



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

Sandeep Sen<sup>1</sup>, G. Ravikanth<sup>2</sup> & N.A. Aravind<sup>3</sup>

<sup>1,2,3</sup>Suri Sehgal Centre for Biodiversity and Conservation, Ashoka Trust for Research in Ecology and the Environment (ATREE), Royal Enclave, Srirampura, Jakkur PO, Bengaluru, Karnataka 560064, India  
Email: <sup>1</sup>sandeep.sen@atree.org, <sup>2</sup>gravikanth@atree.org, <sup>3</sup>aravind@atree.org (corresponding author)

Date of publication (online): 26 September 2012  
Date of publication (print): 26 September 2012  
ISSN 0974-7907 (online) | 0974-7893 (print)

Editor: Fred Naggs

### Manuscript details:

Ms # o2722  
Received 03 March 2011  
Final received 18 July 2012  
Finally accepted 24 August 2012

**Citation:** Sen, S., G. Ravikanth & N.A. Aravind (2012). Land snails (Mollusca: Gastropoda) of India: status, threats and conservation strategies. *Journal of Threatened Taxa* 4(11): 3029–3037.

**Copyright:** ©Sandeep Sen, G. Ravikanth & N.A. Aravind 2012. Creative Commons Attribution 3.0 Unported License. JoTT allows unrestricted use of this article in any medium for non-profit purposes, reproduction and distribution by providing adequate credit to the authors and the source of publication.

**Author Details:** See end of this article

**Author Contribution:** All authors have contributed equally to this manuscript

**Acknowledgements:** The authors greatly acknowledge the Darwin Initiative via DEFRA, Government of UK for funding. We are also grateful to Drs. T. Ganesh, Soubadra Devy and K.V. Gururaja for critical comments on the earlier version of the manuscript. We also thank two anonymous reviewers for their critical comments that greatly helped in improving the manuscript.

**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



OPEN ACCESS | FREE DOWNLOAD

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 endemism 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 19<sup>th</sup> century (Naggs 1997). The Blanford brothers-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 20<sup>th</sup> 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 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<sup>2</sup> and many endemic species having ranges less than 10km<sup>2</sup> (Cameron 1998; Dunk et al. 2004). According to Solem (1984) nearly half of all terrestrial molluscs have a species range of less than 100km<sup>2</sup>. 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

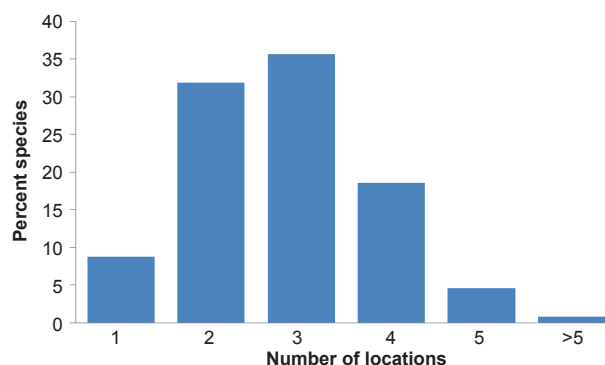
**Table 1. Percent species shared between different regions of the Western Ghats (Division of the Western Ghats is based on Aravind et al. 2005)**

