University of Zurich[UZH]

Phylogenetic Bayesian Inference and Geometric Morphometrics in Neotropical Sea Catfishes: New Species, Support for Miocene Closure of the Panamanian Isthmus, and Conservation of Skull Shape

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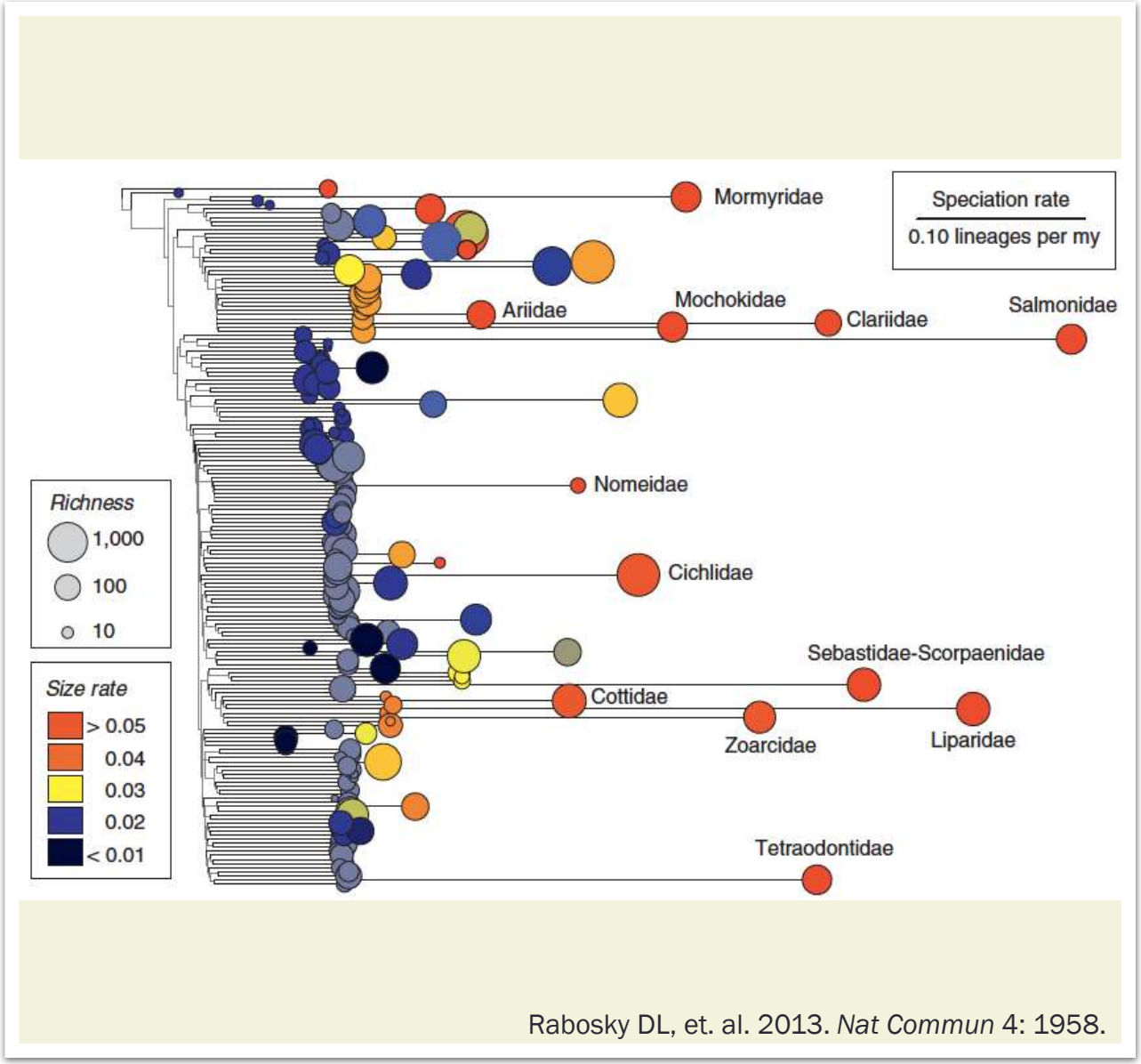
Elevated rates of speciation and phenotypic evolution

Ariidae among the fastest evolving 10% of extant teleost families



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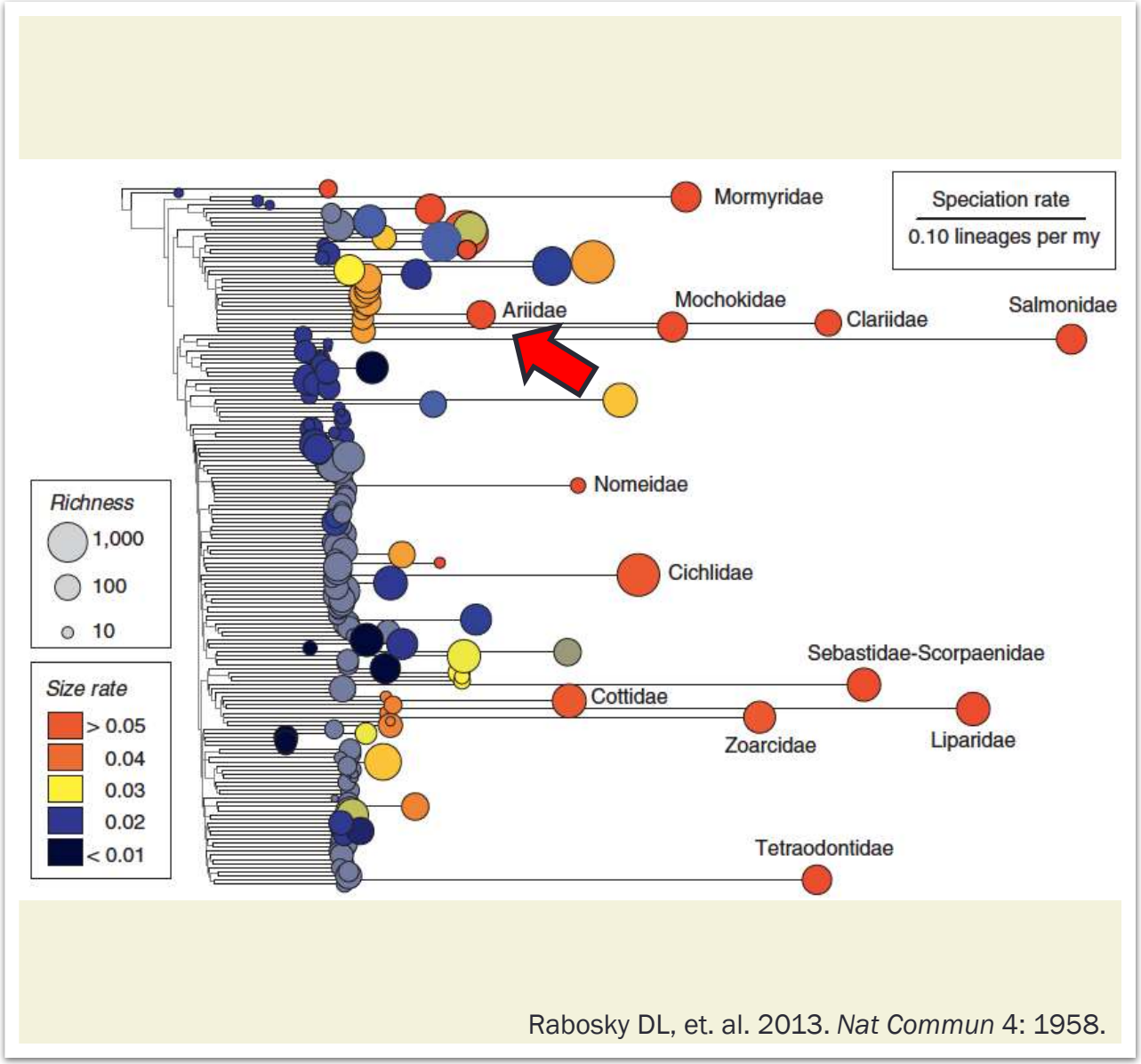

