

TAXONOMY OF MILLIPEDE (DIPLOPODA) FAUNA IN THE SACRED GROVES OF NORTHERN KERALA

Thesis submitted for the degree of
DOCTOR OF PHILOSOPHY IN ZOOLOGY

**Under the Faculty of Science
University of Calicut**



by

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June, 2026



DECLARATION

I, **Aswathy M. D.**, hereby declare that the work embodied in this thesis, “**TAXONOMY OF MILLIPEDE (DIPLOPODA) FAUNA IN THE SACRED GROVES OF NORTHERN KERALA**” submitted to the University of Calicut in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Zoology is a bona fide record of the research work carried out by me under the supervision of Dr. Usha Bagirathan., Assistant Professor, Sree Kerala Varma College, Thrissur and Dr. Sudhikumar A. V., Associate Professor, Department of Zoology, Christ College (Autonomous), Irinjalakuda, affiliated to the University of Calicut. No part of the thesis has formed the basis for the award of any degree, diploma or similar titles of any university. The contents of the thesis have undergone a plagiarism check using iThenticate software at C.H.M.K. Library, University of Calicut, and the similarity index was found to be within the permissible limit. I also declare that this thesis is free from AI-generated content.

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ASWATHY M. D.

Dedicated to Achan & Amma ...

ABSTRACT

Millipedes (Class: Diplopoda) are crucial macroarthropods of the soil ecosystem, contributing significantly to decomposition and nutrient cycling. Despite their ecological importance and wide distribution—excluding only Antarctica—they remain one of the least studied groups in Indian biodiversity research. This study, focused on the sacred groves of north Kerala, represents a pioneering effort in documenting the diversity, biogeography, and seasonal activity of millipedes in the region. Through extensive field surveys conducted over three years and integrative taxonomic approaches, the study elevated the known species count in Kerala from 57 to 70, including the discovery of nine species new to science, along with several new state and regional distributional records.

The study also reported, for the first time in India, a mermithid nematode parasitizing a millipede, revealing unexplored aspects of diplopod parasitology. Observations on seasonality showed peak millipede activity from June to November, corresponding to the monsoon and post-monsoon periods. The documentation of widely distributed as well as endemic species reinforces the biogeographic uniqueness of the Western Ghats, particularly Kerala's sacred groves and high-altitude regions, as critical refugia for rare and endemic taxa.

This study underscores the importance of faunal documentation as the foundation of biological conservation, particularly for poorly studied and culturally sensitive ecosystems. However, challenges such as seasonal limitations, insufficient ecological data, and cultural restrictions on access to sacred groves was faced during field surveys. These barriers, coupled with increasing anthropogenic pressures, highlight the urgent need to integrate millipede taxonomy with conservation planning.

Overall, the findings provide a significant baseline for future research in systematics, ecology, behaviour, and conservation of millipedes in India. The study emphasizes the necessity of habitat preservation, restoration of lost vegetation, and policy-level recognition of soil invertebrates as vital components of biodiversity. By illuminating the overlooked diversity of millipedes, this study reinforces the Western Ghats' status as a global biodiversity hotspot that demands sustained scientific and conservation attention.

Key words: Biogeography, endemic species, diplopodology, myriapods and conservation planning

സംഗ്രഹം

മണ്ണിന്റെ ആവാസവ്യവസ്ഥയിലെ നിർണായക മാക്രോ ആർത്രോപോഡുകളാണ് തേരടുകൾ (ക്ലാസ്: ഡിപ്ലോപോഡ). അന്റാർട്ടിക്ക ഒഴികെയുള്ള അവയുടെ പാരിസ്ഥിതിക പ്രാധാന്യവും വിശാലമായ വിതരണവും ഉണ്ടായിരുന്നിട്ടും, ഇന്ത്യൻ ജൈവവൈവിധ്യ ഗവേഷണത്തിൽ ഏറ്റവും കുറവ് പഠിക്കപ്പെട്ട ഗ്രൂപ്പുകളിൽ ഒന്നായി അവ തുടരുന്നു. വടക്കൻ കേരളത്തിലെ കാവുകളിൽ ശ്രദ്ധ കേന്ദ്രീകരിച്ച ഈ പഠനം, പ്രദേശത്തെ മില്ലിപീഡുകളുടെ വൈവിധ്യം, ജൈവഭൂമിശാസ്ത്രം, കാലാനുസൃതമായ പ്രവർത്തനം എന്നിവ രേഖപ്പെടുത്തുന്നതിൽ ഒരു മുൻനിര ശ്രമത്തെ പ്രതിനിധീകരിക്കുന്നു. മൂന്ന് വർഷത്തിലേറെയായി നടത്തിയ വിപുലമായ ഫീൽഡ് സർവേകളിലൂടെയും സംയോജിത ടാക്സോണമിക് സമീപനങ്ങളിലൂടെയും, പഠനം കേരളത്തിൽ അറിയപ്പെടുന്ന സ്പീഷിസുകളുടെ എണ്ണം 57 ൽ നിന്ന് 70 ആയി ഉയർത്തി, ശാസ്ത്രത്തിന് പുതിയ ഒമ്പത് സ്പീഷിസുകളുടെ കണ്ടെത്തലും നിരവധി പുതിയ സംസ്ഥാന, പ്രാദേശിക വിതരണ രേഖകളും ഇതിൽ ഉൾപ്പെടുന്നു.

ഇന്ത്യയിൽ ആദ്യമായി, ഒരു മെർമിറ്റിഡ് നിമറ്റോഡ് ഒരു മില്ലിപീഡിനെ പരാദമാക്കുകയും ഡിപ്ലോപോഡ് പരാദശാസ്ത്രത്തിന്റെ പര്യവേക്ഷണം ചെയ്യാത്ത വശങ്ങൾ വെളിപ്പെടുത്തുകയും ചെയ്യുന്നതായി പഠനം റിപ്പോർട്ട് ചെയ്തു. ജൂൺ മുതൽ നവംബർ വരെയുള്ള കാലയളവിൽ, മൺസൂൺ, മൺസൂൺ ശേഷം കാലയളവുകൾക്ക് അനുസൃതമായി, സീസണാലിറ്റിയെക്കുറിച്ചുള്ള നിരീക്ഷണങ്ങളിൽ ഉയർന്ന മില്ലിപീഡ് പ്രവർത്തനം കാണിച്ചു. വ്യാപകമായി വിതരണം ചെയ്യപ്പെട്ടതും തദ്ദേശീയവുമായ ജീവജാലങ്ങളുടെ രേഖപ്പെടുത്തൽ, പശ്ചിമഘട്ടത്തിന്റെ, പ്രത്യേകിച്ച് കേരളത്തിലെ കാവുകളുടേയും ഉയർന്ന പ്രദേശങ്ങളുടേയും ജൈവഭൂമിശാസ്ത്രപരമായ പ്രത്യേകതയെ ശക്തിപ്പെടുത്തുന്നു, അപൂർവ്വവും തദ്ദേശീയവുമായ ടാക്സകൾക്ക് നിർണായകമായ അഭയാർത്ഥികളായി.

മൊത്തത്തിൽ, ഇന്ത്യയിലെ സിസ്റ്റമാറ്റിക്സ്, പരിസ്ഥിതി, പെരുമാറ്റം, മില്ലിപീഡ് സംരക്ഷണം എന്നിവയിലെ ഭാവി ഗവേഷണങ്ങൾക്ക് ഈ കണ്ടെത്തലുകൾ ഒരു പ്രധാന അടിത്തറ നൽകുന്നു. ആവാസവ്യവസ്ഥയുടെ സംരക്ഷണം, നഷ്ടപ്പെട്ട സസ്യജാലങ്ങളുടെ പുനഃസ്ഥാപനം, ജൈവവൈവിധ്യത്തിന്റെ സുപ്രധാന ഘടകങ്ങളായി മണ്ണിലെ അകശേരുകങ്ങളെ നയതലത്തിൽ അംഗീകരിക്കൽ എന്നിവയുടെ ആവശ്യകതയെ പഠനം ഊന്നിപ്പറയുന്നു. മില്ലിപീഡുകളുടെ അവഗണിക്കപ്പെട്ട വൈവിധ്യത്തെ പ്രകാശിപ്പിക്കുന്നതിലൂടെ, സ്ഥിരമായ ശാസ്ത്രീയവും സംരക്ഷണപരവുമായ ശ്രദ്ധ ആവശ്യമുള്ള ആഗോള ജൈവവൈവിധ്യ കേന്ദ്രമെന്ന നിലയിൽ പശ്ചിമഘട്ടത്തിന്റെ പദവിയെ ഈ ഗവേഷണം ശക്തിപ്പെടുത്തുന്നു.

മുഖ്യപദങ്ങൾ: ജൈവ ഭൂമിശാസ്ത്രം, തദ്ദേശീയ സ്പീഷിസുകൾ, വർഗ്ഗീകരണം, സംരക്ഷണ ആസൂത്രണം, ആവാസവ്യവസ്ഥയുടെ സംരക്ഷണം

Contents

INTRODUCTION	1
1.1 Taxonomy: Classifying the natural world.....	1
1.1.1 Types of Taxonomy:	2
1.1.2 Why taxonomy matters:	2
1.1.3 Challenges faced by taxonomy globally:	3
1.2 Millipedes:	3
1.2.1 Origin and history:	4
1.2.2 Taxonomy and classification.....	5
1.2.3 Morphology	16
1.2.4 Zoogeography and Distribution of Millipedes:	17
1.2.5 Seasonality of Millipedes:	18
1.3 Sacred groves:	19
1.3.1 Sacred groves of India.....	20
1.3.2 Groves in Kerala with special emphasis to North Kerala.....	21
1.3.3 Sacred groves and Biodiversity	23
1.4 Objectives:	23
REVIEW OF LITERATURE	27
2.1 Taxonomic Studies of Millipedes (Diplopoda): A Global Overview	27
2.2 Diplopoda Taxonomy in India:	30
2.3 Seasonality studies of Millipedes (Diplopoda):	32
METHODOLOGY	39
3.1 Study Area - The Sacred Groves of North Kerala	39
3.1.1 Sacred Groves of Kasaragod district:	40
3.1.2 Sacred Groves of Kannur district:	43
3.1.3 Sacred Groves of Wayanad district:	45
3.1.4 Sacred groves of Kozhikode district:	46
3.2 Climate	47
3.3 Field Surveys and Specimen Collection.....	48
3.4 Collection method	49
3.5 Sampling Techniques used:	50
3.5.1 Hand Picking method:	50
3.5.2 Leaf Litter sampling:	50

3.5.3 Berlese - Tullgren extraction:.....	50
3.6 Sorting and preservation	51
3.7 Imaging: Methodology and Instrumentation.....	51
3.8 Genitalia preparation for imaging:	52
3.9 Identification	52
3.9.1 Literature Review:.....	52
3.9.2 Diagnosis and description:	52
3.9.3 Review of museum collection:	53
3.10 Registering, Labelling and Storage:	53
3.11 Mapping the distribution	53
RESULT.....	55
4.1 Systematic Position of Class Diplopoda:	55
4.1.1 Dichotomous key to the orders of millipedes collected from the sacred groves of North Kerala:.....	55
4.2 Order Polyxenida Verhoeff, 1934	57
4.2.1 Subclass PENICILLATA Latreille, 1831	57
4.2.1.1 Order Polyxenida Verhoeff, 1934	57
4.2.1.1.1 Superfamily Polyxenoidea Lucas, 1840.....	58
4.2.1.1.2 Key to families of order Polyxenida Verhoeff, 1934 collected from sacred groves of North Kerala.....	58
4.2.1.1.2.1 Family Polyxenidae Lucas, 1840	58
4.2.1.1.2.1.1 Subfamily Monographinae Conde, 2008	58
4.2.1.1.2.1.1.1 Genus <i>Silvestrus</i> Jones, 1937	59
4.2.1.1.2.1.1.1.1 Description of species of genus <i>Silvestrus</i> Jones, 1937, collected from sacred groves of North Kerala.....	60
4.2.1.1.2.2 Family Lophoproctidae Silvestri, 1897.....	61
4.2.1.1.2.2.1 Genus <i>Lophoturus</i> Brolemann, 1931	62
4.2.1.1.2.2.1.1 Description of species of genus <i>Lophoturus</i> Brolemann, 1931, collected from sacred groves of North Kerala.....	62
4.3 Order Sphaerotheriida Brandt, 1833	65
4.3.1 Superorder Oniscomorpha Pocock, 1887.....	65
4.3.1.1 Order Sphaerotheriida Brandt, 1833	65
4.3.1.1.1 Family Arthrosphaeridae Jeekel, 1974.....	67
4.3.1.1.1.1 Genus <i>Arthrosphaera</i> Pocock, 1895	68

4.3.1.1.1.1.1 Descriptions of the species of genus <i>Arthrosphaera</i> Pocock, 1895 collected from sacred groves of North Kerala.....	68
4.4 Order Siphonophorida Newport, 1844.....	74
4.4.1 Infraclass Helminthomorpha Pocock, 1887.....	74
4.4.1.1 Subterclass Colobognatha Brandt, 1834.....	74
4.4.1.1.1 Order Siphonophorida Newport, 1844.....	75
4.4.1.1.1.1 Family Siphonorhinidae Cook, 1895.....	76
4.4.1.1.1.1.1 Genus <i>Siphonorhinus</i> Pocock, 1894.....	76
4.4.1.1.1.1.1.1 Descriptions of the species of genus <i>Arthrosphaera</i> Pocock, 1895 collected from sacred groves of North Kerala.	77
4.5 Order Polyzonida Gervais, 1884.....	82
4.5.1 Family Siphonotidae Cook, 1895.....	83
4.5.1.1 Genus <i>Rhinotus</i> Cook, 1896.....	83
4.5.1.1.1 Descriptions of the species of Genus <i>Rhinotus</i> Cook, 1896 collected from sacred groves of North Kerala.....	83
4.6 Order Polydesmida Leach, 1815.....	87
4.6.1 Superorder Merochaeta Cook, 1895.....	87
4.6.1.1 Order Polydesmida Leach, 1815.....	87
4.6.1.1.1 Key to families of the order Polydesmida and diagnosis of millipedes found from the Sacred groves of North Kerala:.....	88
4.6.1.1.1.1 Family Paradoxosomatidae Daday, 1889.....	88
4.6.1.1.1.1.1 Key to the genera of family Paradoxosomatidae Daday, 1889 found in the sacred groves of N. Kerala are as follows:.....	89
4.6.1.1.1.1.1.1 The tribes of family Paradoxosomatidae millipedes collected from Sacred groves of North Kerala.....	89
4.6.1.1.1.1.1.1.1 Key to the genera of tribe Polydrepanini Jeekel, 1968.....	90
4.6.1.1.1.1.1.1.1.1 Descriptions to the species of genus <i>Delarthum</i> , Attems 1936 collected from sacred groves of North Kerala.	90
4.6.1.1.1.1.1.1.1.1.2 Descriptions to the species of genus <i>Telodrepanum</i> , Carl 1932 collected from sacred groves of N. Kerala.....	93
4.6.1.1.1.1.1.1.1.1.1.3 Genus <i>Chondromorpha</i> Silvestri, 1897.....	95
4.6.1.1.1.1.1.1.1.1.1.3.1 Description of the species of Genus <i>Chondromorpha</i> Silvestri, 1897.....	96
4.6.1.1.1.1.1.1.1.1.1.4 Genus <i>Anoplodesmus</i> Carl, 1932.....	99
4.6.1.1.1.1.1.1.1.1.1.4.1 Description of species of genus <i>Anoplodesmus</i> collected from Sacred groves of N. Kerala.....	99
4.6.1.1.1.1.1.1.1.1.1.5 Genus <i>Orthomorpha</i> Bollman, 1893.....	102

4.6.1.1.1.1.1.5.1 Description of species of genus <i>Orthomorpha</i> Bollman, 1893, collected from Sacred groves of North Kerala.....	102
4.6.1.1.2 Family Pyrgodesmidae Silvestri, 1896.....	104
4.6.1.1.2.1 Key to the genera of Family Pyrgodesmidae Silvestri, 1896, collected from Sacred groves of North Kerala.....	105
4.6.1.1.2.1.1 Genus <i>Klimakodesmus</i> Carl, 1932.....	105
4.6.1.1.2.1.1.1 Description of species belonging to Genus <i>Klimakodesmus</i> Carl, 1932, collected from Sacred groves of Kerala	107
4.6.1.1.2.2 Genus <i>Propyrgodesmus</i> Silvestri, 1920	109
4.6.1.1.2.2.1 Description of species belonging to Genus <i>Propyrgodesmus</i> Silvestri, 1920, collected from Sacred groves of Kerala	110
4.6.1.1.2.3 Genus <i>Pagodesmus</i> Carl, 1932.....	112
4.6.1.1.2.3.1 Description of species belonging to Genus <i>Pagodesmus</i> Carl, 1932, collected from Sacred groves of North Kerala.....	113
4.6.1.1.3 Family Trichopolydesmidae Verhoeff, 1910	114
4.6.1.1.3.1 Genus <i>Pseudosphaeroparia</i> Carl, 1932	115
4.6.1.1.3.1.1 Key to the species belonging to Genus <i>Pseudosphaeroparia</i> Carl, 1932, collected from sacred groves of North Kerala	115
4.6.1.1.3.1.1.1 Description of species belonging to Genus <i>Pseudosphaeroparia</i> Carl, 1932, collected from sacred groves of North Kerala.....	116
4.7 Order Spirostreptida Brandt, 1833	124
4.7.1 Superorder Juliformia Attems, 1926	124
4.7.1.1 Key to the orders of superorder Juliformia Attems, 1926.....	124
4.7.1.1.1 Order Spirostreptida Brandt, 1833	125
4.7.1.1.1.1 Suborder Spirostreptoidea Brandt, 1833	126
4.7.1.1.1.1.1 Family Harpagophoridae Attems, 1909	126
4.7.1.1.1.1.1.1 Key to the genera of family HarpagophoridaeAttems, 1909 collected from the sacred groves of North Kerala.	127
4.7.1.1.1.1.1.1.1 Genus <i>Carlogonus</i> Demange, 1961	127
4.7.1.1.1.1.1.1.1.1 Descriptions to the species of genus <i>Carlogonus</i> , Demange, 1961 collected from sacred groves of North Kerala.	128
4.7.1.1.1.1.1.1.2 Genus <i>Fageostreptus</i> Demange, 1961.....	130
4.7.1.1.1.1.1.1.2.1 Descriptions of the species of genus <i>Fageostreptus</i> Demange, 1961 collected from sacred groves of North Kerala.	130
4.7.1.1.1.1.1.1.3 Genus <i>Harpurostreptus</i> Attems, 1936.....	133
4.7.1.1.1.1.1.1.3.1 Descriptions of the species of genus <i>Harpurostreptus</i> Attems, 1936 collected from sacred groves of North Kerala.	133

4.8 Order Spirobolida Bollman, 1893	137
4.8.1 Order Spirobolida Bollman, 1893	137
4.8.1.1 Family Pachybolidae Cook, 1897	138
4.8.1.1.1 Key to the genera of family Pachybolidae Cook, 1897 collected from sacred groves of North Kerala.....	139
4.8.1.1.1.1 Genus <i>Trigoniulus</i> Pocock 1894	139
4.8.1.1.1.1.1 The description of species of <i>Trigoniulus</i> Pocock 1894 collected from the sacred groves of North Kerala.....	140
4.8.1.1.1.2.1 The description of species of <i>Stenobolus</i> Carl 1918 collected from the sacred groves of North Kerala.....	142
4.8.1.1.1.2 Genus <i>Stenobolus</i> Carl, 1918.....	143
4.8.1.1.1.3 Genus <i>Xenobolus</i> Carl 1919.....	144
4.8.1.1.1.3.1 The description of species of <i>Xenobolus</i> Carl 1919 collected from the sacred groves of North Kerala.....	145
4.8.1.1.1.4 Genus <i>Aulacobolus</i> Pocock 1903.....	148
4.8.1.1.1.4.1 The description of species of <i>Aulacobolus</i> Pocock 1903 collected from the sacred groves of North Kerala.....	148
4.8.1.1.1.5 Genus <i>Eucentrobolus</i> Pocock, 1903.....	151
4.8.1.1.1.5.1 The description of species of Genus <i>Eucentrobolus</i> Pocock, 1903 collected from the sacred groves of North Kerala.....	152
4.9 Taxonomic Contributions from the Study: New Species and Distributional Records..	160
4.9.1 Species checklist of diplopods of Kerala	160
4.10 Seasonality in Millipede.....	167
4.10.1 Seasonal Occurrence of Millipedes in Sacred Groves of North Kerala	167
4.10.1.1 Seasonal occurrence of millipede fauna in sacred groves of Kasaragod district.	169
4.10.1.1.2 Kammadam Kavu - KZE02.....	170
4.10.1.1.3 Payyankulam Kavu - KZE03	170
4.10.1.1.4 Puthiyaparambath Kavu -KZE04	170
4.10.1.1.5 Mannampurath Kavu - KZE05.....	171
4.10.1.1.6 Koyithatta Sree Dharma Sashta Kavu- KZE06.....	171
4.10.1.1.7 Sree Malliyodan Kavu - KZE07.....	171
4.10.1.2 Seasonal occurrence of millipede fauna in sacred groves of Kannur district....	172
4.10.1.2.1 Thazhe Kavu - KNN01	172
4.10.1.2.3 Madayi Kavu-KNN02	172
4.10.1.2.3 Neeliyarkottam -KNN03	173

4.10.1.2.4 Chaamakavu-KNN04.....	173
4.10.1.2.5 Poongottukavu-KNN05.....	174
4.10.1.3 Seasonal occurrence of millipede fauna in sacred groves of Kozhikode district.	174
4.10.1.3.1 Muchukunnu Kavv-CLT01	174
4.10.1.3.2 Poyilkavu - CLT02.....	175
4.10.1.3.3 Vallikattukavu-CLT03	175
4.10.1.4 Seasonal occurrence of millipede fauna in sacred groves of Wayanad district.	175
4.10.1.4.1 Manikavu-WYN01	176
4.10.1.4.2 Valliyurkavu - WYN02	176
4.10.1.4.3 Anoth Kavv-WYN03	177
4.11 Parasitic interactions in millipede	179
4.11.1 Endoparasite in Spirobolid Millipede	179
DISCUSSION	181
5.1 Taxonomic Contributions from the Study: New Species and Distributional Records..	182
5.2 Seasonality in Millipedes	184
5.3 Endoparasite in Millipedes:.....	185
CONCLUSION	188
RECOMMENDATIONS	189

LIST OF TABLES

Table	Content
Table 1	Species checklist of millipedes reported from Kerala
Table 2	The species discovered to be new to science obtained from the sacred groves of North Kerala.
Table 3	Species with first report from India.
Table 4	Species with first report from Kerala
Table 5	Seasonal variation in diversity indices and abundance of millipedes across study sites
Table 6	Spearman correlation between environmental variables and millipede diversity metrics.
Table 7	Multiple regression analysis of environmental variables influencing millipede diversity

LIST OF FIGURES

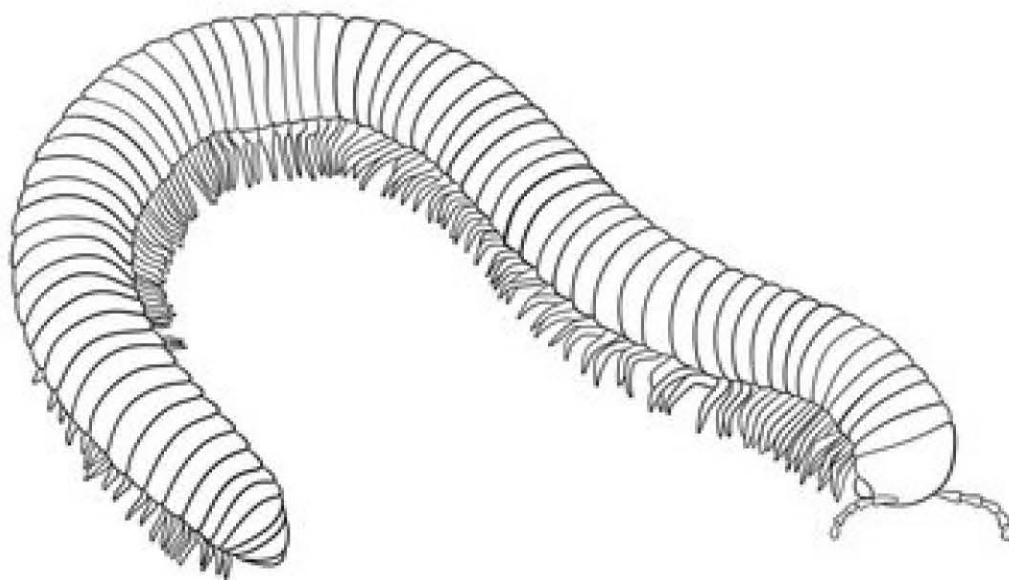
Figure No.	Title
Figure 1	Location Map of Study Area
Figure 2	Study Sites in Kasaragod District
Figure 3	Study Sites in Kannur District
Figure 4	Study Sites in Kozhikode District
Figure 5	Study Sites in Wayanad District
Figure 6	Sampling Equipment Used in Field Surveys
Figure 7	Sampling Techniques
Figure 8	Storing, Preservation and Identification
Figure 9	<i>Silvestrus seminudus</i>
Figure 10	<i>Lophoturus muchukunnensis</i> sp.nov.
Figure 11	<i>Arthrosphaera aurocincta</i> Pocock, 1899
Figure 11.1	Distribution Map of <i>Arthrosphaera aurocincta</i> Pocock, 1899
Figure 12	<i>Arthrosphaera kammadamensis</i> sp.nov.
Figure 12.1	Distribution Map of <i>Arthrosphaera kammadamensis</i> sp.nov.
Figure 13	<i>Siphonorhinus muchukennensis</i> sp.nov.
Figure 14	<i>Siphonorhinus koyithattensis</i> sp.nov.
Figure 15	<i>Rhinotus purpureus</i> Pocock, 1894
Figure 16	Distribution Maps of <i>Rhinotus purpureus</i>
Figure 17	<i>Delarthrum anomalans</i> sp.nov.
Figure 18	Gonopod Structures of <i>Delarthrum anomalans</i> sp.nov.
Figure 19	<i>Telodrepanum badaga</i> Carl, 1932
Figure 20	<i>Chondromorpha kelaarti</i> Humbert, 1865
Figure 21	<i>Anoplodesmus saussurii</i> (Humbert, 1865)
Figure 22	Distribution Maps of <i>Anoplodesmus saussurii</i>
Figure 23	<i>Orthomorpha coarctata</i> (de Saussure, 1860)
Figure 24	Distribution Maps of <i>Orthomorpha coarctata</i>
Figure 25	<i>Klimakodesmus bilobocaudatus</i> sp.nov.
Figure 26	<i>Propyrgodesmus bulbogonopus</i> sp.nov.
Figure 27	Additional Figures of <i>Propyrgodesmus bulbogonopus</i> sp.nov.
Figure 28	Distribution of <i>Propyrgodesmus bulbogonopus</i> sp.nov. and <i>Pagodesmus sulcifer</i>
Figure 29	<i>Pseudosphaeroparia malabarica</i> sp.nov.
Figure 30	Distribution of <i>Pseudosphaeroparia malabarica</i> sp.nov.
Figure 31	Distribution of <i>Pseudosphaeroparia falcata</i> sp.nov.
Figure 32	<i>Pseudosphaeroparia falcata</i> sp.nov.
Figure 33	<i>Carlogonus palmatus</i> Demange, 1977
Figure 34	<i>Fageostreptus hyatti</i> Demange, 1961
Figure 35	Distribution of <i>Fageostreptus hyatti</i>
Figure 36	<i>Harpurostreptus prasadani</i> Demange, 1989
Figure 37	<i>Trigoniulus corallinus</i> (Gervais, 1847)
Figure 38	<i>Stenobolus insularis</i> Carl, 1918

Figure 39	<i>Xenobolus carnifex</i> Carl, 1919
Figure 40	Distribution of <i>Xenobolus carnifex</i>
Figure 41	<i>Aulacobolus gravelyi</i> Silvestri, 1916
Figure 42	Distribution of <i>Aulacobolus gravelyi</i>
Figure 43	<i>Aulacobolus newtoni</i> Silvestri, 1916
Figure 44	<i>Eucentrobolus maindroni</i> (Bouvier, 1903)

LIST OF GRAPHS / SEASONAL ABUNDANCE FIGURES

Figure No.	Title
Figure 45	Seasonal abundance of millipedes - Edeyilakkad Kavu (KZE01), 2021
Figure 46	Seasonal abundance of millipedes - Edeyilakkad Kavu (KZE01), 2022
Figure 47	Seasonal abundance of millipedes - Kammadam Kavu (KZE02), 2021
Figure 48	Seasonal abundance of millipedes - Kammadam Kavu (KZE02), 2022
Figure 49	Seasonal abundance of millipedes - Payyankulam Kavu (KZE03), 2021
Figure 50	Seasonal abundance of millipedes - Payyankulam Kavu (KZE03), 2022
Figure 51	Seasonal abundance of millipedes - Puthiyaparambath Kavu (KZE04), 2021
Figure 52	Seasonal abundance of millipedes - Puthiyaparambath Kavu (KZE04), 2022
Figure 53	Seasonal abundance of millipedes - Mannampurath Kavu (KZE05), 2021
Figure 54	Seasonal abundance of millipedes - Mannampurath Kavu (KZE05), 2022
Figure 55	Seasonal abundance of millipedes - Koyithatta Sree Dharma Sastha Kavu (KZE06), 2021
Figure 56	Seasonal abundance of millipedes - Koyithatta Sree Dharma Sastha Kavu (KZE06), 2022
Figure 57	Seasonal abundance of millipedes - Malliyodan Kavu (KZE07), 2021
Figure 58	Seasonal abundance of millipedes - Malliyodan Kavu (KZE07), 2022
Figure 59	Seasonal abundance of millipedes - Thazhe Kavu (KNN01), 2021
Figure 60	Seasonal abundance of millipedes - Thazhe Kavu (KNN01), 2022
Figure 61	Seasonal abundance of millipedes - Madayi Kavu (KNN02), 2021
Figure 62	Seasonal abundance of millipedes - Madayi Kavu (KNN02), 2022
Figure 63	Seasonal abundance of millipedes - Neeliyar Kottam (KNN03), 2021
Figure 64	Seasonal abundance of millipedes - Neeliyar Kottam (KNN03), 2022
Figure 65	Seasonal abundance of millipedes - Chamakavu (KNN04), 2021
Figure 66	Seasonal abundance of millipedes - Chamakavu (KNN04), 2022
Figure 67	Seasonal abundance of millipedes - Poongottukavu (KNN05), 2021

Figure 68	Seasonal abundance of millipedes - Poongottukavu (KNN05), 2022
Figure 69	Seasonal abundance of millipedes - Muchukunnu Kavu (CLT01), 2021
Figure 70	Seasonal abundance of millipedes - Muchukunnu Kavu (CLT01), 2022
Figure 71	Seasonal abundance of millipedes - Poyikavu (CLT02), 2021
Figure 72	Seasonal abundance of millipedes - Poyilkavu (CLT02), 2022
Figure 73	Seasonal abundance of millipedes - Vallikattukavu (CLT03), 2021
Figure 74	Seasonal abundance of millipedes - Vallikattukavu (CLT03), 2022
Figure 75	Seasonal abundance of millipedes - Maanikavu (WYN01), 2021
Figure 76	Seasonal abundance of millipedes - Maanikavu (WYN01), 2022
Figure 77	Seasonal abundance of millipedes - Valliyurkavu (WYN02), 2021
Figure 78	Seasonal abundance of millipedes - Valliyurkavu (WYN02), 2022
Figure 79	Seasonal abundance of millipedes - Anoth Kau (WYN03), 2021
Figure 80	Seasonal abundance of millipedes - Anoth Kau (WYN03), 2022
Figure 81	Seasonal variation in Shannon diversity (H') of millipede assemblages across study sites
Figure 82	Seasonal variation in Simpson diversity index ($1-D$) of millipede communities
Figure 83	Seasonal variation in Pielou's evenness (J') of millipede assemblages
Figure 84	Seasonal variation in species richness of millipedes across study sites
Figure 85	Seasonal variation in total abundance of millipedes across study sites
Figure 86	Seasonal variation in mean abundance per species of millipedes
Figure 87	Seasonal trend in mean species richness of millipedes
Figure 88	Relative abundance (%) of millipede species across seasons
Figure 89	Relationship between temperature and Shannon diversity of millipedes
Figure 90	Relationship between relative humidity and Shannon diversity of millipedes



CHAPTER 1
INTRODUCTION

INTRODUCTION

1.1 Taxonomy: Classifying the natural world

The inherent human curiosity to understand and categorize the natural world has been present since the dawn of consciousness. The scientific fields of taxonomy and systematics were founded on this natural need of man to identify and understand the plants, animals, and other species in his immediate environment. These fields have now grown to be essential to the larger corpus of biological knowledge. Taxonomy can be defined as the practice and theory of identifying, describing and classifying the organisms (Gillott, 2005). It provides a framework for arranging life's enormous diversity into a structured system that enables scientific communication, biodiversity studies, and ecological studies (Mayr & Ashlock, 1991). Taxonomy is the foundation of biology, that interlinks the disciplines like genetics, ecology, and conservation.

The term Taxonomy was coined by A. P. de Candolle, a Swiss botanist, in 1813. It is an irregular composition of two Greek words “τάξις”, taxis 'order' and “νόμος”, nomos 'law', joined by the French suffix -o- to name the branch of study that deals with the nomenclature itself as Taxonomy.

The origin of this discipline is said to have its roots in ancient Greece when Aristotle pioneered efforts to classify organisms based on observable physical traits and their ecological roles. Through his book *Scala Naturae* (Ladder of life) Aristotle attempted to systematically organize the extant living beings. He was followed by many philosophers of that time such as Theophrastus (370 - 285 AD), Dioscorides (40 - 90 AD) and Pliny the Elder (23 - 79 AD). Afterwards in the 18th century, the branch of taxonomy was given a new outlook by a Swedish biologist, Carl Linnaeus. Carl Linnaeus (1707 - 1777) was one of the greatest minds of Europe in the 18th century and revolutionised taxonomy. This glorious period was marked as the Linnean era in the history of taxonomy. Linnaeus developed the system of the binomial nomenclature through one of his major works *Systema Naturae* (1758). This approach established a systematic way for naming species, which is still used in biological categorization in modern taxonomy. Linnaeus also created a hierarchical structure that classified biological forms into nested categories such as genus, family, order, and class, providing the groundwork for systematic biology.

Since then, the field of taxonomy has evolved significantly, moving from a morphology-based discipline to a more integrative science incorporating genetics, and cutting-edge technologies of molecular biology, and computational tools. Taxonomy involves a set of serial procedures until the classification of an organism is completed. It starts with the identification of the specimen by which the organism is recognized and is assigned to an existing taxon or creating a new taxon if necessary. This is followed by nomenclature, the assignment of a name for the organism applying standardized rules governed by codes such as the International Code for Zoological Nomenclature (ICZN) for animals and International Code of Nomenclature for algae, fungi and plants (ICN). The final step is the classification where the organism is organized into hierarchical groups such as kingdom, phylum, class, family, genus and species.

1.1.1 Types of Taxonomy:

Depending on the complexity and the depth of study, taxonomy can be further subdivided into alpha, beta, and gamma taxonomy (Mayr, 1982).

Alpha Taxonomy: It is concerned with fundamental description and nomenclature of species, using morphological characters.

Beta Taxonomy: It is concerned with organizing species into natural hierarchies and thereby studying their interactions and relationships with one another.

Gamma Taxonomy: Gamma Taxonomy investigates larger ecological and evolutionary links by combining phylogenetic and genetic data.

1.1.2 Why taxonomy matters:

Taxonomy can be said to be a foundational discipline to all biological sciences. It provides critical insights to the diversity of life forms as well as its interconnectedness. Even though it is a descriptive branch of biology, it finds application in all of the major aspects of biology. It is a predictive tool for various applications such as Conservation Biology: Accurate species identification underpins efforts to conserve endangered species and ecosystems (Wilson, 1988), Public Health: Identifying vectors of diseases and pathogens is crucial for managing outbreaks (Raven et al., 2005), and Agriculture: Taxonomy aids in identifying pests, weeds, and beneficial species that impact crop management (Cracraft, 2002). Its

significance extends beyond mere classification and nomenclature, but impacts several domains of knowledge.

1.1.3 Challenges faced by taxonomy globally:

Taxonomy is both an ancient as well as an expanding science. It continues to be the basics to delve into the unravelled mysteries of the natural world. When integrated with the cutting-edge modern technologies and bioinformatics tools it holds promise for addressing the challenges posed by the alarming rate of biodiversity loss. This ensures that this discipline will remain relevant beyond the 21st century. Despite being the fundamental to all the studies, taxonomy has faced many challenges for its existence since time immemorial. The lack of trained experts, taxonomic impediment and insufficient funding for conducting research in this area are a few to name (Wheeler et al., 2004). It is estimated that of the 8.7 million species on Earth, only about 20% have been described (Mora et al., 2011). Global initiatives such as the Global Biodiversity Information Facility (GBIF) and the Catalogue of Life aim to document all known species and make taxonomic data widely accessible. Another challenge or shortcoming of taxonomy or taxonomists is the tendency to overlook certain groups of organisms. So, when it comes to their identity and systematics, there tends to have a large ‘taxonomic impediment’ up to certain level. One such group which was overlooked by taxonomists is the Class Diplopoda. The taxa which consist of the soil dwelling macro-arthropods commonly called as millipedes.

1.2 Millipedes:

Millipedes are a group of ancient arthropods which dates back to the early Silurian period, approximately 428 million years ago. They are believed to be amongst the pioneer organisms to crawl out of water and to breathe air on the land (Wilson, 2006). Millipedes belong to class Diplopoda and are recognized for their seemingly endless looking number of legs and dawdling movement. They are a fascinating group of soil macro-arthropods which have a characteristic elongated and segmented body and the unique feature of having two legs per body ring in most of their body trunk. The Diplopoda (millipedes) is the third biggest class of terrestrial Arthropods, with over 12,000 species reported in 145 families and 16 orders (Adis, 2002; Shelley, 2002; Sierwald & Bond, 2007) and an estimated 80,000 species worldwide counted after the much abundant groups such as Arachnida and Insecta. Millipedes get their name from two Latin words ‘*milli*’ means thousand and ‘*pes*’ means legs.

Even though the name was a misnomer since there wasn't any individual species possessing literally a thousand legs until the subterranean millipede, namely *Eumillipes persephone* was discovered from the depths of the gold mines in the southern Australia (Marek et al., 2021). Until then, the species with most number of legs used to be a South American species named *Illacme plenipes*, with over 750 nominal leg pairs.

Millipedes rely on the detritus as their primary source of nutrition and that has enabled them to play a vital role in the ecosystem as decomposers. By breaking down decaying organic matter, they contribute significantly to nutrient cycling and soil formation, making them indispensable to the health of forest and grassland ecosystems (Hopkin & Read, 1992). Hence they become a vital integral part of ecosystems and play pivotal roles as biogeographical indicators because of their plethoric diversity and geological age, as well as low vagility (Hopkin & Read, 1992).

Millipedes have a worldwide distribution except in the Antarctic. They inhabit a wide range of environments from moist tropical forests to arid deserts. They are particularly abundant and diverse in dense humid forests like the ones seen in the Western Ghats, Amazon rainforest, and Madagascar, where they exhibit high species richness and endemism (Golovatch & Kime, 2009).

Even though they are ecologically important, millipedes are often overlooked in biodiversity studies, leaving out innumerable species undescribed and their ecological roles unexplored.

1.2.1 Origin and history:

The oldest known fossil of a millipede dates back to the mid-Silurian and Devonian, and they appear to have been detritivores (Crawford, 1992). Since the Carboniferous period, however, they have become highly diversified. Six extinct groups were represented by those early diplopods, which are acknowledged as entirely terrestrial because of the existence of a tracheal system (visible spiracles). It is noteworthy that the prehistoric superorder Arthropleuridea had both enormous species (more than 2 m long) and little species (a few mm long). However, fossil millipedes have only been categorized into extant orders and families since the Mesozoic (Sierwald & Bond, 2007).

The great diversification and ecological supremacy of arthropods, including millipedes, happened during the Carboniferous period (about 359 - 299 million years ago). The millipedes contributed significantly to the development of coal reserves by aiding in the breakdown of plant matter. Giant millipedes (such as *Arthropleura* sp.) and other huge arthropods such as huge dragonfly (*Meganeura* sp.), however, declined in number after the Carboniferous, perhaps as a result of competition with vertebrates and declining oxygen levels (Golovatch & Kime, 2009).

There are currently more than 12,000 species of millipedes known to exist, while estimates place the actual number closer to 80,000 (Sierwald & Bond, 2007). In tropical areas, where they flourish in damp conditions that sustain detritivores, their variety is especially noticeable. In India there are more than 290 nominal species of millipedes under 12 different orders (Attems, 1936; Aswathy & Sudhikumar, 2022; Anilkumar et al., 2024)

1.2.2 Taxonomy and classification

Taxonomically placing, diplopods fall under the

Animalia (Kingdom)

Arthropoda (Phylum)

Myriapoda (Subphylum)

Diplopoda (Class)

The higher-level millipede taxonomy seems to be over-split; 12,000 documented species are allocated to 2947 genera (4 species per genus on average) and 145 families (78) (Brewer et al., 2012). Nearly, 68% of all millipede genera are monotypic or include two species, and 715 generic names are now regarded as synonyms (Sierwald & Bond, 2007). Since many millipede species are known from their first description and have never undergone additional systematic study, this suggests a dearth of revisionary effort. Just 441 species of millipedes had been described in 1860, a century after Linnaeus. Between 1890 and 1960, the great majority of species - nearly 7000 - were described, with an average of 100 species annually. In the latter part of the 20th century, there were only around 30 species descriptions per year (1991- 2000). Currently, there are 13,587 accepted species and 24,925 species names including synonyms according to “Millibase”, a global species database for diplopods (Decker et al., 2026).

