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Article · January 2008

DOI: 10.11646/zoosymposia.1.1.17

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Zoosymposia 1: 281–294 (2008)
www.mapress.com/zoosymposia/

ISSN 1178-9905 (print edition)
ZOOSYMPOSIA
ISSN 1178-9913 (online edition)

Micromolluscs of the Western Ghats, India: Diversity, distribution and threats

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Abstract

The Western Ghats, India, is one of the 34 hotspots of biological diversity in India and harbour high levels of endemism in a variety of taxa. Research on the faunistic diversity of this hotspot have focused on higher taxa such as mammals and birds and lesser taxa such as land snails have not been studied. Given the rapid land transformation occurring in the Western Ghats, there is an urgent need to study the impact of land use change on poorly known taxa such as land snails. The first attempt was made here to assess the distribution patterns of the land snails of the Western Ghats in relation to land use and habitat disturbances. We assessed geographical distribution patterns of microgastropods along the Western Ghats on the basis of published literature and data from field studies and the impact of land use change and habitat disturbance on microgastropods in the wet forests of the central Western Ghats: a) approximately 40% of the total 269 species of land snails recorded from the Western Ghats were microgastropods, b) the southern Western Ghats harbours high species richness for both micromolluscs as well as macromolluscs compared to the central and northern Western Ghats, c) micromolluscs occur in very high densities compared to macrospecies and d) land use changes and habitat disturbances has led to 10% increase in macrogastropods over microgastropods. The present study clearly shows that land transformation and disturbance has had a severe impact on land snail diversity. Little effort is currently made in India to include lesser known taxa such as land snails in conservation programmes. This is mainly due to our lack of knowledge on the diversity and ecology of this cryptic group. There is, therefore, an urgent need to study the distribution and landscape ecology of land snails to ensure their effective conservation.

Keywords: Western Ghats, microgastropods, disturbance, geographical distribution

Introduction

In South Asia, as in many other human-dominated landscapes of the tropics, growing demands by humans greatly threaten forests and their resources (Hegde *et al*. 1996; Lugo 1995; Murali *et al*. 1996). Human dependence on forests for the collection of firewood and non-timber forest products (NTFPs), cattle and sheep grazing and legal and illegal logging is widespread in the forested landscapes of tropical countries such as India (Uma Shaanker *et al*. 2004). In India alone it is estimated that approximately 50 million people depend directly on forests for their livelihood (Hegde *et al*. 1996). The impact of these threats on forest ecosystems are usually determined indirect measures. For

Accepted by D.L. Geiger: 3. Jun. 2008; published 25 Jul. 2008

example, groups such as birds, butterflies and plants are often used as indicator taxa in order to assess the qualitative change in the structure, composition and health of ecosystems.

Land snails form an important component of the leaf litter-soil ecosystem. All over the globe, leaf litter-soil biodiversity is virtually unexplored (Groombridge 1992). The majority of tropical leaf litter-soil snails remain undiscovered and undescribed partly because of under-exploration and partly because of their often minute size (Emberton 1996). Several studies worldwide have documented the impact of anthropogenic disturbance on land snails; a range of different types of disturbance have been studied including recreational activities (McMillan *et al.* 2003), fire (Cameron 1986; Karlin 1961; Kiss & Magnin 2003; Mylonas 1984), urbanization (Baur & Baur 1993) and logging and other forestry practices (Bonham *et al*. 2002; Dallinger *et al*. 2001; Graveland & van der Wal 1996; Hawkins *et al*. 1997; Hylander *et al*. 2004; Strayler *et al*. 1986; Tattersfield *et al*. 2001).

Research on the biological diversity of the Western Ghats, one of India's three biodiversity hotspots, has been largely concentrated on plants and charismatic taxa such as mammals, birds and butterflies. Much of the conservation effort has also been biased towards mammals. Although the Western Ghats harbour high levels of endemism for many poorly known invertebrate groups, only a few sporadic studies have been carried out on such taxa. For example, the land snail fauna of the Western Ghats although highly diverse and rich in endemic species (76%; Aravind *et al*. 2005) is relatively poorly known. A small body of distributional data dating from the 19th century is available in the *Fauna of British India* series on land molluscs (Blanford & Godwin Austen 1908; Gude 1914, 1921), but recent data are restricted mainly to a handful of survey reports and checklists (Mavinkurve *et al*. 2004, 2005; Mumbrekar & Madhyastha 2006) and to a few studies on the distribution patterns (Aravind 2005; Aravind *et al*. 2005), conservation review (Madhyastha *et al*. 2004) and disturbance ecology (Aravind 2005) of land snails.

