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Journal of Threatened Taxa

10.11609/jott.2023.15.11.24151-24290
www.threatenedtaxa.org

26 November 2023 (Online & Print)
15(11): 24151-24290
ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)



Open Access



Bhama..



ISSN 0974-7907 (Online); ISSN 0974-7893 (Print)

Publisher
Wildlife Information Liaison Development Society
www.wild.zooreach.org

Host
Zoo Outreach Organization
www.zooreach.org

43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

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continued on the back inside cover

Cover: Leaves and fruits of *Terminalia arjuna* in water colour artwork on cold pressed water colour paper by Bhama Sridharan.



The arboreal microsnail *Insulipupa malayana* (Issel, 1874) (Gastropoda: Stylommatophora: Vertiginidae) from West Bengal, India

Himangshu Barman¹ , Pranesh Paul² & Gautam Aditya³

^{1,2,3}Department of Zoology, University of Calcutta, 35, Ballygunge Circular Road, Kolkata, West Bengal 700019, India.

¹Department of Zoology, Ramnagar College, Depal, Purba Medinipur, West Bengal 721453, India.

¹barman84h@gmail.com, ²plpranesh@gmail.com, ³gautamaditya2001@gmail.com (corresponding author)

Abstract: Studies on occurrence, host plant preference and morphometric features of the arboreal microsnail *Insulipupa malayana* (Issel, 1874) (Gastropoda: Stylommatophora: Vertiginidae) were carried out from selected sites of West Bengal, India. The snail species use the stem and bark of five plant species (*Hibiscus rosa-sinensis*, *Mangifera indica*, *Aegle marmelos*, *Swietenia macrophylla*, and *Roseodendron donnell-smithii*) as microhabitat, and the most preferred host plant was *A. marmelos* (Jacobs' selectivity index $D_{ib} = 0.5 \pm 0.19$). The mean \pm SE values of shell height (SH), shell width (SW), aperture length (AL), aperture width (AW), body weight, apical angle (AA) and spire ratio (SR) of the collected specimens were measured as 1.95 ± 0.06 mm, 1.03 ± 0.01 mm, 0.54 ± 0.02 mm, 0.74 ± 0.02 mm, 0.86 ± 0.06 mg, 0.55 ± 0.02 , and 1.89 ± 0.06 , respectively. The present study will be informative to frame conservation strategies for *I. malayana* in India and elsewhere.

Keywords: Conservation, distribution, Jacobs' selectivity index, morphometry, terrestrial snail.

Editor: Parin Jirapatrasilp, Chulalongkorn University, Bangkok, Thailand.

Date of publication: 26 November 2023 (online & print)

Citation: Barman, H., P. Paul & G. Aditya (2023). The arboreal microsnail *Insulipupa malayana* (Issel, 1874) (Gastropoda: Stylommatophora: Vertiginidae) from West Bengal, India. *Journal of Threatened Taxa* 15(11): 24261–24265. <https://doi.org/10.11609/jott.8613.15.11.24261-24265>

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Funding: The second author PP, acknowledges CSIR-HRDG, India (09/028(1115)/2019-EMR-1, dated 06/08/2019) for the financial support.

Competing interests: The authors declare no competing interests.

Author details: HIMANGSHU BARMAN, assistant professor of Zoology, Ramnagar College, Depal, Purba Medinipur, West Bengal, is engaged in research on land snails and slugs in West Bengal. PRANESH PAUL, senior research fellow, CSIR-HRDG, Government of India, is exploring the applied ecology of land snails and slugs and freshwater snails, including several invasive species, as a part of his PhD programme from Department of Zoology, University of Calcutta. GAUTAM ADITYA, professor of Zoology, University of Calcutta, keeps interest on the ecology of the snails and mosquitoes and small indigenous fish species, with focus on biological control, bioremediation and sustainable resource management.

