How Earth history shapes the origin and assembly of continental vertebrate biotas

Joel Cracraft
Department of Ornithology
AMNH

Dimensions of Biodiversity US-BIOTA-São Paulo
Some major questions about Amazonia

- How is genetic, taxonomic, and ecological diversity distributed within Amazonia?
- What are the drivers of diversity over space and time?
- How has the Amazonian biota assembled over space and time?
- What has been the history of the Amazonian aquatic and terrestrial environments?
- How has the Amazonian environment and its biota evolved together, and what have been the global effects of this evolutionary-ecological system over time?

Requires a new integrated approach
Broad-scale Collaboration

**Brazil**
- Universidade de São Paulo
- Universidade Federal de Goiás
- Universidade Federal do Pará
- Universidade Estadual de Campinas
- Museu Paraense Emílio Goeldi
- Instituto Nacional de Pesquisas da Amazônia

**Argentina**
- CONICET-Instituto Superior de Entomologia, Tucumán

**Great Britain**
- University of Edinburgh

**Canada**
- University of Toronto

**United States**
- American Museum of Natural History
- City University New York
- Field Museum of Natural History
- Middle Tennessee State University
- Natural History Museum Los Angeles County
- New York Botanical Garden
- University of Michigan
- University of Colorado
Integration across disciplines

Systematics

Historical biogeography
Phylogeography

Paleogeography
Tectonics
Geochronology
Remote sensing

Amazonian History

Population genetics

Paleoclimatology
Palynology
Paleoclimate modeling

Landscape ecology
Ecosystem function/
biogeochemical flows
Science stories: Earth & Amazonian biotic histories

- Large spatiotemporal scale: global avian diversification

- Small spatiotemporal scale: speciation in birds
A global timetree and biogeography for birds

Building the tree
- Phylogenomic constraint-tree for basal splits
- Remainder built from 4092 bp RAG-1 & RAG-2
- 230 species, 202 avian families; we eliminated 200+ taxa of songbirds

Building the time-tree
- Identified 24 clades with well-characterized fossil record represented on multiple continents
- 130 fossils used to build empirical probability distributions to construct Bayesian age priors
- "Validated" by reanalysis of phylogenomic dataset

Biogeographic reconstructions
- 8 (5) global regions: ~paleogeographically & tectonically individuated
- optimizations: parsimony (single-state transitions), ML & Bayesian

Claramunt and Cracraft Sci. Adv. 2015;1:e1501005

Collaborator: Santiago Claramunt
A global time-tree for birds

Most comprehensive to date

- First "unbiased" age-estimate of Neornithes: ~91.5 Ma
- No deep outgroup
- No prior on base of Neornithes

- Three deep stem-lineages: Paleognathae, Galloanseres, Neoaves

- All crown-groups are ~K-Pg time in age
- Paleogene fossils directly incorporated
- Major result likely robust to uncertainty
Birds had a West Gondwanan origin

Claramunt and Cracraft 2015
Science Advances:1:e1501005
The K-Pg West Gondwanan avifauna

**Palaeognathae**: tinamous, ratites

**Galloanseres**: waterfowl, galliforms,
bony-toothed birds

**Neoaves**: flamingos + grebes

oilbirds, nightjars,
swift + hummingbirds

hoatzins, rails, cranes,
shorebirds

tropicbirds, sunbittern/
Kagu

penguins, seabirds & allies

seriemas, falcons,
parrots & perching-
birds

**NOTE**: these taxa only represent stem-lineages
Net-diversification: causally linked to climate change

- Warmer, wetter periods increase biotic cosmopolitanism: S and E decline together
- Cool, dryer periods fragment ecosystems/biomes: S and E increase together
- S and E correlated and causally linked

Large-scale Earth history

Tectonics causes & amplifies effects of climate change

Rapid uplift C. & N. Andes

Net diversification rate (Ma⁻¹)

Deep ocean temperature (°C)

Claramunt and Cracraft 2015
Science Advances:1:e1501005
Small-scale biotic history: *Psophia*

Timeline estimated by two independent methods

Small-scale Earth history

North/south east/west patterns

Leads to a predictive Amazonian palaeogeography

Ribas et al. 2012. PRSL
Integrating paleogeography and remote-sensing using SRTM

SRTM % slope at 5 km scale
SRTM and Rio Negro paleogeography

Collaborations and acknowledgments

Dimensions of Biodiversity US-BIOTA-São Paulo

Thanks!