Leaf litter and soil microgastropods (< 5 mm in its greatest dimension) form a substantial component of the regional and local land-snail fauna. Studies focusing exclusively on microgastropods have not been undertaken in India, but a few such studies have been conducted in other parts of the world (Emberton 1996; Gragimony & Ripken 1998; Tattersfield 1998). Microgastropods constitute 40% of the land snail fauna of the Western Ghats (Aravind *et al*. 2005). This study was undertaken to: a) to inventory the micromolluscs present in the Western Ghats; b) to evaluate their geographical distribution pattern and c) to assess their habitat preferences and the threats they face at the level of landscapes and habitats.

Materials and Methods

Geographical distribution patterns of micromolluscs. India has three biologically rich areas, the Eastern Himalayas, the Himalayas and the Western Ghats (Myers 1988; Myers *et al.* 2000; Conservation International 2005). The flora and fauna of the Western Ghats along with Sri Lanka is characterized by high levels of species richness and endemism. The Western Ghats is a 1,600 km-long mountain chain that runs parallel to west-coast of India from the river Tapti (Gujarat) in the north to Kanyakumari (Tamil Nadu) in the south. The Western Ghats extends from latitude 8°N to 21°N and covers an area of about 160,000 km^2 (Daniels 2004). The continuous hill chain is interrupted by the 30 km-wide 'Palghat Gap' at 11°N (Fig. 1). The topography of the Western Ghats is highly undulating; high peaks reaching elevation of over 2,000 m are common features in the Nilgiris, Anamalais and Palani ranges of the southern Western Ghats. Rainfall varies across the different regions of the