Fewer taxonomists and inadequacy of alpha-taxonomic work are likely to blame for the drop in the annual report rate of new species descriptions all across the world. However, it does not suggest that the millipede species discovery is getting close to completion. Therefore, this study aims primarily to contribute towards identifying, documenting and reporting of millipede species localised in the sacred groves of northern region of Kerala, which is located on the south western part of modern India.

There are 16 orders of extant millipede reported globally. The classification based on Shear (2011) is recreated as following:

Class Diplopoda de Blainville in Gervais, 1844

Subclass Penicillata Latrielle, 1831

Order Polyxenida Verhoeff, 1934 (2 superfamilies)

Superfamily Polyxenoidea Lucas, 1940 (3 families)

Family Hypogexenidae Schubart, 1947 (1 genus, 1 species)

Family Lophoproctidae Silvestri, 1897 (5 genera, 30 species)

Family Polyxenidae Lucas, 1840 (19 genera, 47 species)

Superfamily Synxenoidea Silvestri, 1923 (1 family)

Family Synxenidae Silvestri, 1923 (2 genera, 8 species)

Subclass Chilognatha Latrielle, 1802/1803 (2 infraclasses)

Infraclass Pentazonia Brandt, 1833 (2 superorders)

Superorder Limacomorpha Pocock, 1894 (1 order)

Order Glomeridesmida Cook, 1895 (2 families)

Family Glomeridesmidae Latzel 1884 (1 genus, 26 species)

Family Termitodesmidae Silvestri, 1911 (1 genus, 5 species)

Superorder Oniscomorpha Pocock, 1887 (2 orders)

Order Glomerida Brandt, 1833 (2 families)

Family Doderiidae Silvestri, 1904 (3 genera, 36 species)

Family Glomeridae Leach, 1816 (27 genera, 176 species)

Order Sphaerotheriida Brandt, 1833 (4 families)

Family Sphaerotheriidae C. L. Koch, 1847 (2 genera, 55 species)

Family Zephroniidae Gray in Jones, 1843 (14 genera, 140 species)

Family Procyliosomatidae Wesener & VandenSpiegel, 2009 (1 genus, 10 species)

Family Arthrosphaeridae Jeekel, 1974 (4 genera, 100 Species)

Infraclass Helminthomorpha Pocock, 1887 (2 subterclasses)

Subterclass Colobognatha Brandt, 1834 (4 orders)

Order Platydesmida Cook, 1895 (2 families)

Family Andrognathidae Cope, 1869 (12 genera, 32 species)

Family Platydesmidae DeSaussure, 1860 (2 genera, 31 species)

Order Polyzoniida Cook, 1895 (3 families)

Family Hirudisomatidae Silvestri, 1896 (6 genera, 20 species)

Family Polyzoniidae Newport, 1844 (6 genera, 22 species)

Family Siphonotidae Cook, 1895 (12 genera, 32 species)

Order Siphonocryptida Cook, 1895

Family Siphonocryptidae Pocock, 1894 (2 genera, 6 species)

Order Siphonophorida Newport, 1844 (2 families)

Family Siphonophoridae Newport, 1844 (10 genera, 60? species)

Family Siphonorhinidae Cook, 1895 (4 genera, 10 species)

Subterclass Eugnatha Attems, 1898 (3 superorders)

Superorder Juliformia Attems, 1926 (3 orders)

Order Julida Brandt, 1833 (5 superfamilies)

Superfamily Blaniuloidea C. L. Koch, 1847 (4 families)

Family Blaniulidae C. L. Koch, 1847 (19 genera, 46 species)

Family Galliobatidae Brolemann, 1921 (1 genus, 1 species)

Family Okeanobatidae Verhoeff, 1942 (2 genera, 4 species)

Family Zosteractinidae Loomis, 1943 (2 genera, 2 species)

Superfamily Juloidea Leach, 1814 (4 families)

Family Julidae Leach, 1814 (88 genera, 500? species)

Family Rhopaloiulidae Attems, 1926 (1 genus, 1 species)

Family Trichoblaniulidae Verhoeff, 1911 (1 genus, 4 species)

Family Trichonemasomatidae Enghoff, 1991 (1 genus, 1 species)

Superfamily Nemasomatoidea Bollman, 1893 (5 families)

Family Chelojulidae Enghoff, 1991 (1 genus, 1 species)

Family Nemasomatidae Bollman, 1893 (7 genera, 22 species)

Family Pseudonemasomatidae Enghoff, 1991 (1 genus, 1 species)

Family Telsonemasomatidae Enghoff, 1991 (1 genus, 1 species)

Superfamily Paeromopodoidea Cook, 1895 (2 families)

Family Aprosphylosomatidae Hoffman, 1961 (1 genus, 1 species)

Family Paeromopodidae Cook, 1895 (2 genera, 16 species)

Superfamily Parajuloidea Bollman, 1893 (2 families)

Family Mongoliulidae Pocock, 1903 (8 genera, 23 species)

Family Parajulidae Bollman, 1893 (27 genera, 115 species)

Order Spirobolida Cook, 1895 (2 suborders)

Suborder Spirobolidea Cook, 1895 (11 families)

Family Allopocockiidae Keeton, 1960 (3 genera, 7 species)

Family Atopetholidae Chamberlin, 1918 (14 genera, 45 species)

Family Floridobolidae Keeton, 1959 (1 genus, 1 species)

Family Hoffmanobolidae Shelley, 2001 (1 genus, 1 species)

Family Messicobolidae Loomis, 1968 (3 genera, 25 species)

Family Pseudospirobolellidae Brölemann, 1913 (2 genera, 4 species)

Family Rhinocricidae Brölemann, 1913 (16 genera, 110 species)

Family Spirobolellidae Brölemann, 1913 (8 genera, 90 species)

Family Spirobolidae Bollman, 1893 (6 genera, 22 species)

Family Typhlobolellidae Hoffman, 1969 (5 genera, 6 species)

Suborder Trigoniulidea Brölemann, 1913 (2 families)

Family Pachybolidae Cook, 1897 (33 genera, 150? species)

Family Trigoniulidae Attems, 1909 (21 genera, 45 species)

Order Spirostreptida Brandt, 1833 (2 suborders)

Suborder Cambalidea Cook, 1895 (5 families)

Family Cambalidae Bollman, 1893 (21 genera, 75? species)

Family Cambalopsidae Cook 1895 (10 genera, 80? species)

Family Choctellidae Chamberlin and Hoffman, 1950 (1 genus, 2 species)

Family Iulomorphidae Verhoeff, 1924 (9 genera, 35 species)

Family Pseudonannolenidae Silvestri, 1895 (7 genera, 50? species)

Suborder Spirostreptidea Brandt, 1833 (2 superfamilies)

Superfamily Odontopygoidea Attems, 1909 (2 families)

Family Atopogestidae Hoffman, 1980 (1 genus, 1 species)

Family Odontopygidae Attems. 1909 (40 genera, 335 species)

Superfamily Spirostreptoidea Pocock, 1894 (3 families)

Family Adiaphorostreptidae Hoffman, 1977 (1 genus, 1 species)

Family Harpagophoridae Attems, 1909 (31 genera, 160 species)

Family Spirostreptidae Brandt, 1833 (61 genera, 275 species)

Superorder Nematophora Verhoeff, 1913 (4 orders)

Order Callipodida Pocock, 1894 (3 suborders)

Suborder Callipodidea Pocock, 1894 (1 family)

Family Callipodidae Bollman, 1893 (2 genera, 5 species)

Suborder Schizopetalidea Hoffman, 1973 (5 families)

Family Abacionidae Shelley, 1979 (3 genera, 10 species)

Family Caspiopetalidae Lohmander, 1931 (1 genus, 8 species)

Family Dorypetalidae Verhoeff, 1900 (4 genera, 11 species)

Family Paracortinidae Wang & Zhang, 1993 (2 genera, 11 species)

Family Schizopetalidae Verhoeff, 1909 (20 genera, 85 species)

Suborder Sinocallipodidea Shear, 2000 (1 family)

Family Sinocallipodidae Zhang, 1993 (1 genus, 5 species)

Order Chordeumatida Pocock 1894 (4 suborders)

Suborder Chordeumatidea Pocock, 1894 (1 superfamily)

Superfamily Chordeumatoidea C. L. Koch, 1847 (2 families)

Family Chordeumatidae C. L. Koch, 1847 (5 genera, 21 species)

Family Speophilosomatidae Takakuwa, 1949 (1 genus, 6 species)

Suborder Craspedosomatidea Cook, 1895

Superfamily Anthroleucosomatidea Verhoeff, 1899 (4 families)

Family Anthroleucosomatidae Verhoeff, 1899 (7 genera, 15 species)

Family Haasiidae Hoffman, 1980 (1 genus, 11 species)

Family Origmatogonidae Verhoeff, 1914 (3 genera, 5 species)

Family Vandeumatidae Mauriès, 1970 (3 genera, 8 species)

Superfamily Brannerioidea Cook, 1896 (12 families)

Family Brachychaeteumatidae Verhoeff, 1910 (3 genera, 13 species)

Family Branneriidae Cook, 1896 (1 genus, 2 species)

Family Chaemosomatidae Verhoeff, 1913 (2 genera, 8 species)

Family Golovatchiidae Shear, 1992 (1 genus, 1 species)

Family Heterolatzeliidae Verhoeff, 1899 (2 genera, 3 species)

Family Kashmireumatidae Mauriès, 1982 (2 genera, 6 species)

Family Macrochaeteumatidae Verhoeff, 1914 (2 genera, 2 species)

Family Microlympiidae Shear & Leonard, 2003 (1 genus, 1 species)

Family Niponiosomatidae Verhoeff, 1941 (2 genera, 3 species)

Family Tingupidae Loomis, 1966 (3 genera, 10 species)

- Family Trachygonidae Cook, 1896 (3 genera, 3 species)
- Superfamily Cleidogonoidea Cook, 1896 (6 families)
 - Family Biokoviellidae Masic, 1992 (1 genus, 1 species)
 - Family Cleidogonidae Cook, 1896 (8 genera, 152 species)
 - Family Entomobielziidae Verhoeff, 1899 (1 genus, 2 species)
 - Family Lusitaniosomatidae Schubart, 1953 (1 genus, 1 species)
 - Family Opisthocheiridae Ribaut, 1913 (6 genera, 24 species)
 - Family Trichopetalidae Verhoeff, 1914 (6 genera, 40 species)
- Superfamily Craspedosomatoidea Gray in Jones, 1843 (3 families)
 - Family Attemsidae Verhoeff, 1899 (16 genera, 24 species)
 - Family Craspedosomatidae Gray in Jones, 1843 (37 genera, 181 species)
 - Family Haplobainosomatidae Verhoeff, 1909 (4 genera, 7 species)
- Superfamily Haaseoidea Attems, 1899 (1 family)
 - Family Haaseidae Attems, 1899 (3 genera, 17 species)
- Superfamily Neoatractosomatoidea Verhoeff, 1901 (5 families)
 - Family Altajellidae Mikhaljova & Golovatch, 2001 (2 genera, 2 species)
 - Family Cynosomatidae Mauriès, 2003 (1 genus, 3 species)
 - Family Faginidae Attems, 1926 (1 genus, 1 species)
 - Family Hoffmannesomatidae Golovatch, 1978 (2 genera, 2 species)
 - Family Mastigophorophyllidae Verhoeff, 1899 (9 genera, 35 species)
 - Family Neoatractosomatidae Verhoeff, 1901 (9 genera, 12 species)
- Superfamily Verhoeffioidea Verhoeff, 1899 (1 family)
 - Family Verhoeffiidae Verhoeff, 1899 (1 genus, 4 species)
- Suborder Heterochordeumatidea Shear, 2000 (4 superfamilies)
 - Superfamily Conotylloidea Cook, 1896 (2 families)
 - Family Adritylidae Shear, 1971 (1 genus, 3 species)
 - Family Conotylidae Cook, 1896 (16 genera, 65 species)
 - Superfamily Diplomaragnoidea Attems, 1907 (1 family)
 - Family Diplomaragnidae Attems, 1907 (6 genera, 45 species)
 - Superfamily Heterochordeumatidea Pocock, 1894 (5 families)
 - Family Eudigonidae Verhoeff, 1914 (2 genera, 4 species)
 - Family Heterochordeumatidae Pocock, 1894 (2 genera, 5 species)
 - Family Megalotylidae Golovatch, 1978 (2 genera, 8 species)
 - Family Metopidiotrichidae Attems, 1907 (7 genera, 60 species)

Family Peterjohnsiidae Mauriès, 1987 (1 genus, 2 species)

Superfamily Pygmaeosomatoidea Carl, 1941 (2 families)

Family Lankasomatidae Mauriès 1978 (2 genera, 16 species)

Family Pygmaeosomatidae Carl, 1941 (1 genus, 2 species)

Suborder Striariidea Cook, 1896 (2 superfamilies)

Superfamily Caseyoidea Verhoeff, 1909 (2 families)

Family Caseyidae Verhoeff, 1909 (7 genera, 45 species)

Family Urochordeumatidae Silvestri, 1909 (1 genus, 1 species)

Superfamily Striarioidea Bollman, 1893 (3 families)

Family Apterouridae Loomis, 1966 (1 genus, 2 species)

Family Buotidae Shear, 2009 (1 genus, 1 species)

Family Rhiscosomididae Silvestri, 1909 (1 genus, 8 species)

Family Striariidae Bollman, 1893 (4 genera, 12 species)

Order Stemmiulida Cook, 1895 (1 family)

Family Stemmiulidae Pocock, 1894 (6 genera, 155 species)

Order Siphoniulida Cook, 1895 (1 family), NEW PLACEMENT

Family Siphoniulidae Pocock, 1894 (1 genus, 2 species)

Superorder Merochaeta Cook, 1895 (1 order)

Order Polydesmida Pocock, 1887 (4 suborders)

Suborder Leptodesmidea Brölemann, 1916 (5 superfamilies)

Superfamily Chelodesmoidea Cook, 1895 (1 family)

Family Chelodesmidae Cook, 1895 (230 genera, 450? species)

Superfamily Platyrrhacoidea Pocock, 1895 (2 families)

Family Aphelidesmidae Brölemann, 1916 (17 genera, 119 species)

Family Platyrrhacidae Pocock, 1895 (40 genera, 250? species)

Superfamily Rhachodesmoidea Carl, 1903 (2 families)

Family Rhachodesmidae Carl, 1903 (17 genera, 62 species)

Family Tridontomidae Loomis & Hoffman, 1962 (2 genera, 4 species)

Superfamily Sphaeriodesmoidea Humbert & DeSaussure, 1869 (3 families)

Family Campodesmidae Cook, 1896 (1 genus, 8 species)

Family Holistophallidae Silvestri, 1909 (7 genera, 11 species)

Family Sphaeriodesmidae Humbert & DeSaussure, 1869 (14 genera, 85 species)

Superfamily Xystodesmoidea Cook, 1895 (5 families)

Family Eurymerodesmidae Causey, 1951 (1 genus, 30 species)

Family Euryuridae Pocock, 1909 (2 genera, 15 species)

Family Gomphodesmidae Cook, 1896 (54 genera, 146 species)

Family Oxydesmidae Cook, 1895 (34 genera, 153 species)

Family Xystodesmidae Cook, 1895 (56 genera, 465 species)

Suborder Dalodesmidea Hoffman, 1980 (2 families)

Family Dalodesmidae Cook, 1896 (55 genera, 250? species)

Family Vaalagonopodidae Verhoeff, 1940 (3 genera, 8 species)

Suborder Strongylosomatidea Brölemann, 1916 (1 family)

Family Paradoxosomatidae Daday, 1889 (142 genera, 650? species)

Suborder Polydesmidea Pocock, 1887 (2 infraorders)

Infraorder Oniscodesmoides Simonsen, 1990 (2 superfamilies)

Superfamily Oniscodesmoidea Simonsen, 1990

Family Dorsoporidae Loomis, 1958 (1 genus, 1 species)

Family Oniscodesmidae DeSaussure, 1860 (15 genera, 26 species)

Superfamily Pyrgodesmoidea Silvestri, 1896 (3 families)

Family Ammodesmidae Cook, 1896 (2 genera, 2 species)

Family Cyrtodesmidae Cook, 1896 (3 genera, 30 species)

Family Pyrgodesmidae Silvestri, 1896 (162 genera, 210 species)

Infraorder Polydesmoides Pocock, 1887 (4 superfamilies)

Superfamily Haplodesmoidea Cook, 1895 (1 family)

Family Haplodesmidae Cook, 1895 (6 genera, 30 species)

Superfamily Opisotretoidea Hoffman, 1980 (1 family)

Family Opisotretidae Hoffman, 1980 (6 genera, 8 species)

Superfamily Polydesmoidea Leach, 1815 (2 families)

Family Cryptodesmidae Karsch, 1880 (38 genera, 125 species)

Family Polydesmidae Leach, 1815 (27 genera, 235? species)

Superfamily Trichopolydesmoidea Verhoeff, 1910 (4 families)

Family Fuhrmannodesmidae Brölemann, 1916 (55 genera, 80? species)

Family Macrosternodesmidae Brölemann, 1916, (6 genera, 18 species)

Family Nearctodesmidae Chamberlin & Hoffman, 1958 (8 genera, 30 species)

Currently, the extant species of the class Diplopoda are placed in 16 orders: Penicillata, Glomerida, Glomeridesmida, Sphaerotheriida, Platydesmida,

Polyzoniida, Siphonocryptida, Siphonophorida, Stemmiulida, Chordeumatida, Polydesmida, Callipodida, Spirobolida, Spirostreptida, Julida and Siphoniulida.

Subclass Penicillata Latreille, 1831

Order Polyxenida Verhoeff, 1934

They are micro millipedes which usually grow up to 1.5 - 4 mm. They are commonly called as bristle millipedes owing to their bristly tuft of serrated setae arranged all over their body. Unlike other millipede orders, they have soft body walls as there are no calcium deposits on them. They have global distribution and are often seen in dry places (Hopkin & Read, 1992).

Subclass Chilognatha Latreille, 1802/1803

Infraclass pentazonia Brandt, 1833

Superorder Limacomorpha Pocock, 1894

Order Glomeridesmida Latzel, 1884

These are a group of small millipedes with adult body length of 4 - 8 mm and 15mm in exceptional cases. They are primitive looking anophthalmic millipedes abundantly found in the tropics. They have 22 body rings and are dorsoventrally flattened. Penultimate leg pair is modified into a telopod.

Superorder Oniscomorpha Pocock, 1887

Order Sphaerotheriida Brandt, 1833

They are commonly called the giant pill millipedes. They have this exceptional ability to roll into a sphere (Minelli, 2015). Their body length is up to 10 cm and consists of 13 body rings. They are found predominantly in the southern hemisphere and males of some species in this order have a unique ability to stridulate.

Order Glomerida Leach, 1814

This is also a group of pill millipedes which are exclusive to the Northern hemisphere. Unlike their southern relatives, they are smaller in size (up to 2 cm). Similar to their southern relatives, they have 13 segments and can roll into spheres. They are visually striking with their bright spots on their body.

Infraclass Helminthomorpha Pocock, 1887

Subterclass Colobognatha Brandt, 1834

Order Platydesmida de Saussure, 1860

These are medium sized millipedes with around 6 cm body length and 27 - 110 body rings. They have a unique flattened body structure and are anophthalmic. They have

a simple, leg like gonopods. They show a special behaviour of brooding the clutch of eggs until hatching.

Order Siphonocryptida Pocock, 1894

Small and enigmatic group of millipedes, known for their highly specialized morphology and cryptic behaviour. This order is composed of slender, elongated species with soft, flexible bodies, often adapted for life in leaf litter and other microhabitats. Found predominantly in Southeast Asia, their exact distribution remains poorly documented due to their rarity and secretive nature. They have a body length of 5 - 15mm and a pyriform head capsule (Minelli, 2015). They have two ommatidia on each side of their head. They are the second smallest millipede order in terms of species diversity.

Order Siphonophorida Newport, 1844

They are a tiny and distinct group of millipedes, characterized by their fragile, delicate exoskeletons and long, thin bodies. Compared to other millipedes, this group has fewer body segments and a more vermiform (worm-like) overall appearance, which are highly specialized characteristics. Mostly found in tropical and subtropical areas, especially in the Americas, Africa, and certain parts of Asia, members of this group are cryptic. They grow around 5 - 70 mm. They have modified mouthparts evolved into a beak-like structure for siphon feeding enabling them to adapt to a fungivorous mode of nutrition.

Order Polyzoniida Gervais, 1884

Members with a 10 - 50mm long body which are flat and wide. They have a dome shaped cross section with simple legs like gonopods. They have small and pointed heads. They are mostly found in temperate and tropical regions.

Subterclass Eugnatha Attems, 1898

Superorder Merochaeta Cook, 1895

Order Polydesmida Leach, 1815

They are commonly called the flat backed millipedes. This is the largest order in millipedes in terms of number of species. They have strong lateral projections called paranota or keels and a terminal segment called telson. Most of the species have 20 segments and are blind. They are mostly soil surface dwellers and have their gonopods located on their 7th segment. They have worldwide distribution and are a largely studied group.

Superorder Nematophora Verhoeff, 1913

Order Chordeumatida Pocock, 1894

Chordeumatids are commonly found in the northern hemisphere. They have 18 - 32 segments depending on species and have sub cylindrical body with prominent lateral projections. Even though they are not true flatback millipedes, the broad and extended paranota gives them a flat body appearance. The ultimate body ring of Chordeumatids consists of spinnerets. They are commonly found in cold damp places.

Order Callipodida Pocock, 1894

These are cylindrical millipedes with a large number of segments. They usually grow up to 10 cm in length. They bear silk producing spinnerets on the posterior borders of their telson. Most species have large numbers of ommatidia and some species have carnivorous modes of nutrition.

Order Stemmiulida Pocock, 1894

They are a very active group of millipedes. They are mostly confined to tropics. They grow up to 15 - 40 mm. They have eyes which are strongly reduced with only single or double ommatidia. They have body rings with more height than breadth. The second pair of legs in male is modified to hook like structure and bear setae. They are the only millipede group to be highly agile and active, apparently the only known ones able to jump.

Superorder Juliformia Attems, 1962

Order Julida Brandt, 1833

They are smaller, cylindrical millipedes consisting of head and 24 - 101 body rings and telson. The adult julid can grow about 4 - 165 mm. They are widely distributed in the holarctic region, partially in oriental region and neotropical region. They prefer temperate climates. Several species are studied to be distributed through anthropochory.

Order Spirostreptida Brandt, 1833

They are a group of millipedes consisting of the giants of the class Diplopoda. They can grow up to a length of 10 - 344 mm and 20 mm wide. They have a very smooth body without any setae, and have their 8th and 9th leg pairs modified as gonopods. The posterior gonopod is less active or reduced. In some cases, they are absent. While the anterior gonopod is unique and active. They are found in vibrant colours and are often considered to be pets.

Order Spirobolida Bollman, 1893

Adult body length of 18 - 250mm. The head is noted with a very prominent median suture extending from the forehead between the antennae towards the clypeus. They have large numbers of ommatidium arranged in a sub triangular fashion. Both pairs of the legs on the 7th segment are modified to become gonopods. They are generally and abundantly found in tropics. They are often brightly colored and aesthetically pleasing.

Helminthomorpha *incertae sedis*

Order Siphoniulida Pocock, 1894

They are very small, slender and nematode like millipedes. They grow up to 2 - 7.5 mm in length. They have a very small head with a mouth modified into a beak like rostrum and short legs. Only leg pair 8 is modified into gonopod. This order is poorly known and is mostly based on female specimens.

1.2.3 Morphology

The morphology and body organisation of millipedes is remarkable. It stood the test of time and evolved to better adapt to the changing environment since its origin. The body of millipedes is usually elongate, cylindrical or subcylindrical in shape. There are also millipedes which are wormlike, with short legs and ones which are capable of complete volvation. The body consists of a head and largely homonomous trunk composed of body segments consisting of two pairs of legs per body ring (Minelli, 2015).

The head capsule is heavily calcified to facilitate the burrowing behaviour of millipedes. Head is a compact structure consisting of a pair of antennae, and two appendage derived mouthparts namely mandibles and gnathochilarium. It also bears different sensory organs such as the organ of Tomosvary, trichobothria, and cluster of eyes (ocelli). The organ of Tomosvary is believed to be chemosensory, and are sensitive to pressure, vibration, humidity and magnetic fields as well (Kavaliers & Ossenkopp, 1994). The presence of this sense organ is species dependent.

Antenna is another sense organ located on the anterior top portion of the head. It is made up of 7 antennomeres and sensory cones (in varied numbers) on the retractable tip of the ultimate antennomere. This organ serves as the prime sensory organ in blind millipedes. The eyes of millipedes mostly occur in clusters. They are made up of single ocellus to form the eye cluster. The mouthparts of millipedes are mainly

the mandibles and gnathochilarium. Gnathochilarium is a plate-like lower lip formed by fusion of leg bases namely cardo and stipes. It has numerous sensory sites along its edges. The head is followed by the trunk. The region between the head and first leg bearing body ring forming a neck covered by a tergite called the Collum. In taxonomy the collum is counted as the first ring in the trunk. The collum aids in the bending of the head and volvation in millipedes. It is also used as a shield during burrowing through soil and litter strata. Followed by collum is the diplosegment. The diplorings are the body rings of a millipede with two pairs of walking legs.

The diplorings start from the 4th body ring preceded by body rings bearing single pairs of legs (haplorings). The walking legs are made up of 6 segments (coxa, prefemur, femur, post femur, tibia and tarsus), followed by a claw for better anchorage. On the 7th body ring, there exists a special, modified leg called Gonopods. Gonopods are the secondary sexual character of a male millipede and their function is to collect the sperm from the male gonopore located on the second coxa, and to transfer it to the female gonopore/ vulva. The gonopods are a unique feature of millipedes and are species specific. The structure and details of the gonopods is considered as the delimiting factor in diplopod taxonomy. In pill millipedes, the last leg pair at the rear end is modified to form a pincer shaped organ called a telopod. They serve the same purpose as the gonopods. The rear end of the trunk ends in the segment called telson. Telson is counted as the last segment and it is also called as anal segment (Golovatch, 2003). In groups such as nematophora, the pre anal sclerite bears spinnerets, a fiber producing organ. Before the telson there is an apodus ring, the body ring without any legs. This region is considered to be the site of proliferation, and addition of new body rings during moulting.

The defence mechanism is also a remarkable feature exhibited by millipedes. They engage in physical defence by rolling up into spheres or balls to protect their vulnerable ventral parts. Others who aren't capable of rolling produce chemical substances from the repugnatorial glands (ozadenes) and are flushed out on to the tergites through an opening located on the lateral keels (paranota) or on lateral margins of the body rings.

1.2.4 Zoogeography and Distribution of Millipedes:

Millipedes are found all across the world in almost every kind of terrestrial environment irrespective of temperature and humidity except Antarctica. However,

it is observed that they are especially diverse in tropical and subtropical regions where the humid climate and dense vegetation provide ideal conditions for their survival. Hopkin & Read (1992) emphasize that millipedes display remarkable patterns of endemism - many species are confined to specific areas due to their low dispersal ability and reliance on stable, moist habitats.

Regions like the Amazon rainforest, the forests of Southeast Asia, and parts of Africa are biodiversity hotspots for millipedes, hosting numerous species adapted to different environments. The geographic distribution of ancient lineages, such as those found in Madagascar or the Western Ghats of India, provides insights into historical biogeography, including the effects of continental drift on millipede evolution. The survival of millipedes is influenced by their microhabitats to a great extent. The calcium and debris rich, damp forest floors attract millipedes and help them flourish. Sacred groves are one such ecosystem which mimics the rich and favourable microhabitat of tropical forest floor which are suitable for millipedes and similar soil organisms.

1.2.5 Seasonality of Millipedes:

The distribution and occurrence of millipedes is greatly influenced by microhabitats to a vast extent. Their life cycle and activities are controlled and regulated by the environmental factors, exhibiting distinct patterns of seasonality that are closely linked to fluctuations in temperature, precipitation, humidity, and soil moisture. seasonality of millipedes represents a complex interaction of environmental factors and physiological constraints, shaping both individual life histories and broader community structures. The biology and natural history of millipedes has always been connected with the microclimate of its habitat that even a slight variation in the climatic condition can cause an abrupt decrease in the population of millipedes (Kadamannaya et al., 2009). In the case of the reproductive cycles of the group, they are directly controlled by moist seasons for optimal hatching, food availability and moulting, hence the completion of its life cycle (Minelli, 2015). The Community-level seasonal changes are also reflected in shifts in species composition, abundance, and activity density. Certain species exhibit narrow ecological preferences and are active only during specific times of the year, while others show broader tolerance and are present throughout multiple seasons (Golovatch & Kime, 2009). On a broader aspect, in tropical and sub-tropical regions, millipedes are mostly found

abundantly during the rainy season, when elevated humidity levels and the abundance of decaying organic matter provide favourable conditions for feeding, reproduction, and dispersal (Sankaran & Sridhar, 2002). During dry or summer periods, many species exhibit behavioural adaptations such as burrowing or retreating into microhabitats like decaying logs and leaf litter to avoid desiccation (David & Handa, 2010).

1.3 Sacred groves:

The people of ancient times kept a close connection with nature and its forces. They had deep rooted belief in protection of forests and worshiped the trees. Since time immemorial, different civilisations across the globe have practiced a similar tradition of assigning forest as the abode for gods. Apart from India and the Indian subcontinent, there are many other references of forest worship from different parts of the world such as in the societies of America, Australia, Africa, Asia and Europe (Gadgil & Vartak, 1975; Ramakrishnan, 1996; Hughes, 1997 & Warriar et al., 2023).

Such forest patches, of near natural vegetation preserves which are worshiped and dedicated to a deity are called to be as the sacred groves (Pushpangadan et al., 1998). These forests are considered divine and are protected by the respective clans or communities. Sacred groves are integral to nature worship and are classified as 'Sacred Natural Sites' according to the definition provided by IUCN (Verschuren et al., 2010). Sacred groves are found everywhere in the world except Antarctica (Bhagwat & Rutte, 2006). Some of them are ancient and reverent. Starting from West Asia, there are sacred groves planted and worshiped since the Babylonian civilization. Evidence from Paleo - anthropological studies indicates that the Neanderthals engaged in the cult of ancestor burials and are considered one of the origins of sacred sites. Ancestor worship and veneration of burial grounds was a common trait of every culture of modern human. As well as the adoration of significant natural landmarks such as towering mountains and great rivers. The Indian concept of 'Pancha Maha Bhoota' the worship of five great elements such as earth, water, fire, air, and sky, aligns with this tradition.

The sacred natural sites or sacred groves serve as an example for habitat preservation through community participation. Sacred groves are the repositories of rare and endemic species and can be regarded as the remnant of the primary forest

left untouched and protected by the local inhabitants (Nganso et al., 2012; Sambandan & Dhatchanamoorthy, 2012).

The sacred groves can be considered as a place where humanity meets nature. They were the socio - religious centers of many ancient communities. The sacred groves have nurtured the growth of diverse art forms and cultural traditions. In the sacred grove of Australia, has rock arts and neolithic henges associated with it. There are many dance forms and art forms that originated in the premises of these sacred groves. These are performed to satisfy the deity and bring prosperity to the people.

The taboos and beliefs associated with such sacred natural sites culminate in the protection of these forest patches and preservation of the gene pool present there creating a haven for the flora and fauna to flourish undisturbed. Not only it would help in building a forest in the upstream area but also aids in the preservation of soil moisture eventually improving the productivity of downstream agriculture (Chandrakanth et al., 1990)

1.3.1 Sacred groves of India

The practice of associating trees or forests with the divine has been mentioned in many early literatures from India such as the Sangam literature dating back to 300 BC. There are also mentions about sacred forests and “upavanas”, the small groves or divine orchards, in the epic literature of Mahabharata. In the Sanskrit play *Vikramōrvaśīyam* there are prominent references of sacred forests. In the play dating back to 5th century BC, Kalidasa wrote, "Then ignoring the pleadings of the king, she wandered into the sacred grove of Kumara. Her mind bewildered by the curse of her Guru, she failed to notice this transgression into an area forbidden to women. No sooner did she enter than she was transformed into a vine clinging to a tree at the boundary of the grove".

Sacred groves in India are predominantly located across states of Andhra Pradesh, Chhattisgarh, Haryana, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Manipur, Meghalaya, Odisha, Rajasthan, Tamil Nadu, Uttarakhand, West Bengal, and the Union Territory of Puducherry (Warrier et al., 2023). India's National Environmental Policy says that the ancient sacred groves of India should be recognised for their ‘incomparable values’ (Warrier et al., 2023) These sites are located in biodiversity rich ecoregions and cover a wide range of habitats such as evergreen forest, estuaries, and mangroves (Shonil & Rutte, 2006). The estimated

count of sacred groves of India falls between one hundred thousand and one hundred fifty thousand in number (Malhotra, 2007). According to Malhotra et al., (2007), the estimation of the count of sacred groves is far from complete. The most recent data shows there are 22,968 sacred groves across the country (Malhotra et al., 2007). The sacred natural sites or sacred groves are found in diverse ecological contexts. There are groves ranging within the location on the top of Khasi - Garo hills in the North Eastern Himalayas to estuaries in Alleppey, Kerala. The other prominent sacred groves are situated on the Aravali hill ranges of Rajasthan and Sarguja, the Western Ghats, Chhatisgarh and Bastar region of Central India. Sacred groves are known by different names in different parts of the country. In Assam - *Than or Madaico*, in Chhattisgarh - *Matagudi, Devgudi or Sarana*, in Himachal Pradesh - *Dev Van*, in Jharkhand - *Jaherthan or Sarana*, in Karnataka - *Devarakaadu or Kans*, in Kerala - *Kavu, Kottam, Mundy or Vallikettu*, in Maharashtra - *Devrai or Devgudi*, in Manipur - *Umang Lai*, in Meghalaya - *Law Kyntang or Law Niam*, in Odisha - *Jahera or Thakuramma*, in Rajasthan - *Orans*, in Tamil Nadu - *Kovilkaadu*, in Uttarakhand - *Bugyal or Dev Van* and in West Bengal they are colloquially called as *Garamthan or Jahiristhan*. Sacred groves are established to serve a multitude of purposes. They are mainly considered as a mystical abode for a deity or comprises an object or water body that encompasses the deity. These forests are preserved for sociocultural and religious purposes. These kinds of groves are called as fetish groves (Dorm-Adzobu et al., 1991). In most of the sacred groves pre-vedic deities are worshiped and non-brahmanical practices and rituals are conducted (Appffel & Parajuli, 2000). The deities are often female and are linked to the cult of mother goddesses (Gadgil & Vartak, 1976). The other deities worshiped in these groves are snake deities and a few male deities. Apart from that there are groves which were burial grounds or a location for an important event that took place in the village and are thought to be the realm of the guardian spirits. The sacred groves in India are owned by a family, community, clan or a trust. Religious rituals and festivals such as harvesting festivals are carried out in the grove and promote the people to believe in the taboos associated with them.

1.3.2 Groves in Kerala with special emphasis to North Kerala

Kerala is a small state in India which is located on the west coast region of the Indian peninsula. It is known for its tourism, rich culture and heritage. The people of

Kerala are grounded to their beliefs and continue to preserve their traditions. The sacred groves present in Kerala serve as one of the best examples for that. The sacred groves in Kerala are distributed widely from the eastern highlands of the Western Ghats to the coastal plains in the West. They are generically called *Kavu*. A *Kavu*, like any other sacred grove is a relatively untouched patch of vegetation which is dedicated to a deity or preserved as an abode to a deity. The common deities worshiped in Kerala are female mother goddesses and male deities like lord Ayyappa, lord Shiva and snake deities. The worship of mother goddess had existed in India since time immemorial. The sacred groves associated with mother goddess deities are called *Amman Kavu*, *Bhagavathy Kavu*, *Vanadevatha Kavu*, and *Cheerumba Kavu*. *Sarpakavu* and *Naagar Kavu* are the colloquial names given for sacred groves dedicated to snake deities. In Kerala, snake worship has long been a major part of religious life; testimony of this goes back as far as the eighth century. Many Keralites believe that the prosperity of the family depends on the blessing of snake gods because they are associated with fertility and life-giving powers (Notermans et al., 2016). The *Sarpakavu* and *Bhagavathy Kavu* are mostly situated amongst the human settlements. While the *Ayyappan Kavu* or *Sasthan Kavu*, which is dedicated to lord Ayyapa is usually found in the mountain ranges amidst thick forests. In Kerala, the sacred groves are distributed in the districts of Kollam, Pathanamthitta, and Alappuzha in the south and Kannur, Kasargod, and Kozhikode in the north. Here, around 79 percent of the groves are small with less than 0.02 ha. But it is not a criterion to be neglected as a grove since many of them are rich in biodiversity (Basha, 1998). The groves can exist in a variety of ecosystems such as mangroves, freshwater myristica swamps, or tropical forest namely evergreen, semi evergreen, and moist deciduous. Kerala has the greatest number of sacred groves in India followed by the states of Karnataka with 1214 numbers and Andhra Pradesh with 800 numbers of groves (Rajendraprasad, 1995; Rao, 1996). In Kerala, North Kerala is studied to have a greater number of groves compared to central and southern Kerala (Pushpangadan & Rajasekharan, 2010). A sacred grove in Kerala is generally associated with temples. They can either be located in the premises of the temple or can be far away from the temple. The groves located farther from the temple are accessed only during the annual festival happening there. Rituals vary with the region, cast, and patron deity of the grove. The main rituals happening in the sacred groves of North Kerala are *Theyyam* or *Theyyattam*. *Theyyam* is a ritual

danceform of sacred groves of Kolethunaadu, the present Kasargod and Kannur districts. The Theyyam is based on mythical stories of local heroes and heroines who were later worshiped as the deities of the sacred grove. Another form of ritual conducted in ‘*Sarpa kavu*’ is *Sarpathullal* and *Sarpa Kalam*. This is done in the honour of snake deities of the grove. These groves are strictly protected from unauthorised and untimely entrance of the people by folk stories and cultural restrictions. Traditionally people are cautious when entering these sacred groves. They are afraid to anger the deities when damaging the vegetation as it is strongly believed that the deities will punish by bringing illness, deaths, or misfortune (Notermans et al., 2016)

1.3.3 Sacred groves and Biodiversity

These groves are important today because they are the sanctum sanctorum of rare and endangered plant species, many of which may have disappeared from the region outside the grove. Besides being indicators of forests that might have flourished in the region, these groves are a laboratory for botanists, a bank of plant diversity and germplasm for geneticists and a community's medicine chest (Mitra & Pal, 1994). Therefore, it's high time to study such an important and encroachment prone ecosystem before it vanishes from sight.

1.4 Objectives:

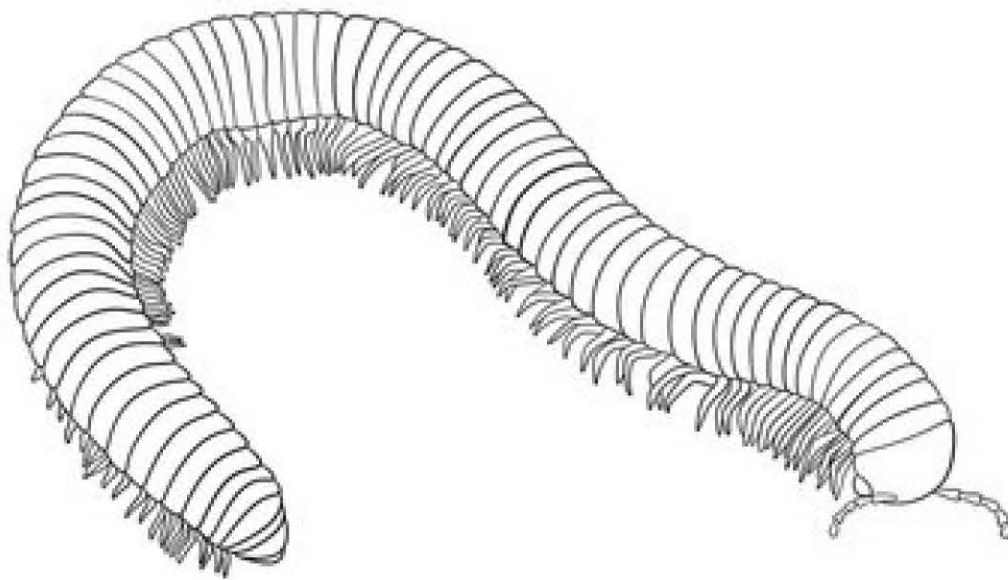
1. Conduct survey for millipede fauna in the sacred groves of North Kerala and identify, and describe of new taxa encountered if any and redescription of poorly described taxa from the collection.
2. Develop a workable dichotomous key as an aid to the identification of species and other higher taxa of millipede fauna of sacred groves of North Kerala.
3. To generate the distribution map for the species under study and prepare a checklist of the order Diplopoda.
4. Study the seasonal occurrence of millipede fauna across the sacred groves of North Kerala.