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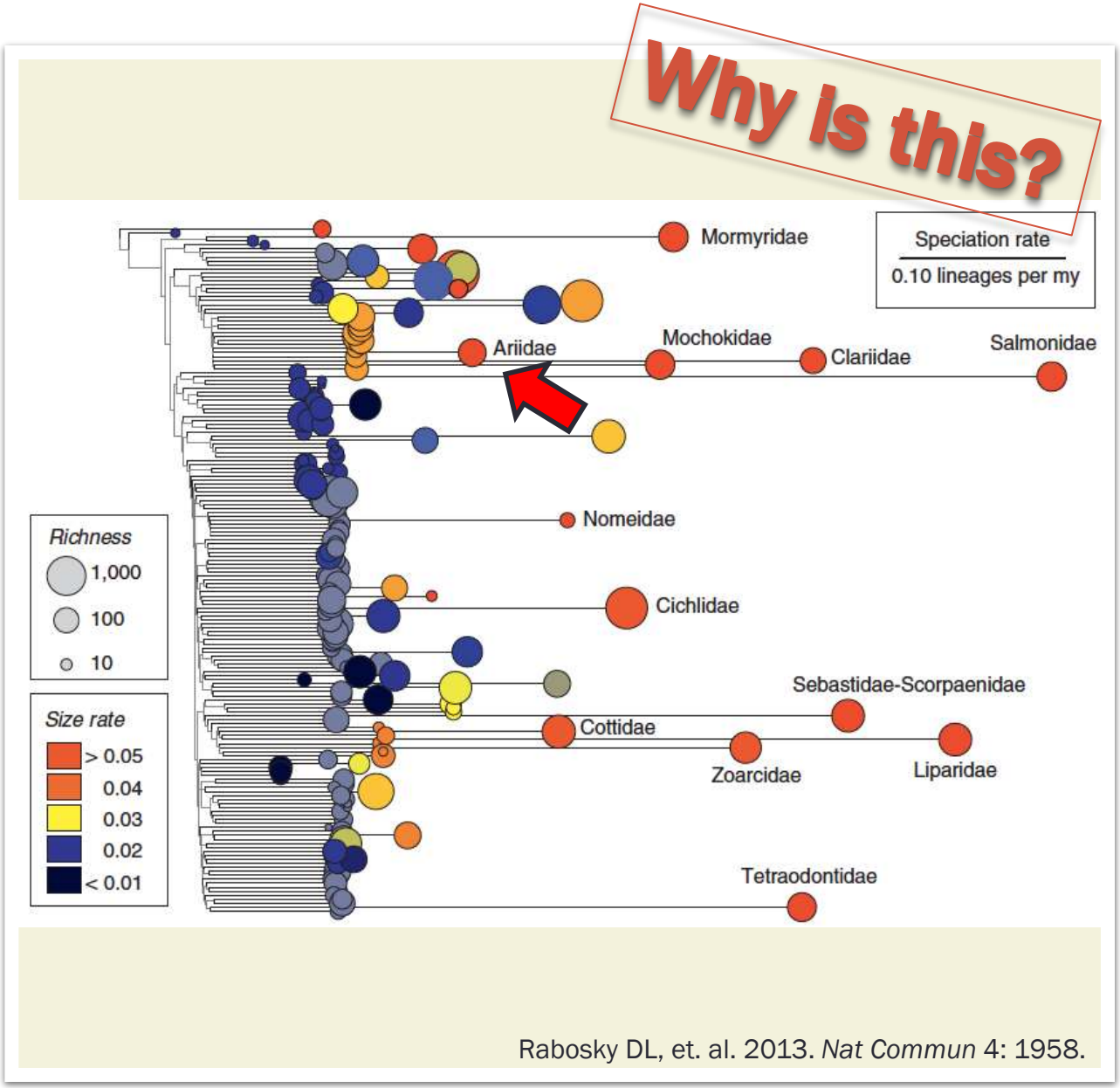