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

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



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

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

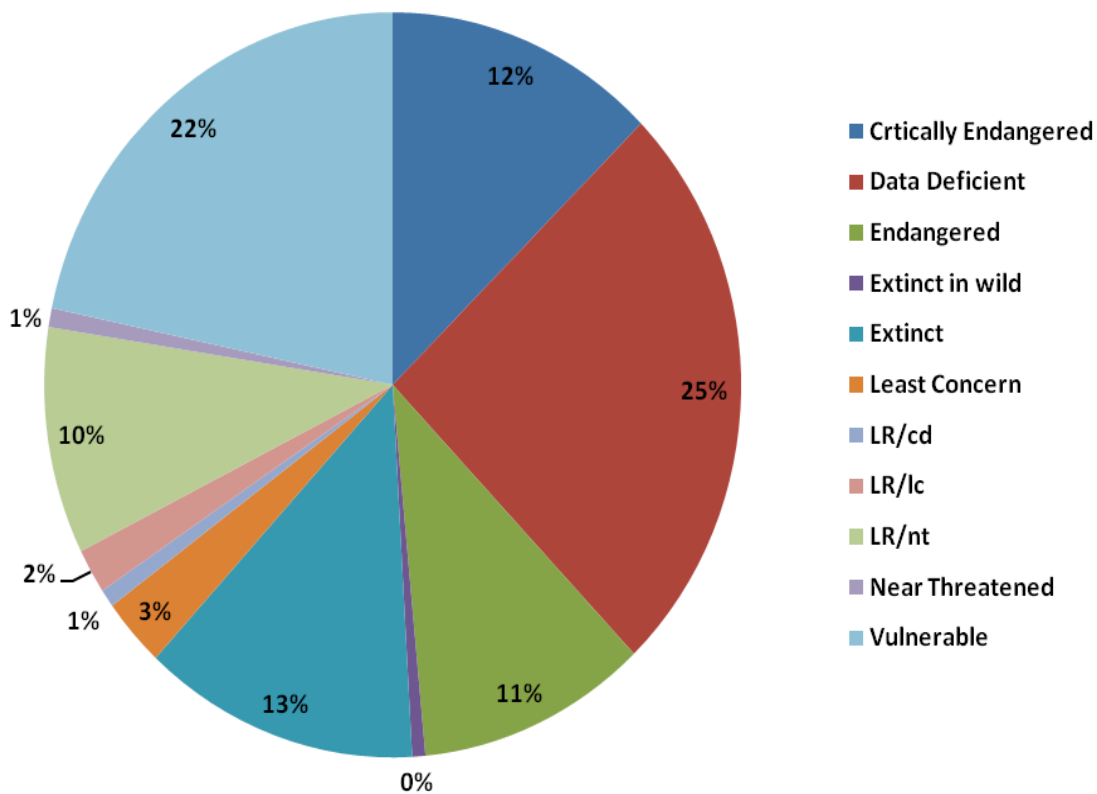


Figure 2. Status of Mollusks. Data from 2010 IUCN Red List of Threatened Species (www.redlist.org)

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](http://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](http://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 (Boesma 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 subcontinent 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 Caenogastropoda) 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

*Gllessula* 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 Ark Project ([www.frozenark.org](http://www.frozenark.org)), where the viable cells of a number of near extinct species could be stored for possible use in the future.