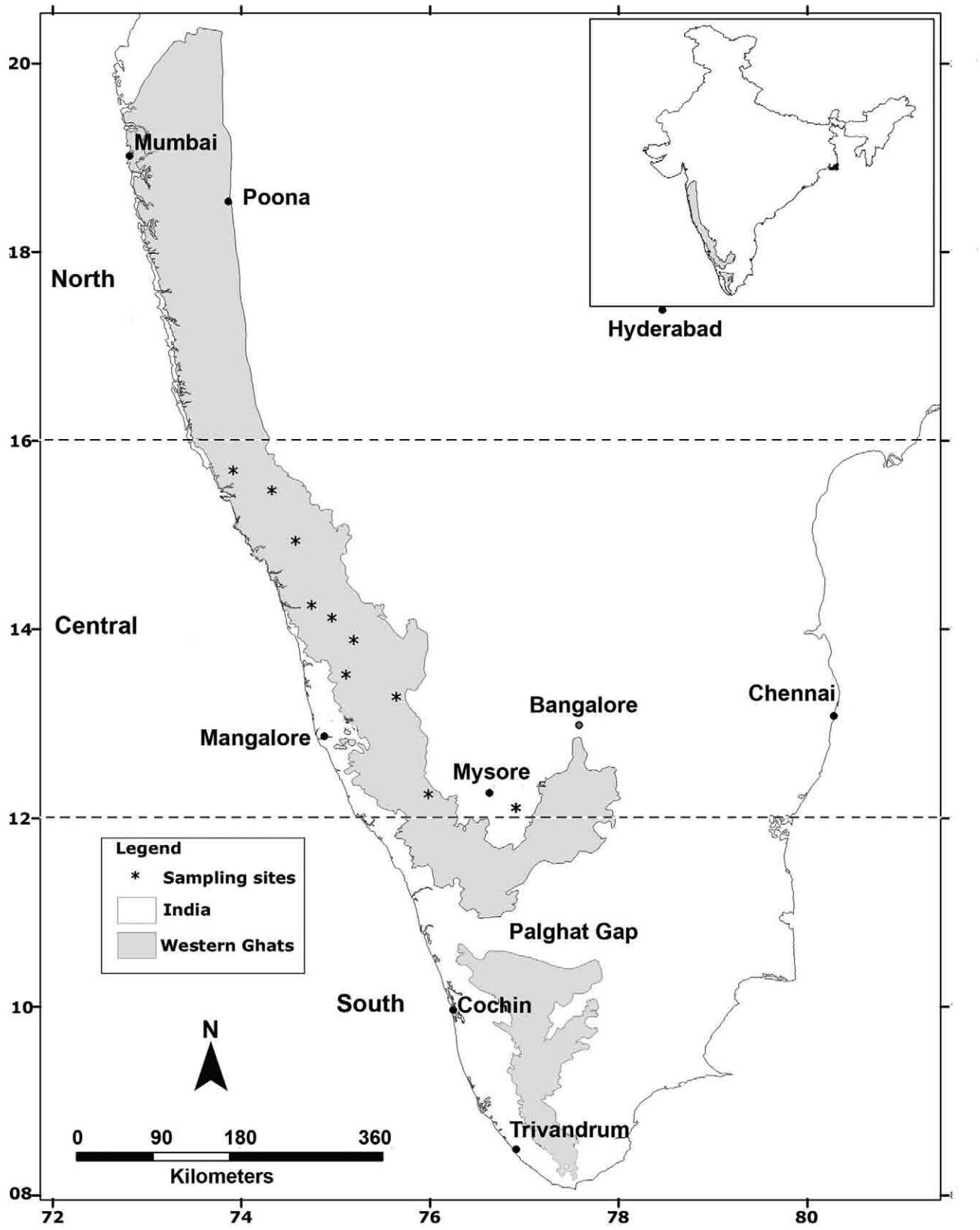


Figure 1. Map of the Western Ghats with sampling localities (inset shows location of the hotspot in India).

Western Ghats, ranging from < 1,000 mm to > 7,600 mm per annum, with an average of 2,500 mm (Gadgil 1994, 1996a,b). The southwest monsoon, which blows from June to October, contributes the bulk of the rainfall. However, the rainy season in the southern latitudes is often prolonged due to pre-monsoon and winter showers. Mean temperature ranges between 20° and 24°C. Forest cover in the Western Ghats is around 20% and over a period of years forest cover has been reduced drastically due to high population growth, expansion of agriculture and the development of roads and dams; population pressure is the single largest cause of habitat loss and degradation in the Western Ghats (Cincotta *et al.* 2000). The landscape of the Western Ghats is very heterogeneous with a variety of vegetation types and has greatly changed over the past century. The nature, extent and causes of the transformation have been debated extensively (Gadgil 1987). The geology, biodiversity and ecological history of Western Ghats are described in detail elsewhere (Chandran 1997; Daniels 2004; Gadgil 1996a; Valdiya 2002).

Data source. Data on species richness, endemism and the distribution of individual species in the Western Ghats were obtained from various published sources and our own field studies. The major source of information was the *Fauna of British India* (Blanford and Godwin-Austen 1908; Gude 1914; Gude 1921), supplemented by some recently published books and journal articles (Aravind 2005; Mavinkuruve *et al*. 2004, 2005; Mumbrekar & Madhyastha 2006; Ramakrishna & Mitra 2002; Sathyamurthi 1960; Subbarao & Mitra 1979; Tonapi & Mulherkar 1963; Tonapi 1971) and unpublished data from our own field studies. The classification we follow is that of Vaught (1989). The following data categories were extracted from the database maintained at Ashoka Trust for Research in Ecology and the Environment (ATREE), Bangalore, for each of the species assessed: family name, species name, latitudinal range, altitudinal range, shell size, endemic/non-endemic status, year species was discovered, and localities species has been recorded. To analyse distributional patterns, we divided the Western Ghats into three regions, north (between latitudes 16° to 21°N), central (between latitudes 12° to 16°N) and south (between latitudes 08° to 12°N; Danankar *et al*. 2004; Ramesh & Pascal 1996; Subramanian & Shivaramakrishnan 2002).

Micromollusc diversity of different Landscape Element (LSE) Types. Field studies were carried out at 10 localities in the central Western Ghats between 12° and 16°N. A range of different vegetation types was sampled: evergreen forest (both disturbed and less disturbed sites were chosen), moist deciduous forest, dry deciduous forest, scrub forest and three types of plantations, areca palm (*Areca catechu*), acacia (*Acacia auriculiformis*) and teak (*Tectona grandis*). The total number of plots sampled in each vegetation type was as follows: 20 plots in moist deciduous forest, 18 in dry deciduous forest, 20 in teak plantation, 30 each in acacia and areca palm plantations, 35 in disturbed evergreen and 40 in evergreen forest.

