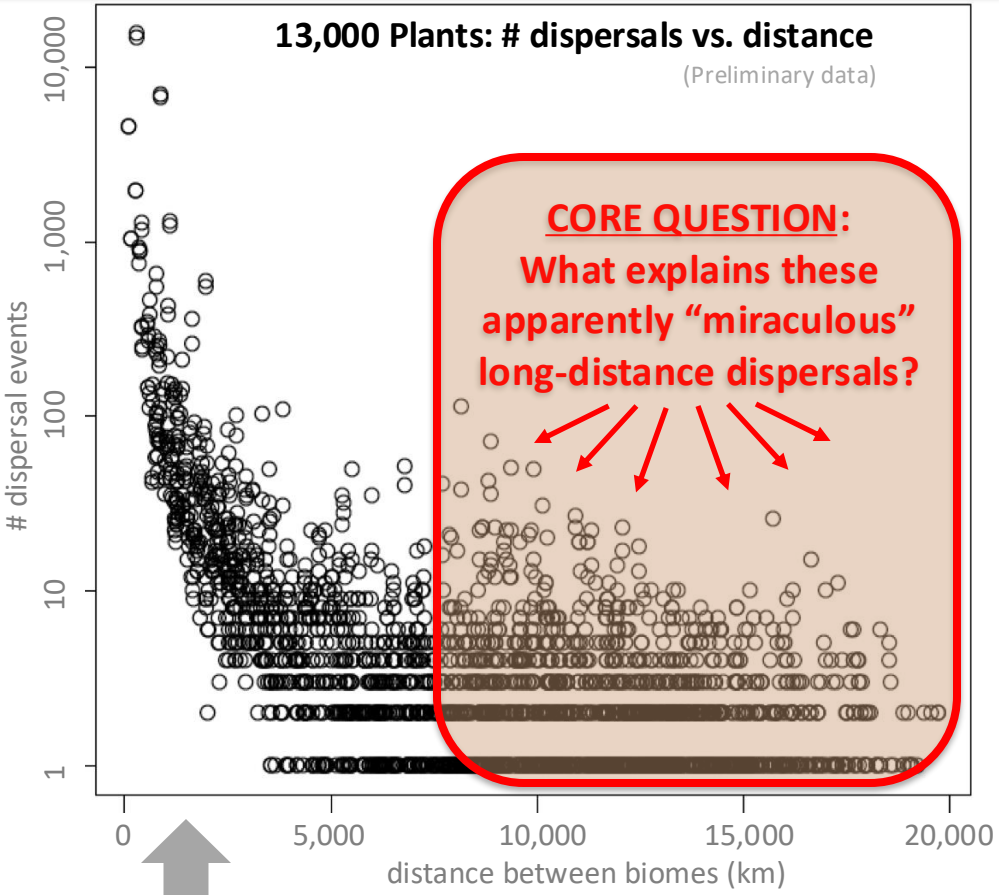
Example work:
Rallidae (e.g. Pukeko)

Garcia-R; Matzke (2021)
Journal of Biogeography



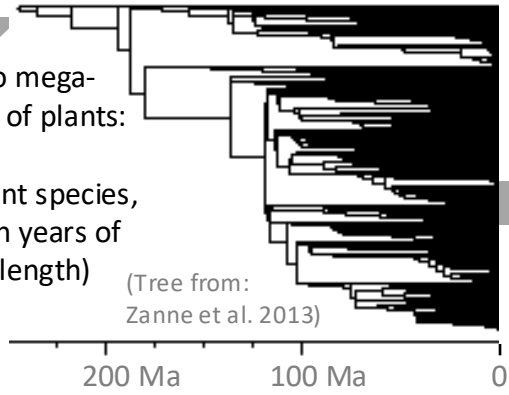
Package 'BioGeoBEARS'

- **753 citations**
- **21 workshops on 5 continents**
- **59 publications, 20 since coming to Auckland**

