German Centre for Integrative Biodiversity Research (iDiv)
Halle-Jena-Leipzig

Africa as an evolutionary arena for large fruits

F. Wölke[1,4], A. Cabral[1], J. Lim[2], W. D. Kissling[3] & R. Onstein[1,5] (2023)

[1] Evolution and Adaptation, German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Germany
[2] Department of Biological Sciences, National University of Singapore, Singapore
[3] Institute for Biodiversity and Ecosystem Dynamics (IBED), University of Amsterdam, The Netherlands
[4] Faculty of Environmental Sciences, Czech University of Life Sciences Prague, Czech Republic
[5] Naturalis Biodiversity Center, Leiden, The Netherlands

Friederike J. R. Wölke
PhD Student at Modelling of Biodiversity (MOBI) Lab
Czech University of Life Sciences in Prague

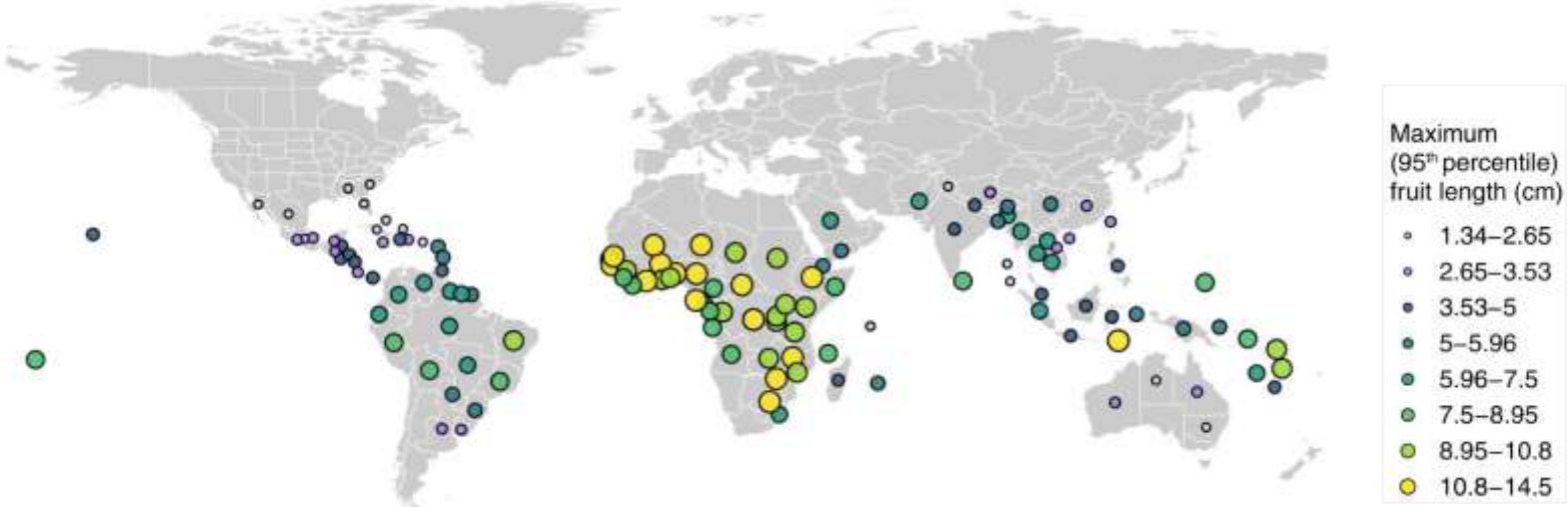
DOI: 10.1111/nph.19061

New Phytologist

IBS Conference 2024, Tue. 09.01.2024, Prague
S09: Historical Biogeography

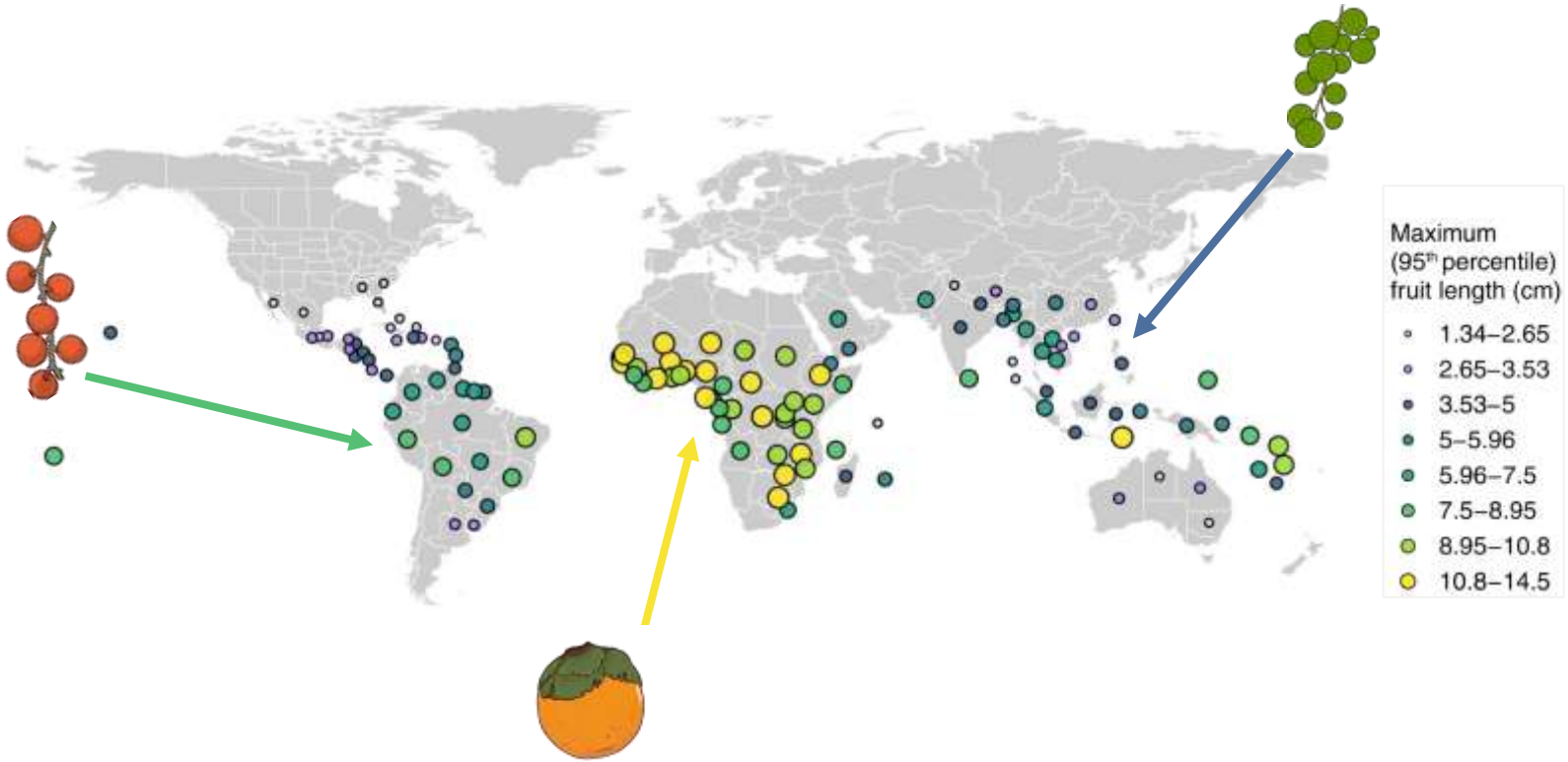
iDiv is a research centre of the
DFG Deutsche Forschungsgemeinschaft

Fruit sizes differ across broad-scale ecological communities



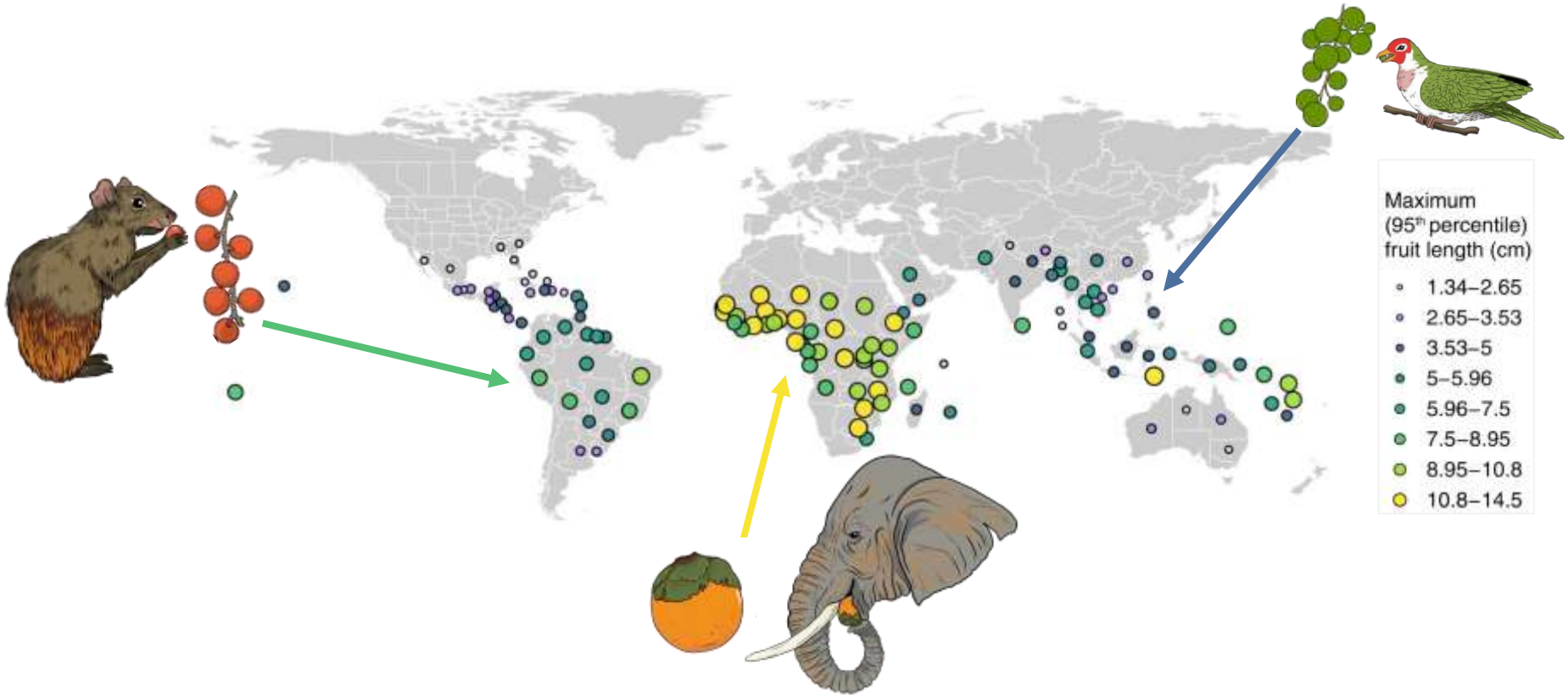
Data = Palms (Arecaceae), N = 2040, scale = botanical countries (TDWG3) (Wölke et al., 2023)