To assess the impact of habitat disturbance on land snails, we selected sites in the evergreen forests of Agumbe (75°5.756′E and 13°30.524′N), Thirthahalli Taluk, Shimoga District, South India. We selected this area for the purposes of our study because of its almost uniform altitudinal range (640–750 m Above Sea Level). Agumbe receives an average rainfall of 7,500 mm year $^{-1}$ and much of the rain falls during the south-west monsoon (June to November). It is one of the most important lowland evergreen forests of the Western Ghats. The vegetation series is of the *Dipterocarpus indicus - Humboldtia brunonis - Poeciloneuron indicum* type (Pascal 1988). Other typical plants of this forest

also include *Kingiodendron pinnatum, Hopea ponga* and *Vateria indica* (Aravind 2005). A total of 88 sites were selected of which 53 were less disturbed and 35 were highly disturbed.

Land snail sampling. Land snails were sampled in 1 m × 1 m quadrats, using stratified random sampling method. At each site sampled quadrats generally covered all the major microhabitats (*e.g.,* wet logs, base of buttresses of large trees, natural depressions in the forest floor). Edge effects were minimized by locating plots away from forest edges and from tracks and roads. Approximately 1 kg of soil and leaf litter samples was collected from each plot and stored in a polythene bag for subsequent sorting. Soil and leaf litter were visually searched for snails in the laboratory in an enamel coated tray under a stereo-microscope. All live individuals were preserved in 70% ethanol for later identification. Sampling was carried out once during the early monsoon (June and July) and once during the late monsoon (October and November). To ascertain if disturbance favours large bodied snails, the collected land snails species were classified as microgastropods (maximum shell width of < 5 mm) or macrogastropods (maximum shell width > 5 mm; Emberton *et al*. 1996).

Computation of Composite Threat Index. For the disturbance study, a total of 88 plots were sampled and for each plot, several human activities were recorded (Table 1); the presence of cut and broken stems and cattle dung are one of the best indicators of disturbance (Aravind *et al*. 2001, 2002; Aravind 2005; Barve *et al.* 2005; Ganeshaiah *et al.* 1998). These measures of disturbance have been recently used by several workers and have been shown to affect flora and fauna (Aravind *et al*. 2001; Barve *et al*. 2005; Gadgil 1996a; Ganeshaiah & Uma Shaanker 1999) and considered as useful qualitative measures. In the present study, several disturbance activities have been identified in each plot. Based on the degree of disturbance, each activity was ranked from 0 (undisturbed/very low level of

Table 1. Type and intensity of human disturbance recorded for plots. The numbers indicate the average pressure exerted in overall little and overall highly disturbed plots. The numbers of each type of plot indicate the level of each activity recorded (0 = no indication of activity and 5 = high incidence of activity). *Hunting among locals is prevalent. However, the exact information cannot be obtained hence no values have been attached (Patil & Aravind in press).

Activities	Less disturbed sites	Highly disturbed sites
Collection of firewood	2	5
Collection of NTFP (other than medicinal plants)	3	2
Grazing	2	5
Incidence of fire	0	2
Presence of footpaths	1	3
Illegal logging	2	3
Encroachment	1	5
Collection of dry leaves	1	5
Collection of green leaves	0	5
Hunting*	?	?
Presence of cut and broken stems	2	5
Presence of invasive weeds	1	2
Other activities (*e.g.*, collection of medicinal plants)	2	2

disturbance) to 5 (highly disturbed). Finally, a composite thereat index was computed by taking average of all activities recorded for that plot. Thus, the plots with the average composite rank of > 2 was considered as highly disturbed. Based on disturbance levels, the 88 sampling plots were divided into 53 less disturbed plots and 35 highly disturbed plots. The composite threat index is qualitative assessment since several disturbance activities such as fire incidence, presence of roads, and invasive species cannot be quantified. Nevertheless, this index gives a fair idea of the amount of disturbance for each plot.

Analysis. Mean species richness and the Shannon diversity index was computed following Magurran (2002). In order to assess the similarity of the land snail fauna of the different LSE types a Principal Component Analysis (PCA) was carried out using *Statistica* software for Windows (StatSoft Inc, USA).