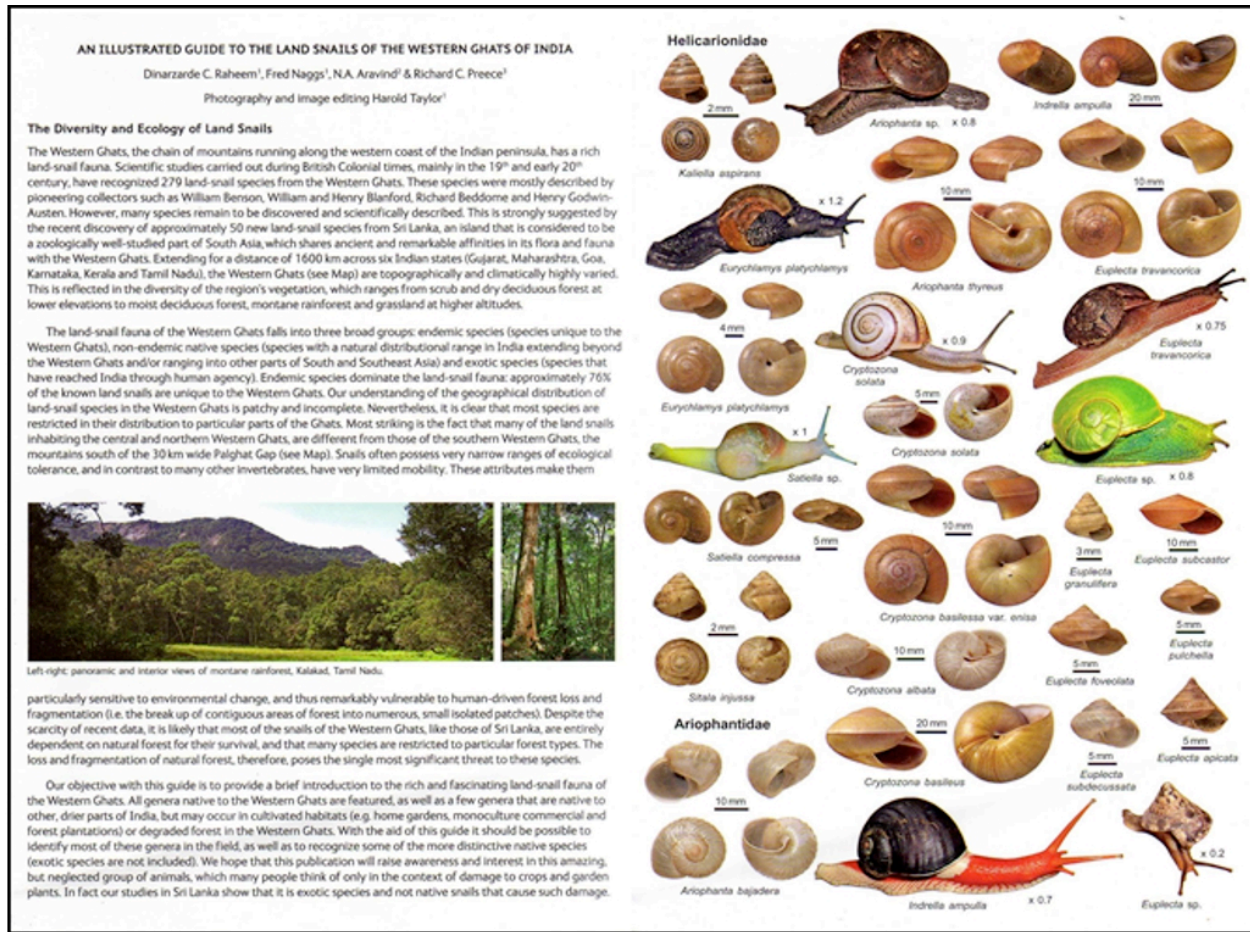
## REFERENCES

- Aravind, N.A. (2005).** Ecology of Land Snails of Western Ghats. PhD Thesis, Department of Applied Zoology, Mangalore University, Mangalore, 182pp.
- Aravind, N.A. & F. Naggs (2012).** Snailing up the Canopies of Western Ghats, pp. 43–46. In: Devy, M.S., T. Ganesh & A. Tripaty (eds.), *Canopies of South Asia - A Glimpse*. ATREE, Bangalore.
- Aravind, N.A., K.P. Rajashekhar & N.A. Madhyastha (2005).** Species diversity, endemism and distribution of land snails of Western Ghats, India; *Records of Western Museum Supplement* 68: 31–38.
- Aravind, N.A., K.P. Rajashekhar & N.A. Madhyastha (2008).** Micromolluscs of Western Ghats, India: Diversity, distribution and threats. *Zoosymposia* 1: 281–294.
- Aravind, N.A., K.P. Rajashekhar & N.A. Madhyastha (2010).** A review of ecological studies on patterns and processes of distribution of land snails of the Western Ghats, India. *Proceeding of World Congress of Malacology*, 222pp.
- Bar-Yosef Mayer, D.E. (2002).** Archaeomalacology: Molluscs