Fruit sizes differ across broad-scale ecological communities



© illustrations of characteristic regional palm fruits by Alexandra Koch: *Ceroxylon* (left), *Borassus* (bottom), *Corypha* (right)

Fruit sizes differ across broad-scale ecological communities



© illustrations of characteristic regional palm fruits and seed dispersers by Alexandra Koch: *Ceroxylon* & Agouti (left), *Borassus* & elephant (bottom), *Corypha* & fruit dove (*Ptilinopus jambu)* (right)

Quantifying community downsizing of Late Pleistocene frugivorous megafauna

(~ 130,000 years ago until present)

Diprotodon (Giant wombat, Australia, ~2,800 kg, † 46,000 years ago)

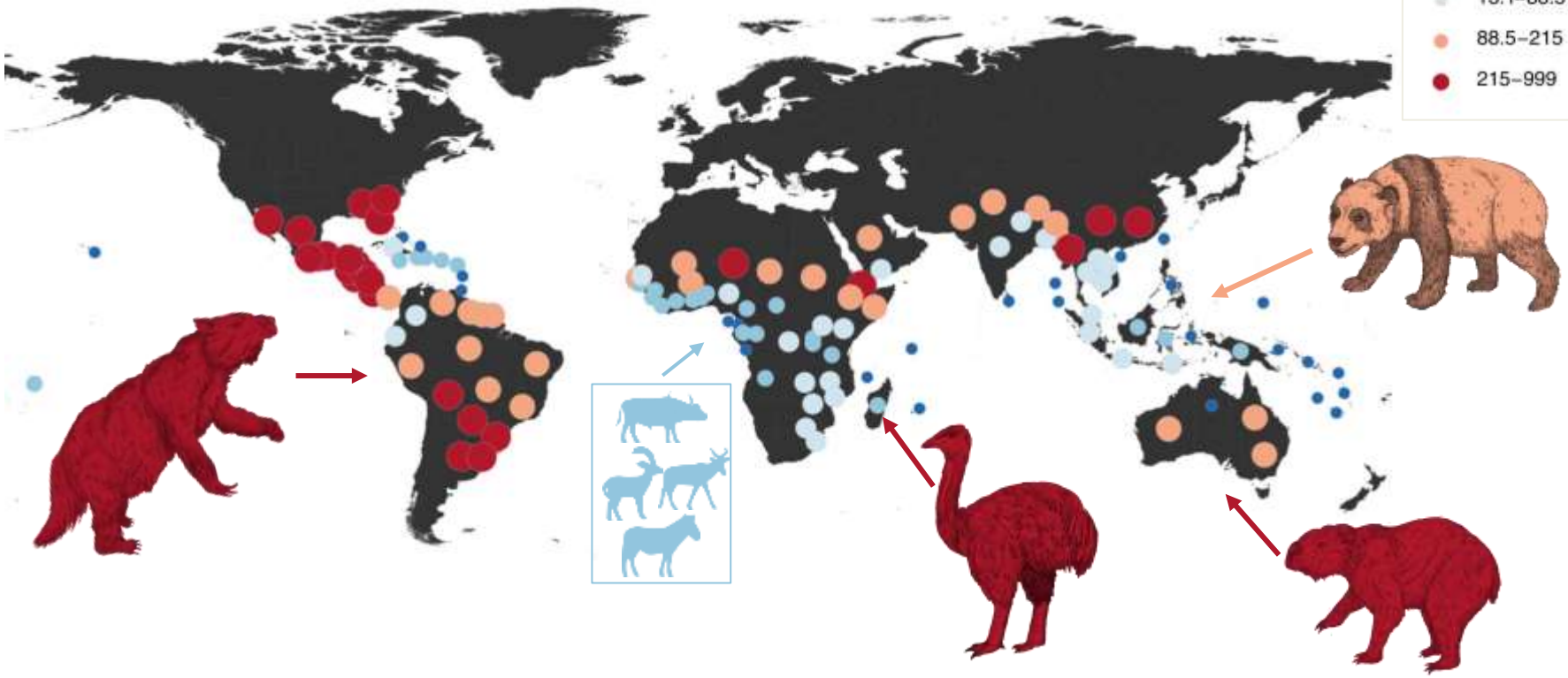
Ailuropoda baconi (Panda, Indo-Malay region, † unknown, 129,000-11,700 years ago)