Author contributions: Conceived by GA; HB and PP carried out the field study, the data collection and analysis of the data. HB, GA and PP drafted the manuscript including the interpretation of the data.

Acknowledgements: We thank Dr. Thor Seng Liew for providing critical comments that improved the manuscript to its present form. The authors are grateful to the head, Department of Zoology, University of Calcutta, Kolkata, West Bengal, India, and the principal, Ramnagar College, Depal, Purba Medinipur, West Bengal, India, for the facilities provided. PP acknowledges CSIR-HRDG, India (09/028(1115)/2019-EMR-1, dated 06/08/2019) for the financial support.



INTRODUCTION

Terrestrial molluscs are an important biota of the terrestrial ecosystem (Astor et al. 2015), and extensive variation is observed in their shape and size, ranging from the smallest *Angustopila dominikae* (approximately 0.86 mm in shell length) (Páll-Gergely et al. 2015) to the Giant African Land Snail *Lissachatina fulica* (approximately 39.3 cm in shell length). In total, there are about 35,000 described species of terrestrial molluscs globally (Lydeard et al. 2004). Land snails that are less than 5 mm in shell length are considered as microsnails (Panha & Burch 2005), and they are potential bioindicators because of their limited dispersal capacity and need for specific microhabitats (Gheoca et al. 2021), such as caves (Dumrongrojwattana et al. 2021), and tree leaf and bark (Nandy et al. 2022). Although there are several promising studies on the diversity and conservation of Indian land snails (Aravind et al. 2005; Ramakrishna et al. 2010; Sen et al. 2012), only a few studies focused on the micro land snails of the Western Ghats (Aravind et al. 2008) and northeastern part of India (Barman et al. 2021; Das & Aravind 2021).

Indian micro land snails are represented by the genera *Kaliella*, *Rahula*, *Georissa*, *Pupilla*, *Pupa*, *Pupisoma*, and *Nesopupa* (Gude 1914, 1921). Among them, eastern Indian snails in the family Vertiginidae contain a few genera, including *Cylindrovertilla* Boettger, *Costigo* Boettger, *Insulipupa* Pilsbry & C.M. Cooke, and *Nesopupa* Pilsbry (Pilsbry 1900). The genus *Nesopupa* is widespread throughout the tropics in the Ethiopian and Oriental regions and the Pacific islands (Hausdorf 2008). Based on the whorl numbers, aperture shape and size, apertural lamellae and folds, striae and shell colour, the genus *Nesopupa* has been grouped into eight groups designated as I to IV (for islands groups), V (species of India and Sri Lanka), VI (Mascarene Islands and Comoros), VII (African species), and VIII (St. Helena species) (Pilsbry 1919). The taxonomic account of the genera *Vertigo*, *Pupilla*, *Nesopupa*, and *Insulipupa* is quite complicated and perplexing. In most literature, the genus names *Vertigo*, *Nesopupa*, and *Insulipupa* were used erroneously, and emphasis was given to the shell dimension, apertural lamellae and folds for identification (Pilsbry 1919). For instance, the genus *Nesopupa* Pilsbry, 1900 was conserved by suppressing the name *Ptychochilus* Boettger, 1881 (Cowie et al. 1994). Though it was not clear whether the specimen collected by Dr. J.F. Bacon was *Pupilla brevicostis* or *Pupilla barrackporensis* (Gude 1914), the species identification shifted from *Vertigo malayanus*, *Pupilla*

barrackporensis, *Nesopupa (Insulipupa) barrackporensis* to *Insulipupa malayana* (Gittenberger & Bruggen 2013; MolluscaBase 2021). However, the currently accepted name of *Pupilla barrackporensis* (Gude, 1914) (described from Barrackpore, India) is *Insulipupa brevicostis* (Benson 1849; MolluscaBase 2023). Among the micro land snails, *Insulipupa malayana* (Issel, 1874) (Stylommatophora: Vertiginidae) has not yet been evaluated for the IUCN Red List and has no detailed distribution range (GBIF 2022). In comparison to the information on the land snails and particularly the microsnails on a worldwide scale (Vermeulen & Liew 2022), the information in the Indian context is limited, mostly to the Western Ghat (Aravind et al. 2008), and most studies were focused on taxonomy while little is known about the ecology and biology of the micro land snails. Documentation of land snail records in various habitats is necessary to evaluate and prioritise threats and enhance conservation efforts. Hence, the reports on the occurrence and bio-ecology of the micro land snail *I. malayana* will be helpful in this regard.

