

## Species diversity, endemism and distribution of land snails of the Western Ghats, India

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**Abstract** – As elsewhere, invertebrate taxa have received little attention in conservation planning in India. The Western Ghats has been designated as a global biodiversity hotspot, one of only two such designations in India. We have assembled a database for land snail records in the region, incorporating both published records and the results of our own surveys over the last three years. Of the 269 species so far recorded, 75% are endemic to the region. Many species have very restricted ranges within the region. There is a decline in diversity and local endemism from south to north. The southernmost division (8–12°N) has much the richest recorded fauna (210 species), and the highest level of local endemism (56%). The latter is much lower in the central (12–16°N) and northern (16–21°N) divisions. There is thus considerable faunal turnover within the region. The overall level of endemism is higher than that recorded for other taxa, and our data have already been used to identify three local hotspots within the region. These results are discussed in terms of present climate and habitats, and in terms of environmental history. Comparisons are made with studies on other continents, and the impact of human activity by destruction and fragmentation of habitats is considered.

**Key words:** Land snail distribution, Western Ghats, endemism, species diversity

### INTRODUCTION

Although conservation of biological diversity as a whole is now a matter of global concern, most analyses, effort and resources have been allocated to charismatic mammals and birds. In the Indian context, this is evident from the setting aside of large areas of habitats as protected areas (PAs) where such animals are known to occur (Uma Shaanker *et al.*, 2004). In general, invertebrate species have been neglected despite their far greater numbers, and despite the fact that recent evidence shows that they can be more reliable indicators of "hotspots" of high diversity and endemism overall (Moritz *et al.*, 2001). Efficient conservation planning requires awareness of invertebrate distribution, diversity and endemism patterns.

India has two internationally recognised biologically rich areas, one being Eastern Himalaya and the other being the Western Ghats. The Western Ghats, coupled with Sri Lanka, is one of the twenty-five prime hotspots of the world (Myers, 1988; Myers *et al.*, 2000), and is known for its rich flora and fauna with a high degree of endemism (Groombridge, 1992). Existing knowledge of distribution and habitats is, however, largely concentrated on birds, plants, amphibians and

fishes (Ali, 1935; Daniels, 1992; Dahanukar *et al.*, 2004; Ramesh and Pascal, 1996). The region is undergoing rapid transformation due to anthropogenic activities (Jha *et al.*, 2000), making the identification and protection of key areas an urgent priority. As Moritz *et al.* (2001) have shown, land snails are very good indicators of conservation importance and of centers of endemism, and they can be used to identify significant localities at much smaller scale than those identified by studies on vertebrates.

Unfortunately, there have been few modern studies of land snail distribution in India, even though it is known to have hotspots of molluscan diversity. Most data come from the *Fauna of British India*, published between 1908 and 1921. Later studies are few. Although one recent study has tried to assess the diversity of land snails in Western Ghats based on earlier literature (Madhyastha *et al.*, 2004), there are no modern data available on the distribution and endemism of this group. In this study, we report the results of new fieldwork, and use our results, together with earlier work to: (a) identify areas of high species richness and endemism of land snails in Western Ghats; (b) compare the endemism of land snails with that of