Results

1. The micromollusc assemblage of the Western Ghats

a. Species diversity. The Western Ghats molluscan fauna harbors 269 species belonging to 23 families and 57 genera (Aravind *et al*. 2005), among these 40% of the species are micromolluscs. A significantly higher proportion of micromolluscs are endemic to the Western Ghats region (92%) when compared to macromolluscs (68%; Fig. 2). Of the 57 genera, 19 harbour micromollusc species. Of the families occurring in the Western Ghats, the Diplommatinidae is composed exclusively of microscopic species. The family Cyclophoridae is the most diverse with many micromollusc genera such as *Leptopomoides, Japonia, Alycaeus* and *Cyathopoma*. The genera *Kaliella* (8 m^{-2} ; Helicarionidae) and *Nicida* (10 m^{-2}; Diplommatinidae) were the most common and abundant, being found in almost all of the localities sampled in the Western Ghats. The genus *Nicida* showed a marked preference for forest habitats with bamboo and large, buttressed trees, whereas *Kaliella barrakporensis* (Pfeiffer, 1852) usually prefers disturbed habitats, such as plantations and home gardens.

b. Distributional patterns. Like other groups in the Western Ghats, land snails as well as the micromolluscs show a typical decline in the species richness from south to north (Aravind *et al*. 2005). The decline from south to north in the Western Ghats is significant ($r_s = -0.697$; $p = 0.003$; $df = 12$; Fig. 3). However, latitudes between 10°–12°N has more species than those between latitudes 8°–10°N and above 12°N. With respect to micromolluscs, however, Southern Western Ghats harbors more species followed by central and northern regions. This pattern is also evident for endemic land-snail species. The proportion of endemic species is higher than of non-endemic species in the southern and central Western Ghats unlike the northern Western Ghats, where endemic and non-endemic are of equal numbers (Fig. 4).

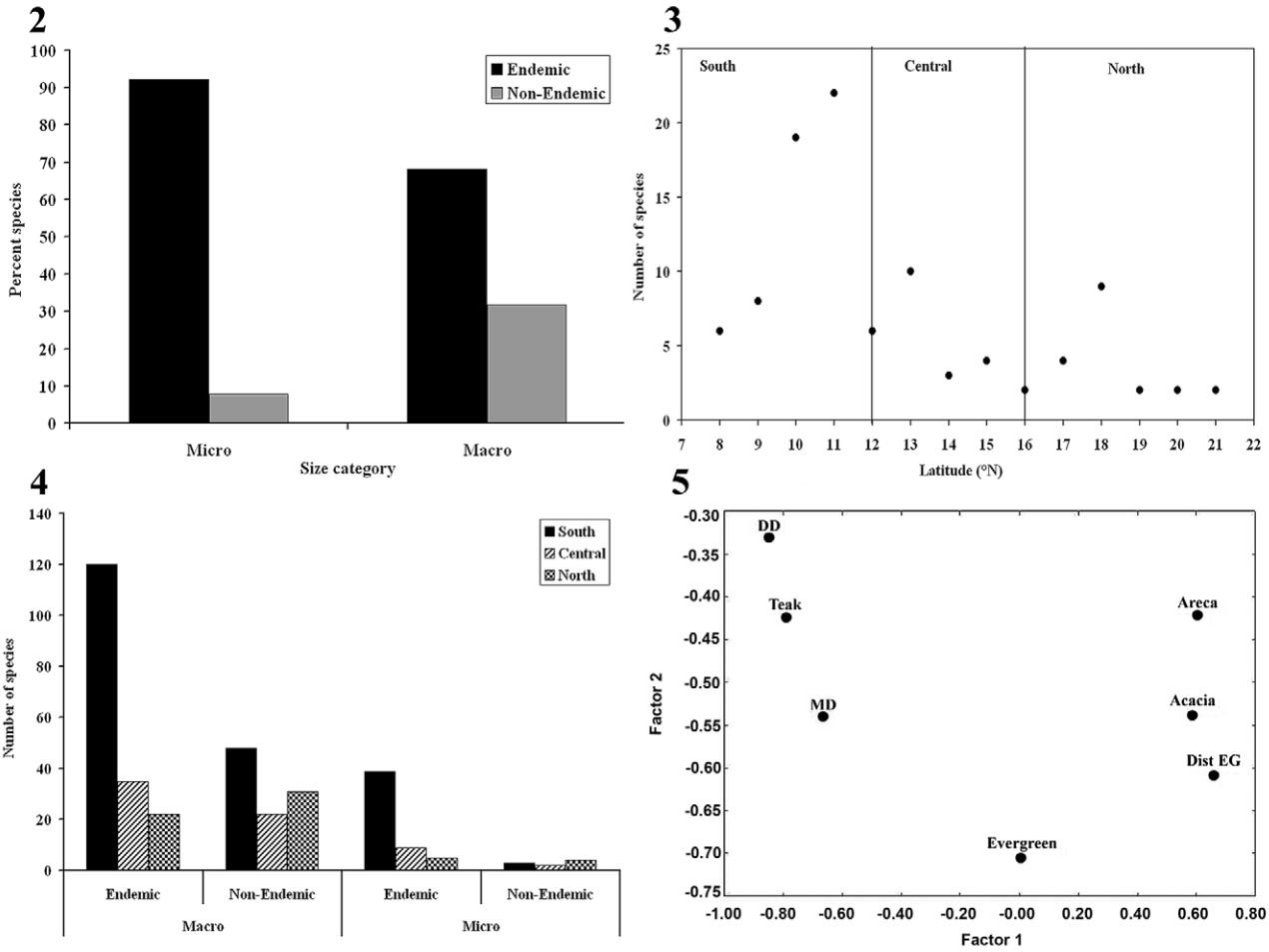
2. Micromollusc assemblages of different habitat types in the Western Ghats