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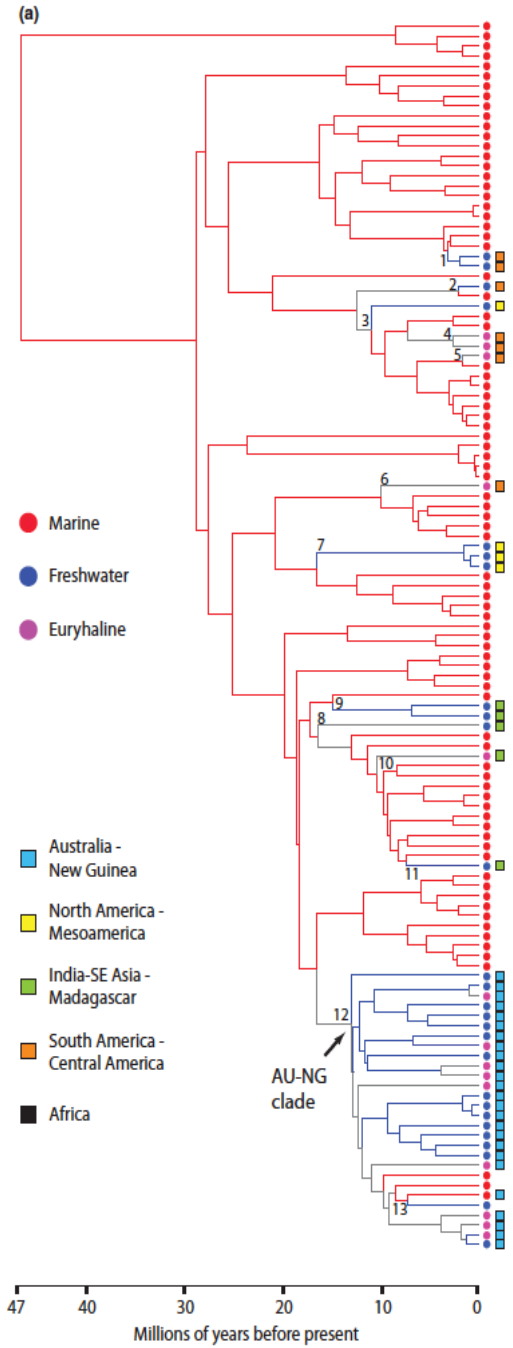
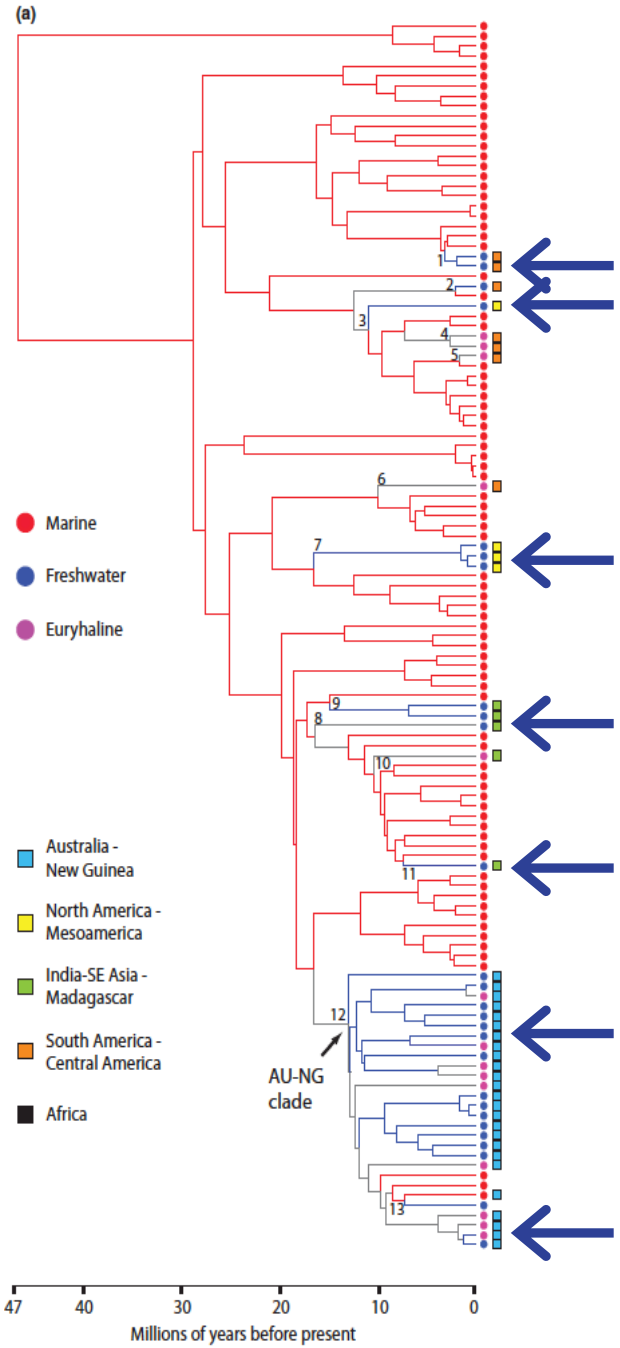


Betancur-R. R, et. al. 2012. *Ecol Let* 15: 822–830.

Ariidae are adapted to **marine** environment

repeated secondary colonisation of **freshwater** habitat



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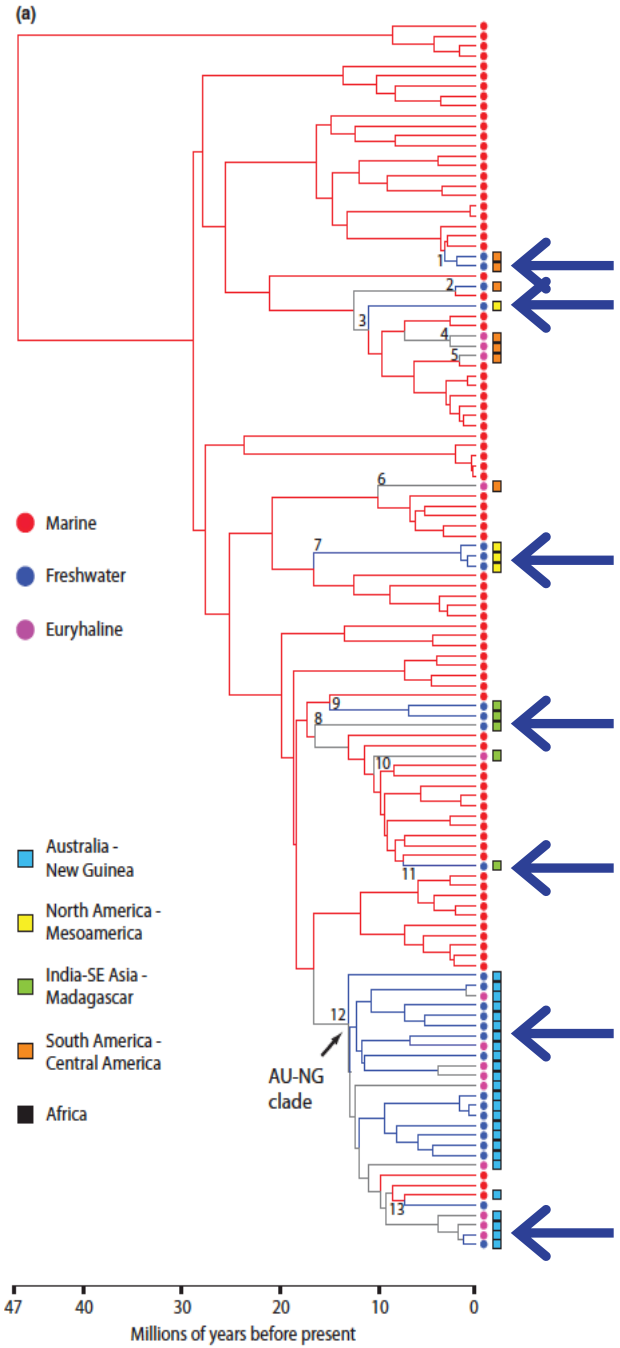

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Macrohabitat transitions as drivers of speciation