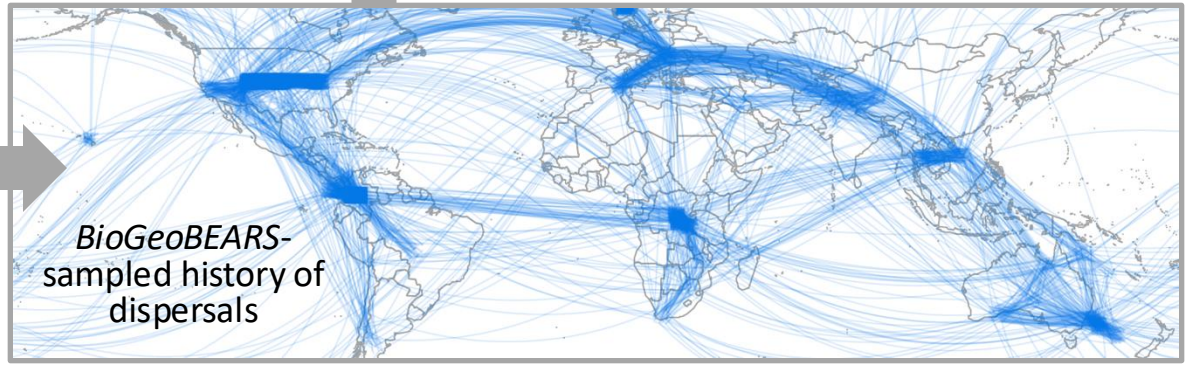


Apply to mega-phylogeny of plants:

(13,000 plant species, 173 billion years of branch length)

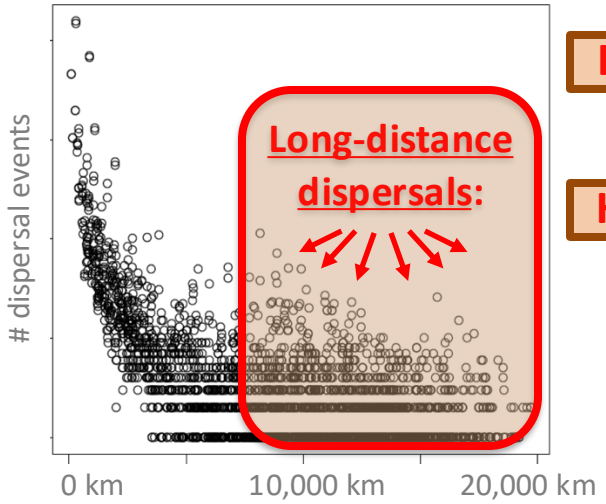


(Tree from: Zanne et al. 2013)



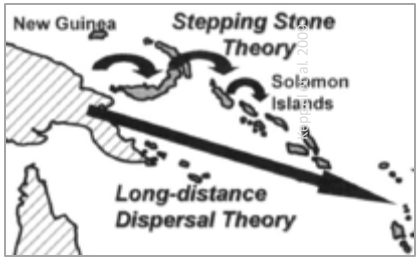
BioGeoBEARS-sampled history of dispersals

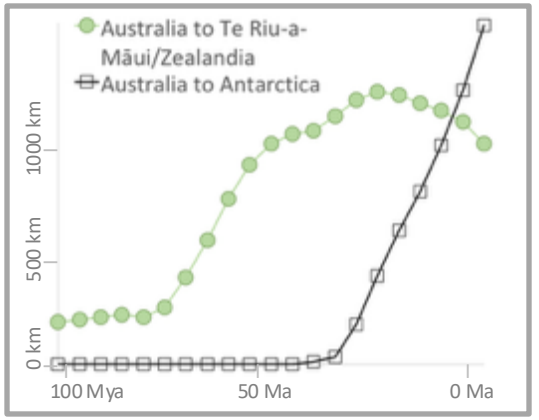
Possible LDD Explanations (Hypotheses)



