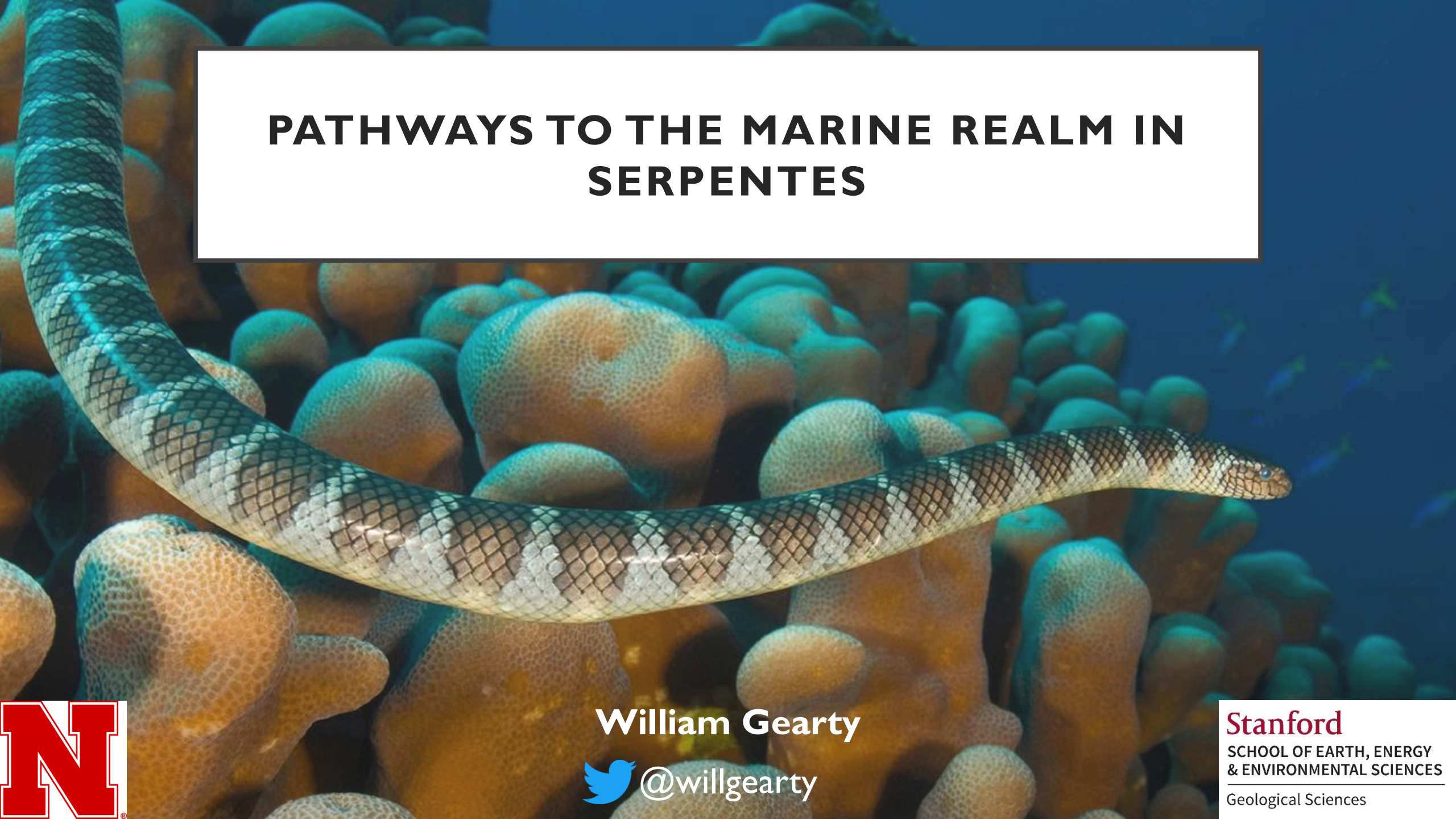
PATHWAYS TO THE MARINE REALM IN SERPENTES



William Gearty

@willgearty

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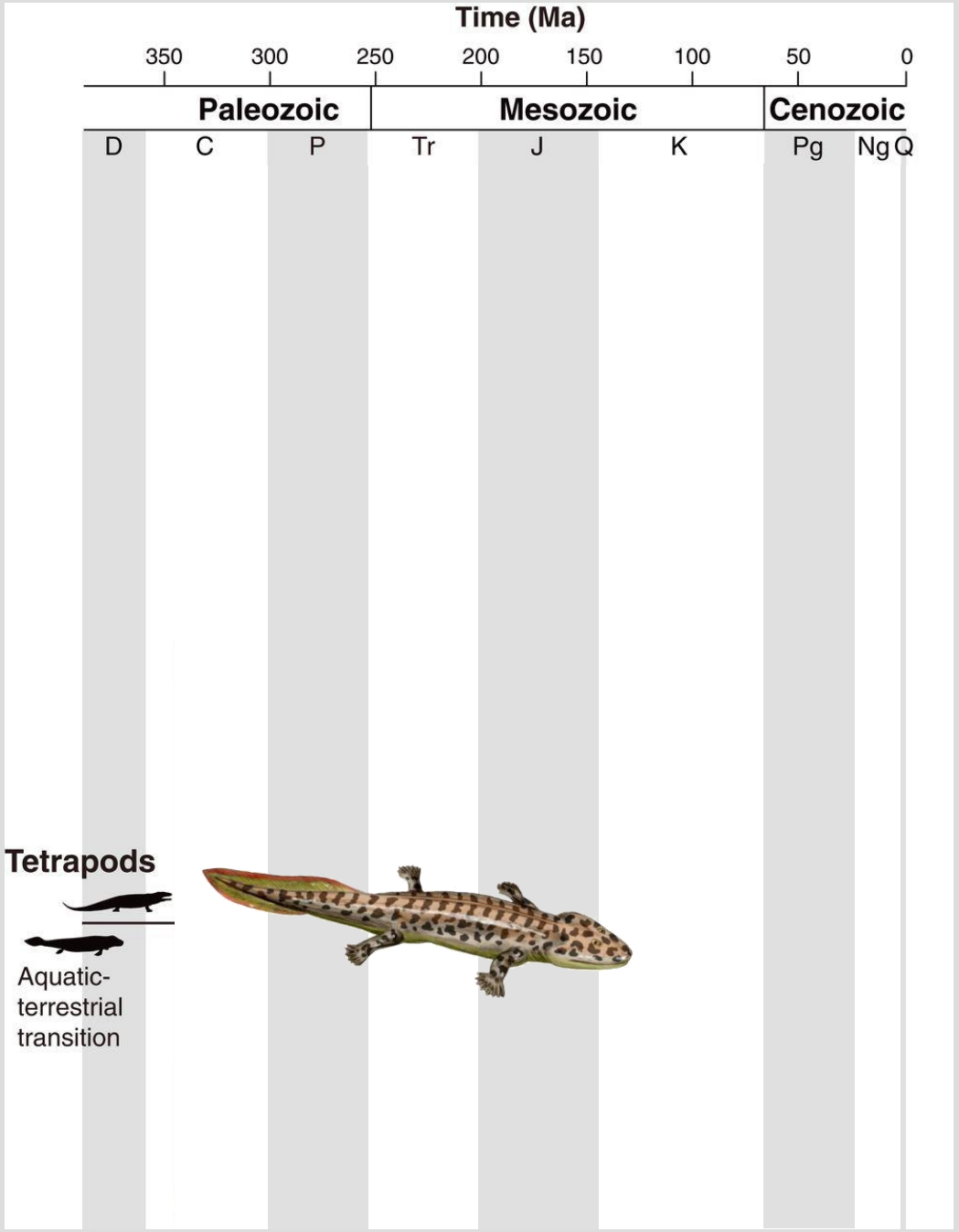
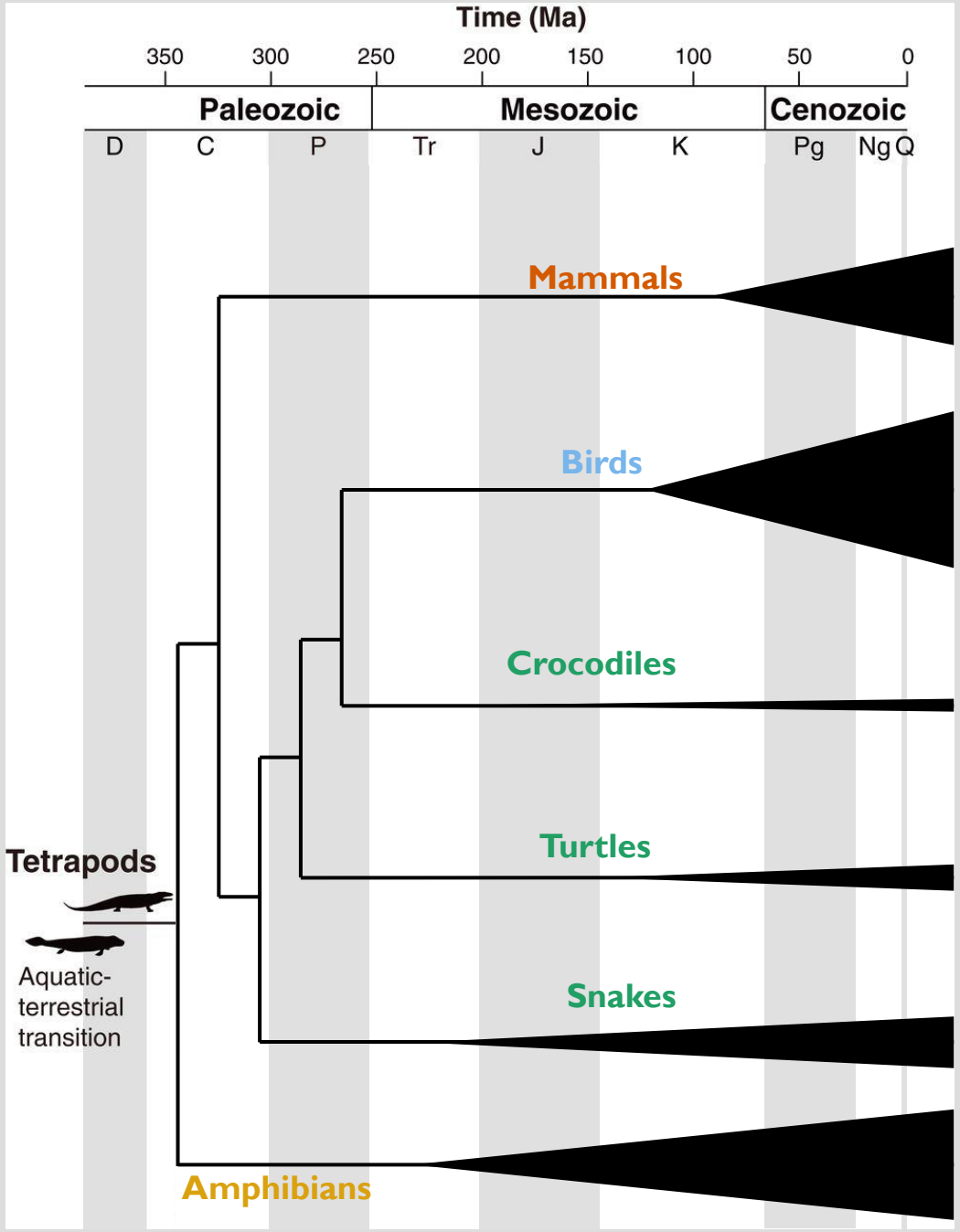
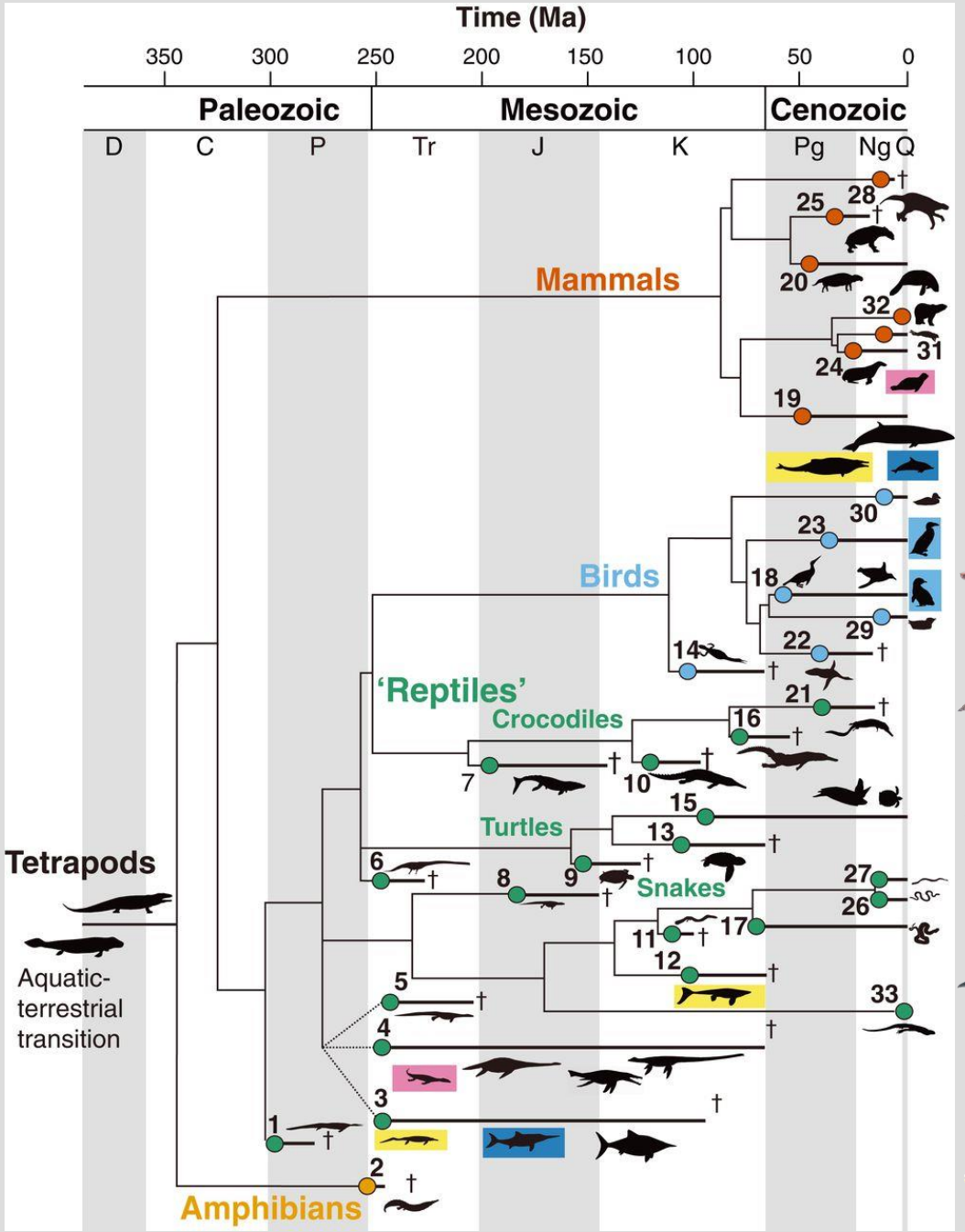
SCHOOL OF EARTH, ENERGY & ENVIRONMENTAL SCIENCES
Geological Sciences

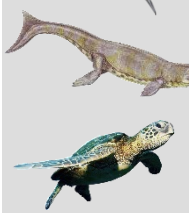


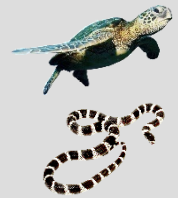
Modified from Kelley and Pyenson 2015, *Science*