- in former environments of human behaviour (1. An Introduction to Archaeomalacology). 9<sup>th</sup> ICAZ Conference, Durham.
- Baur, B. & A. Baur (1993).** Climatic warming due to thermal radiation from an urban area as possible cause for the local extinction of a land snail. *Journal of Applied Ecology* 30: 333–340.
- Bezemer, T.M & K.J. Knight (2001).** Unpredictable responses of garden snail (*Helix aspersa*) populations to climate change. *Acta Oecologica* 22: 201–208.
- Boresma, D.P., P. Kareiva, F.W. Fagan, A.J. Clarak & M.J. Hoekstra (2001).** How good are endangered species recovery plans? *Bioscience* 51: 643–649.
- Bouchet, P. (1992).** Extinction and preservation of species in the tropical world: What future for Molluscs? *American Conchologist*: 20: 20–24.
- Budha, P.B. (2005).** Nepalese malacology trails behind “catch up”. *Himalayan Journal of Sciences* 3: 9–10.
- Burch, J.B. (1955).** 1962 *How To Know the Eastern Land Snails*. Wm. C. Brown, Dubuque, 214pp.
- Burner, A.G., E.G. Raymond, R.E. Rice & da G.A.B. Fonseca (2001).** Effectiveness of parks in protecting tropical biodiversity. *Science* 291: 125–128.
- Cameron, R.A.D. (1998).** Dilemmas of rarity: biogeographical insights and conservation priorities for land mollusca. *Journal of Conchology. Special Publication* 2: 51–60.
- Čejka, T. & L. Hamerlik (2009).** Land snails as indicators of soil humidity in Danubian woodland (SW Slovakia). *Polish Journal of Ecology* 57: 741–747
- Clark, J.A. & R.M. May (2002).** Taxonomic bias in Conservation Research. *Science* 297: 191–192.
- Davison, A. & S. Chiba (2008).** Contrasting response to Pleistocene climate change by ground-living and arboreal Mandarin snails from the oceanic Hahajima archipelago. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences* 363: 3391–3400.
- Deepak, V., K. Vasudevan & B. Pandav (2010).** Preliminary observation on the diet of the cane turtle (*Vijayachelys silvatica*). *Hamdaryad* 34: 166–168.
- Dipti, H. & N. Velho (2007).** The need for studies on amphibians in India. *Current Science* 92: 1032.
- Dunk, J.R., W.J. Zielinski & H.K. Preisler (2004).** Predicting the occurrence of rare mollusks in northern California forests. *Ecological Applications* 14: 713–729.
- Emberton, K.C. (1996).** Conservation priorities for the forest flower invertebrates of the south eastern half of the Madagascar evidence from two land-snail clades. *Biodiversity and Conservation* 5: 729–741.
- Forys, E.A., C.R. Allen & D.P. Wojcikthe (2001).** Likely cause of extinction of the tree snail *Orhtalicus reses reses* (Say). *Journal of Molluscan Studies* 67: 369–376.
- Gaston, K.J. (1996).** Biodiversity congruence. *Progress in Physical Geography* 20: 105–112.
- Gerlach, J. (2007).** Short-term climate change and the extinction of the snail *Rhachistia aldabrae* (Gastropoda: Pulmonata). *Biology Letters* 3: 581–585.
- Golding, J.S. & J. Timberlake (2002).** How taxonomists can bridge the gap between taxonomy and conservation science. *Conservation Biology* 17: 1177–1178.
- Graveland, J.R, van der WAL, J.H. van Balen & A.J. van Noordwijk (1994).** Poor reproduction in forest passerines from decline of snail abundance on acidified soils. *Nature* 368: 446–448.
- Gümüş, B.A. (2009).** Anadolu’da Gerçekleştirilen Arkeomalakolojik Çalışmalar. Paleontoloji-Stratigrafi Çalıştayı, 01–04 Ekim 2009, Kemaliye, Erzincan (Sözlü Sunum, kitapçık, s. 22).
- Herbert, D.G. (1998).** Molluscan conservation in South Africa: Diversity, issues and priorities, pp. 61–76. In: Killeen, I.J., M.B. Seddon & A.M. Holmes (eds.). *Molluscan Conservation: A Strategy for the 21st Century. Journal of Conchology Special Publication* 2. Dorchester (United Kingdom): Conchological Society of Great Britain and Ireland, Dorset Press.
- Hotopp, K.P. (2002).** Land snails and soil calcium in central Appalachian Mountain forest. *South Eastern Naturalist* 1: 27–44.
- Jha, C.S., C.B.S. Dutt & K.S. Bawa (2000).** Deforestation and land use changes in Western Ghats, India. *Current Science* 79: 231–238.
- Killeen, I.J. & M.B. Seddon (2004).** Molluscan Biodiversity and Conservation. *Journal of Conchology Special Publication* 3: 172.
- Lydeard, C., R.H. Cowie, W.F. Ponder, A.E. Bogan, P. Bouchet, S.A. Clark, K.S. Cummings, T.J. Frest, O. Gargominy, D.G. Herbert, R. Hershler, K.E. Perez, B. Roth, M. Seddon, E.E. Strong & F.G. Thompson (2004).** The Global Decline of Non-marine Molluscs. *BioScience* 54: 321–330
- Madhyastha, N.A., R.G. Mavinkuruve & S.P. Shanbhag (2004).** Land snails of Western Ghats. In: Gupta, A.K., A. Kumar & V. Ramakantha (eds). *ENVIS Bulletin: Wildlife and Protected Areas, Conservation of Rainforest in India* 4: 143–151.
- Mavinkurve, R.G., S.P. Shanbhag & N.A. Madhyastha (2004a).** Checklist of land snails of Karnataka. *Zoos’ Print Journal* 19(11): 1684–1686.
- Mavinkurve, R.G., S.P. Shanbhag & N.A. Madhayasta (2004b).** Non-Marine mollusks of Western Ghats. *Zoos’ Print Journal* 19(12): 1708–1711.
- Mavinkurve, R.G., S.P. Shanbhag & N.A. Madhayasta (2005).** The land snails of Sharavati Wildlife Sanctuary. *Records of Zoological Survey of India* 104: 123–131
- Moritz, C., K.S. Richardson, S. Ferrier, G.B. Monteith & J. Stanisic (2001).** Biogeographical concordance and efficiency of taxon indicators for establishing conservation priority in a tropical rainforest biota. *Proceedings of the Royal Society of London B*. 268: 1875–1881.
- Naggs, F. (1997).** William Benson and the study of land snails of British India and Ceylon. *Archives of Natural History* 24: 37–88.
- Naggs, F. & D. Raheem (2005).** Sri Lankan snail diversity:

