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Land snails (Mollusca: Gastropoda) of India: status, threats and conservation strategies

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Abstract: Land snails form an important component in the forest ecosystem. In terms of number of species, the phylum Mollusca, to which land snails belong, is the largest phylum after Arthropoda. Mollusca provide unique ecosystem services including recycling of nutrients and they provide a prey base for small mammals, birds, snakes and other reptiles. However, land snails have the largest number of documented extinctions, compared to any other taxa. Till date 1,129 species of land snails are recorded from Indian territory. But only basic information is known about their taxonomy and little is known of their population biology, ecology and their conservation status. In this paper, we briefly review status, threats and conservation strategies of land snails of India.

Keywords: Biodiversity, conservation, land snails, taxonomic bias, reintroduction, Western Ghats

INTRODUCTION

The tropics have faced massive biodiversity loss due to intensive anthropogenic activities such as changes in land use and degradation of environment. Recent reports suggest that the tropics are losing biodiversity at an alarming rate (Sodhi 2008). Much of this biodiversity loss has been reported for vertebrates and plants. However, there is very little knowledge on the extent of loss in lesser known groups, especially the invertebrates. In this paper, we highlight the importance of land snails and the need for their conservation.

Land snails include several distinct lineages of terrestrial gastropods and belong to the second largest phylum after arthropods in terms of number of species with more than one lakh described species (Lydeard et al. 2004). Land snails constitute about six per cent of the total species on Earth (Clark & May 2002). A large part of molluscan fauna in many tropical regions of the world is still poorly known. They form an important component of the forest ecosystem by recycling nutrients (Graveland et al. 1994; Dunk et al. 2004) and are the prey base for a number of small mammals, birds, reptiles, amphibians and other invertebrates, including carnivorous snails (Deepak et al. 2010). In calcium poor habitats land snails can form an important source of calcium for other animals. Land snails also serve as an indicator of ecological conditions, and are very sensitive to climatic and ecological change (Shimek 1930; Simone 1999; Čejka & Hamerlík 2009). Thus, they are useful for reconstructing past environments (Bar-Yosef Mayer 2002; Gümüş 2009). As early as 1839 Charles Darwin showed the value of land snails in studying environmental change (Naggs et al. 2006). Terrestrial snails prove to be

valuable research subjects for studies in evolutionary biology, biogeography, phylogeography, biodiversity, ecology and conservation biology (Schilthuizen et al. 2007; Davison et al. 2008; Richards & Davison 2010). With their generally low dispersal powers, land snails tend to exhibit conservative distribution patterns, making them valuable subjects in studying historical biogeography (Solem 1984; Naggs & Raheem 2005; Wade et al. 2006). Highly diverse and narrowly distributed, land snails are good indicators of areas of conservation importance and endemicity when compared to widely distributed groups such as vertebrates (Moritz et al. 2001).

The distribution and activity of land snails depends on several factors including precipitation, soil pH, soil Ca content, canopy density, etc. Calcium availability in the soil is a major limiting factor for their survival as it is required for their shell formation. Several studies have shown that Ca is positively correlated with species richness and density (Burch 1955; Hotopp 2002; Aravind 2005). However, in the regions such as the Western Ghats, where the soil is usually acidic the snail richness is usually high but abundance is low.

The past two decades have seen a large number of studies highlighting the need for mollusc conservation globally (Bouchet 1992; Ponder 1997; Herbert 1998; Killeen & Seddon 2004; Budha 2005; Solymos & Feher 2005; Régnier et al. 2009). Killeen & Seddon (2004) notably edited a volume with global coverage on molluscan biodiversity and conservation, highlighting the importance of molluscan ecology and conservation. However, very little information is available on the status and threats of land snails in India. Here, we review current status of ecology, conservation and threats to land snails with particular reference to India and discuss the strategies required for conserving this important group.