Ariidae are adapted to marine environment

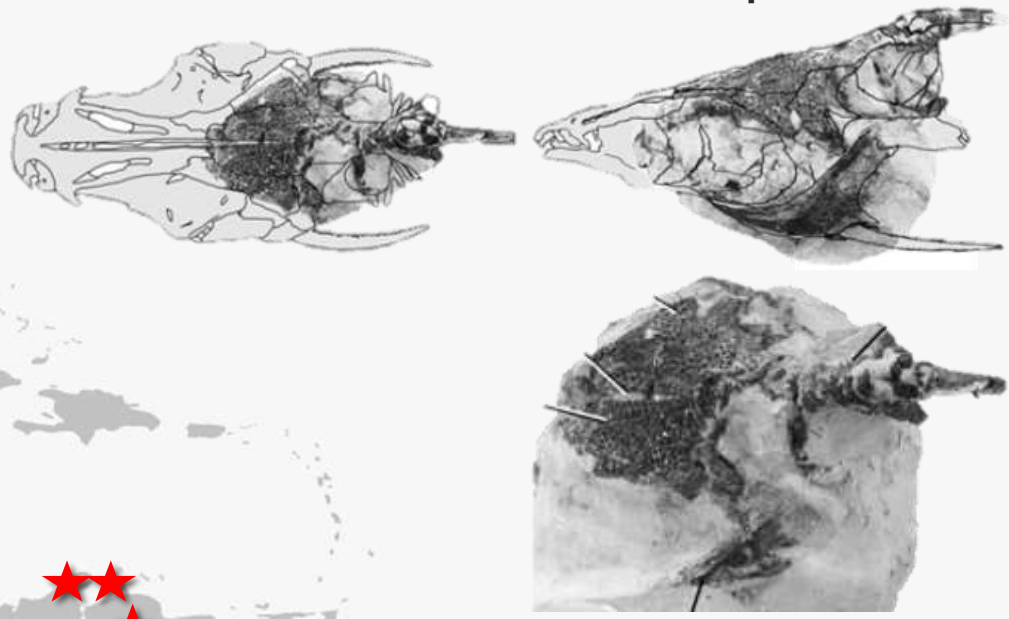
repeated secondary colonisation of freshwater habitat

Convergent evolution during adaptive radiations

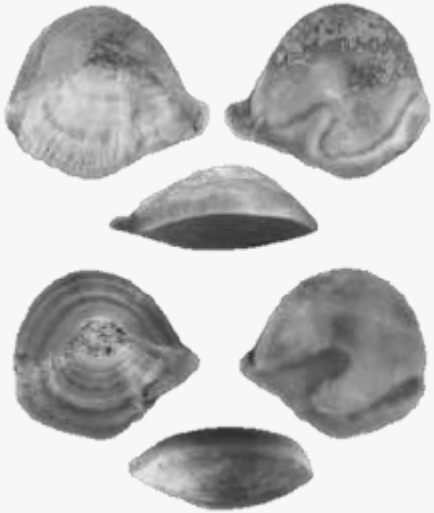
- sticklebacks (marine-fresh)
  - independent lake populations express the same opercle shape (Kimmel CB, *et al.* 2012. *Evol Dev* 14: 326–337)

- cichlids (lake-lake)
  - visual system in Midas cichlids (Torres-Dowdall J, *et al.* 2017. *Mol Biol Evol*, ahead of print)
  - overall shape among LT and Malawi cichlids (Kocher TD, *et al.* 1993. *Mol Phylogenet Evol* 2: 158–165.)

neurocrania and dorsal spines



otoliths (ear stones)



Aguilera O. *et. al*, Swiss J Palaeontol, 2013

Ariidae in general provide...

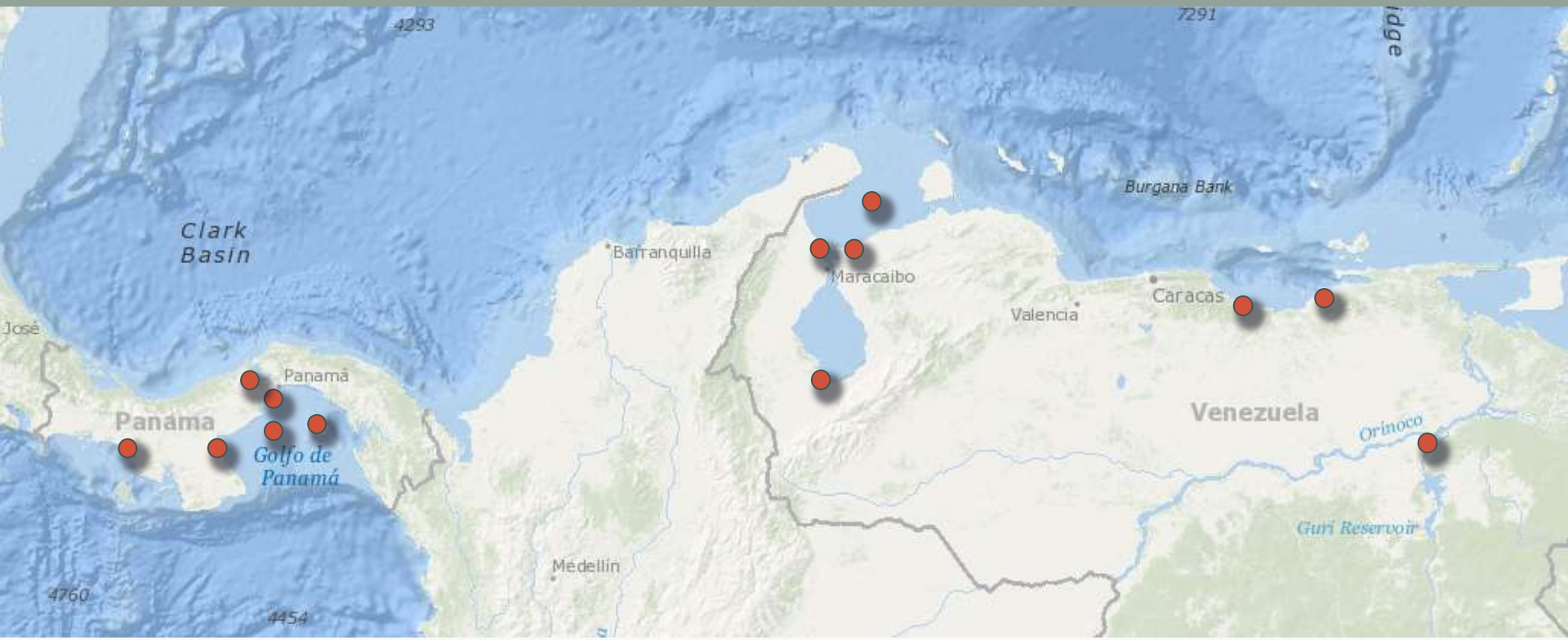
- elevated rate of morphological evolution
- repeated occurrence of macrohabitat transitions (sea → fresh water) in different genera with the occurrence of intermediate (brackish) species

Northern Neotropical Ariidae provide...

- species assemblage that was affected by the formation of the Panamanian Isthmus
- revised systematics and taxonomy
- a well-dated Miocene (23-5 million years ago, Ma) fossil record

1) Do northern Neotropical Ariidae support a Miocene closure of the Panamanian isthmus?

2) Do northern Neotropical Ariidae exhibit convergence in shape in similar habitats?



Sciades

Notarius

Bagre

Ariopsis

Cathorops

333 specimens (including fin tissues, skeletal features)
size range (SL): 10.5 – 79.0 cm, median 28.5 cm

fish images from FAO, www.fao.org

Species identification

fish images by M. Stange

Species identification

Notarius kessleri

Notarius biffi

fish images by M. Stange

Species identification

reference *ATPase 8/6* dataset of 129 worldwide distributed ariid species
(Betancur-R. R. 2009. *BMC Evol Biol* 9: 175.)

+

+ 263 *ATPase 8/6* sequences (this study)

Stange M, et al. 2016 *Ecol. Evol.* 6, 5817–5830.