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CHAPTER 2

REVIEW OF LITERATURE

"If I have seen further, it is by standing on the shoulders of giants"
Sir Isaac Newton

REVIEW OF LITERATURE

A comprehensive literature review is an inevitable part of any scientific research. It serves a multitude of purposes that contributes to the relevance and robustness of the study. It provides a comprehensive overview of existing knowledge, identifies gaps in the current body of work, and establishes the context for the researcher's contribution to the field (Boote & Beile, 2005; Hart, 1998). As far as the field such as taxonomy is concerned, the historical, morphological and geographical aspects play pivotal roles in conducting research. This demands a well-structured review of literature for the smooth, reliable and replicable execution of the study. A thorough literature review in taxonomy helps to consolidate fragmented information into a coherent framework and highlights the unexplored species, regions, or methodological advancements that can enhance the understanding of the subject (Randolph, 2009), thus providing the knowledge about the gaps that the research seeks to address. It is an essential step in advancing knowledge and contributing meaningful insights to the chosen field.

2.1 Taxonomic Studies of Millipedes (Diplopoda): A Global Overview

Millipedes, (Class: Diplopoda) are a very ancient group of terrestrial organisms with their legacy dating back to the early Silurian period (Hopkin & Read, 1992). The Millipede taxonomy has evolved gradually but significantly over the centuries. These detritivorous organisms, belonging to the class Diplopoda, have presented unique challenges and opportunities for taxonomic exploration because of their cryptic natural history and unprepossessing appearance. The millipede taxonomy has been shaped by contributions from early naturalists, morphologists, and more recently, molecular biologists.

Carl Linnaeus (1758), who is considered the pioneer of all taxonomic studies, grouped the millipedes under the genus *Julus* in his *Systema Naturae*. This is considered as the first recorded mention of millipedes in the scientific literature. Linnaeus' work was foundational thus providing only limited details reflecting the incipient development of arthropod taxonomy at that time. A significant progress was made by Pierre André Latreille (1802), when he proposed the term "Diplopoda"

to formally differentiate millipedes from other myriapods like centipedes (Chilopoda). It was during this time that millipedes began to be acknowledged as a separate group of ecological importance.

The 19th century experienced a surge in species descriptions and nomenclature. This happened largely because of worldwide colonial exploration. Species ranging from Southeast Asia to South America were described, named and published by significant contributors such as Johann Friedrich Brandt (1833) and Henry Walter Bates (1863). It was during this time, Carl Attems emerged as a prominent figure in diplopod taxonomy describing more than 1,000 species and revolutionised the classification systems based on external morphology and gonopod structures (Attems, 1926). His research underscored the intricate nature of millipede diversity and stressed the necessity for more thorough and methodical taxonomic approaches. Many genera (most of which are now considered to belong to different orders) were first introduced only some decades later, such as *Polyxenus*, *Glomeris* and *Polydesmus* by Pierre André Latreille (1762-1833) in 1802/1803, *Craspedosoma* by William Elford Leach (1790-1836) in 1814, *Narceus* and *Pleuroloma* by Constantine Samuel Rafinesque-Schmaltz (1783-1840) in 1820, *Fontaria* by John Edward Gray (1800-1875) in 1832, *Spirostreptus* and *Strongylosoma* by Johann Friedrich von Brandt (1802-1879) in 1833. A global checklist of the Myriapoda, was also created by Gervais (1847), during the mid-1800s. Authors like François Louis Paul Gervais (1816-1879) in 1873, and Carl (1932, 1940) significantly enhanced the understanding of myriapods, especially millipedes. Ludwig Koch (1778-1857) and Henri Louis Frédéric de Saussure (1829-1905), along with George Newport (1803-1854), who provided anatomical and biological observations, in addition to describing new species and refining the group's taxonomic arrangement. It was during this time Verhoeff (1937) developed a regional taxonomic monograph. On the other hand, Chamberlin (1921) described numerous species from North America and Asia, emphasizing regional endemism and Eason (1964) contributed to the taxonomy of African millipedes and was one of the first to discuss their ecological roles in detail. These major works provided elaborate and meticulous morphological keys and laid the groundwork for understanding the millipedes even today.

The diplopod taxonomy was moreover refined when it reached the 20th century. There was a remarkable shift from using just the descriptive morphology in doing

the taxonomy. A more integrative approach that incorporated biogeographic, ecological, and comparative morphological analyses were included in the taxonomic studies. Taxonomists during this period made significant contributions from the species rich but overlooked tropical areas of Africa, South America and Asia, which were still poorly studied and documented. The prominent taxonomists who carried out such research were Chamberlin (1921) and Cook (1895). The works of Cook and Chamberlin amplified the scope and possibilities of millipede taxonomy by cataloging species from such understudied regions across the globe. Chamberlin (1921) described a few hundreds of species new to science from Asia and the Americas. Numerous genera that he described and reported still remain valid today (Chamberlin, 1921). Along with performing taxonomy and description, Cook (1895) addressed the evolutionary history, biology and natural history of millipedes, helping in expanding the knowledge on millipedes and their significance in tropical ecosystems. The comparative morphological studies were also widely developed and accepted during this time when the gonopod (a modified leg pair functioning as male secondary sexual organ) morphology was counted as the delimiting character in taxonomic studies. The intricate morphology of gonopods provides crucial diagnostic characters for distinguishing between closely related species and higher taxa (Hopkin & Read, 1992). This method helped to address the inconsistencies in the earlier taxonomic methods (Eason, 1964). This systematic framework laid the groundwork for subsequent taxonomic studies in both temperate and tropical regions. Schubart (1944) has contributed notably to the taxonomy of tropical Asian and American millipedes. Schubart's studies were among the first to combine morphological descriptions with ecological observations, noting the importance of habitat specificity in millipede distribution and evolution. His work also projected the relation between the role of geographical isolation in speciation of millipedes. Later Golovatch (1983, 1989) studied the millipedes of Central and Southeast Asia as well as Caucasus. During the same time William Shear conducted similar work in studying the millipedes of North American, Asian, and Australasian regions. His work on the higher classification of millipedes provided a more robust phylogenetic framework, particularly for the orders Polydesmida and Spirobolida (Shear, 1972; 2000). The classification of orders like Polydesmida, Spirostreptida, and Julida benefited significantly from these developments. Taxonomic revisions by Hoffman (1980) and Mauriès (1987) used gonopod morphology and geographic data to

propose phylogenetic relationships within these groups, laying the foundation for modern millipede taxonomy.

The modern millipede taxonomy, in the 21st century has a more integrative approach. The fine amalgamation of classical taxonomic techniques and the cutting-edge tools of molecular taxonomy have leveraged the field. Recent decades have witnessed an explosion of alpha taxonomic studies across Asia, particularly in biodiversity-rich regions like Southeast Asia, the Indian subcontinent, and China (Srisonchai et al. (2018a, 2018b); Nguyen & Sierwald (2013); Zhang (1995); Liu et al. (2020); Golovatch et al. (2009, 2011); Jeekel (2001) and Wesener & Enghoff (2009)). These studies have highlighted the rich diversity of species and high endemism in these areas. A comprehensive and recent classification of the class Diplopoda, which is considered valid to date, was proposed by Shear (2011). According to this, there are approximately 147 families and 1868 genera.

DNA barcoding, phylogenetics, and phylogenomics have emerged as pivotal tools for addressing challenges associated with cryptic species, convergent morphological traits, and unresolved phylogenetic relationships. These techniques have always remained as the supporting tools for the classical taxonomic studies. Some major works done by these integrative methods are by Akkari et al. (2018), Enghoff et al. (2013), Wesener et al. (2016), Brewer et al. (2012), Giska et al. (2017), and Enghoff et al. (2015). These studies helped to understand the significant genetic divergence among populations previously considered a single species, evolutionary complexity of millipedes, the role of geographic isolation, climatic gradients, and historical events.

2.2 Diplopoda Taxonomy in India:

India, with its diverse habitat is expected to host a diverse fauna of millipedes and the study on the millipedes of India is as old as a century and more. Despite significant progress, many regions of this biodiversity rich country remain underexplored, and numerous species await discovery and description. The taxonomic work done on millipede taxonomy is scarce and with many gaps. There have been decades of gap between the studies conducted posing significant gaps in the discoveries. Therefore, there are hundreds of more species remaining to be discovered and described from India.

Studies on Indian millipedes (Diplopoda) started with Linnaeus (1758), who proposed two species from India, among the 12 diplopods he described: *Julus indus* Linnaeus, 1758 and *Julus fuscus* Linnaeus, 1758. So, the first millipedes unquestionably coming from present-day India were two species that Fabricius (1775) described from Tranquebar, near Madras: *Julus stigma* Fabricius, 1775 and *Julus carnifex* Fabricius, 1775. A third species, *Julus depressus* Fabricius, 1793, from “eastern India”, may also be from the India of today (Fabricius, 1793).

The colonial period (late 19th - early 20th century) can be considered as the golden period for millipede taxonomy in India. The foundational work in millipede taxonomy was done by Reginald Innes Pocock (1892, 1893, 1899a, 1899b) and described numerous species from the Indian subcontinent. Additionally, his exploration of species distribution laid the groundwork for biogeographic studies in tropical Asia (Pocock, 1909). His work was continued by Attems (1936, 1937) and described numerous species and proposed the first comprehensive monograph for not only the current Indian, but also for Sri Lanka, Indo-China and Myanmar millipede species. Another contemporary of his, Silvestri, also described several species from the Indian and Malayan region after the Yale - North India expedition (1923, 1924, 1936). This was followed by notable contributions by Turk, by describing a handful of species from the caves of the Himalayan belt and also incorporated the zoogeographical significance of their existence in that region (1945a, 1945b, 1972). Indian taxonomists such as Rajulu (1970) proposed a checklist for Indian millipedes followed by Tikader cataloguing the millipedes and centipedes of the Andaman and Nicobar Islands (1985).

Afterwards in the 21st century Khanna (2008) from Zoological Survey of India, listed the millipedes of India but it is also fragmentary. The most reliable checklist on Indian millipedes was proposed by Golovatch & Wesener (2016) while the most recent checklist was proposed by Chezhian (2022). This comprehensive checklist of the millipedes of India, lists over 270 species or subspecies across various genera, families, and orders. This checklist serves as a valuable resource for researchers and aids in biodiversity assessments. The following year, Sankaran & Sebastian (2017, 2020) described a new species, redescribed and synonymised a few millipedes from Kerala, Southern India. In 2022, Anilkumar et al. made a remarkable contribution to the species list of India by adding a few new species and a genus to it also from

Kerala. Despite the advancement in the diplopod taxonomy, India remains a rather understudied region and a huge percentage of the extant Indian millipede fauna have to be unveiled. As the country faces significant environmental challenges, such as habitat degradation and climate change, understanding the diversity of millipedes is vital for assessing ecosystem health and function. A meticulous, extensive effort to taxonomically study the Indian millipede fauna is essential for advancing the field of biodiversity research. It will not only contribute to global millipede systematics but also offer significant ecological insights, support conservation strategies, and enhance our understanding of India's rich natural heritage.

2.3 Seasonality studies of Millipedes (Diplopoda):

The periodic occurrence of biological events in response to changing environmental conditions; otherwise called the seasonality of an organism is a prime aspect of animal ecology. For soil-dwelling arthropods such as millipedes, seasonal variations affect their abundance, activity, reproductive cycles, and ecological functions (Blower & Gabbutt, 1964). The initial studies on millipede seasonality can be traced back to the descriptive literature by Verhoeff (1937) where the effect of seasons on abundance and activity period of millipedes was recorded in the temperate regions. Other significant studies conducted by field-based, in-situ studies in the temperate forests of Europe, substantiated that the millipede abundance, feeding, reproduction and surface activity are strongly influenced by climatic parameters such as soil moisture and ambient temperature. (Haacker, 1968; David, 1987; Hopkin and Read 1992 and Dangerfield et al., 1992). Another behaviour of seasonal dormancy, particularly in response to high summer temperatures, has also been documented. This is called as summer quiescence. Bailey & Kovaliski (1993) reported this behaviour in the species *Ommatoiulus moreleti* that it enters a state of summer quiescence, as a mechanism to conserve moisture and energy during unfavorable hot and dry conditions. This was later substantiated by Dangerfield (1998) by the similar activity pattern in the species of Kalahari Desert, where the millipede resort to burrowing and aestivation to cope with extended dry seasons.

Coming to tropical and subtropical regions extensive studies were conducted by Nguyen Duy-Jacquemin and colleagues (1990s) reported the seasonal activities of millipedes were strongly influenced by the monsoon (rainfall) patterns, where

millipede emergence and mating occurred at the onset of the rainy season. This was substantiated by Banarjee (1967), where he studied the seasonal activity of *Cylindroiulus punctatus*. More such studies, both in-situ and ex-situ studies were conducted in the Western ghats region by the means of pill millipedes to assess their seasonal abundance, periodicity, assemblage, biomass production and distribution to once again substantiate and conclude the peak activity time of millipedes in the tropical region is the time after the monsoon and they are largely dependent on the rainfall patterns and humidity for the completion of their life cycles (Ashwini & Sridhar, 2006; Kadamannaya et al., 2009; Sridhar & Kadamannaya, 2009; Kadamannaya et al., 2010; Ambarish & Sridhar, 2013; Sridhar et al., 2013; Ambarish & Sridhar, 2015, Rannavre et al., 2024 and Patne et al., 2024).

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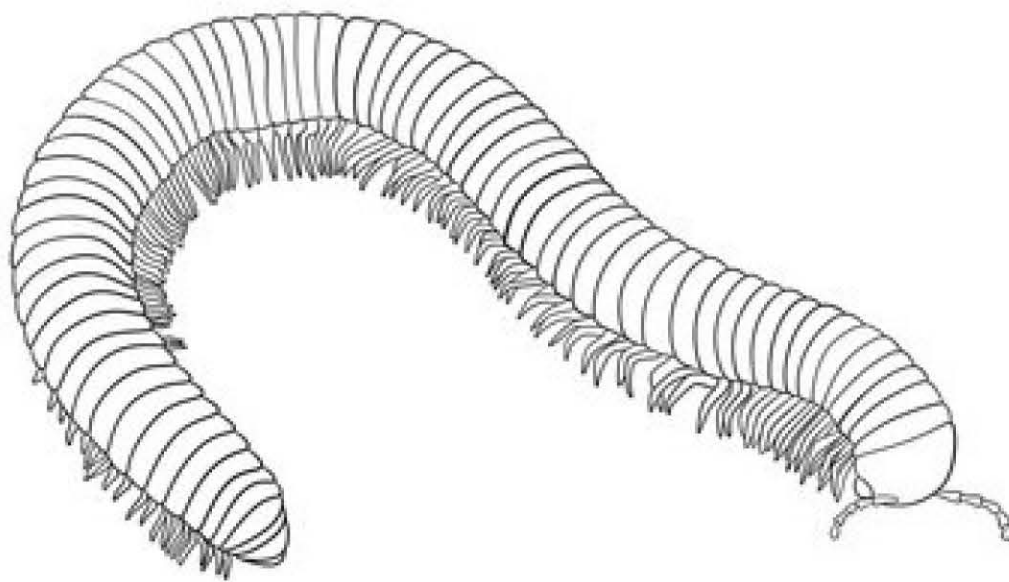
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CHAPTER 3
METHODOLOGY

METHODOLOGY

A robust methodology ensures the relevance, reproducibility and reliability of a research (Godfray, 2002). A well designed and executed methodology promises impactful contributions to the field of research. It leads to the discovery of species or resolves the existing taxonomic ambiguities. A well-designed methodology is therefore considered the backbone of any scientific research. Accurate species identification depends on systematic sampling, preservation, and examination of specimens, which reduces errors and obscurity (Dayrat, 2005).

3.1 Study Area - The Sacred Groves of North Kerala

The study area is located in Kerala (8°17' 30" -12° 47' 40" N and 074°27'47" -077° 37' 12" E), the southwestern coastal state of the Indian peninsula (Fig 1. A). The state is bounded by the Western Ghats in the east, the Arabian Sea in the west, and the Indian Ocean in the south. North Kerala shares its border with Karnataka state extending to an area of about 38,852 km². Kerala demonstrates considerable altitudinal variation, with elevations spanning from 5 meters above sea level in the west to 2,695 meters at its highest point, Anamudi, in the east.

The state is divided into Southern Kerala (Alappuzha, Kollam, Kottayam, Pathanamthitta and Thiruvananthapuram), Central Kerala (Ernakulam, Idukki, Palakkad and Thrissur) and Northern Kerala (Kannur, Kasaragod, Kozhikode, Malappuram and Wayanad). The current study is conducted in the northern region of Kerala localised to the sacred groves located there. A total of 18 sacred groves were selected for the study. The groves are distributed across the districts of Kasaragod, Kannur, Wayanad and Kozhikode (Fig 1. B). These sacred groves are associated with temples and have semi-evergreen, evergreen or deciduous vegetation. They are protected by a temple and sacred grove protecting committee or by a family or by a group of families.

A basic evergreen forest and the sacred grove have a similar floristic composition and physiognomy of plants. The undisturbed or least disturbed groves have lush flora with many tree levels interspersed with lianas, shrubs, and plants (Sumesh, 2021).

The flora of each grove is different but certain plant groups are commonly found in most of the groves such as *Artocarpus hirsutus*, *Vateria indica*, *Hopea* sp., *Artocarpus heterophyllus* (plavu), *Alstonia scholaris* (ezhilampala), *Tabernaemontana alternifolia* (koonampala), *Corypha umbraculifera* (Kodappana), *Caryota urens* (choondapana), *Calycopteris floribunda* (pullani), *Canthium angustifolium*, and flowering plants like *Chassalia curviflora* (vellakurinji), *Barleria prionitis* (manjakanakambaram), and *Sarcostigma kleinii* (odappazham) comprise the top canopy. Among the most common climbers are *Plumbago zeylanica* (vellakoduveli), *Piper nigrum* (kurumulaku), *Cyclea pellata* (padathali), and *Pothos scandens* (paruvakodi). This area is also home to medicinal plants such as *Holoptelea integrifolia*, *Zizyphus oenoplia*, and *Canthium parviflorum* (Sumesh, 2021). Certain threatened flora namely, *Ampelocissus indica*, and *Tabernaem*

ontana alternifolia and members belonging to Eriocaulaceae family, *Drosera* sp., *Polycarpaea* sp., and *Utricularia* sp. are also found here. The soil goodness and critical climatic condition substantiates this rich and diverse flora, which also distinct these groves from their surrounding ecosystems or habitats.

3.1.1 Sacred Groves of Kasaragod district:

A total of 8 sacred groves were selected for the study. The groves namely, Edeyilakkad Kavu (KZE01), Kammadam Kavu (KZE02), Payyankulam Kavu (KZE03), Mannapurath Kavu (KZE04), Puthhiya parambath Kavu (KZE05), Koyithatta Kavu (KZE06), and Malliyodan Kavu (KZE07) (Fig 2 A-G).

3.1.1.1 Edeyilakkad Kavu (KZE01)

Edeyilakkad Kavu is located on the marshy island of Edeyilakkad, Valiyaparambath Panchayath in Kasaragod district (Fig 1 B). It is located amidst the Kavvayi backwaters (12° 08 '10.72" N, 75° 09' 23.88" E). The sacred grove is the abode to the snake deity (*naagam*) and goddess (*Bhagavathy*). The sacred grove encloses an area of 6.40 ha and has an evergreen type vegetation (Fig 2 E). The sacred grove is the home to a plethora of plants and animals. A wide variety of invertebrates and large mammals such as Bonnet macaque (*Macaca radiata*), Indian crested porcupine (*Hystrix indica*) was observed. Birds like Indian pond heron (*Ardeola grayii*), cattle egret (*Bubulcus ibis*), Blue tailed bee eater (*Merops philippinus*), Kukoo bird (*Cuculus micropterus*), and red vented bulbul (*Pynconotus cafer*) were also observed.

This patch is a less disturbed sacred grove where a large number of people visit only during the temple festival which occurs only once in a year.

3.1.1.2 Kammadam Kavu (KZE02)

Kammadam kavu (12° 18 '41.0"N, 75° 18' 55.8" E) is located amidst the hilly regions of Kasaragod district (Fig 1 B). This grove is located in the Chittaarikkal village, in the West Elery region of Kasaragod. This grove is associated with Chittarikkal Kammadam Bhagavathy temple and is situated around 500m. away from the temple. The grove serves as the main ground for the yearly temple festival, 'Kaliyattam' to take place and is where important rituals associated with the temple are performed. Kammadam Kavu has thick evergreen vegetation with patches of primitive freshwater myristica swamp (Fig 2 F). The thick vegetation and the variety of fauna makes this sacred grove distinct amongst the sacred groves of Kasaragod. Many mammal groups such as Indian wild pig (*Sus scrofa*), Bonnet macaque (*Macaca radiata*), Indian crested porcupine (*Hystrix indica*), three-striped palm squirrel (*Funambulus palmarum*) and reptiles such as common krait (*Bungarus caeruleus*), Brahmini blind snake (*Indotyphlops braminus*), Russell's Viper (*Daboia russelii*), and long-nosed vine snake (*Ahaetulla oxyrhyncha*) were observed during field collection. The sacred grove also housed a long list of birds like, crow pheasant (*Centropus sinensis*), spotted owlet (*Athene brama*), golden oriole (*Oriolus kundoo*) were observed.

3.1.1.3 Koyithatta Sree Dharma Sastha Kavu (KZE06)

The sacred grove is located 17 km from Nileshwaram in Kasaragod district (12° 17 ' 11.4"N, 75° 14' 53.88" E) ((Fig 1 B)). The grove is associated with Koyithatta Sree Dharma Sastha temple and is located right behind the temple building. Since the temple is active with its daily rituals, the sacred grove located in its premises is mostly intruded by humans. This is not an undisturbed one as the nearby people access this patch for firewood and has a road through the grove leading to a tunnel well (*Suranga*) located very close to this grove. This is a small patch of forest (3.00 ha) with evergreen vegetation and with huge woody trees in it (Fig 2 C). No big mammals were observed during sampling but a colony of bats were observed.

3.1.1.4 Puthiya Parambath Kavu (KZE05)

The Puthiya Parambath kavu is the abode to the serpent gods (*naaga devtas*) and is a vast patch of grove (2.83 ha). This sacred grove is located around 3 km from Nileschwaram in Kasaragod district (12° 15 ' 34.56"N, 75° 07' 41.16" E) ((Fig 1 B)). This serpent grove is associated with the Bhagavathi (goddess) temple within the premises. The temple and the sacred grove associated with it is known for the yearly Theyyam festival. The grove is slightly disturbed and has a semi evergreen type of vegetation (Fig 2 A). No big mammals were observed during sampling.

3.1.1.5 Mannampurathu Kavu (KZE04)

This sacred grove is also located in close proximity to Puthiya Parambath Kavu, around 1.5 km from Nileschwaram (12° 15 ' 27.6"N, 75° 07' 59.4" E) ((Fig 1 B)). This grove is associated with Mannampurath devi temple and is located in the premises of the temple building. The grove is dedicated to the goddess and serpent gods and has a semi evergreen type of vegetation (Fig 2B). The grove is located adjacent to the railway track and the nearby railway station which makes this sacred grove highly accessible to humans and largely disturbed and patchy.

3.1.1.6 Payyankulam Kavu (KZE03)

This sacred grove is a moderately large one located (12° 17 ' 41.7"N, 75° 12' 18.96" E) around 7 kms from Nileschwaram in Kasaragod district ((Fig 1 B)). The sacred grove is located in Kinaur, Karinthalam with an area of 5 ha. It is dedicated to *Poomala bhagavathy* (goddess) and is rather an undisturbed and pristine patch of forest. The vegetation it holds is an evergreen type, with a narrow stream bordered by myristica trees flowing through it (Fig 2D). The grove is located on slopes of a laterite barren hill and is a home for several medicinal herbs. Large mammals such as Indian crested porcupine (*Hystrix indica*), three-striped palm squirrel (*Funambulus palmarum*) and Indian jackal (*Canis aureus indicus*) were observed during field visits. Birds such as Indian myna (*Acridotheres tristis*), Asian koel (*Eudynamys scolopaceus*), jungle babbler (*Argya striata*), and white-cheeked barbet or small green barbet (*Psilopogon viridis*) were observed. This grove is also the home to the members of poisonous reptiles such as Indian cobra (*Naja naja*), common krait

(*Bungarus caeruleus*), and some non-venomous members like checkered keelback (*Fowlea piscator*) and Oriental Rat snake (*Ptyas mucosa*).

3.1.1.7 Sree Malliyodan Kavu (KZE07)

This grove is located in Konnakad (12° 22 ' 1.24"N, 75° 19' 22.8" E), hilly and forested area of Kasaragod district (Fig 1 B). It covers an area of around 3 ha and has a semi evergreen type of vegetation. This grove is dedicated to a regional deity *Malliyodan deiva* and is considered to be his abode. The sacred grove is highly fragmented and there are roads constructed across the sacred grove (Fig 1 2G). No large mammals were observed during field visits. A stream running through the grove has some groups of fishes in it. Some non-venomous reptile members like checkered keelback (*Fowlea piscator*) and Oriental Rat snake (*Ptyas mucosa*) were observed.

3.1.2 Sacred Groves of Kannur district:

A total of 05 sacred groves were visited during field study and sampling. They are namely, Thekkumbad koolom Thazhe Kavu (KNN01), Madayi Kavu (KNN02), Neeliyarkottam (KNN03), Chaama Kavu (KNN04), and Poongottu Kavu (KNN05).

3.1.2.1 Thekkumbad Koolom Thazhe Kavu (KNN01):

Thazhe Kavu is located in Thekkumbad of Mattul region in Kannur district. It is located on an inland island located (11° 57 ' 59.3"N, 75° 17' 50.9" E) amidst the Valapattanam river and has thick vegetation dominated by mangrove forests ((Fig 1 B)). This sacred grove is associated with Tekkumbad devi temple and is located 500 m away from the temple (Fig 3 A). The temple and sacred groves host the yearly *Theyyam* festival or *Kaliyaattam*. The land between the sacred grove and the temple premises is separated with a stretch of paddy field which is actively used for farming. This area is a site of resting place for many migratory birds such as Asian openbill stork (*Anastomus oscitans*), painted stork (*Mycteria leucocephala*), and black-headed ibis (*Threskiornis melanocephalus*). The sacred groves also housed a large population of mangrove crabs inhabiting the peripheral boundaries of the grove. This patch of forest has a huge number of rattan plants (*Calamus rotang*) in the grove which is also a special feature of this sacred grove.

3.1.2.2 Madayi Kavu (KNN02)

Madayi Kavu is located (12°2'4.99"N, 75°15'41.14"E) on top of a barren laterite hill of Madayi Para, near Pazhayangadi in Kannur district (Fig 1 B). This is a 6.06 ha vast sacred grove with a moist deciduous type of vegetation (Fig 3 C). Madayi Kavu is one of the most studied sacred groves in Kerala (Lijin, 2022; Vijisha & Raja, 2015; Krishnan, 2014) not only in biological aspects but also in sociological, philosophical and anthropological aspects. The sacred grove is dedicated to Kali (the goddess of warfare) and is located in the premises of the temple. The grove has a myriad variety of birds and butterflies, both rare and common. The grove is almost fragmented with pocket roads through it. The birds observed during the survey were orange minivet (*Pericrocotus flammeus*), crow pheasant (*Centropus sinensis*), and common pigeon (*Columba livia*). No large mammals were observed during the survey. Large reptiles such as monitor lizards (*Varanus bengalensis*) and common garden lizards (*Calotes versicolor*) were observed.

3.1.2.3 Neeliyar Kottam (KNN03)

Located near Dharmasala (11° 56 '03.8" N, 75° 21' 50.0" E), in Kannur district, Neeliyarkottam is a sacred grove dedicated to goddesses (*Bhagavathi/ Neeliyamma*) (Fig 1 B). The vegetation in this grove is evergreen and it encompasses an area of about 8.7 ha. The sacred grove shares its boundary with human settlements and is a heavily disturbed ecosystem (Fig 3 C). The grove is fragmented and modified largely in the periphery but the interiors are preserved in all its serenity. The sacred grove supports many species of birds, butterflies and moths. Some butterflies observed during the survey are Common rose (*Pachilocta aristochiae*), Common blue bottle (*Graphium sarpedon*), Common mime (*Papilio clytia*), Three spot green yellow (*Eurema blanda*), and Malabar tree nymph (*Idea malabarica*). No large mammals or reptiles were observed during the survey.

3.1.2.4 Chamakkavu (KNN04)

Chaamakkavu is located in Vellur (12° 09 '07.03" N, 75° 12' 35.5" E), near Payyanur in Kannur district (Fig 1 B). The grove is located in close proximity to the temple associated with it, which is dedicated to the goddess. The sacred grove has thick vegetation of evergreen type and has an area of about 3.64 ha (Fig 3 D). This

sacred grove is also partially fragmented with mild human activity. The ritual of annual *Theyyam* festival is conducted in the temple and sacred grove premises. No big mammals were observed during the survey.

3.1.2.5 Poongottukavu (KNN05)

Poongottukavu is the largest sacred grove in Kannur district. It is located near Mattanur region (11° 55 '14.7" N, 75° 36' 58.9" E) in Kannur district (Fig 1 B). The sacred grove shares its boundary with the forest in the Iritty forest range, Kannur. The grove is dedicated to *Sasthav* and has myristica swamp vegetation (Fig 3 E). There is no temple or rituals associated with it. But a small shrine of deity is preserved amidst the thick forest. Mammals such as wild boar (*Sus scrofa*) and monkeys (*Macaca radiata*) were observed during the survey.

3.1.3 Sacred Groves of Wayanad district:

Three sacred groves were studied in Wayanad district namely Maanikavu (WYN01), Valliyurkavu (WYN02), and Anoth Kavuvu (WYN03).

3.1.3.1 Maanikavu (WYN01)

Maanikavu is located in Choothupaara (12°2'4.99"N, 75°15'41.14"E), Wayanad (Fig 1 B). The sacred grove and the temple associated with it is spread in an area of 32 acres. This was once densely covered with a variety of trees rare and endemic to the region, of which almost 30 acres were lost because of heavy deforestation. The temple which is associated with the sacred grove is dedicated to lord *Shiva* while the sacred grove is dedicated to and encompasses the shrines of the snake deities (*Naagadevatha*). The vegetation in this grove is evergreen and has many small wild animals residing in it (Fig 5 A). A fairly large population of monkeys (*Macaca radiata*) were observed during the survey.

3.1.3.2 Valliyurkavu (WYN02)

The sacred grove associated with Valliyurkavu temple is located near Mananthavady (11° 48 '16.1"N, 76° 01' 48.1"E) in Wayanad district on the banks of Kabani River (Fig 1 B). The sacred grove is located in close proximity to the temple and is a small patch of evergreen vegetation of around 2 ha. The temple and the grove are dedicated to goddess (*Durga*) and is known for the annual *Theyyam* festival. The grove is

fragmented with pocket roads and forest roads running through it. During the survey period of early mornings and early evenings, no big mammals or reptiles were observed in the grove. Some common birds like Mynah (*Acridotheres tristis*), Crow (*Corvus splendens*), and Barbet (*Psilopogon viridis*) were observed.

3.1.3.3 Anoth Kavu (WYN03)

Anoth Kavu is located amidst the tea plantations in Pozhuthana village (11°31'57" N, 75° 56' 38" E) in Vythiri, Wayanad (Fig 1 B). The sacred grove has thick evergreen vegetation and is spread across an area of about 2 ha (Fig 5 C). The grove is dedicated to the goddess and the temple is located far away from the sacred grove. The grove is an untouched patch of forest where the entry of people is permitted only during the annual temple festival time. No mammals or reptiles were observed during the survey.

3.1.4 Sacred groves of Kozhikode district:

A total of 03 sacred groves were visited for surveys in Kozhikode district. They are namely Muchukunnu Kotta Kavu (CLT01), Poyikavu (CLT02) and Vallikattukavu (CLT03).

3.1.4.1 Muchukunnu Kotta Kavu (CLT01)

This sacred grove is located in Moodadi (11°29'20"N, 75°40'10"E), in Kozhikode district (Fig 1 B).. The sacred grove has thick evergreen vegetation surrounding a large picturesque temple pond (Fig 4 A). The sacred grove covers an area of 4 ha and is dedicated to lord *Shiva* and the snake deities (*Naagadevathas*). This grove is located on a laterite hill and in close proximity to the temple. The scenic beauty of the temple pond and the evergreen groves attracts many tourists and photography enthusiasts from near and far. The grove is largely fragmented and is highly disturbed by humans due to lack of entry restrictions. The grazing by domestic animals and the plastic littering by the visitors are some of the major threats to this mystical abode. No large mammals were observed during the survey. The rich foliage in the grove attracts many birds such as Indian cuckoo (*Cuculus micropterus*), Grey heron (*Ardea cinerea*), Spotted owlet (*Athene brama*), Eurasian hoopoe (*Upupa epops*), and Common kingfisher (*Alcedo atthis*), and butterflies like southern birdwing (*Troides minos*) were observed during the survey.

3.1.4.2 Poyilkavu (CLT02)

This dense patch of forest is located in a lowland coastal stretch (11.4096° N, 75.7162° E) near Kappad beach in Kozhikode district (Fig 1 B). The grove covers an area of 4.62 ha and has lowland evergreen vegetation (Fig 4 C). This sacred grove is dedicated to goddess (*Bhagavathy*) and the grove is highly protected by the temple governing body and by the local inhabitants in the premises. The sacred grove holds a well like water body aimed to promote water conservation namely “*Thrikuzhi*”. The decrease in rainfall and rising temperature have notably diminished the water level in the reserve. The temple hosts yearly festivals in the temple and sacred grove premises only when the public are given access to the groves. No animals were observed during the survey.

3.1.4.3 Vallikkattu Kavu (CLT03)

The sacred groves of Vallikattukavu are located on the eastern valley of Eliyode Mala (11°23'17"N, 75°47'10"E), in Edakkara, Kozhikode district (Fig 1 B). The sacred grove covers an area of 10.4 ha and is dedicated to goddess *Durga*. A stream running through the forest beside the shrine is a speciality of this grove (Fig 4 B). The thick vegetation of this grove has evergreen and fresh water myristica swamps in it. Daily rituals and annual festivals are carried out in the temple associated with the grove. A good population of monkeys were observed during the field survey.

3.2 Climate

The surveys were conducted for two years from January 2021 - January 2023. The 12 months of the year were divided into 3 categories based on the monsoon patterns in the state; Pre-monsoon (February-May), Monsoon (June-September) and Post-monsoon (October-January). In this duration of two years, there was a notable change in the climate of Kerala characterized by changes in temperature, rainfall patterns and humidity. There was an increase in the temperature where average maximum temperature rose from 31.6°C in 2021 to 32.9°C in 2023, while the average minimum temperature increased from 23.6°C to 24.3°C. This pattern shows the gradual warming up of the atmosphere. Humidity levels remained consistently high throughout the period, with atmospheric humidity often exceeding 80% during Monsoon months due to the state’s coastal location and dense vegetation. Kerala has a tropical climate. The Southwest Monsoon (June to September) and the Northeast

Monsoon (October to December) are the two main Monsoon systems that provide rainfall to the state. Due to geography, closeness to the Western Ghats, and changes in Monsoon dynamics, Kerala has a geographically and temporally variable rainfall distribution.

In 2021, Kerala experienced Monsoon rainfall that was near-normal and closely aligned with historical averages. The Southwest Monsoon arrived on schedule, bringing consistent precipitation across the state. Data from the India Meteorological Department (IMD) indicated that Kerala received an annual rainfall of approximately 2,600 mm, marginally exceeding the long-term average of 2,500 mm. The Northeast Monsoon further contributed to the state's total rainfall, with steady precipitation occurring during October and November. The onset of the Monsoon was delayed, and its distribution was irregular in 2022, resulting in rainfall deficits in several districts. A slightly below average rainfall, especially during the Southwest Monsoon season was observed all across Kerala. The Northeast Monsoon, which usually offsets shortfalls in the latter part of the year, also underperformed. The total annual rainfall for the year was approximately 2,400 mm, falling below the long-term average. These variations highlighted the increasing unpredictability of Monsoonal patterns in the region. The climatic changes underscore the growing unpredictability of weather patterns in Kerala, which could affect agriculture, water resources, and the stability of ecosystems.

3.3 Field Surveys and Specimen Collection

The specimen collection was done across the year 2021 January till 2023 January. The study period was divided into Pre-monsoon (February-May), Monsoon (June-September) and Post-monsoon (October-January). Samples were collected in the morning from 06.00 am to 09.00 am and evening from 03.00 pm to 06.00 pm. This time was regulated and chosen as per the activity time of millipedes and the accessibility to the collection sites. The early mornings and late evenings are considered as the high activity time for millipedes as they are crepuscular organisms (Sierwald & Bond, 2007). Taking seasons into account, special focus was given to the post monsoon collections as the abundance was observed to be particularly high during that period.

3.4 Collection method

An effective and focused methodology is essential for ensuring a reliable and replicable sampling. For a ground dwelling group like millipedes, it is vital to consider several methods to collect specimens. The worldwide accepted techniques to collect millipedes include, pitfall traps, hand picking method, and leaf litter collection method using Berelese - Tullgren funnel extraction (Snyder et al., 2006). In this study, the hand picking and Winkler extraction was extensively used because of the heavy rainfall during collection seasons and due to cultural restrictions prevailing in the sacred groves of North Kerala.

As this project mainly focuses on studying the alpha taxonomy of millipedes, the opportunistic method of sampling was implemented for specimen acquisition. It is the most effective way to collect a wide diversity of specimens in a short span of time and encouraged to search for millipedes in their preferred microhabitats such as the decaying wooden logs and leaf litter, tree bases, root systems, under rocks and moist shaded areas (Sierwald & Bond, 2007).

3.5 Sampling Kit:(Fig 6 A- O)

The sampling kit consists of the following items:

- Tray - for collecting litter samples.
- Gloves.
- Vials of different capacities (5 ml, 20 ml, 50ml, 100 ml, and 250 ml vials for collecting specimens of different sizes).
- A thermo - humidity meter to collect meteorological data.
- A rechargeable head torch - 300 lumen - HL500 USB V3.
- A magnifying lens.
- Ziplock bags.
- 70 percent ethyl alcohol for fixing the injured specimen in the field.
- Narrow and wide tip featherweight forceps and camel hair painting brush.
- Hand shovel.
- Rake.
- Digital Camera.
- Field notebook.

- Graphite pencils and permanent marker pens.
- Mobile phone with inbuilt GPS.
- A cooler or Ice Box with ice packs for transporting live specimens.
- Berlese - Tullgren extractor.

3.5 Sampling Techniques used:

3.5.1 Hand Picking method:

Hand picking method or the manual searching method was carried out for the collection of larger specimens. In this method the collector uses the wooden rake (Fig 7 A) to sift the top litter strata to expose the millipedes hiding among the leaves. They are collected using hands, forceps or brushes. Wearing gloves is given utmost importance while handling the specimens during this method because the live organism tends to secrete its defensive chemicals when disturbed (Means et al., 2015). The millipedes are found from moist logs, decaying plant debris, under rocks and under the root system of trees other than the upper litter strata. This method is also effective for collecting macrospecies as they can be located. If these macrospecies are found in any wood or rock crevices they are collected using an insect aspirator and transferred to collection vials.

3.5.2 Leaf Litter sampling:

This method is utilised to collect some macro species which were overlooked during manual searching and the macrospecies in the top litter strata (Fig 7 B). This method targets millipedes that inhabit the microhabitats within and beneath the leaf litter layer, where they find food, shelter, and optimal moisture conditions. It is especially effective for uncovering species richness in areas where millipedes are abundant but cryptic. A plot of 1m x 1m is selected in the study site and the top litter layer is collected focusing on the upper layer of decaying leaves and any underlying humus. Tools like rakes, trowels, or gloved hands are used to carefully remove the litter without harming the underlying soil structure (Sierwald & Bond, 2007). This is transferred to a sifter, which separates the millipedes and other soil arthropods from the litter. The millipedes collected from the bottom of the sifter.

3.5.3 Berlese - Tullgren extraction:

The litter remaining in the sifter is then transferred to a Berlese - Tullgren extractor where mild heat and light from an incandescent lamp are applied to drive the

organisms down through the litter and into a collecting container with alcohol or soapy solution (Golovatch & Kime, 2009) (Fig 7 C).

3.6 Sorting and preservation

After the collection, the live and healthy specimens were stored in respective vials as per their size with a piece of moss or leaf litter from the collection site to reduce desiccation. The moisture level inside the vial was controlled as there should not be any water logging inside, but the walls of the container have enough condensation droplets on it. The lid of the container was punctured with small holes prior to the transfer of specimens for aeration. The containers were labeled and sealed in a ziplock bag. These bags were stored in an icebox cooled with ice packs. This method reduces the stress throughout the transportation and also increases the rate of survival during the commute. On the other hand, the injured specimens were killed immediately after collection using 70 percent ethanol. They were also labelled and stored in specific ziplock bags according to their place, date and time of collection.

3.7 Imaging: Methodology and Instrumentation

Once the specimens were brought to the laboratory, the live specimens were subjected to photography using a Sony camera with 90mm lens and Raynox DCR-250. The hyperactive specimens such as polydesmids were sedated using a cotton plug dipped in ethyl acetate to restrict their movement and then photographed. After this the specimens were killed using 70 percent ethyl alcohol. The unknown or unidentified specimens (paratype) were taken for dissection where the gonopods and other morphological characters are studied, measured and photographed using Leica DMC4500 digital camera mounted on a Leica M205 C stereo microscope. Photographs were stacked, and the measurements (in mm) taken, using Leica Application Suite (LAS) version 4.3.0 software and a Keyence VH6000 digital microscope (Fig 8 B). Line drawings of the gonopods and antennae were created using Autodesk SketchBook, version 6.0.6. The final images were processed with Adobe Photoshop CS3 and GNU Image Manipulation Program (GIMP 2.8.22) software. Microspecimens were examined with the images obtained using a Scanning Electron microscope. The specimens subjected for the imaging were prepared by following the standard protocols (Marek et al., 2021).