Early studies on land snails in India

Indian malacology was pioneered by William Henry Benson (1803–1870), who contributed significantly to our knowledge on Indian land snails in the mid 19th century (Naggs 1997). The Blanford bothers-William and Henry, H. Theobald, L. Pfeiffer, G.K. Gude, H.H. Godwin-Austen and R. Beddome, led Indian land snail research until the early 20th century, but Gude and Pfeiffer's research was based entirely on museum material as neither visited India. These malacological pioneers laid the foundation of our knowledge on the taxonomy and distribution of Indian land snails. Following this period of intensive study, there was a drastic decline in studies on Indian land snails. More recent studies in India, have mainly concentrated on inventorying regional snail faunas (like state or protected areas) and less on species description, ecology and conservation (Aravind et al. 2010). While globally, there has been a renewed interest in land snail research, in India the research has truly been at a snail's pace (Aravind et al. 2005, 2008, 2010; Aravind & Naggs 2012). Little information is available on species limits, distribution ranges and patterns of diversity. Recent analysis of Indian land and freshwater molluscan literature has confirmed that that there are hardly any studies on the ecology and conservation of Indian land snails compared to the wide range of historical literature available on taxonomy (Aravind et al. 2010). There are no studies on the population status, phylogeny and taxonomic revision of different families or genera of Indian land snails.

Species diversity and rarity in land snails

Globally, nearly 35,000 species of land snails have been described and there may be 30,000 to 60,000 additional species yet to be described (Lydeard et al. 2004). Within modern India's boundaries 1129 species belonging to 140 genera and 26 families of land snails have been recorded (Ramakrishna et al. 2010). The Western Ghats hotspot has 270 species of land snails of which 76% are endemic to this region (Aravind 2005) and 40% are micro-gastropods (i.e. <5mm on greatest dimension) (Aravind et al. 2008). Unlike most other systematic groups many land snail species have restricted range distributions with some endangered species having a range of less than 5km^2 and many endemic species having ranges less than 10km^2 (Cameron 1998; Dunk et al. 2004). According to Solem (1984) nearly half of all terrestrial molluscs have a species range of less than 100km^2. Within the Western Ghats, species distributed in the southern region are absent in the northern region. Further, there is very little overlap between the southern and central, and central and northern regions (Table 1; Aravind 2005). Nearly 75% of land snails from the Western Ghats have been reported from less than three sites (Fig. 1). This data clearly indicates how vulnerable this

Table 1. Percent species shared between different regions of the Western Ghats (Division of the Western Ghats is based on Aravind et al. 2005)

Region	South	Central	North
South	100		
Central	E-17.19 NE-11.11	100	
North	E-0.00 NE-2.78	E-1.56 NE-1.39	100

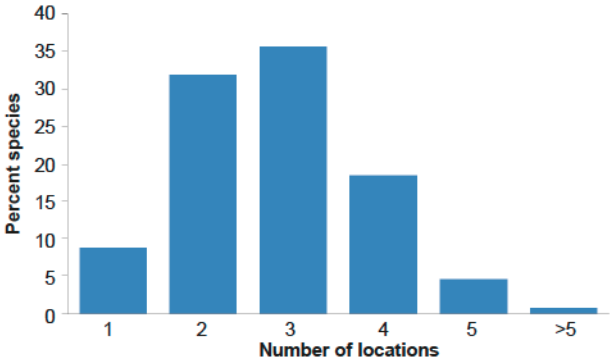

Figure 1. Distribution pattern of land snails in the Western Ghats

group is to any small scale change in the ecosystem. The situation in other regions of India is also cause for concern. Northeastern India harbours a rich mixture of Indian and Burmese/Malayan snail groups resulting in the highest species diversity in this region, but there are hardly any studies on their distribution and threats. Our information on the land snails of northeastern India, is basically from the *Fauna of British India* and a few Zoological Survey of India reports. Conversely, though less rich, the land snail fauna of the Western Ghats is better known when compared to other regions of India (Rao 1924; Sathyamaurthi 1960; Subbarao & Mitra 1979; Ramakrishna & Mitra 2002; Madhyastha et al. 2004; Mavinkurve et al. 2004a,b; 2005; Aravind 2005; Aravind et al. 2005, 2008; Rajashekhar & Aravind 2012).