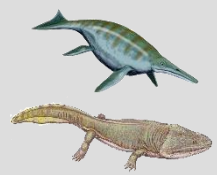


Modified from Kelley and Pyenson 2015, *Science*

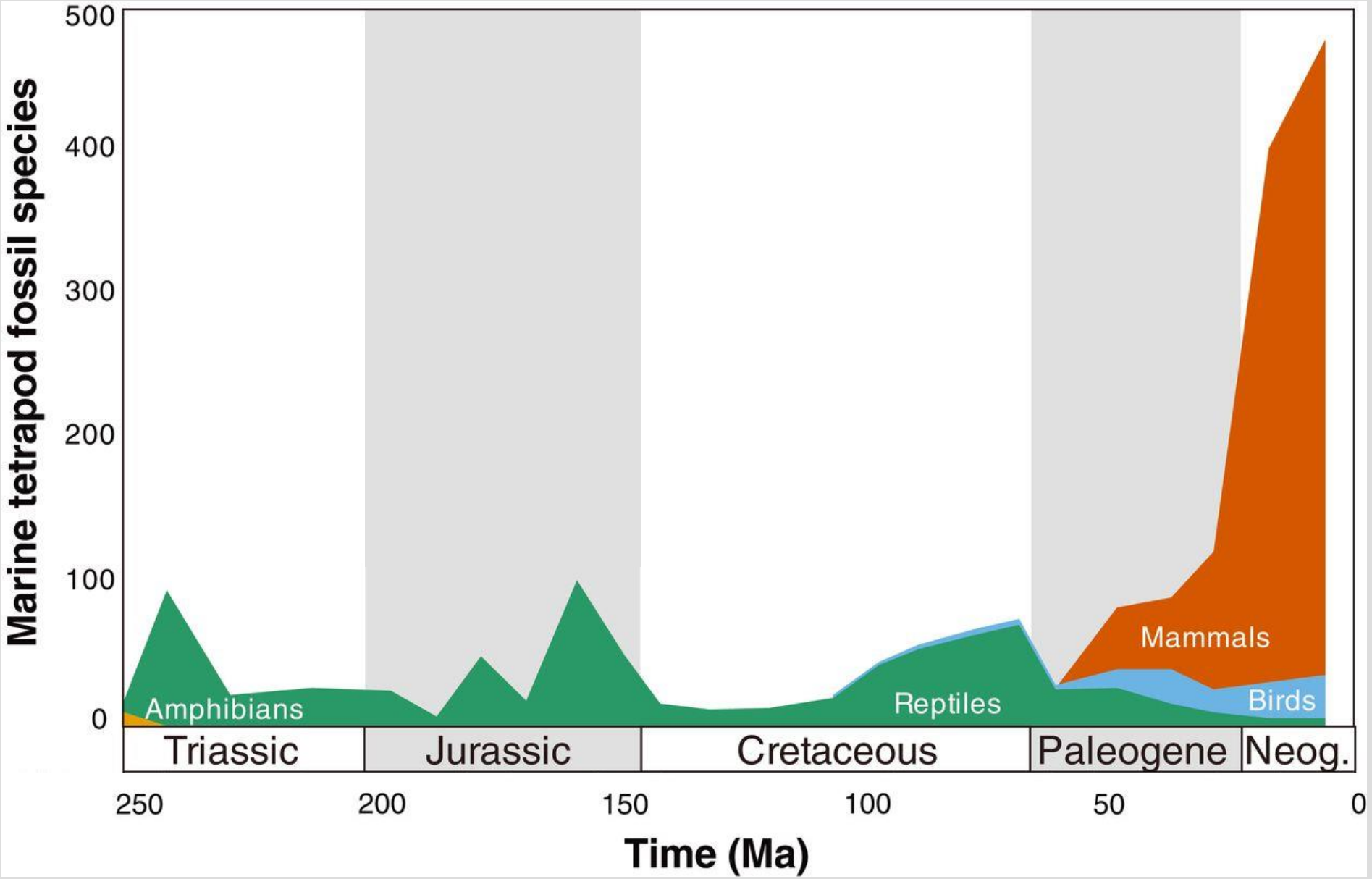




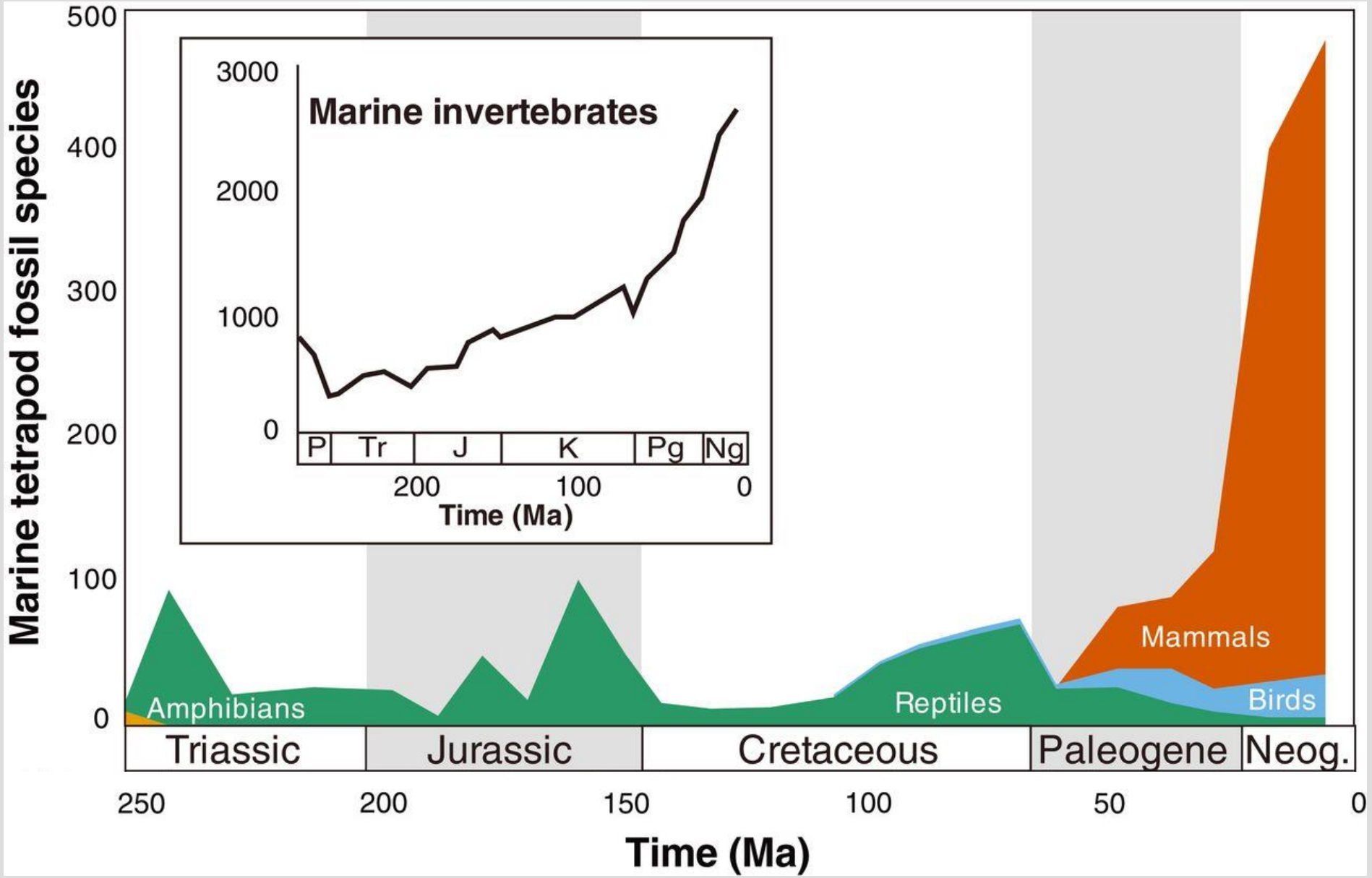




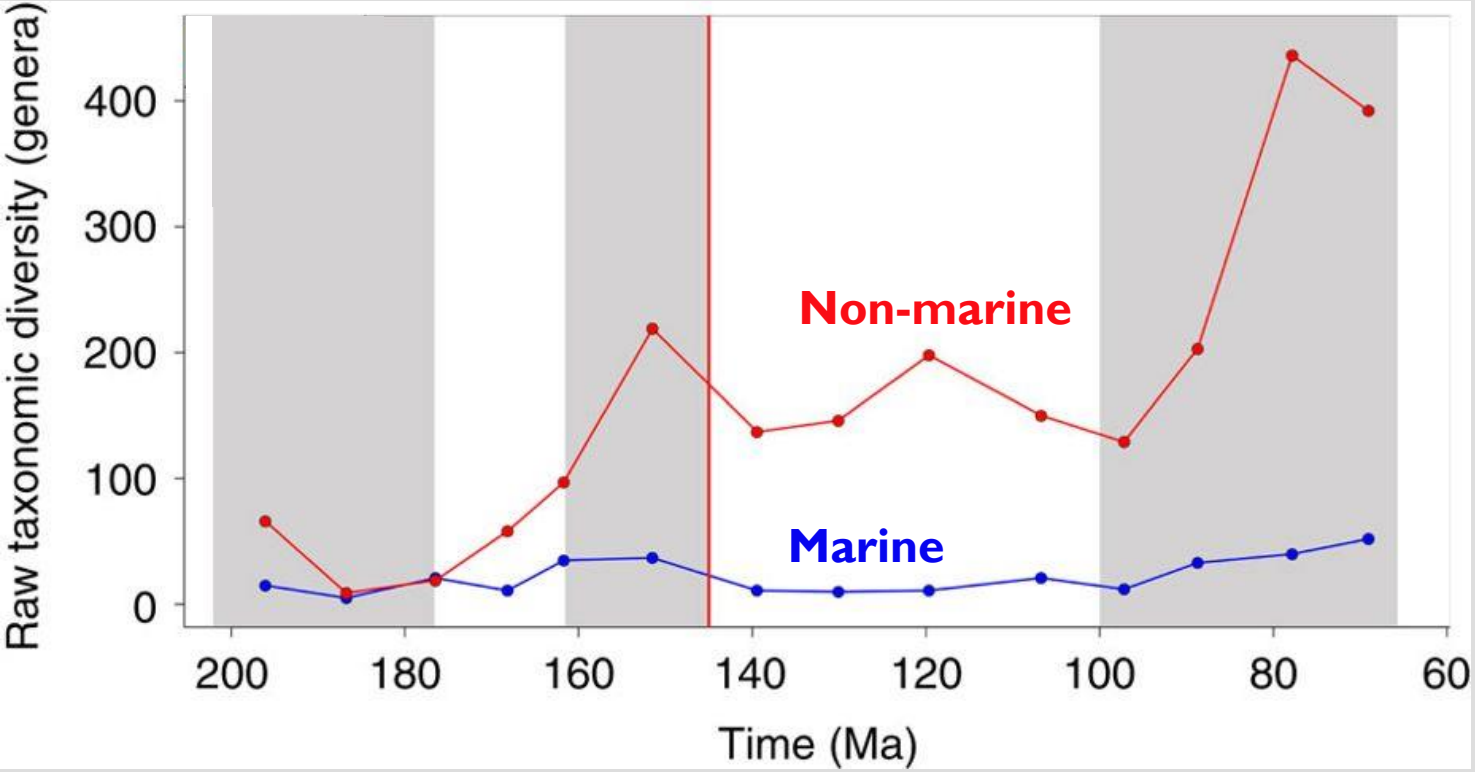
Kelley and Pyenson 2015, *Science*



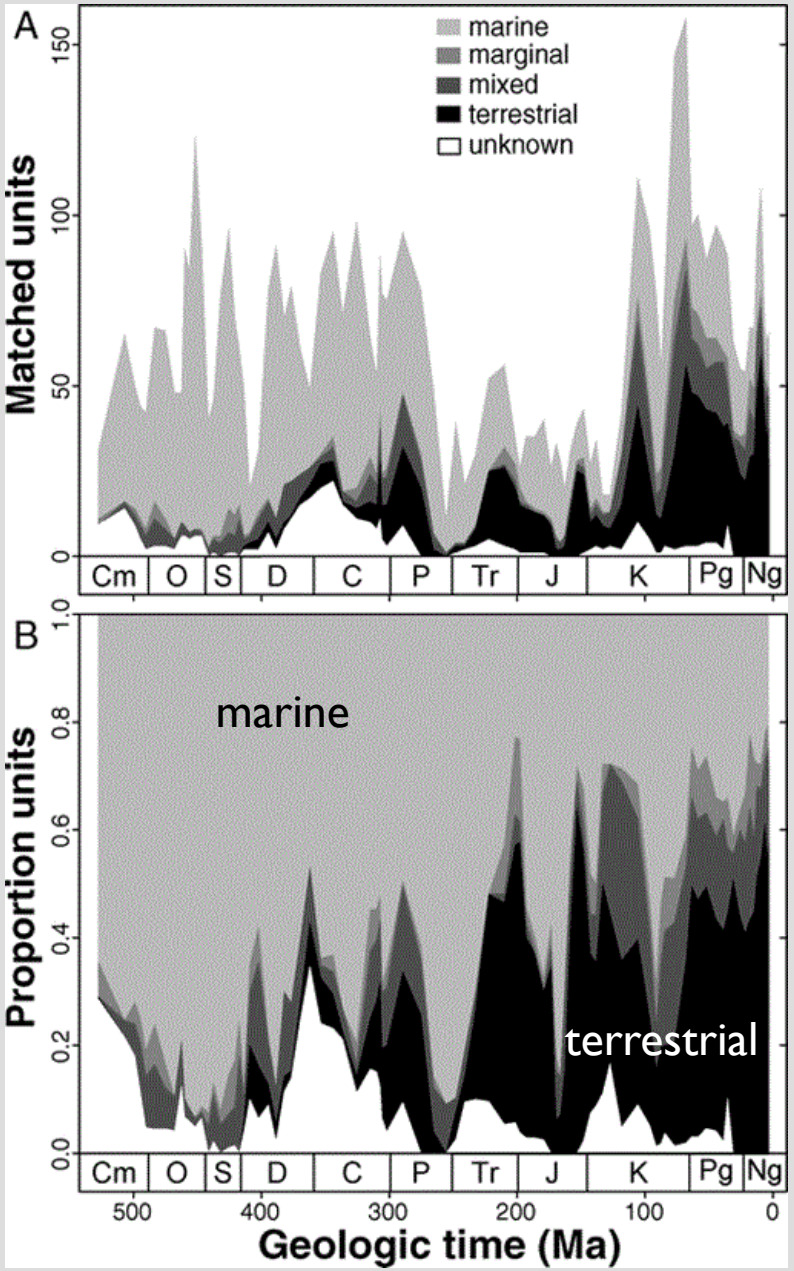
Modified from Kelley and Pyenson 2015, *Science*



Kelley and Pyenson 2015, *Science*



Modified from Tennant et al 2016, *Nature Communications*



Peters and Heim 2010, *Paleobiology*

- Lots of oxygen
- Very low salinity
- No buoyancy
- Low heat loss
- Low viscosity

- Less oxygen
- Very high salinity
- High buoyancy
- High heat loss
- High viscosity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DALLAS

PERMANENT LIFE IN THE OCEAN IS HARD*
*WHEN YOU'VE ADAPTED TO LIVING ON LAND

FOOD ACQUISITION

SALT BALANCE

THERMOREGULATION

PERMANENT LIFE IN THE OCEAN IS HARD*

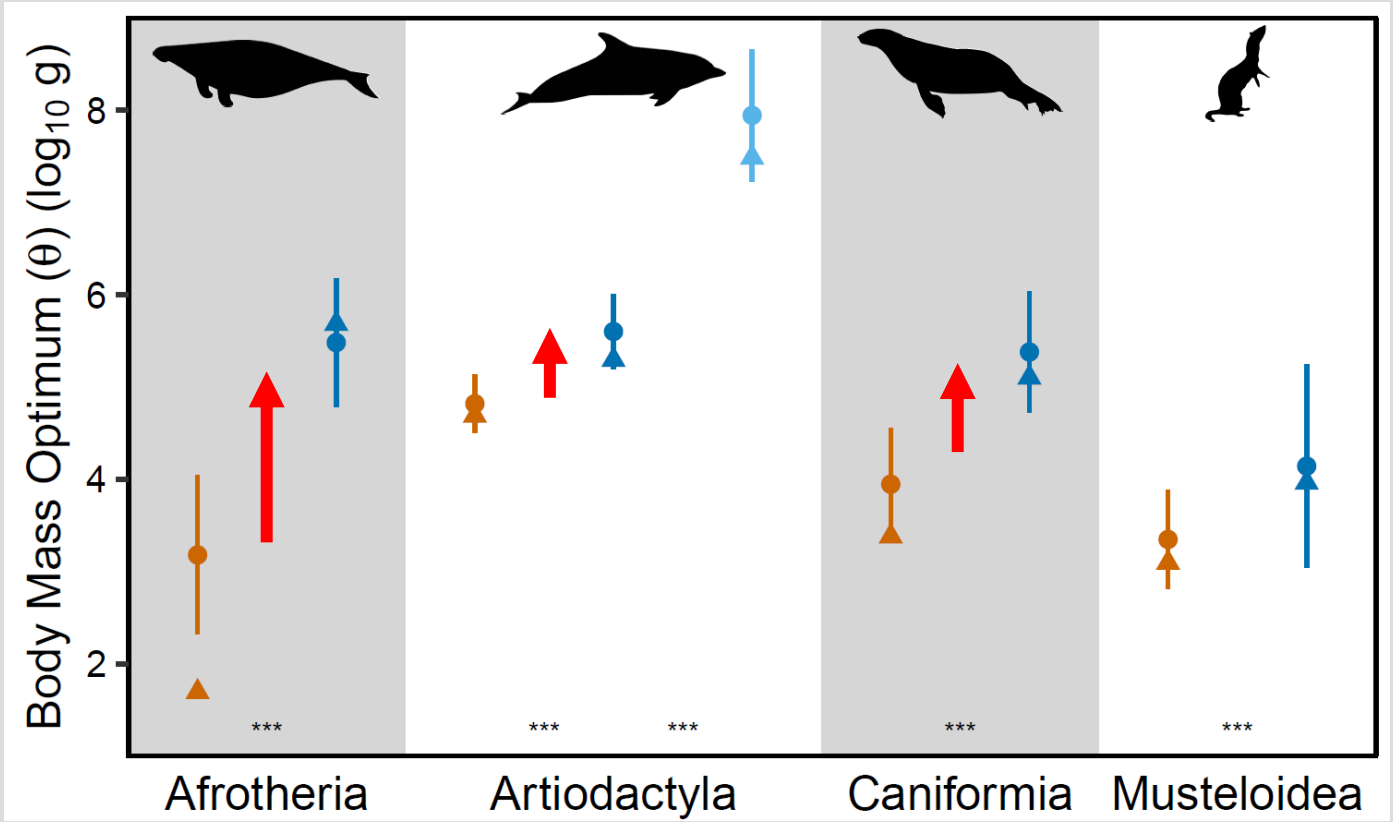
*WHEN YOU'VE ADAPTED TO LIVING ON LAND

DEHYDRATION

LOCOMOTION

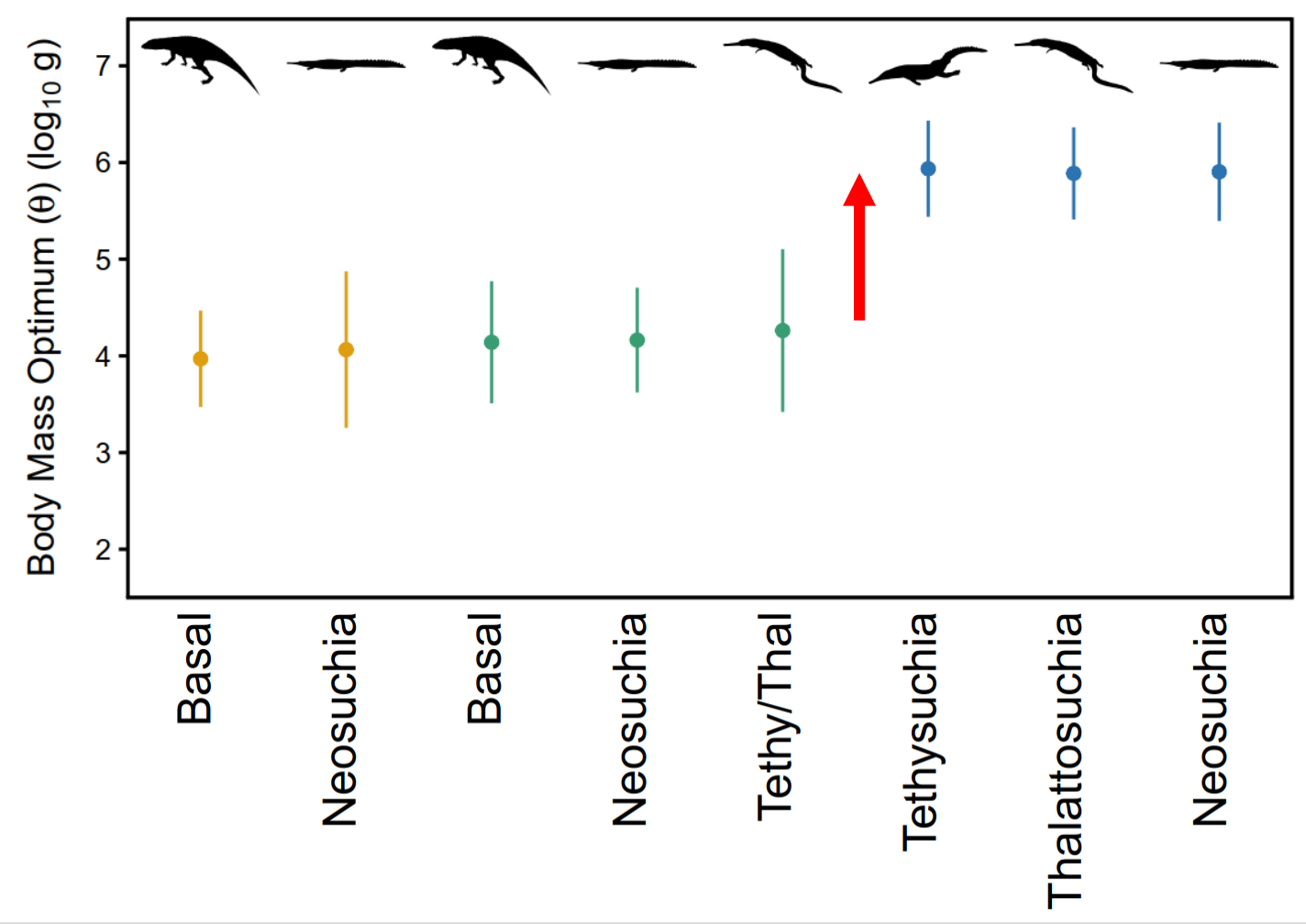
REPRODUCTION

MAMMALS GET MUCH BIGGER

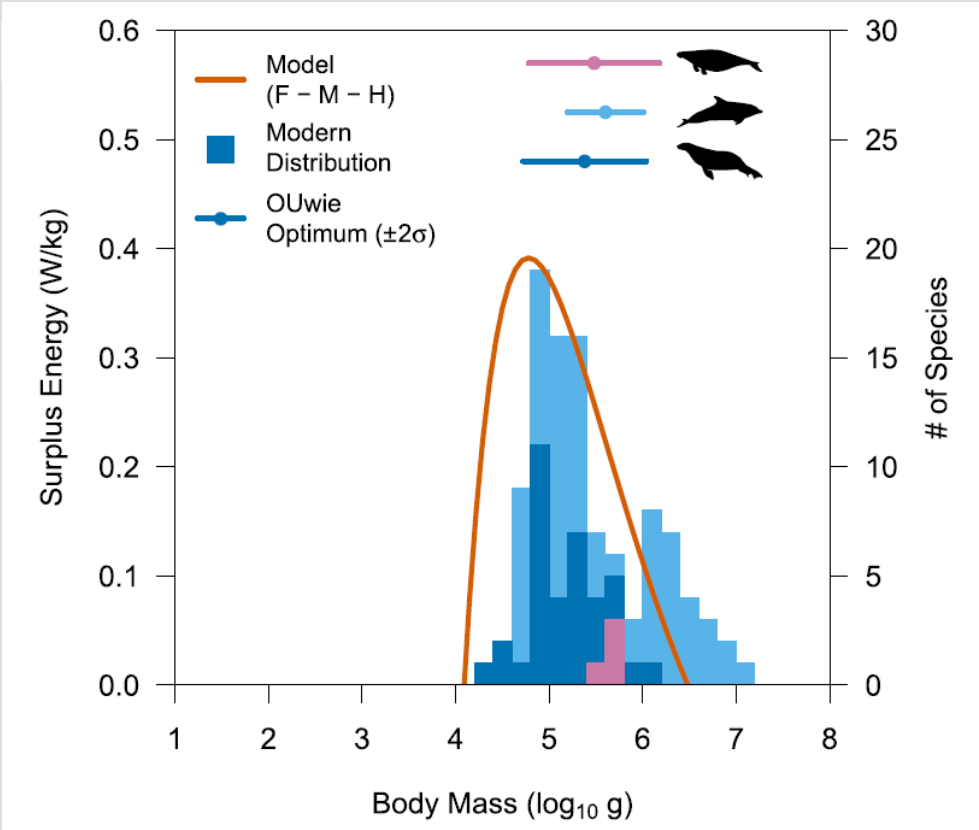


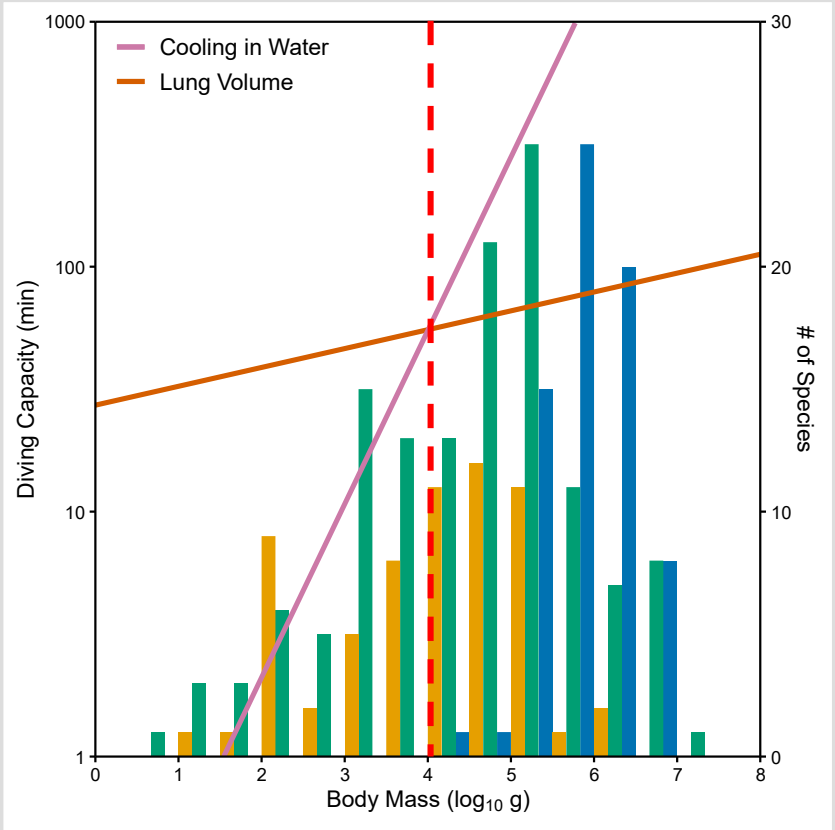
Modified from Gearty et al. 2018, *PNAS*