3.8 Genitalia preparation for imaging:

The gonopods (telopods in the case of Sphaerotheriida) were dissected out of the body ring and transferred to a vial containing 10 % KOH solution overnight. These were then washed in distilled water (for removing the fat bodies) and kept in 80% ethyl alcohol. The sclerotized gonopods were removed from alcohol and dried under an incandescent lamp before imaging it under microscope.

3.9 Identification

The gonopods are the delimiting character in diplopod taxonomy. The specimens were identified using standard keys and original descriptions. For the identification of Indian millipedes, the following steps are carried out:

3.9.1 Literature Review:

A thorough literature review was carried out from many online and offline sources. This aided in understanding the biology of diplopods to a deeper level and supplemented in gaining more knowledge regarding the alpha taxonomy of Indian diplopods which are considered to be enigmatic ones across the world.

3.9.2 Diagnosis and description:

The diagnosis and description were initiated using the external morphological features such as size, shape, number of rings, position and number of ozopores and gonopodal characteristics. This was carried out by referring to the pioneer works done by Attems (1936), Carl (1932), Jeekel (2001), Golovatch & Wesener (2016).

Original descriptions and comparisons with type specimens kept in different museums were utilized to identify species as there were no updated or standardized species keys for millipedes of the Indian subcontinent. The frameworks offered by Sierwald & Bond (2007), and Enghoff et al. (1993) are followed in the morphological nomenclature and terminologies for gonopods and other relevant morphological features. While previously known species are redescribed thoroughly, emphasizing their diagnostic characteristics, the recently discovered species have been described in full length.

3.9.3 Review of museum collection:

The type specimens from various museums were studied for species conformation such as Natural History Museum, London (NHML); National Museum of Natural History (NMNH), Paris, France; Muséum d'Histoire Naturelle (MHN), Geneva, Switzerland; and Museum of Natural History Vienna (MHNV), Austria. This was very crucial in understanding the German manuscripts and original descriptions of the species.

3.10 Registering, Labelling and Storage:

Temporary labels were assigned to the specimens after collection and sorting. Once identification was completed the specimen were given permanent label specifying the essential information, including the country name (in uppercase), the state name, the locality where the specimens were collected, the collector's name, and the date of collection, with months represented in Roman numerals (e.g., 18.iv.2020). The specimens were also given unique identification codes which were printed separately. All collected specimens were systematically registered in a Microsoft Excel datasheet, incorporating all relevant metadata.

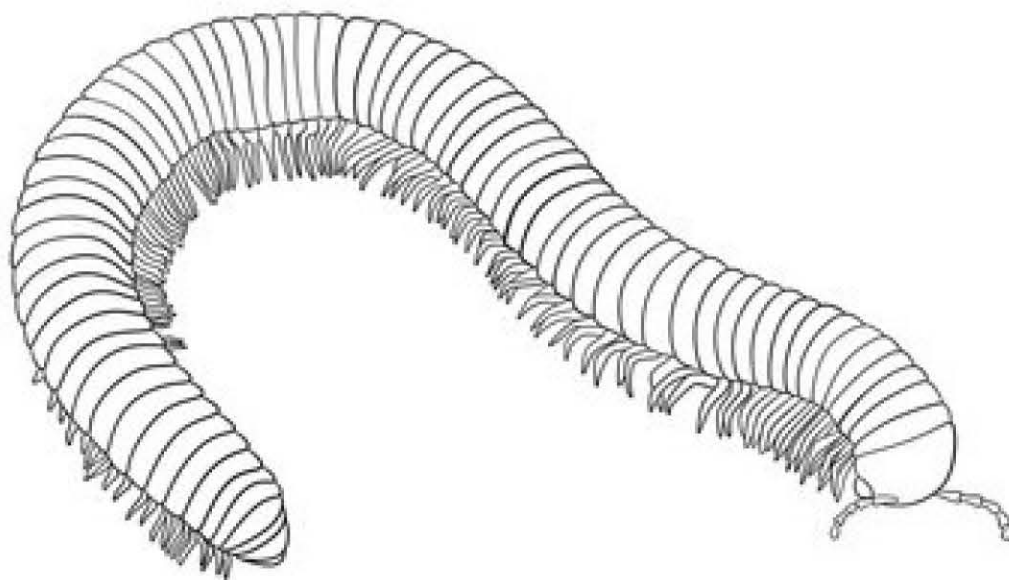
These samples were later stored in the diplopod collections Centre for Animal Taxonomy and Ecology (CATE), Department of Zoology, Christ College, Irinjalakuda. The alcohol in the storage vials is refilled periodically (Fig 8 A, C, & D).

3.11 Mapping the distribution

The distribution map of the species was created using the software QGIS 3.28.1., Google Earth pro (version 7.3.4.8248) and Simple Mappr online service (<http://www.simplemappr.net>).

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CHAPTER 4

RESULT

RESULT

According to the latest checklist on millipedes, there are 275 millipede species from 12 different orders reported from India (Chezhian, 2022).

The survey of the sacred groves of North Kerala brought 26 species of millipedes to light. The study reported 9 species new to science and 7 out of 12 orders reported from India.

4.1 Systematic Position of Class Diplopoda:

Millipedes (Diplopoda) are a megadiverse group of soil arthropods. They are classified together with the centipedes (Chilopoda), the pauropods and the symphylans in the group Myriapoda. They have two subclasses (extant), Chilognatha and Eugnatha and an extinct subclass namely, Arethropleuridea. The systematic position of class Diplopoda is given as follows;

Domain: Eukaryota, Chatton (1925) Whittaker & Margulis (1978)

Kingdom: Animalia, Linnaeus (1758)

Phylum: Arthropoda, Gravenhorst (1843)

Sub Phylum: Myriapoda, Latreille (1802)

Class: Diplopoda, Blainville *in* Gervais, 1844

4.1.1 Dichotomous key to the orders of millipedes collected from the sacred groves of North Kerala:

1 (2) Calcareous and hard body wall with short setae sparsely arranged on the body ring (3)

2 (1) Soft body wall, body rings with tufts of short feathery setae arranged on lateral sides of the body and lateral metazonal margins, and long tuft of setae on the posterior terminus **Polyxenida**

- 3 (4) Hard body wall with ability to undergo complete volvation**Sphaerotheriida**
- 4 (3) Hard body wall without the ability to undergo complete volvation but can coil into spiral or semi rings (5)
- 5 (6) Body with 20 segments or more in mature males and females, with single ommatidia or cluster of eyes..... (7)
- 6 (5) Body with up to 20 segments in mature males and females, without eyes (fig)**Polydesmida**
- 7 (8) Triangular head with single or two pairs of eye spots, beak/ snout/ siphon like mouth parts specialized for fluid feeding and fungivory and body with over 30 body rings..... (11)
- 8 (7) Capsular head with eye cluster arranged in pairs of triangular or oval sets, mouthparts with sets of teeth specialised for scraping and feeding, generally specialised for saprophagy and body with over 32 body rings (10)
- 9 (10) Head with prominent suture line not extending to clypeus**Spirostreptida**
- 10 (9) Head with prominent suture line extending across the clypeus, reaching towards the labrum.....**Spirobolida**
- 11 (12) Two dark eye spots present, animals much wider than thick, dorsal side convex, the ventral side flat, head acuminate; adult males with paired penes on or behind the coxae of 2nd leg pair..... **Polyzoniida**
- 12 (11) Cross section of animal forms a half circle, the ventral side of the animal is flat; animal densely covered with fine setae; distal segments of antennae enlarged and thickened.....**Siphonophorida**

4.2 Order Polyxenida Verhoeff, 1934

4.2.1 Subclass PENICILLATA Latreille, 1831

The subclass Penicillata Latreille, 1831, one of two subclasses within Class Diplopoda, includes a single order, Polyxenida Verhoeff, 1934, which comprises fewer than 200 species. This group is significant in discussions of Myriapod and Arthropod evolutionary relationships, as it is often regarded as basal to the subclass Chilognatha Latreille, 1802-1803. Key plesiomorphic traits of Penicillata include an uncalcified cuticle, trichobothria, serrate trichomes, and the absence of defense glands (Enghoff, 1984; Miyazawa et al., 2014). The currently recognized taxonomy divides the order into three families and four subfamilies (Condé & Nguyen Duy-Jacquemin, 2008). Taxonomic distinctions are based on characteristics such as the number of segments in adults, telson structure, caudal trichome arrangement, the presence of ommatidia, and antenna structure.

4.2.1.1 Order Polyxenida Verhoeff, 1934

Body length 1.5–4 mm (rarely up to 6 mm); cuticle soft, uncalcified. Head covered with anterior and posterior rows of trichomes; posterior margin with 3+3 trichobothria. Flexible labrum. Ommatidia (11 or fewer) present in most, absent in *Lophoproctidae* and some *Polyxenidae*. Organ of Tömösváry: small circular pit near antennal base. Antennae with 8 segments; apical sensory cones (4 on segment 8), coeloconic and basiconic sensilla on segments 6-7. Mandible with basal joint and gnathal lobe (3-part structure). Gnathochilarium with central and outer palps covered in sensilla. Trunk: 9–11 segments (excluding telson), 11–17 leg pairs. Tergites, pleurites, sternites undivided; tracheae open near coxae. Tergites with trichome patterns; telson trichomes hooked or barbate, shed defensively and replaced during moulting. Females use caudal trichomes to create protective nests for eggs. Legs: variable podomeres; first leg has 6, second has 7, others have 8. Tarsus 2 with claws and processes. Males: coxal pores (0–6 pairs) secrete threads for spermatophores; sexual openings behind second coxae; penes pointed, shorter than vulvae. Indirect sperm transfer; anamorphic development, juveniles hatch with 3 leg pairs. Some species reproduce parthenogenetically. Distributed worldwide (except Antarctica), ~148 species. In India, 8 nominal species from 2 families are reported yet.

4.2.1.1.1 Superfamily Polyxenoidea Lucas, 1840

Trichomes linked to telson form two dense bundles of elongated trichomes, with a few distinctive medial trichomes positioned dorsally to the caudal bundles, known as ornamental trichomes. Hooked trichomes may feature barbs along the stem and 1–7 hooks facing proximally at the distal end.

4.2.1.2 Key to families of order Polyxenida Verhoeff, 1934 collected from sacred groves of North Kerala.

- 1 (2) Pigmented body with multiple ommatidia and a distinct eye hill..... **Polyxenidae**
- 2 (1) Unpigmented body, anophthalmic and no coxal pores..... **Lophoproctidae**

4.2.1.2.1 Family Polyxenidae Lucas, 1840

Individuals measure 1.2–4.2 mm in body length, excluding the caudal bundle. The body consists of 10 tergites plus a telson and has 13 pairs of legs (Minelli, 2015). Most species possess eyes and pigmentation, while males typically have 2–6 pairs of coxal pores located on leg pairs 6–11. The gnathochilarium features well-developed outer palps, and external leg buds are present. The group comprises 22 recognized genera and approximately 96 species, showcasing notable diversity in morphology and adaptations. India has a diversity of 7 species in 6 genera reported yet (Golovatch & Wesener, 2016; Chezian, 2023; Subramanian & Senraj, 2024).

Diagnosis. Individuals with body pigmentation and ophthalmic head region.

4.2.1.2.1.1 Subfamily Monographinae Conde, 2008

In general scenario, individuals possess eight ommatidia on each side. The telson features caudal trichome bundles that are closely aligned, giving the appearance of a single bundle (hence the prefix "mono") (Minelli, 2015). Ornamental trichomes are arranged in a linear pattern anterior to the caudal bundle. These shorter ornamental trichomes are symmetrically distributed around the midline, with each side containing 3–15 short trichomes arranged in one or two rows, a compact group of

3–8 long barbate trichomes (commonly three, forming a triangular arrangement), and a single long, thin trichome internal to each bundle. The caudal bundle generally consists of both long barbate trichomes and hooked trichomes, the latter having barbs along the stem and 1–7 hooks facing proximally near the distal end. In some species, only adult females possess hooked trichomes. Males exhibit coxal pores on leg pairs 8 and 9. The gnathochilarium's median palps contain 20–23 cylindrical sensilla, and outer palps are also present. Antennomere 6 usually has three basiconic sensilla, while antennomere 7 has two, with sensilla arranged transversely. A conical sensillum is located posteriorly, and a setiform sensillum is positioned more anteriorly. The group encompasses 9 genera and 4 genera are reported from India.

Diagnosis. Distinguishable from the congeners as the telson features caudal trichome bundles that are closely aligned, giving the appearance of a single bundle.

4.2.1.2.1.1 Genus *Silvestrus* Jones, 1937

Small species with 3 - 3.5 mm in length. The trunk comprises 11 tergites and 13 pairs of legs. The Organ of Tömösváry is located within the antennal groove. The final antennal segment is the smallest and contains four sensory cones (Jones, 1937). The palps are equipped with simple gustatory bristles. Eyes are present. Each side features three acoustic setae, while the tergites and pleura bear long, slender, curved setae that are not uniformly serrated. On the tergites, the setae are arranged exclusively in two lateral clusters. Along the sides, there are nine long pleural bundles of setae. The last segment is as long as the penultimate one and is not concealed by the preceding tergite. The postanal bundle consists of dense setae, including both simple setae and those with one to five or more barbed hooks. The penis is short. The most distinctive characteristic of this genus is the absence of transverse rows of setae along the posterior edge of the tergites. Instead, only two clusters of setae are present on the dorsal surface, one on each side of the tergite.

Diagnosis. Diagnosed from congeners with the presence of a large spine on Tarsi 2 and presence of setae only in two lateral clusters on the tergite. Shows remarkable similarities with *Polyxenus* in terms of the arrangement of appendage and the mouthparts

4.2.1.2.1.1.1.1 Description of species of genus *Silvestrus* Jones, 1937, collected from sacred groves of North Kerala.

Taxonomy

Family Polyxenidae Lucas, 1840

Subfamily Monographinae Conde, 2008

Genus *Silvestrus* Jones, 1937

Type-species: *Silvestrus seminudus* Jones, 1937, by original designation.

***Silvestrus seminudus* Jones, 1937**

Silvestrus seminudus Jones, 1937: 143 (D).

Silvestrius (sic!) *seminudus*—Silvestri, 1948: 216 (M); Condé & Jacquemin, 1962: 268 (M); 1963: 68 (M).

Silvestrus seminudus—Nguyen Duy-Jacquemin & Condé, 1967: 45 (M); Condé & Nguyen Duy-Jacquemin, 1987:

103 (M); Nguyen Duy-Jacquemin & Geoffroy, 2003: 101 (M).

Material examined. Male (CATE-10251A - C), and 5 female paratypes (CATE-10251D - H) India, Kerala state, Kasaragode district, Sree Malliyodan Kavu, Konnakad, (12° 22 ' 1.24"N 75° 19' 22.8" E), 115 m a.s.l., M.D. Aswathy leg.

Diagnosis. Resembles *Polyxenus lagurus*, by having eyes with eight ocelli, and the palps. It shows similarity with *Unixenus padmanabhii* by two rows of setae flanking the sulcus on the head, and the first segment having reduced pleura, featuring 4–5 setae forming a rudimentary pleural bundle.

Description. Males around 2.8 - 3.3 mm and female around 2 - 3.5 mm in length and 0.7 mm wide mid body metaterga in males and females. Body with 10 +1 body rings and nut-brown color and light grey setae after preservation in absolute alcohol.

Head with a median sulcus, and the antennae with 8 antennomeres, with the smallest last segment bearing four small cones. The Organ of Tömösváry is present as a small pit in the antennal groove. Eyes consist of eight ocelli, and the palps possess simple gustatory bristles (Fig 9 C). There are three lateral setae on each side, with two groups of setae at the vertex, one on each side of the sulcus. Double rows of setae flank the sulcus on the head. The trunk consists of 11 tergites and 13 pairs of legs, with a median sulcus on all tergites (Fig 9 A & B). The first tergite is smaller,

while the last tergite features long setae positioned above the postanal bundle. Most setae are long, thin, curved, and serrated on the convex side, though the head setae are comparatively shorter. The postanal bundle is single and contains simple setae and setae with 1–5 barbed hooks. The simple setae are long, serrated, and have stout tips, while the barbed setae are finer, shorter, and those at the periphery have more hooks. The legs include a 6-jointed first pair and 7-jointed subsequent pairs, excluding the articulum, which has two claws and a central adhesive pad. The tarsus has a prominent spine in the middle, and the coxae bear 2–5 papillae, with the trochanter and femur each having papillae at their distal joints. In males, the coxae of the 8th and 9th leg pairs have grooves with small knobs. The last segment is as long as the penultimate and bears the postanal median bundle of setae, which can measure up to 0.7 mm in large specimens (Fig 9 D) . The sides have nine conical pleural projections, each with thick bundles of setae. The first segment has reduced pleura, featuring 4–5 setae forming a rudimentary pleural bundle. On the tergites, clusters of long, curved setae are positioned near the hind end on each side of the sulcus, pointing centrifugally.

Distribution. India, Kerala, Kovalam, Trivandrum, and Anjengo, Travancore State and Kozhikode district (Fig 9 E).

4.2.1.2.2 Family Lophoproctidae Silvestri, 1897

Body length 1.2–4.2 mm (excluding caudal bundle). Homogeneous family inhabiting upper soil layers and caves. Nine or ten tergites plus telson, with 11 (in one species) or 13 leg pairs (Minelli, 2015). Leg buds internal; anophthalmic, unpigmented; without coxal pores. Anterior trichobothrium slightly dilated, ending in a short spine hair. Gnathochilarium with palps lacking lateral extensions; palps dimorphic—males have 30–86 sensilla, females retain juvenile count of 17–25. Antennomeres 6 and 8 elongated, with article 6 longest and article 8 domed, as long or longer than article 7. Telotarsus lacks lamella but often has spines and denticles on claws. Leg setae pubescent and pear-shaped basally. Telson features closely aligned caudal trichome bundles resembling a single bundle, with linear ornamental trichomes on either side of the midline. Ornamental trichomes include rows of short barbate trichomes interrupted by clusters of two long trichomes plus a distinct single long trichome; a few short barbate trichomes occur external to each cluster.

Linguiform processes on the labrum's anterior edge are key for genus distinction. Includes six genera and 43 species.

Diagnosis. Family can be diagnosed with the characteristics of leg buds being internal; anophthalmic head, unpigmented body lacking coxal pores.

4.2.1.2.2.1 Genus *Lophoturus* Brolemann, 1931

The individuals of this genus lack eyes, antennal articles VII and VIII equal in length, four sensory cones reduced in size, gnathochilarium with medial palp only, coxal gland absent and claws simple. *Lophoturus* has 0 to 4 pairs of linguiform processes on each side of a median cleft of the labrum and antennal article VI with 3 thick sensilla.

Genus with at least 28 species, which possess only 11 pairs of legs in adults. The species has a circumtropical distribution: southern Algeria, Ivory Coast, Jamaica, Florida, Cape Verde Islands, Tonga, Cook Islands and Barrow Island, northern Australia (Minelli, 2015).

Diagnosis. It is characterized by 0 to 4 pairs of linguiform processes on each side of median opening of labrum and antennal article VI with 3 thick sensilla, named anterior (a) intermediate (i) and posterior.

4.2.1.2.2.1.1 Description of species of genus *Lophoturus* Brolemann, 1931, collected from sacred groves of North Kerala.

Taxonomy

Family Polyxenidae Lucas, 1840

Subfamily Monographinae Conde, 2008

Genus *Lophoturus* Brolemann, 1931

Type-species: *Lophoproctus obscurus* Brolemann, 1931, by original designation

***Lophoturus muchukunnensis* sp.nov**

Material examined. 2 Female (CATE-10101A and B), India, Kerala state, Kozhikode district, Muchukunnu Kotta kavu, 11°29'20"N 75°40'10"E, 29 m, 30m a.s.l., M.D. Aswathy leg (Fig 10 C).

Diagnosis. Telotarsus as the adults: with 2 sternal lamellate processes and 2 shorter denticles; 2 latero-dorsal subequal scales Telotarsus as the adults: with 2 sternal lamellate processes and 2 shorter denticles; 2 latero-dorsal subequal scales

Description. Measurements Body length (without caudal penicil) 3.93 mm.

Antennal article VI with 3 basiconic sensilla, article VII with 2 basiconic sensilla (Fig 10 B). Surface of labrum without cuticular setae; 2+2 linguiform processes on anterior margin; 10 short setae along the posterior margin. Palpus of gnathochilarium with 18 sensilla. Trichobothria is a generic feature. Collum with left tuft of 50 trichomes and right of 57. Lateral protuberances of tergite I with 6 barbate trichomes. Oval clusters of tergites II with 35 and 36 trichomes. Coxae with 2 to 5 setae; trochanters with 2 setae (except 5 with only 1); prefemur with one seta, rarely two; femora with 1 seta. Telotarsus as the adults: with 2 sternal lamellate processes and 2 shorter denticles; 2 latero-dorsal subequal scales.

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4.3 Order Sphaerotheriida Brandt, 1833

4.3.1 Superorder Oniscomorpha Pocock, 1887

Short-bodied millipedes with not more than 13 body rings. Commonly called as Pill-millipedes (Pentazonia: Oniscomorpha) resemble woodlice (Armadillidiidae: Isopoda) in appearance. Capable of enrolling into a ball (volvation) when disturbed (Minelli, 2015).

Characterised by marked reduction in size of the collum (VandenSpiegel & Golovatch, 2012). The collum is hidden when rolled up. In Oniscomorpha the penultimate and sometimes also the antepenultimate leg-pair are transformed into accessory telopods.

4.3.1.1 Order Sphaerotheriida Brandt, 1833

Adult body length ranges from 30–45 mm, with rolled-up individuals about the size of a ping-pong ball (Minelli, 2015). Head wide and short, lack genae, and features large lateral antennal grooves. Each eye consists 60–90 ommatidia arranged in a cluster, with single ommatidium located laterally in the antennal groove. Tömösváry organ small, circular pit, slightly smaller than ommatidium, and positioned in the antennal groove. Antennae short, placed laterally in large grooves, and consist of six antennomeres plus a disc. Antennomeres usually cylindrical, with disc bearing 4–80 apical cones, depending on the species. Antennomere 6 is typically larger than the others, and some antennomeres, particularly 1, 5, and 6, have isolated sensilla basiconica.

The mandibles are massive, with a single external tooth, 2–3 inner teeth, six or more pectinate lamellae, and a prominently developed molar plate, which lacks membranous fringes. The mandibular condylus is strongly developed. The gnathochilarium has a normally sized gula, almost reduced cardines, and a fused mentum forming a large central plate with the lamellae linguales. The stipites are large and located laterally, with inner palps present and outer palps reduced to 4–6 tiny sensory cones. Median palps are transformed into centrally located pads, lacking sensory cones in the apical half, while the posterior half of the underside contains single sensory cones.

Body consists of 12 tergites plus an anal shield, 12 pairs of pleurites, and 21 pairs of legs in females or 23 in males. Tergite 13 is completely fused to the anal shield, though sutures may occasionally be visible. The first tergite (collum) is greatly reduced, while the second (thoracic shield) is significantly enlarged, nearly twice the size of the following tergites. The anal shield is bell-shaped. All species in this order are capable of complete volvation, where the head and collum fit into the spherical shape, and the bell-shaped anal shield engulfs the anterior margin of the enlarged thoracic shield.

Second tergite lacks a lateral schism (gap) except in juveniles. Features deep lateral pits to house tergite tips during enrolment (Minelli, 2015). Tergite tips and anal shield have specialized locking carinae for securing above the thoracic shield brim during enrolment. All tergites are thick, heavily calcified, with endotergum structures on the underside of posterior margins to block dirt and parasites during incomplete volvation. Pleurites appear as large sclerotized plates between tergites and stigmatic plates. Stigmatic plates are loosely attached to coxae and carry spiracles. Sternites are completely reduced. Legs have six podomeres (coxa, prefemur, femur, postfemur, tibia, tarsus) and are long, massive, and laterally compressed. Femur always features a posterior ridge. Tarsi include an apical claw and spine but lack paronychium. Tarsi 1 and 2 lack an apical spine. Coxal pores are absent. Male leg-pairs 22 and 23 are modified into anterior and posterior telopods, respectively, sometimes equipped with stridulation organs. Both telopods have fused coxae. Anterior telopods have 3–4 podomeres distal to syncoxite, forming chelae or pincers with processes. Posterior telopods form chelae, with 3 podomeres distal to syncoxite. Telopoditomere 2 has a large process as the immovable finger, while telopoditomere 3 (sometimes divided) forms the movable finger. Syncoxite has inner lobes and sharp-edged inner horns. Male and female gonopores are located on the posterior side of coxa 2. Male gonopore is covered by a simple plate. Female gonopore features a vulva with two sclerotized basal plates (bursa) and one sclerotized apical plate (operculum), often protruding above the coxa. There are over 340 identified species belonging to five families and 24 genera, found in a disjunct distribution. These species are located in regions such as eastern South Africa, Madagascar, the Seychelles, southern India, Sri Lanka, parts of Southeast Asia (stretching from Nepal to southwestern China, Myanmar, and the Philippines), as

well as Java, Sulawesi, Australia, and New Zealand (Wesener & Wägele, 2008; Minelli, 2015)

4.3.1.1.1 Family Arthrosphaeridae Jeekel, 1974

Members of this family typically range from 25–50 mm in length, with some island forms reaching 100 mm in length and 48 mm in width, while dwarf forms measure only 8–15 mm. Anterior and posterior telopods have three or four podomeres distal to the syncoxite. The anterior telopod forms a pair of clamps, with telopoditomer 2 and 3 featuring fields of sclerotized knobs. The first telopoditome of the anterior telopods is enlarged and carries the harp, a stridulation organ with 1–12 large stridulation ribs. Posterior telopods lack a stridulation organ, and the inner horns of the syncoxite are broad. The vulva consists of three plates, with the operculum typically well-rounded but sometimes featuring a median notch. The inner plate of the bursa is strongly protruding. The female subanal plate is greatly enlarged, forming the washboard—a stridulation organ with 2–24 ribs. Stigmatic plates are free and possess a spine-like process that protects the spiracle of the preceding stigmatic plate. Coxal lobes may be absent or present. Tarsi always end in a single apical spine. Tergite 13 is completely fused to the anal shield. The endotergum lacks callosities, with its inner area adorned with triangular spines and hair. Marginal bristles are always arranged in rows. Sensory cones on the palps of the gnathochilarium are grouped in a single field.

The family includes four genera and about 100 species distributed across southern India, Sri Lanka, and Madagascar, with one species introduced to a former forest garden in the Usambara Hills, Tanzania (Wesener et al., 2010; Minelli, 2015; Wesener & Sagorny, 2021).

Diagnosis. Medium to large sphaerotherids with basal part of vulva bipartite. Anterior telopodites clamp like, with field of sclerotized knobs, harp with 1–12 stridulation ribs. Posterior telopodite without stridulation organ. Antennal short, axe shaped and numerous cones on the final antennomere.

4.3.1.1.1.1 Genus *Arthrosphaera* Pocock, 1895

Species within this genus are 25–45 mm in length. Anterior telopod with four podomeres distal to the syncoxite, with telopoditomere 4 bearing a lobe covered in sclerotized spots, and the harp having one or two stridulation ribs. Posterior telopods include three telopoditomeres, with telopoditomere 3 featuring two membranous lobes. In females, the vulva has a well-rounded operculum that is shorter than the bursa, while the inner plate is heavily elongated, protruding as far as or beyond the operculum (Minelli, 2015). The female washboard typically has four to six stridulation ribs. The legs have a coxal lobe, with tarsi that are usually broad and paddle-like, though occasionally slender. The underside of the anal shield generally features two locking carinae, which are reduced in some species. The first antennomere lacks a groove and has only isolated sclerotized scales, with no sensilla basiconica present. Antennomere 6 is large, flattened, and axe-shaped, bearing numerous apical cones. Genus comprises about 40 species found in southern India and Sri Lanka.

Diagnosis. Individuals can be diagnosed with 2 white lappets in the third podomere of posterior telopodite. Anterior telopodite with broad globular fourth podomere with margins of the same beset with knob-like protrusions. The genus shows great similarity with genus *Zoosphaerium* with the characteristic of having 1 or 2 stridulation ribs on harp and relative similarity in external morphology and tergal ornamentation. But, differs from it by the number of podomeres on the anterior telopodite distal to syncoxite. *Arthrosphaera* is observed to have 4 distinct podomeres post syncoxite whereas only 3 are counted in *Zoosphaerium*.

4.3.1.1.1.1.1 Descriptions of the species of genus *Arthrosphaera* Pocock, 1895 collected from sacred groves of North Kerala.

Taxonomy

Order Sphaerotheriida Brandt, 1833

Family Arthrosphaeridae Jeekel, 1974

Genus *Arthrosphaera* Pocock, 1895

Type-species: *Zephronia heterostictica* Newport, 1844, by original designation.

= *Trochosoma* Chamberlin, 1921: 56 (D), synonymized under *Arthrosphaera* by Jeekel (2001: 7).
Type-species: *Trochosoma pelloceps* Chamberlin, 1921.

= *Trivandrobium* Verhoeff, 1937: 82 (D), synonymized under *Arthrosphaera* by Jeekel (2001: 7).
Type-species: *Trivandrobium stridulum* Verhoeff, 1937.

= *Odontosternum* Attems, 1944: 62 (D), synonymized under *Arthrosphaera* by Jeekel (2001: 7).
Type-species: *Odontosternum fuscum* Attems, 1944

***Arthrosphaera aurocincta* Pocock, 1899**

Arthrosphaera aurocincta Pocock, 1899: 276 (D).

Arthrosphaera aurocincta—Gravely, 1915: 518 (R); Attems, 1914: 147 (M); 1936: 165 (M); Rajulu, 1970: 125 (M); Jeekel, 2001: 7 (M); Sridhar & Ashwini, 2013: 18 (R); Sridhar, 2015: 3 (M).

Materials examined. 7 male (CATE-3202A-G) and 12 female paratypes (CATE-3202 H -S) from the sacred groves of Valliyur kavu, Manathavady, Wayanad district, 11°48'08''N, 76°01'55''E, 716 m a.s.l., M.D. Aswathy leg.

Diagnosis. Specimens similar to *A. wroughtoni* by the characteristics of telopodites and vulva similar to *A. zebracia*. Distinct from the congeners by characteristic body colour, ornamentation and combination of structures of male and female sexual characters.

Description. Body length - Male length 32.7 mm, width of thoracic shield up 24.3 mm (widest), height of thoracic shield 11.5 mm (highest) (Fig 11 A)

Color - Body of mature male and female olive brown, posterior margin of each tergite with sharply defined brownish - red stripe. Head and collum are black, while the antennae and legs are olive to dark brown.

Head - Setiferous pits and hairs present around clypeus and lateral part of eyes. Vertex smooth. Posterior margin of head with some isolated hairs.

Antennae – Six jointed. Length of the antennomeres: 1>2=3=4<5>6. Sixth antennomere oval shaped with more than 50 sensorial cones (Fig 11 D).

Mouthparts - Mandible molar plate process devoid of step. Five pectinate lamellae. Number of teeth declines proximally.

Collum - Anterior margin with a few isolated hairs and the posterior margin bald. Lateral margins latero-distally thickened (Fig 11 A).

Thoracic shield - Lateral extension of the thoracic shield has a few hairs and ridges - Anterior marginal brim broader than the rest of the brim.

Tergites - Anterior part of the terga densely punctured. Posterior half sparingly punctured, mostly smooth. Paratergite depression has hairs and possesses a few ridges in the posterior tergites. Tips of posterior margins of paratergites project posteriorly.

Anal shield - Lower margin at posterior end tapered. Covered with dense sculpturing of coarse anastomosing punctures, with marginal groove, a small inferior anterior notch and a long double inner crest, the posterior part of which is about twice the length of the anterior.

Legs - The first and second leg pair with 4 ventral spines and weakly curved claws. Remaining pairs of leg have 7-11 ventral spines with curved claws. All podomeres possess isolated dense hairs.

Female sexual characters - The operculum of the vulvae is broad, without a central depression, and extends to the base of the second joint. The inner plate is short and stout, with a broad, hook-shaped apical end that surpasses the operculum tip above. The exterior plate is robust, encircling the base of both the operculum and the inner plate. The operculum's margin is adorned with a few short hairs. The sub-anal plate is rounded with a central indentation, while the washboard features 3-4 small, irregular stridulating ribs on each side. Fine hairs are scattered across the surface (Fig 11 B & C).

Male sexual characters - Anterior telopod - Syncoxite with a few hairs (Fig 11 G & H). First joint possesses a harp like process with 2 ridges and possesses slightly sharp borders. They form a rim around the 2nd joint. The 2nd joint is curved with a superior slender lobe. The 3rd and 4th joints are coalased with 3 lobes (Fig 11 E).

Posterior telopod - Syncoxite with dense hairs. The coxal horn (inner horn) slender, bent at an angle of 45 degrees with hook-like structure. Sub-anal lobe with numerous hairs. The 2nd joint (femoral process) is equal to the 3rd joint (tibia or movable finger) in length. The movable segment has 2 white lappets and other crenulations. A wide gap is visible between these two podomeres (Fig 11 F).

Distribution. "East Indies" (Pocock 1899a), Parambikulam. India, Cochin Ghats (Gravely 1915), Valliyurkavu; Wayanad. (Fig 11.1 A)

***Arthrosphaera Kammadamensis* sp.nov.**

Materials examined. 4 male (CATE-32031A-D) and 6 female paratypes (CATE-32031E-J) from the sacred groves of Kammadam Kavu, Chittarikkal, West Elery, Kasaragode district, 12°18'41.0"N 75°18'55.8"E, 71 m a.s.l., M.D. Aswathy leg.

Diagnosis. Specimens similar to *A. craspedota* by the characteristics of telopodites and vulva similar. Distinct from the congeners by characteristic body colour, ornamentation and combination of structures of male and female sexual characters and number of stridulation ribs on female harp. *A. craspedota* have 1-5 irregular and non-prominent ribs while *Arthrosphaera Kammadamensis* sp.nov. have 2 prominent ribs on female harp.

Description. Body length - Male length 38.5 mm, width of thoracic shield up 29.4 mm (widest), height of thoracic shield 15.5 mm (highest)

Color - Body of mature male and female uniform dark olive brown without any stripes on metatergal margin. Head and collum are black, while the antennae and legs are olive to dark brown (Fig 12A).

Head - Setiferous pits and hairs present around clypeus and lateral part of eyes. Head coarsely and densely punctate, also the vertex. Posterior margin of head with some isolated hairs.

Antennae – Six jointed. Length of the antennomeres: 1>2>3=4=5>6. Sixth antennomere oval shaped with more than 50 sensorial cones (Fig 12B).

Mouthparts - Mandible molar plate process devoid of step. Five pectinate lamellae. Number of teeth declines proximally.

Collum - Anterior margin with hairy and posterior margin bald.

Thoracic shield - Lateral extension of the thoracic shield has a few hairs and ridges - Anterior marginal brim broader than the rest of the brim.

Tergites -The anterior portion of the terga densely punctured, posterior half with sparse punctuations. Paratergite depression contains hairs and features a few ridges on the posterior tergites. Tips of the posterior margins of the paratergites extend backward.

Anal shield - Lower margin at posterior end tapered. Anal shield with one well developed black locking carina on each side.

Legs - First and second leg pair with only 2-3 ventral spines and weakly curved claw. Following leg pairs with 7-11 ventral spines and curved claw. Coxal lobe of ninth leg pair absent. All the podomere with isolated dense hairs.

Female sexual characters - Operculum of vulvae is small without any depression at the center, basal margin devoid of outgrowth and almost straight. The inner plate is long and broad reaching above the operculum. Exterior plate is not as long as the inner one reaching only the basal part of the operculum. Sub-anal plate with wash board shows a depression at the median line and has long hair at the periphery. Short hairs are present all over the surface. The wash board consists of 2 prominent stridulation ribs. Length of ribs is uniform (Fig 12 C).

Male sexual characters - Anterior telopod -Syncoxite with only few hairs. The first joint (podomere) features a lobe along with a stimulatory ridge (Fig 12 E & F). The femoral process broad with a lobe at its apex. The tibia and tarsus are fused, with tibial section bearing a rounded lappet, while the tarsal section has a rounded lappet at the top and a blunt lappet on the lateral side.

Posterior telopod - Syncoxite with dense hairs. The coxal horn (inner horn) slender, bent at an angle of 45 degrees with hook-like structure. Sub-anal lobe with numerous hairs. The 2nd joint (femoral process) is slightly shorter than 3rd joint (tibia or movable finger) in length. The movable segment has 2 white lappets and other crenulations. A wide gap is visible between these two podomeres (Fig 12 G & H).

Distribution. Kammadam Kav, Kasaragod (Fig 12.1 A).

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4.4 Order Siphonophorida Newport, 1844

4.4.1 Infraclass Helminthomorpha Pocock, 1887

Millipedes with 19 - 220 body rings and 30 - 375 leg pairs (Minelli, 2015). Head capsule features a transverse suture, and an occipital phragma. Genae present. The labrum typically has three teeth, though this is reduced in Colobognatha. The presence or absence of ommatidia varies depending on taxonomic level, whether order, family, genus, or species. Antennae with seven segments (podomeres) plus a disc, though in rare cases, there may be eight segments plus a disc. The disc bears four apical cones, with a few genera exhibiting more. Gnathal lobes always devoid of condylus. Ozopores present on the lateral surface of tergite. Legs with 6 podomeres. Coxal pores present or absent. Male gonopore opens through second coxa or sometimes through penes located behind leg pair 2. Leg pairs or either one leg pair of body ring 7 modified to form gonopods.

Has worldwide distribution except in Antarctica.

Diagnosis. Flat, worm like millipedes usually without dorsal longitudinal grooves.

4.4.1.1 Subterclass Colobognatha Brandt, 1834

Adults with ca. 5 - 70 mm flat body consisting of 28 - 192 body segments and 45 - 375 leg pairs (Minelli, 2015). Head capsular, small and subtriangular. Head anteriorly extended without median suture but occipital phragma. Eyes if present posses one to four ommatidia. Antenna with 7 antennomeres and the distal ultimate antennomere usually large with apical cones. The penultimate antennomeres with basiconic sensilla. Ozopores laterally located on tergites starting from segment 5. Legs usually covered by tergites and consists of 6 podomeres. Legs 9 and 10 modified into gonopods. Coxal pouches present starting from leg pair 3. Male gonopore located on or behind coxa 2.

Diagnosis. Distinguished from congeners by the pyriform head, triangular to beak-shaped; adult males with eight pairs of walking legs anterior to gonopods, two pairs of leg-like gonopods directed anteriad.

4.4.1.1.1 Order Siphonophorida Newport, 1844

Individuals range from 5 to 70 mm in length, with a typically slender trunk, where the width-to-length ratio is less than 1:10. The trunk can have up to 192 segments, making these the ‘leggiest’ millipedes, with sexually mature individuals of the same species ranging from 50 to 182 segments (Minelli, 2015). The head capsule is relatively small, either pyriform or distinctly elongated into a beak. Ommatidia are absent. The antennae are robust, with antennomeres 5 and 6 usually thicker than the others. The mandibles exhibit significant modifications, with the basal joint completely reduced to unique sclerites. The gnathal lobe is heavily reduced in family Siphonorhinidae and almost entirely absent in family Siphonophoridae. metazonites extend laterally, causing the prozonites to appear particularly narrow. Ozopores first appear on segment 5 and are often positioned on lateral metatergal projections, though the composition of their secretion remains unknown. The body sclerites remain free, with tergites, pleurites, and sternites not fused. Tergites are either smooth or, more commonly, covered with hair-like structures, and in several species, they bear anchor-shaped projections. Unlike many other millipedes, tergites lack a dorsal suture. The sterna are large, especially in the stigmatic region, while the coxae are closely set. Each leg comprises six podomeres (coxa, prefemur, femur, postfemur, tibia, and tarsus), with the tarsi always bearing an accessory claw. In males, leg pairs 9 and 10 are modified into gonopods, which are leg-like and composed of distinct podomeres. The anterior gonopods vary in podomere number, while the posterior gonopods typically have five to seven podomeres and are generally slenderer than the anterior ones. The male gonopore opens directly through coxa 2.

Order consists of 14 genera with ca. 120 species distributed in tropics and subtropics of Americas, South Africa, and Asia.

Diagnosis. Distinguishable from congeners by the attributes of the cross section of the animal being a half circle, the ventral side of the animal flat and body densely covered with fine setae. Distal segments of antennae enlarged and remarkably thickened.

4.4.1.1.1.1 Family Siphonorhinidae Cook, 1895

Pyriiform subtriangular head which is not extended into a beaklike structure without any setae on head. Geniculate antennae, bending at the junction between antennomeres 3 and 4. Sensory cone pits on antennomeres 5 and 6 are absent, with only a field of sensilla basiconica present. Antennomere 2 is twice the length of antennomere 3.

The last podomere of the posterior gonopod is divided into two or more branches. It comprises 4 genera and ca 15 species, distributed across the western USA (California), southern Africa, Madagascar, India, Vietnam, Laos, Cambodia, and Indonesia.

Diagnosis. Pear-shaped head, with mouthparts not extending into a beak. Gnathochilarium divided into separate plates; antennomere 2 twice as long as antennomere 3; antennae elbowed between antennomeres 3 and 5 which are all otherwise in family siphonophoridae.

4.4.1.1.1.1 Genus *Siphonorhinus* Pocock, 1894

Body slender with 4 -50 mm long. Flat body with semi oval body segment and non glabrous. Head acuminate or pear shaped. Geniculate antennae, bending at the junction between antennomeres 3 and 4. Sensilla basiconica on antennomere 5 and 6 in sensory circular pit. Coxa and sternite of leg pair 1 fused. Paranota prominent (Attems, 1938). Last podomeres of posterior gonopod extending into thin long filament, dividing apically in to leafy shaped styliform articles and lacking any spines (Anilkumar et al., 2024).