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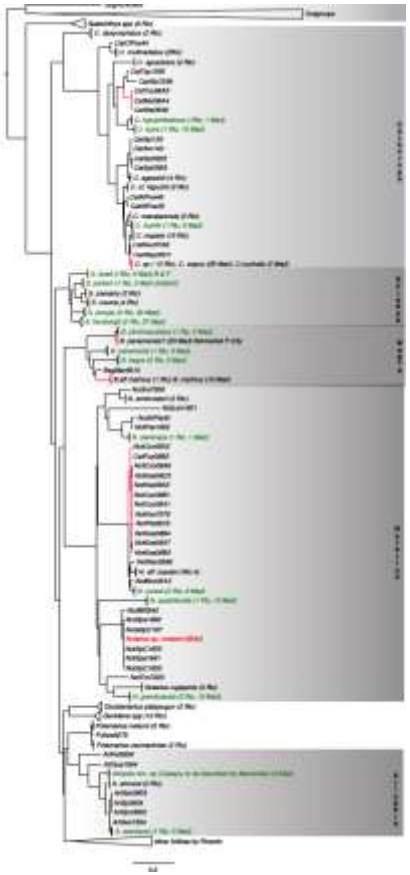

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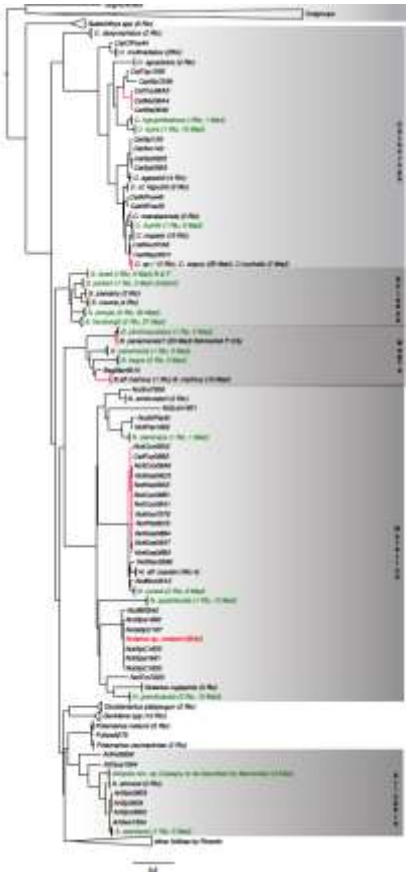

- most of the sequences clustered accordingly, or identity was corrected
- confirmed the occurrence of *Notarius biffi* in Central America, South of El Salvador
- two sequence clusters within *Sciades herzbergii*
- two sequence clusters within *Bagre pinnimaculatus*

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Notarius biffi in Central America, South of El Salvador

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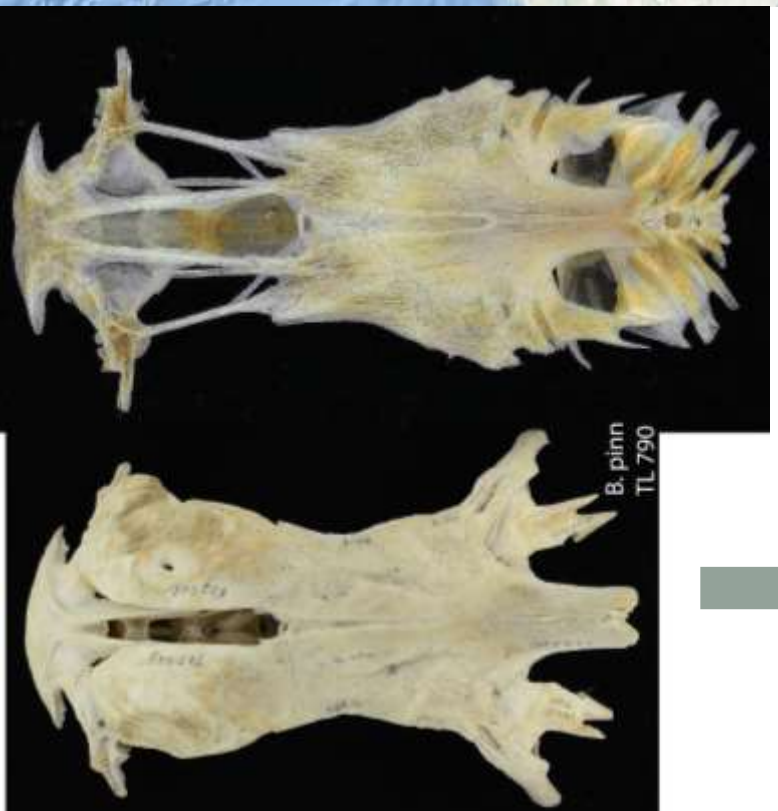

Notarius biffi in Central America, South of El Salvador

- two sequence clusters within ***Sciades herzbergii***
- two sequence clusters within ***Bagre pinnimaculatus***

two morphotypes in *B. pinnimaculatus*

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Do northern Neotropical Ariidae support a Miocene closure of the Panamanian isthmus?