a) Micromollusc assemblages of different landscape elements in the Western Ghats. A total of 265 individuals belonging to 26 genera and 74 species were recorded. Micromolluscs generally occur in very low abundance. Microgastropod diversity was highest in the primary evergreen forests of

the Western Ghats followed by moist deciduous forest (Table 2). It is interesting to note that acacia, teak and areca palm plantations are characterized by lower species richness and lower total snail abundances when compared to natural habitats. Of the plantations, acacia harbours more species and higher snails abundances than the other two habitats (data not shown).

Glessula, *Macrochalmys* and *Philalanka* are ubiquitous genera found in all seven LSE types. *Leptopomoides*, *Opeas*, *Ophisthosoma*, cf. *Vallonia* and *Alycaeus* were exclusive to evergreen forest. The introduced micromollusc *Caecilioides* is found only in areca plantations. *Nicida nitidula* Blanford, 1868, and *Nicida* sp. occur at high abundances in all LSE types. *Nicida* spp., *Ophistosoma* spp. and *Glessula* spp. show a marked preference for microhabitats with thick decaying litter and soft and porous soil, especially near buttress roots, huge trees and the bases of rocks that are not directly exposed to rain and sun.

The Principal Component Analysis (PCA; Fig. 5) showed a distinct pattern. The LSE types in the high rainfall area (areca, acacia and disturbed evergreen forest rainfall of > 3,000 mm year $^{-1}$) form a cluster, which is distinct from those LSE types that are in the low rainfall area (dry deciduous and moist deciduous forest and teak plantation, rainfall of 1,500 to 3,000 mm year $^{-1}$). Evergreen forest



Figures 2-5. 2. Percentage endemism of micromolluscs and macromolluscs of the Western Ghats, India. **3.** Relationship between latitude and species richness of micromolluscs in the Western Ghats, India. **4.** Number of endemic and non-endemic species of micromolluscs in the three regions of the Western Ghats, India. **5.** PCA computed for micro-mollusc abundance in different Landscape Element types in the Western Ghats, India.

is distinct from these two clusters, suggesting that it contains unique species. Also, species turnover across the different evergreen forest sites is high (N.A. Aravind unpubl. data).

b) Impact of habitat disturbance on the structure of the micromollusc assemblage. Habitat disturbance in the form of NTFP harvesting, grazing, litter collection and burning has a negative impact on micromollusc richness and abundance (Table 3). Less disturbed sites have more species and higher abundance than highly disturbed sites. Only 29% of the total species recorded belongs to microgastropods. However, there is no significant difference in the number of species of microgastropods and macrogastropods between less disturbed and highly disturbed sites ($\chi^2 = 0.15$, $p = 0.696$). This contrasts with the trend for abundance: the relative abundance of microgastropods and macrogastropods in less disturbed and highly disturbed sites are significantly different ($\chi^2 = 24.41$, $p < 0.01$; Table 4), with macromolluscs being proportionately more abundant in highly disturbed sites. This suggests that disturbance increases macrogastropods at the cost of microgastropods.

c) Relationship between micromollusc diversity and the composite threat index. The composite threat index shows a significant negative correlation with species richness ($r = -0.25$; $p < 0.05$) and abundance ($r = -0.263$ $p < 0.05$) of micromollusc. This shows that both species richness and abundance are reduced with increase in habitat disturbance.