H0 **Null hypothesis: "It's just luck." Can we reject this?**

H1 **Island "stepping stones"**





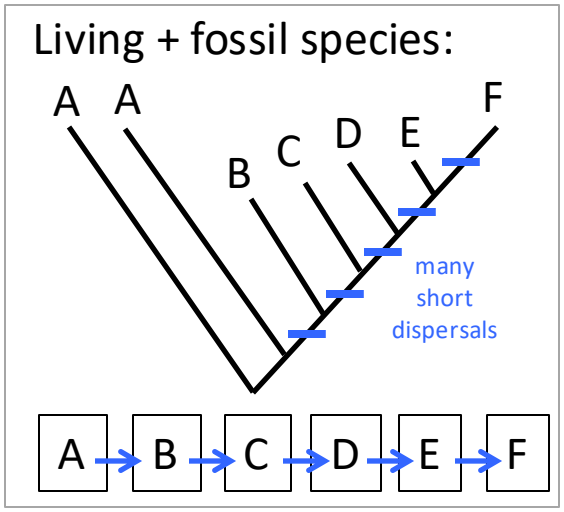
H2 **Changing palaeodistances**

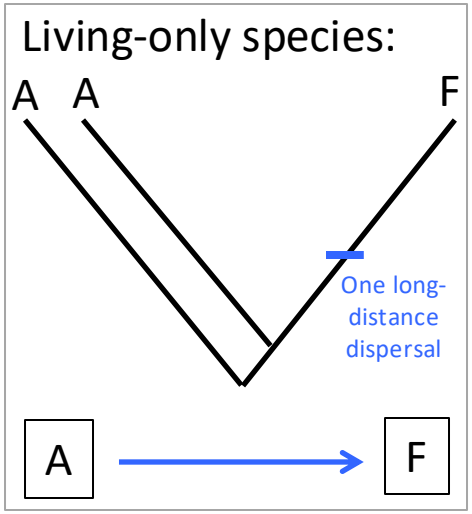
H3 **Changing palaeoclimates**

H4 **Palaeo-winds & currents**

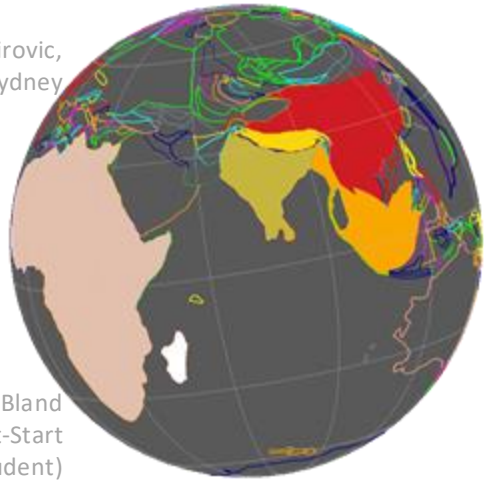
Hx:

Artefact Hypothesis: Extinction makes fake LDDs





GPlates: Sabin Zahirovic, U. Sydney



Animation: Wallis Bland (Marsden Fast-Start Ph.D. student)

...plus obvious factors like: current distances, connectivity, evolving traits (Matzke 2016-2021)

The Big Stretch: Integration for Realism

Marsden Fast-Start

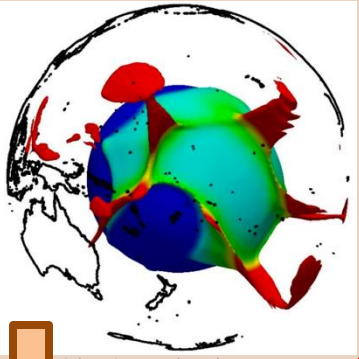
Problem: Extinction + Biogeography=SLOW

$$D_{N,i}(t+\Delta t) = D_{N,i}(t) + \left[-\left(\sum_j \sum_k \lambda_{ijk} + \sum_{j\neq i} Q_{ij} + \mu_i\right) D_{N,i}(t) + \sum_{j\neq i} Q_{ij} D_{N,j}(t) + \sum_j \sum_k \lambda_{ijk}\left(D_{N,k}(t)E_j(t) + D_{N,j}(t)E_k(t)\right)\right]\Delta t$$

10 areas = 2048 ODEs = too slow

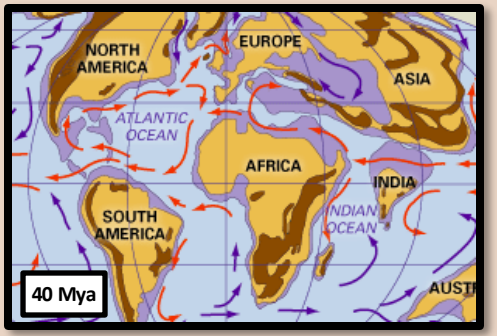
Rutherford H1: Stepping stones improve model fit

Not just current islands - Past plume islands accessible!