Divergence-Time Estimation of Species-Trees

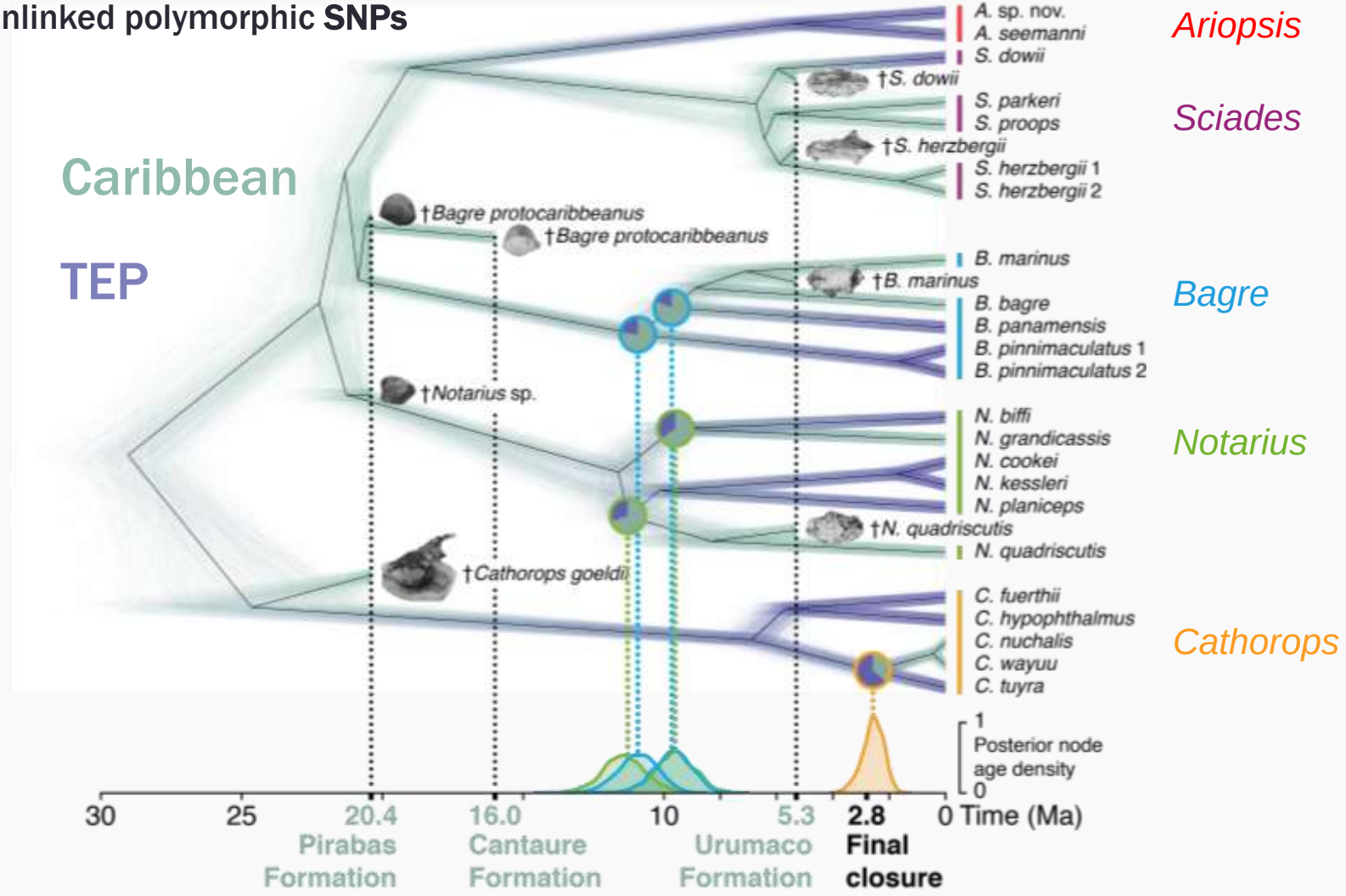
- Concatenation approach
  - assumes no recombination
  - results in potentially misleading branch lengths and divergence times
- Multispecies coalescent (MSC)
  - accounts for incomplete lineage sorting (ILS)
  - BUT ignores within-locus recombination if based on sequences
  - computationally demanding for time calibration if based on sequences
  - time calibration based on SNPs has not been tested
- Novel approach: SNAPP (based on MSC), run with SNPs, combined with fossil or biogeographic constraints

https://github.com/mmatschiner/snapp_prep

Beast2 Bayesian evolutionary analysis by sampling trees SNAPP

Bayesian Divergence-Time Estimation with SNPs

1768 unlinked polymorphic **SNPs**



Stange *et. al.*, in revision; bioRxiv doi:10.1101/102129

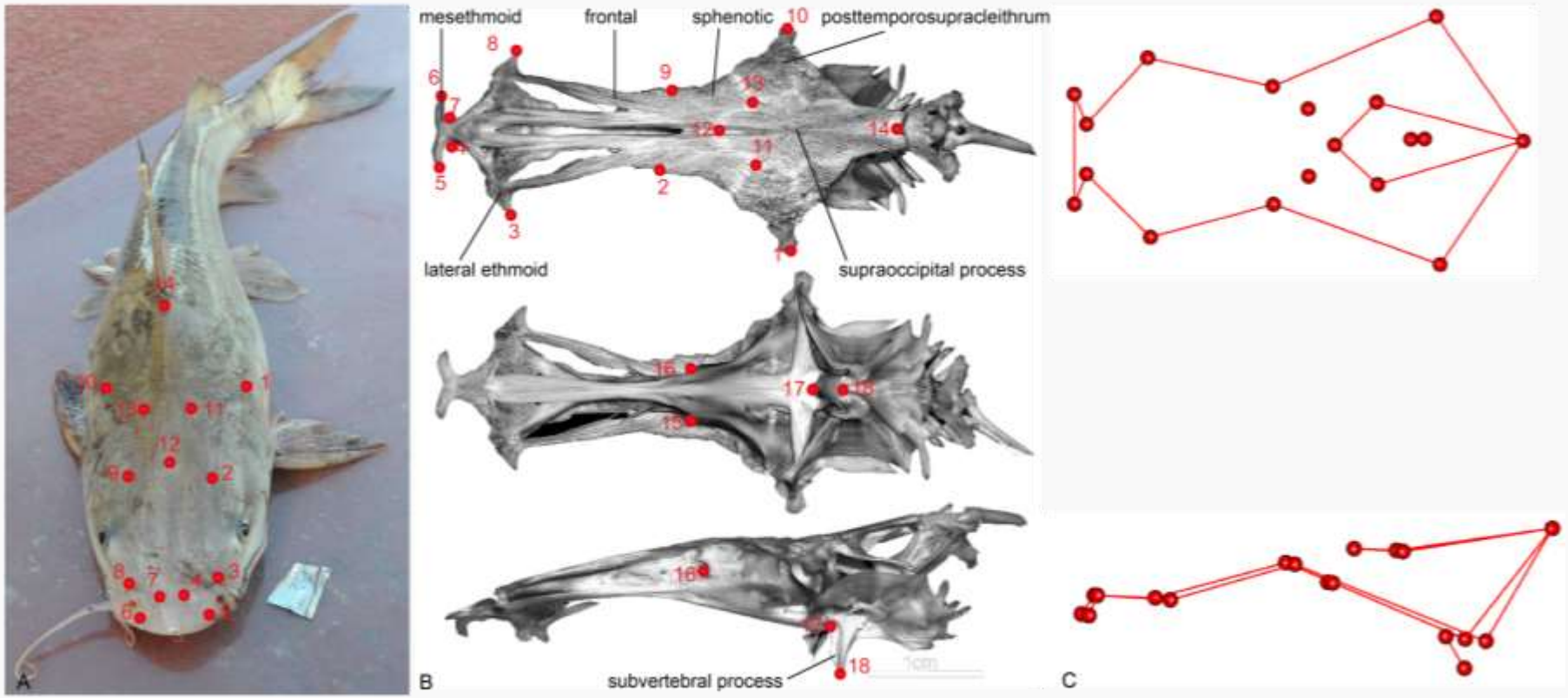
Take home message - Bayesian Divergence-Time Estimation with SNPs

a solid phylogenetic hypothesis for northern Neotropical Ariidae...

- support cryptic species (*B. pinnimaculatus*, *S. herzbergii*)
- provide the first molecular evidence of *C. nuchalis* and *C. wayuu* being molecularly distinct
- does not support to raise *Bagre* to family status
- adds strong support for the hypothesis of Miocene isthmus closure

Did sea catfishes develop similar shapes in similar habitats?