CROCS GET MUCH BIGGER TOO

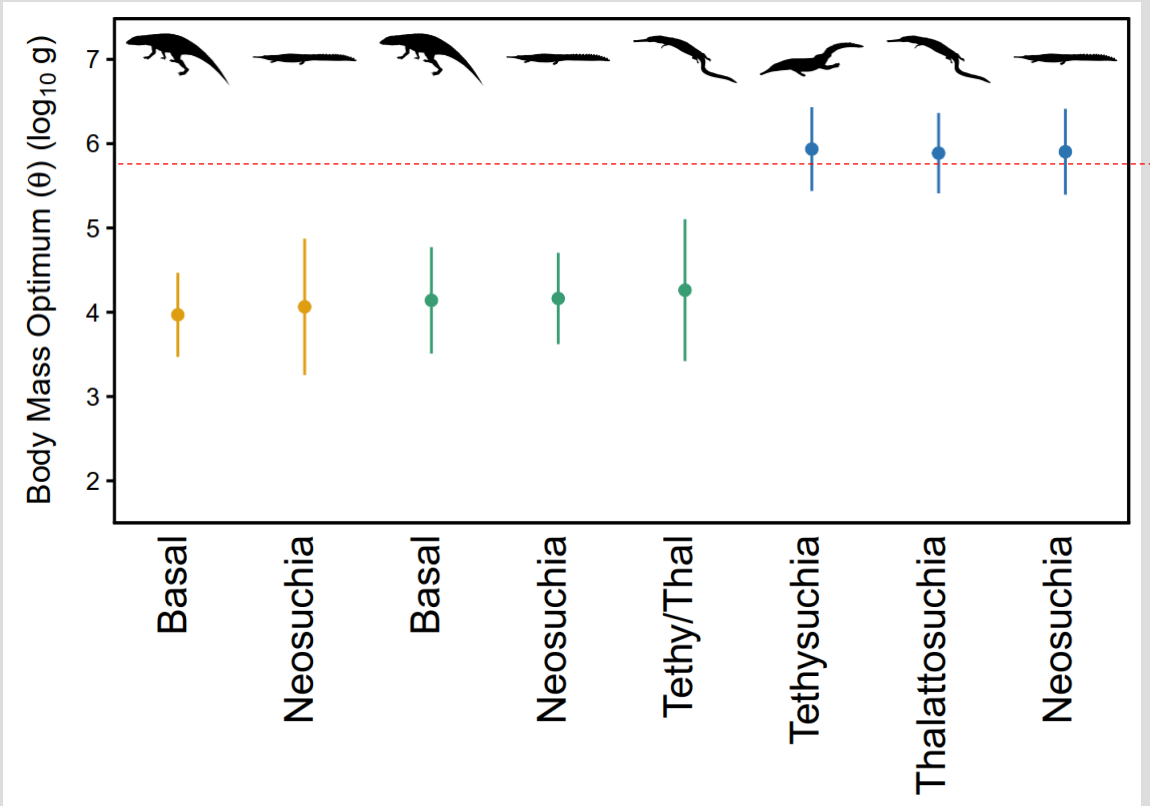


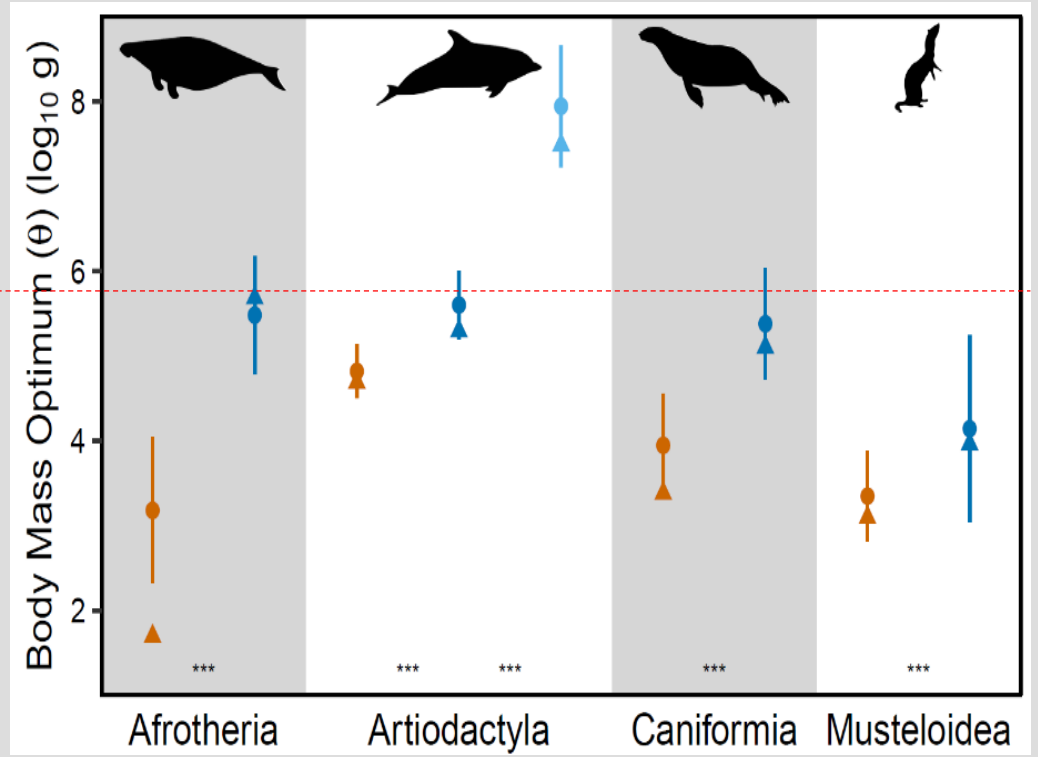
Gearty and Payne, in review, *Evolution*



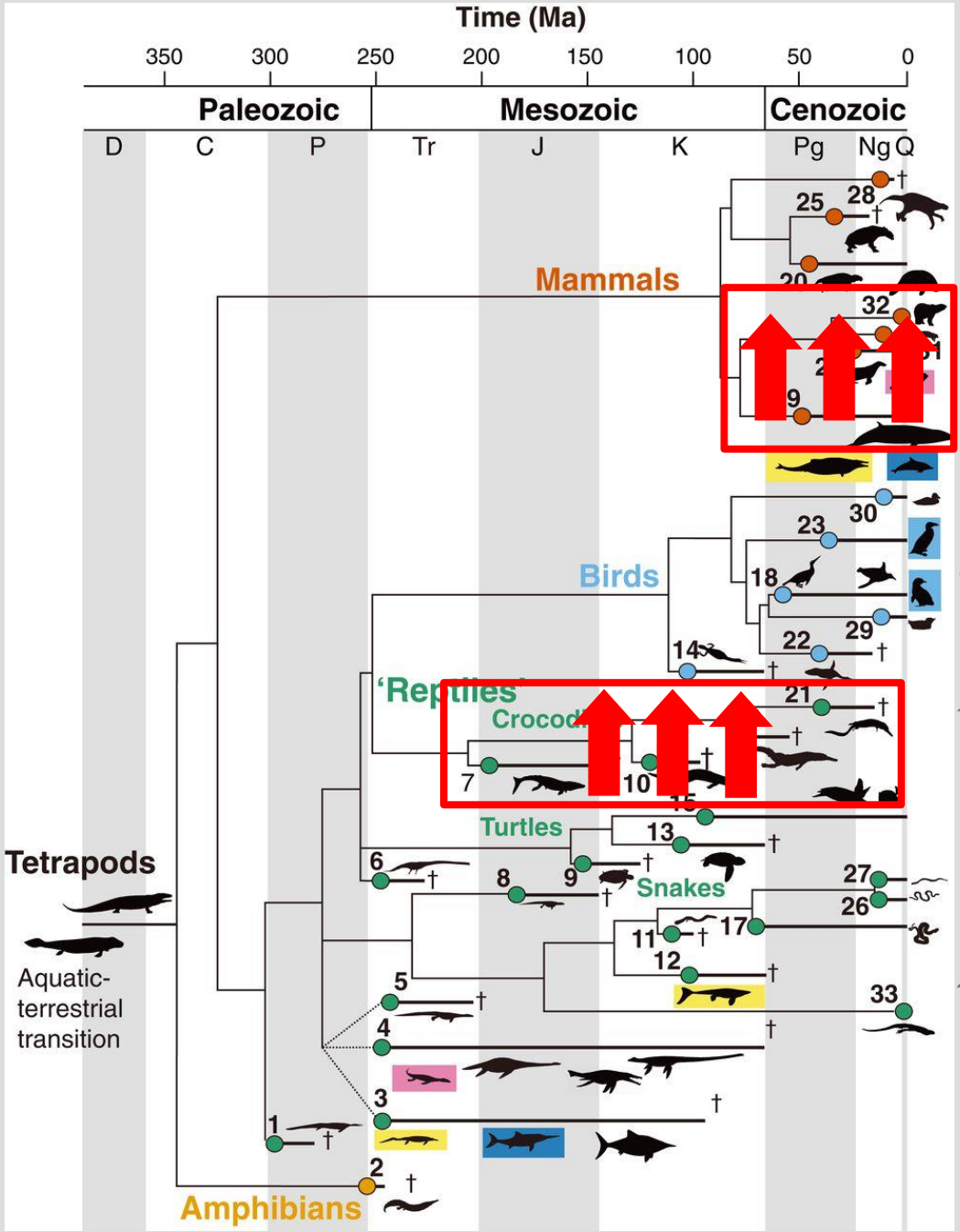


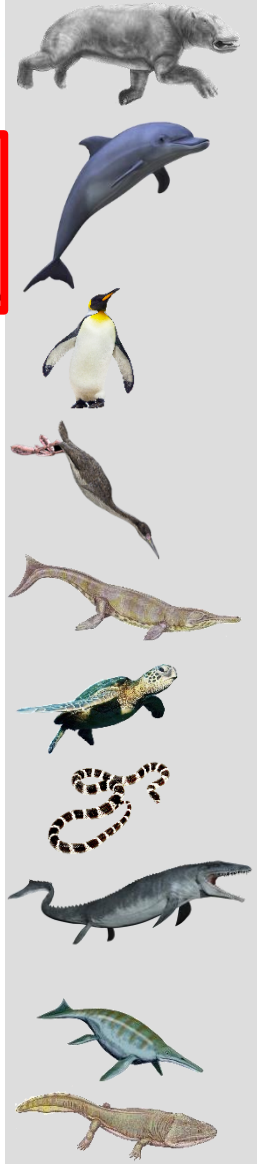
Gearty and Payne, in review, *Evolution*
Gearty et al. 2018, *PNAS*



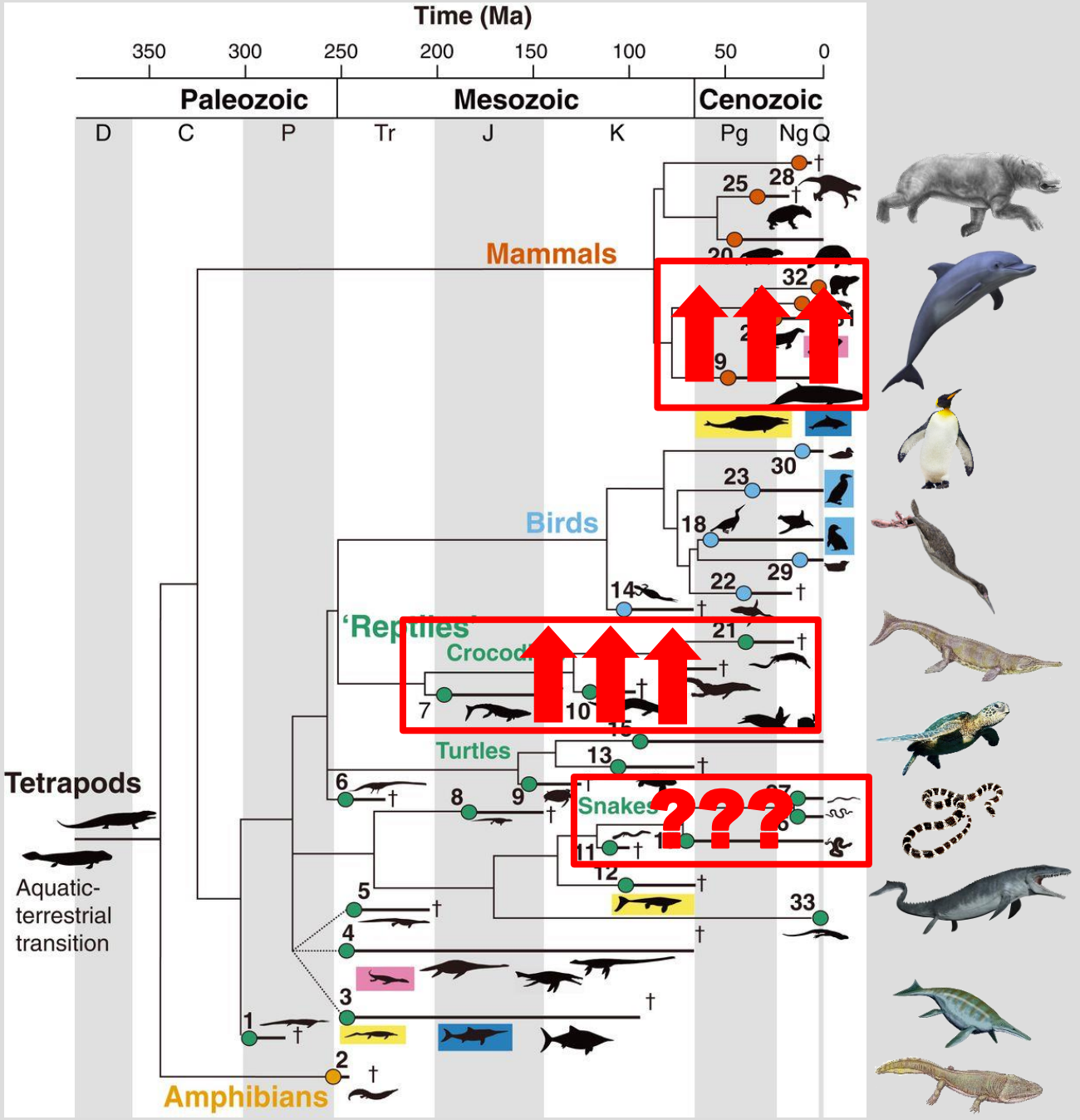


Gearty and Payne, in review, *Evolution*
Gearty et al. 2018, *PNAS*





Kelley and Pyenson 2015, *Science*



Kelley and Pyenson 2015, *Science*

SNAKES

wikipedia.org

PREVIOUS WORK

Fully-sampled phylogenies of squamates reveal evolutionary patterns in threat status

João Filipe Riva Tonini [a,*], Karen H. Beard [b], Rodrigo Barbosa Ferreira [b,c], Walter Jetz [d], R. Alexander Pyron [a]

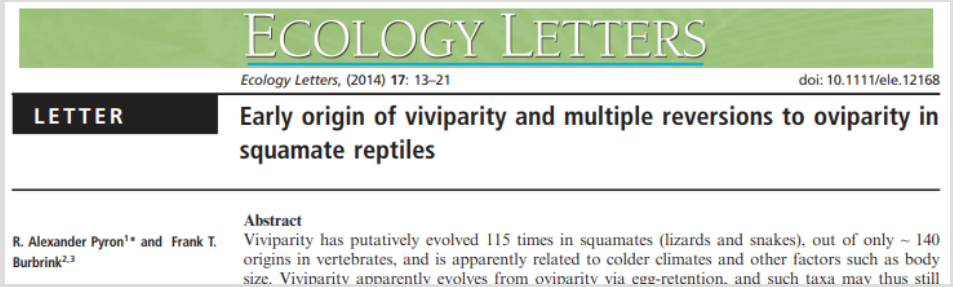
[a] Department of Biological Sciences, The George Washington University, 2029 G St NW, Washington, DC 20052, USA
[b] Department of Wildland Resources and the Ecology Center, Utah State University, Logan, UT 84322-5230, USA
[c] Laboratório de Ecologia de Populações e Conservação, Universidade Vila Velha, Rua Comissário José Dantas de Melo 21, Boa Vista, Vila Velha, ES 29102-920, Brazil
[d] Department of Ecology and Evolutionary Biology, Yale University, 165 Prospect Street, New Haven, CT 06520, USA

Global Ecology and Biogeography, (Global Ecol. Biogeogr.) (2016) 25, 187–197

RESEARCH PAPER

Body sizes and diversification rates of lizards, snakes, amphisbaenians and the tuatara

Anat Feldman[1], Niv Sabath[2], R. Alexander Pyron[3], Itay Mayrose[2] and Shai Meiri[1]*



ECOLOGY LETTERS

Ecology Letters, (2014) 17: 13–21 doi: 10.1111/ele.12168

LETTER

Early origin of viviparity and multiple reversions to oviparity in squamate reptiles

R. Alexander Pyron[1]* and Frank T. Burbrink[2,3]

Abstract

Viviparity has putatively evolved 115 times in squamates (lizards and snakes), out of only ~ 140 origins in vertebrates, and is apparently related to colder climates and other factors such as body size. Viviparity apparently evolves from oviparity via egg-retention, and such taxa may thus still

Global Ecology and Biogeography, (Global Ecol. Biogeogr.) (2015) 24, 1433–1442

RESEARCH PAPER

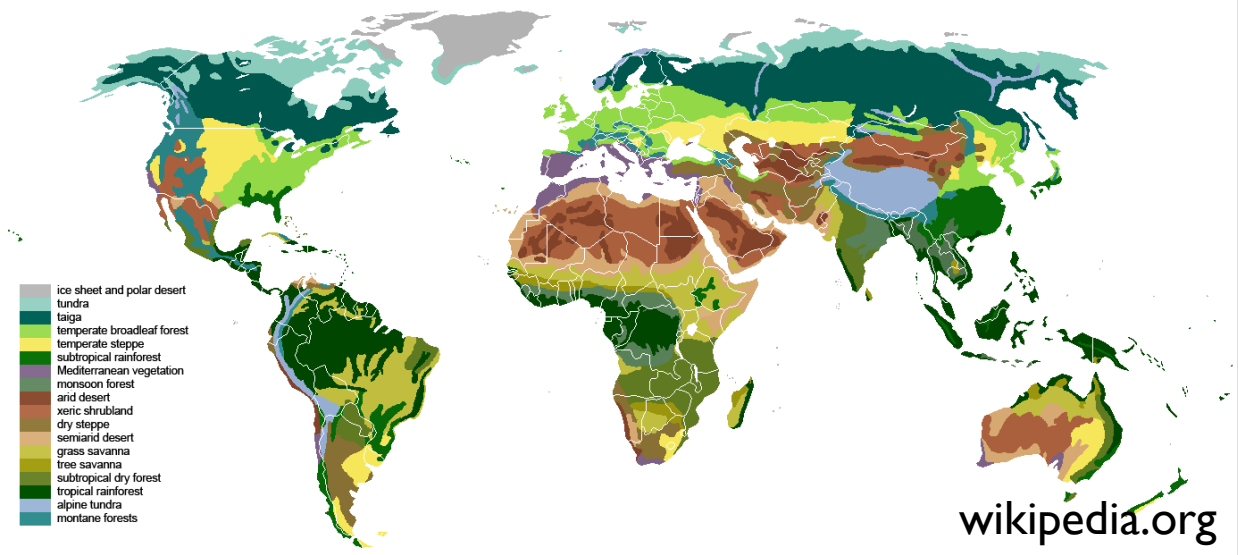
The geography of snake reproductive mode: a global analysis of the evolution of snake viviparity

Anat Feldman[1]*, Aaron M. Bauer[2], Fernando Castro-Herrera[3], Laurent Chirio[4], Indraneil Das[5], Tiffany M. Doan[6], Erez Maza[1], Danny Meirte[7], Cristiano de Campos Nogueira[8], Zoltán Tamás Nagy[9], Omar Torres-Carvajal[10], Peter Uetz[11] and Shai Meiri[1]

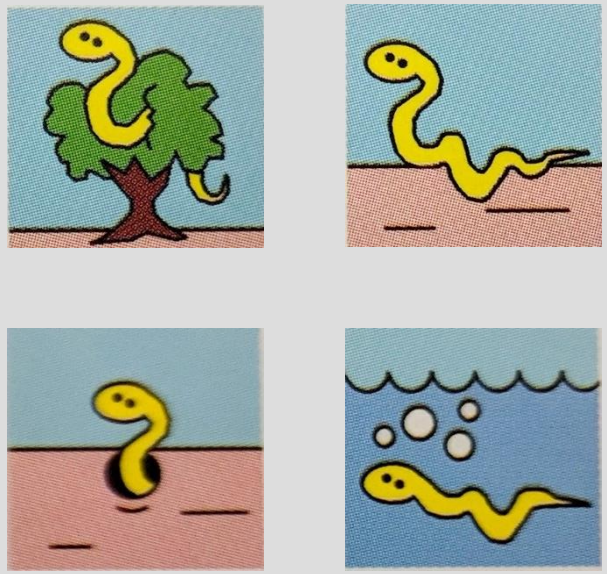
- Phylogeny ➡ Timescaled with ape::chronos() with fossil calibrations
- Body mass (g)
- Reproductive mode (eggs vs. live birth)
- Reproductive mode (eggs vs. live birth)
- Average temperature
- Average elevation

HABITAT DATA COLLECTION

BIOME



TIERING



Marques, Eterovic, and Sazima 2012

HABITAT DATA COLLECTION

BIOME

- Marine
- Brackish
- Freshwater
- Semi-aquatic
- Forest
- Grassland
- Desert
- Tundra/montane

TIERING

- Arboreal
- Scansorial (“semi-arboreal” or “climber)
- Surficial (“terrestrial”)
- Semi-fossorial (occasional diggers)
- Fossorial (“digger”)
- Aquatic