- faunal origins and future prospects. *Records of the Western Australia Museum*, Supplement No. 68: 11–29.
- Naggs, F., S. Panha & D. Raheem (2006)**. Developing Land Snail Expertise in South and Southeast Asia, a New Darwin Initiative Project. *The Natural History Journal of Chulalongkorn University* 6: 43–46
- Pearce-Kelly, P., D. Clarke, C. Walker & P. Atkin (1997)**. A conservation programme for the partulid tree snails of the Pacific region. *Memoirs of Museum of Victoria* 56: 431–433.
- Ponder, W.F. (1997)**. Conservation Status, Threats and Habitat requirements of Australian Terrestrial and Freshwater Mollusca. *Memoirs of Museum of Victoria* 56: 421–430.
- Pounds, J.A. & M.I. Crump (1994)**. Amphibian declines and climate disturbance: the case of the golden toad and the harlequin frog. *Conservation Biology* 8: 72–85.
- Pounds, J.A., M.P.L. Fogden & J.H. Campbell (1999)**. Biological response to climate change on a tropical mountain. *Nature* 398: 611–615.
- Prathapan, K.D., D.R. Priyadarsanan, T.C. Narendran, C.A. Viraktamath, K.A. Subramanian, N.A. Aravind & J. Poorani (2006)**. Biological Diversity Act, 2002: Shadow of permit-raj over research. *Current Science* 91: 1006–1007
- Raheem, C.D., F. Naggs, R.C. Preece, Y. Mapatuna, L. Kariyawasam & P. Eggleton (2008)**. Structure and conservation of Sri Lankan land- snail assemblages in fragmented lowland rainforest and village home gardens. *Journal of Applied Ecology* 45: 1019–1028.
- Raheem, C.D., F. Naggs, N.A. Aravind & R.C. Preece (2009)**. *An Illustrated Guide to The Land Snails of Western Ghats of India*. The Natural History Museum London.
- Raheem, C.D., F. Naggs, P.D.J. Chimonides, R.C. Preece & P. Eggleton (2009)**. Fragmentation and pre-existing species turnover determine land-snail assemblages of tropical rain forest. *Journal of Biogeography* 36: 1923–1938.
- Rajasheshkar, K.P. & N.A. Aravind (in press)**. Perturbation in the pattern of land snail diversity due to anthropogenic disturbance to wet evergreen forests of the Western Ghats, India. In: Priyadarsanan, D.R., M.S. Devy, K.A. Subramanian, N.A. Aravind & N. Seená (eds.). *Invertebrate Diversity and Conservation in the Western Ghats*. ATREE, Bangalore.
- Ramakrishna & S.C. Mitra (2002)**. Endemic land molluscs of India. *Records of Zoological Survey of India, Occasional Paper* 196: 1–65
- Ramakrishna, S.C. Mitra & A. Dey (2010)**. *Annotated Checklist of Indian Land Mollusc*. Zoological Survey of India, Kolkata, 359pp.
- Rao, H.S. (1924)**. Asiatic Succineidae in the Indian Museum. *Records of Indian Museum* 26: 367–408.
- Régnier, C., B. Fontaine & P. Bouchet (2009)**. Not Knowing, Not Recording, Not Listing: Numerous Unnoticed Mollusk Extinctions. *Conservation Biology* 23: 1214–1221.
- Richards, P.M & A. Davison (2010)**. Adaptive Radiations: Competition Rules for Galápagos Gastropods. *Current Biology* 20: R28–R29.
- Satyamurti, S.T. (1960)**. *The land and freshwater mollusca in the collection of the Madras Government Museum*. Bulletin of the Madras Government Museum, Madras.