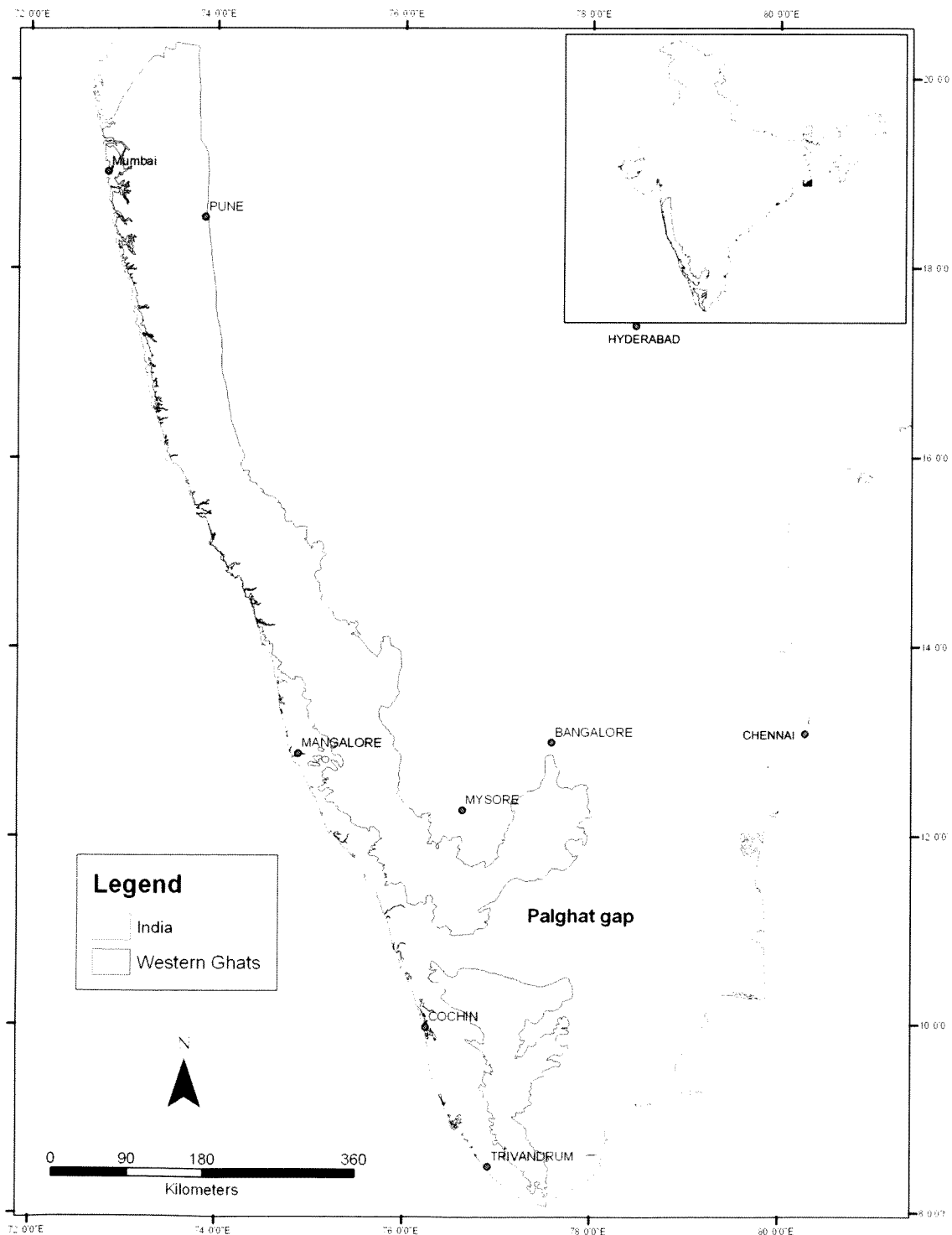
other groups, and (c) determine the distributional patterns of land snails in Western Ghats.

## MATERIALS AND METHODS

### Study area

The Western Ghats region is a mountain chain running for 1,600 km parallel to the west coast of

India from the river Tapti (Gujrat) in the north, to Kanyakumari (Tamil Nadu) in the south, between the latitudes 8°N to 21°N, and covering an area of about 160,000 km<sup>2</sup> (Daniels, 2004). The continuity of this hill chain is interrupted by the 30 km wide 'Palghat Gap' near 11°N (Figure 1). Between the Arabian Sea to the west and the mountains to the east is a coastal region of varying width ranging from 30 to 60 km. The narrowest strip is at latitude