Distributed in indonesia, India, Vietnam, Laos, Cambodia and Madagascar.

Diagnosis. The head shape is more acuminate and less rounded than in *Illacme* and *Notiorhinus*. Antennomere 6 is strongly rounded and bulged, unlike its cylindrical form in *Illacme*, *Nematozonium*, *Madagascarhinus*, and *Notiorhinus* (Anilkumar et al., 2024). The fusion of coxae 1 with sternite of leg pair 1 is the most prominent of the characters to distinguish the genus from the other genera of the family.

4.4.1.1.1.1.1 Descriptions of the species of genus *Arthrosphaera* Pocock, 1895 collected from sacred groves of North Kerala.

Taxonomy

Order Siphonophorida Newport, 1844

Family Siphonorhinidae Cook, 1895

Genus *Siphonorhinus* Pocock, 1894

Type species. *Siphonorhinus pallipes* Pocock, 1894

***Siphonorhinus muchukennensis* sp.nov.**

Materials examined. Male holotype (CATE-5104A), 2 male (CATE-5104B and CATE-5104C) and 2 female paratypes (CATE-5104D and CATE-5104E), Muchukunnu Kavu (N 11°29'49'', E 75°39'50'', 33 m a.s.l.), Kozhikode district, Kerala, India

Diagnosis. *Siphonorhinus muchukennensis* sp.nov. differs from the incompletely described *S. larwoodi* from the Himalayas in the higher segment number (58 vs. 40 in *S. larwoodi*), the longer antenna (shorter than the head in *S. larwoodi*), and the number of macrosetae (3 vs. 2 in *S. larwoodi*) on the lateral margin of the gnathochilarial stipes. The gonopodal characters also differ from congeners as *S. coniceps* was described based on female specimens and the location of collection of specimens can also contribute the *Siphonorhinus muchukennensis* sp.nov. is different from other Indian species as well.

Description. Male 82 -90 tergites + telson, ~30 mm in length and ~3.15 mm in width. Coloration [after 6 months in ethanol]. Head pallid brown, antennae white, tergites orange-brown in the anterior segments and fading to creamish white towards telson, legs creamish-white (Fig. 13 B).

Head elongated and pear-shaped, nearly three times the length of the collum (Fig 13 A). The epicranium arches slightly above the antennal base and is densely covered with setae. The gnathochilarium is divided, featuring a central mentum, paired flap-like lamellae lingualis positioned anteriorly, paired stipites laterally, and lamellae

lingualis with sensory palps at the apex. Mandibles are internalized and not externally visible.

The antennae are long, reaching the fifth tergite, and are geniculate between antennomeres 3 and 5. They consist of seven antennomeres plus an apical disc. The antennomeres vary in length as follows: $6 > 2 > 5 > 3 = 4 > 1 > 7$ (Fig 13 C). Antennomere 2 is longer than wide, while antennomeres 3–5 is cup-shaped. Antennomere 6 is the widest, rounded, and bulged, with antennomere 7 retracted within it. Antennomeres 1–3 are setose dorsally, while antennomere 6 is densely setose. Circular sensory pits with sensilla basiconica are present on the ventrolateral anterior margins of antennomeres 5 and 6, with the pit on antennomere 6 appearing more circular. The apical disc contains four apical cones.

Collum; Trapezoidal in dorsal view and triangular laterally, slightly overlapping the epicranium. It is densely setose and entirely covered with hairs. Separate from the pleurites and sternites. The prozonites are overlapped by the preceding metazonites, with their anterior three-fourths covered in scales and the posterior fourth bearing hairs. Metazonites are twice as long as prozonites, arched, and laterally extended into paranota. They are densely setose and entirely covered with tubercles. Paranota appear from tergite 7, extending slightly backward, with ozopores starting from tergite 5. The ozopore on tergite 5 is near the lateral-anterior margin of the paranota, while in subsequent tergites, it is positioned farther from the lateral-posterior margin. The last tergite (91st) is apodous, twice as long as and narrower than the preceding tergites, with triangular paranota extending posteriorly. The preanal ring is narrower than the body rings and forms a complete ring, fully covered with tubercles and densely setose. The paraprocts are oval, with a central tubercle-free area and crossing setae near the opening. The hypoproct is small, semi-hemispherical, and about one-fifth the length of the paraprocts.

The first pair of legs is slightly longer and thicker than the subsequent legs, with the coxa fused to the sternite. It consists of five free podomeres, with a triangular prefemur distally. The tibia and tarsus are densely setose, bearing long mesal setae. From the third pair onwards, the legs have seven podomeres, including a trochanter and a coxal sac. The relative lengths of midbody podomeres are as follows: femur > tarsus > prefemur > coxa > postfemur = tibia > trochanter.

Legs 9 and 10 modified into anterior and posterior gonopods (Fig 13 D). With six podomeres; twice as thick as posterior gonopod. Podomeres 1 and 2 forming a rounded, stout base, tapering from podomere 3. Relative length of podomeres: 6>4>1>3>5>2. Podomeres 1–3 with a few setae. Podomeres 4 and 5 with a row of setae. Podomere 6 completely covered with setae, a few anterior setae apically serrated and twisted. Posterior gonopod not clearly visible as it is tucked inside anterior gonopod. Tapering from podomere 4. Podomere 6 cylindrical. Podomeres 4 and 5 mesally with few short setae. Podomere 7 extending into a thin, long branch, apically divided into 2 styliform articles (upper and lower) with leaf-shaped tip.

Distribution. Kozhikode, Kerala, India (Fig 13 E).

Taxonomy

Order Siphonophorida Newport, 1844

Family Siphonorhinidae Cook, 1895

Genus *Siphonorhinus* Pocock, 1894

Type species. *Siphonorhinus pallipes* Pocock, 1894

***Siphonorhinus koyithattensis* sp.nov.**

Materials examined. Male holotype (CATE-5105A), 3 female (CATE-5105B and CATE-5105D), Koyithatta sree dharma sastha Kavu, Koyithatta (12° 17 ' 11.4"N 75° 14' 53.88" E), Kasaragode district, Kerala, India.

Diagnosis. *Siphonorhinus koyithattensis* **sp.nov.** differs from the congener *S. larwoodi* by lesser segment number (28 vs. 40 in *S. larwoodi*), the longer antenna (shorter than the head in *S. larwoodi*). It differs from *Siphonorhinus muchukunnensis* **sp.nov.** by their shorter body and unpigmented whitish body.

Description. Male 27 tergites + telson, ~2.5mm in length. Coloration [after 6 months in ethanol]. Head, antennae and tergites white and legs creamish-white (Fig. 14 A).

Head elongated and pear-shaped, nearly three times the length of the collum. The epicranium arches slightly above the antennal base and is densely covered with setae. Mandibles are internalized and not externally visible.

The antennae are long, reaching the third tergite when extended backwards, and are geniculate between antennomeres 3 and 5. They consist of seven antennomeres plus an apical disc. The antennomeres vary in length as follows: $6 > 2 > 5 > 3 = 4 > 1 > 7$ (Fig 14 C). Antennomere 2 is longer than wide, while antennomeres 3–5 are cup-shaped. Antennomere 6 is the widest, rounded, and bulged, with antennomere 7 retracted within it. Antennomeres 1–3 are setose dorsally, while antennomere 6 is densely setose. The apical disc contains four apical cones.

Collum; Trapezoidal in dorsal view and triangular laterally, slightly overlapping the epicranium. It is densely setose and entirely covered with hairs. Separate from the pleurites and sternites. The prozonites are overlapped by the preceding metazonites, with their anterior three-fourths covered in scales and the posterior fourth bearing hairs. Metazonites are twice as long as prozonites, arched, and laterally extended into paranota. They are densely setose and entirely covered with tubercles. Paranota not prominent but slightly appear from tergite 7, extending slightly backward, with ozopores starting from tergite 5. The last tergite (27th) is apodous, twice as long as and narrower than the preceding tergites, with triangular paranota extending posteriorly (Fig 14 B). The preanal ring is narrower than the body rings and forms a complete ring, fully covered with tubercles and densely setose. The paraprocts are oval, with a central tubercle-free area and crossing setae near the opening. The hypoproct is small, semi-hemispherical, and about one-fifth the length of the paraprocts.

The first pair of legs is slightly longer and thicker than the subsequent legs, with the coxa fused to the sternite. It consists of five free podomeres, with a triangular prefemur distally. The tibia and tarsus are densely setose, bearing long mesal setae. The relative lengths of midbody podomeres are as follows: femur > tarsus > prefemur > coxa > postfemur = tibia > trochanter.

Distribution. Kasaragod, Kerala. (Fig 14 D)

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4.5 Order Polyzonida Gervais, 1884

Micromillipedes with ca. 10 - 15 mm length and flat body. Commonly called “beaked millipedes” (Wesener, 2014). Capable of limited volation. Head pyriform, small and mouthparts modified in to elongated snout. Body with plallid colouration; varying from yellow to purplish pink.

Eyes located on either lateral sides and observed as black spots usually 3 + 3 and 1+1/ 2+2/ 4+4 in rare cases (Minelli, 2015). Two pairs of prominent macrosetae situated between the macrosetae. Antennae thick with all antennomeres with equal sizes. Mouth part modified to form an elongated structure. Gnathal lobe slightly decreased, mandibular basal joint shortened to create thin sclerite. Gnathochilarium can often be recognized and significantly altered into three sclerites. Ozopores located directly on the lateral corner of tergites starting from segment 5. Trunk with tightly packed segments with around 20 - 90 segments. The number of segments is observed to be remarkably different even in mature adults of the same species. Tergites, pleurites and sternites unfused. Dorsal suture on tergites absent. Legs with six podomeres. Tarsi with or without an accessory claw called as paronychium. Coxal sac present, usually starting from leg pair 3. Leg pairs 9 and 10 modified to form gonopods. Number of podomeres variable in anterior and posterior gonopods with the retminal podomere largely modified. Last podomere of posterior gonopod usually found slender than the preceding podomers. Gonopores located near second coxa as usual.

Shows worldwide distribution, but reported only from S. Africa and Madagascar from African continent (Shelley & Golovatch, 2011).

Diagnosis. Can be distinguished from the congeners with 2 dark eye spots present, animals much wider than thick, dorsal side convex, the ventral side flat and head pyriform with modified and reduced mouthparts; adult males with paired penes on or behind the coxae of 2nd leg pair.

4.5.1 Family Siphonotidae Cook, 1895

Polyzoniidae family is characterized by wide trunk and vasa deferentia that open through conical lobes on the second coxae. Anal segment completely encircles the paraprocts and narrow in structure. Male gonopore located posterior to coxa 2. Ozopores are positioned well inward from the lateral margins of the metaterga. Additionally, the tarsal claws feature long, prominent accessory structures. This family is primarily restricted to the Southern Hemisphere with 11 genera and 29 species, with the exception of populations in West Africa and the Caribbean, which may have been introduced (Hoffman, 1977).

Diagnosis. Different from congeners by the presence tarsus with paronychium, preanal ring narrow and forming a complete ring around paraprocts, male gonopore positioned on coxa of leg two, tergal margins not upturned.

4.5.1.1 Genus *Rhinotus* Cook, 1896

Monotypic genus, with species of small wide body (05 -12 mm), pale coloured (pallid yellow - purple). 30 - 40 body rings with slightly slender males and wider female. Gonopods with huge coxa. Telopodite massive, bulbous and stout with around 4 setae at the terminal. Posterior gonopods with slightly fused podomeres with a long and slender tarsus.

Diagnosis. Recognized by the presence of single ommatidia on either lateral side of the head with a pair of prominent setae below the eyes. The anterior gonopod pair is also highly modified in this species.

4.5.1.1.1 Descriptions of the species of Genus *Rhinotus* Cook, 1896 collected from sacred groves of North Kerala.

Taxonomy

Subclass Chilognatha

Infraclass Helminthomorpha

Subterclass Colobognatha

Order Polyzoniida

Family Siphonotidae

Genus *Rhinotus* Cook, 1896

Boninozonium Takakuwa, 1942 · unaccepted (junior subjective synonym)

Orsilochus Attems, 1900 · unaccepted (preoccupied in Hemiptera and Coleoptera)

Paraburenia Verhoeff, 1939 · unaccepted (junior subjective synonym)

Paroconus Chamberlin, 1945 · unaccepted (junior subjective synonym)

Rhinotus purpureus (Pocock, 1894)

Siphonotus purpureus Pocock 1894: 479 (D)

Siphonotus purpureus—Loomis 1934: 9 (R)

Siphonoconus purpureus—Causey 1965: 53 (R, M)

Rhinotus purpureus—Hoffman 1977: 429 (M).

Rhinotus purpureus—Hoffman 1999: 36 (M).

Siphonotus africanus Cook, 1896: 842; Hoffman 1977: 429,

[suggested synonymy; listed as a potential synonym in Hoffman (1999)].

Siphonotus miamiensis Causey, 1953: 71 Synonymized by Causey 1965: 53.

Polyzonium malagassum De Saussure & Zehntner, 1902, Synonymized by Wesener 2014 (R)

Materials examined. Male holotype (CATE-61604A), 2 male (CATE-61604B and CATE-61604C) and 2 female paratypes (CATE-61604D and CATE-61604E), India, Kerala state, Thrissur district, 10°21'19''N, 76°12'48''E, 29 m a.s.l., in June 2021 and 1 male (CATE-61604J) and 2 female paratypes (CATE-61604K and CATE-61604L all in 5302B–CATE-5302I) from the sacred groves of Valliyur kavu, Manathavady, Wayanad district, 11°48'08''N, 76°01'55''E, 716 m a.s.l., M.D. Aswathy leg.

Diagnosis. Same as generic diagnosis.

Description. The male millipedes were 1.6 cm in length and 0.66 mm wide, females were 1.5–2.3 cm in length and 0.57–0.84 mm wide. Male with 31 body rings + 1 telson, females up to 35 + 1 telson. Body pinkish purple color with pale pink legs, after preserving for 6 months in 96% ethanol (Fig. 15 A & B).

The millipede has a triangular head with a single large ocellus on each side. A macroseta is located along the bottom of each ocellus. Antennae stout, slightly broader at the end. Collum large, faintly convex and partially extending forward to head covering initial half of ocelli. Collum is sparsely setaceous with short setae. Body slightly convex and flat. Circular ozopores, located at mesozonite. Tergites smooth with two lateral rows of short setae. Legs short without any tarsal brushes, tarsi of legs arranged as thick tufts of hair. Slight extension of tarsi commonly referred as an accessory claw present on walking legs. Preanal ring slightly pointed downwards and hardly extending the telson. Telson is much shorter than preanal ring. Three pairs of setae on anal valves and a single pair of anal setae present on telson. Gonopods clearly resemble the previous descriptions and illustrations.

Anterior gonopod has a huge coxa (cx) and the sternite (st) of the anterior gonopod has bilobulated extensions with each lobe carrying a long seta on the telopodite (post femoral segments) region of the anterior gonopod. Telopodite massive, bulbous and stout with around 4 setae at the terminal. Posterior gonopod also with a huge coxa (cx) and indistinguishable (slightly fused) podomeres with a long and slender tarsus. The sternite is separate with rectangular lobes carrying 4 or 5 setae (Fig 15 C & D.).

Distribution. Caribbean, Central America, North America, and South America. It has also been recorded in West Africa, Mauritius, the East Indies, Madagascar, and Asia (Fig 16 A & B).

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4.6 Order Polydesmida Leach, 1815

4.6.1 Superorder Merochaeta Cook, 1895

4.6.1.1 Order Polydesmida Leach, 1815

They are called the true flat-backed millipede. Head without eyes and a pair of prominent antennae. Antennae each consisting of seven antennomeres plus disc, apically with four, exceptionally up to at least 20 sensory cones, antennomeres 5-7 normally with sensory fields or pits. Collum variable, often smaller than or equal to the terga that follows, flabellate in certain groups, covering the head from above, and exhibiting radiating furrows or frontal lobulations. Axial suture is absent.

The body ring is made up of a metazonite (posterior) that typically has more or less prominent lateral projections (paraterga or paranota) and an anterior, cylindrical, smooth, or microsculptured prozonite.

The species in this group has a flat, partial cylindrical body with a maximum of 20 body rings. The size, shape, inclination, colouration and ornamentation of metaterga and paraterga are extremely variable in this group, making the Polydesmida the morphologically most diverse order of millipedes. The paranota has the ozadenes/ozopores located on them. They are arranged in a pattern of 5, 7, 9, 10, 12, 13, 15-17 (18, 19) (normal pore formula). Deviations from this formula are observed in families such as pyrgodesmidae. Gonopods usually observed to be projecting outside under the 7th segment of the mature male body even when not in use. Each gonopod is bi-articulate, consisting of a coxa and a telopodite. Coxa is usually with a distomedial cannula (= hollow coxal horn, or solenite). Telopodite usually directed forward, parallel or crossing, extremely variable in size, shape and ornamentation, but normally with a densely setose basal part conventionally denominated “prefemoral”; part of telopodite distal to prefemoral part, collectively termed “acropodite”. The acropodite is generally a complex structure, with various processes and outgrowths. One of which is termed as “solenomere”, which helps in supporting most or a part of the seminal groove.

Polydesmids have the widest worldwide distribution. They are found all across the globe except the Antarctica.

Diagnosis. They are distinguished from other millipede orders by the dorsoventral flattening of their body, presence of prominent and sometimes ornamental paranota or keels. The adult Polydesmida millipede will only have a maximum of 20 body rings in the case of both male and females.

4.6.1.1.1 Key to families of the order Polydesmida and diagnosis of millipedes found from the Sacred groves of North Kerala:

1 (2) Collum smaller than the head capsule, with oval, convexed or notched shaped..... (3)

2 (1) Collum larger than head, partially or completely covering the head capsule with rounded or sub trapezoidal shape, with smooth or slightly lobed lateral margins **Pyrgodesmidae**

3 (4) Large species with adult ca. 5 cm in length. Paranota of 2nd segment set lower than those of 3rd, and lateral end of collum; paranota of most body segments very small, sometimes wanting; gonopods independent and never fused medially **Paradoxosomatidae**

4 (3) Small species with adult ca. 0.4cm in length Paranota of 2nd and 3rd segments set in same plane, body segments larger and more strongly projecting laterad; gonopods fused medially with large and prominent squarish or round coxae covering the telopodites **Trichopolydesmidae**

4.6.1.1.1.1 Family Paradoxosomatidae Daday, 1889

The largest and most diverse group of millipedes with over 2000 species described worldwide (Jeekel, 1980; Shelley, 2003). They have a prominent distribution in the tropics but also scattered distribution globally except the Antarctic. The majority of adults of species found in the sacred groves of N. Kerala is from 30 to 80 mm in length, with convex, smooth tergites (each with a shallow transverse groove) and relatively small paranota sometimes wanting. The exoskeleton is heavily calcified, with surface ornamentation that may include ridges, tubercles, or setae. Antennae are clavate and composed of seven segments, with the distal segment bearing sensory cones. They are distinguished by the arrangement of paranota. The paranota of 2nd segment set lower than those of 3rd, and lateral end of collum. The gonopods of this group are also peculiar with extensive variety of gonopodal telopodite with different

types of apical branches and solenophore sheaths. A total of 5 genera of millipedes were collected from the sacred groves of N. Kerala. They are *Anoplodesmus*, *Chondromorpha*, *Orthomorpha*, *Delarthum* and *Telodrepanum*.

Diagnosis. The family is diagnosed by its congeners by the declining angle of the second segment from the following segments.

4.6.1.1.1.1 Key to the genera of family Paradoxosomatidae Daday, 1889 found in the sacred groves of N. Kerala are as follows:

- 1 (2) Paranota of the second segment lies in same line with the adjacent following paranotas..... (3)
- 2 (1) Paranota of the second body ring slightly set lower than the adjacent following paranotas.... (5)
- 3 (4) Paranota have thick lateral rolls*Anoplodesmus*
- 4 (3) Paranota without thick lateral rolls but a hollow channel-like structure instead*Chondromorpha*
- 5 (6) Telopodite thin and straight and the solenomere branch is not sheathed by solenophore..... (7)
- 6 (5) Telopodite untwisted and solenomere covered by laminar solenophore sheath.....*Orthomorpha*
- 7 (8) Second leg pair of males with femoral adenostyles..... *Telodrepanum*
- 8 (7) First leg pair of male (also second leg pair in exceptional cases) with femoral adenostyles *Delarthum*

4.6.1.1.1.1.1 The tribes of family Paradoxosomatidae millipedes collected from Sacred groves of North Kerala

The specimens collected from the sacred groves of North Kerala were belonging to two subfamilies namely Alogolykinae Hoffman, 1963 and Paradoxosomatinae Daday, 1889. It was identified that only one tribe, Polydrepanini was collected from subfamily Alogolykinae (Hoffman, 1963) and two tribes Sulciferini and Orthomorphini were collected from subfamily Paradoxosomatinae (Daday, 1889).

4.6.1.1.1.1.1.1 Key to the genera of tribe Polydrepanini Jeekel, 1968.

The tribe Polydrepanini is diagnosed by an elongate, mostly slender, sometimes twisted/helicoid gonofemurite and a more or less thin, mostly flagelliform, suberect, apical or subapical solenomere often forming a conspicuous loop/curve near the base (Golovatch et al., 2022). The tribe presently encompasses seven genera, of which 2 are collected from the sacred groves of N. Kerala.

The key to the genera is given below:

- 1 (2) Solenomere with a distant basal loop and a lobular structure at the solenomere base (3)
- 2 (1) Solenomere without any basal loop or any basal lobes (4)
- 3 (4) Solenophore large and varied in shape and structure..... *Delarthum*
- 4 (3) Solenophore complex, large and coiled.....*Telodrepanum*

4.6.1.1.1.1.1.1.1 Descriptions to the species of genus *Delarthum*, Attems 1936 collected from sacred groves of North Kerala.

Taxonomy

Order Polydesmida Latreille, 1802/03

Family Paradoxosomatidae Daday, 1889

Subfamily Alogolykinae Hoffman, 1963

***Delarthrum anomalans* sp.nov. (Golovatch et al., 2022)**

Material examined. Male holotype (CATE-61604A), 2 male (CATE-61604B and CATE-61604C) and 2 female paratypes (CATE-61604D and CATE-61604E), India, Kerala state, Thrissur district, 10°21'19''N, 76°12'48''E, 29 m a.s.l., in June 2021 and 1 male (CATE-61604J) and 2 female paratypes (CATE-61604K and CATE-61604L all in 5302B–CATE-5302I) from the sacred groves of Valliyur kavu, Manathavady, Wayanad district, 11°48'08''N, 76°01'55''E, 716 m a.s.l., M.D. Aswathy leg.

Name. To emphasize the anomalous absence of adenostyles from both male legs 1 and 2.

Diagnosis. Differs from congeners by the absence of adenostyles from both male legs 1 and 2, coupled with the sexually dimorphic colour pattern, the transverse tergal sulci starting with the collum, and the peculiar gonopodal conformation, primarily the presence of a small, thumb-shaped, distoventral projection (a) basal to the division of the postfemoral part into (1) the main, dorsal piece of the solenophore (sph), which is long, obliquely truncate dorsad at the base, bifid in the distal third and slightly curved mesad, and (2) a dorsal process that is split immediately at the base into a longer, stalked, leaf-shaped outgrowth (b) with peculiar, ragged, saw-like distal margins, and a much shorter, simple, dorsobasal peg (z).

Description. Length of holotype, 17.9 mm, of paratypes, 17.0–17.6 mm (male) or 14.0–14.8 mm (female).

Width of midbody rings, 2.6 mm (holotype), 1.9–2.1 mm (male paratypes) or 2.0–2.3 mm (female paratypes). Coloration sex-dimorphic: in vivo, dorsum dark brown to black, venter chestnut brown (male) (Figs.) to yellowish white (female) (Fig.); paraterga mostly contrasting pale. Legs light brown (male) or whitish (female). Coloration after one month of preservation in 96% ethanol somewhat darkened, but pattern evident (Figs 17 C & D).

Body with 20 rings in both sexes. In width, collum < head < ring 2<3<4<5<6<7<8<9=10, body gradually tapering thereafter. Vertex glossy and bare; stipes, cardo and clypeus moderately setose, epicranial sulcus distinct and ending before the level of antennal sockets. Clypeal region with ca 5+5 setiferous pits. Antennae moderately long, only slightly clavate, extending back to ring 4 when stretched caudolaterally (Fig 17 A). Relative antennomere lengths: 1<6<4<2<5<3. Antennomere 6 broadest apically, post-antennal groove shallow, diameter of antennal socket and isthmus between sockets subequal, 0.24 and 0.23 mm, respectively (Fig. 17 E). Antennomeres 5–7 each with a distinct dorso-apical group of basiconic sensilla (both male and female), these being especially conspicuous on antennomere 5 Paraterga mostly well developed, keel-shaped, set at about upper third of body height. Collum ovoid, paraterga small, subtriangular and broadly rounded. Anterior margin of collum with a single transverse row of fragile short setae. Anterior and posterior margins of following rings rather straight and parallel. Anterior margin with a transverse row of 2+2 short setae similar to those on collum. Paraterga 2 as usual,

set clearly lower than 3rd, squarish in shape, anterior corner/lobe drawn anteriorad. Following paraterga 3–17 regularly rounded anterolaterally and increasingly drawn caudolaterad into acute triangles, but still lying within rear tergal margins, vs. small, spiniform and slightly drawn past rear tergal margin on rings 18 and 19. Lateral calluses of paraterga thin, only slightly thicker on pore-bearing rings than on poreless ones, smooth, delimited by distinct sulci both dorsally and, to a lesser degree, ventrally; usually with a few short setae retained at lateral margin. Tegument generally smooth and shining, prozonae very delicately shagreened, metazonae mostly striate/striolate at bases of paraterga and near transverse sulci, surface being slightly undulate. Tergal setae mostly short and inconspicuous, present both on paraterga and in anterior half of metaterga. Two deep transverse sulci present on collum, followed by one prominent sulcus on metazonae 2–18, smooth at bottom and reaching the base of paraterga. A faint axial line traceable on most metazonae until 18th. Strictures between pro- and metazonae narrow, nearly smooth, at most faintly striolate.

Pore formula normal (5, 7, 9, 10, 12, 13, 15–19), ozopores small, circular, opening at ca 1/3 off caudolateral corner of pore-bearing calluses. Pleurosternal carinae decreasing in size from 2 to 4. Epiproct conical and flattened dorsoventrally, extending well beyond anal valves; tip truncate, subapical lateral incisions evident; hypoproct subtriangular, with 1+1 setae on minute knobs.

Legs moderately long and slender, clearly longer and thickened in male compared to female, rather densely setose ventrally and with short claws; male legs with tarsal brushes absent only from last two leg-pairs. Prefemora and coxae each bearing a moderately long and stiff distoventral seta. Podomere length ratios: coxa < prefemur < tibia = postfemur < tarsus < femur. Neither male leg-pair 1 nor 2 with any adenostyles, only coxae 2 as usual, with gonopores on small knobs (Fig 18 B). Sternal lobe between male coxae 4 small, conical and densely setose.

Gonopodal aperture transverse and suboval in shape, about 2/3 as wide as prozonite 7, its rim being not elevated, but thickened laterally (Fig. 18 B). Gonopods high, complex, in situ held parallel to each other. Coxite darkened, about as long as femorite, subcylindrical, setose distoventrally; cannula a short-curved tube, as usual. Prefemoral part short, globose, densely setose as usual, with a particularly long seta

distoventrally. Femorite (fe) relatively stout and short, somewhat enlarged distad, subclavate, almost as long as acropodite (= postfemoral part), subcylindrical, without evidence of torsion; a small, thumb-shaped, distoventral projection (a) basal to acropodite bifurcation into a longer, larger, more slender, subacuminate, ventral, solenophore branch (sph), rather slightly curved dorsad and bearing both a strong spine (k) in distal third and a free solenomere (sl), and a shorter, more elaborate, dorsal process divided immediately at base into a longer, stalked, leaf-shaped outgrowth (b) with peculiar, ragged, saw-like distal margins, and a much shorter, simple, dorsobasal peg (z). Seminal groove first running all along mesal side of femorite, then turning slowly towards bifurcation point before moving onto a free, flagelliform sl tightly attached to mesal side of sph, with only a short tip of sl remaining exposed over sph. Division of fe and acropodite through a transverse sulcus, or of sph into laminae, wanting (Figs 18 A, C & D).

Distribution: Wayanad, Kerala, India (Fig 18 E).

4.6.1.1.1.1.1.2 Descriptions to the species of genus *Telodrepanum*, Carl 1932 collected from sacred groves of N. Kerala

Taxonomy

Order Polydesmida Latreille, 1802/03

Family Paradoxosomatidae Daday, 1889

Subfamily Alogolykinae Hoffman, 1963

Genus *Telodrepanum*, Carl 1932

Type-species: *T. badaga* Carl, 1932, by monotypy.

Telodrepanum badaga Carl, 1932

Telodrepanum badaga Carl, 1932: 458 (D). India, Nilgiris, Kotagiri.

Telodrepanum badaga—Attems, 1936: 233 (R); 1937: 153 (D); Jeekel, 1968: 85 (M); Bano, 1997: 12 (M); 1998a: 89 (M); Nguyen & Sierwald, 2013: 1183 (M).

Telodrepanum bedga (sic!)—Bano, 1983: 168 (M).

Teledrepanum (sic!) *badaga*—Bai, 2001: 46, 49 (R)

***Telodrepanum badaga* Carl, 1932 (Fig 19)**

Material examined. Male holotype (CATE-61604A), from the sacred groves of Muchukunnu Kotta Kavu, Moodadi, Kozhikode district, 11°29'20"N 75°40'10"E, 50 m a.s.l., M.D. Aswathy leg.

Diagnosis. This is the only species reported yet from South India from the genus *Telodrepanum*. Species differ from their congener species by the length and orientation of the distofemoral process of the gonopod. It is longer and distad in *T. badaga* while the distofemoral process is a short spinelike structure with laterad orientation in the other congener *Telodrepanum* sp. From Dharwar.

Description. Length of specimen, ca. 24.9 mm (male). Width of midbody rings, ca. 1.6 mm

Colouration sex-dimorphic: Coloration after one month of preservation in 96% ethanol, dorsum black or dark brown, venter chestnut colour with pale yellowish-brown appendages. Paranota not distinctly colored, dark brown or black. (Fig 19 A).

Body with 20 rings in both sexes. In width, collum < head < ring 2<3<4<5<6<7<8<9=10, body gradually tapering thereafter (Fig 19 A). Vertex glossy and bare; stipes, cardo and clypeus moderately setose, epicranial sulcus distinct and ending before the level of antennal sockets. Antennae moderately long, only slightly clavate, extending back to ring 4 when stretched caudolaterally. Relative antennomere lengths: 1<4<5<6<2<3. Antennomere 6 broadest apically, post-antennal groove shallow, diameter of antennal socket and isthmus between sockets subequal, 0.21 and 0.24 mm, respectively (Fig.19 C). Paraterga not well developed, present as a slight projection laterally, set at about upper third of body height. Collum ovoid, paraterga small, subtriangular and broadly rounded. Paraterga 2 as usual, set clearly lower than 3rd, squarish in shape, anterior corner/lobe drawn anteriorad. Following paraterga 3–17 regularly rounded anterolaterally and increasingly drawn caudolaterad into acute triangles, but still lying within rear tergal margins vs. small, spiniform and slightly drawn past rear tergal margin on rings 18 and 19 (Fig 19 B). Lateral calluses of paraterga thin, only slightly thicker on pore-bearing rings than on poreless ones, Tegument generally smooth and shining. Tergal setae mostly short and inconspicuous, present both on paraterga and in anterior half of metaterga. Two deep transverse sulci present on collum, followed by one prominent sulcus on metazonae 2–18, smooth at bottom and reaching the base of paraterga. A faint axial line

traceable on most metazonae until 18th. Strictures between pro- and metazonae narrow, nearly smooth, at most faintly striolate.

Pore formula normal (5, 7, 9, 10, 12, 13, 15–19), ozopores small, circular, opening at ca 1/3 off caudolateral corner of pore-bearing calluses. Pleurosternal carinae decreasing in size from 2 to 4. Epiproct conical and flattened dorsoventrally, extending well beyond anal valves; tip truncate, subapical lateral incisions evident; hypoproct subtriangular, with 1+1 setae on minute knobs.

Legs moderately long and slender, clearly longer and thickened in male compared to female, rather densely setose ventrally and with short claws; male legs with tarsal brushes absent only from last two leg-pairs. Prefemora and coxae each bearing a moderately long and stiff distoventral seta. Podomere length ratios: coxa < prefemur < tibia = postfemur < tarsus < femur. Male leg-pair 2 with femoral adenostyles, only coxae 2 as usual, with gonopores on small knobs. Tarsi with thick tarsal brush. Sternal lobe between male coxae 4 small, bilobular and densely setose.

Gonofemorite slender, long, suberect and untwisted, with two distomesal processes (a and b), of which b is unusually large and shield-like; solenophore (sph) large and strongly coiled, with a basomesal protecting lobe (lo) to shield the basal loop of a free flagelliform solenomere (sl) (fig 19D)

Distribution. Nilgiris, Kotagiri, Tamil Nadu and Muchukunnu kottaKavu, Kozhikode district kerala, India (Fig 19E).

4.6.1.1.1.1.1.1.3 Genus *Chondromorpha* Silvestri, 1897

Body with 20 segments. Well-developed Paranota with thick granulated metaterga. Medium-sized species with normal pore formula. Pleural keels indistinct. A well-developed sternal lamella between male coxae 4. Gonopod aperture with only a posterior rim projection. Gonopodal femorite short, without any torsion. Seminal groove running along medial face of femorite. Postfemoral portion with a moderately long solenophore and a basal process. Solenophore with a distal lappet to accommodate a curved distal part of solonomere, with a well-developed lamina lateralis and a moderately developed lamina medialis. Lamina lateralis with lateral splits forming saw-like teeth of varying size and number. Solenomere simple, its distal part being sheathed by lamina lateralis, with a barely exposed tip.

Diagnosis. Distinguished from congeners by well-developed Paranota with thick granulated metaterga.

4.6.1.1.1.1.1.3.1 Description of the species of Genus *Chondromorpha* Silvestri, 1897

Taxonomy

Order Polydesmida Pocock, 1887

Suborder Strongylosomatidea Brölemann, 1916

Family Paradoxosomatidae Daday, 1889

Tribe Sulciferini Attems, 1898

Genus *Chondromorpha* Silvestri, 1897

Type-species: *C. severini* Silvestri, 1897, by monotypy.

= *Polydesmopeltis* Verhoeff, 1936, [synonymized by Attems (1937)].

Type-species: *Polydesmus kelaarti* Humbert, 1865.

= *Ceylonpeltis* Verhoeff, 1936, [synonymized by Jeekel (1963)].

Type-species: *Prionopeltis xanthotrichus* Attems, 1898.

***Chondromorpha kelaarti* Humbert, 1865**

Polydesmus Kelaarti (sic!) Humbert, 1865: 25.

Paradesmus kelaarti: Pocock, 1892: 149.

Prionopeltis Kelaarti (sic!): Attems, 1898: 358.

Anoplodesmus Kelaarti (sic!): Attems, 1914: 205.

Anoplodesmus kelaarti: Carl, 1932: 461.

Polydesmopeltis (Polydesmopeltis) kelaarti (genuinus) (sic!): Verhoeff, 1936: 112.

Polydesmopeltis (Polydesmopeltis) kelaarti, carli (sic!): Verhoeff, 1936: 112.

Polydesmopeltis kelaarti (sic!): Bhakat, 2014: 186.

Chondromorpha kelaarti:—Attems, 1936: 210, 212; 1937: 110; Karandikar and Rodgi, 1955: 11; Jeekel, 1968: 82; Rajulu, 1970: 131; Rangaswamy and Channabasavanna, 1969: 9; Demange, 1977: 232; Rangaswamy et al., 1978a: 96; 1978c: 100; 1983: 8; Bano, 1983: 169; 1997: 12; 1998: 89; Prasad and Janardanan, 1994: 197; Bano and Murthy, 1997: 159; Stoev et al., 2010: 127; Nguyen and Sierwald, 2013: 1282; Minelli, 2015: 407.

Chondromorpha keelarti (sic!): Chamberlin and Wang, 1953: 6.

Chondromorpha atopus — Chamberlin, 1920: 395

Chondromorpha indus — Chamberlin, 1920: 393

Chondromorpha kelaarti kelaarti (Humbert, 1865): Attems, 1937: 11; Nguyen and Sierwald, 2013: 1282; Golovatch and Wesener, 2016: 43 [Synonymized by Sankaran & Sebastian. 2017].

Chondromorpha kelaarti longipes (Verhoeff, 1936): Attems, 1937: 111; Nguyen and Sierwald, 2013: 1282; Golovatch and Wesener, 2016: 43 [Synonymized by Sankaran & Sebastian. 2017].

Chondromorpha kelaarti valparaiensis: Attems, 1936: 213; 1937: 111. Nguyen and Sierwald, 2013: 1282; Golovatch and Wesener, 2016: 44 [Synonymized by Sankaran & Sebastian. 2017].

Remark: Carl (1932) and Attems (1937) believed that both *C. atopus* and *C. indus* (Chamberlin, 1920) represent

junior synonyms of *C. kelaarti*, which Jeekel (1965) transferred from *Anoplodesmus* (Golovatch & Wesener, 2016).

Material examined. Male specimen (CATE-60304A - CATE 60304M), and female specimens (CATE 60304N - CATE 60304 G (i)) from the sacred groves of Muchukunnu Kotta Kavu, Moodadi, Kozhikode district, 11°29'20"N 75°40'10"E, 50 m a.s.l., and Valliyoor Kavu in Wayanad, 11°48'16.1"N 76°01'48.1"E, 30 a.s.l. M.D. Aswathy leg (Fig 20 F).

Diagnosis: *Chondromorpha kelaarti* can be seen very similar to its congener, *C. severini* in many morphological features. But both the species can be differentiated by the characteristics of their sternal lobe between coxae 4 being in trapezoid shape with short pair of anterior processes while in *C. severini* sternal lobe is spherical without any processes. Another difference is with the solenophore bearing a prominent distal lappet in *C. kelaarti* while this is not observed in *C. severini*

Description:

Body with 20 segments (male and female). Length ca 43 – 45 mm (male) and 39 – 52 mm (female), width of midbody pro- and metazona 2.2 and 2.9 mm (male) or 2.6 and 4.8 mm (female), respectively. Width of midbody paranota 3.0 mm (male) and 4.3 mm (female).

Colouration of live animals brownish black; antennae brownish; angular part of paranota yellowish; surface below paranota, as well as legs yellowish brown;

sternites pallid brown coloured. Colouration of alcohol material after preservation faded to brownish, posterior part of paranota, as well as legs pale brown coloured.

Body with 20 rings in both sexes. In width, collum < head < ring 2<3<4<5<6<7<8<9=10, body gradually tapering thereafter (Figs 20 A). Vertex smooth; frons, stipes, cardo sparsely setose, clypeus moderately setose; epicranial sulcus distinct, ending at midanterior level of antennal sockets. Antennae long, reaching dorsally mid of ring 4; relative antennomere lengths: 2 < 3 > 4 < 5 > 6; antennomere 6 widest apically; post-antennal groove shallow; antennal socket diameter and isthmus between them 0.9 mm and 1.24 mm, respectively. Collum with lateral margin strongly produced as a paranotum, anterior and lateral margins concave, without any marginal setae (Fig. 20 B); collum dorsally bearing three transverse rows of short setae.

lateral margins of paranota thicker on pore-bearing rings. Pleural keels less evident, represented as narrow thickenings. Prozonites smooth. Metazonites, dorsal surface of paranota and surface below paranota granulate; transverse furrow on metazonites distinct from haplosegments 2–3 and diplosegments 4–16, not reaching paranotal base; limbus a thin, continuous ribbon. Axial line barely traceable both on pro- and metazonae. Pore formula normal (5, 7, 9, 10, 12, 13, 15–19); ozopore small, circular, opening laterally on thickened paranotal margin at level of transverse furrow of metazonites. Legs slender, without tarsal brushes, with moderately long claws (Fig.), all coxae and prefemora bearing a single, ventral, stiff, long seta; relative podomere lengths: femur > tarsus > postfemur > prefemur > tibia; all prefemora swollen laterally (Fig.); leg I without modifications. Pre-anal ring sparsely setose; epiproct conical, flattened dorso-ventrally, extending behind anal valves, tip subtruncate; hypoproct roundly subtriangular.

Gonopod located on the 7th segment in transversely oriented aperture, with raised lateral rim, Gonopods slender, simple, lying close to sternites. Coxite long, subcylindrical, setose distodorsally (Fig. 20 C). Cannula cylindrical, normal (Fig. 20 D). Prefemur long, densely setose (Figs), with a long and stiff seta distoventrally, with a clear-cut, oblique, distal sulcus demarcating the acropodite. Femorite short, subcylindrical, without evidence of torsion, with a median longitudinal fold

seminal groove running medially along femorite. Solenophore moderately long, strongly curved mesally; distal lappet with lateral margins placed closely, with a short triangular process mesally; lamina lateralis wide, only mesally with paired wide splits resulting into a pair of teeth, median tiny, basal short; basal postfemoral process wide proximally, narrow distally, lying close to femorite. Solenomere simple, long, with a wide base, abruptly curved mesally, distal part sheathed by lamina lateralis.

Distribution. Sri Lanka, introduced to Great Britain. Also, India, Tanjore; Madras; Coimbatore; Nilgiris, Anaimala Hills; Courtalam, Muchukunnu Kotta Kavu, Kozhikode and Valliyurkavu in Wayanad districts of Kerala.

