



## Phylogeny and cryptic diversification in Southeast Asian flying geckos

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### ARTICLE INFO

#### Article history:

Received 8 March 2012

Revised 31 May 2012

Accepted 13 June 2012

Available online 26 June 2012

#### Keywords:

Canopy specialists

Flying geckos

Parachute geckos

Southeast Asia

Vertebrate gliders

### ABSTRACT

The closed-canopy forests of Southeast Asia are home to an impressive number of vertebrates that have independently evolved morphologies that enhance directed aerial descent (gliding, parachuting). These assemblages include numerous mammal, frog, snake, and lizard clades. Several genera of gekkonid lizards, in particular, have evolved specialized structures such as cutaneous expansions, flaps, and midbody patagia, that enhance lift generation in the context of unique gliding and parachuting locomotion. The genus *Ptychozoon* represents arguably the most morphologically extreme, highly specialized clade of gliding geckos. Despite their notoriety and celebrated locomotor ability, members of the genus *Ptychozoon* have never been the subject of a species-level molecular phylogenetic analysis. In this paper, we utilize molecular sequence data from mitochondrial and nuclear gene fragments to estimate the evolutionary relationships of this unique group of flying geckos. Capitalizing on the recent availability of genetic samples for even the rarest of known species, we include the majority of known taxa and use model-based phylogenetic methods to reconstruct their evolutionary history. Because one species, *P. kuhli*, exhibits an unusually wide distribution coupled with an impressive range of morphological variation, we additionally use intensive phylogeographic/population genetic sampling, phylogenetic network analyses, and Bayesian species delimitation procedures to evaluate this taxon for the possible presence of cryptic evolutionary lineages. Our results suggest that *P. kuhli* may consist of between five and nine unrecognized, distinct species. Although we do not elevate these lineages to species status here, our findings suggest that lineage diversity in *Ptychozoon* is likely dramatically underestimated.

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### 1. Introduction

Among Southeast Asia's myriad of highly specialized gliding vertebrates (Colbert, 1967; Russell, 1979a; Emerson and Koehl, 1990; Goldingay and Scheibe, 2000; Dudley et al., 2007), flying geckos of the genus *Ptychozoon* have inspired more awe<sup>1</sup> and speculation than perhaps any other group of Asian geckos (Annandale, 1904, 1905; Barbour, 1912; de Rooij, 1915; Tweedie, 1954; Tiwari, 1961; Pong, 1974; Tho, 1974; Taylor, 1975; Russell, 1979a,b). Most species in this small genus (seven species) are rarely encountered

by biologists and, as a consequence, are poorly represented in natural history collections (Brown et al., 1997). The majority of species are known from the Southeast Asian mainland and adjacent Sundaland island archipelagos (Taylor, 1915, 1922a,b; Brown et al., 1997; Das and Vijayakumar, 2009), but three taxa, *P. kuhli*, *P. lionotum*, and *P. trinotaterra*, possess geographic ranges extending northward well into Indochina (Taylor, 1963; Inger and Colwell, 1977; Biswas and Sanyal, 1980; Das, 1994a,b; Brown, 1999; Pauwels et al., 2000; Stuart and Emmett, 2006; Grismer et al., 2008; Grismer, 2011), and a single species (*P. lionotum*) has been recorded from the Indian subcontinent (Pawar and Biswas, 2001; Venugopal, 2010).

Until recent taxonomic work clarified species boundaries (Brown et al., 1997; Brown, 1999; Das and Vijayakumar, 2009), specimen identification in museum collections was often tenuous (RMB, pers. obs), with numerous conflicting literature accounts resulting in general confusion regarding species identifications and geographic distributions (Cantor, 1847; Günther, 1864, 1885; Boulenger, 1885; Flower, 1896; Stejneger, 1907; Smith, 1930, 1935; Taylor, 1928, 1963; Wermuth, 1965; Dring, 1979; Bobrov,

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<sup>1</sup> "Tiny wing like flaps were on either side of the face, other broad winglike expansions were along the side of its body, a similar flap bordered the back of the thigh. The long tail had a series of frills on each side, as if scalloped lace had been sewn on the sides for decoration" (Taylor, 1975, p. 47).