Aepyornithiformes (Elephant birds, Madagascar, ~1,000 kg, † 900-1,200 years ago)

Megatherium (Giant sloth, South America, ~4,000 kg, † 12,000 years ago)

© illustrations by Alexandra Koch

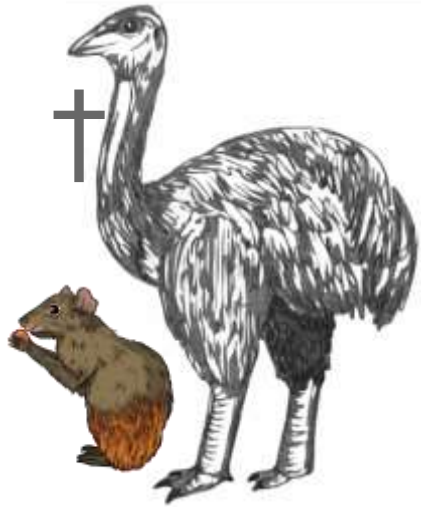
Africa is unique in downsizing of mammalian frugivore assemblages



Data: PHYLACINE (primary and secondary frugivores), scale: botanical countries (TDWG3) (Wölke et al., 2023)
© characteristic regional extinct megafrugivores by Alexandra Koch: Madagascar: *elephant bird,* Americas: *Megatherion,* Asia: *Ailuropoda,* Australia: *Diprotodon* | selection of extinct African browsers adapted from Stuart 2014 (Geol. J.)

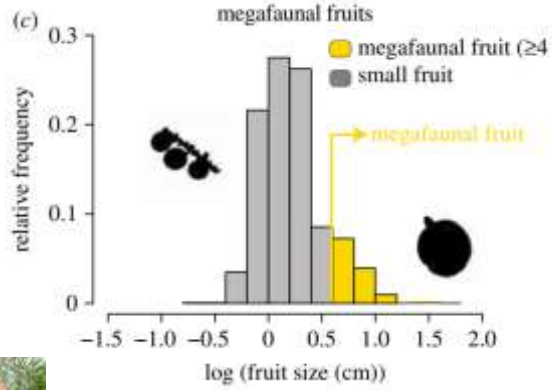
Is the current distribution of large fruits related to the long-term stability of seed-dispersing megafaunal communities through time?

→ Macroevolutionary and macroecological framework for palms



© illustrations by Alexandra Koch

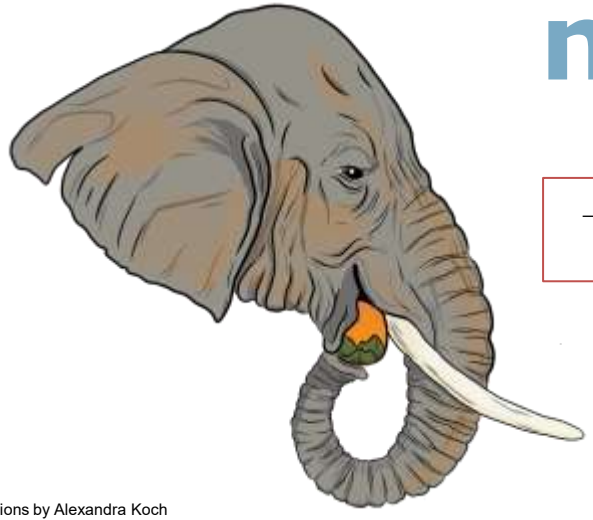
Study system: Palm family (Arecaceae)