- Schilthuizen, M., T-S.Liew, B.B. Elhahan & I. Lackman-Ancrenaz (2007)**. Effects of Karst Forest Degradation on Pulmonate and Prosobranch Land Snail Communities in Sabah, Malaysian Borneo. *Conservation Biology* 19: 949–954.
- Seddon, M. (1998)**. Red listing of Molluscs: a tool for conservation? *Journal of Conchology* (Special Publication) 2: 27–44.
- Shimek, B. (1930)**. Land Snails as Indicators of Ecological Conditions. *Ecology* 11: 673–686.
- Simone, L.R.L. (1999)**. Mollusca Terrestres, p. 5: 3–8. In: Brandão, C.R. & E.M. Canello, (Org.). Biodiversidade do Estado de São Paulo, Brasil: síntese do conhecimento ao final do século XX: Invertebrados Terrestres. FAPESP Editora, São Paulo, São Paulo, Brasil.
- Sodhi, N.S. (2008)**. Tropical biodiversity loss and people- a brief review. *Basic and Applied Ecology* 9: 93–99.
- Solem, A. (1984)**. A world model for land snail diversity and abundance. In: Solem A. & A.C. van Bruggen (eds). *Worldwide snails: Biogeographical Studies on Non-Marine Mollusca*. E.J. Brill/Dr W. Backhuys, Leiden, 289pp.
- Sólymos, P. & Z. Fehér (2005)**. Conservation prioritization using land snail distribution data in Hungary. *Conservation Biology* 19: 1084–1094.
- Sternberg, M. (2000)**. Terrestrial gastropods and experimental climate change: A field study in a calcareous grassland. *Ecological Research* 15: 73–81.
- Subbarao, N.V. & S.C. Mitra (1979)**. On the land and freshwater molluscs of Pune district, Maharashtra. *Records of Zoological Survey of India* 75: 1–37.
- Thomas, C.D., A. Cameron, R.E. Green, M. Bakkenes, L.J. Beaumont, Y.C. Collingham, B.F.N. Erasmus, M.F. de Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A.S. van Jaarsveld, G.F. Midgley, L. Miles, M.A. Ortega-Huerta, A.T. Peterson, O.L. Phillips & S.E. Williams (2004)**. Extinction risk from climate change. *Nature* 427: 145–148
- Wade, C.P., P.B. Mordan & F. Naggs (2006)**. Evolutionary relationships among the Pulmonate land snails and slugs. *Biological Journal of the Linnean Society* 87: 593–610.





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



**Author Details:** MR. SANDEEP SEN is a research intern at the Conservation Genetics Department at ATREE. Basically a geneticist by training, He is studying phylogenetics and population genetics of land snails of the Western Ghats. He is also developing species pages for Indian mollusk fauna.

DR. RAVIKANTH leads the conservation Genetics Lab at ATREE. He has been actively involved in working out genetic structure of threatened species in the Western Ghats. He has undertaken a number of research projects related to the conservation and species recovery of economically important and/or endangered species.

DR. ARAVIND is a Fellow at ATREE. He has been working on ecology and taxonomy of non-marine mollusk of the Western Ghats for a decade. He is collaborating with Natural History Museum, London on non-marine mollusc taxonomy.