Discussion

a) Geographical distributional patterns. The Western Ghats is a globally important hostpot of high diversity and endemism and is extremely important for the conservation of rare, endemic and biogeographically important biota. The land snails of the Western Ghats are relatively poorly studied when compared with charismatic higher taxa (Aravind *et al*. 2005). The present study is the first to focus exclusively on the diversity and distribution of micromolluscs in the tropical forests of the Western Ghats. Studies on geographical distribution patterns in the Western Ghats have been carried out for

Table 2. Diversity attributes of micromolluscs in different landscape element (LSE) types of the Western Ghats.

LSE Types	Mean Abundance/site	Species Richness	Genera
Evergreen Forest	114	53	24
Disturbed Evergreen Forest	27	24	16
Moist Deciduous Forest	34	28	13
Dry Deciduous Forest	20	20	10
Acacia Plantation	31	27	16
Teak Plantation	23	20	10
Areca Plantation	16	16	12

Table 3. Species richness and abundance of micromolluscs in less disturbed and highly disturbed sites

Attributes	Less Disturbed Sites	Highly Disturbed Sites
Number of species	20	13
Number of individuals	619	178

a range of different taxa such as bats (Korad *et al.* 2007), amphibians (Daniels 1992), fishes (Dahanukar *et al*. 2004), land snails (Aravind *et al*. 2005), odonates (Subramanian & Shivaramakrishnan 2002), aquatic insects (Subramanian 2004) and endemic plants (Ramesh & Pascal 1996). The southern Western Ghats (region below 12°N) is species rich for fishes, endemic plants, odonates, birds and land snails including micromolluscs. However, for amphibians and aquatic insects, the latitudinal range of 12°–14°N shows the highest species richness (Daniels 1992; Subramanian 2004). The high level of species diversity and endemism of land snails in the south may be due to relatively less variable climate in the southern compared to the central and northern Western Ghats. A short dry period (2 –3 months; Ramesh & Pascal 1997) and high habitat heterogeneity (*i.e.*, very mountainous terrain) of the southern Western Ghats may also contribute to the high species richness and endemism of land snails (Aravind *et al*. 2005). Relatively less diversity of land snails of 8°–10°N may be due to unequal sampling effort.

b) Habitat preference of the Micromolluscs of the Western Ghats. Our data show that land snails generally occur at low abundances in the Western Ghats (Aravind 2005). Micromolluscs occur at higher relative abundances (10 m^{-2}) in the Western Ghats when compared to macromolluscs (3 m^{-2}). The land snail species composition also changes with vegetation types. Among different habitats, the evergreen forest is highly diverse for micromolluscs. Evergreen forests provide a wide range of microhabitat, thick layer of decomposing litter and high moisture resulting in increased narrow range endemics.

Mean species richness and mean abundance were lower in the plantations relative to natural forest types. Due to habitat homogeneity and number of microhabitats being drastically reduced, the diversity levels of the micromollusc fauna is low in monoculture plantations. Thus, our results support Bonham *et al*. (2002) and Ganesh *et al.* (2002) that exotic tree plantations harbour less diverse land snail fauna than native forests (Bonham *et al.* 2002).

Habitat disturbance and destruction leads to changes in floristic composition and micro-climatic conditions and this in turn leads to a decline in the species richness and abundance of land snails (Kunte 1997). Sites in low and high rainfall areas are clustered indicating that the rainfall regime influences species composition over and above the effect of habitat types.

Of the different species, *Kaliella barrakporensis* (Pfeiffer, 1852), *Nicida liricincta* Blanford, 1868, and *Philalanka quinquelirata* Gude, 1914, are found in almost all LSE types and occur at high abundances compared to other species. The presumably introduced micromollusc *Caecilioides* sp. is found only in areca palm plantation; the path of introduction of this species into this LSE is not known and this is the first report of this species in the Western Ghats. Another species of micromollusc, *Allopeas*

Table 4. Observed and expected frequencies of micromollusc and macromollusc abundances in less disturbed and highly disturbed sites.