**Figure 1** Map showing the location of the Western Ghats hotspot in India

14° and 15°N where the Ghats are close to the west coast. Rising from the coastal strip, the mountains reach 2,800 m at the highest peak. High peaks above 2,000 m are found in the Nilgiris, Anamalais and Palnis in the southern region. To the east, the mountains descend to plains at about 600 m. Different regions of the Western Ghats receive varying amounts of rainfall ranging from less than 1,000 mm to more than 7,600 mm per annum (Agumbe, Karnataka), with an average of 2,500 mm (Gadgil, 1996). The bulk of the rainfall is received in the southwest monsoon between June and October, but the rainy season in the south is often prolonged due to pre-monsoon and winter showers. Thus, the dry periods in the southern parts of the Western Ghats are shortest, lasting for 2 to 5 months while in the northern parts it varies from 5 to 8 months. Mean annual temperature ranges between 20° and 24°C. However, it frequently reaches beyond 30°C during April-May and sometimes falls to 0°C during winter at the higher altitudes (Dahanukar *et al.*, 2004).

Further details of geology, biodiversity and ecological history of the Western Ghats are available elsewhere (Chandran, 1997; Gadgil, 1994, 1996; Valdiya, 2002; Daniels, 2004). The combination of particular environmental and historical factors make the Western Ghats an area of exceptional biological diversity and conservation interest, and it is "one of the major Tropical Evergreen Forest regions in India" (Rodgers and Panwar, 1988). The landscape of the Western Ghats has undergone a great change over the past century. The nature, extent and cause of the transformation have been debated extensively (Gadgil, 1996). The high rate of human population growth, infiltration into forests through roads, dams and expansion of agriculture has reduced forest cover drastically. According to Cincotta *et al.* (2000), human population pressure in the Western Ghats will continue to rise which is in their highest category of risk and could lead to future extinctions in this region.

#### Data sources

The land snail data regarding the richness, diversity, endemism and distribution in the Western Ghats were obtained from various published sources and our own field analysis. The major source of published information was *Fauna of British India: Mollusca* (Blanford and Godwin-Austen, 1908; Gude, 1914 and 1921). Some additional data come from Sathyamurthi (1960), Tonapi and Mulherkar (1963), Subbarao and Mitra (1979), and Ramakrishna and Mitra (2002). Apart from the published sources we have also included the data on land snails from nine sites from the Western Ghats for the present analysis (Table 1). In each study site, we collected the data such as number of species, habitat in which the species was recorded, altitude, latitude and longitude (using Garmin GPS Map 76s) and number of individuals of each species using the sampling method described in Emberton (1996). However, we have not used the abundance data for the present analysis. A total of 15 new locality records for species were added, but no new species have been added to the overall list. The classification we followed is of Vaught (1989). However, we split the family Subulinidae into Glessulidae and Subulinidae.

#### Methods

All reliable records, old and new, have been entered into a database which is continuously updated. Information entered includes data (where available) on family, species, latitude, altitude, size, endemic, non-endemic, year of discovery of the species, and locality. Early records are not always precisely located. Because of this, we have held back any analysis of relationships between the snail fauna and altitude, although we believe such relationships exist. For the same reason, there are some records for which we have had to make assumptions about the latitude and longitude, taking into account the latitude and longitude of the nearest named place. While this may result in a

**Table 1** Sites, region, latitude and number of land snail species.

| Site   | Region     | Latitude (°N)      | No. of species | References                                      |
|--|------------|--------------------|----------------|---|
| Agumbe   | Karnataka  | 13° 30'            | 22             | Aravind unpublished                             |
| Aralasurali  | Karnataka  | 13° 48'            | 18             | Aravind unpublished                             |
| Nagara   | Karnataka  | 13° 47'            | 25             | Aravind unpublished                             |
| Biligiri Rangaswamy Temple Wildlife Sanctuary (BR Hills) | Karnataka  | 11° 47' to 12° 09' | 23             | Aravind unpublished                             |
| Rajiv Gandhi (Nagarahole) National Park                  | Karnataka  | 11° 45' to 12° 15' | 41             | Ganesh <i>et al.</i> , 2002                     |
| Kudremukh National Park                                  | Karnataka  | 13° 01' to 13° 29' | 73             | Madhyastha <i>et al.</i> personal communication |
| Sharavathi Wildlife Sanctuary                            | Karnataka  | 13° 42' to 14° 00' | 22             | Mavinkurve <i>et al.</i> in press               |
| Madikeri   | Karnataka  | 12° 25'            | 62             | Mavinkurve <i>et al.</i> unpublished            |
| Kalakkad-Mundanthurai Tiger Reserve (KMTR)               | Tamil Nadu | 08° 20' to 08° 53' | 25             | Mavinkurve <i>et al.</i> unpublished            |