Threats

The major threats to the native land snail fauna include habitat loss and fragmentation as a result of anthropogenic activities such as intense land use, construction of roads, dams, plantations, pollution and the spread of invasive species (Aravind 2005; Aravind et al. 2005) which reduce diversity and change the community structure of land snails (Aravind 2005; Rajashekhar & Aravind 2012). Between 1973 and 1995 the southern Western Ghats lost nearly 25 percent of forest cover (Jha et al. 2000). This region of the Ghats harbours high species diversity and endemism in land snails (Aravind 2005). Poor dispersal and small distribution ranges of many land snails have undoubtedly contributed to high levels of extinction. Because of strict habitat preference, any fragmentation of populations could affect their gene flow. Even, cutting of roads within a protected area could fragment populations of snails. However, for a subset of forest snail species, man-made habitats such as home gardens and plantations can act as either refugia or corridors between forest patches (Aravind 2005; Raheem et al. 2008). Climate change is considered to be a threat to many species (Thomas et al. 2004), and land snails are particularly vulnerable (Pounds & Crump 1994; Pounds et al. 1999; Sternberg 2000; Bezemer & Knight 2001; Gerlach 2007). Changes in rainfall patterns and fluctuation in soil temperature could lead to the death of juvenile snails and impair mobility across a fragmented mosaic of natural and transformed habitats in response to climate change. Extinction of land snail species due to change in climatic conditions such as a decrease in rainfall and global warming has also been reported (Baur & Baur 1993; Gerlach 2007). In India, we do not have any information on potential impact of climate change on land snails.

A vast extent of the Western Ghats is covered in plantations such as tea, coffee, areca, rubber etc. A wide variety of pesticides/herbicides are used to control several species of arthropods, fungi and plants that infest these plantation crops (Dipti & Velho 2007). The impact of these chemicals on the local flora and fauna including endemic land snails as well as other invertebrates is unknown. Forest fires (even surface fires) and reduction in vegetation cover are also major threats to land snails.

Neglected taxa in conservation

The scarcity of malacologists in India has had a serious impact on studies related to taxonomy, diversity, distribution, endemism, threats and conservation of land snails. Lack of interest in land snail research is also due to poor funding opportunities for taxonomy and basic biology, unavailability of good taxonomic keys and field guides. The science of taxonomy is practised on an international level. Indian Biodiversity

Act of 2002 does not permit exchange of specimens with international scientific communities, which further hinders the taxonomic studies on land snails (Prathapan et al. 2006). Further, most researchers and conservation biologists show considerable interest in "charismatic conservation" (Burner et al. 2001). Molluscs have the largest number of documented extinctions since 1500AD (www.redlist.org). Non-marine species (terrestrial and freshwater) constitute 99 percent of all molluscan extinctions. Among the 566 extinct molluscs, the largest proportion is of the land snails (422 species) followed by freshwater molluscs (140 species). Till date there are only four recorded extinctions of marine molluscs (Lydeard et al. 2004; Regnier et al. 2009). In the last 300 years, the Indian Ocean Islands of Mauritius, Rodrigues and Reunion have lost 30 species of land snails (Burner et al. 2001) and St. Helena and Madeira in the Atlantic Ocean have lost 36 species of land snails (WCMC 1992). Although terrestrial vertebrate extinctions are well documented, invertebrate extinctions often go unnoticed. Only a small fraction, i.e., <2% of known molluscan species have had their conservation status properly assessed (Lydeard et al. 2004; Naggs et al. 2006). Despite having the largest extinction rates and highest number of threatened species (Fig. 2), land snails are still not considered worthy for conservation efforts despite having deep independent phylogenetic lineages in many groups.

CONSERVATION OF LAND SNAILS IN INDIA

The role of communities and organisations

Land snails have a very poor image among the public, forest managers and policy makers (Seddon 1998) and a lack of public support. Recently, an attempt was made to popularise land snails to a wider audience in India in the form of an illustrated guide, produced by the Natural History Museum, London in association with ATREE, Bengaluru on land snails of the Western Ghats (Appendix 1). This guide not only assists conservation biologists but also amateur naturalists, students and the lay public alike to identify land snails of the Western Ghats (Raheem et al. 2009).