4.6.1.1.1.1.1.1.4 Genus *Anoplodesmus* Carl, 1932

Body with 20 segments. Well-developed Paranota with thick granulated metaterga. Medium-sized species with normal pore formula. Pleural keels indistinct. A well-developed sternal lamella between male coxae 4. Gonopod aperture with only a posterior rim projection. Lateral rolls of paraterga thick and round. Femur and prefemur of 1st legs of male without a gland and generally without a process.

Diagnosis. The genus is distinguished from other genera of the tribe by solenophore of gonopod being triramous with a large two-pointed lamella or deeply bifid, one branch directed basally.

4.6.1.1.1.1.1.1.4.1 Description of species of genus *Anoplodesmus* collected from Sacred groves of N. Kerala

Taxonomy

Family Paradoxosomatidae Daday, 1889

Subfamily Paradoxosomatinae Daday, 1889

Tribe Orthomorphini Brölemann, 1916

Genus *Anoplodesmus* Carl, 1932

Type-species: *A. anthracinus* Pocock, 1895, by subsequent designation (cf. Jeekel 1971: 216).

= *Paranedyopus* Carl, 1932, [synonymized by Golovatch (2000)].

Type-species: *P. subcylindricus* Carl, 1932.

= *Himantogonus* Carl, 1932, [synonymized by Jeekel (1968)].

Type-species: *H. rufocinctus* Carl, 1932.

= *Akribosoma* Carl, 1935, [synonymized by Golovatch (1984)].

Type-species: *A. cylindrica* (recte: cylindricum) Carl, 1932.

= *Jonespeltis* Verhoeff, 1936, [synonymized by Attems (1937)].

Type-species: *J. splendidus* Verhoeff, 1936.

***Anoplodesmus saussurii* (Humbert, 1865)**

Polydesmus Saussurii Humbert, 1865: 26 (D).

Anoplodesmus saussurei (sic!)—Prasad et al., 1981: 125 (M, R); Dey & Prasad, 1985: 111 (M); Joy et al., 1998: 117 (M); Pramanik et al., 2001: 53 (M); Decker & Tertilt, 2012: 142 (D); Sanyal et al., 2012: 865 (R).

Anoplodesmus saussurii—Bano, 1996a: 74 (M); 1997: 1 (M); 1998a: 89 (M); Bano & Murthy, 1997: 158 (D);

Shelley & Lehtinen, 1998: 88 (D); Nguyen, 2010: 53 (M); Nguyen & Sierwald, 2013: 1277 (M); Bhakat, 2014: 186

(R); Rukhsana et al., 2015: 650 (R); Minelli, 2015: 86 (M); Dash & Priyadarsini, 2016: 55 (R, D); Chezhan &

Prabakaran, 2016: 91, 92 (R, D).

Material examined: Male specimes (CATE-61607A – CATE 61607O), and female specimens (CATE 61607P – CATE61607 V(ii)) from the sacred groves of Muchukunnu Kotta Kavvu, Moodadi, (11°29'20"N 75°40'10"E), Poyilkavu, Chemencheri, (11° 24' 34.56" N 75° 42' 58.32" E), Vallikattukavu, Atholi, (11°23'17"N 75°47'10"E), Kozhikode district; Valliyurkau, Mananthavady (11° 48 '16.1"N 76° 01' 48.1"E), Maanikavu, Choothupara, (12°2'4.99"N 75°15'41.14"E) in Wayanad district; Poongottukavu, Mattanur (11° 55 '14.7" N 75° 36' 58.9" E), Chamakavu, Vellur (12° 09 '07.03" N 75° 12' 35.5" E), Neeliyarkottam, Dharamshala (11° 56 '03.8" N 75° 21' 50.0" E), and Madayi Kavvu, Pazhayangadi (12°2'4.99"N 75°15'41.14"E) in Kannur district and Sree Malliyodan Kavvu, konnakad (12° 22 ' 1.24"N 75° 19' 22.8" E), Payyankulam Kavvu, Karinthalam (12° 17 ' 41.7"N 75° 12' 18.96" E), Mannampurath Kavvu, Nileschwaram (12° 15 ' 27.6"N 75° 07' 59.4" E), Puthiyaparambath Kavvu, Nileschwaram (12° 15 ' 34.56"N 75° 07' 41.16" E), Koyithatta sree dharma sastha Kavvu, Koyithatta (12° 17 ' 11.4"N 75° 14' 53.88" E), and Edeyilakad Kavvu, Valiyaparambath (12° 08 '10.72" N 75° 09' 23.88" E) in Kasaragod district. M.D. Aswathy leg.

Diagnosis. Organism diagnosed from the congeners by the attributes of coxite with a few strong setae distodorsally, prefemoral part prominent, only slightly shorter than acropodite; femorite with a strong ventral tooth (a), solenophore bipartite, with two apical lobes (b, c), lobe c supporting a short solenomere (sl).

Description: Length *ca* 35 – 47 mm, width of pro- and metazona 3.1 and 4.3 mm, respectively (♂), or 42, 4.0 and 4.6 mm, respectively (♀). Colour pattern highly vivid (Fig.21 C & D), shiny black to dark brown, with contrasting bright yellowish paraterga and the immediately adjacent regions.

Body with 20 rings in both sexes. In width, head <collum < ring 2<3<4<5<6<7<8<9=10, body gradually tapering thereafter (Figs). Vertex smooth; frons, stipes, cardo sparsely setose, clypeus moderately setose; epicranial sulcus distinct, ending at midanterior level of antennal sockets. Antennae moderately long, reaching up to ring 3; relative antennomere lengths: 2 <3 > 4 < 5 > 6. Collum with lateral margin strongly produced as a paranotum, anterior and lateral margins blunt and and anterior angles rounded, without any marginal setae (Fig.21 A). Paraterga grow narrower towards the telson. Metatergal transverse groove not exceeding the paraterga. Pleurosternal Carinae strong with projections placed rather high in the segment almost horizontally and slightly wanting or drooping towards the 3rd or 4th ring. Sternal lobe between coxae 4 is bilobed, bulbous and hairy.

Paraterga well-developed, set rather high (about 1/4th of midbody height), callus wide, thicker in pore-bearing paraterga. Pore formula normal, 5, 7, 9, 10, 12, 13, 15— 19. Ozopores small circular openings located in the mid metateral region. Legs only slightly enlarged in male, rather long and slender, about 1.3 (♂) or 0.9 (♀) times as long as midbody height. Epiproct subtruncate. Hypoproct roundly subtrapeziform (Fig 21 B.).

Gonopods simple exposed and proximally directed telopodite. Both the gonopods parallelly located inside a sub-oval cavity. coxite with a few strong setae distodorsally, prefemoral part prominent, only slightly shorter than acropodite; femorite with a strong ventral tooth (a), solenophore bipartite, with two apical lobes (b, c), lobe c supporting a short solenomere (sl) (Fig 21 E).

Distribution: Sri Lanka, Mascarene Islands (Mauritius), Singapore, Fiji, Vanuatu. Also, India, West Bengal, Hugli; Ballavpur Reserve Forest near Santiniketan; Howrah, Nischindapur; Bangalore; Malappuram, Kerala; Gujarat; Tamil Nadu (Fig 22 A & B).

4.6.1.1.1.1.1.1.5 Genus *Orthomorpha* Bollman, 1893

Body with 20 segments. Body medium- to largesized, adults ca 15–50 mm long, ca 1.1–3.1 and 1.5–6.7 mm wide on midbody pro and metazona, respectively. Paraterga well-developed, Adenostyles on ♂ legs 1 missing. Sternal lobe or cone(s) between ♂ coxae 4 sometimes present (Likhitrakarn et al., 2011).

Densely setose, the prefemoral region is around two to three times shorter than the femorite. Femorite without torsion (i.e., seminal groove solely going mesally). Only a moderately strongly curved mesad or caudomesad, the solenophore is made up of moderately developed laminae lateralis and medialis, with the latter slightly larger than the latter (Likhitrakarn et al., 2011). Both sheath a similarly long, simple, flagelliform solenomere with a barely exposed tip; the tip of the solenophore is never deeply split, typically poorly bi- or trifold, and some of its apical prongs being either minute denticles or lappets, or small teeth, or completely reduced (Likhitrakarn et al., 2011).

Diagnosis. *Orthomorpha* characterized by broad paraterga. Gonopod with elongate, slender femorite (+ possible postfemoral part). Solenophore long, slightly curved, without midway or basal structures. Tip not deeply split, usually weakly bi- or trifold, with apical prongs as small denticles, lappets, teeth, or reduced (Likhitrakarn et al., 2011).

4.6.1.1.1.1.1.1.5.1 Description of species of genus *Orthomorpha* Bollman, 1893, collected from Sacred groves of North Kerala

Taxonomy

Family Paradoxosomatidae Daday, 1889

Subfamily Paradoxosomatinae Daday, 1889

Tribe Orthomorphini Brölemann, 1916

Genus *Orthomorpha* Bollman, 1893

***Orthomorpha coarctata* (de Saussure, 1860)**

Type-species: *Polydesmus beaumontii* Leguilou, 1841, by subsequent designation of Pocock (1909).

Orthomorpha coarctata—Mukherjee, 1962: 25 (R); Mukhopadhyaya & Saha, 1981: 357 (M); 1984: 374 (M, R);

Bandyopadhyay & Mukhopadhyaya, 1988: 7 (M, R); Bhakat, 1989a: 49 (M, R); 2014: 186 (R); Bano & Murthy,

1997: 160, 161 (D); Bano, 1998a: 89 (M). All over India.

Orthomorpha coarctata coarctata—De & Mitra, 1999: 117 (M, R).

Asiomorpha coarctata—Dash & Priyadarsini, 2016: 56 (R, D).

Polydesmus coarctatus De Saussure 1860: 297 (D).

Paradesmus flavocarinatus Daday 1889: 136 (D). [Synonymised by Enghoff, 2005]

Orthomorpha coarctata – Attems 1937: 62 (D); Jeekel 1968: 45 (M) et auctorum. *Orthomorpha coarctata gigas* Attems

1927: 63 (D).

Asiomorpha coarctata – Verhoeff 1939: 117 (D) et auctorum.

Orthomorpha coarctata gigas – Jeekel 1968: 45 (M); Golovatch 1998: 43 (D) et auctorum [Synonimized by Jeekel, 1986].

Remarks: This common, pantropical, anthropochoric species is also known from various parts of India. It is often placed in the monotypic genus *Asiomorpha* Verhoeff, 1939 (e.g. Nguyen & Sierwald 2013), but Likhitrakarn et al.'s (2011) revision of *Orthomorpha* is followed here.

Material examined. 3 Male and 1 female (CATE-60801A – CATE60801 C), and CATE-60801D, from the sacred groves of Poyilkavu (11.4096° N, 75.7162° E), Kozhikode district, 5 m a.s.l., M.D. Aswathy leg.

Diagnosis Can be diagnosed from the congeners by tip of solenophore produced into a single lobe, all other spikes or denticles being either missing or nearly missing.

Description

Length *ca.* 18– 24 mm, width of pro- and metazona 3 and 3.3 mm, respectively (♂), or 3.0 and 3.5 mm, respectively (♀). Colour pattern highly vivid (Fig 23 B.), shiny black to dark brown, with contrasting bright yellowish paraterga and the immediately adjacent regions. Body with 20 rings in both sexes. Antennae moderately long (Fig.), reaching behind midway of body segment 3 (♂) or beyond segment 2 (♀). Head in

width < collum < segments 3 and 4 < segment 2 < segments 5–16(17), gently and gradually tapering thereafter. (Figs 23 C). Vertex smooth; frons, stipes, cardo sparsely setose, clypeus moderately setose; epicranial sulcus distinct, ending at midanterior level of antennal sockets. Antennomere lengths: 2 < 3 > 4 < 5 > 6. Collum with lateral margin strongly produced as a paranotum, anterior and lateral margins blunt and anterior angles moderately rounded, without any marginal setae (Fig 23 C.). Paraterga grow narrower towards the telson. Metatergal transverse groove prominent and reaching up to paraterga. Pleurosternal Carinae strong with projections placed rather high in the segment almost horizontally and slightly wanting or drooping towards the 3rd or 4th ring. Sternal lobe between coxae 4 is absent or rudimentary.

Pore formula normal, 5, 7, 9, 10, 12, 13, 15—19. Ozopores small circular openings located in the mid metateral region. Legs only slightly enlarged in male, rather long and slender. Epiproct subtruncate. Hypoproct roundly subtrapeziform (Fig 23 G)

Gonopods simple exposed and proximally directed telopodite. Both the gonopods parallelly located inside a sub-oval cavity. Gonopods (Fig 23 A) with tip of solenophore produced into a single lobe, all other spikes or denticles being either missing or nearly missing.

Distribution: All over India (Fig 24 A & B).

4.6.1.1.1.2 Family Pyrgodesmidae Silvestri, 1896

Species with length 3–16 mm, tergal colouration brownish to grayish, rarely variegated. Incapable of volvation: paraterga 2 is not substantially expanded, but the collum, which has clear radiating lines or frontal lobulations, covers the head from above. Strongly differentiated metatergal tubercles normally have two paramedian rows of notably robust tubercles; paraterga often have anterior and/or posterior border lobulations (Minelli 2015). On porosteles, the pore formula typically deviates from normal, either decreased or extended. Over 170 largely monotypic genera and almost 400 tropical species, found sporadically in southern Europe, northern Africa, the United States, Japan, Taiwan, and central China.

**4.6.1.1.1.2.1 Key to the genera of Family Pyrgodesmidae Silvestri, 1896,
collected from Sacred groves of North Kerala**

Of the 170 genera described yet 3 genera have been collected from the sacred groves of North Kerala. And the key to which is as follows.

- 1 (2) Species with pores located on porosteles and follow a specific sequence of pore formula.....(3)
- 2 (1) Species with ozopores not located on porostele, and the ozopore located on the 5th body ring only.....*Pagodesmus*
- 3 (4) Species with pore formula 5, 9, 12, 15, 17 — 19. *Propyrgodesmus*
- 4 (3) Species with pore formula 5, 7, 9, 10, 12, 13, 15, & 16*Klimakodesmus*

4.6.1.1.2.1.1 Genus *Klimakodesmus* Carl, 1932

This genus shows a body shape and an ornamentation pattern typical of Pyrgodesmidae, characterized by 20 segments/rings (19+T) both in the male and female; a flabellate collum is strongly domed and tuberculate, completely covering the head from above, with 5+5 distinct, equal, clearly incised and rounded lobulations at a subhorizontal anterior margin; the antennae are short, two basal antennomeres of each antenna being sunken inside a distinct transverse groove, and antennomere 5 being much longer and thicker than the 6th; a cerotegument crust with microvilli covers most of the dorsal surface of the collum and following metaterga, the limbus being microlobulate and microspiculate caudally; body rings are strongly arched dorsally, each with 2+2 longitudinal rows of basically 2+2 or 3+3 larger and fused tubercles/lobes (paramedian, PM, and dorsolateral, DL), both rows largely representing higher bilobed keels mostly slightly inclined either forward or caudad, but PM always being higher than DL. PM of only ring 19 is abruptly and unusually strongly elongate and more or less clearly bilobate caudally, conspicuously overhanging and concealing a short epiproct from above (Figs 2–4, 8–10). Neither intercalary (i) series of grains nor antero- (Am), nor truly caudomarginal lobulations (Cm) are distinguished. The pore formula is normal: ozopores 5, 7, 9, 10, 12, 13, 15 and 16 are borne on distinct porosteles, vs. 17, 18 and 19 which open flush on the surface. The paraterga are set low (at about half the height of midbody metazonae), slightly declivous to subhorizontal, leaving the dorsum very convex, moderately bi-

or trilobate laterally regardless of a cylindrical porostele or ozopore located just before or upon the ultimate lobulation, respectively. The legs are short and stout, rather sparsely setose, the prefemur bearing a particularly strong seta distomesally, the tibia a distodorsal one. The gonopods are fairly simple, in situ either slightly diverging or distally crossing each other; each coxite is moderately enlarged, hemispherical or squarish, microgranulate and microsetose laterally, and concave medially, the gonocoel thus being moderately deep; the cannula is as usual, simple, moderately long and strongly unciform. The telopodite is simple, slender, unipartite, represented by a very strong, moderately long, but mostly exposed, gradually attenuating and acuminate solenomere.

Diagnosis. *Klimakodesmus* seems to be particularly similar to *Pyrgodesmus* in most somatic characters, as correctly noted by Carl (1932), but both genera are distinct primarily in gonopodal structure: clearly hypertrophied gonocoxites and “blade-like” telopodites (Pocock, 1892) vs. moderately incrassate, apparently smaller, subspherical or squarish gonocoxites, each of which supports a strong and unipartite telopodite represented solely by a slender, strongly exposed, increasingly attenuating and acuminate solenomere. In addition, PM crests, including the one on the penultimate ring that overhangs and fully conceals the epiproct from above, are much higher and stronger, whereas DL reduced, in *Pyrgodesmus* compared to *Klimakodesmus* species. A similar, remarkably strong, massive and largely exposed solenomere taking up most of the gonopod telopodite is also observed in the genus *Pseudocatapyrgodesmus* Miyosi, 1957, with *P. glaucus* Miyosi, 1957, the type species from Honshu, Japan (Miyosi 1957), and *P. pulcher* Golovatch, Semenyuk, VandenSpiegel & Anichkin. 2011, from southern Vietnam (Golovatch et al. 2011). Yet their gonopods are considerably more elaborate and clearly branched, vs. relatively very simple and unipartite in *Klimakodesmus*. They are the gonopods of *P. pulcher* that seem to be especially similar to those of *Klimakodesmus* (Golovatch et al. 2011). The strong, flattened, dorsal crest PM on the penultimate ring that overhangs and conceals the epiproct from above, however conspicuous, is unique to neither *Klimakodesmus* nor *Pyrgodesmus* species. For instance, several, but not all of the Afrotropical species of the genera *Monachodesmus* Silvestri, 1927 or *Udodesmus* Cook, 1896 show the same or very similar conditions (Golovatch et al. 2015, 2017).

4.6.1.1.1.1.1.1 Description of species belonging to Genus *Klimakodesmus* Carl, 1932, collected from Sacred groves of Kerala

Taxonomy

Family Paradoxosomatidae Daday, 1889

Subfamily Paradoxosomatinae Daday, 1889

Family Pyrgodesmidae Silvestri, 1896

Genus *Klimakodesmus* Carl, 1932

Type-species: *K. graveleyi* Carl, 1932, by monotypy.

***Klimakodesmus bilobocaudatus* sp.nov.(Aswathy et al., 2021)**

Material examined. Adult male holotype (CATE-5302), 2 adults male and 6 subadult female paratypes (CATE-5302B–CATE-5302I), 1 adult male and 2 subadult female paratypes, India, Kerala state, Kannur district, N11°58'2.5", E75°17'46.6", 5 m a.s.l., 27/01/2021, M.D. Aswathy leg.

Name. To emphasize a caudally relatively deeply bilobed dorsal keel (PM) on ring 19 in the new species; adjective.

Diagnosis. The new species differs clearly from *K. graveleyi*, the only other congener to be accepted (Carl 1932), by the more regularly tuberculate, the lower PM and DL which are mostly inclined caudad (vs. inclined forward until ring 16, , the caudally more deeply bilobed dorsal keel (PM) on ring 19 (vs. indistinctly bilobulate, , the laterally bi- (rings 3 and 4) or trilobate (remaining postcollum rings) paraterga (vs. mostly bilobate, trilobate only on ring 2), and the gonopods showing subspherical coxites (vs. squarish) and subcontiguous, apically subunciform and crossing each other (vs. divergent and suberect) telopodites, each of the latter additionally reinforced with a mesobasally thickened wall (vs. a laterobasal lobe).

Description. Length ca. 3.68 mm, width of midbody segments 0.10 and 0.14 mm on pro- and metazonae, respectively (holotype). Length of adult male paratypes ca. 3.0–3.8 mm, that of subadult female paratypes 3.2–3.5 mm. Width of adult male paratypes ca. 0.40–0.45 mm, that of subadult female paratypes 0.44–0.48 mm. Live

colouration generally pink; antennae, legs and venter translucent, lighter than dorsum. Colouration in alcohol after 2 months of preservation pale brown to pinkish brown, legs and antennae faded to translucent (Fig A, B C & D). No earth crust visible on body. Most characters as in the generic description above, except as follows. Body with 20 segments (likely in both sexes, see below). In width, head << collum < segment 2=3 < 4–6 < 7–9 < 10–15, body gradually tapering towards telson thereafter. Head circular, labral region moderately setose, epicranial suture rather deep, vertex microgranulate. Interantennal isthmus nearly as wide as diameter of antennal socket. Antennae short, weakly clavate, in situ reaching body segment/ring 3 when stretched ventrolaterally. In length, antennomere 7<3<1<6<4<2<<5; antennomeres 5–7 each with a more or less compact apicodorsal group of bacilliform sensilla (Figs). Collum flabellate, completely covering the head from above; anterior margin with 5+5 distinct, equal, moderately incised and rounded lobulations; central part domed, with 2+2 and 3+3 prominent and rounded tubercles arranged in two transverse rows (Figs 25 F). Paraterga set low (at about half of midbody height), subhorizontal to faintly declivous. Dorsum strongly arched, its outline smoothly extending onto paraterga. Prozonae, as well as deep and thin strictures between pro- and metazonae finely alveolate. Postcollum metaterga with strongly differentiated dorsal tuberculations: 2+2 longitudinal crests/rows of mostly 2+2 fused tubercles, those before ring 19 slightly inclined caudad, but PM on ring 19 abruptly modified into a mid-dorsal, strongly elongate, conspicuous and caudally clearly bilobate ridge overhanging and concealing a short epiproct (Fig 25 E). Paraterga broad, thin, rather irregularly tuberculate near bases and clearly lobulated laterally, with three rounded and moderately incised lobulations on rings 2–19, regardless of cylindrical porosteles located between the 2nd and 3rd lobulations on rings 5, 7, 9, 10, 12, 13, 15 and 16 only paraterga 3 and 4 with last lobulation in a clearly caudolateral position. Epiproct finger-shaped, tip bent down and divided into two round bulbs. Hypoproct semi-circular, with 1+1 strong setae borne on minute, caudal, paramedian knobs. Legs with neither adenostyles nor tarsal brushes. In length, tarsi > femora > prefemora > tibiae > coxae > postfemora; claws simple, slightly curved ventrally.

Gonopods (Figs 25 G & H) relatively simple, placed inside a transversely oblong-oval gonopodal aperture, the latter with thin and slightly elevated caudal and lateral margins; in situ, both gonopods strongly exposed, held mostly parallel to one another,

with only tips crossing each other. Coxites (cx) voluminous, but moderately enlarged, gono-coel thus being relatively shallow; cannulae simple. Telopodites directed caudally, each unipartite and subtriangular, long and slender, gradually attenuating distad and acuminate apically, each represented solely by a solenomere (sl) and supporting a seminal groove running along lateral margin to the end of a laterally directed and u//nciform apical part, and additionally reinforced basally through a distinctly thickened caudomesal wall of a prominent, membranous, mesal lobe (lo); prefemorite as usual, relatively short, densely and strongly setose.

Distribution. Thazhe Kavu, Kannur district (Fig 25 J).

4.6.1.1.1.2.2 Genus *Propyrgodesmus* Silvestri, 1920

The genus shows the typical characters of the family Pyrgodesmidae with 20 body rings in both male and female. Collum dome-shaped, flabellate and tuberculate, covering the head from above, with 5+5 moderately incised rounded lobulations at a subhorizontal anterior margin. Frons and vertex clearly granulated. Antennal pit/groove deep. Antennae short, antennomere 5 being the longest and thicker than remaining antennomeres. A cerotegument crust with microvilli covering the collum and following metaterga. Body rings strongly arched dorsally, each with 2+2 longitudinal rows of 3+3 larger and fused tubercles (paramedian and dorsolateral), both rows representing bilobed tubercles most of them slightly inclined caudad, but paramedian tubercles higher than dorsolateral tubercles. Paramedian tubercle of ring 19 overhanging the body and concealing the telson (ring 20) from above. Intercalary series of grains, as well as anteromarginal and caudomarginal lobulations largely indistinguishable. Pore formula abnormal (5, 9, 12, 15, 17–19), ozopores 5, 9, 12 and 15 borne on distinct porosteles, vs 17–19 open flush on the surface. Epiproct small, directed ventrad, with terminal bristles located on ventral side. Legs short and stout, sparsely setose, with neither any adenostyles nor tarsal brushes. Gonopods fairly simple, in situ directed caudad and held parallel to each other. Coxites moderately enlarged, hemispherical and microgranulate laterally, concave medially and devoid of any spines or hairs. Telopodite simple, bipartite, branching only at about midway, characterized by the presence of structures resembling lobes or prongs.

Diagnosis. *Propyrgodesmus* differs from other genera of the family mainly by the abnormal pore formula (5, 9, 12, 15, 17–19) vs normal pore formula (5, 7, 9, 10, 12,

13, 15–19); the arrangement of metatergal tubercles (trilobed paramedian tubercles in combination with overhanging paramedian tubercles of the ring 19 concealing the telson); the laterally extended lobular paraterga, and the medial rather than subcaudal position of porosteles (Carl, 1932). This genus seems to be especially similar to *Lobiferodesmus* Silvestri, 1920 in somatic features, but show significant differences in gonopodal structure: the presence of flattened, cylindrical telopodites, each of which is split into an acuminate main branch and a lobular medial branch, vs a unipartite and uncinat main branch which is sheathed by a lateral lamina (Silvestri, 1920; Golovatch et al., 2008).

4.6.1.1.1.2.2.1 Description of species belonging to Genus *Propyrgodesmus* Silvestri, 1920, collected from Sacred groves of Kerala

Taxonomy

Family Pyrgodesmidae Silvestri, 1896

Genus *Propyrgodesmus* Silvestri, 1920

Type-species: *P. lobulatus* Silvestri, 1920, by original designation.

***Propyrgodesmus bulbogonopus* sp.nov.(Aswathy & Sudhikumar, 2022)**

Material examined Holotype ♂ (CATE-5503A), Sacred groves of Kottayil Siva Kshethram, Muchukunnu, Kozhikode district, Kerala, India 11°29'42''N, 75°39'55''E, 9 m a.s.l., collected from rotting wood, hand collection, 08.10.2021, M.D. Aswathy leg.

Paratypes: 1 ♂ (CATE-5503B), 2 ♀♀ (CATE-5503C, D), 3 ♀♀ juveniles (CATE-5503E, F, G), same locality, hand-collected together with holotype, but from top soil.

Name. To emphasize the bulbous appearance of the medial branch of the gonopodal telopodite.

Diagnosis. When comparing to *P. lobulatus*, the new species shows major differences in the tergal ornamentation by having most paraterga only vaguely trilobulate laterally vs clearly trilobate and by the presence of a ventral cone on antennomere 4 bearing a long sensillum trichodeum, vs a ventral cone on antennomere 4 absent. On the contrary, the new species shows some similarities to

the tergal ornamentation of *P. frater*, but differs significantly in the biramous gonopod with a bulbous lateral branch of the telopodite vs with prong—and lobe-like structures on the main branch of the telopodite.

Description. Holotype ca 7.6 mm long, width of mid-body pro—and metazonae 0.78 and 1.5 mm, respectively. Male paratype ca 7.5 mm, width of pro—and metazonae 0.78 and 1.5 mm, respectively. Adult female paratypes ca 7.5 and 9 mm long, width of pro—and metazonae 0.76–0.85 and 1.5–1.6 mm, respectively. Live colouration dark brown, dorsum encrusted with soil particles; antennae, legs and venter pale whitish (Fig. Fig A & B). Both vertex and frons light brown, clypeolabrum whitish. Body broad due to large paraterga with 20 body rings in both sexes In width, head $\ll$ collum $\leq 2 < 3$ –16, body tapering thereafter towards telson. Head ovoid, slightly transverse and sparsely setose in clypeolabral region, granulate above antennal sockets either side of epicranial suture. Genae sub-quadrate and granulate. Interantennal isthmus twice as wide as diameter of antennal socket. Antenna short, weakly clavate, reaching up to body ring 3 when stretched ventrolaterally. In length, antennomere $7 < 6 < 1 < 3 < 4 < 2 < 5$ (Fig 26 C.). Dense and sharply delimited fields of sensilla basiconica located distodorsally on antennomeres 5 and 6. Sensory field of 5th antennomere not extending up to base of long sensillum trichodeum. Antennomere 4 with ventral sensillum trichodeum borne on a small, but evident cone/hump.

Collum flabellate (Fig 26 A.), completely covering the head from above, fore margin with 5+5 distinct, sub-equal, faintly incised, rounded lobulations, middle with 4+4 distinct tubercles. Dorsum strongly convex, paraterga lying below mid-body height, moderately sloping down at about 20–25°. Tegument covered with a microspiculate cerotegument. Postcollum paraterga thick and rather indistinctly lobulated laterally, three lobulations on 2nd and pore-bearing rings, vs two lobes on poreless ones. Pore formula: 5, 9, 12, 15, 17–19, ozopores borne on porosteles behind second lobulation of paraterga. All paraterga starting with 5th directed caudad. Metaterga behind collum with 2+2 longitudinal rows of 3+3 larger and fused tubercles, those before ring 19 slightly inclined caudad. Paramedian tubercle on ring 19 abruptly modified to form an elongated ridge overhanging and concealing the epiproct (Fig 2 D). Epiproct directed ventrad, with four setae on top. Hypoproct triangular, caudal edge with two strong and well separated setae on knobs (Fig.26 F). Legs with neither adenostyles

nor tarsal brushes, short, stout and enlarged, femur the longest (Fig 26 G). In length, femur > prefemur > tarsus > postfemur > tibia > coxa. Gonopods taking up nearly entire ventral surface of metazonum 7, almost reaching the base of paraterga (Fig.26 H). Gonopods relatively simple, placed inside a transversely oblong gonopodal aperture, with thin and slightly elevated caudal and lateral margins. Both gonopods held parallel to each other, strongly exposed, telopodite tips directed caudally. Coxites (cx) voluminous, transverse and microgranulate laterally. Gonocoel distinct, but not too deep; telopodites short, simple, biramous and distally carrying a long, in situ caudally directed and slightly bifurcate lamina with fringed/microspiculate lamellae; solenomere (sl) slender and barely exposed; medial branch (b) stalked, with a short bulbous structure emerging distolaterally. A laminar sheath covering the postfemoral part of telopodite with a caudally directed hook-shaped/unciform tip (h).

Distribution. Kozhikode, Kerala (Fig 28 A).

4.6.1.1.1.2.3 Genus *Pagodesmus* Carl, 1932

Males with 19 segments and 28 pairs of legs and females with 20 segments. Body unevenly covered with cerotegument. Head covered from above by the flabellate Collum. Antennae short, strongly clubbed. Collum and paraterga fully developed. Keels large, rectangular, on top with characteristic chitin loop; ozopores only present on the 5th segment, located distant from the margin. Arched convex back, with cusps or fields on the metazonites. The anal segment is hidden under the penultimate telson. Gonopods with large, bowl-shaped coxae, partially protruding, undivided telopodite, without femoral process; solenophore slender, straight and biramous.

Diagnosis. It differs from the other Cryptodesmid genera by the unequal number of segments in both sexes and by the simple shape of the gonopod telopodite. It has the adenostyle on the last pair of legs in common with species of *Archandrodesmus* and *Cryptocorypha*. The restriction of the ozopores to one pair, on the 5th segment, the character which is shared with the systematically distant South American genus *Biporodesmus* Attems, 1898. Only with the Cryptodesmid genus *Diporodesmus* Silv., from West Africa, which is also similar in body shape. But in *Diporodesmus* the ozopores are very close to the side edge of the paranota, the tail of the anal segment is completely visible from above and the antennae have a cylindrical 5th and 6th antennomeres.

4.6.1.1.1.2.3.1 Description of species belonging to Genus *Pagodesmus* Carl, 1932, collected from Sacred groves of North Kerala

Taxonomy

Family Pyrgodesmidae Silvestri, 1896

Genus *Pagodesmus* Carl, 1932

Type-species: *P. biporus* Carl, 1932, by original designation.

***Pagodesmus sulcifer* Carl, 1932**

Pagodesmus sulcifer Carl, 1932: 504 (D). India, Nilgiris, Coonoor.

Pagodesmus sulcifer—Attems, 1936: 245 (R); 1940: 310, 311 (D); Rajulu, 1970b: 137 (M); Bai, 2001: 46, 50 (R).

Material examined. Male specimens (CATE-61901A- CATE-61901I), and female specimens (CATE-61901J -CATE61901S) from Sacred groves of Kottayil Siva Kshethram, Muchukunnu, Kozhikode district, Kerala, India 11°29'42''N, 75°39'55''E, 9 m a.s.l., collected from rotting wood, hand collection, 08.10.2021, M.D. Aswathy leg (Fig 28 A).

Diagnosis. In comparison with the congeners, only *P. biporus* was described based on gonopods while others were described using female specimens. Therefore, this species can only be differentiated by the position of the chitin loop on the paraterga. The chitin loop on the paraterga is long, enclosing a sharp furrow extending towards the lateral edge of the paraterga unlike the congeners of the taxa.

Description. Specimen with ca 4.5 mm long, width of mid-body pro—and metazonae 0.7 and 1.3 mm, respectively.

Live colouration ashy brown brown, dorsum encrusted with soil particles; antennae, legs and venter pale whitish (Fig.27 A, B, & C). Both vertex and frons light brown, clypeolabrum whitish. Body broad due to large paraterga, with 20 body rings in both sexes. In width, head $\ll$ collum $\leq 2 < 3$ –16, body tapering thereafter towards telson (Fig 27 C.). Head ovoid, slightly transverse and sparsely setose in clypeolabral region, granulate above antennal sockets either side of epicranial suture. Genae sub-quadrate and granulate. Interantennal isthmus twice as wide as diameter of antennal socket. Antenna short, weakly clavate, reaching up to body ring 3 when stretched

ventrolaterally. In length, antennomere 6>3>5>2>4>7>1 (Fig 27 D). Dense and sharply delimited fields of sensilla basiconica located distodorsally on antennomeres 5 and 6. Sensory field of 5th antennomere not extending up to base of long sensillum trichodeum.

Collum flabellate (Fig.27 D), completely covering the head from above, fore margin with 5+5 distinct, sub-equal, faintly incised, rounded lobulations, middle with 4+4 distinct tubercles (Fig.). Dorsum strongly convex, paraterga lying below mid-body height, moderately sloping down at about 20–25°. Tegument covered with a microspiculate cerotegument. Postcollum paraterga thick and rectangular. An ozopore is present only on the 5th segment. Metaterga behind collum with 2+2 longitudinal rows of 3+3 larger and fused tubercles, those before ring 19 slightly inclined caudad. Paramedian tubercle on ring 19 abruptly modified to form an elongated ridge overhanging and concealing the epiproct (Fig 27 E.). Epiproct directed ventrad, with four setae on top. Hypoproct triangular, caudal edge with two strong and well separated setae on knobs. Legs with neither adenostyles nor tarsal brushes, short, stout and enlarged, femur the longest. In length, femur > prefemur > tarsus > postfemur > tibia > coxa. Gonopods taking up nearly entire ventral surface of metazonum 7, almost reaching the base of paraterga (Fig 27 F.). Gonopods relatively simple, placed inside a transversely oblong gonopodal aperture, with thin and slightly elevated caudal and lateral margins. Both gonopods held parallel to each other, strongly exposed, telopodite tips directed caudally. Coxites (cx) voluminous, transverse and microgranulate laterally (Fig.27 F). Gonocoel distinct, but not too deep; telopodites short, simple, biramous and distally carrying a long, in situ caudally directed and slightly bifurcate lamina with fringed/microspiculate lamellae; solenomere (sl) slender and barely exposed; medial branch (b).

Distribution. India, Nilgiris, Coonoor, Kozhikode, Kerala.

4.6.1.1.1.3 Family Trichopolydesmidae Verhoeff, 1910

3–16 mm in length. Only exceptional paraterga deeply lobulate laterally with a polydesmoid body. Rarely sphaerotrichomes exist. Telopodites can occasionally be hidden inside the coxal cavity, but gonopod coxae typically include cannulae. About 140 species from 75 genera, mostly in the northern hemisphere, both temperate and particularly tropical

Diagnosis. Can be distinguished from the congeners by the presence of prominent trichomes forming unique ornamentation on metaterga.

4.6.1.1.3.1 Genus *Pseudosphaeroparia* Carl, 1932

The endemic Indian genus *Pseudosphaeroparia* consists of small-sized species with 20 body rings (♂, ♀). Head large with swollen genae. Male vertex unmodified. Collum small and much narrower than head when viewed from above. Metatergites incised laterally and each with three transverse rows of clavate setae located on knobs or bosses. Pore formula normal (5, 7, 9, 10, 12, 13, 15–19). Ozopores flush open dorsally close to lateral margin of poriferous paraterga. Paraterga relatively moderate to well-developed. Gonopod coxites large, round or squarish. Telopodite from deeply sunken inside coxal cavity to clearly exposed. Solenophore uni- or bipartite with various outgrowths. Solenomere an apical branch. Parabasal process can be present or absent (Golovatch et al., 2014).

Diagnosis: The genus *Pseudosphaeroparia* is closely related to the African genus *Sphaeroparia* and differs from them in the number of body rings and the distribution of ozopores. In *Pseudosphaeroparia* the number of body ring is 20 in both sexes, however in the genus *Sphaeroparia* the number of body ring is 19 in both sexes. Pore formula of *Sphaeroparia* is 5, 7, 9, 10, 12, 13, 15 –18, in *Pseudosphaeroparia* 5, 7, 9, 10, 12, 13, 15 –19. African *Sphaeroparia* with simple gonopod having spherical coxae and deeply sunken telopodite with distinct solenophore and solenomere. *Pseudosphaeroparia* having simple gonopod with broad coxae and moderately or deeply sunken telopodite with distinct solenophore and solenomere.

4.6.1.1.3.1.1 Key to the species belonging to Genus *Pseudosphaeroparia* Carl, 1932, collected from sacred groves of North Kerala

1(2) Gonopodal telopodite clearly exposed, bipartite, solenophore with a lateral laminar sheath and caudad unciform solenomere..... *P. malabarica*

2(1) Gonopodal telopodite only partially exposed, with a laterad, subfalcate solenomere, and a laminar solenophore.....*P. falcata*

4.6.1.1.1.3.1.1.1 Description of species belonging to Genus *Pseudosphaeroparia* Carl, 1932, collected from sacred groves of North Kerala

Taxonomy

Order Polydesmida Leach, 1815

Family Trichopolydesmidae Verhoeff, 1910

Genus *Pseudosphaeroparia* Carl, 1932

Type species: *Pseudosphaeroparia palnensis* Carl 1932, by original designation.

***Pseudosphaeroparia malabarica* sp.nov..**

Material examined. Adult male holotype CATE– 10435A and 4 male and 9 female paratypes CATE–10495B – CATE–10435N, all collected from sacred groves named Muchukunnu Kavu, (N 11°29'49'', E 75°39'50'', 33 m a.s.l.) (Fig.) and Poyilkavu (N 11°24'31'', E 75°42'52'', 47 m a.s.l.) (Fig. 17 D), forest areas of Kakkad (N 11°29'41'', E 75°57'37'', 116 m a.s.l.) (Fig. 18 D) and Poolacode (N 11°34'49'', E 76°01'23'', 799 m a.s.l.) (Fig. 17 A) in Kozhikode district, Anoth Kavu (N 11°18'51'', E 75°55'51'', 79 m a.s.l.) (Fig. 18 E), Maanikavu (N 11°42'06'', E 76°09'36'', 823 m a.s.l.) (Fig. 18 B) and Valliyurkavu (N 11°48'16'', E 76°01'45'', 781 m a.s.l.) (Fig.) in Wayanad district, Madayi Kavu (N 12°02'06'', E 75°15'23'41'', 61 m a.s.l.) (Fig.) in Kannur district and Payyankulam Kavu (N 12°18'28'', E 75°14'00'', 126 m a.s.l.) (Fig.) in Kasaragod district, collected between July 2022 and August 2023, M.D. Aswathy leg.

Etymology. To emphasize the presence of this species all over the Malabar, a region in southwestern India located in the north of modern Kerala.

Diagnosis. Differs from congeners by the bipartite telopodite and the laminar structure of the solenophore (**sph**). More similar to *P. palnensis* in antennal structure and tergal ornamentation, but showing drastic differences in gonopodal structure.

Description. Length of adult ca. 5.5–6.2 mm (♂) or 5.4–5.8 mm (♀), width of mid-body rings 0.85 mm (♂). Colouration in live specimens uniformly pale brown with whitish metatergal setae, legs and antennae. Specimens preserved in alcohol with

faded brown tegument and translucent whitish legs and antennae. Paraterga with faint mottled round patches (Fig 29 A).

Body with 20 rings (♂, ♀). Head smooth and sparsely pilose, epicranial suture superficial, genae squarish. Isthmus between antennae about 1.5 times as wide as diameter of antennal socket (Fig 29A). Antennae moderately long, reaching up to ring 2 when stretched dorsally, strongly clavate with the largest antennomere 6, the latter with a prominent distodorsal group of bacilliform sensilla. Antennomere 7 with a small mid-dorsal knob beset with bacilliform sensilla. In length, antennomere $3 > 5 > 6 > 2 > 4 > 7 > 1$ (Fig.29 B).