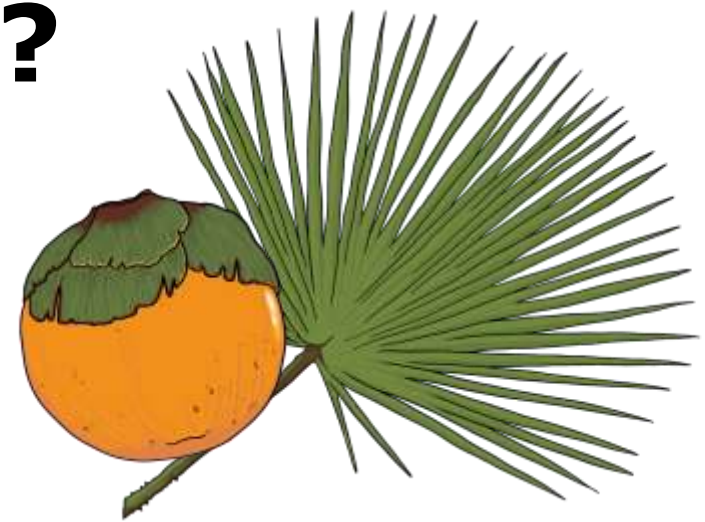
Onstein *et al.*, 2018

- 2500+ species
- pantropical distribution
- environmental heterogeneity: savanna and forest
- large diversity of fruits and fruit sizes: few seeds and animal-dispersed
- year-round fruiting times: keystone resource for frugivores
- high proportion of megafauna-adapted species

Has fruit size evolved in response to adaptive processes or has it evolved neutrally?



→ Phylogenetic comparative methods
(evolutionary trait models)



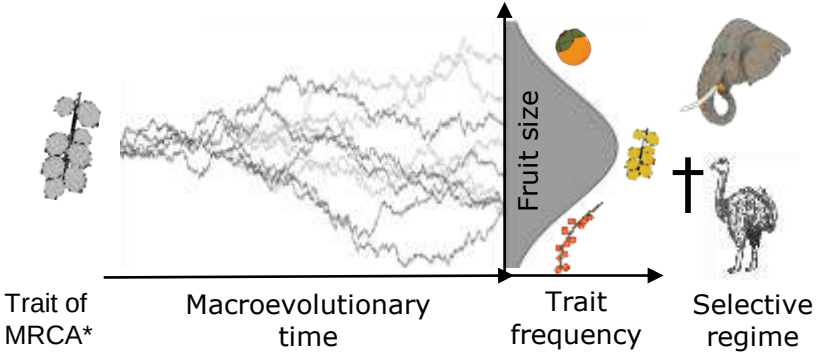
© illustrations by Alexandra Koch

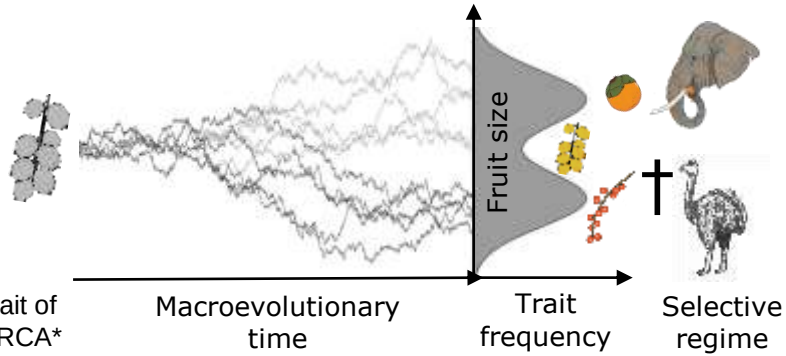
Neutral evolution
(Brownian Motion process)

- Trait evolves **stochastically** along the branches of a phylogeny (e.g., following genetic drift)
- Parameter:
  (1) stochastic rate

Adaptive evolution
(Ornstein-Uhlenbeck process)

- Trait evolution is driven by a **selective force** that pulls the trait towards a certain **optimum** trait value under different **selective regimes**
- Parameters:
  (1) stochastic rate
  (2) strength of selection
  (3) optimum trait value