HABITAT DATA COLLECTION

BIOME

- Marine
- Brackish
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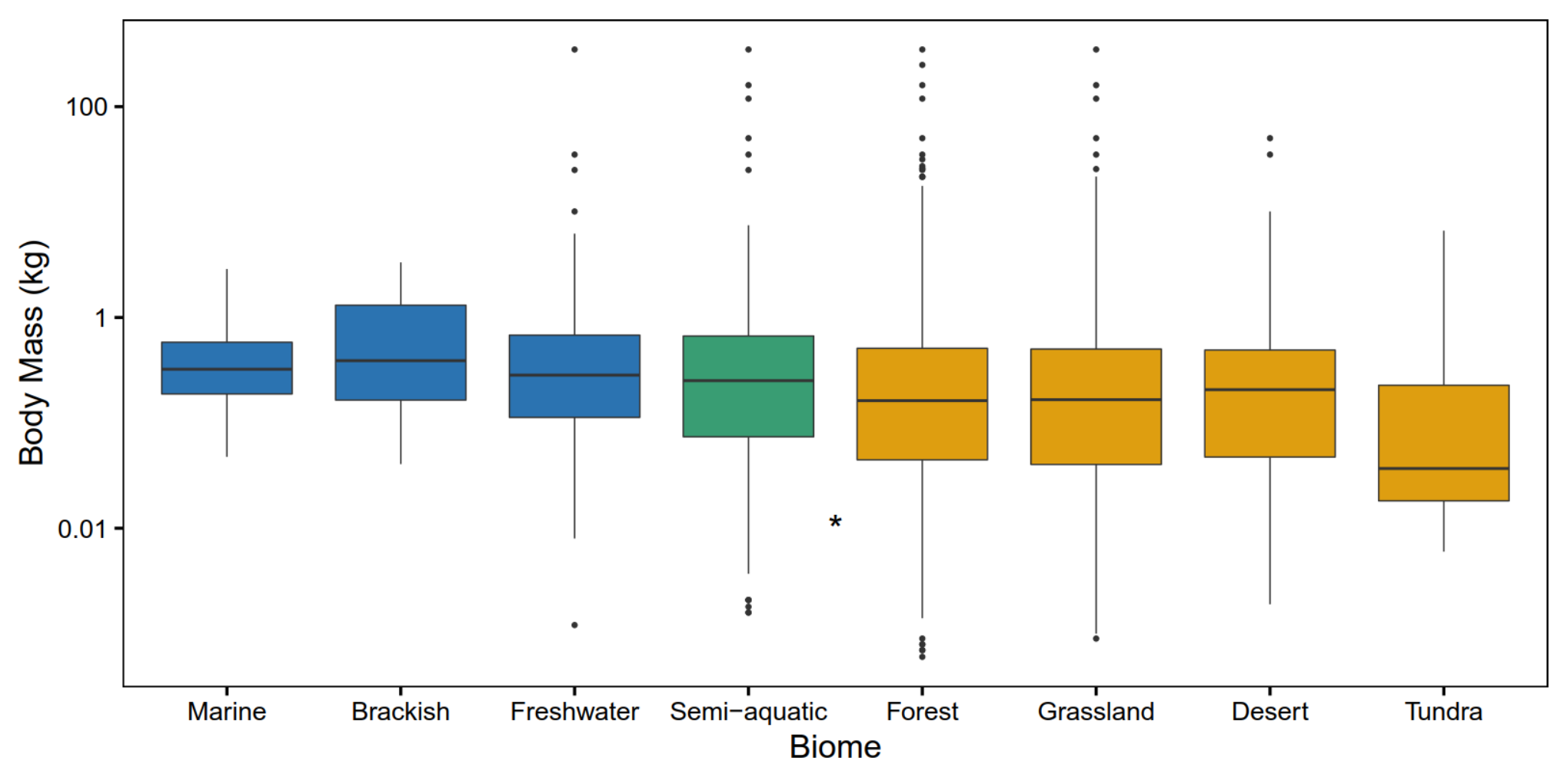
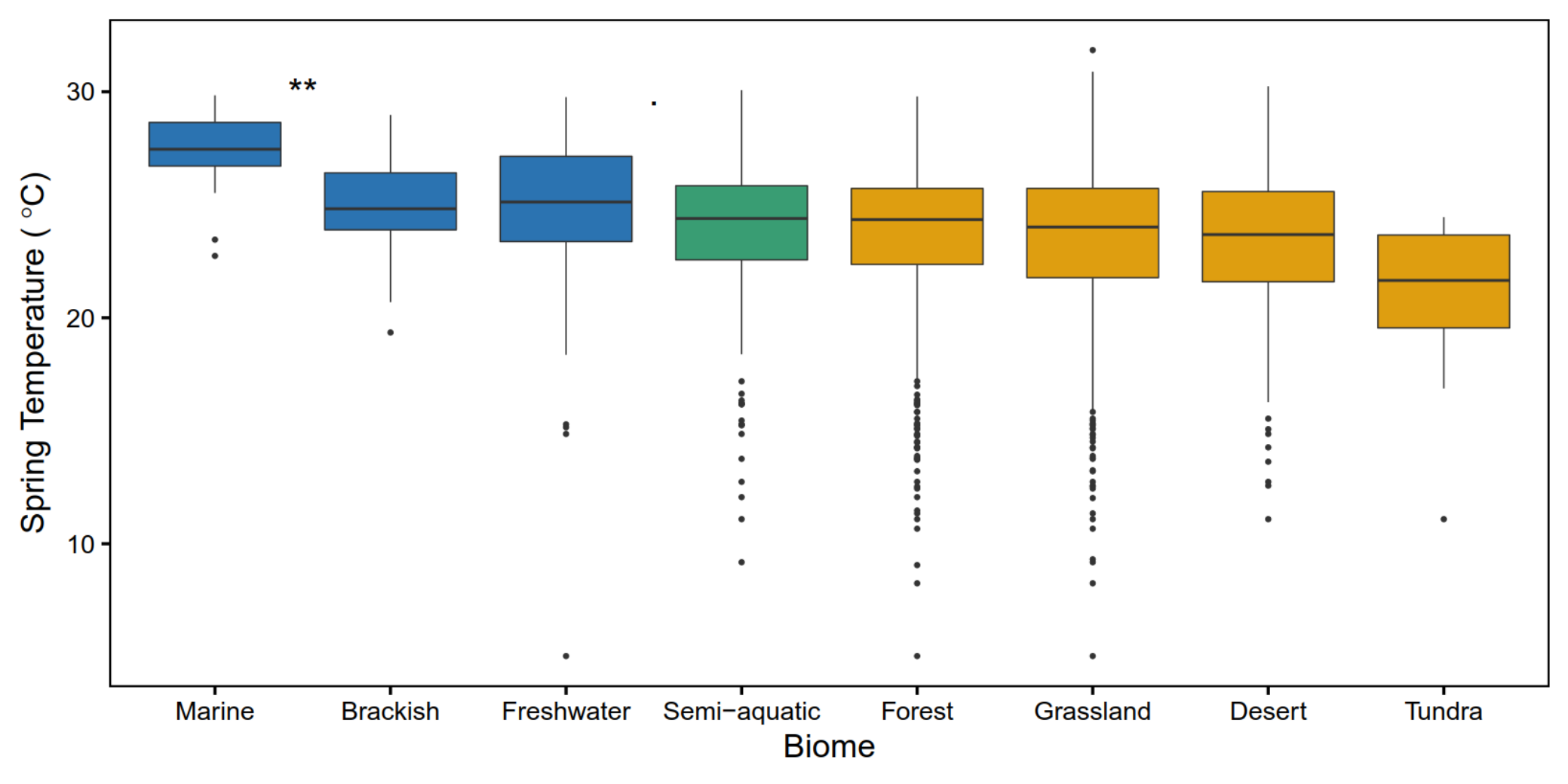
- Surficial (“terrestrial”)
- Semi-fossorial (occasional diggers)
- Fossorial (“digger”)
- Aquatic

BODY SIZE BY BIOME



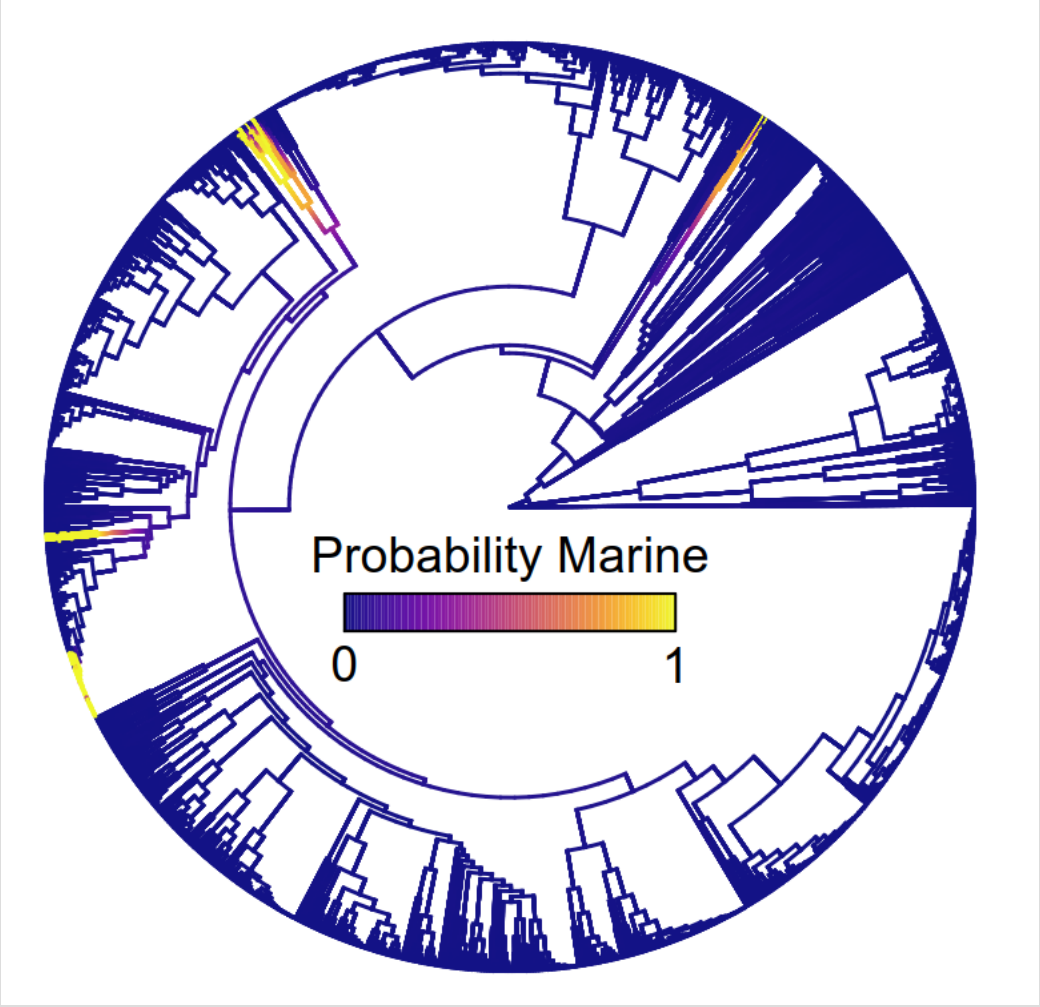
WAIT, HOW?

TEMPERATURE BY BIOME

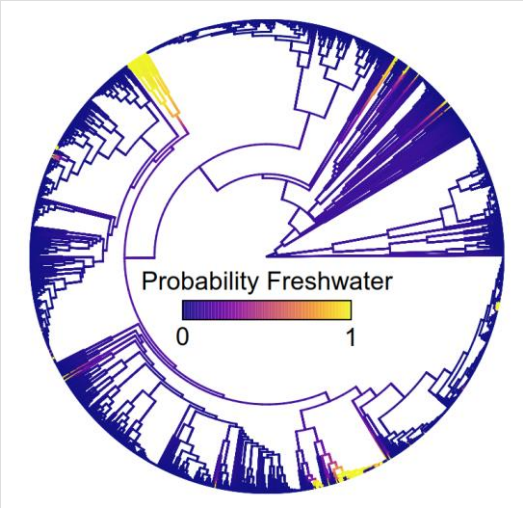


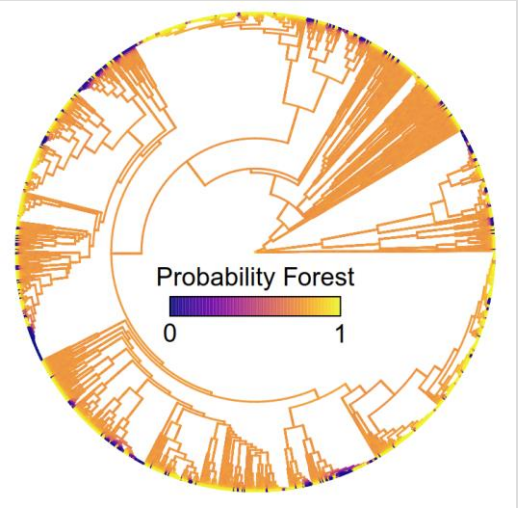
WHICH ADAPTATIONS/CONDITIONS PRECEDED THE MARINE INVASIONS? (PERHAPS ENABLING THEM)