3D Geometric Morphometrics

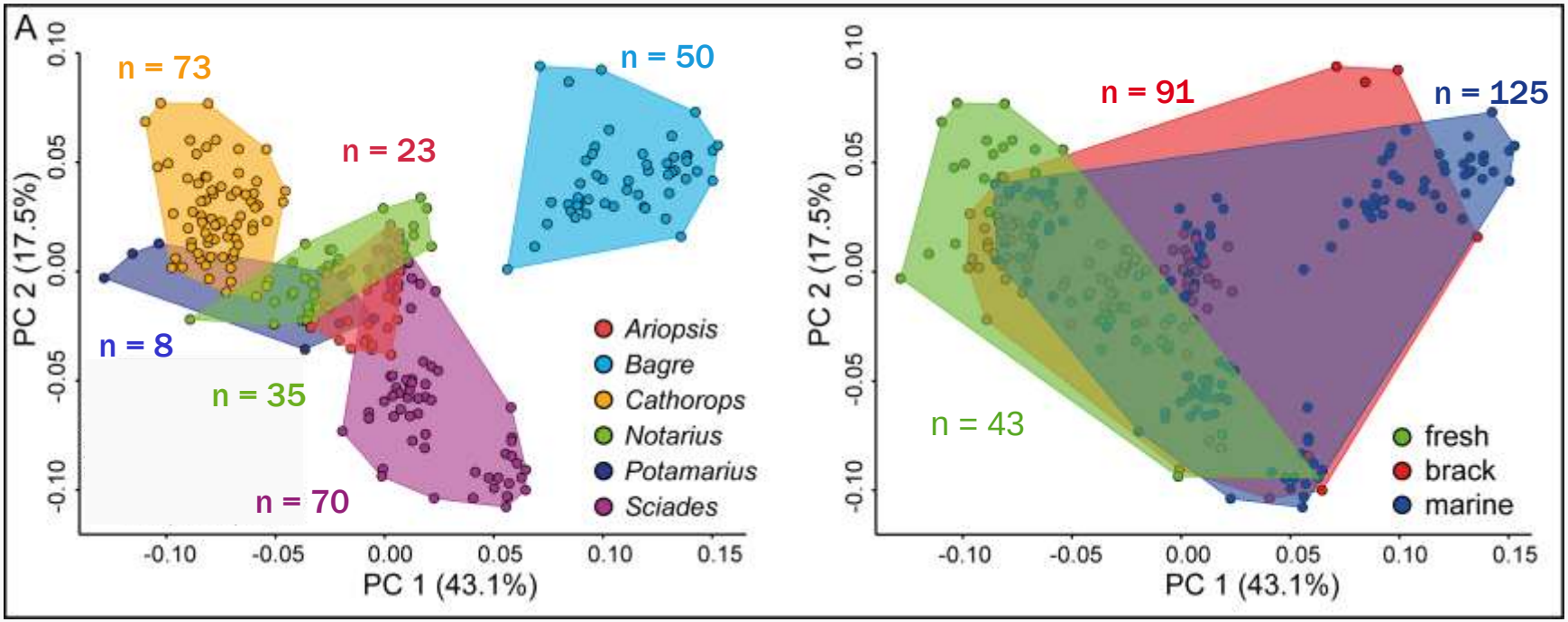


Stange *et. al*., in prep

Morphospace analysis

genus

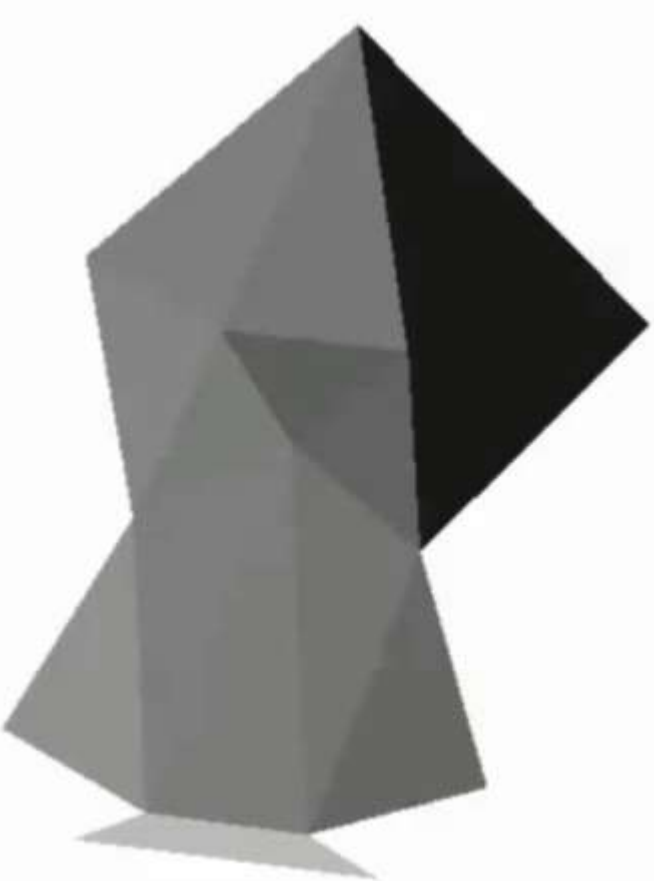
habitat

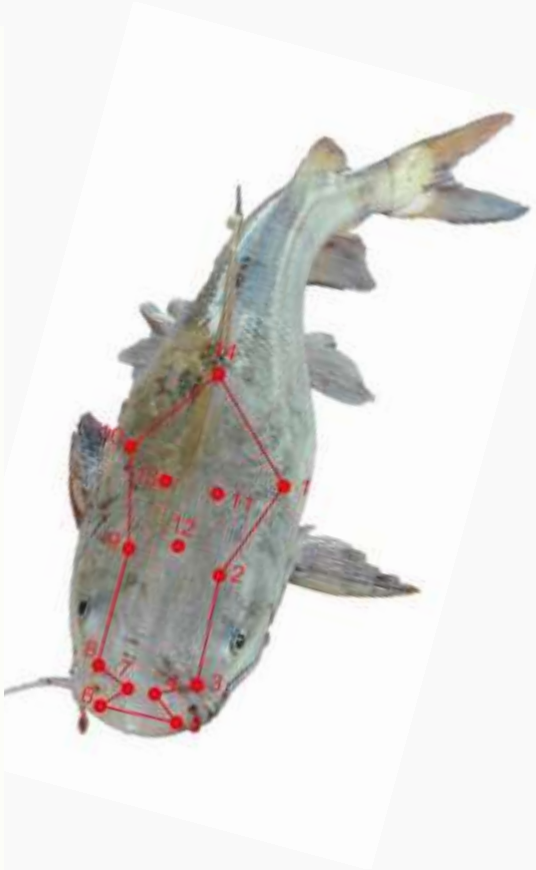


Principal Component Analysis (PCA), 259 specimens, 28 species

Stange *et. al.*, in prep

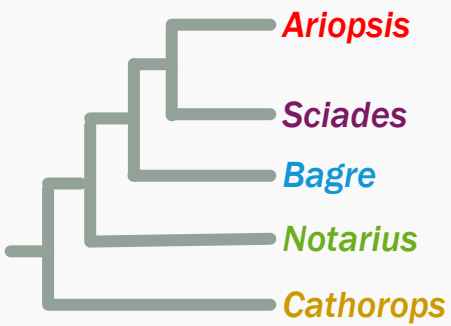
Skull Shape Changes from sea to fresh water in PC1/2 shape space