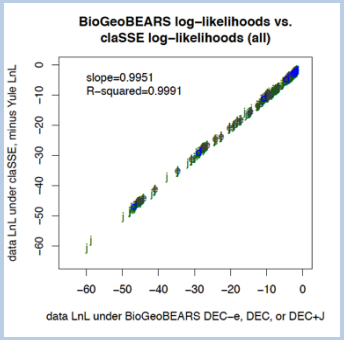
GPlates integrated; EarthByte.org

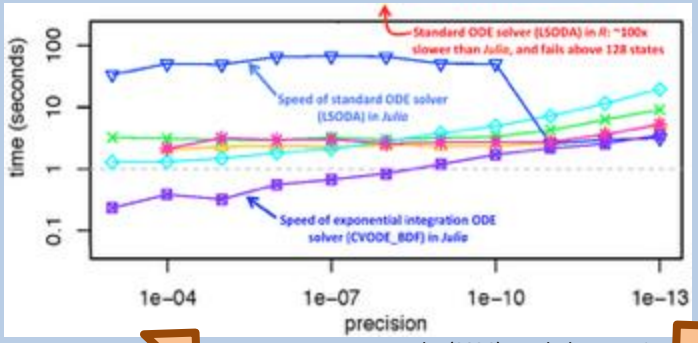
Rutherford H4: Palaeocurrents / winds improve fit



Solution: BioGeo julia

Exponential integrators: $\frac{e^{Q_{ij}t} - I}{Q_{ij}t} t \frac{dD_{N,i}(t_0)}{dt} + \int_{s=t_0}^{s=t_0+t} e^{(t_0+t-s)e^{Q_{ij}t}} R(y(s))ds$



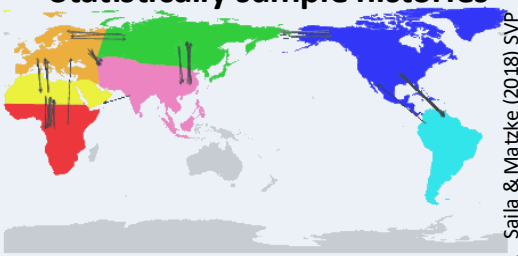


Matzke (2021) *J. Biogeography*, accepted

Matzke (2020) NZ Phylogenomics

Goal: Realistic, accurate biogeog.

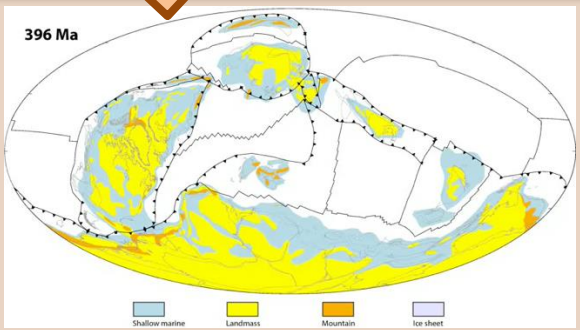
- Compare candidate models using AIC, Bayes
- Statistically sample histories



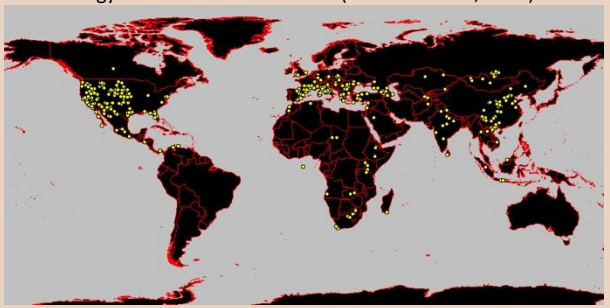
Saila & Matzke (2018) SVP

Rutherford H2, H3: Palaeogeography, Palaeoclimates improve model fit

Cao, **Zahirovic** et al. (2017), *BioGeoSciences*: "Improving global paleogeography since the late Paleozoic using paleobiology."