Body moniliform in both sexes. In width, head $\gg$ collum $>$ ring 2 $>$ 3 $>$ 4 $>$ 5=16 (♂), thereafter body gradually tapering towards telson. Paraterga well-developed, set low (at about $1/3-1/2$ body height). Front edges moderately convex and forming shoulders, caudal edges strongly concave and caudad. Lateral edges mostly straight featuring three setigerous knobs. Caudal ends nearly sharp with a seta directed caudally (Fig 29 C). First paratergal seta towards cephalic region, and second paratergal seta laterad until ring 17 and thereafter increasingly well produced past rear margin. Ozopores flush open on dorsal surface, placed closer to lateral than to caudal margin of poriferous paratergites. Pore formula normal: 5, 7, 9, 10, 12, 13, 15–19 (Fig 29 C & E).

Collum biconvex, subovoid, with three rows of short setae. Each following metatergum with 3+3 short, slightly blunt and clavate setae arranged in three transverse rows and borne on minute knobs. Sulci between the rows absent. Limbus very fine, sparsely microdenticulate. Pleurosternal carinae absent. Epiproct short, conical, truncate and directed caudoventrally. Pre-apical papillae short. Hypoproct subtrapeziform, caudal setigerous papillae well-developed and clearly separated.

Sterna devoid of modifications, sparsely setose. Legs short, ca 1.3–1.4 times as long as mid-body height (♂); in length, tarsi $>$ femora $>$ prefemora $>$ tibiae $>$ postfemora $>$ coxae. Sphaerotrichomes absent, claws slightly curved and simple. Male coxae 2 with short, membranous and cylindrical gonapophyses. Gonopod aperture transversely oblong-oval, taking up most of ventral part of male metazonite 7, with thin and slightly elevated caudal and lateral margins. *In situ*, both gonopods strongly

exposed and held almost parallel to each other. Coxites with lateral microgranulations large, transverse, bare and voluminous. Both coxites fused medially, with normal cannulae and connected by a lateral ribbon-like lamella dorsally. Telopodite moderately deeply sunken inside a deep gonocoel. Prefemorite as usual, short and densely setose. Telopodites strongly exposed, *in situ* held parallel to each other, bipartite and directed caudad. Solenophore (**sph**) with a lateral, biramous, laminar sheath (**ls**) with a bottom lobular lappet (**lp**) and an unciform apex (**u**). Solenomere (**sl**) branch diverging from **ls** base, and an unciform apex (**u**). Solenomere (**sl**) branch diverging from **ls** base, gradually attenuating and an unciform apex (**u**). Solenomere (**sl**) branch diverging from **ls** base, gradually attenuating distad and acuminate apically with a curl at tip. Starting with **sl** base, an apically curved basal branch (**bb**) present (Figs 29 F & G).

Taxonomy

Order Polydesmida Leach, 1815

Family Trichopolydesmidae Verhoeff, 1910

Genus *Pseudosphaeroparia* Carl, 1932

***Pseudosphaeroparia falcata* sp.nov..**

Material examined. Adult male holotype, (CATE –10436A) and 1 mature male, 3 female and 1 subadult paratypes (CATE 10436B –10436F), India, Kerala, Kannur (N 11°59'14'', E 75°21'48'', 50 m a.s.l.) (Fig. 17 B), M.D. Aswathy leg (Fig 31 A).

Etymology. To emphasize the falcate arrangement of the gonopodal telopodites *in situ*.

Diagnosis. Differs from congeners mainly by the structure of the gonopod, as well as by the relatively long antennae and the antennomere length ratio. The species also shows unusually long legs which is particularly evident in live specimens.

Description. Length of adult 7.93–9.22 mm (♂), 7.02–7.09 mm (♀), width of mid-body metazona 0.97 mm (♂). Colouration in live specimens uniformly deep brown metazona with prominent mottled circular patches on paraterga (Fig.). Prozona

yellowish orange. Metatergal setae and antennae whitish. Legs slightly brown on coxae and fading to translucent white towards tarsus. Specimens preserved in alcohol with faded brown tegument and translucent whitish legs and antennae (Fig 32A & B).

Body with 20 rings (♂, ♀). Head smooth and sparsely pilose, epicranial suture superficial, genae squarish. Isthmus between antennae about 1.7 times as wide as diameter of antennal socket. Antennae moderately long, reaching up to ring 3 when stretched dorsally, strongly clavate, with the largest antennomere 6, the latter with multiple, long, distodorsal sensory hairs. Antennomere 7 with a small mid-dorsal knob beset with bacilliform sensilla. Antennomere 3 with a mesoventral blunt spike (p). In length, antennomere $7 < 1 < 2 < 4 < 3 < 6 < 5$.

Body moniliform in both sexes. In width, collum $<$ head $<$ 2 $<$ 3 $<$ 4 $<$ 5 $<$ 6 = 16, thereafter body gradually tapering towards telson. Paraterga well-developed, set low (at about $1/3$ – $1/2$ body height), front edges moderately convex and forming shoulders, caudal edges strongly concave caudad, lateral edges with a marginal groove and a callus, each with three distinct setigerous indentations. Caudal corner of paraterga nearly sharp, with a seta directed caudally (Fig 32C). Front edge towards cephalic region and middle seta laterad until ring 17, thereafter increasingly well produced past rear margin. Ozopores evident, flush open on tergal surface, round, located laterally in front of caudalmost incision of paraterga. Pore formula normal: 5, 7, 9, 10, 12, 13, 15–18 (Fig. 32 B). Collum subovoid with three rows of short setae. Following metaterga with 3+3 short, slightly blunt, clavate setae arranged in three transverse rows and borne on minute tubercles. Setae of 1st and 2nd rows directed caudad, distad and laterad in a random fashion while last row of setae directed caudad. Sulci between the rows shallow. Limbus very fine, sparsely microdenticulate. Pleurosternal carinae prominent on segments 2-4 and traceable as faint lines on most of the following segments. Epiproct short, conical and truncate, directed caudoventrally. Pre-apical papillae not too long. Hypoproct subtrapeziform, caudal setigerous papillae well-developed and clearly separated. Sterna devoid of modifications, sparsely setose. Legs long, ca 3 times as long as mid-body height (♂); in length, tarsi $>$ femora $>$ prefemora $>$ tibiae $>$ postfemora $>$ coxae. Sphaerotrichomes absent, claws slightly curved and simple.

Gonopod aperture transversely oblong-oval, taking up most of ventral part of metazonite 7, with thin and slightly elevated caudal and lateral margins (Figs 32 D). *In situ*, both gonopods strongly exposed and held almost parallel to each other. Large, transverse, voluminous coxites (**cx**) with microgranules at lateral edges. Both coxites fused medially, with normal cannulae and connected by a lateral, lamella-like ribbon dorsally. A short and stout seta (**s**) located at lower mesal edge of each coxite. Telopodite moderately deeply sunken inside a deep gonocoel. Prefemurite as usual, short and densely setose. Telopodites strongly exposed, elongate, unipartite and crossing each other *in situ*, both directed mesally. Each represented solely by a solenomere (**sl**), supporting a seminal groove running along lateral margin to end of a mesally directed, unciform, apical part. Acropodite distal to gonofemurite possess a lateral laminar solenophore (**sph**) with complex convolutions. Solenomere (**sl**) branch diverging from **sph** base. A subinvolute depression (**i**) extending as a lamellar fold at base of **sl**, to join **sph** base (Fig 32 E.).

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4.7 Order Spirostreptida Brandt, 1833

4.7.1 Superorder Juliformia Attems, 1926

The members of superorder Juliformia Attems, 1926 are basically cylindrical or sub cylindrical individuals. They have an elongated body that measures 4–344 mm in length and 0.4–20 mm in diameter (Minelli, 2015). Typically, the head is capsular that has eyes with one (*Sinostemmiulus*) to at least 68 ommatidia. This exists as a patch, which is often grouped in a triangular to oval patch, and sometimes existing on a single line. Tömösváry's organ is not present. Six antennomeres and an apical disc make up each antenna, which can also have four or, in rare cases (such as in certain Spirobolida), up to 20 sensory cones. Labrum tridentates, a simple or lobed premandibular tooth, a lobed dentate lamella, four or more pectinate lamellae, and a strongly developed molar plate are all features of the large gnathal lobe. Gnathochilarium is ordered, diverse, and frequently family-specific. trunk, excluding the telson, with 18–101 body rings. The big column covers the back of the skull.

Stigmatic plates, terga, pleurites, and sternites all fused into full body rings, with the exception of the sterna, which is seldom secondarily free on all rings but may be free on the first few (*Nemasomatidae*). There are defense glands with a single compartment that open through lateral ozopores and mostly secrete benzoquinones. Legs made up of the coxa, tibia, tarsus, femur, postfemur, and prefemur podomeres. Pairs 8 and 9 of the male legs changed into gonopods; in some Spirostreptida, pair 9 was nearly entirely eliminated. The morphology of gonopods varies greatly. Male gonopores open through the distal portion of the gonoduct eversible (Spirobolida) or paired (rarely unpaired) penes behind leg pair 2.

Distributed over all non-Antarctic zoogeographical zones and are often the dominant millipede group aside from Polydesmida.

4.7.1.1 Key to the orders of superorder Juliformia Attems, 1926

- 1 (2) Head with prominent suture line not extending to clypeus (3)
- 2 (1) Head with prominent suture line extending across the clypeus, reaching towards the labrum **Spirobolida**

3 (4) oval shaped eye cluster, body ring with longitudinal ribs or striations either entirely around body or, more seldom, only laterally but not dorsally, normal appearing first leg pair, gnathochilarium with separate side pieces **Spirostreptida**

4 (3) Subtriangular eye cluster, body rings smooth dorsally and laterally without any ribs or striations, first leg pair short and hook like with enormous claspers and side pieces of gnathochilarium not separate but meeting in the middle portion of it **Julida**

4.7.1.1.1 Order Spirostreptida Brandt, 1833

The order Spirostreptida includes worm-like millipedes with elongated, cylindrical bodies made up of 40–70 body rings. Body length ranges from 10 to 344 mm, with a diameter of 0.6 to 20 mm (Minelli, 2015). The head usually bears eyes, each consisting of up to at least 68 ommatidia, and lacks a median suture. The ocelli form a compact triangular cluster at the base of the antennae. The gnathochilarium is variable in structure, but the stipites are always separated by a mentum and extend to the base of the gnathochilarium. The body comprises a head and 18 to 93 body rings, excluding the telson. The fifth body ring is associated with two pairs of legs. Frontal setae are absent, and body rings are generally devoid of setae. The first pair of male legs is often modified, frequently exhibiting a retrorse prefemoral lobe. Gonopods located on the 7th segment. Posterior gonopods (leg pair 9) are often reduced or may appear completely absent. Gonopodite has two prominent parts namely telocoxite and telopodite (Hamer, 1999). The form of the telopodite, particularly the number and shape of processes arising from it, is essential for generic identification.

Diagnosis. The individuals of this order resemble the species of order Spirobolida and Julida in terms of morphology to a fair extent. Externally distinguishable from the worm-like order *Spirobolida* by the absence of a fleshy pad on the terminal segment of the male legs. It also shows a characteristic suture line running from the forehead not extending to clypeus. On the other hand, this character is shared by both Julida and Spirostreptida. They are differentiated from Julida by the structure of gnathochilarium in males as it is with two separate side pieces and otherwise in Julida.

4.7.1.1.1.1 Suborder Spirostreptoidea Brandt, 1833

Eyes always present, composed of numerous ommatidia arranged in a triangular-ovoid cluster. Gnathochilarium relatively consistent, with stipites reaching the prebasilar sclerite on each side of the large mentum; mentum not or scarcely extending between the lamellae linguales, which remain contiguous along their entire length. Prefemora of the first pair of male legs each bearing a process directed toward the base and the mouth. Gonopods represented by a single pair (leg pair 8), with leg pair 9 completely reduced, retaining only a remnant of the sternum. Gonopods comprising a robust coxal portion sheathing the basal region of the telopodite; distal telopodite equipped with various spines, lamellae, and associated structures (Minelli, 2015).

4.7.1.1.1.1.1 Family Harpagophoridae Attems, 1909

Cylindrical and slender body. Dark green to dark brown or black colored body with or without bright metagargal stripe. Body consists of a head and 40–79 rings, measuring 35–350 mm in length and 2–30 mm in diameter. The preanal ring typically bears an upward-curved, or downward curved, long or short pointed process. Anal valves are smooth, lacking spines. Gonocoel of gonopods opening along its entire length on the lateral side, or with the basal portion opening on the oral side and running obliquely to the lateral side, exposing only a small portion of the lateral leaf (posterior telocoxal fold or distal part of telocoxite) from the oral view. Telopodite of gonopod terminating in a plate, typically bearing a row of strong, hooked spines. Anal segment usually bearing a prominent tail (Redman et al., 2003). Comprising 44 genera and over 220 species, this group is distributed across southern Africa, India, Sri Lanka, Southeast Asia, Indonesia, and the Philippines. In Kerala, 15 species belonging to 10 genera are reported till date.

Diagnosis. The family is differentiated from its congeners by the defining attribute of preanal ring. Preanal ring with a large spike which can be long or short, upturned or downward hooked but certainly pointed with a ratio of body length to body width about 12: 1 (Hamer, 1999).

4.7.1.1.1.1.1 Key to the genera of family Harpagophoridae Attems, 1909 collected from the sacred groves of North Kerala.

1 (2) Short bodied millipede with less than 10cm in length, darkly coloured (reddish black to brown), prominent ridges or striation on ventro lateral surface of body ring usually beneath the level of ozopores.....*Harpurostreptus*

2 (1) Millipedes with large, slender body circa 5 - 30 cm in length, usually brightly colored (yellowish green to dark reddish brown), without prominent latero-ventral ridges on the body ring (3)

3 (4). Sternite of gonopod short with globular posterior parts. Anterior coxal fold lamelliform with modifications on the lateral margin and an antero-mesal hook-like. Telopodite palette unbranched with a tibial spine.....*Carlogonus*

4 (3) Posterior coxa surmounted by a helical lamella. Telopodite short and wide, in a groove. Extremity of the telopodite divided into two branches: a smooth seminal branch and a spinous branch. Spines or tooth along the telopodite absent, replaced by transparent flaps which are almost invisible. A notable tibial and femoral spine present.....*Fageostreptus*

4.7.1.1.1.1.1.1 Genus *Carlogonus* Demange, 1961

Moderately large to large millipedes (60–150 mm). Caudal spine prominent, acute, evenly curved downward. Collum antero-lateral border abruptly sinuate. Gonopod sternite short, with globular posterior parts. Anterior coxal fold lamelliform, with lateral margin modifications and an antero-mesal hook-like process. Posterior coxal fold mesal margin internally folded, positioned between anterior coxal fold and telopodite. Telopodite strongly spiralled, unbranched palette with femoral and tibial spines; palette bearing blepharochaetae.

A total of 10 nominal species of the genus are recognized from India and Sri Lanka. This classification is based on the morphological characters of the gonopod alone. Specie *Carlogonus spinicaudus* (Gervais, 1847) is excluded due to the lack of relevant character information. Additionally, this species is likely a junior synonym of *Carlogonus subvalidus* (Carl, 1941) (Mauriès et al. 2001).

Exaratus-group: Characterized by a single tibial spine on the gonopod telopodite. This group includes five species: *C. auriculus* Demange, 1983; *C. exaratus* (Attems, 1936); *C. gayathri* (Sankaran & Sebastian, 2020); *C. robustior*; and *C. subvalidus*.

Acifer-group: Defined by paired tibial spines on the gonopod telopodite. This group comprises four species: *C. acifer* Demange, 1977; *C. chowdaiahi* Demange, 1977; *C. palmatus* Demange, 1977; and *C. verhoeffi* Demange, 1981.

The genus is confined to India and Sri Lanka, comprising nine recognized species, with eight occurring in India and one in Sri Lanka (De Zoysa et al. 2016; Golovatch & Wesener 2016). In India, *Carlogonus* species are primarily distributed in the southern regions, except for *Carlogonus exaratus* (Attems, 1936), which extends its range into northern India (Demange 1961, 1977a, b, 1981, 1983; Mauriès et al. 2001; Golovatch & Wesener 2016, Sankaran & Sebastian, 2020).

Diagnosis. Distinguished from other genera of the family mainly by the structural attributes of gonopod and tibial spines. Differentiated from *Harpurostreptus*, another genus collected from sacred groves of North Kerala, by modified lateral margin of anterior coxal fold, presence of a tibial spine on the telopodite, and absence of short median spines on the telopodite's inner surface (*Harpurostreptus* lacks these modifications and tibial spines but has short median spines).

4.7.1.1.1.1.1.1.1 Descriptions to the species of genus *Carlogonus*, Demange, 1961 collected from sacred groves of North Kerala.

Taxonomy

Order Spirostreptida Brandt, 1833

Suborder Spirostreptidea Brandt, 1833

Family Harpagophoridae Attems, 1909

Subfamily Harpagophorinae Attems, 1909

Tribe Harpurostreptini Hoffman, 1980

Genus *Carlogonus* Demange, 1961

Type species. *Thyropygus subvalidus* Carl, 1941, by original designation.

***Carlogonus palmatus* Demange, 1977**

Carlogonus palmatus Demange, 1977a: 232 (D).

Carlogonus palmatus—Achar & Chowdaiah, 1979: 21, 22 (R); Chowdaiah & Kanaka, 1979: 18 (M); Janardanan

& Ramachandran, 1981: 417 (M); 1982b: 294 (M); 1987a: 145 (M); Bano, 1983: 169 (M); Achar, 1983b: 191 (M,

R); 1984b: 373 (R); 1987: 150 (M); Prasadnan & Janardanan, 1995: 317 (M); Bano, 1998b: 186 (M).

Material examined. Male (CATE-93105A & B), 1 female (CATE-93105C), India, Kerala state, Chaamakavu, Vellur, Kannur district (12°09'07.03"N 75°12'35.5"E) 07 m a.s.l., M.D. Aswathy leg.

Diagnosis. Species can be distinguished based on the morphological features of the gonopod, particularly the telopodites. The telopodite of the gonopod has paired tibial spines. The anterior coxal fold lacks deep lateral indentations, and the tibial spines on the telopodite are of unequal length. The internal fold of the posterior coxal fold bears an irregular mesally directed process. The first tibial spine on the telopodite is blunt and lacks basal curvature. New species close to *C. subvalidus* (Carl); differs in more voluminous, rounded lateral coxoid expansion without pointed projection (Demange, 1977).

Description. Males ca. 90 - 95 mm, female ca. 92 - 110 mm and subadult ca. 70 mm in length and 2 - 4 mm wide mid body metaterga in males and females. Body with 59 - 64 body rings and Colour. Head, collum yellowish with broad coffee-brown patches on both. Antennae, anal valves, legs coffee- brown. Clypeal margin with a coffee-brown, serration-like pattern (Fig 33 A).

The specimen discoloured to muddy brown, almost black border on the segments after preservation in absolute alcohol. Head and collum brown-red. The head has a typical structure, and the elongated, slender antennae reach the edge of the 4th ring. The collum features elongated lateral edges with a broadly rounded anterior angle, a marginal groove doubled by a deeper groove in the middle, and two short grooves at the posterior edge. The diplosegments shiny, striated-punctate. Legs ventral podomere pads starting from the third ring extending to the end of the body. Last ring bears a long caudal appendage with a slightly downward-curved tip, while the valves have a deep premarginal groove positioned at the base. Gonopods display an internal

coxal laminar spread in a subtriangular palette with a subhorizontal, slightly oblique summit and an internal angle cut into a lobe. The inner lamina has a high, narrow, globular apex, and the lateral edge forms an oval lamella. The telopodite is spirally coiled, with its distal end abruptly narrowing into a short seminal branch bearing spines. A robust spine is located near the tip of the seminal groove, with an additional robust, curved spine in the middle and a short vertical spine before the greater curvature. The species is distinct by having a more voluminous, rounded lateral expansion of the coxoids without a pointed projection. The telopodite end is strongly and abruptly narrowed into a slender branch with spines (Fig 33 B& C).

Distribution. Chaamakavu (Kannur), Kerala, India (Fig 33 D).

4.7.1.1.1.1.1.2 Genus *Fageostreptus* Demange, 1961

Monotypic genus, with species of large body (250 - 300 mm), dark coloured (dark brown - black). 74 -80 body rings with slightly slender males and wider female. Posterior coxal leaflet surmounted by a helical lamella. Gonopods with conspicuous sternite. Telopodite short and wide, in a groove. Extremity of the member divided into two branches: a smooth seminal branch and a spinous branch Classic spines absent replaced by transparent flaps which are almost invisible. Tibial and femoral spine present.

Diagnosis. The genus shows a close resemblance to *Phyllogonostreptus*. The telopodite of *Fageostreptus* possesses a distinctive branch for the seminal groove and a femoral spine, which differentiates it from that of *Phyllogonostreptus*, its overall structure resembles the morphological features of *Phyllogonostreptus*.

4.7.1.1.1.1.1.2.1 Descriptions of the species of genus *Fageostreptus* Demange, 1961 collected from sacred groves of North Kerala.

Taxonomy

Order Spirostreptida Brandt, 1833

Suborder Spirostreptidea Brandt, 1833

Family Harpagophoridae Attems, 1909

Subfamily Harpagophorinae Attems, 1909

Tribe Harpurostreptini Hoffman, 1980

Genus *Fageostreptus* Demange, 1961

Type-species: *Fageostreptus hyatti* Demange, 1961, by original designation.

***Fageostreptus hyatti* Demange, 1961**

Fageostreptus hyatti Demange, 1961: 196 (D). India, Trivandrum.

Fageostreptus hyatti—Demange, 1962: 370 (R, D); Janardanan & Ramachandran, 1981: 417 (R); 1982b: 293, 294

(M); Prasadán & Janardanan, 1995: 317 (M); Jeekel, 2006: 30 (M).

Fageostreptus hyathi (sic!)—Bano, 1983: 169 (M); Achar, 1987: 150 (M).

Fageostreptus hyati (sic!)—Bano, 1998b: 186 (M).

Materials examined. Male (CATE-93401A), from the sacred groves of Valliyur kavu, Manathavady, Wayanad district, 11°48'08''N, 76°01'55''E, 716 m a.s.l., M.D. Aswathy leg.

Diagnosis. Same as generic diagnosis.

Description. Males around 270 mm and female around 300mm in length and 28 -33 mm wide mid body metaterga in males and females. Body with 76 -78 body rings and coloration of reddish brown, antennae, body rings and walking legs pallid. The specimen discoloured to dark brown, almost black with a thin reddish border on the segments after preservation in absolute alcohol. Head and collum brown-red. Last segment and valves reddish (Fig 34 A & B).

Head smooth with deep occipital furrow. Prelabial area with 3+3 setiferous foveole. Labrum not very deeply notched, with 3 large rounded teeth. Median tooth single, well isolated. Ocellar fields subovular in shape with around 59 ocelli (Fig 34 C). Antennae short not extending beyond the edge of the collum. Mandibular stipes with very large, digitiform protuberances, directed anteriad. Collum broad with strongly narrowed lobes, subrectangular with voluminous and protruding process forward at the anterior angle (fig. 34 A). Normal marginal ridge at right angles to the anterior edge. 1 or 2 fine striations of folds at posterior edge.

Smooth prozonites with fine, slightly sinuous raised circular lines. Triangular stigmatic cavity, slightly elongated, barely exceeding the posterior edge of the first

podomere. Very finely punctuated metazonites. Deep longitudinal grooves, few in number, spaced apart from each other, located at the lower part, not going up along the sides. Large repugnatory pore, far from the metatergal suture which is strongly deviated at its level. Anal segment wrinkled and densely punctate. Caudal appendage not extending beyond the edge of the valves, curved upwards. Valves with very numerous microscopic punctations. Thinned edge, without groove. Sternite entirely free, with almost straight posterior edge. Walking legs with smooth sternites. Ventral pads on two penultimate podomeres starting from 3rd leg pair.

Gonopods with sternite. Posterior coxal leaflet (fig.34 E) anteriad, very narrow initially, progressively widened towards terminus. This one is oblique and presents at its base, an oblique depression near the internal angle, isolating the spinous process coming from the internal edge and developed upwards. Posterior surface the laminar coxite wide with very large orifice of the coxal sheath. Internal edge develops perpendicularly into a large rounded lobe. At the top of the laminar complex, free lamellar apparatus, developed in height and convoluted in a helix. The helical movement of the process builds grooves in a helix, external lateral and internal lateral. The external lateral groove houses the femoral spine of the telopodite which follows the shape of this groove and is therefore sinuous. Anterior coxal process strongly developed especially in height since its terminal end, in a point, is at the same level as that of the preceding process. Large telopodite (fig. 34 F) coiled in a spiral coil. Relatively thin ascending branch, bearing at the level of the great curvature at a right angle a long helical spine whose lamellar base is isolated from the rest of the limb and continues the vertical direction of the ascending branch. Extremity of telopodite developed and hollowed out in a groove whose two edges are almost completely folded. Lower edge extended by a robust formation corresponding to the lower tip of the telopodite. Posterio-lateral edge thick, armed with a wide and long sharp spine cut into the edge itself. Anterio-lateral edge very thin, lamellar, pushing at its distal angle two delicate flaps, superimposed at the base in the form of elongated and thin hooks. One of these processes leads the seminal groove, the second bears a few spines or more exactly translucent formations along the edge. In mesal view of this anterior edge furrowed with numerous longitudinal striations.

Distribution. Valliyurkavu (Wayanad), Trivandrum, Kerala, India (35 A & B).

4.7.1.1.1.1.1.3 Genus *Harpurostreptus* Attems, 1936

Small bodied slender species with deep brownish red to black body rings. Metazonites are dorsally weakly sculptured or smooth, with longitudinal striations below the pores. Prozonites display encircling striae covering nearly the entire surface. The pores are small, beginning at the 6th segment and positioned away from the suture, which is sharply defined. Sternites are transversely striated, and stigmal grooves are triangular, equal to or slightly longer than the sternites. Gonopod features a long, straight femoral spine, with an elongated, band-like tibio-tarsus twisted into spirals and a simple, unbranched tip. The canal terminates near a row of bristles, which are partially or entirely colorless, with slightly broader tips. The anal segment has a long, tapering tail that curves downward evenly. The marginal thickening of the anal valves is either simple, bears a fine furrow near the median border, or is divided into two rounded keels by a longitudinal furrow. The anal scale is free, broadly rounded, or nearly straight. In males, the postfemur and tibia are padded, and the distal part of the gnathochilarial stipites has a low, rounded protuberance. The basal joint of the mandibles is equipped with an acute process directed medially.

Diagnosis. Distinguished from congeners by the relatively smaller body and dark colouration. The longitudinal striations in the ventrolateral region of the metazonae.

4.7.1.1.1.1.1.3.1 Descriptions of the species of genus *Harpurostreptus* Attems, 1936 collected from sacred groves of North Kerala.

Taxonomy

Order Spirostreptida Brandt, 1833

Suborder Spirostreptidea Brandt, 1833

Family Harpagophoridae Attems, 1909

Subfamily Harpagophorinae Attems, 1909

Tribe Harpurostreptini Hoffman, 1980

Genus *Harpurostreptus* Attems, 1936

Type-species: *Harpurostreptus attemsi* Carl, 1941, by direct substitution of Carl (1941b: 656) to replace

Spirostreptus hamifer Humbert, 1866, as misidentified by Attems (1936: 286).

= *Indiothauma* Verhoeff, 1938, synonymized by Demange (1961: 24).

Type-species: *Indiothauma jonesi* Verhoeff, 1938.

***Harpurostreptus prasadani* Demange, 1989**

Harpurostreptus prasadani Demange, 1989: 774, 776 (D).

Harpurostreptus prasadani—Prasadan & Janardanan, 1995: 311 (R); Bano, 1998b: 186 (M); Jeekel, 2006: 32 (M).

Materials examined. Male (CATE-93706A -C), 1 female (CATE-93706D) and 2 subadult CATE-93706E and F) from the sacred groves of Valliyur kavu, Manathavady, Wayanad district, 11°48'08''N, 76°01'55''E, 716 m a.s.l., M.D. Aswathy leg.

Diagnosis. *H. prasadani* differs from related species in the coxal layer structure, with elongated triangular lateral extensions and a well-developed posterior leaflet lobe. The telopodite has a distal spine and smaller spines near the extremity, resembling *H. attemsi* (Carl) but with distinct spine count and placement.

Description. Head without distinctive features; antennae reach the 3rd ring edge. Collum has rounded anterior angles (Fig 36 A & B); mandibular stipes bear a robust triangular internal point folded towards the gnathochilarium. Marginal edge prominent. Rings display longitudinal striations across their circumference, including dorsally. Appendages feature soles on the penultimate articles, even in the last leg pairs. Pygidium has a broad, downward-curved blade with a lighter longitudinal crest. Gonopods follow the genus *Harpurostreptus*, with anterior leaflets narrow at the base, laterally expanded into a triangular form, and pointed. Posterior leaflets are prominently outward at the base with lateral and median projections along the coxal sheath edge. The apex forms a perpendicular blade folded into a lobe that covers the telopodite's curvature, connected to the anterior leaflet at an internal notch (Fig 36 c & D). Telopodite forms a complete spiral, featuring a large curvature with a long vertical spine at the coxal layer tip. The posterior end is square-cut, bearing a subdistal spine near the seminal groove. The coxal layer structure, with elongated triangular lateral extensions and a well-developed posterior leaflet lobe. Telopodite has distal spine and smaller spines near the extremity, but with distinct spine count and placement.

Distribution. Valliyurkavu (Wayanad), Malappuram, Kerala, India (Fig 36E).

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4.8 Order Spirobolida Bollman, 1893

4.8.1 Order Spirobolida Bollman, 1893

Adult body length 40–80 mm with exceptional cases with the biggest species that may reach 250 mm, while the smallest species are 18–30 mm. The skull has a very noticeable median suture that breaks off between the antennae and then continues toward the back of the head. No frontal setae on the head. There are genae and a typically visible, open incisura lateralis. A suture in the postantennal region triggers a unique parietal sclerite, which frequently touches or even overlaps the mandibular cardo and stipes. One row of marginal setae, two to eight setiferous foveolae, two (rarely four) blunt lateral teeth, and a single middle tooth make up the labrum. typically has an uneven oval or subtriangular cluster of more than 20 ommatidia. Typically, robust antennae with six antennomere are present, along with a disc that typically has four, but seldom more, apical cones. Sensilla basiconica are arranged in a field of two to four rows near the distal border of antennae 5 and 6. Mandible is enormous with a big cardo and somewhat smaller stipes.

Trunk with 35–60 rings. Body rings are invariably devoid of setae. There are ozopores, which often starts to appear starting from body rings 5 or 6 (occasionally ring 3 of Typhlobolellidae). One tergite, two pleurites, and two stigmatic plates make up each body ring. Body ring 7 fused ventrally in adult male individual. The body's surface is glabrous, smooth, and seldom has spines. Telson is made up of a dorsal pre-anal scale that can lengthen, two well-rounded anal valves that seldom ever contain a dorso-apical spine, and a little subanal scale. There is just one set of legs connected to body ring 5. Body ring 6 and following with 2 leg pairs each. Legs consisting of six podomeres (coxa, prefemur, femur, postfemur, tibia, tarsus). Leg pairs 1 and 2 modified in both sexes, coxae fused to sternites and greatly elongated. Legs 3 and the following ones similar, lacking coxal pores, only male leg pairs 3-7 often with special modifications, especially on coxa. Male tarsi 3 and following ones often with a ventral pad, sometimes also tibiae. Male leg pairs 8 and 9 on body ring 7 modified into anterior and posterior gonopods, respectively, which develop gradually through a few (usually two or three) moults. Anterior gonopods simple, consisting of a sternite, coxites and telopodites. Sternite and coxite often with sclerotized tracheal apodemes. Sternite often triangular with lateral extensions which anteriorly engulf

basal part of coxite. Coxite and telopodite often extended mesad, forming a pouch for accommodation of the posterior gonopods. The coxite with a big tracheal apodeme and the telopodite, which are more or less joined, make up posterior gonopods, which are spermatopositors. Membrane tissue or a little sternal remnant (suborder Trigoniulidea) connects the posterior gonopods. Gonopod traits—typically primarily those of the posterior gonopod—are the primary basis for families and subfamilies. Behind coxa 2, the male gonopore is a paired, extendable, membrane pseudopenis.

Diagnosis. The individuals of the order are very similar to the orders Spirostreptida and Julida typically but differ from them with the stouter body organisation. The other difference is head with prominent suture line extending across the clypeus, reaching towards the labrum and the structure of gnathochilarium from the other orders.

4.8.1.1 Family Pachybolidae Cook, 1897

Stout body with length of 20–100 mm and generally dark pigmented Head with ocelli arranged in an oval cluster and short, stout antennae and trunk bearing ozopores from body ring 5. There are very few species with scobinae (*Centrobolus*), which have setiferous foveolae on the head that are typically 2 + 2 and seldom 3-5. Paraprocts flatter, usually with a broad flat distal margin with edges not inturned and meeting at a visible surface suture (Hoffman et al., 1996). Males of the most genera with ventral membranous pads on 1 or 2 podomeres. Gonopods with large, coxite posterior gonopods with lengthy apodemes often have one or two interior chambers. Around 60 genera and over 280 species may be found in India, Southeast Asia, New Guinea, Australia, Oceania, Madagascar, the Seychelles, South America (Brazil, Suriname, and Peru), and western, eastern, and southern sub-Saharan Africa (Minelli, 2015).

Diagnosis: This family can be distinguished from other families of the order by small sternal apodemes and the absence of coxal apodemes on the anterior gonopod. The conspicuous remnants of a sclerotized sternite connect the posterior gonopods, which are oriented parallel to the body axis. The posterior gonopod's apodeme forms a 90° angle with the gonopod proper (Minelli, 2015). The mandible's base portions are visible and not even partially hidden by the head.

4.8.1.1.1 Key to the genera of family Pachybolidae Cook, 1897 collected from sacred groves of North Kerala.

- 1 (2) Body not smooth, with ornamentation (5)
- 2 (1) Body smooth, without ornamentation (3)
- 3 (4) Males with ventral pads on either podomeres (5)
- 4 (3) Males without ventral pads on any podomeres *Stenobolus*
- 5 (6) Anal spine extending beyond body rings and terminally uncinating..... (7)
- 6 (5) Anal spines barely extended or slightly extended beyond body ring without terminal hook(9)
- 7 (8) Posterior area or tergite not longitudinally grooved and furnished with a row of large and smaller tubercles irregular in size and spacing *Eucentobolus*
- 8 (7) Posterior area of terga longitudinally grooved and furnished with a series of low tubercles equal in size and evenly spaced situated upon areas between the grove *Aulacobolus*
- 9 (10) Coxite and telopodite of the posterior gonopod at a right angle. Medial arm of posterior gonopod densely and finely hairy. Dorsum without bright stripe or patches (Attems, 1936) *Trigoniulus*
- 10 (9) Coxite and telopodite of posterior gonopod nearly in the same line. Medial arm not hairy. Dorsum with a broad, bright stripe or with a row of bright patches (Attems, 1936) *Xenobolus*

4.8.1.1.1.1 Genus *Trigoniulus* Pocock 1894

Diagnosis. Cylindrical millipedes with length ca. 7 - 9 cm. First tergite acutely angled without scobinae. Males with ventral pads. The genus is very similar to the genera *Stenobolus* and *Xenobolus* in overall morphology, the presence of smooth body and short or wanting telson without any extended hooklike structures but differs from them with the structure of gonopods being simple and distinct from the individuals of other genera of the family

4.8.1.1.1.1 The description of species of *Trigoniulus* Pocock 1894 collected from the sacred groves of North Kerala.

Taxonomy

Family Pachybolidae Cook, 1897

Genus *Trigoniulus* Pocock 1894

Type-species: *Spirobolus goesi* Porat, 1876, by original designation.

***Trigoniulus corallinus* (Gervais, 1847)**

Trigoniulus goesi—Demange, 1977a: 231 (R); Janardanan & Ramachandran, 1982a: 249 (R); Bano, 1983: 170

(M); Achar, 1987: 149 (M).

Trigoniulus lumbricinus—Attems, 1936: 303 (M); Carl, 1941b: 604 (M); Schubart, 1947: 35 (M); Mukherjee,

1962: 25 (R); Banerjee, 1974: 132 (M, R); Shukla & Tripathi, 1974: 223 (R); 1985: 56 (R); Tripathi & Shukla,

1980: 118 (M); Bano, 1983: 170 (M); Rangaswamy et al., 1983: 8 (M, D); Shukla, 1982: 112 (R); 1984a: 56 (R);

1984b: 55 (R); Shukla & Misra, 1984: 39 (M); Shukla & Shukla, 1981: 159 (M); 1986: 281 (M); 1987: 25 (M);

Bhakat, 1996: 10 (M); 2014: 186 (R).

Trigoniulus corallinus—Tikader & Das, 1985: 87 (M); Shelley & Lehtinen, 1999: 1391 (R); Jeekel, 2001c: 72 (M)

Bjamare et al., 2014: 100 (R); Chezian & Prabakaran, 2016: 91, 92 (R, D).

Trigoniulus corallines (sic!)—Choudhari et al., 2014: 254, 255 (D).

Material examined. Male (CATE-101701 A - D), female (CATE-101701 E - K) and subadults (CATE-101701 L-T), India, Kerala state, from the sacred groves of Muchukunnu Kotta Kavu, Moodadi (11°29'20"N 75°40'10"E), Poyilkavu, Chemencheri, (11° 24' 34.56" N , 75° 42' 58.32" E), Vallikattukavu, Atholi, (11°23'17"N, 75°47'10"E), in Kozhikode district; Madayi Kavu, madayi Para (12°2'4.99"N 75°15'41.14"E), Neeliyarkottam, Dharamshala (11° 56 '03.8" N 75° 21' 50.0" E), and Chamakavu, Vellur (12° 09 '07.03" N 75° 12' 35.5" E) in Kannur district; Mannampurath Kavu, Nileshwaram (12° 15 ' 27.6" N 75° 07' 59.4" E),

Puthiyaparambath Kavu, Nileshwaram (12° 15 ' 34.56''N 75° 07' 41.16'' E), Sree Malliyodan Kavu (12°22'1.24"N 75°19'22.8"E) in Kasaragod district.

Diagnosis. The species is easily recognized by the strong and uniform rusty red body without any marks or coloration. The body without any stripes of rings on either prozonae or metazonae. The coxae of the anterior gonopods narrowly separated by sub triangular sternum indented in midline and telopodites of the posterior gonopods rounded and with broad medial lobe at midlength; two inner projections arising basally from lobe and directed distad; and outer projection with notch on inner margin, expanded distad.

Description. Males around 60 mm and female around 65mm in length and 0.7 - 10mm wide mid body metaterga in males and females. Body with 50 body rings and coloration of bright rusty red for head, antennae, body rings and walking legs. The specimen discoloured to dark brown after preservation in absolute alcohol (Fig 37 A).

Antennae thick, very short, slightly compressed, reaching only to caudal edge of the collum. The lateral lobes of the first segment are narrowly triangular. Upper body segments densely punctate, sub coriaceous; metazona less densely but more strongly sculptured, the posterior margin, however, being smoothed. Metazona gradually smoothed and striated below. Prozones more or less punctate, opaque, finely striated.

Ozopores located a little above the medial groove and around the middle height of the body rings, posteriorly provided with a longitudinal groove. Preanal segment blunt, leathery. sinuous on both sides, the apex forming a minute triangle covering the angles of the valves. Anal valves smooth, punctate at the margin, subcanaliculate, margin compressed, narrow, slightly prominent. Short walking legs; with a ventral pad on the tarsus in males.

Gonopods simple located on the 7th body ring. The coxae of the anterior gonopods are narrowly separated by a subtriangular sternum, indented along the midline. The telopodites are subtriangular and extend directly medially (Fig 37 B & C.). The telopodites of the posterior gonopods are rounded and possess a broad medial lobe at midlength. Two inner projections arise basally from the lobe and are directed

distally, while the outer projection, featuring a notch on its inner margin, is expanded distally.

Distribution. India, various places: Bengal, Calcutta (= Kolkata), Behala and Dakhindari; Bihar, Pusa; Andaman Islands; Pollachi; Nilgiris, Coonoor; Nasinigudi; Anaimala Hills, Attakatti; Assam, Cinnamara; Tamil Nadu, Kerala; Kerala state, Kozhikode Kannur and Kasaragod district (Fig 27 D & E).

4.8.1.1.2 Genus *Stenobolus* Carl 1918

Cylindrical millipedes with short antennae with 4 sensory cones. 2+2 setiferous foveole present on the labrum. Cheeks devoid of dentate process. Smooth body rings without scobina. Ozopores placed on prozonite. Anal tergite cut at an angle, but not extending beyond the apex of the valves. Legs prominent with absence of a tarsal pad.

Anterior gonopods with ventral blades abruptly narrowed above the base and extended into a large median apophysis. Posterior gonopods connected to each other by a membrane, straight and lamellar; basal article placed in the axis of the telopodite, which its basal frame cuts almost at right angles. Seminal groove replaced by a simple dilatation of the groove and the seminal ridge, which have a simple course and do not describe a spiral loop, but detach towards the end and end in a tapered flagellum. The structure of the posterior gonopods assigns this genus a place alongside *Mystalides*, *Metiche* and *Cingalobolus*, where it differs by the presence of a pseudoflagellum, by the shape of the ventral blade of the anterior gonopods.

4.8.1.1.2.1 The description of species of *Stenobolus* Carl 1918 collected from the sacred groves of North Kerala.

Taxonomy

Family Pachybolidae Cook, 1897

Genus *Stenobolus* Carl 1918

Type-species: *Stenobolus insularis* Carl, 1918, by monotypy.

= *Dekanbolus* Verhoeff, 1938, synonymized under *Stenobolus* by Hoffman (1962: 779).

Type-species: *Dekanbolus rubellus* Verhoeff, 1938.