MATERIALS AND METHODS

In course of land snail surveys in different regions of West Bengal, India, during July 2017 to October 2019 (irrespective of time and season), we encountered the microsnails on the stem of shrubs in Gobordanga, North 24 Parganas (22.879791 °N, 88.760227 °E), under the bark of woody plants in The Acharya Jagadish Chandra Bose Indian Botanic Garden, Howrah (22.554885 °N, 88.292322 °E) and Kansrakatai, Howrah (22.534442 °N, 87.908341 °E) (Figure 1). During the survey, the abundance of the snails on different plants was noted, and the collected snails were brought to the laboratory for identification and morphometric analysis. Initially, the snails were photographed using a microscope digital camera (DGI 510, Dewinter, India) fitted with a binocular microscope (SZ2-ILST, Olympus, Japan) for identification. Few shells were cleaned, dried, and placed in carbon tape and platinum-coated to obtain the scanning electron micrograph through scanning electron microscopy (EVO 18 special edition, Zeiss, Germany). Lamellae and folds in the aperture of the specimens were named as teeth structures and represented with International, Westerland, and Steenberg formulas (Pilsbry 1919). Using a binocular light microscope fitted with an ocular micrometre (Erma, Japan), the shell height (SH), shell width (SW), aperture length (AL) and aperture width (AW) of the collected snails were

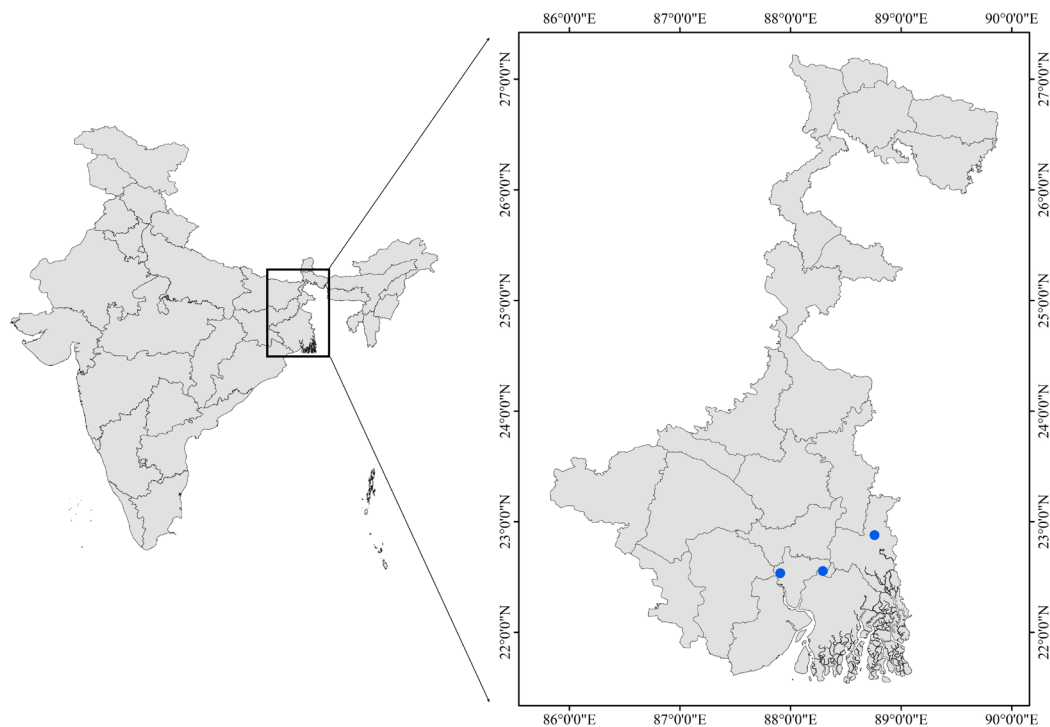


Figure 1. Occurrence points (circles in blue) of *Insulipupa malayana* in West Bengal, India.