few misattributions, we are confident that the results of our analyses are robust overall.

For analysis we split the Western Ghats into three latitudinal divisions: north (between 16° and 21°N), central (between 12° and 16°N) and south (between 8° and 12°N), following Ramesh and Pascal (1996), Subramanian and Shivaramkrishnan (2002) and Danankar *et al.* (2004). Sorensen's similarity index (using presence and absence data) was used to assess the similarity between the faunas in latitudinal bands.

## RESULTS

### Species diversity and endemism of land snails of the Western Ghats

To date, 1,488 species belonging to 26 families and 140 genera have been recorded from India (Wiktor *et al.*, 1999; Ramakrishna and Mitra, 2002; Madhyastha *et al.*, 2004). Of these, 269 species of land snails have been recorded from the Western Ghats area and constitute about 18 per cent of the country's total land snail fauna. The land snail fauna of the Western Ghats includes members of 24 families and 57 genera (Madhyastha *et al.*, 2004; Table 2). Three families viz., Glessulidae (56

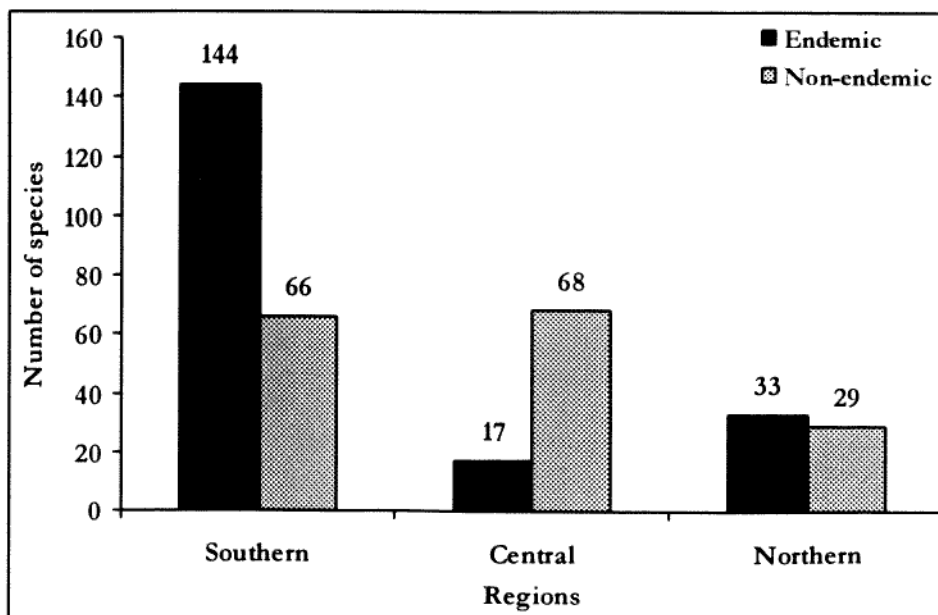
species), Cyclophoridae (54 species) and Ariophantidae (53 species) dominate the assemblage. These three families together constitute 63 per cent of the species of Western Ghats. 204 of the 269 species, c. 76 per cent, are endemic to Western Ghats. *Indrella* (Ariophantidae) a monospecific genus is restricted to the Western Ghats (Front cover).