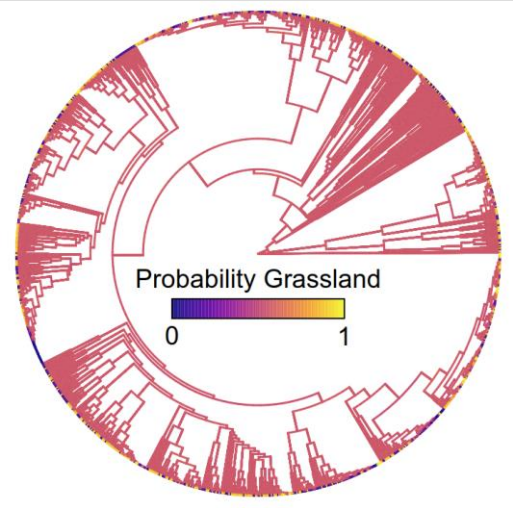
FIRST, RECONSTRUCT WHEN THE MARINE INVASIONS OCCURRED

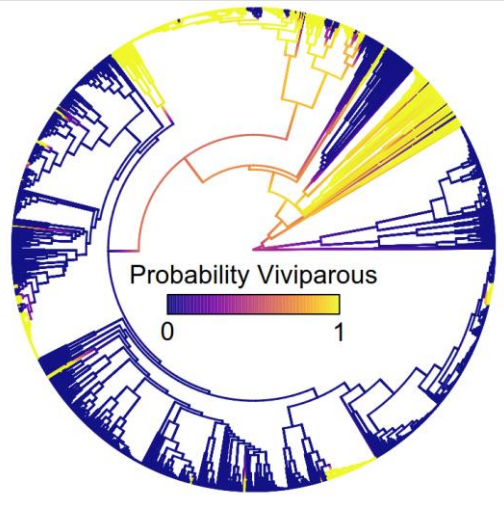


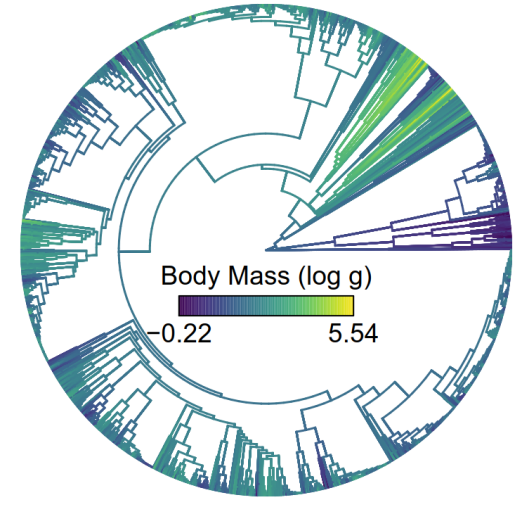
THEN, RECONSTRUCT OTHER TRAITS AND ENVIRONMENTAL VARIABLES

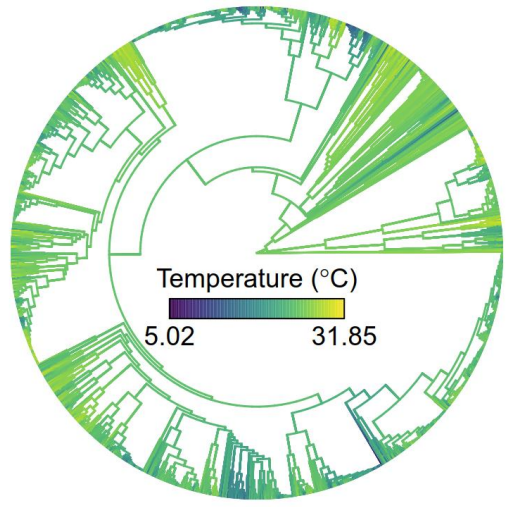


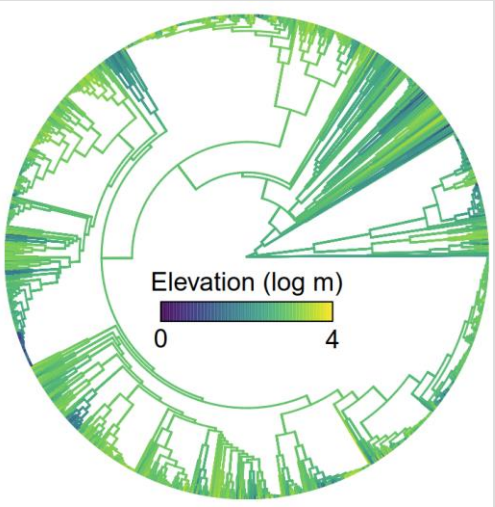




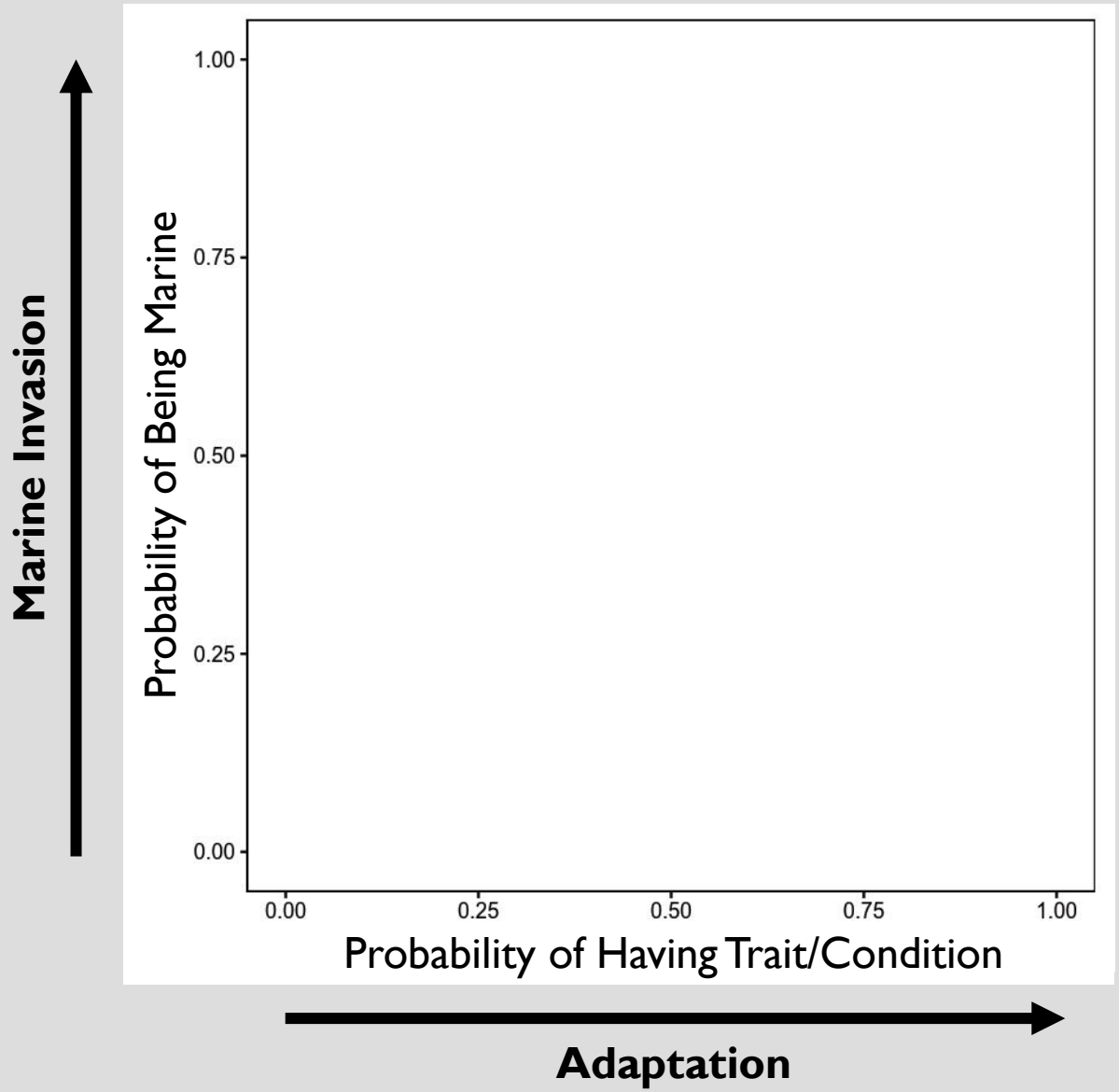




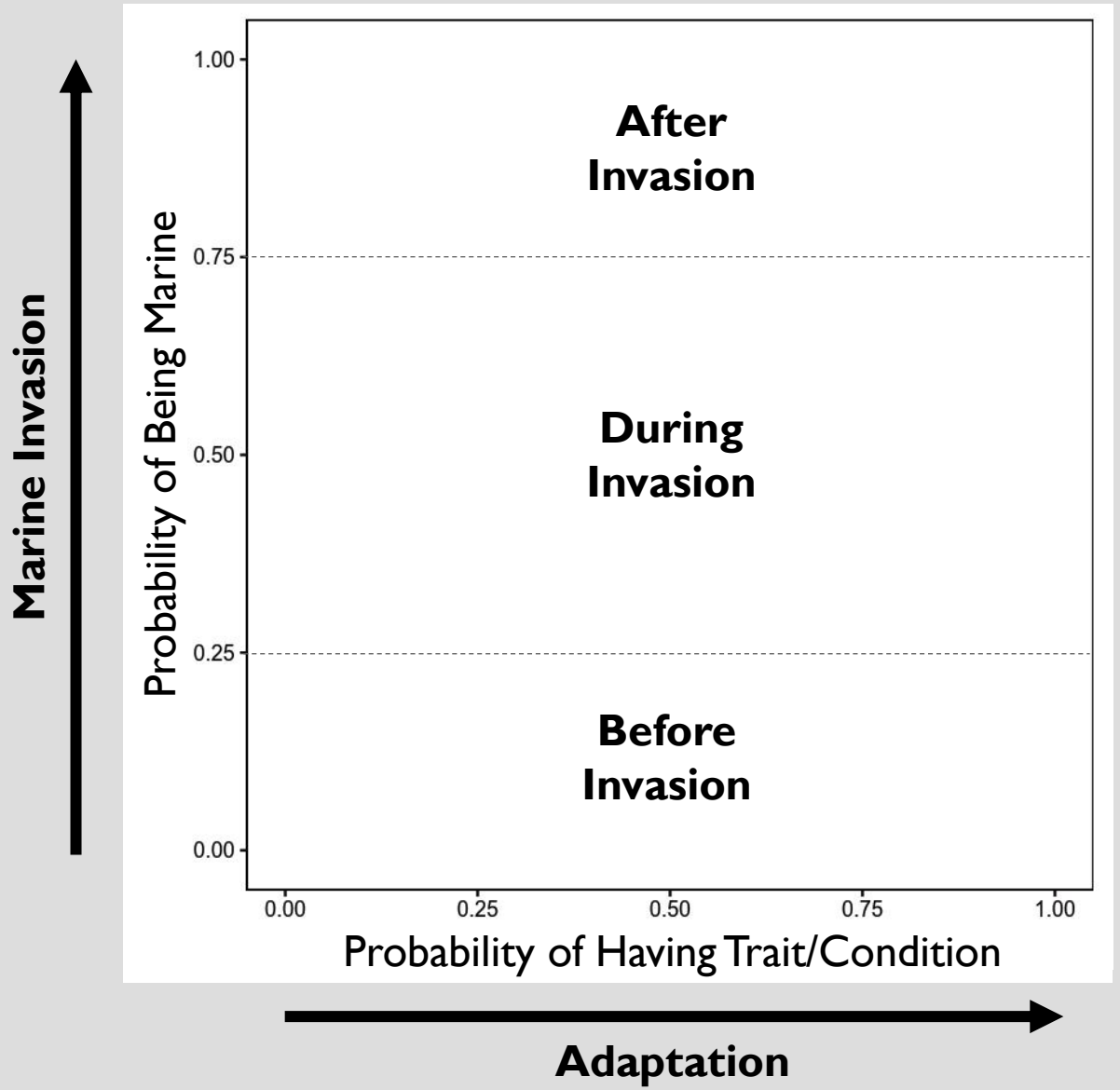




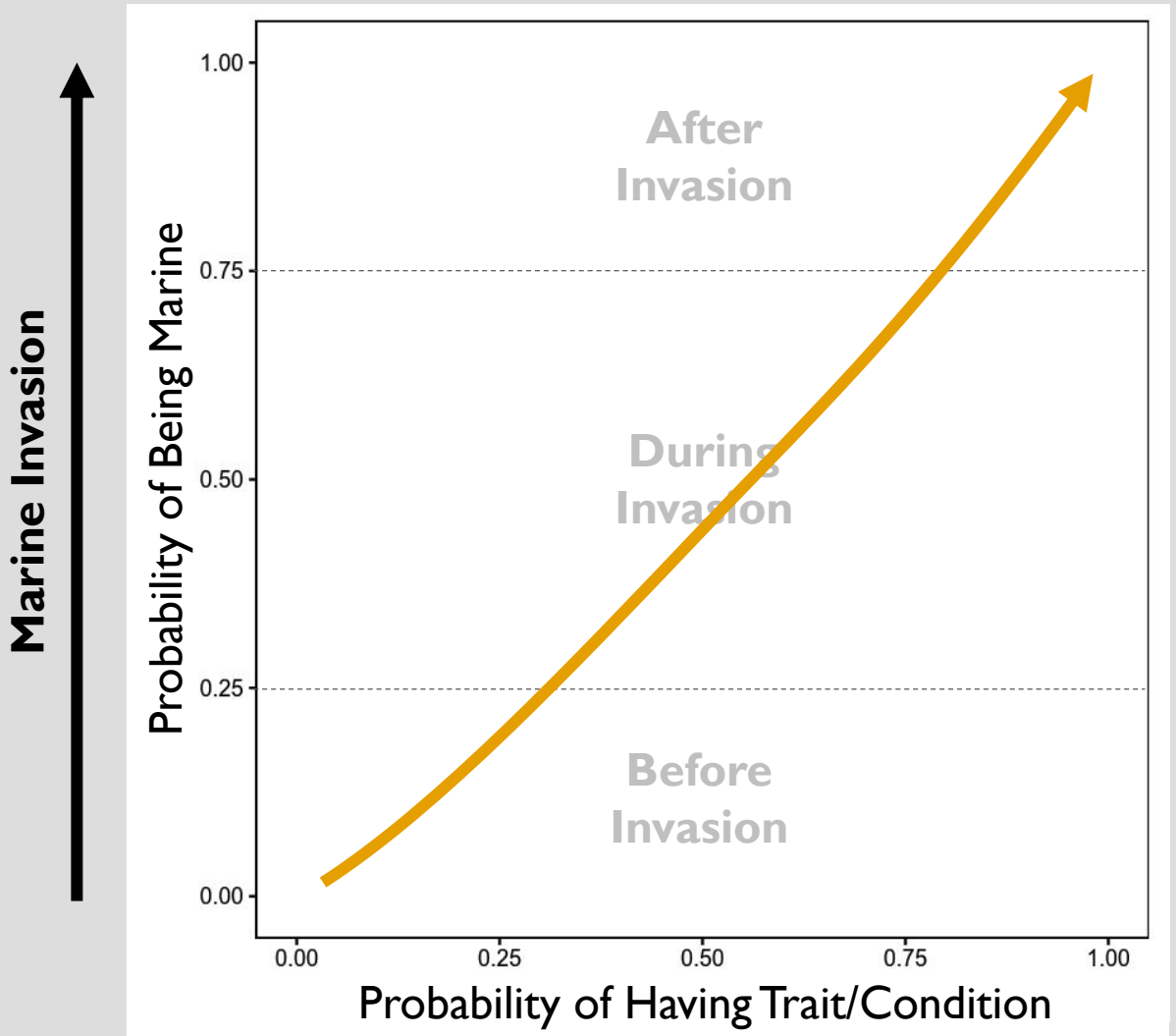
JOINT RECONSTRUCTIONS



JOINT RECONSTRUCTIONS

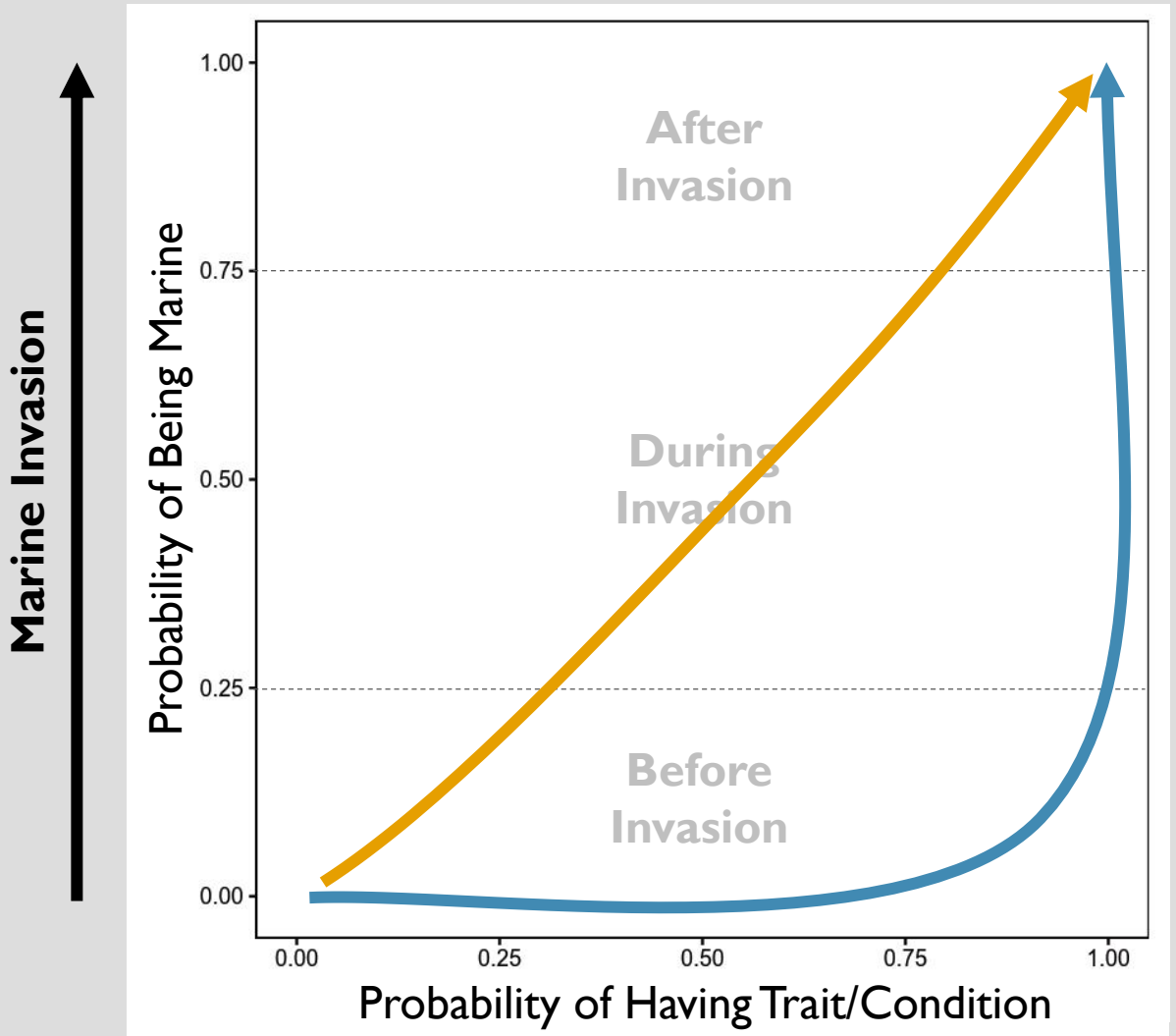


JOINT RECONSTRUCTIONS



Adaptation

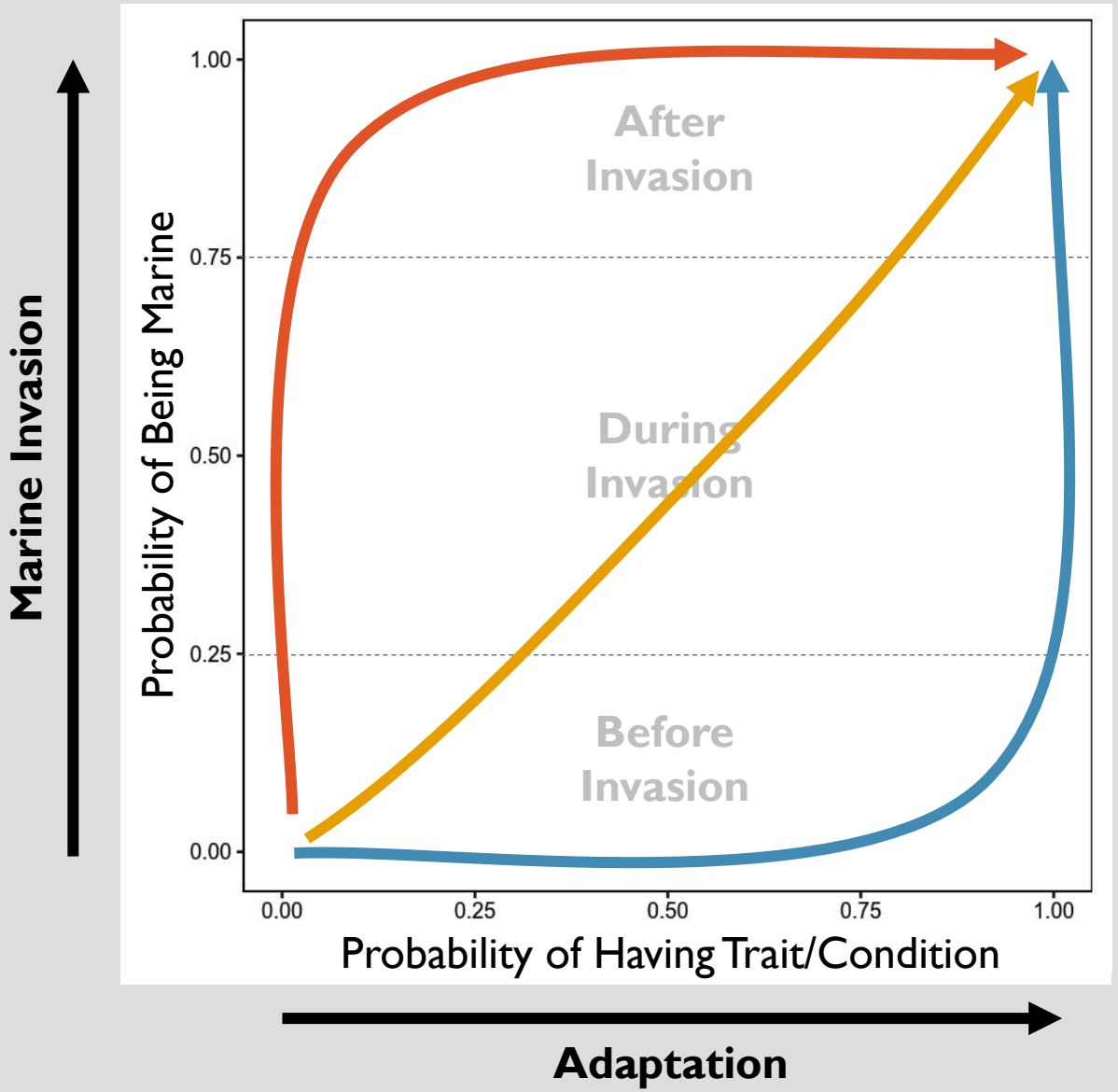
JOINT RECONSTRUCTIONS



Adaptation

Exaptation/Ecological Filtering

JOINT RECONSTRUCTIONS

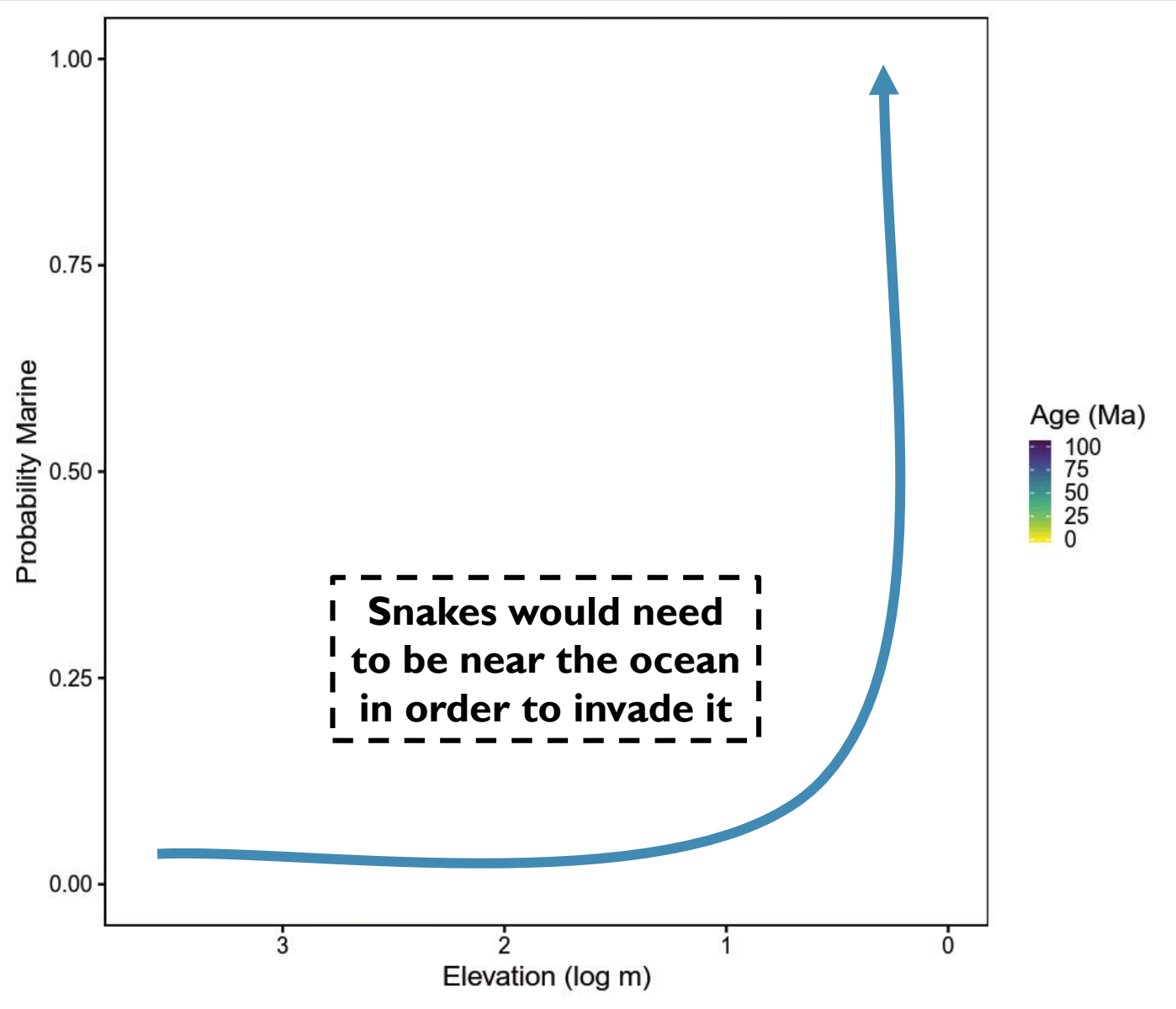


Adaptation

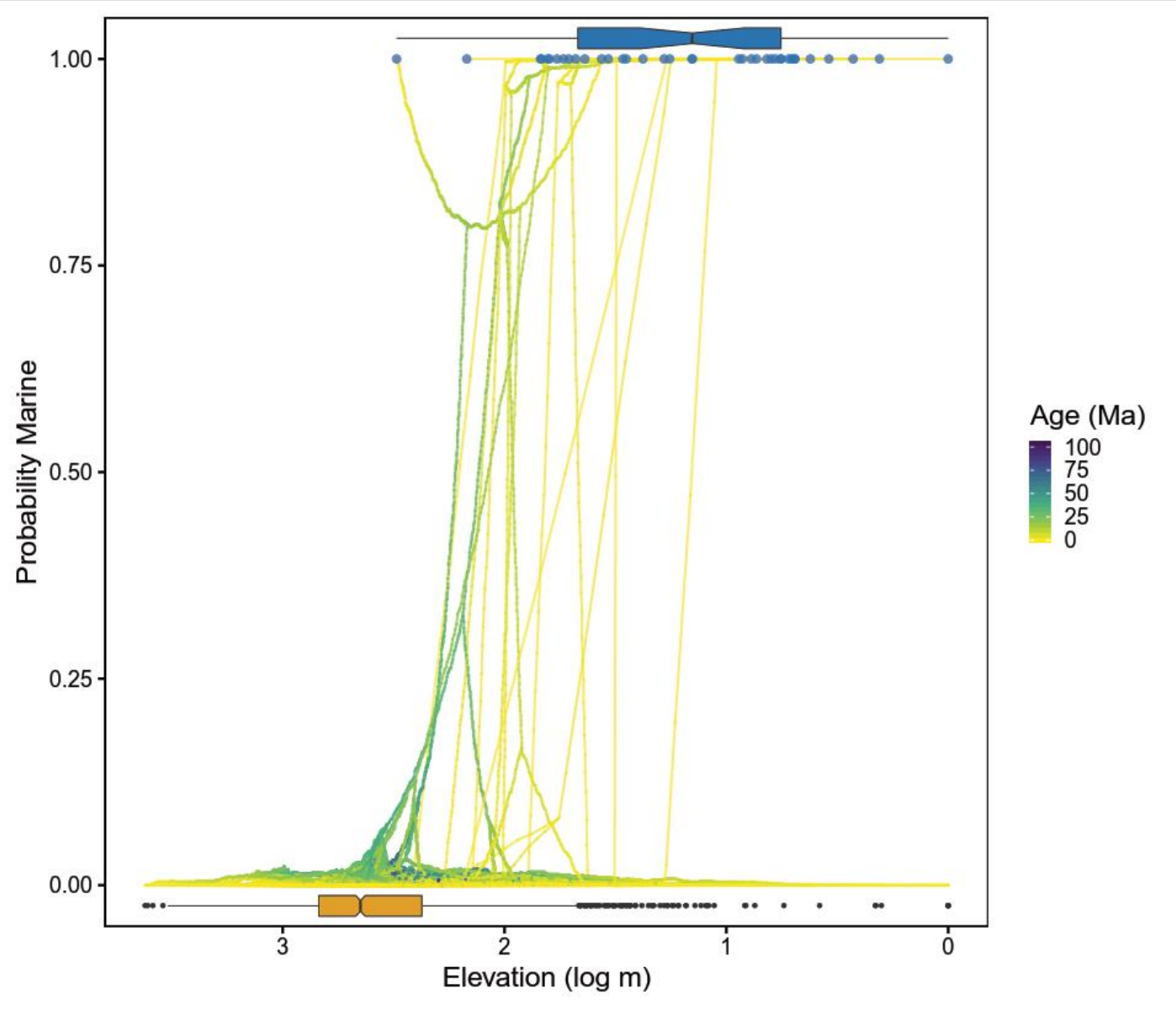
Exaptation/Ecological Filtering

Nonaptation (or adaptation for something else)

