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## Revision and phylogeny of narrow-mouthed treefrogs (*Cophyla*) from northern Madagascar: integration of molecular, osteological, and bioacoustic data reveals three new species

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### Abstract

We provide a revision of microhylid treefrogs of the genus *Cophyla*, the type genus of the subfamily Cophylinae. A phylogeny inferred from DNA sequences of multiple mitochondrial and nuclear genes, with representatives of all cophyline genera except *Madecassophryne* and including representatives of the two most divergent intrageneric lineages within *Cophyla*, placed *Cophyla* as sister group of *Platypelis* and confirmed both genera as reciprocally monophyletic. We describe three new *Cophyla* species based on osteological, morphological and bioacoustic characters as well as genetic differentiation in one nuclear and several mitochondrial markers. As in the vast majority of cophyline, all species of *Cophyla* emit long, stereotyped repetitions of a single tonal note, and we here consider one of these notes as a call; call duration thus equals note duration and the intervals between calls are named inter-call intervals. *Cophyla maharipeo* **sp. nov.** collected in Joffreville and Forêt d'Ambre Special Reserve (adult SVL 22–27 mm) is characterized by having long calls (1166–1346 ms) with long inter-call intervals (2154–3881 ms). *Cophyla noromalalae* **sp. nov.** collected in Montagne d'Ambre National Park (adult SVL 22–29 mm) is characterized by having short calls (662–821 ms) and short inter-call intervals (874–1882 ms). *Cophyla puellarum* **sp. nov.**, also from Montagne d'Ambre National Park, is larger than the other two species (adult SVL 27.3–33.6 mm) and characterized by the shortest calls (326–390 ms) and long inter-call intervals (1961–3996 ms). Osteological analyses based on micro-CT scans and cleared and stained specimens confirms that the shape of the posterior vomer (centrally divided vs. undivided) may be a useful character to diagnose most species as belonging to either *Platypelis* and *Cophyla*, and suggest the absence of clavicles (present in *Platypelis*) is a derived character of most *Cophyla*. However, clavicles were present in *C. puellarum*, the only known *Cophyla* occurring at relatively high elevations (1250–1300 m a.s.l.) while otherwise in northern Madagascar, forests at higher elevations up to 2700 m a.s.l. are occupied by *Platypelis* species. *Cophyla maharipeo* was found at relatively low elevations (630–720 m a.s.l.), similar to the three previously known congeners (*C. berara*, *C. occultans*, *C. phyllodactyla*). *Cophyla noromalalae* occurs at intermediate elevations (900–1050 m a.s.l.). The molecular phylogeny inferred herein suggests that the ancestor of a clade containing all *Cophyla* species except *C. puellarum* evolved a modified shoulder girdle structure without ossified clavicles, and adapted to low-elevation habitats.

**Key words:** Amphibia, Anura, Microhylidae, *Platypelis*, conservation status, integrative taxonomy, Montagne d'Ambre, micro-CT scanning

### Introduction

Compared to other tropical regions, the amphibians of Madagascar are relatively well studied. Due to the intensive studies of the last 20 years significant gaps in species inventory have become obvious (Vieites *et al.* 2009). These

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