



Contents lists available at ScienceDirect

## Molecular Phylogenetics and Evolution

journal homepage: [www.elsevier.com/locate/ympev](http://www.elsevier.com/locate/ympev)

## Phylogenetic relationships of the Asian palm civets (Hemigalinae &amp; Paradoxurinae, Viverridae, Carnivora)

Marie-Lilith Patou<sup>a,\*</sup>, Régis Debruyne<sup>b,c,1</sup>, Andrew P. Jennings<sup>a</sup>, Akbar Zubaid<sup>d</sup>,  
Jeffrine Japning Rovie-Ryan<sup>e,f</sup>, Géraldine Veron<sup>a</sup><sup>a</sup>Unité Origine, Structure et Evolution de la Biodiversité (CNRS UMR 5202), Département Systématique et Evolution, Muséum National d'Histoire Naturelle, CP 51, 57 rue Cuvier, 75231 Paris Cedex 05, France<sup>b</sup>Service de Systématique Moléculaire, IFR CNRS 101, Muséum National d'Histoire Naturelle, 43 rue Cuvier, 75005 Paris, France<sup>c</sup>Unité Paléobiodiversité, CNRS UMR 5143, Muséum National d'Histoire Naturelle, CP38, 57 rue Cuvier, 75231 Paris Cedex 05, France<sup>d</sup>School of Environmental & Natural Resource Sciences, Faculty of Science & Technology, University Kebangsaan Malaysia, 43600 UKM Bangi, Malaysia<sup>e</sup>Ex-Situ Conservation Division, Department of Wildlife & National Parks (DWNP), Peninsular Malaysia, Ministry of Natural Resources and Environment Malaysia (NRE), KM 10 Jalan Cheras, Kuala Lumpur, Malaysia<sup>f</sup>Institute for Biodiversity, DWNP, NRE, 28500 Bukit Rengit Lanchang, Pahang, Malaysia

## ARTICLE INFO

## Article history:

Received 18 September 2006

Revised 6 March 2008

Accepted 12 March 2008

Available online 22 March 2008

## Keywords:

Viverridae

Hemigalinae

Paradoxurinae

Molecular phylogeny

Molecular dating

## ABSTRACT

The Viverridae (Mammalia, Carnivora), one of the least studied groups of carnivorans, include two subfamilies of Asian palm civets: Hemigalinae and Paradoxurinae. The relationships between and within these two subfamilies have never been thoroughly tested using an extensive molecular sample set. In this study, we gathered sequences of four genes (two mitochondrial: Cytochrome *b* and ND2 and two nuclear:  $\beta$ -fibrinogen intron 7 and IRBP exon 1) for eight of the eleven extant species representing these two subfamilies. The results showed that: (1) the Asian palm civets (Hemigalinae and Paradoxurinae) have a single origin and form the sister-group of the (Genettinae + Viverrinae) clade, (2) the Hemigalinae (including the otter civet *Cynogale bennettii*) are monophyletic, (3) the Paradoxurinae are monophyletic and (4) the small-toothed palm civet (*Arctogalidia trivirgata*) is an early offshoot within the Paradoxurinae. Using a relaxed molecular clock analysis, the differentiation of the (Hemigalinae + Paradoxurinae) was inferred to occur in the Late Oligocene/Early Miocene.

© 2008 Elsevier Inc. All rights reserved.

## 1. Introduction

The Viverridae are medium-sized, nocturnal, solitary carnivorans (Nowak, 1999). They are elusive and poorly known, and until recently, were long overlooked by researchers. Wozencraft (2005) recognized four subfamilies: Hemigalinae, Paradoxurinae, Prionodontinae and Viverrinae. However, recent studies have shown that the Prionodontinae (Asian linsangs—*Prionodon*) are a sister-group of the Felidae and should now be erected as a family, the Prionodontidae (Gaubert and Veron, 2003; Gaubert et al., 2005). Gaubert and Cordeiro-Estrela (2006) have argued that the Viverrinae should be split into two subfamilies: the Viverrinae (terrestrial civets) and the Genettinae (*Genetta* and *Poiana*).

The Hemigalinae and Paradoxurinae—the Asian palm civets—are two subfamilies confined to South and South-East Asia,

whereas the Viverrinae are distributed across Asia and Africa, and the Genettinae across Africa and part of Europe. Although little is known about the ecology of most of the palm civet species, they are generally nocturnal, some are arboreal and frugivorous (Grassman, 1997; Nowak, 1999; Veron, 1999; Mudappa, 2001), and others are omnivorous or invertebrate eaters (Kowalczyk, 1989; Nowak, 1999). Some palm civets may play an important role in seed dispersal (Corlett, 1998). These taxa are of important conservation concern, with five species listed in the IUCN (2007) Red List of Threatened Species as endangered or vulnerable (<http://www.iucnredlist.org>), although this situation could be underestimated given the scarcity of data about their current biological status (Schreiber et al., 1989). The destruction of habitat by intensive deforestation is the major threat to this group (Brooks et al., 1999; Laurance, 1999; Brook et al., 2003; Sodhi et al., 2004).

To date, the systematics of the Hemigalinae and Paradoxurinae has been mainly assessed by morphological data (Pocock, 1933; Gregory and Hellman, 1939; Wozencraft, 1989; Veron, 1994, 1995). Molecular studies of feliform carnivorans have included very few representatives of these subfamilies due to the difficulties in obtaining biological material (see Veron and Heard, 2000; Gaubert

\* Corresponding author. Fax: +33 (0) 1 40 79 30 63.

E-mail address: [patou@mnhn.fr](mailto:patou@mnhn.fr) (M.-L. Patou).<sup>1</sup> Present address: McMaster Ancient DNA Centre, Department of Anthropology, McMaster University, Chester New Hall, Room 524, 1280 Main Street, West Hamilton, Ont., Canada L8S 4L9.