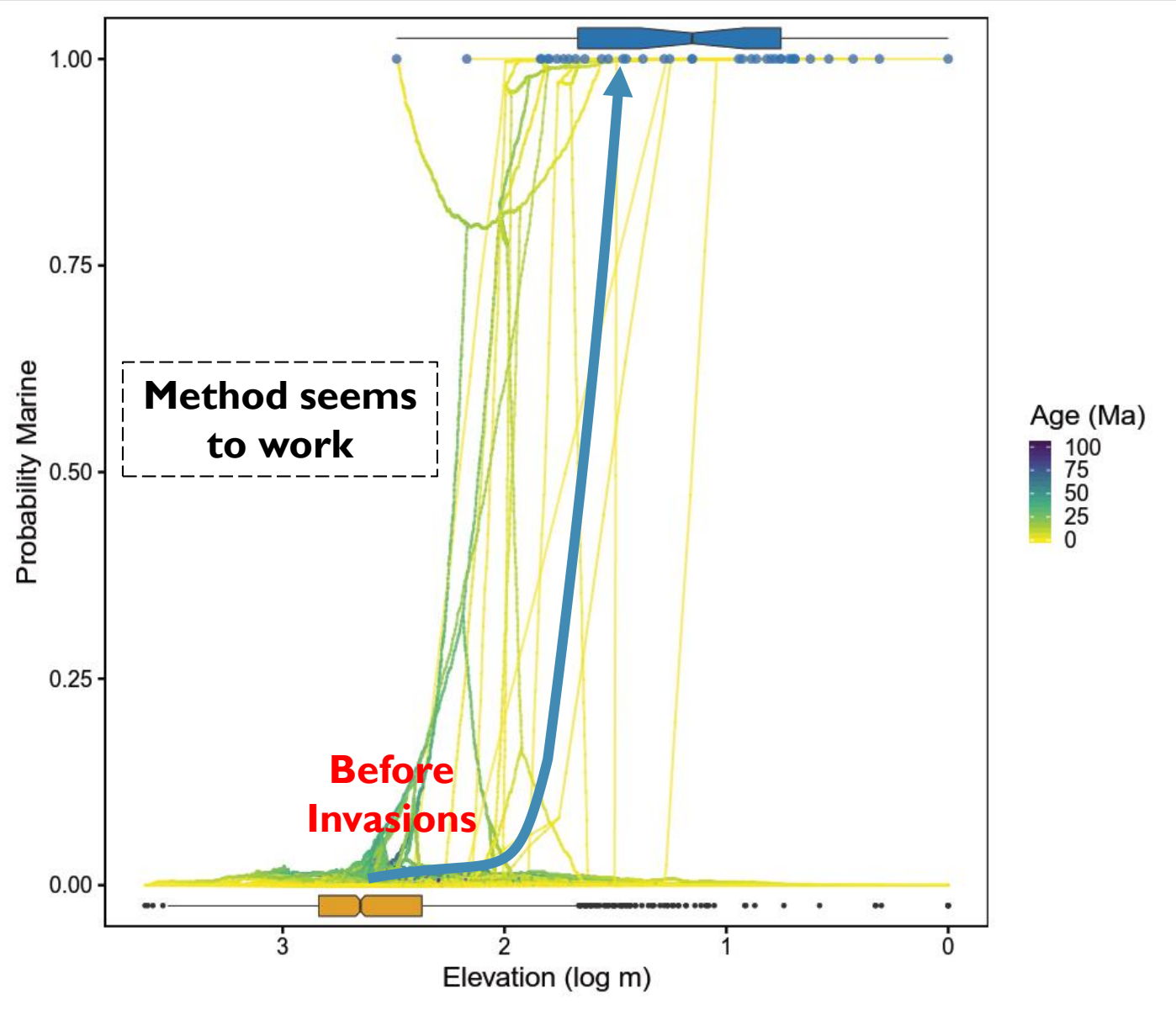
TESTING THE METHOD: ELEVATION



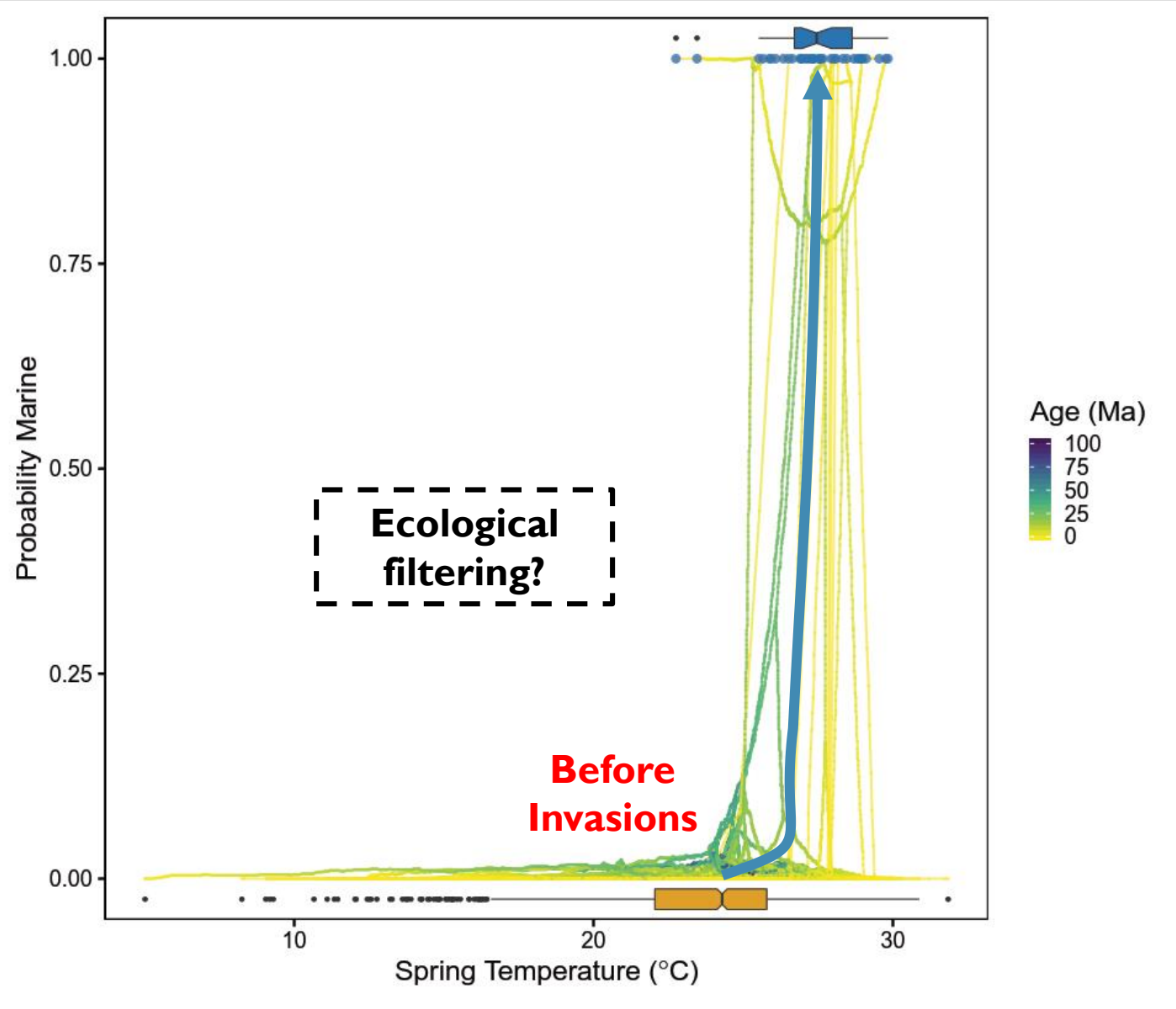
TESTING THE METHOD: ELEVATION



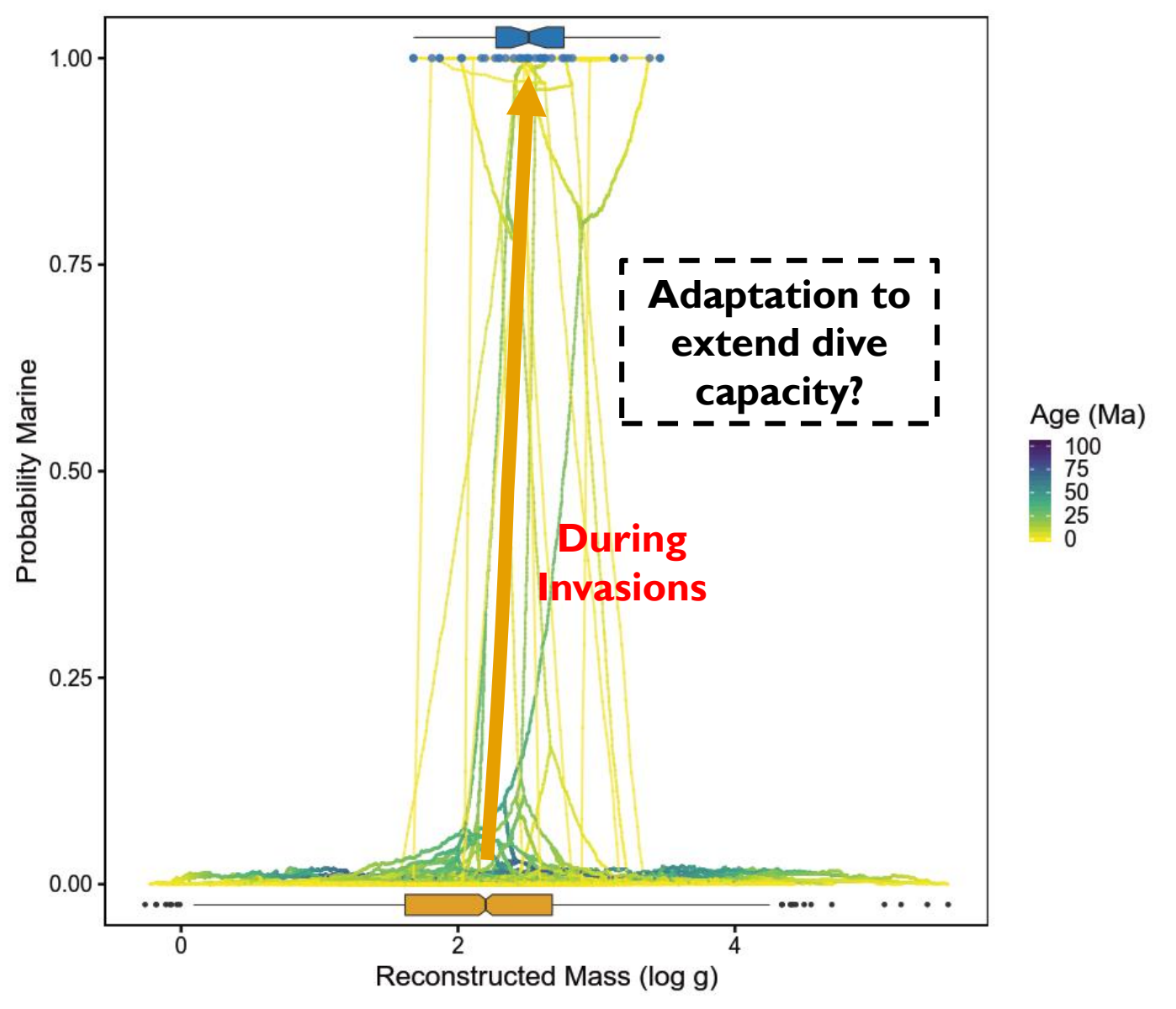
TESTING THE METHOD: ELEVATION



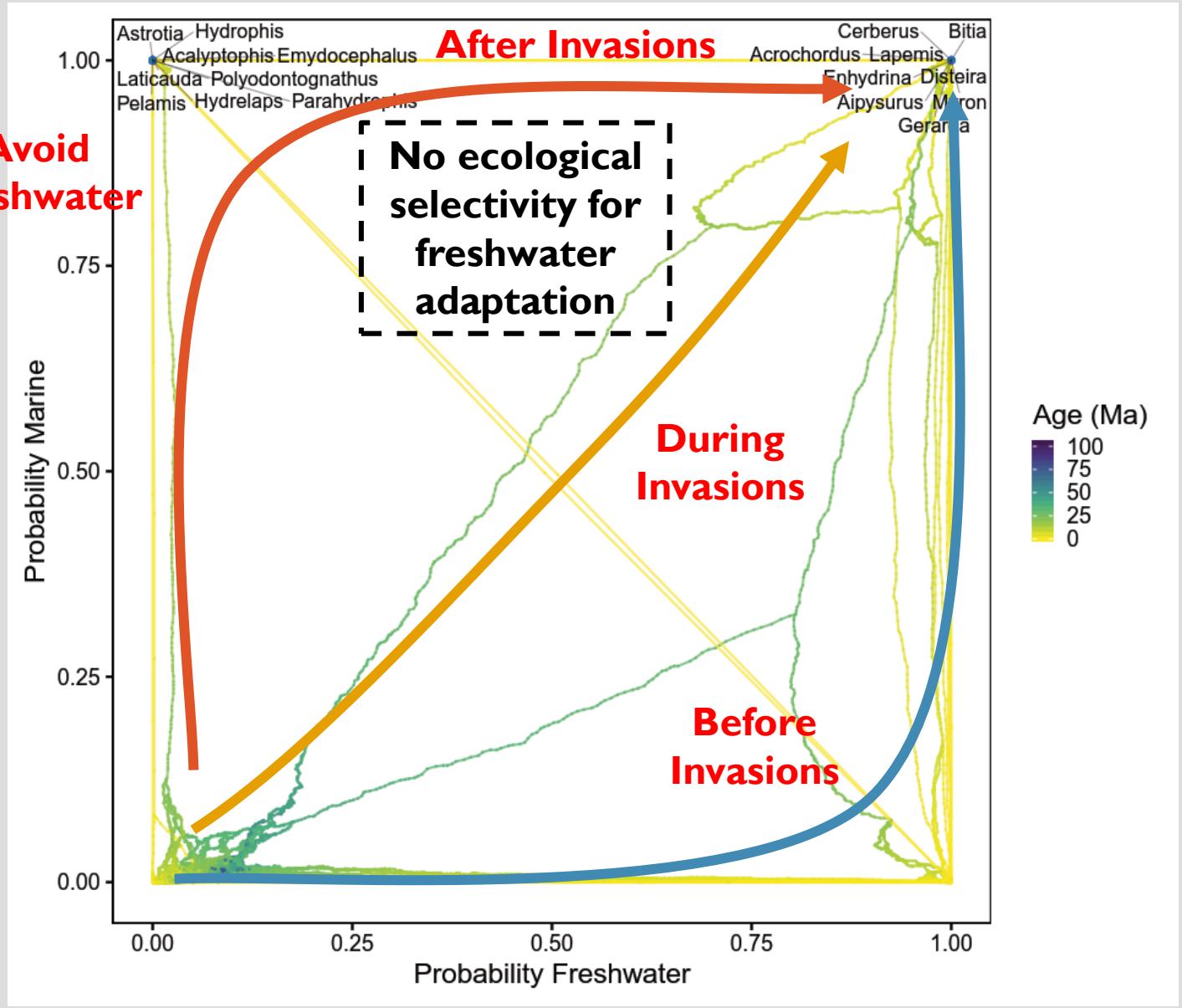
TEMPERATURE



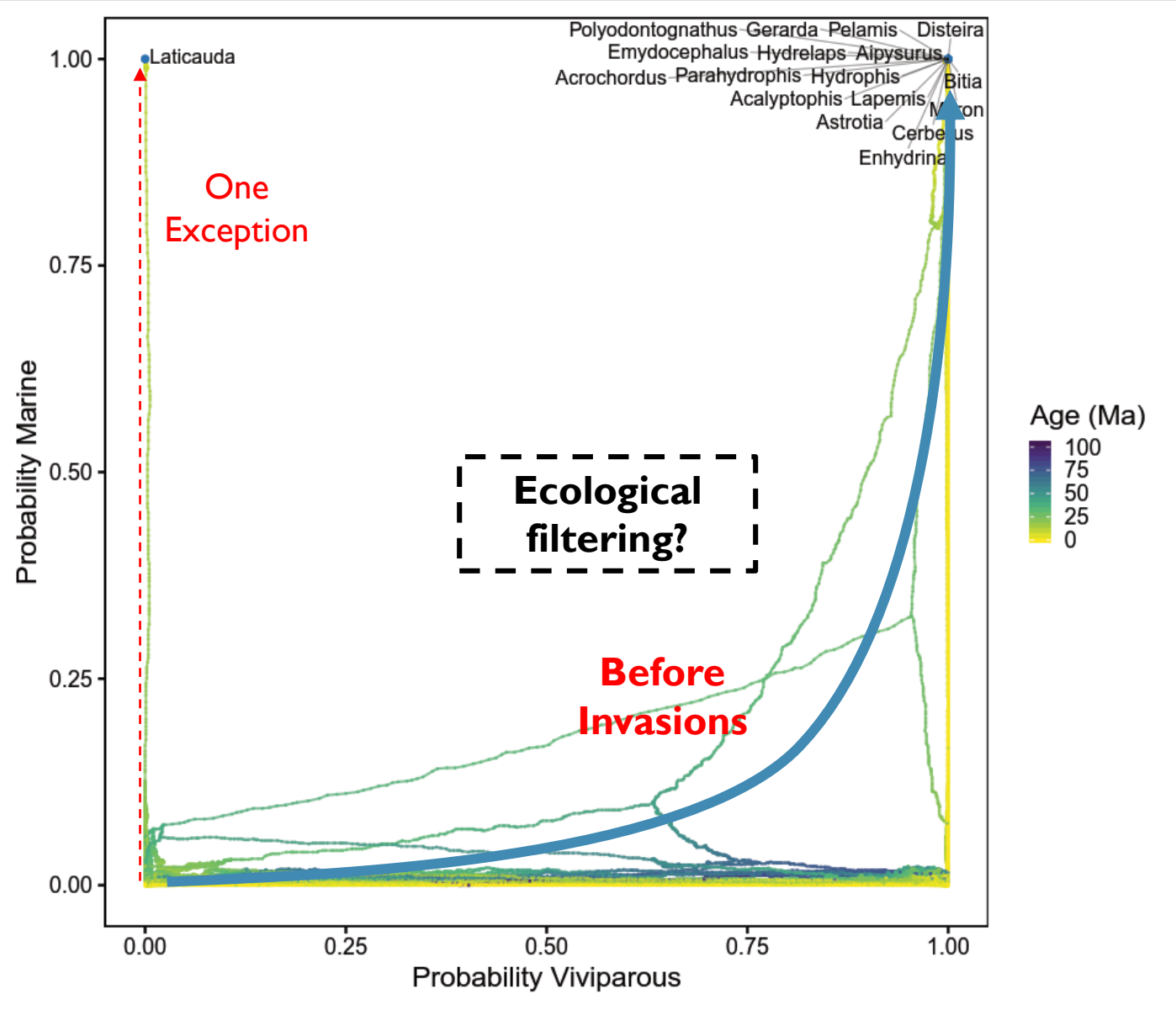
BODY MASS


1.00
0.75
0.50
0.25
0.00
Probability Marine
0
2
4
Reconstructed Mass (log g)
Adaptation to extend dive capacity?
During Invasions
Age (Ma)
100
75
50
25
0

FRESHWATER OCCUPANCY



VIVIPARITY


Laticauda
Polyodontognathus Gerarda Pelamis Disteira
Emydocephalus Hydrelaps Aipysurus
Acrochordus Parahydrophis Hydrophis
Bitia
Acalyptophis Lapemis
Astrotia
Cerbe us
Enhydrina
One
Exception
Ecological
filtering?
Before
Invasions
Probability Marine
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
Probability Viviparous
Age (Ma)
100
75
50
25
0

CONCLUSIONS

- While aquatic snakes are significantly larger than their terrestrial counterparts, it doesn't match the extent in mammals or crocs
- Viviparity appears to have evolved before these lineages invaded the ocean, likely as an adaptation for some other reason
  - This facilitated marine invasions of snakes from many different environments, but only if those environments were in tropical regions at low elevation