Effective conservation also requires awareness regarding importance of this taxa in the ecosystem

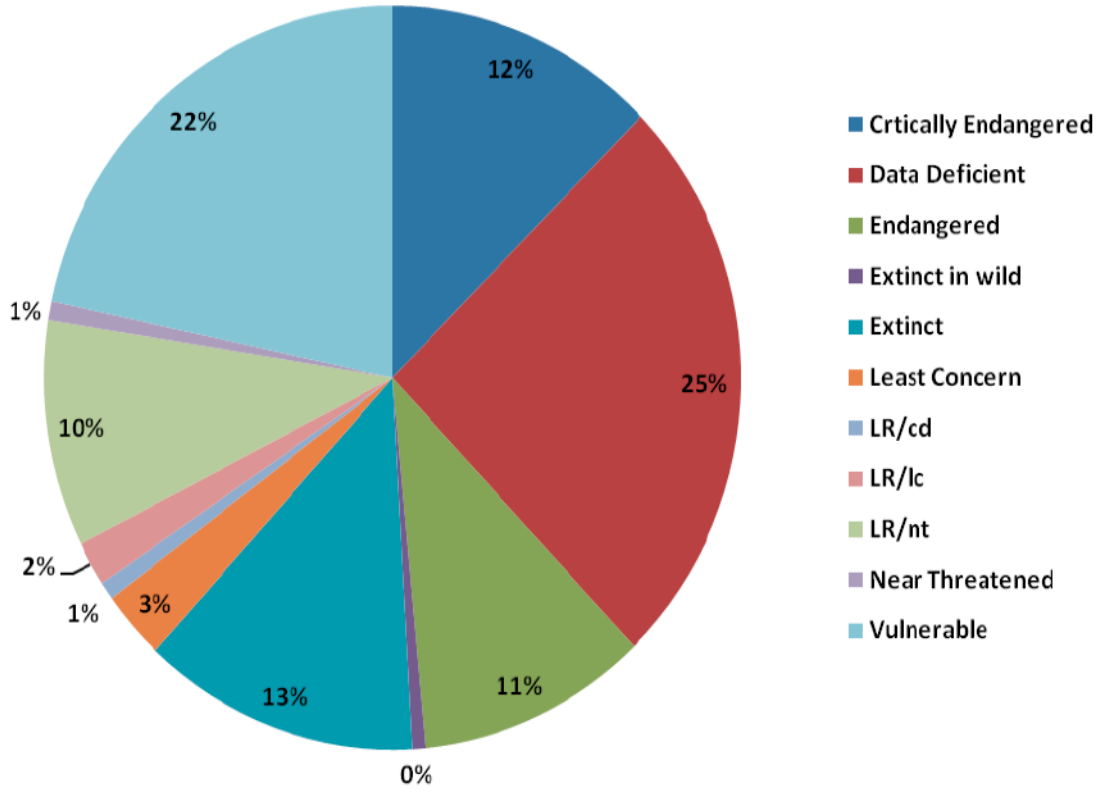

Figure 2. Status of Mollusks. Data from 2010 IUCN Red List of Threatened Species (www.redlist.org)

and the services they provide. Communicating the importance of snails and their role in ecosystem health, could also attract interest of wider ranging audience. An organization called Buglife in Europe was set up to conserve rare invertebrates in Britain (www.buglife.org.uk). Such efforts are needed in this country for effective conservation of invertebrates in general and land snails in particular.

Species-specific conservation plans

A notable exception to the general apathy towards snail conservation is the International *Partula* Conservation Programme, a unique ex-situ breeding programme initiated by Prof. Bryan Clarke at the University of Nottingham and coordinated by the Zoological Society of London. About 25 *Partula* snail species were exterminated in the wild by the predatory snail, *Euglandina rosea* that was introduced from Florida in a misguided attempt to control the introduced Giant African Snail *Lissachatina fulica*. This program involved a managed breeding programme for 25 species of *Partula* in 15 collaborating zoos globally along with local conservationists, local communities and the French Polynesian Government. To date more than 30 species of *Partula* have been rescued and captive breeding populations have been established in 18 zoos and laboratories throughout the world (Pearce-Kelly et al. 1997). In another collaborative effort of the Natural History Museum, Bermuda and London Zoo, 56 species of highly endangered land snails from Bermuda were captive bred and reintroduced as a part of their species conservation action plan (www.zsl.org/zsl-london-zoo//news/snail-mail-from-bermuda,123,NS.html). In the USA plans for reintroductions to conserve the Stock Island Tree Snail *Orthalicus reses* have been taken up (Boresma et al. 2001; Froys et al. 2001). In India the lack of information base, studies on the distribution, ecology, genetics and threats, has hindered the development of an informed conservation plan. However, a captive breeding program for selected species would help in increasing public awareness. Hence, setting up of "snailariums" for breeding of endemic snails could usefully be taken up by national parks and zoos. This might raise public interest in snail conservation across the country.