### Distribution patterns of land snails in the Western Ghats

Figure 2 shows the numbers of species recorded in the three major divisions of the region. The south is decisively the most species-rich with 210 species overall, followed by central and north with 85 and 62 species respectively. There is a high rate of species turnover within the region. Only 15 species are found in all three major divisions (north, central and south), and of these only five are widespread within each. 101 species are currently known only from one locality each; while this may reflect deficiencies in surveying intensity, it is clear that many ranges are very restricted. Comparisons of faunal similarity between 2° latitudinal bands, using the Sorensen index (Table 3), shows a rapid rate of faunal change. This is partly due to the decline in diversity northwards. The latitude range between 10° and 12°N harbours nearly 65 per cent of the land snails of the Western Ghats, and there is a significant decrease in the species richness ( $r = -0.737$ ,  $p < 0.001$ , Figure 3a) and number of families from south to north ( $r = -0.743$ ,  $p < 0.001$ ). Seven families are found throughout the Western Ghats, whereas three families are restricted to latitude 10° to 12°N and two families to 18° - 20°N. The same trend is seen in both endemic ( $r = -0.747$ ,  $p < 0.001$ )

**Table 2** Comparison of land snail diversity of the Western Ghats with India

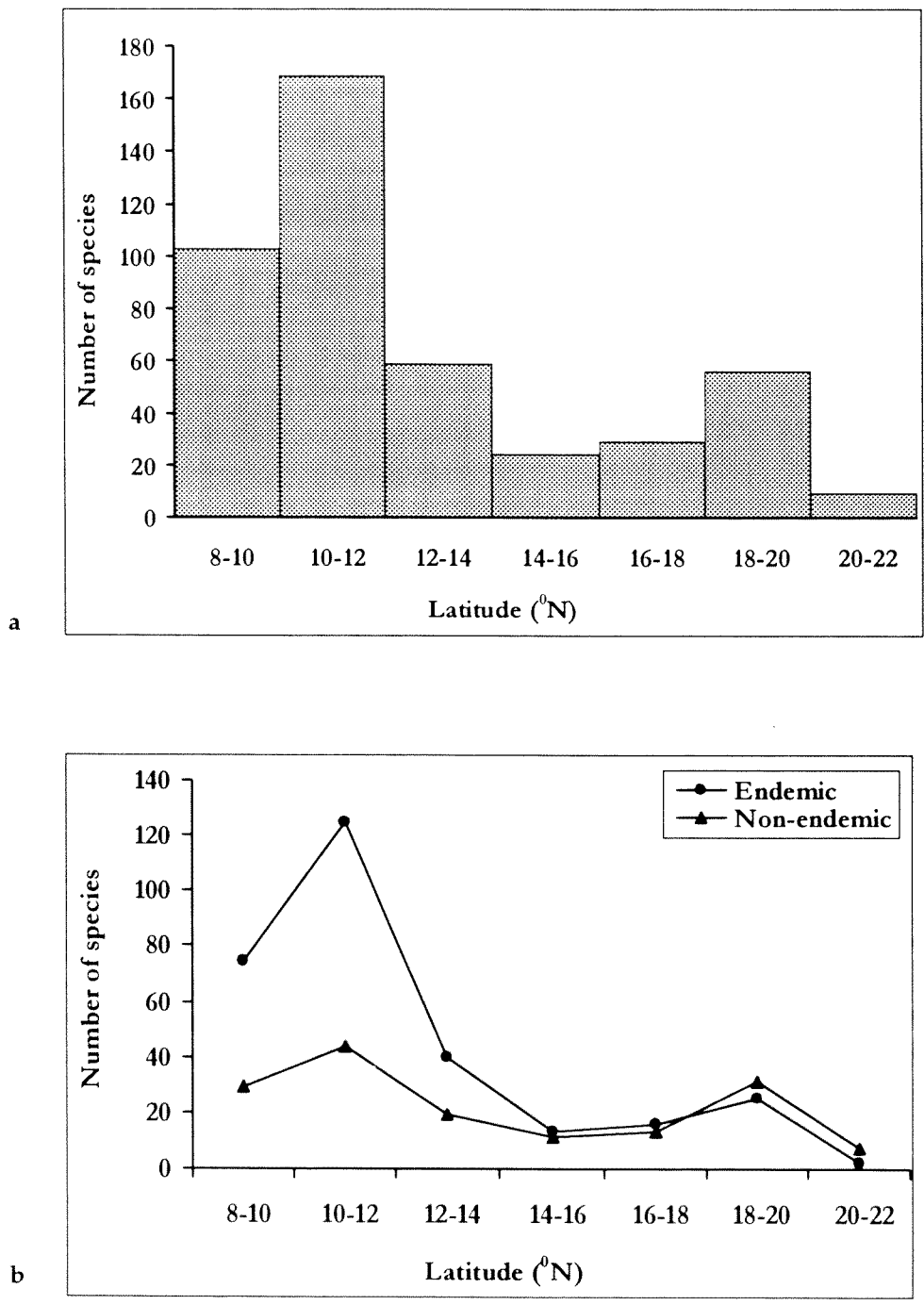
|          | Occurrence in India | Occurrence in Western Ghats | Percentage |
|----------|---------------------|-----------------------------|------------|
| Families | 26                  | 24                          | 92.31      |
| Genera   | 140                 | 57                          | 40.71      |
| Species  | 1,488               | 269                         | 18.10      |



