

New light on the paleobiogeography of the labyrinth fishes

Feixiang Wu^{1,*}, Dekui He², Mee-mann Chang¹ and Desui Miao³

¹Key Laboratory of Vertebrate Evolution and Human Origins of Chinese Academy of Sciences, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing 100044, China

²The Key Laboratory of Aquatic Biodiversity and Conservation, Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan, China

³Biodiversity Institute, University of Kansas, Lawrence, KS 66045, U.S.A.

(Received 16 May 2017; accepted 8 June 2017)

Abstract - The labyrinth fishes (Anabantoidei/Anabantiformes) have an African-Asian disjunctive distribution; however, their biogeographical history remains elusive due to the scarcity of their fossil records, especially for the Anabantidae itself, the only anabantoid family with a disjunctive biogeography. A time-calibrated anabantoid phylogeny incorporating both fossil and extant taxa and a likelihood dispersal extinction and cladogenesis (EDC) model in the software package of LAGRANGE were used to infer the ancestral areas of main lineages of the anabantoid fishes. The results suggest that "before" the split of the Asian and African anabantids is a recent event. The split of the Asian-African anabantid is a recent event. The traditional drift vicariance hypothesis and the late Cretaceous or early Tertiary dispersal hypotheses are now called into question for the interpretation of the anabantid biogeographical pattern.

Keywords: †*Eoanabas*, paleobiogeography, labyrinth fishes

1. Introduction

The labyrinth fishes (Anabantoidei/Anabantiformes) have an African-Asian disjunct distribution; however, their biogeographical history remains elusive due to the scarcity of their fossil records, especially for the Anabantidae itself, the only anabantoid family with a disjunctive biogeography (Murray *et al.*, 2015; Rüber *et al.*, 2006). Previously, hypotheses of Gondwanan continental drift vicariance or late Mesozoic to early or middle Cenozoic dispersals from Asia to Africa, or *vice versa*, were proposed to interpret their current distribution pattern (Liem, 1963; Skelton, 1980; Rüber *et al.*, 2006). Recently, we discovered a fossil climbing perch, †*Eoanabas thibetana*, from the upper Oligocene of the central Tibetan Plateau, which has a mosaic character combination of African and Asian anabantids and represents the oldest and most primitive lineage to date of the Anabantidae and also the only fossil labyrinth fish with well-constrained age (Murray *et al.*, 2015; Wu *et al.*, 2017). Motivated by this discovery, we attempt to explore the biogeography history of the labyrinth fishes and test the validity of former relevant hypotheses.

2. Materials and methods

A time-calibrated anabantoid phylogeny incorporating both fossil and extant taxa and a likelihood dispersal extinction and cladogenesis (EDC) model in the software package of LAGRANGE (Ree and Smith, 2008) were used to infer

the ancestral areas of main lineages of the anabantoid fishes. The divergence times were estimated by using an uncorrelated model of molecular evolutionary rate heterogeneity that assumes a lognormal distribution of molecular rates (UCLN) implemented in the computer program BEAST version 1.7.5 (Drummond and Rambaut, 2007).

3. Results

The results of our analyses echoed the placement of †*Eoanabas* as a stem anabantid and the reciprocal monophyly of African and Asian anabantids (Wu *et al.*, 2017). The divergence of the African and Asian anabantids was estimated to occur at the middle Miocene, and hence 20 to 74 Myr younger than estimated by previous molecular analyses (Rüber *et al.*, 2006) and even younger than the age (165-121 Ma) of the geological split between India and Africa continents (Storey, 1995).

4. Discussion and conclusion

The split of the Asian-African anabantid is a recent event. The traditional drift vicariance hypothesis and the late Cretaceous or early Tertiary dispersal hypotheses are now called into question for the interpretation of the anabantid biogeographical pattern. Our analyses inferred that the anabantid fishes probably had originated in southeast Asian during the middle Paleogene and subsequently dispersed to Africa in middle Miocene via the land bridge created by

* Author for correspondence: wufeixiang@ivpp.ac.cn.

the connection of Eurasia and Arabo-Africa in the early Miocene (Rögl, 1999).

Acknowledgement

We thank E. M. Friis and J. Qiu for helpful suggestions; B. Kang, S. O. Kullander, T. Su, Y. Lin and J. Xue for valuable discussions; Z. Wang for preparing and W. Gao, G. Xu, W. Zhang for photographing fossils; L. Dong, F. Shi, Y. Chen, C. Jin, F. Wu, C. Song and other colleagues for help in collecting fossils; X. Sa, B. Kang for supplying extant specimens; Y. Zhao and L. Liang for helping with making cleared and stained specimens; and two anonymous reviewers for their helpful suggestions. This work was supported by the Strategic Priority Research Program of the Chinese Academy of Sciences (grant XDB03020104), the National Basic Research Program of China (grant 2012CB821900), National Natural Science Foundation of China (grants 41430102, 41272028 and 41206173).

References

- Drummond, A. J. and Rambaut, A. 2007. BEAST: Bayesian evolutionary analysis by sampling trees. *BMC Evolutionary Biology* 7, 214.
- Liem, K. 1963. The comparative osteology and phylogeny of the Anabantoidei (Teleostei, Pisces). *Illinois Biological Monographs*, 30, 1-149.
- Murray, A. M., Zaim, Y., Rizal, Y., Aswan, Y., Gunnell, G. F. and Ciochon, R. L. 2015. A fossil gourami (Teleostei, Anabantoidei) from probable Eocene deposits of the Ombilin Basin, Sumatra, Indonesia, *Journal of Vertebrate Paleontology* 35 (2), e906444.
- Ree, R. H. and Smith, S. A. 2008. Maximum likelihood inference of geographic range evolution by dispersal, local extinction, and cladogenesis. *Systematic Biology* 57, 4-14.
- Rögl, F. 1999. Mediterranean and Paratethys. Facts and hypotheses of an Oligocene to Miocene paleogeography (short overview). *Geologica Carpathica* 50, 339-349.
- Rüber, L., Britz, R. and Zardoya, R. 2006. Molecular phylogenetics and evolutionary diversification of labyrinth fishes (Perciformes: Anabantoidei). *Systematic Biology* 55, 374-397.
- Skelton, P. 1980. Systematics and biogeography of the redbfin *Barbus* species (Pisces, Cyprinidae) from southern Africa. Ph.D. dissertation, Rhodes University, Grahamstown, South Africa.
- Storey, B. C. 1995. The role of mantle plumes in the continental breakups: Case histories from Gondwanaland. *Nature* 377, 301-308.
- Wu, F. Miao, D., Chang, M. M., Shi G. and Wang, N. 2017. Fossil climbing perch and associated plant megafossils indicate a warm and wet central Tibet during the late Oligocene. *Scientific Reports* 7, 878.