measured to the nearest 0.1 mm (Barman et al. 2021). The apical angle (AA) and spire ratio (SR) of the shells were also calculated using the following formula: $AA = 2 \cdot \tan(0.5 \cdot SW/SW)$ (Preston & Roberts 2007) and $SR = SH/SW$, respectively. Host plant preference was assessed using Jacobs' selectivity index (D_{ia}) (Jacobs 1974), which was calculated using the equation-

$$D_{ia} = \frac{(r_i - p_a)}{(r_i + p_a - 2r_i p_a)}$$

where D_{ia} is the selectivity index of snail species 'i' on plant 'a', ' r_i ' is the ratio of plant type 'a' used to all other plant types used by that species, and ' p_a ' is the ratio of plant type 'a' to all other plants available for the individual to use within the local area.

RESULTS AND DISCUSSION

In rainy seasons, the microsnails were observed to be active on the bark and in dry seasons, they were found with epiphragm under the bark. The collected micro land snails were identified as *Insulipupa malayana* (Issel, 1874). This species has a minute, cylindrical shell shape with five whorls, with vermiculated shell sculpture. The body whorl and part of the adjacent whorl are brown, while the remaining part of the shell is dark brown. The

last whorl has a broad, shallow impression behind the lip, with the presence of five aperture teeth, comprising relatively low angular teeth and the largest parietal tooth, a quite deeply placed single columellar tooth and two palatal teeth (Pilsbry 1919; MolluscaBase 2021) (Image 1). In total, 53 snail individuals were encountered during the survey. The morphometric features of the collected snails ($n = 17$) are shown in Table 1. The apertural teeth of *I. malayana* can be represented by the International formula: AP-.–PiPs, Westernlund formula: 2–1–2; and Steenberg formula: $V_{2,3} - A_1 - G_{3,5}$.

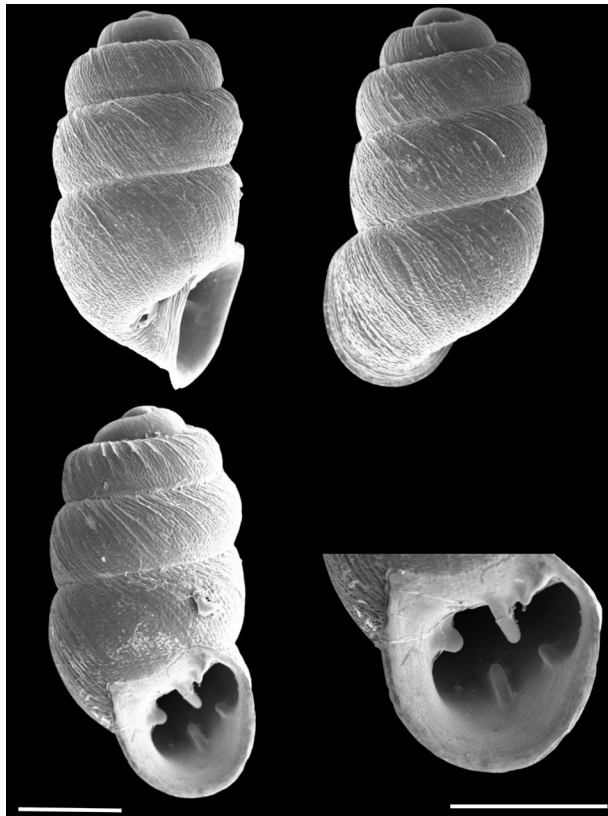
The previous records of *I. malayana* with accepted and different synonymised names from islands of Banggi and Balambangan, Malaysia (Schilthuizen et al. 2011), islet of Misali, off Pemba Island, Zanzibar, Tanzania (Gittenberger & Bruggen 2013), Sabah, Borneo (Phung et al. 2017), Singapore (Sow-Yan & Lup 2019) and other locations are as follows: (i) *Nesopupa (Insulipupa) malayana* (Pilsbry 1918–1920; Thompson & Dance 1983; Maassen 1997; Vermeulen & Whitten 1998; Clements et al. 2008; Schilthuizen et al. 2011, 2013; Phung et al. 2017), (ii) *Vertigo malayanus* (Issel 1874), (iii) *Pupa malayana* (Pfeiffer 1877; Tenison-Woods 1888; von Martens 1908), and (iv) *Pupa (Vertigo) malayana* (Pfeiffer & Clessin 1881 – Type from Borneo).