Habitat conservation

In India, many forested areas, which are devoid of large and charismatic mammal species, have high land snail diversity. However, these reserve forests generally receive little protection status as they fall outside the protected area network. These reserve forests are open access and hence they are prone to a variety of anthropogenic disturbances such as collection of minor forest products, grazing, fire, etc. Significant proportions of endemic species are distributed in these non-protected areas and hence are vulnerable to extinction. Current habitat conservation practice is focussed on encompassing iconic but generally widely distributed/low risk species. Conversely habitats with the highest total of biological diversity are not targeted. Land snails are of potential value as indicators of high diversity habitats for a wide range of plant and animal groups. Thus, snails can be utilised for identifying biodiversity rich habitats that should be given high conservation priorities. In addition, the high geographical turnover of many land snail species exemplifies the value of local scale conservation in capturing biological diversity in general (Ponder 1997; Raheem et al. 2009). For example, the low elevation evergreen reserve forests of Agumbe, Hulikal, etc., in the central Western Ghats have lower levels of protection but harbour high species diversity of land snails (Aravind 2005). The top down approach of conserving large mammals will exclude the majority of land snails, other invertebrates and plants from protection (Aravind et al. 2005). Hence, for effective conservation of land snails, some of the species rich areas surrounding the protected areas such as Agumbe, Hulikal and similar areas rich in land snail diversity need to be given additional protection. In India and other developing countries, where information is seriously lacking, an alternative approach to maximise the conservation of rare and endemic species is by identifying sites with high diversity and endemism and protecting the habitat itself (Gaston 1996).

Need for future research

Research on land snails in India should focus on their distribution patterns, taxonomy and ecology. Taxonomic expertise is a basic foundation for estimation of global biodiversity and formulation of policy on conservation of biological diversity (Golding & Timberlake 2002; Budha 2005). One of

the greatest impediments for malacological research in India has been a severe lack of trained malacologists. The initiative such as All India Coordinated Project on Taxonomy (AICOPTAX) by Ministry of Environment and Forests (MoEF) produced little work on molluscan taxonomy. The recent collaborative project "Developing land snail expertise in South and Southeast Asia" funded under Darwin Initiative Project by DEFRA, UK, helped build capacity on land snail taxonomy not only in India but also in Sri Lanka, Nepal, Laos, Thailand, Malaysia and Vietnam (Naggs et al. 2006). However, more funds need to be allocated for capacity building in the areas of taxonomy, natural history, ecology and biology of the species in India. Developing databases on ecology, breeding behaviour, distribution and other details of land snails should be encouraged and made accessible in the public domain, which could change the esoteric status of malacology. In recent years, there have been accidental introductions of alien and invasive species into the Indian subcontinent. The impact of these invasive snails and slugs such as *Lissachatina fulica*, *Derocerus leave*, *Semiperula* sp. on native land snail populations needs to be monitored. The introduced species generally occupy transformed habitats and their agricultural/horticultural pest status is more of an issue than being a threat to the native snails. However, impact of invasive and pest species on native land snails and on the economic damage they incur to agriculture and horticultural crops needs to be assessed. For the exotic invasive malacofauna of the Indian sub-continent to be controlled in a timely way its status urgently needs to be assessed. Land snails such as the African Giant Snail and others are hosts for the rat-lung worm, which can transmit meningitis to humans. In India, we hardly have any information on what percent of human population is affected by this parasite; what are the health implications and how many species are carriers for the same. Hence, research is needed in this direction as well. Indian land snails include lineages (Pulmonata and Caenogastropda) that diverged as far back as the Devonian (416 to 359.2 million years ago) and there are a number of deep independent lineages of ancient groups some of which are unique to South Asia (Wade et al. 2006). Thus, research should also focus on the biogeographical patterns, phylogeny and evolution of Indian land snail fauna. Further, studies to resolve the taxonomically problematic groups such as *Glessula* through molecular phylogenetic applications or through DNA barcoding should be initiated.