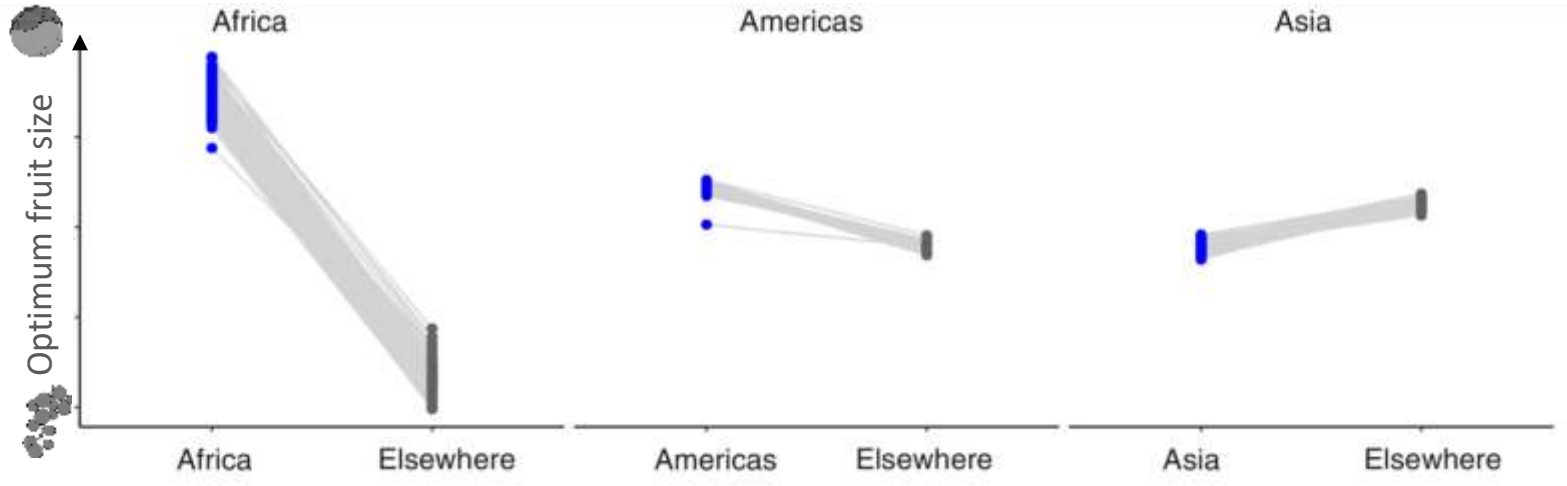




*MRCA = Most recent common ancestor

Adapted from Butler & King, 2004

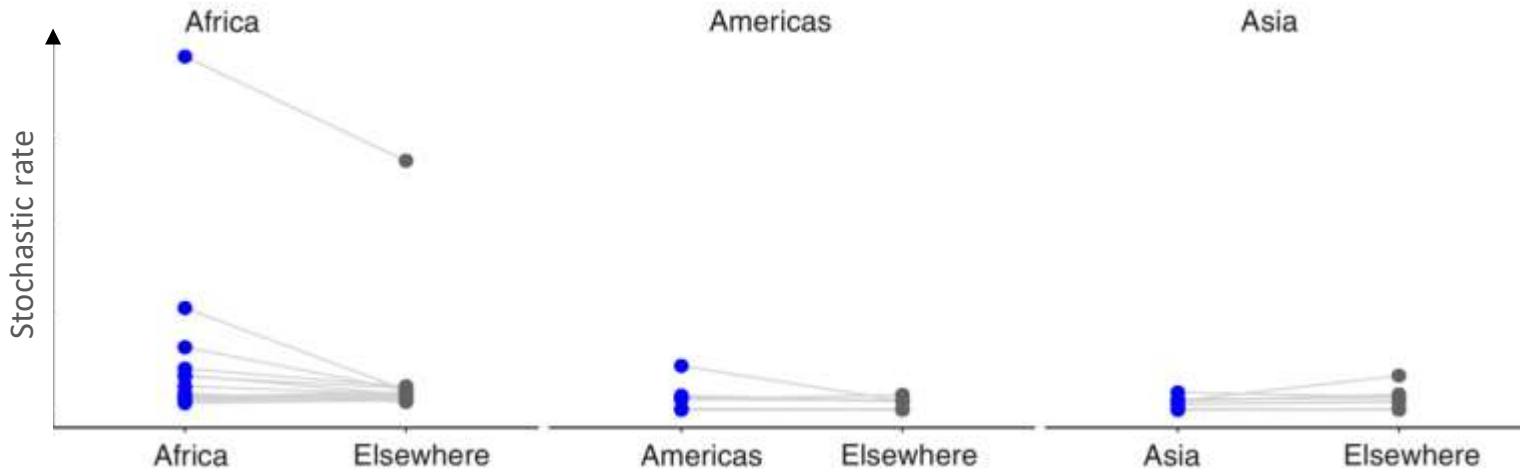
Adaptive processes drive fruit size evolution in palms



Optimal fruit size in Africa is twice as large than elsewhere.

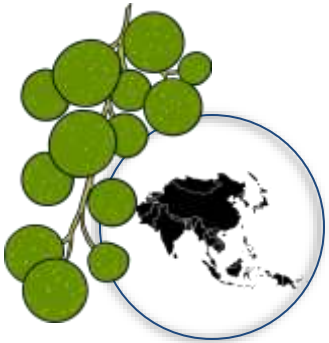
© illustration of fruits by Alexandra Koch

Faster trait disparification in Africa

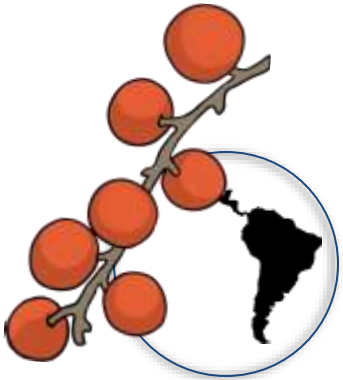


Evolutionary constraints on fruit sizes were lifted in Africa
(potentially through the stable availability of seed-dispersing megafauna)

What (else) drives the current broad-scale distribution of the largest fruits?