Among the 45 plant species of the present study area, *I. malayana* was found on only five species. The

Table 1. Morphometric features (range and mean \pm SE) of the collected living *Insulipupa malayana* (n = 17).

SL (mm)	SW (mm)	AL (mm)	AW (mm)	BW (mg)	AA°	SR
1.44–2.26 (1.95 \pm 0.06)	0.94–1.09 (1.03 \pm 0.01)	0.36–0.71 (0.54 \pm 0.02)	0.56–0.90 (0.74 \pm 0.02)	0.31–1.21 (0.86 \pm 0.06)	0.44–0.74 (0.55 \pm 0.02)	1.42–2.31 (1.89 \pm 0.06)

SL—shell length | SW—shell width | AL—aperture length | AW—aperture width | BW— body weight | AA°—apical angle | SR—spire ratio.


Image 1. Scanning electron microscope micrograph of the shells of *Insulipupa malayana*. Scale bar = 0.5 mm. © Authors.

snails were observed on the stems of *Hibiscus rosa-sinensis* and *Mangifera indica*, under the bark of *Aegle marmelos*, *Swietenia macrophylla*, and *Roseodendron donnell-smithii*. Among the host plants, *I. malayana* showed the highest selectivity to *A. marmelos* ($D_{ia} = 0.5 \pm 0.19$), followed by *H. rosa-sinensis* ($D_{ia} = 0.25 \pm 0.16$), *R. donnell-smithii* ($D_{ia} = 0.12 \pm 0.12$), *S. macrophylla* ($D_{ia} = 0.10 \pm 0.10$), and *M. indica* ($D_{ia} = -0.06 \pm 0.15$). Although *I. malayana* was previously recorded from twigs, dead leaves and moss-laden concrete walls in Singapore (Sow-Yan & Lup 2019), we observed that this species is completely arboreal in West Bengal, India. The preference for *A. marmelos*, *H. rosa-sinensis*, *R. donnell-smithii*, and *S. macrophylla* as host plants may be for food, as lichens were present on these host plants. Alternatively, the choice of the barks of these

plants may be to camouflage against the predators as the underside colour of the bark of these host plants is nearly the same as the shell colour of *I. malayana*. These microsnails were also encountered on *M. indica*, but the Jacobs' selectivity index was negative in the study. The high apical angle and spire ratio support the arboreal life of *I. malayana*, similar to other plant-dwelling snail species of the family Achatinillidae, Amastridae and Pupillidae (Cowie 1995). The present information will be useful in understanding the preferred habitat conditions of *I. malayana* and thus sustenance and conservation of its population.

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ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

November 2023 | Vol. 15 | No. 11 | Pages: 24151–24290

Date of Publication: 26 November 2023 (Online & Print)

DOI: 10.11609/jott.2023.15.11.24151-24290

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