ACKNOWLEDGMENTS

Elsie Carrillo

Christianne Orsmby

Jonathan Payne

Payne Paleobiology Lab

Lyons Paleoecology Lab

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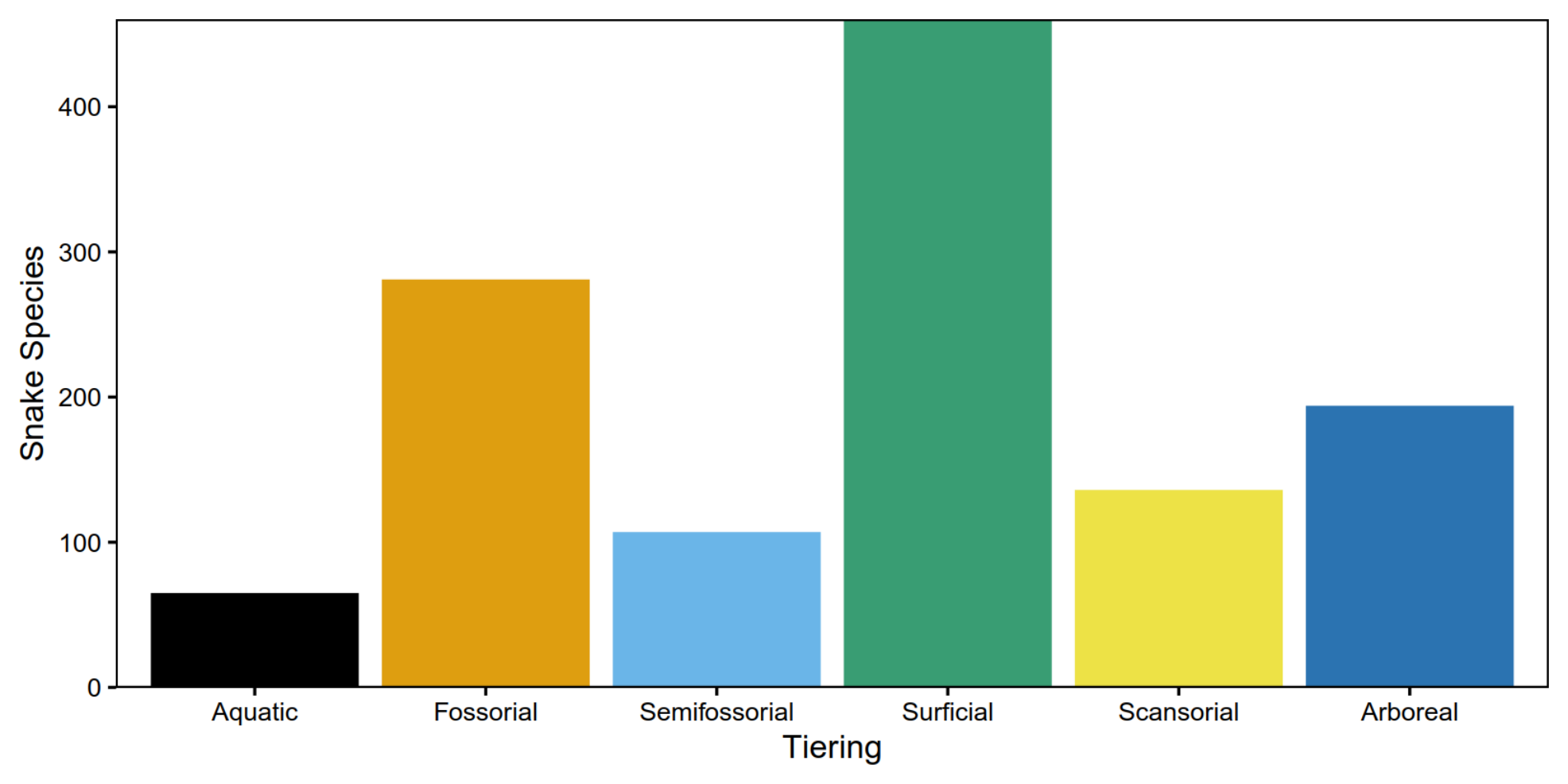
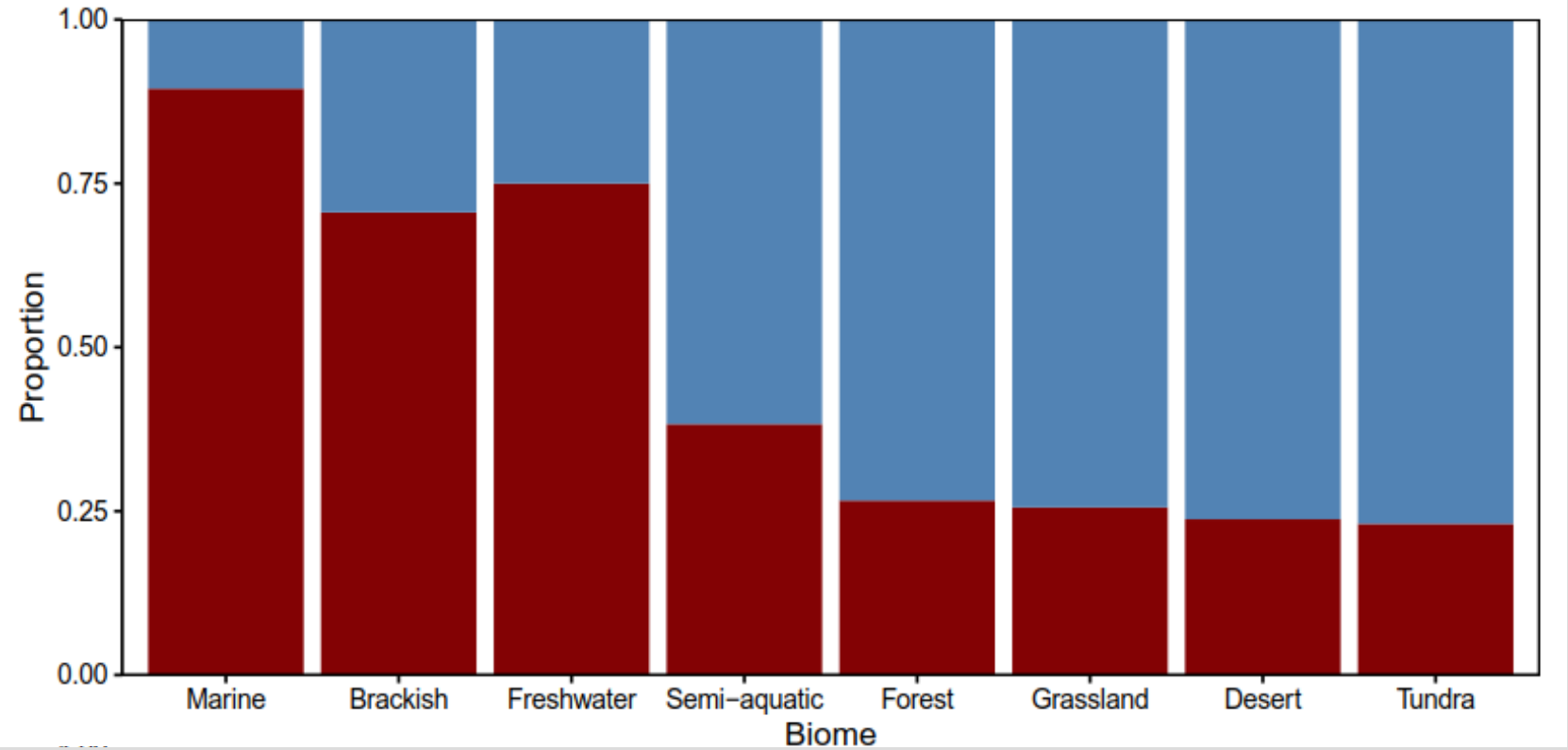
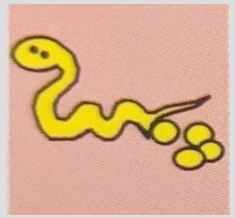
QUESTIONS?

TIERING

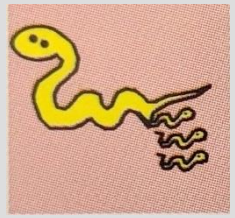

Snake Species
400
300
200
100
0
Aquatic
Fossorial
Semifossorial
Surficial
Scansorial
Arboreal
Tiering