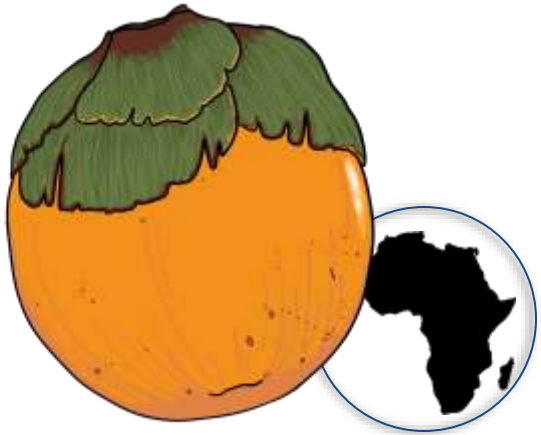


Corypha utan



Ceroxylon quindiuense

Calamus ornatus

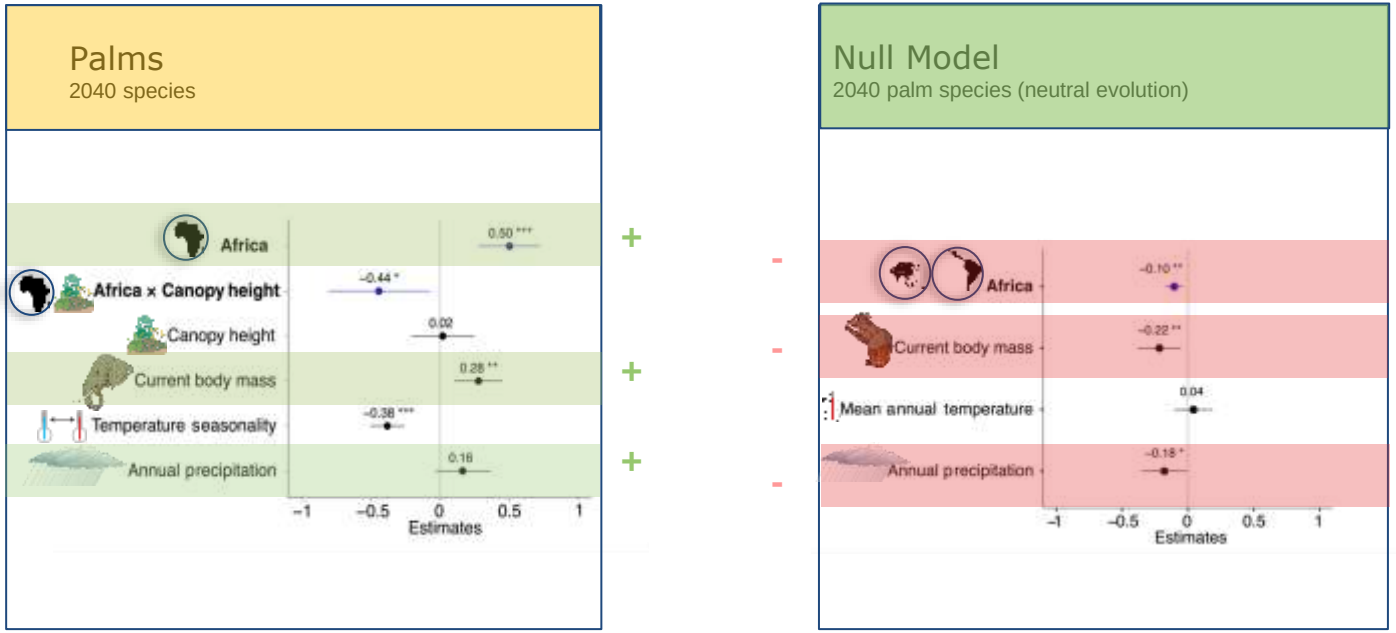


Borassus aethiopum

→ Linear models, spatial-autoregressive models

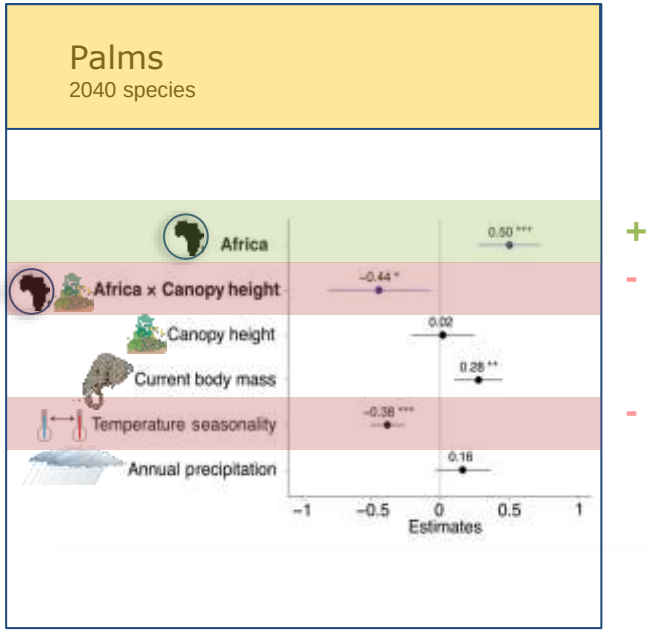
© drawings by Alexandra Koch

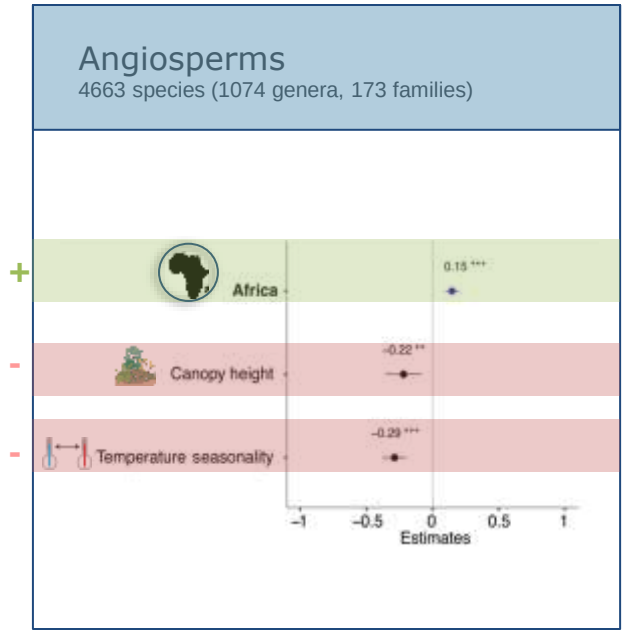
Savanna expansion and paleoclimatic fluctuations played a unique role in the evolution of large fruits in Africa



No significant interaction between current frugivore body mass and Africa
→ similar effect across continents

More general trend: Largest fruits in Africa, under low canopies and stable temperatures





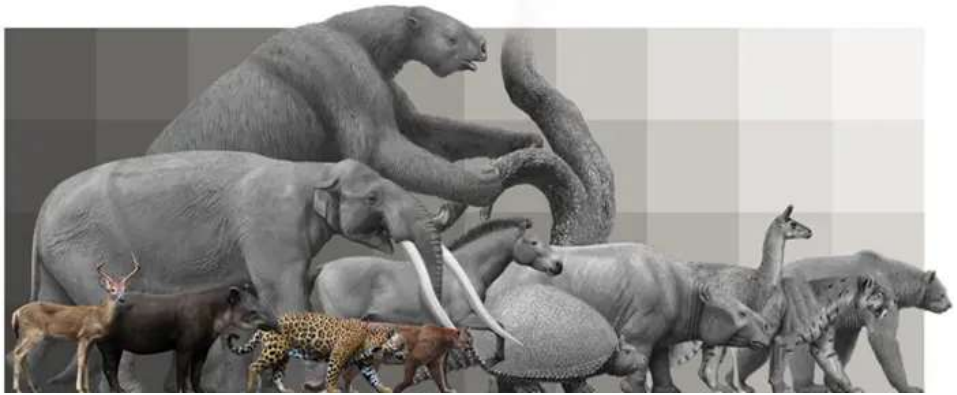
No correlation between community frugivore body mass and Angiosperms
→ many depend on bird-dispersal or seed is the dispersal unit (not fruit)

Take-Home Messages

- Adaptive processes millions of years ago have influenced the distribution of fruit sizes we see today