**Figure 2** Distribution of endemic and non-endemic species in three regions of the Western Ghats, India

**Table 3** Sorensen's similarity index between different latitude ranges in the Western Ghats and number of species recorded in each latitudinal band.

| Latitude (°N) | 08-10 | 10-12 | 12-14 | 14-16 | 16-18 | 18-20 | 20-22 | No. of species |
|---------------|-------|-------|-------|-------|-------|-------|-------|----------------|
| 08-10         | 1.00  |       |       |       |       |       |       | 103            |
| 10-12         | 0.46  | 1.00  |       |       |       |       |       | 169            |
| 12-14         | 0.31  | 0.36  | 1.00  |       |       |       |       | 59             |
| 14-16         | 0.22  | 0.13  | 0.34  | 1.00  |       |       |       | 24             |
| 16-18         | 0.18  | 0.16  | 0.36  | 0.49  | 1.00  |       |       | 29             |
| 18-20         | 0.16  | 0.15  | 0.19  | 0.28  | 0.40  | 1.00  |       | 56             |
| 20-22         | 0.11  | 0.07  | 0.15  | 0.30  | 0.21  | 0.22  | 1.00  | 9              |



**Figure 3** a) Number of land snail species found in different latitudinal ranges and b) number of endemic and non-endemic species of land snails found in different latitudinal ranges in the Western Ghats

and non-endemic species ( $r=-0.628$ ,  $p<0.002$ ), but the proportion of non-endemic species increases from south to north (Figure 3b).

Several distinct distributional patterns can be seen in the Western Ghats fauna. Species may be restricted to one or two contiguous divisions within the Western Ghats, they may be found in all three, and beyond. They may show a discontinuous or disjunct distribution within the Western Ghats, while some occur within the region and also in far distant regions with a gap in distribution between. For example, *Ennea bicolor* (Streptaxidae) and *Kaliella barrakporensis* (Helicarionidae) are tropical cosmopolitan species and found throughout the Western Ghats, whereas the monotypic genus *Indrella ampulla* (Ariophantidae) is found only between 10° and 13°N latitude (Front cover). Several species show very restricted distributions. For example, the amphibious species, *Lithotis rupicola* (Succineidae) is found only near waterfalls near Khandala, Northern Western Ghats, *Glessula calkadensis* is restricted to the southern Western Ghats and *Glessula orophila* shows a discontinuous distribution within the region and the genus *Crapedotropis* shows a discontinuous distribution, with species occurring in Western Ghats, Eastern Ghats and North-eastern India, but not in between.