CONCLUSION

For informed conservation measures to be implemented, detailed studies on land snail systematics, on threats to survival and on identifying "hot-spots" for narrow range endemics are urgently needed. Serious attention needs to be paid towards protecting remaining forested areas, maintaining and possibly restoring connectivity, especially in the tropical rain forests which support rich snail diversity (Emberton 1996). More funds need to be allocated to capacity building in malacology. Land snail expertise is urgently needed for economic reasons; awareness of native species will certainly help in recognizing newly introduced exotic species allowing effective control or management before they become invasive. Efforts should be made to establish snailariums in zoos in order to create awareness about snails among people. Priority should be given to conserve critical habitat for conservation of land snails. India should also start an initiative such as the Frozen Arc Project (www.frozenark.org), where the viable cells of a number of near extinct species could be stored for possible use in the future.

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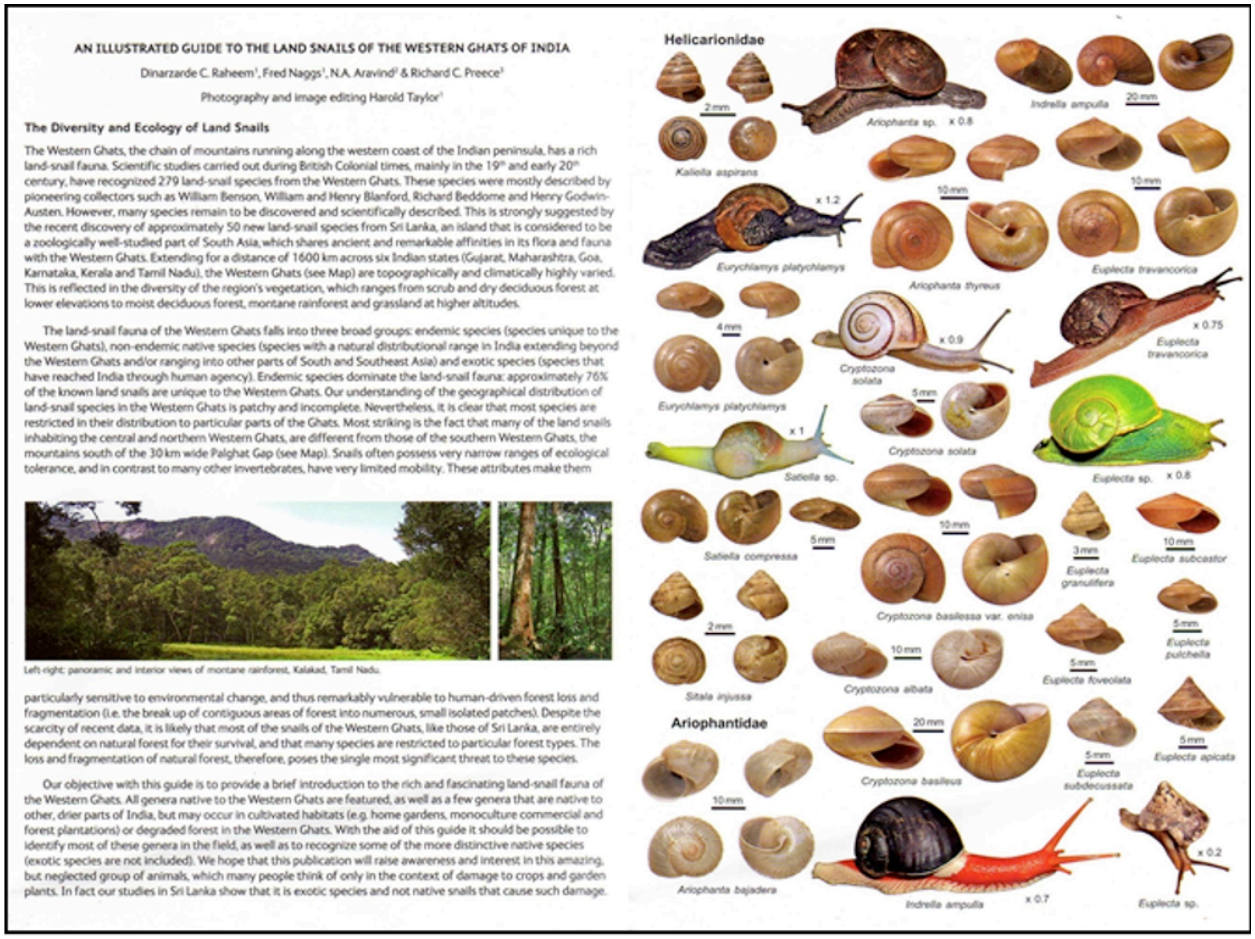