REPRODUCTIVE MODE BY BIOME





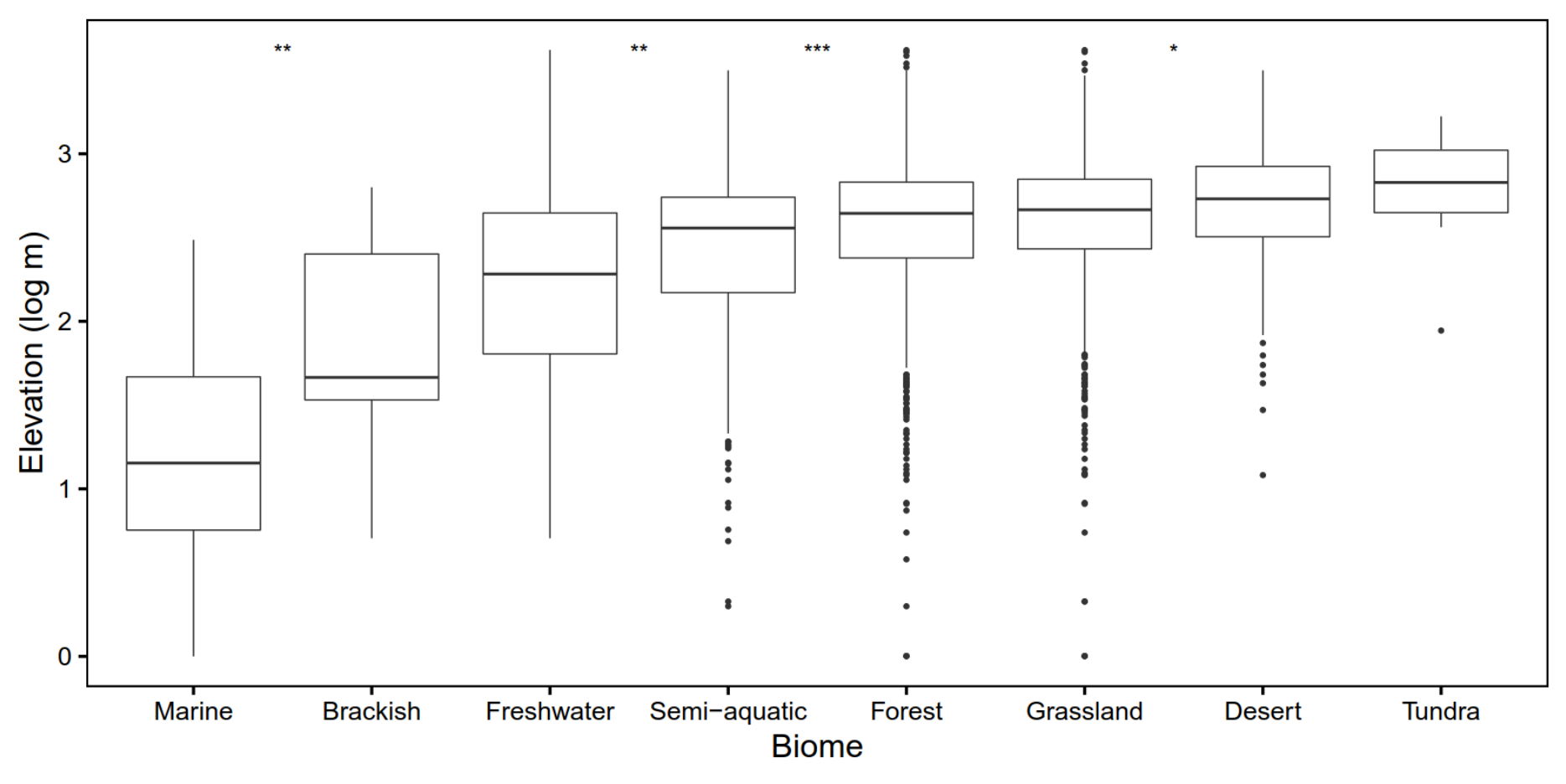
Oviparous



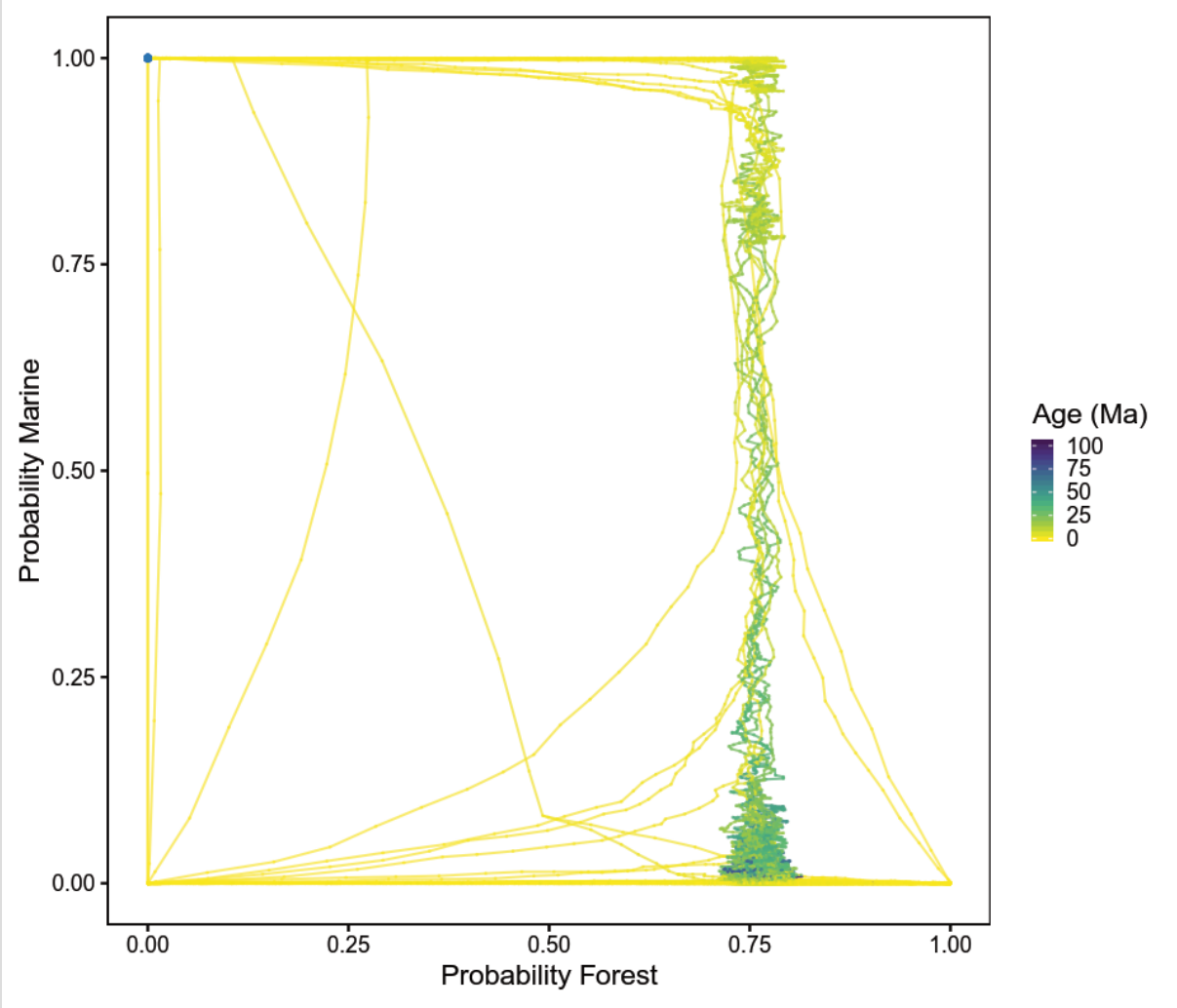
Viviparous

Marques, Eterovic, and Sazima 2012

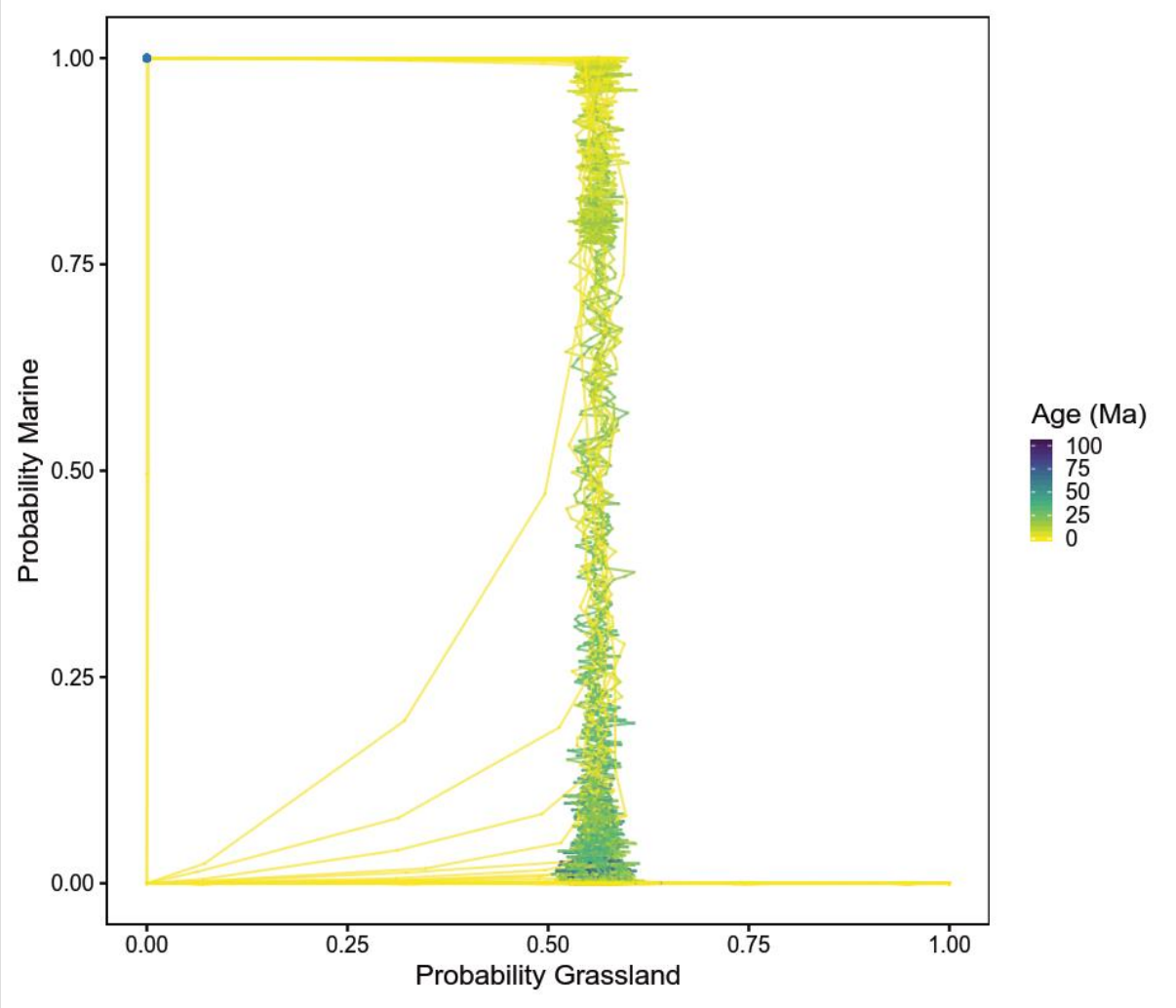
ELEVATION BY BIOME



Forest Occupancy



Grassland Occupancy



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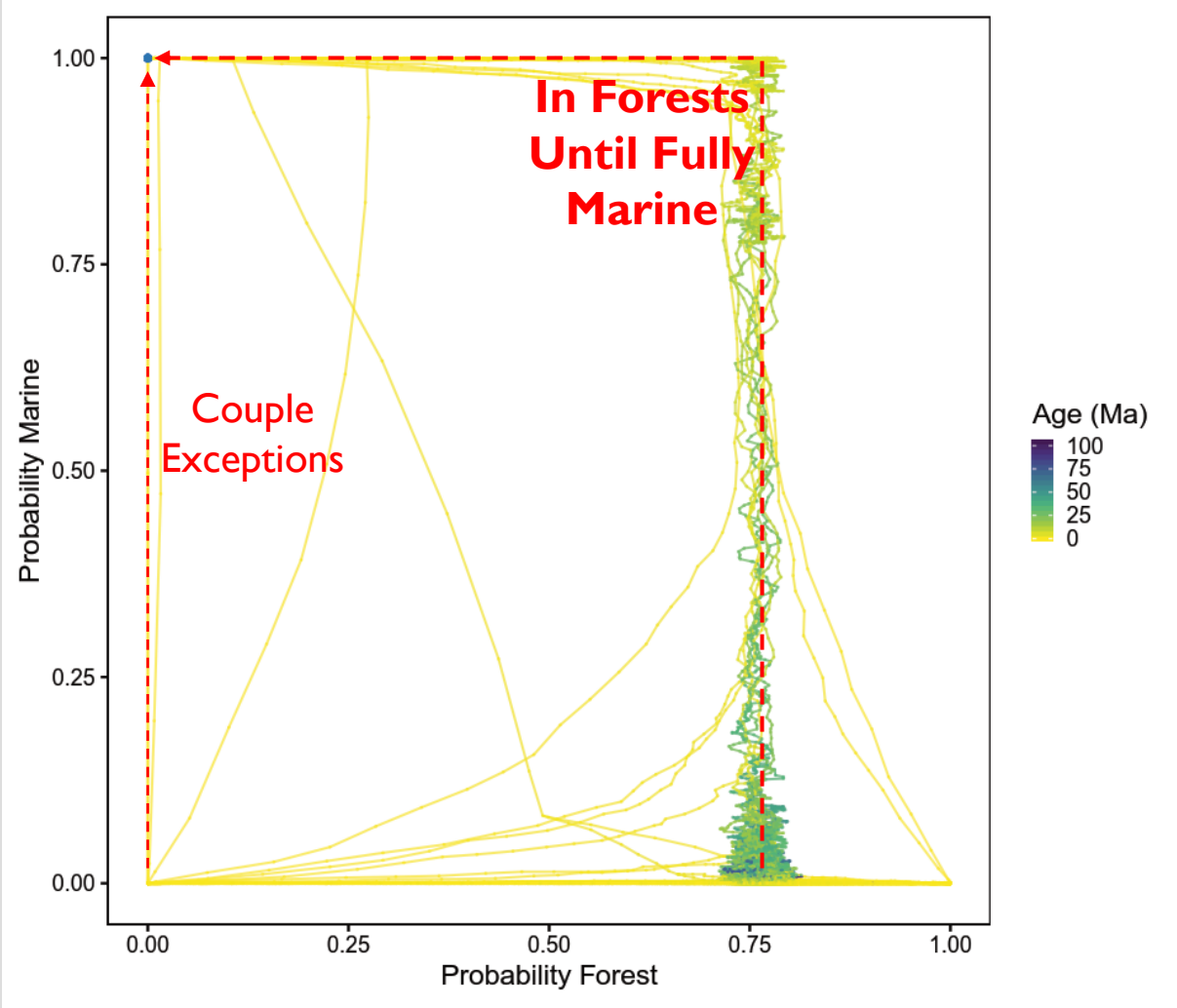
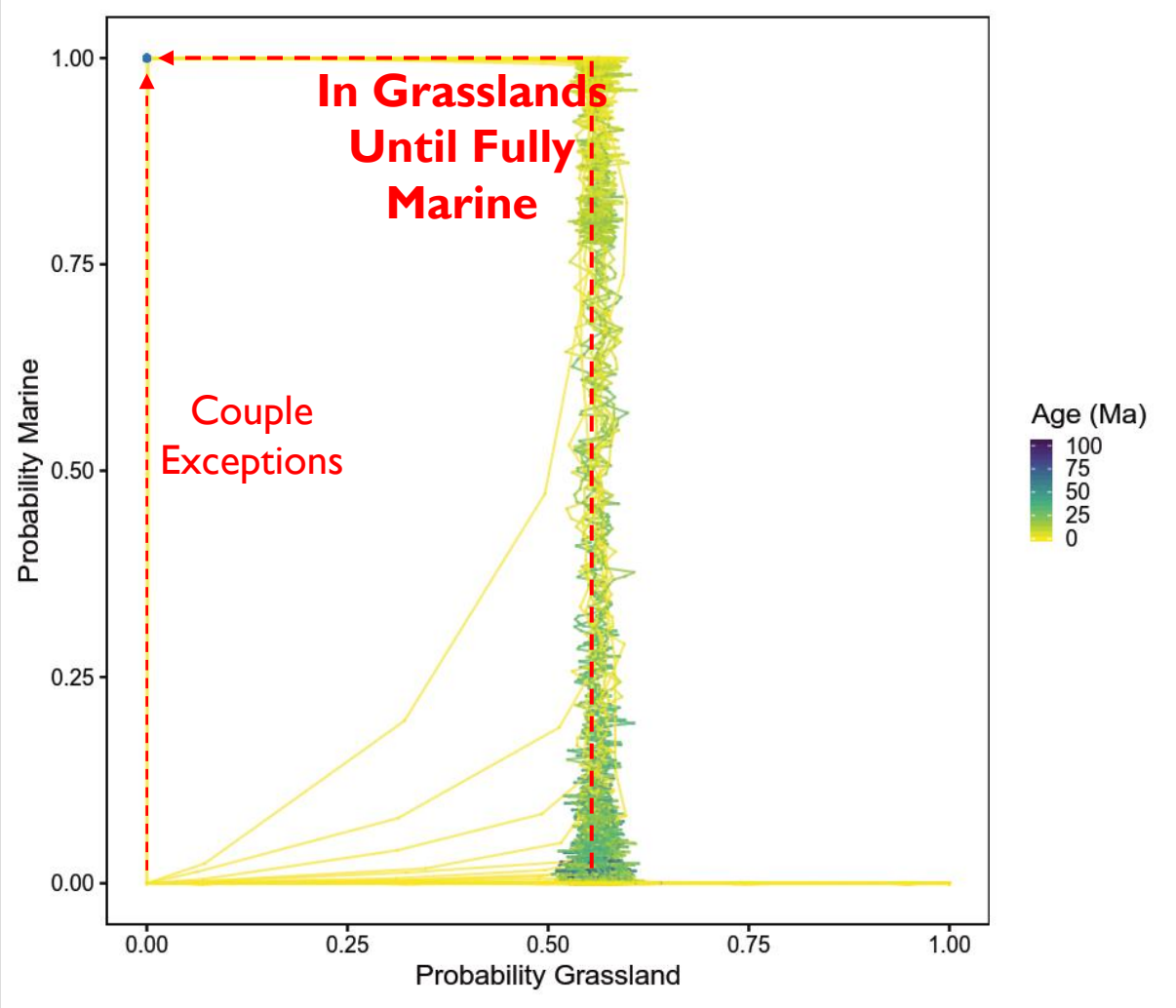
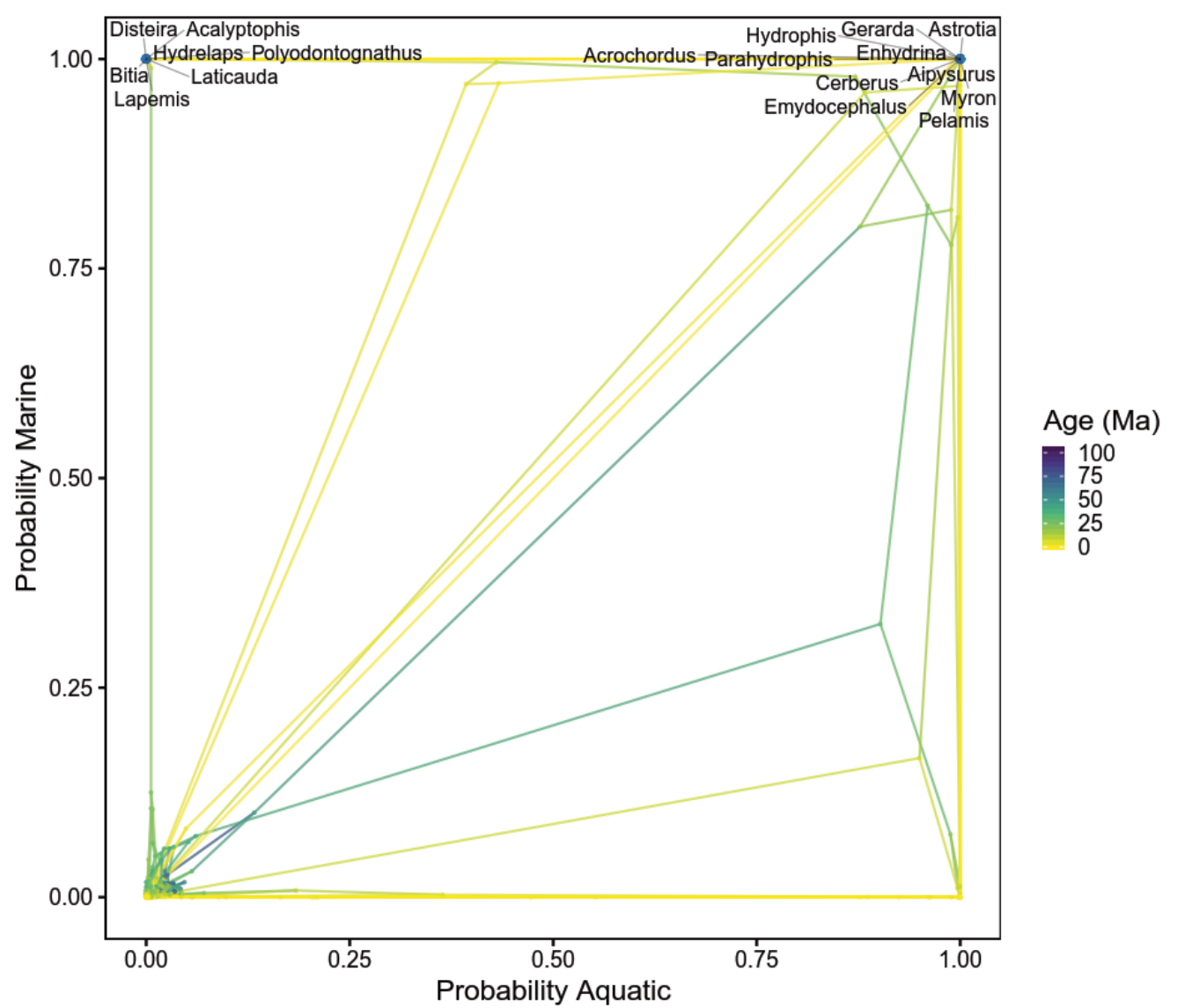


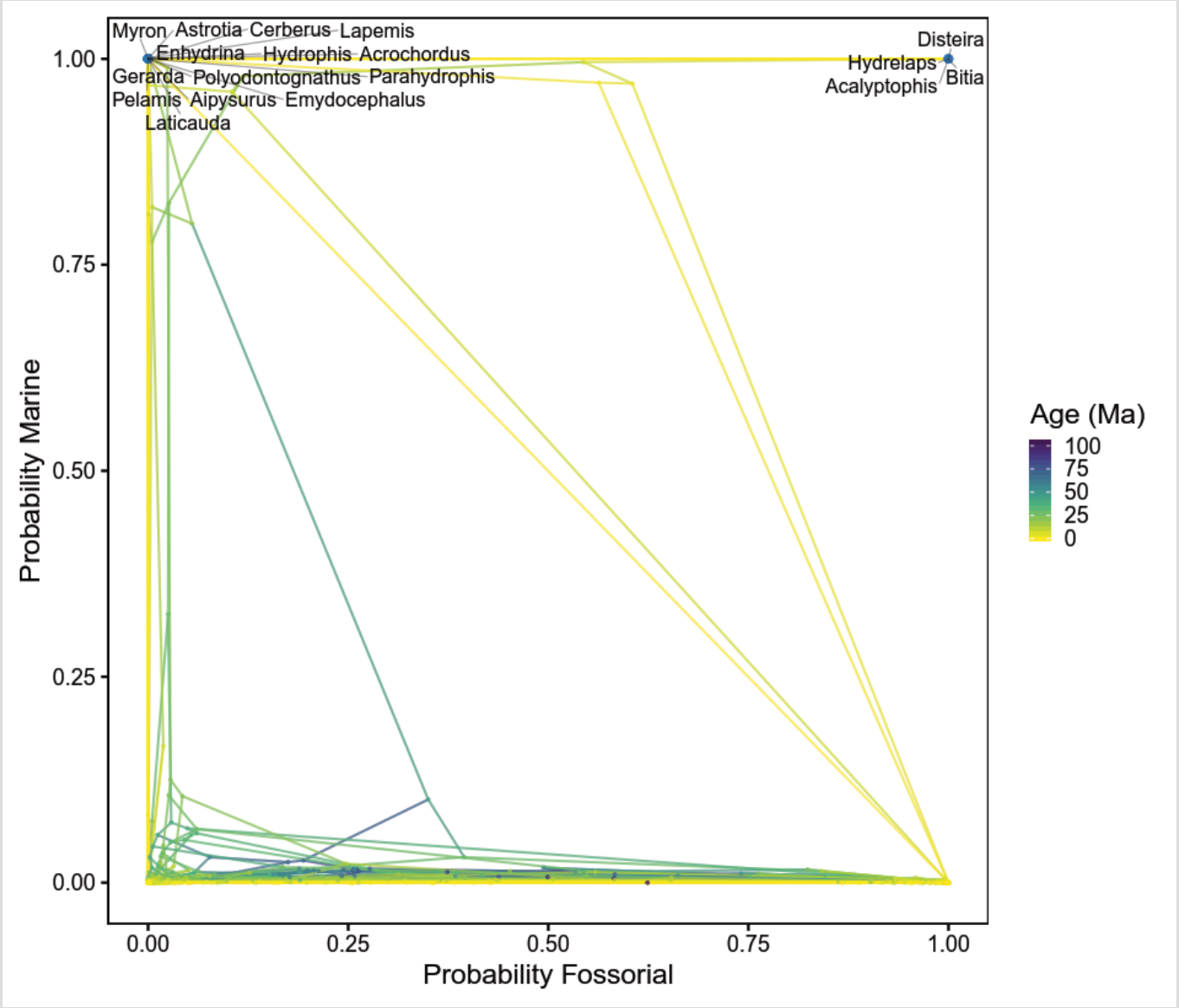
Grassland Occupancy



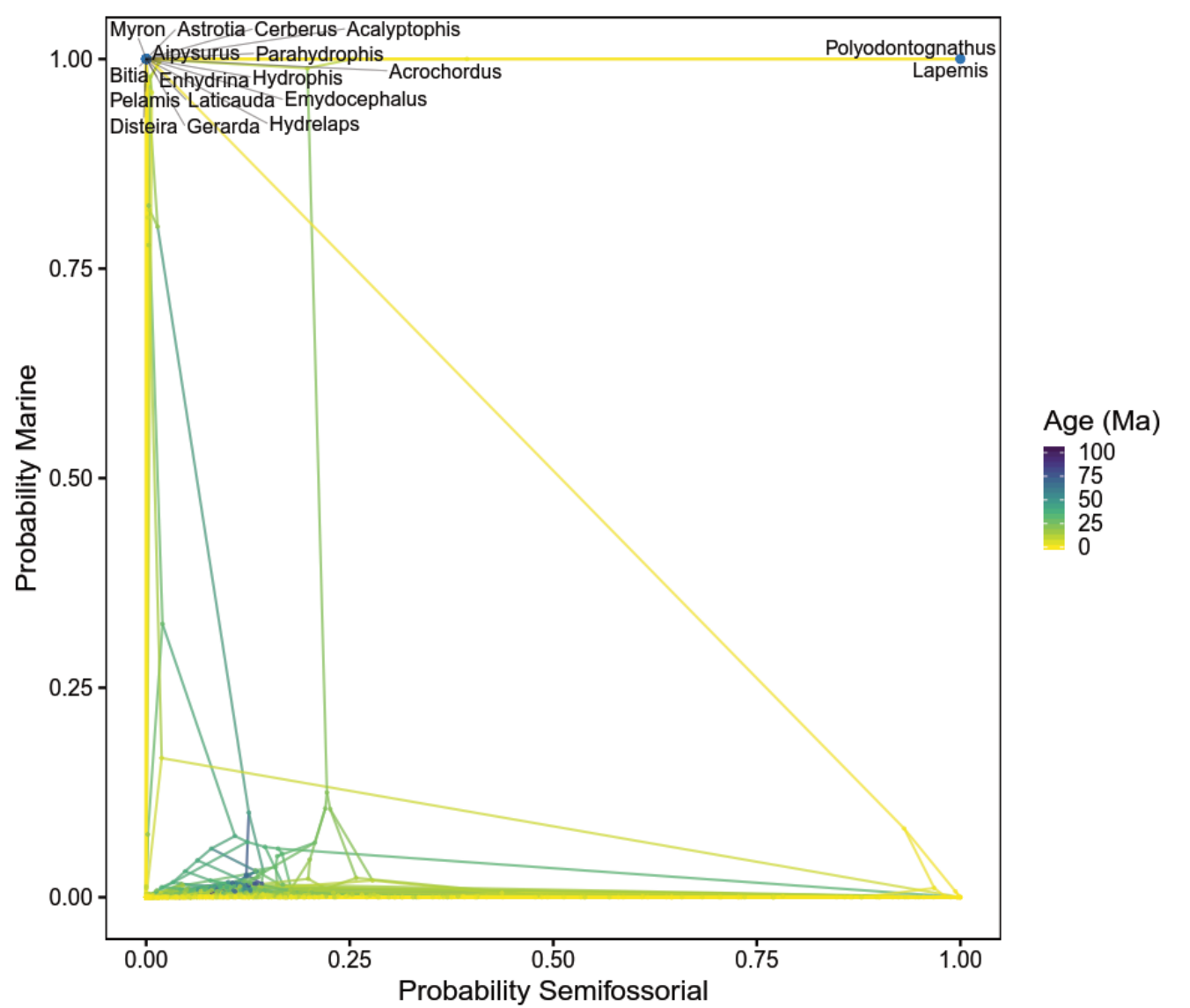
Aquatic Tier



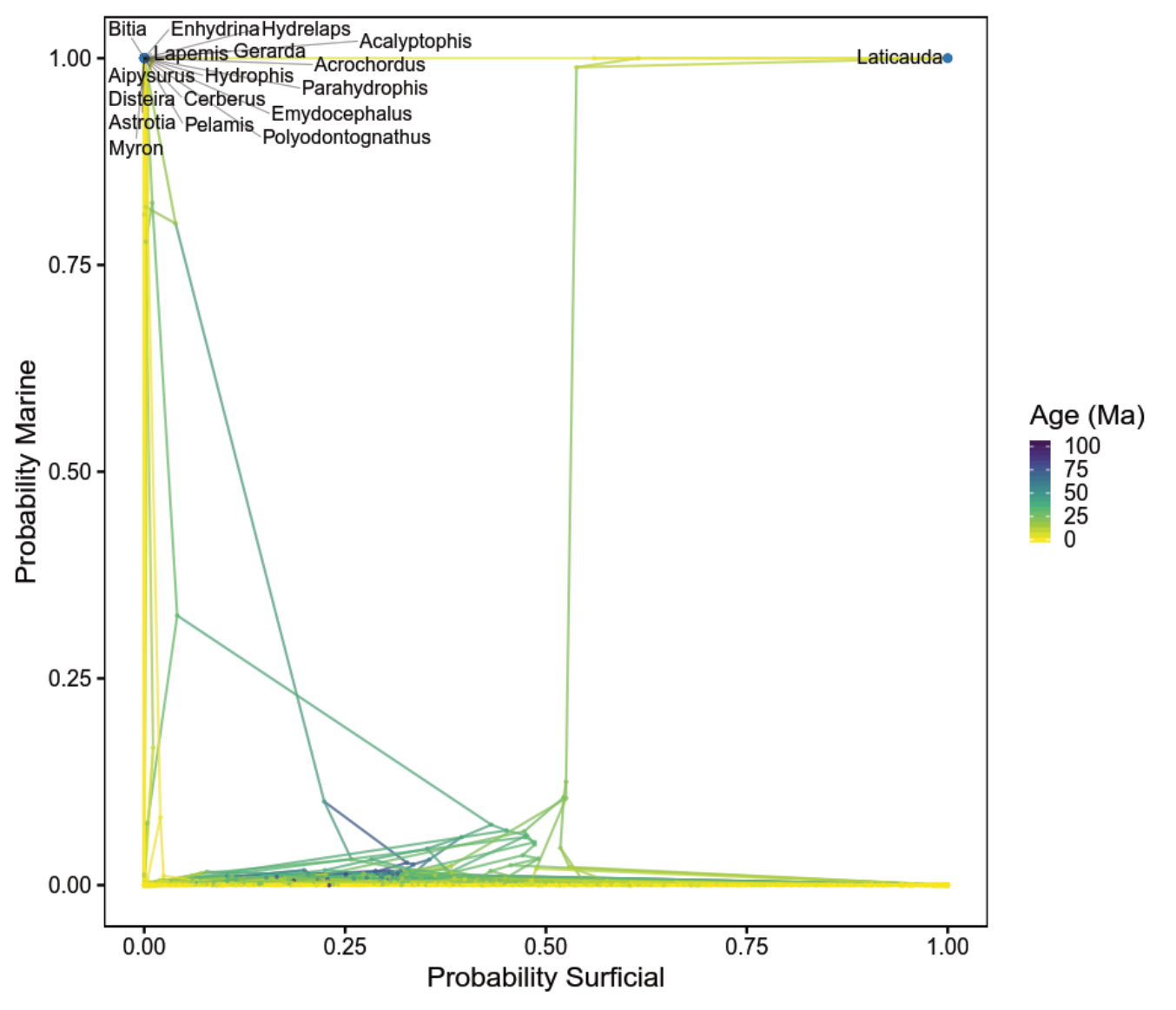
Fossorial Tier



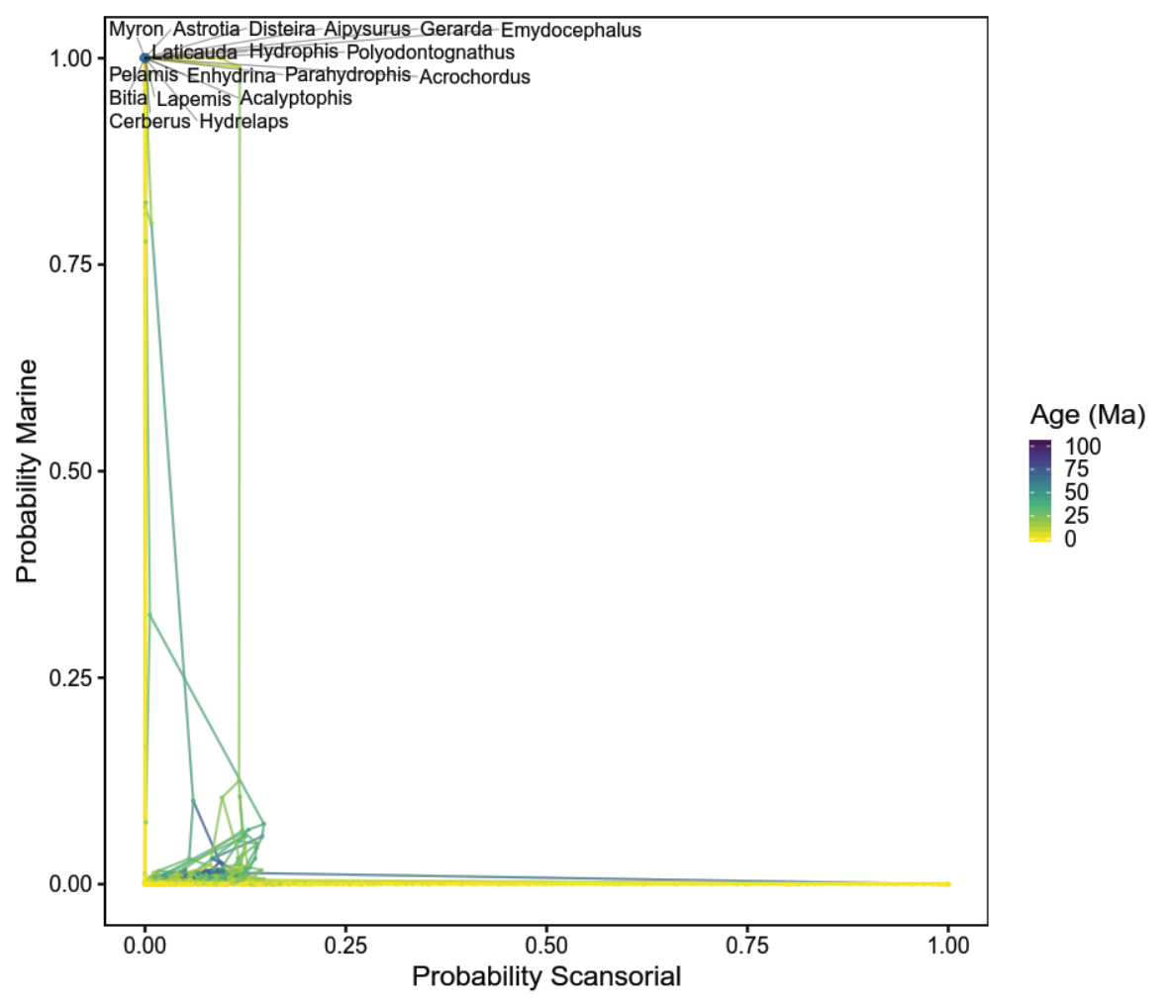
Semifossorial Tier



Surficial Tier



Scansorial Tier



Arboreal Tier