- Environmental filtering by the loss/lack of megafauna to disperse large fruits contributes substantially to the distribution patterns

- Implications for the future under intensified aridification and defaunation with global change



Thank you!

link to paper:

Coauthors: Renske Onstein, Andressa Cabral, Jun Lim, Daniel Kissling

iDiv's Evolution and Adaptation group (led by Renske Onstein)

HPC-Cluster: Helmholtz Centre for Environmental Research

Illustrator: Alexandra Koch (B.A. student at KISD)

Illustration :

My current funding: ERC & CZU

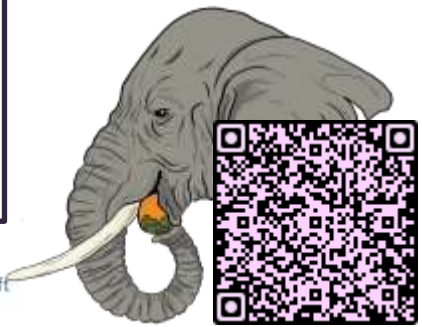
Funded by the European Union

European Research Council

BEAST Project

MOBI Lab

Funded by the European Union (ERC, BEAST, 101044740)



KISD
Köln International School of Design

Technology
Arts Sciences
TH Köln

iDiv

UFZ HELMHOLTZ Centre for Environmental Research

Funded by DFG Deutsche Forschungsgemeinschaft German Research Foundation