AN ILLUSTRATED GUIDE TO THE LAND SNAILS OF THE WESTERN GHATS OF INDIA

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The Diversity and Ecology of Land Snails

The Western Ghats, the chain of mountains running along the western coast of the Indian peninsula, has a rich land-snail fauna. Scientific studies carried out during British Colonial times, mainly in the 19th and early 20th century, have recognized 279 land-snail species from the Western Ghats. These species were mostly described by pioneering collectors such as William Benson, William and Henry Blanford, Richard Beddome and Henry Godwin-Austen. However, many species remain to be discovered and scientifically described. This is strongly suggested by the recent discovery of approximately 50 new land-snail species from Sri Lanka, an island that is considered to be a zoologically well-studied part of South Asia, which shares ancient and remarkable affinities in its flora and fauna with the Western Ghats. Extending for a distance of 1600 km across six Indian states (Gujarat, Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu), the Western Ghats (see Map) are topographically and climatically highly varied. This is reflected in the diversity of the region's vegetation, which ranges from scrub and dry deciduous forest at lower elevations to moist deciduous forest, montane rainforest and grassland at higher altitudes.

The land-snail fauna of the Western Ghats falls into three broad groups: endemic species (species unique to the Western Ghats), non-endemic native species (species with a natural distributional range in India extending beyond the Western Ghats and/or ranging into other parts of South and Southeast Asia) and exotic species (species that have reached India through human agency). Endemic species dominate the land-snail fauna: approximately 76% of the known land snails are unique to the Western Ghats. Our understanding of the geographical distribution of land-snail species in the Western Ghats is patchy and incomplete. Nevertheless, it is clear that most species are restricted in their distribution to particular parts of the Ghats. Most striking is the fact that many of the land snails inhabiting the central and northern Western Ghats, are different from those of the southern Western Ghats, the mountains south of the 30 km wide Palghat Gap (see Map). Snails often possess very narrow ranges of ecological tolerance, and in contrast to many other invertebrates, have very limited mobility. These attributes make them

Left-right: panoramic and interior views of montane rainforest, Kalakad, Tamil Nadu.

particularly sensitive to environmental change, and thus remarkably vulnerable to human-driven forest loss and fragmentation (i.e. the break up of contiguous areas of forest into numerous, small isolated patches). Despite the scarcity of recent data, it is likely that most of the snails of the Western Ghats, like those of Sri Lanka, are entirely dependent on natural forest for their survival, and that many species are restricted to particular forest types. The loss and fragmentation of natural forest, therefore, poses the single most significant threat to these species.

Our objective with this guide is to provide a brief introduction to the rich and fascinating land-snail fauna of the Western Ghats. All genera native to the Western Ghats are featured, as well as a few genera that are native to other, drier parts of India, but may occur in cultivated habitats (e.g. home gardens, monoculture commercial and forest plantations) or degraded forest in the Western Ghats. With the aid of this guide it should be possible to identify most of these genera in the field, as well as to recognize some of the more distinctive native species (exotic species are not included). We hope that this publication will raise awareness and interest in this amazing, but neglected group of animals, which many people think of only in the context of damage to crops and garden plants. In fact our studies in Sri Lanka show that it is exotic species and not native snails that cause such damage.

Helicarionidae

Ariophanta sp. x 0.8

Indrella ampulla

Kaliella aspirans

Eurychlamys platychlamys x 1.2

Ariophanta thyreus

Euplecta travancorica

Cryptozona solata x 0.9

Euplecta travancorica x 0.75

Eurychlamys platychlamys

Satiella sp. x 1

Cryptozona solata

Euplecta sp. x 0.8

Satiella compressa

Cryptozona basilessa var. enisa

Euplecta granulifera

Euplecta subcastor

Sitala injussa

Cryptozona albata

Euplecta foveolata

Euplecta pulchella

Ariophantidae

Cryptozona basileus

Euplecta subdecussata

Euplecta apicata

Ariophanta bajadera

Indrella ampulla x 0.7

Euplecta sp. x 0.2

Appendix 1. An illustrated guide to the land snails in India (Raheem et al. 2009)

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