	Less Disturbed Sites		Highly Disturbed Sites	
Number of Individuals	Observed	Expected	Observed	Expected
Micromollusc	57.959	53.997	43.627	53.997
Macromollusc	42.041	46.003	56.373	46.003
Level of Significance		χ^2 =24.41, p < 0.01, df =1		

gracile (Hutton, 1834) is mostly confined to disturbed habitat such as areca and acacia plantations. Members of the genus *Nicida* prefers certain microhabitat, tending to occur under clumps of bamboo, near buttress roots and at base of rocks. *Kaliella barrakporensis* prefers disturbed habitats like plantations and home gardens. These marked differences in habitat preferences highlight the usefulness of these microsnails as credible bio-indicators. Differential species composition between habitat types is evident from the Figure 5. It has also been shown that there is high level of species turnover between sites within the same habitat type (Aravind 2005; N.A. Aravind & R.K. Patil unpubl. data). This indicates that the narrow habitat preference and restricted distribution of micromollusc in the Western Ghats.

The collection and identification of microgastropods is an extremely labour-intensive process (Emberton *et al*. 1996). Due to the low densities and patchy distribution of micro mollusc in the Western Ghats, sampling would be most productive with large teams of collectors sampling as varied a range of habitats and microhabitat as possible. A recent extensive survey has yielded some 20 species that still remain to be described (N.A. Aravind unpubl. data).

c) Threats and conservation issues. The southern Western Ghats lost nearly 22% of its primary forest between 1975 and 1991 (Jha *et al*. 2000). The extent of forest loss in other areas of the Western Ghats is unknown. The best conserved forests in the Western Ghats are restricted to 58 protected areas (14 National Parks and 44 wildlife sanctuaries). The total area covered by these protected areas is 13,595 km^2 representing only 9.06% of the Western Ghats (Rodgers & Panwar 1988). Conservation effort in the Western Ghats is currently biased towards large charismatic species (Uma Shaanker *et al*. 2003). Delineation as protected areas (PAs) in the Western Ghats is based on the subjective evaluation by expert consultants (Das *et al.* 2006 and references therein; Rodgers & Panwar 1988) and hence they are highly biased towards areas for which information is either already exists or from rapid ground surveys (Das *et al*. 2006). An analysis of effectiveness of current protected area network in the Western Ghats by Das *et al*. (2006) has shown that 70% of the irreplaceable sites (sites with high biodiversity) are outside PAs. Also, they show that current PAs fail to protect small mammals, endemic plants and endemic amphibians. Information is scarce on the conservation status of land snails in general and micromolluscs in particular. Microgastropods being a component of the litter invertebrate fauna that are threatened by grazing, fire, litter removal and habitat fragmentation. Hence, conservation should be approached holistically and encompass the full spectrum of measures from protecting species' microhabitats right through to the conservation of entire landscapes.

It is increasingly felt that conservation in human dominated landscape such as the Western Ghats, where population density of ~350 km^{-2} is the highest in any hotspot region of the world (Cincotta *et al*. 2001), should also include forests outside protected areas and should involve local communities. The cultivation of mixed tree plantations (i.e., containing both exotic and native tree species) on degraded land may allow snails to colonize from adjacent forest patches thus helping to reduce the risk of local extinctions. Changes in landscape structure through fragmentation or degradation of habitats can alter patterns of abundance for a species or entire community (Bierregaard *et al*. 1992; Becker *et al*. 1991; Quinn & Harrison 1988; Saunders *et al*. 1991). A decrease in the size and number of natural habitat patches increases the probability of local extirpation, whereas a decline in connectivity between habitat patches can negatively affect regional species persistence (Fahrig & Merriam 1985). Thus, there is justification for managing entire landscapes, and not just individual habitat

types, in order to ensure that diversity is sustained in the long term (McCarigal & Marks 1995). In the Western Ghats, the most serious loss of biodiversity has been through the transformation of montane evergreen shola forests and high altitude grasslands to monoculture plantations (Pramod *et al*. 1997). Therefore, further conversion of primary evergreen forest to monoculture plantations has to be limited and minimizing the disturbance of these forests is important for the conservation of endemic, highly cryptic taxa such as land snails.

Acknowledgements

This work was funded by a DEFRA Darwin Initiative Grant (No. 15-018) and by the International Foundation for Science (IFS), Sweden, Unitas Malacologica (UM), USA and the Edda G. Sehgal Foundation. The last author is grateful to grateful to the Ministry of Environment and Forest, Government of India. The authors like to thank Dr. T. Ganesh, Dr. Soubadra and Dr. Dinesh Rao for their useful comments and to the editors of this publication. We are grateful to the editors for giving this opportunity to contribute to this special edition.

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