Paleobiology Database: Fossil Canidae (Saila & Matzke, 2018)



The Team. The Plan.

Faculty of Science

THE UNIVERSITY OF SYDNEY

Dr Sabin Zahirovic

Expertise:
- Lead author of *GPlates*
- Plate tectonics
- Palaeogeography

+ Ph.D. student 1

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

Questions? AskAuckland Contact us

Search

Dr Shane Donald Tukukino Wright

Senior Lecturer

In: Biological Sciences » Faculty of Science

+ Ph.D. student 2

Expertise:
- Pacific biogeography
- Plant dispersal
- Palaeoclimate of NZ and region
- Indigenous names in taxonomy

Biogeography: current status

The Biogeographical Jump Forwards:

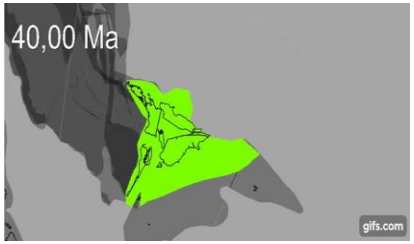
Models in use: Features of biogeographical models:	*Markov*-k (and e.g. DNA models)	*Lagrange* (DEC (Python))	*BioGeoBEARS* (DEC+J etc. (R package))	*ClaSSE* (*diversitree* R package)	**Rutherford (*BioGeoJulia*)**
Probabilistic model of range evolution	X	X	X	X	**X**
Ranges can occupy multiple areas		X	X	X	**X**
Range expansion/contraction		X	X	X	**X**
Vicariance (large range can divide at speciation)		X	X	X	**X**
Plate tectonics/paleogeography (by hand)		X	X	X	**X**
Jump dispersal			X	X	**X**
Statistical comparison of multiple models			X	X	**X**
Distance-dependent dispersal			X	X	**X**
Trait-dependent dispersal			X	X	**X**
Speciation rate depends on region				X	**X**
Lineage extinction				X	**X**
High-speed exponential integrators for ODEs					**Marsden**
GPlates data importation					**Marsden**
Incomplete species sampling					**(M)**

SCIENTIFIC AMERICAN

Change Species Names to Honor Indigenous Peoples, Not Colonizers, Researchers Say

New Zealand scientists make a case for updating long-held scientific names to incorporate more meaningful terms

Te Riu-a-Māui/Zealandia



Müller, **Sahirovic** et al. (2018), U. Sydney "Modelling and visualising distributed crustal deformation of Australia and Zealandia using *GPlates 2.0*."

Understanding LDD: Benefits

This Rutherford Project will:

- *determine* how much apparent LDD is artefactual
- *measure* the relative importance of LDD mechanisms
- *provide tools* for including palaeogeography, palaeoclimate, and other dynamic factors in the ODEs necessary for realistic spatial phylogenetics
    - E.g. for epidemiology

Broader impacts

- Training workshops at meetings (21 workshops on 5 continents so far)
- Joint visualisations of geographic & biogeographic history (classrooms, museums)
- Advance NZ leadership in open-source code, data for education

Understand Aotearoa's biota in global context

"…explain New Zealand and the world falls into place around it."

--*JRSNZ* (2021), call for papers, Evolutionary Biogeography of Aotearoa New Zealand; citing Gareth Nelson (1975).

"The past is the key to the present."

--anthology on Charles Lyell, "Father of Geology"

"I walk backwards into the future with my eyes fixed on my past."
/ "Kia whakatōmuri te haere whakamua."

--Lesley Rameka (2016). *Contemp. Iss. Early Child*. 17(4), 387-398.