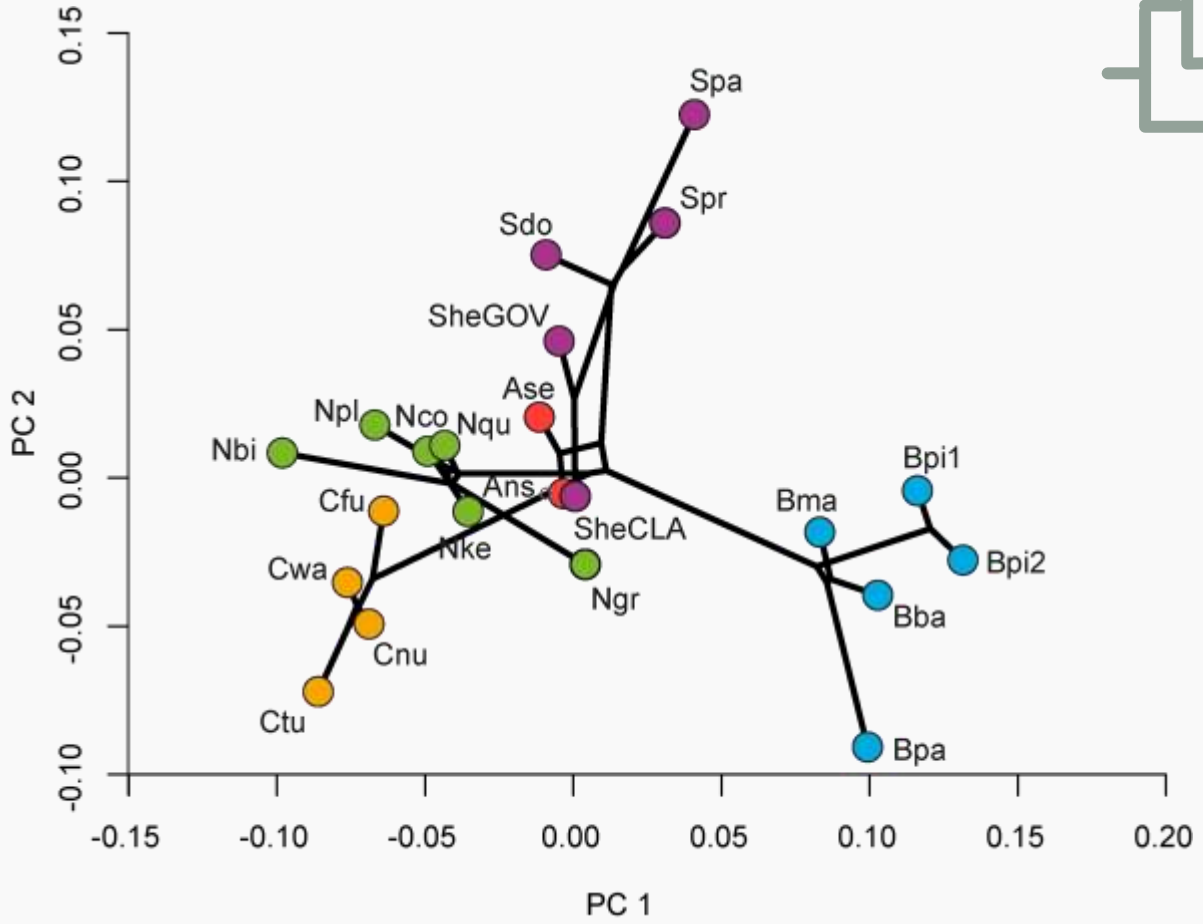




Stange *et. al.*, in prep

Phylogeny Mapped On PC Scores





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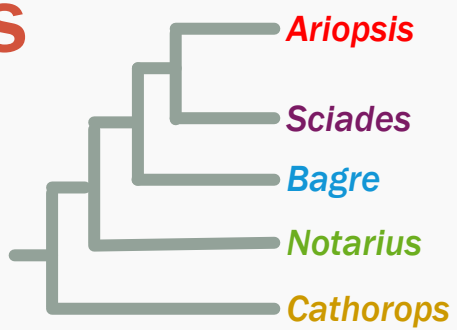
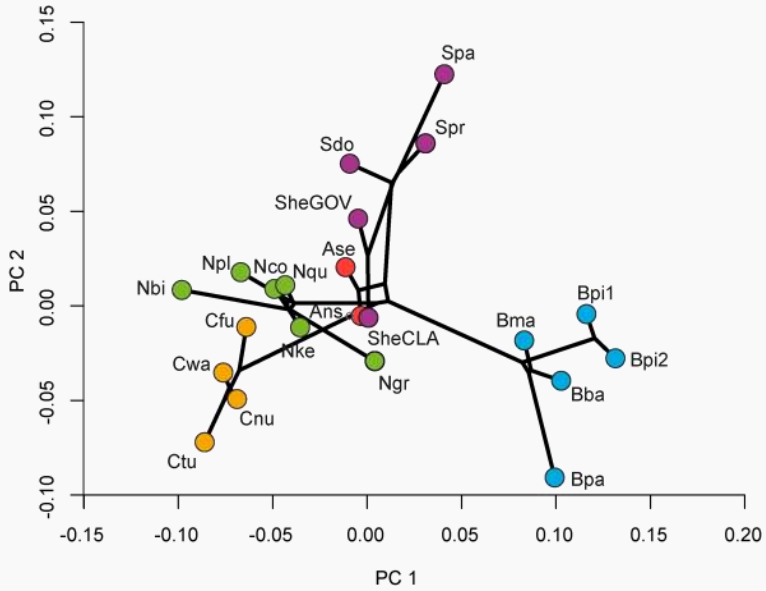
Phylogenetically Informed Analyses



Shape variation in PC1 and PC2 is explained by phylogeny

- observed phylogenetic signal in shape data: K=0. 6854, *P = 0.001*
  in PC1: λ=1, *P* = 1
  in PC2: λ=0.81, *P* = 0.14

- no significant differences among skull shapes of different habitats (phylogenetic ANOVA)



Stange *et. al*., in prep

Take Home Message – Neotropical Ariidae

- taxonomic richness is not fully explored
  - cryptic species identified by mtDNA, nuclear SNP dataset, + either skull morphology (*B. pinnimaculatus*) or GM (*S. herzbergii*)
- *Bagre* is a taxonomic unit within other ariid genera (determined by SNP data) and it is not justified to be raised to family status (as claimed by morphological studies)
- skull shape is, opposed to many other phenotypically diverse and species-rich teleost species, primarily determined by phylogeny
- dating of lineage splitting events between Caribbean and TEP species provides additional biological evidence for a temporary closure of the Panamanian Isthmus

Acknowledgments

SNF Sinergia project granted to W. Salzburger & M. Sánchez-Villagra (CRSII3-136293)

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Venezuela:
Cathy Villalba
Universidad del Zulia:
Tito Barros & Gilson Rivas

Panama:
Smithsonian Tropical Research Institute:
Richard Cooke, Aureliano Valencia, Máximo Jiménez, and Carlos Jaramillo

Switzerland:
University of Zürich:
Jorge Carrillo-Briceño, Alexandra Wegmann, Thodoris Argyriou

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Thank you very much for your attention! Questions?

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