### DISCUSSION

The results presented here on diversity, endemism and distribution of land snails of the Western Ghats are, inevitably, heavily influenced by variation in the completeness of the sampling effort. The southernmost region of the Western Ghats, between 8° and 12°N, is relatively better sampled than the other areas. To date, only 269 species have been recorded from the Western Ghats. With ongoing work, the rate of discovery of new species remains high, and we have no firm basis for predicting the actual number of species present in the region. Evidence from incompletely surveyed tropical and subtropical forest regions on other continents suggests that 500 or more species could be present (Stanisic, 1994; Tattersfield, 1998). The smaller area of Sri Lanka, to the south, has more than 350 species, and is still incompletely surveyed (Naggs and Raheem, this volume). Most records of new species and new localities for known species may come from regions between 12° and 16°N, as this area is the least surveyed. This applies also to fishes and amphibians (Dahanukar *et al.*, 2004; Gururaja, personal communication).

However, some general conclusions can be drawn. As in some other studies (Moritz *et al.*, 2001), endemism in snails is higher (at *c.* 75%) than in other taxa in the Western Ghats (Subramanian and Shivaramakrishnan, 2002) and there are many very restricted endemics with tiny ranges. Existing

knowledge has enabled us already to identify three regions of high species richness and endemism in each of the three divisions: the Nilgiris-Annamalais-Palni hills-Travancore region in southern Western Ghats, the South Kanara-North Kanara region in central Western Ghats, and the Mahabaleshwar-Khandala-Poona region in northern Western Ghats (Aravind *et al.*, in preparation).

On the evidence available at present, the southern Western Ghats (below 12°N) are more diverse than areas further north. This pattern is also true for other groups such as fishes (Dahanukar *et al.*, 2004), endemic plants (Ramesh and Pascal, 1996), and Odonata (Subramanian and Shivaramakrishnan, 2002). However, for amphibians and aquatic insects, the latitudes between 12° and 14°N are richest (Daniels, 1992; Subramanian, 2004). Trends for decreasing regional diversity at higher latitudes are also found elsewhere, for example in New Zealand (Barker, this volume), North America (Nekola, this volume) and in Europe (Cameron, 2004). There may be diverse reasons for this pattern; in the Western Ghats, it seems likely that the combination of a favourable rainfall regime in the south, the presence of high mountains, and a great diversity of habitats contribute to the pattern. In Sri Lanka, the region of highest diversity and local endemism is in the southwest of the island, the area of highest rainfall, with relict stands of rainforest (Naggs and Raheem, 2005).

Several species of land snails are sporadically distributed along the Western Ghats. No doubt some of this patchiness is a product of the unevenness of effort throughout the range of the Ghats. The patchiness in the distribution, however, is not unique to land snails; a similar pattern has been shown for amphibians and birds of the Western Ghats (Ali, 1935; see Daniels, 1992). For example, *Glessula orophila* (Glessulidae) occurs in scattered sites in southern, central and northern Western Ghats. It seems likely that this patchy distribution is a result of local extinction and poor dispersal ability (Diamond, 1973; Daniels, 1992). It has been shown that the Western Ghats has a long history of human impact (Chandran, 1997). The major change in the landscape has occurred in the moist evergreen forests. The vast original extent of this forest type has been reduced and fragmented by a variety of other land use types (Nair and Daniel, 1986; Daniels *et al.*, 1990; Daniels, 1992). This habitat fragmentation, coupled with geological and climatic history, might have created the patchy distribution of some land snails and other taxa of the Western Ghats (Ali and Ripley, 1983; Daniels, 1989, 1992).

Our observations so far reveal the broad pattern of diversity, endemism and geographical distribution of land snails of the Western Ghats. It is clear that, as in other mountainous tropical

regions, the land snail fauna is rich, and largely endemic. Further studies are required to get better insight into the patterns and processes of land snail distribution in this hotspot of biodiversity, studies which will contribute directly to good conservation planning.

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