4.8.1.1.2 Genus *Stenobolus* Carl, 1918

Stenobolus insularis Carl, 1918: 453 (D). Maldive Islands. Also, India, Trivandrum, Nedumangad.

Stenobolus insularis—Attems, 1936: 303 (M); Hoffman, 1962: 779 (D); Rajulu, 1970b: 143 (M); Shelley & Lehtinen, 1999: 1389 (M); Jeekel, 2001c: 51 (M).

Dekanbolus rubellus Verhoeff, 1938: 631 (D), synonymized under *S. rubellus* by Hoffman (1962).

Dekanbolus rubellus—Moritz & Fischer, 1975: 253 (M).

Remark: Additional material: 6 males and females (Zoologisches Forschungsmuseum Alexander Koenig,

MYR4610), India, Karnataka, Karike, 06.2015, coll. C.N. Ambarish.

Materials examined. Male (CATE-101601 A - G), female (CATE-101601 H - T) and subadults (CATE-101601 U - X), India, Kerala state, from the sacred groves of Madayi Kavu, madayi Para (12°2'4.99"N 75°15'41.14"E), , and Neeliyarkottam, Dharamshala (11° 56 '03.8" N 75° 21' 50.0" E), in Kannur district; Kammadam Kavu, Chittarikal (12°18'48"N 75°18'55"E), Edeyilakad Kavu, Valiyaparamba (12° 8' 2.4" N, 75° 9' 21.6" E), Payyankulam Kavu, Karinthalam Payyankulam Kavu, Karinthalam (12° 17 ' 41.7"N 75° 12' 18.96" E) , Koyithatta Sree Dharma Sasta Kavu, Koyithatta (12° 17 ' 11.4"N 75° 14' 53.88" E) and Puthiyaparambath Kavu, Nileshwaram (12° 15 ' 34.56"N 75° 07' 41.16" E) in Kasaragod district. Leg Aswathy M.D.

Diagnosis. Bright red coloured millipede with lateral black stipes across the metazonite and males without tarsal pads (Fig 38 B).

Description. Males around 43 mm and female around 49 mm in length and 3- 3.4 mm wide mid body metaterga in males and females. Body with 48-50 body rings and coloration of bright reddish brown for head, antennae, body rings and walking legs. Metazonae with horizontal blackish brown stripe. The specimen discoloured to dark brown after preservation in absolute alcohol (Fig 38 A).

Slender body, slightly compressed towards the end. Capsular head, clypeus with a short median groove and some transverse striae: forehead smooth and shiny, without median groove. Eyes large, subtriangular; their distance about equal to their transverse diameter. Antennae short. Collum smooth and shiny; its lateral lobes descending as low as the following segments, rather narrow by the fact that their anterior and posterior edges are slightly concave.

Prozonites smooth, Metazonites smooth and shiny on the back, up to the level of ozopore and sometimes little above the ozopore, fine and very loosely packed longitudinal striations present. Ozopores located on the prozonite, in a small smooth area not surrounded by a ring. Suture marked, on the sides, by a constriction and a fine furrow; the latter is almost erased on the back, where the limit between the two zonites is mainly indicated by the sculpture of the prozonite and the fact that the metazonite rises slightly in a very flat ridge. Anal tergite smooth and shiny, forming a fairly acute angle which covers the apex of the valves. Paraprocts slightly dome shaped, a little rough towards their apex, with moderately prominent edges, not compressed, and with a slightly pronounced premarginal groove. Hypoproct separated from the anal ring by a groove; its posterior edge is arched. Walking legs quite slender; podomeres 1 to 5 each bearing, a stiff subapical ventral bristle; the 6th podomere bears a series of 4 to 6 bristles, but tarsal pad absent (Fig 38 B).

Anterior gonopods with ventral blades abruptly narrowed above the base and extended into a large median apophysis. Coxites with oblique and notched distal edge; femorites large, extending well beyond the ventral blade and the coxites. Posterior gonopods connected to each other by a membrane, straight and lamellar; basal article placed in the axis of the telopodite, which its basal frame cuts almost at right angles. Seminal groove replaced by a simple dilatation of the groove and the seminal ridge, which have a simple course and do not describe a spiral loop, but detach towards the end and end in a tapered flagellum; no prostatic ampulla or digitiform condyle.

Distribution.Maldiv Islands. Also, India, Trivandrum, Nedumangad, Kannur and Kasargod districts of Kerala (Fig 38 C & D).

4.8.1.1.1.3 Genus *Xenobolus* carl 1919

Slender and cylindrical millipede. Male and female pachybolids almost similar in length and thickness; medium-sized and colorful. mature individuals with fifty body rings. Apodous rings absent before telson. Scobinae absent. Male leg tarsal pads absent. Males with significantly larger ventral body ring 6 that shields the gonopod pouch. Large, somewhat retractable anterior gonopods with a median process that are sternite telopodite anteriorly with a thin mesal process; coxite anteriorly with a slender mesal process. Posterior gonopods with a thin sternite; unaltered coxite; and

a telopodite with two bent mesad branches, the main branch with an apical fringe pointing toward the mesal branch and the mesal branch anteriorly with lateral processes.

Diagnosis. Same as description.

4.8.1.1.3.1 The description of species of *Xenobolus* carl 1919 collected from the sacred groves of North Kerala.

Taxonomy

Family Pachybolidae Cook, 1897

Genus *Xenobolus* Carl, 1919

Type-species: *Iulus* (recte: *Julus*) *carnifex* Fabricius, 1775, by original designation.

= *Diaphoropus* Silvestri, 1897, rejected, being a preoccupied name (cf. Jeekel 1971, 2001c).

Type-species: *Iulus* (recte: *Julus*) *carnifex* Fabricius, 1775.

= *Erythroprosopon* Verhoeff, 1936, synonymized by Hoffman (1962).

Type-species: *E. phoenix* Verhoeff, 1936.

***Xenobolus carnifex* Carl, 1919**

Iulus (recte: *Julus*) *carnifex* Fabricius, 1775: 428 (D).

Iulus (sic!) *carnifex*—Fabricius, 1781: 530 (D);

Julus Carnifex (sic!)—Linnaeus, 1788: 3019 (D).

Julus carnifex—Fabricius, 1781: 530 (D); 1793: 395 (D); Olivier, 1792: 416 (D); Latreille, 1802: 76 (D); Brandt,

1833: 205 (D), 1841a: 127 (M); 1841c: 121 (M); Humbert, 1865: 57 (D).

Iulus (sic!) *carnifex*—Fabricius, 1781: 530 (D); Gervais, 1837: 13 (D), 1847: 163 (D); Lucas, 1842: 532 (D).

Julus (*Spirobolus*) *carnifex*—Brandt, 1841b: 368 (D), 1841c: 121 (M).

Spirobolus ruficollis Newport, 1844a: 269 (D), synonymized by Pocock (1892).

Spirobolus ruficollis—Newport, 1844b: 13 (M); Preudhomme de Borre, 1884b: 76 (M); Attems, 1914: 355 (M).

Iulus ruficollis—Gervais, 1847: 175 (D).

Spirobolus Carnifex (sic!)—Koch, 1847: 102 (M), 1863: 62 (D).

Spirobolus carnifex—Karsch, 1881a: 79 (M); Preudhomme de Borre, 1884b: 73 (M); Tömösváry, 1885: 69 (M);

Daday, 1889: 129 (R); Pocock, 1892: 166 (D).

Trigoniulus carnifex—Silvestri, 1896a: 28 (M).

Diaphoropus carnifex—Silvestri, 1897: 651 (D), synonymy in Hoffman (1962).

Xenobolus carnifex—Carl, 1919: 394 (D); Attems, 1936: 304 (R); Hoffman, 1962: 780 (R); Mukherjee, 1962: 25

(R); Rajulu, 1970b: 143 (M); Bano, 1983: 170 (M); Achar, 1987: 149 (M); Alagesan & Vanithapriya, 1992: 299

(M); Valli, 1994: 322 (M); Jeekel, 2001c: 54 (M); Alagesan et al., 2003: 111 (M); Alagesan & Muthukrishnan,

2003: 313 (M); 2005a: 5 (M); 2005b: 3 (M); 2009: 237 (R); Wesener et al., 2008: 38 (D); Wesener & Enghoff,

2009: 111–113 (D); Karthigeyan & Alagesan, 2011: 62 (M, R); Alagesan & Ramanathan, 2013: 1, 2 (R); Bhakat,

2014: 186 (R); Chezhian & Prabakaran, 2016: 91, 92 (R, D).

Erythroprosopon phoenix Verhoeff, 1936c: 505 (D), synonymized by Hoffman (1962).

Erythroprosopon phoenix—Moritz & Fischer, 1975: 251 (M).

Xenobolus acuticonus Attems, 1936: 303, fig. 87a–d (D). (synonymized by Sankarn & Sebastian, 2020)

Xenobolus acuticonus—Natarajan, 1959: 92 (M). Hoffman, 1962: 780 (suggested possible synonymy with *X. carnifex*). Nagarbhushanam & Gokhale, 1968: 133 (M). Rajulu, 1970: 143 (M). Sharma & Handa, 1974: 678 (M). Demange, 1977: 231 (M). Chowdaiah & Kanaka, 1979: 17 (M). Janardanan & Ramachandran, 1982: 239 (M). Rangaswamy et al., 1983: 8 (M). Bano, 1983: 170 (M). Achar, 1987: 149 (M). Bai & Indra, 1997: 231 (D). Jeekel, 2001: 54 (M). Basil-Rose et al., 2014: 331 (M). Golovatch & Wesener 2016: 34 (M).

Materials examined. Male (CATE-101801 A - C), and female (CATE-101801 D - H), India, Kerala state, from the sacred groves of Neeliyarkottam, Dharamshala (11° 56 '03.8" N 75° 21' 50.0" E) in Kannur district; Leg Aswathy M.D.

Diagnosis. Monotypic genus, diagnosis same as the generic diagnosis.

Description. Cylindrical, slender and smooth body. Male and female with 50 body rings, ca 70 - 76 mm long, 4.1 - 5.9 mm wide. Brightly colored with red dorsomedial stripe starting from body ring 3. Head, antennae, collum, ring 2, pre-anal ring, anal valves, legs with red to rusty orange. Body rings except ring 2 laterally black, latero-basally and ventrally (Fig 39 A & B).

Vertex prominent, head capsular and micropunctate. Each eye patch has 7 - 8 vertical rows of about 48 to 50 ommatidia. prominent axial sulcus that ends at the frons. A single row of eight or nine small marginal setae and four uneven teeth characterizes the labrum. 2+2 setiferous foveolae, present on Clypeus. Short antennae that extend back to ring 2. Antennomeres' relative length is $1 < 2 > 3 > 4 < 5 < 6$. Four sizable sensory cones are grouped together in a terminal antennomere within a membrane. Collum with lateral boundary rounded and limited to ring 2; the surface is only faintly punctured. Dorsally, the body rings' prozonae and metazonae micropunctate. oblique and longitudinal striations on the ventral body. Ozopore is situated on the mesozona, beginning with ring 6, near the meso-metazona suture but not touching it. Sharp-edged pre-anal ring or epiproct that extends slightly past anal valves or paraprocts; more noticeable in females. Anal valves that lack setae and grooves but have well-developed lips and micropunctuations. Widely triangular, inconspicuous hypoprot.

Coxae 1 and 2 elongated and merged with sternites. Leg pair two is longer than the first; each podomere has thin and robust apical, ventral, and mesal setae. Podomeres extend subdistally or distally from the coxa to the tibia, with a single ventral spine, in males from leg pair 8 onwards and in females from all legs. With one, Tarsus sturdy dorso-apical and, in males, three or four ventral/ventro-mesal stout/slender spines; in females, four or five. Large, curved claw post tarsi.

Gonopod located on 7th ring with the body ring being enlarged towards bottom to encompass the gonopod structure. Sternite inverted V-shaped, with a median paddle shaped process (Fig 39 C & D.); Coxite broad, with a pollical mesal process, flat laterally. Telopodite medio-laterally with paired globular processes; retrorse process short, with a flat proximal half, distal half with a downwards directed, broad, conical process and a finger-shaped, laterally oriented, mesal process with apical bifurcations. Posterior gonopods featuring a slender sternite, an unmodified coxite, and a telopodite divided into two curved mesal branches. The main branch is adorned with an apical fringe directed toward the mesal branch, while the mesal branch bears lateral processes on its anterior side.

Distribution. Sri Lanka, Malaysia (Borneo). Also, India, Tranquebar; Madras, Shevaroy Hills, Yercaud; Central Provinces, Chanda; Tamil Nadu, Palakkad, Ernakulam, Kannur; Kerala, Vijayawada; Andra Pradesh (Fig 40 A & B).

4.8.1.1.1.4 Genus *Aulacobolus* Pocock 1903

Diagnosis. Species with unusual and unique body rings (Minelli, 2015). Body without any ornamentations but possesses grooves / striations. Pre-anal scale extending the telson and body. The shape and structure of pre-anal segment is variable being almost straight & slightly to moderately protruding above the anal valve with blunt end or may be elongated and pointed which extends far beyond the anal valves which can be straight, slightly hooked or twisted and curved downwards. Body rings with prozonites without dense dorsal Longitudinal grooves or striations or with dorsally almost smooth or weak striations. Legs have peculiarities in the second pair in males with high sternocoxite with acute angled shoulders or with low, rounded lateral shoulders. Gonopods with lance shaped coxal process. Slender telopodile with variable solenophore. Posterior gonopods with higher degree of variability with the inner arm having differently sculptured which may be developed or not. Posterior gonopod with telopodile having multiple lobes and structures such as saber shaped, hook shaped or boat shaped.

4.8.1.1.1.4.1 The description of species of *Aulacobolus* Pocock 1903 collected from the sacred groves of North Kerala.

Taxonomy

Family Pachybolidae Cook, 1897

Genus *Aulacobolus* Pocock 1903

***Aulacobolus* Pocock, 1903**

Type-species: *Spirobolus uroceros* Pocock, 1892, by monotypy.

= *Titsonobolus* Chamberlin, 1920, synonymized by Carl (1941b: 623)

Type-species: *T. uncopygus* Chamberlin, 1920.

= *Atopochetus* Attems, 1953, conditionally synonymized by Hoffman (1962, 1980).

Type-species: *A. rubrodorsalis* Attems, 1953.

***Aulacobolus gravelyi* Silvestri, 1916**

Aulacobolus gravelyi Silvestri, 1916: 43 (D).

Aulacobolus gravelyi—Attems 1936: 311 (M); Carl, 1941b: 613 (D); Rajulu, 1970b: 144 (M); Demange, 1977a:

231 (R), 235 (D); Bano, 1983: 169 (M); Achar, 1987: 149 (M); Jeekel, 2001c: 49 (M).

Materials examined. Male (CATE-101105 A - H), female (CATE-101601 I - P) and subadults (CATE-101601 Q - U), India, Kerala state, from the sacred groves of Vallikattukavu, Atholi, (11°23'17"N, 75°47'10"E) in Kozhikode district Leg. Aswathy M.D.

Diagnosis. Large bodied millipede with uniform glossy black tergites and brick red antennae and appendages. Pre anal segment slightly protruded beyond anal valves. Metazonite with dense longitudinal stripes or grooves. This species is distinct from other congeners with anterior gonopod with short triangular telopodite, with blunt apex. The posterior gonopod is highly variable with well-developed apodemes and boat shaped telopodite and tending towards each other.

Description. Cylindrical, stout and smooth body. Male and female with 50 - 55 body rings, ca 100 - 130 mm long. Body black with head, antennae and walking legs brick red in color in live specimens, discolors to dark brown trunk and pallid red colored head, antennae and legs.

Head smooth, subcontinuous median furrow and a lateral depression of the shield small eyes. Eyes with ca 35 ocelli, arranged longitudinally in 7-serial rows. Antennae short, not exceeding the apex of the mandibular stem (Fig 41F).

Collum with the sides somewhat more produced downwards than the sides of the neck, forming a longitudinal keel with an entire margin, with an acute anterior angle, somewhat produced anteriorly and downwards; the sides of the second segment are slightly thickened and produced a little backwards in relation to the preceding segment of the carina; the other segments are cylindrical. Prozonae of all segments above ozopore longitudinally and very thickly striated, below ozopore scarcely leathery or granulated, mesozonite above ozopores impressed with small dots, below ozopores obliquely striated, metazona smooth, set ozopores scarcely striated, far below pores longitudinally striated (Fig 41 B). Large ozopores; sternum transversely and deeply striated. The preanal segment (Fig 41 C.) is long process, sub-straight thick, slightly attenuated, obtuse at the apex, surpassing the anal fins by a long

distance. Anal valves with margins compressed especially posteriorly, premarginal depression well developed.

On the anterior gonopods, the blunt process of the telopodite, which extends laterally in a manner characteristic of the species, is more strongly developed. On the posterior gonopods, the telopodite ends in the form of a boat (Fig 41 D & E.) with two unequals, pointed keel wings in place of the rounding and lanceolate appendage of the two more southern forms.

Distribution. India, Cochin State, Kavalai; Palni Hills; Kodaikanal; Trivandrum, Travancore; Anaimala Hills, Attakatti; Quilon District, Pathanamkhitta and Vallikattukavu, Atholi, Kozhikode district (Fig 42 A & B).

***Aulacobolus newtoni* Silvestri, 1916**

Aulacobolus newtoni Silvestri, 1916: 45 (D).

Aulacobolus newtoni—Carl, 1941b: 613, 614 (D); Jeekel, 2001c: 49 (M); Alagesan & Ramanathan, 2013: 1, 2 (R)

Bhavani & Umamaheswari, 2013: 27 (R).

Alacobolus (sic!) *newtoni*—Ramanathan & Alagesan, 2012a: 55, 56 (R).

Materials examined. Female (CATE-101106 A and B), subadults (CATE-101601 C - F) and, India, Kerala state, from the sacred groves of Kammadam Kavu, Chittarikal (12°18'48"N 75°18'55"E), and Payyankulam Kavu, Karinthalam (12° 17 ' 41.7"N 75° 12' 18.96" E), in Kasaragod district. Leg. Aswathy M.D.

Diagnosis. Distinguished from the congeners by the vibrant yellowish colour of the prozonae and blackish transverse stripe of the metazonae.

Description. Slender and long millipede with glossy trunk. Body with alternating transverse stripes of pale greenish yellow and reddish brown to black for prozonae and metazonae respectively. Antennae and walking legs pallid yellow for the live specimen. Upon preservation in absolute alcohol, the specimen discolours to pale brown (Fig 43 A).

Head capsular with minute and intermittent pits. Median suture runs along the middle face from antennae to the lip and transversely striated. Eye cluster semi oval shape with around 35 ocelli arranged in 7 rows. Lateral corners of collum more

rounded and cut posteriorly than anteriorly, surface slightly leathery, and places the outer border of the eyes slightly emarginate. Trunk cylindrical and slender. Lateral edges of ring 2 slightly more downwardly produced than collum, creating a longitudinal keel at an acute angle anteriorly (Fig 43 B). Of all the segments, the prozone above the ozopore label is longitudinally striated, sternae is transversely striated, mesozona is punctately wrinkled, prozone below the ozopores is gradually more distinctly obliquely striated, metazona is slightly higher than mesozona is transversely striated. Lower part of carina and back are hardly produced, while other segments are cylindrical. The preanal segment (fig. 43 C) process is long, thick, slightly arched (superior convex), obtuse at the apex, the anal valves a small space. Infra-anal plate short, broad, posteriorly subrectally truncate. The anal valves are fairly long, the margins are more compressed posteriorly than anteriorly, and the premarginal depression is relatively large.

Distribution. India, Pulney Hills, near Kodaikanal; Anaimala Hills, Attakatti and Valparai; Palnis. Maryland & Tigershola, Thandikudi and Kukkal Shola; Alagarmalai Hills; Kerala, Kammadam Kavu, Chittarikal, and Payyankulam Kavu, Karinthalam, Kasaragod (Fig 43 E).

4.8.1.1.1.5 Genus *Eucentrobolus* Pocock, 1903

Diagnosis. Monotypic genus. Cylindrical and stout millipedes. Head capsular and short antennae. The distance between the antennae is roughly equal to the distance between the edge of the labrum and the antennal socket summit, and the distance between the antennal socket and the closest point on the head's lateral border is equal to half the distance between the two sockets and three times the diameter of the basal antennal segment. The antennae are roughly as long as the exposed portion of the head and are comparatively close together. The head's subocular region hollowed out longitudinally, allowing the inferior border of the ocular region to protrude as a clear, obtuse ridge. Labrum with 2+2 setiferous foveole.

The first tergal plate large, featuring a row of tubercles along its posterior margin, which is slightly elevated. Post sulcal region of all subsequent terga, except the last, is elevated and bears a transverse row of 12–15 irregularly spaced blunt tubercular spines, with smaller tubercles occupying the intervals. Sterna are transversely ridged. Ozopores commence on the sixth segment, are small, and located anterior to the

sulcus, with those on the sixth segment aligned with the others. The anal tergite extends into a long caudal process. This genus is very similar to *Acanthiulus*, a New Guinean species which is the only group with similar body ornamentation and differs from it by the presence of large and strong preanal process.

4.8.1.1.5.1 The description of species of Genus *Eucentrobolus* Pocock, 1903 collected from the sacred groves of North Kerala.

Taxonomy

Family Pachybolidae Cook, 1897

Genus *Eucentrobolus* Pocock, 1903

Type-species: *E. tamulus* Pocock, 1903, by monotypy.

***Eucentrobolus maindroni* (Bouvier, 1903)**

Acanthiulus Maindroni (sic!) Bouvier, 1903: 263 (D).

Acanthiulus maindroni—Brölemann, 1903: 469 (D).

Eucentrobolus tamulus Pocock, 1903: 528 (D), synonymized under *E. maindroni* by Carl (1941b: 611).

Eucentrobolus maindroni—Brölemann, 1913: 108 (D); Attems, 1936: 311 (M); Carl, 1941b: 610, 611 (D); Rajulu,

1970b: 144 (M); Bai, 2001: 46, 52 (R); Jeekel, 2001c: 51 (M).

Eucentrobolus Maindroni (sic!)—Attems, 1914: 352 (M).

Eucentrobolus tamulus—Attems, 1914: 352 (M).

Eucentrobolus hamulus (sic!)—Attems, 1936: 311 (M); Rajulu, 1970b: 145 (M); Bai, 2001: 46, 52 (M, R).

Materials examined. Female (CATE-101401 A), from the sacred groves of Kammadam Kavu, Chittarikal (12°18'48"N 75°18'55"E), in Kasaragod district. Leg Aswathy M.D.

Diagnosis. Diagnosed by the large size or the species with prominent and heavy tergal ornamentation which is only present in the genus *Eucentrobolus* and the genus is monotypic.

Description. Sub-cylindrical millipede with stout body and prominent heavy ornamentation on the body rings. Live specimens with greyish-black, non-glossy trunk; legs and antennae ferruginous. Upon preservation in absolute alcohol, the specimen discoloured to blackish brown trunk and pallid brown walking legs and antennae (Fig 44 A).

Head granularly rugose, with a transverse groove inferiorly; median groove deep dorsally and ventrally but obsolete medially; forehead slightly depressed. Eyes composed of approximately 35 ocelli. First segment very large, the widest in the body, with a coarsely coriaceous surface; anterior margin of metazonae slightly concave ventrally; inferior angle acute yet rounded; posterior margin abruptly and obliquely truncated to form the posterior boundary of the inferior angular termination. Second segment with an infero-lateral portion tubercular, extending below collum, and thickened with an external and inferior projection. Posterior margin of metazonae obtusely rounded, anterior margin acute and positioned beneath the corresponding margin of the first segment. In addition to low and irregular tubercles along the inferior crest, the segment bears 15 prominent tubercles along with several smaller ones.

Third and fourth segments narrower than the second and fifth segments, with the fifth slightly wider than the second. The anterior and median regions of all segments form a continuous area, undifferentiated and covered with a fine reticulation of ridges. On the anterior inferior portions of the segments, these ridges transition into distinct transverse ridges at the front and obliquely transverse ridges at the rear.

Posterior elevated portions of the segments are coarsely ridged inferiorly beneath the tubercles. These elevated areas are adorned with an anterior row of smaller tubercles, along with the larger and smaller tubercles forming the posterior rows.

Distribution. India, Western Ghats, Malabar; Anaimala Hills, Attakatti; Valparai; Tinnevely; Travancore, Trivandrum, Kammadam Kavu, Chittarikal, Kasargode (Fig 44 B & C).

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4.9 Taxonomic Contributions from the Study: New Species and Distributional Records

4.9.1 Species checklist of diplopods of Kerala

India's diverse topography, unique geographical location, and rich tropical and subtropical vegetation create a highly suitable environment for the extensive diversification of millipede species. However, the existing literature on Indian diplopods is both limited and outdated, often encompassing regions that were historically part of British India, such as China, Myanmar, Pakistan, and Sri Lanka. A comprehensive account of Indian millipedes was provided by Golovatch and Wesener (Golovatch & Wesener, 2016). This checklist enumerated around 290 nominal species across the country. An updated version following this checklist was composed by Chezhiyan (2022) and Subramanian & Senraj (2024) adding the newly reported species up until 2023. The new checklist of millipede fauna depicted here consists of 70 species from 7 orders.

An updated checklist dedicated to the diplopod fauna of Kerala is as follows;

Table 1. Species checklist of millipedes reported from Kerala

Sl. No	Species	Location	Family	Order
1	<i>Prosopodesmus jacobsoni</i> (Silvestri, 1910)	Thiruvananthapuram	Haplodesmidae Cook, 1895	Polydesmida Leach, 1815
2	<i>Pseudosphaeroparia palnensis palnensis</i> Carl, 1932	Travancore	Trichopolydesmidae Verhoeff, 1910	
3	<i>Pseudosphaeroparia malabaricus</i> sp n.	Kasaragode, Kannur, Kozhikode, Wayandad		
4	<i>Pseudospaeroparia falcata</i> sp.nov.	Kozhikode		
5	<i>Klimakodesmus bilibocaudatus</i> sp.nov.	Kannur		
6	<i>Cryptocorypha areata</i> (Carl, 1932)	Trivandrum		
7	<i>Pagodesmus biporus</i> (Carl, 1932)	Trivandrum		

8	<i>Pagodesmus sulcifer</i> (Carl 1932)	Kozhikode	Paradoxosomatidae Daday, 1889	
9	<i>Propyrgodesmus bulbogonopus</i> sp.nov	Kozhikode, Thrissur		
10	<i>Propyrgodesmus lobulatus</i> (Silvestri, 1920)	Kochin		
11	<i>Anoplodesmus anthracinus</i> (Pocock, 1895)	Trivandrum		
12	<i>Anoplodesmus insignis</i> (Attems, 1936)	Kerala overall.		
13	<i>Anoplodesmus rufocinctus</i> (Carl, 1932)	Valparai		
14	<i>Anoplodesmus sabulosus</i> (Attems, 1898)	Trivandrum		
15	<i>Anoplodesmus saussurii</i> (Humbert, 1865)	Malappuram, Kozhikode, Kannur, Wayanad, Kasaragod		
16	<i>Anoplodesmus splendidus</i> (Verhoeff, 1936)	Trivandrum		
17	<i>Anoplodesmus subcylindricus</i> (Carl, 1932)	Trivandrum		
18	<i>Anoplodesmus tanjoricus</i> (Pocock, 1892)	Trivandrum		
19	<i>Anoplodesmus ursula</i> (Attems, 1936)	Kannur		
20	<i>Antichirogonus hirtus</i> (Carl, 1932)	Trivandrum		
21	<i>Antichirogonus laevisulcatus</i> (Carl, 1932)	Kerala		
22	<i>Chondromorpha kelaarti longipes</i> (Verhoeff, 1936)	Trivandrum		
23	<i>Chondromorpha kelaarti</i> (Carl, 1932)	Thiruvananthapuram, Kozhikode, Kannur		

24	<i>Delarthum anomalans</i> sp.nov	Valliyoorkavu, Wayanad		
25	<i>Gyrodrepanum lamprum</i> (Chamberlin, 1920)	Kerala		
26	<i>Orthomorpha coarctata</i> (de Saussure, 1860)	All over India (Poyilkavu in Calicut in this study)		
27	<i>Telodrepanum badaga</i> (Carl, 1932)	Kozhikode		
28	<i>Xiphidiogonus dravidus</i> (Carl, 1932)	Trivandrum		
29	<i>Silvestrus seminudus</i> (Jones, 1937)	Trivandrum, Kozhikode, Kannur	Polyxenidae Lucas, 1840	Polyxenida Verhoeff, 1934
30	<i>Monoxenus padmanabhai</i> (Jones, 1937)	Trivandrum		
	<i>Lophoturus muchukunnesis</i> sp.nov.	Muchukunnu Kav, Kozhikode	Lophoproctidae silvestri, 1897	
31	<i>Arthrosphaera attemsi</i> (Jeekel, 2001)	Trivandrum	Arthrosphaeridae Jeekel, 1974	Sphaerotheriid a Brandt, 1833
32	<i>Arthrosphaera aurocincta</i> (Pocock, 1899)	Parambikulam, Kochi, Kozhikode.		
33	<i>Arthrosphaera craspedota</i> (Attems, 1936)	Parambikulam, Kochi.		
34	<i>Arthrosphaera dalyi</i> (Pocock, 1895)	Kannur, Wayanad		
35	<i>Arthrosphaera disticta</i> (Pocock, 1895)	Kannur		
	<i>Arthrosphaera gracillis</i> (Attems, 1936)	Kerala		
36	<i>Arthrosphaera inermis</i> (Humbert, 1865)	Kerala		
37	<i>Arthrosphaera lutescens</i> (Butler, 1872)	Trivandrum		

38	<i>Arthrosphaera nitida</i> (Pocock, 1895)	Kannur, Wayanad		
39	<i>Arthrosphaera stridula</i> (Verhoeff, 1937)	Trivandrum		
40	<i>Arthrosphaera kammadamensis</i> sp.nov.	Kammadam Kavu, Kasaragod		
41	<i>Aulacobolus excellens</i> (Silvestri, 1916)	Kochin	Pachybolidae Cook, 1897	Spirobolida Bollman, 1893
42	<i>Aulacobolus ejaculans vallisensis</i> (Carl, 1941)	Trivandrum		
43	<i>Aulacobolus gravelyi</i> (Silvestri, 1916)	Trivandrum, Kochin, Quilon		
44	<i>Cingalobolus carli</i> (Attems, 1936)	Thrissur		
45	<i>Eucentrobolus maindroni</i> (Bouvier, 1903)	Trivandrum, Kannur		
46	<i>Stenobolus insularis</i> (Carl, 1918)	Trivandrum, Kasaragode, Kannur, Kozhikode		
47	<i>Xenobolus carnifex</i> (Fabricius. 1775)	Palakkad, Kozhikode		
48	<i>Trachyjulus modestior</i> (Silvestri, 1923)	Kochi	Cambalopsidae Cook, 1895	Spirostreptida Brandt, 1833
49	<i>Podoglyphiulus jonesii</i> (Verhoeff, 1936)	Trivandrum		
50	<i>Carlogonus palmatus</i> (Demange, 1977)	Kannur		
51	<i>Carlogonus spinicaudus</i> (Gervais, 1847)	Malabar Coast	Harpagophoridae Attems 1909	
52	<i>Carlogonus gayatri</i> (Sankaran & Sebastian, 2020)	Palakkad		

53	<i>Carlogonus verhoeffi</i> (Demange, 1981)	Trivandrum		
54	<i>Fageostreptus hyatti</i> (Demange, 1961)	Trivandrum, Wayanad		
55	<i>Gnomognathus minisculus striatus</i> (Carl, 1941)	Travancore		
56	<i>Harpurostreptus jonesi jonesi</i> (Verhoeff, 1938)	Trivandrum		
57	<i>Harpurostreptus prasadani</i> (Demange, 1989)	Malappuram, Wayanad		
58	<i>Janardananepetus kannanorensis</i> (Demange, 1989)	Kannur		
59	<i>Ktenostreptus calcaratus</i> (Demange, 1962)	Kannur, Calicut, Wayanad		
60	<i>Organognathus Janardhani</i> (Demange, 1977)	Kannur		
61	<i>Organognathus multidentatus</i> (Verhoeff, 1936)	Trivandrum		
62	<i>Phyllogonostreptus poculifer</i> (Demange, 1975)	Kannur		
63	<i>Phyllogonostreptus nigolabiatus</i> (Newport, 1884)	All over south India		
64	<i>Rhinotus purpureus</i> (Pocock, 1894)	Thaze kavu, Kannur	Siphonotidae Cook 1895	Polyzoniida Gervais, 1844
65	<i>Theratta mannavan</i> (Anilkumar et al., 2022)	Idukki		
66	<i>Theratta eravikulam</i> (Anilkumar et al., 2022)	Idukki		

67	<i>Theratta shola</i> (Anilkumar et al., 2022)	Idukki		
68	<i>Siphonirhinus prambikulam</i> (Anilkumar et al., 2024)	Palakkad	Siphonorhinidae Cook, 1895	Siphonophorida Newport, 1844
69	<i>Siphonorhinus muchukunnesis</i> sp.nov.	Muchukunnu Kavu, Kozhikode		
70	<i>Siphonorhinus Koyithattensis</i> sp.nov.	Koyithatta sree Dharma Sastha Kavu,, Kasaragode		

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4.10 Seasonality in Millipede

4.10.1 Seasonal Occurrence of Millipedes in Sacred Groves of North Kerala

The occurrence of millipedes in nature is always linked to the changing seasons and climatic factors of their habitat. In tropical and subtropical regions, millipedes are most abundant during the monsoon and post-monsoon seasons, retreating into deeper soil layers or entering dormancy during dry months. The seasonality in millipedes is often associated with temperature, humidity, food availability and breeding (Delinger, 1986). The reproduction and the juvenile development require moist environmental conditions.

Millipede diversity exhibited pronounced seasonal variation across the study sites. The Shannon–Wiener index (H') (Fig. 81 & Table 5) was highest during the post-monsoon season, indicating increased species diversity and a more balanced community structure under favorable environmental conditions. Lower values observed during the pre-monsoon season suggest reduced diversity associated with dry conditions.

Simpson index values (Fig 82 & Table 5) corroborated this trend, with higher diversity and reduced dominance during the monsoon season, whereas pre-monsoon communities were characterized by dominance of fewer species.

Evenness values (Fig 83 & Table 5) were also elevated during the post-monsoon, indicating a more equitable distribution of individuals among species, while reduced evenness during the pre-monsoon suggests uneven community composition.

Kruskal–Wallis test showed significant seasonal differences ($p < 0.05$). Pairwise comparisons indicated significant differences between post-monsoon and monsoon ($p < 0.05$).

Table 5. Seasonal variation in diversity indices and abundance of millipedes across study sites

Season	N	Shannon	Simpson	Evenness	Richness	Abundance
Monsoon	36	0.314	0.193	0.339	1.583	8.972
Post-monsoon	36	0.451	0.261	0.437	2.139	29.806
Pre-monsoon	36	0.079	0.053	0.101	0.556	1.083
p-value		0.0005	0.0008	0.0016	<0.001	<0.001

N indicates the number of sampling units (site $\times$ year combinations). Statistical significance was assessed using the Kruskal–Wallis test.

Species Richness and Abundance Patterns

Species richness increased from pre-monsoon to monsoon and remained relatively high during the post-monsoon season (Fig 84). The line plot of mean species richness confirmed a clear seasonal trend, with peak richness observed during the post-monsoon period (Fig 87).

Total abundance of millipedes was highest during the post-monsoon season, suggesting favourable conditions for population growth following the monsoon. Pre-monsoon abundance was consistently lower across sites (Fig 85).

Mean abundance per species also followed a similar pattern, with higher values during the post-monsoon season, indicating increased population sizes at the species level (Fig 86).

Kruskal–Wallis test confirmed significant variation ($p < 0.05$).

Community Composition

Relative abundance analysis revealed distinct seasonal shifts in species composition. The post-monsoon season exhibited a more evenly distributed community, with 26 species contributing to overall abundance. In contrast, pre-monsoon and monsoon communities were dominated by fewer taxa, indicating reduced diversity and increased dominance. However, differences were not statistically significant ($p > 0.05$).

Rare species were present across seasons but contributed minimally to overall abundance, reflecting high spatial heterogeneity among study sites (Fig 88).

In the study conducted here, no millipede species were seen or collected throughout the year (collection period). The analysis of occurrence data shows a pattern of high abundance of the species during monsoon and post monsoon seasons. The species *Anoplodesmus sassurii* shows its occurrence in most of the months except the months of march and april, which is summer with around 40 degree celsius in the Southern India. A similar pattern is observed in *Chondromorpha kelaarti*, which occurs in January and from June through December, but is absent during February, March, April, and May. *Trigoniulus corallinus* also demonstrated remarkable persistence, maintaining a consistent presence throughout the year, albeit at varying abundances.

Some large species such as *Fageosteptus hyatti* and *Eucentrobolus maindroni* were collected only during one or two months falling in the post monsoon period of the year. In the pre monsoon period, the community structure was characterized by the

co-occurrence of *Trigoniulus corallinus*, *Xenobolus carnifex*, *Aulacobolus gravelyi*, and *Eucentrobolus maindroni*. By the onset of monsoon, species such as *Delarthrum anomalans* **sp.nov.**, *Telodrepanum badaga*, *Chondromorpha kelaarti*, *Orthomorpha coarctata*, *Pseudosphaeroparia malabarica* **sp.nov.** emerged. Maximum species richness was observed during the peak monsoon and the post monsoon seasons with high activity of *Rhinotus purpureus*, *Carlogonus palmatus*, *Fageosrteptus hyatti*, *Harpurostreptus prasadani*, *Silvestrus seminudus*, *Siphonorhinus muchukunnensis* **sp.nov.**, and *Arthrosphaera kammadamensis* **sp.nov.**.

A notable absence of data during March-April suggests potential aestivation or reduced activity during the peak summer months. The distribution patterns showcase intricate community dynamics among millipede species in North Kerala's sacred groves, highlighting distinct seasonal successions and species-specific temporal niches. These trends likely indicate adaptations to micro-habitat, environmental factors and cyclical variations in resource availability.

4.10.1.1 Seasonal occurrence of millipede fauna in sacred groves of Kasaragod district.

During the study period of January 2021 - January 2023, a total of 8 sacred groves were surveyed and 2 and 4 nominal species were collected in 2021 and 2022 respectively. The site wise occurrence of millipede fauna is given as follows:

4.10.1.1.1 Edeyilakad Kavu - KZE01:

In the year 2021, a single species, *Stenobolus insularis*, was documented from the study site where a minimum number of specimens were collected in the pre-monsoon period. It is followed by the monsoon period where there is a gradual increase in the number of individuals (17 numbers) which is followed by sudden spike in number with around 30 individuals being collected (Fig 45). The same pattern is followed by *S. insularis* in the successive year of 2022 where there is a rapid increase in the population during the post-monsoon period with 2 individuals in pre-monsoon followed by 9 and 32 individuals in monsoon and post-monsoon periods respectively. In 2022, *Anoplodesmus saussurii* was also collected monsoon in minimum numbers (1 individual) but was not recorded during the pre-monsoon or post-monsoon periods (Fig 46). There is an overall low species diversity in the site KZE-01, which is

indicated by the absence of all other species recorded during the study. The fluctuation in the abundance of *S. insularis* emphasizes the substantial impact of seasonal variations on species distribution and abundance in Edeyilakad Kavuv by indicating that the species is highly seasonal and potentially well-adapted to post-monsoon conditions.

4.10.1.1.2 Kammadam Kavuv - KZE02

The survey in 2021 resulted in the documentation of one species, *S. insularis*. In pre - monsoon period, no individuals were recorded and a gradual increase in the population is observed from mid monsoon with a significant increase in number towards post - monsoon period, from 3 individuals in monsoon to 10 individuals in post-monsoon period (Fig 47). In 2022, along with *S. insularis*, two more species were collected from the site i.e., *Aulacobolus newtoni* and *Arthrosphaera kammadamensis* **sp.nov.** (Fig 48). The post monsoon period of 2022, is dominated by a remarkable population of *A. kammadamensis* **sp.nov.** (29 individuals) preceded by a smaller presence in the Monsoon (5 individuals) and Pre Monsoon seasons (0 individuals). *S. insularis* (10 individuals) and *E. maindroni* (3 individuals) also exhibit noticeable occurrences, especially Post Monsoon, though in much lower numbers compared to *A. kammadamensis* **sp.nov.** This pattern of abundance supports the post monsoon period to favour higher population counts.

4.10.1.1.3 Payyankulam Kavuv - KZE03

In 2021, only 2 individuals of *S.insularis* was reported from the sacred grove only during the post- monsoon period (Fig 49). Whereas in 2022, few individuals of *Aulacobolus newtoni* (2 individuals) and *Anoplodesmus saussurii* (6 individuals) were again collected in the post- monsoon season with only a small population of *A.saussurii* (4 individuals) being collected in the monsoon period (Fig 50). This also implies the inevitability of humidity and moisture content variation in millipede microhabitat has the potential to increase the proliferation of population.

4.10.1.1.4 Puthiyaparambath Kavuv -KZE04

The site KZE04, is amongst the least diverse sacred groves of North Kerala. In 2021, a single species with a minimal population were recorded from here during monsoon and post monsoon, with 1 and 2 individuals respectively (Fig 51). In 2022, *A. saussurii* showed a minimal population in pre-monsoon (1 individual) and sharp

spike in post-monsoon (26 individuals), with a similar pattern exhibited by *S. insularis* (Fig 52).

4.10.1.1.5 Mannampurath Kavuv - KZE05

KZE-05 also shows similar abundance with bare minimum number of species (2 species) and shows similar abundance pattern with KZE04. The species recorded from this site are *S. insularis* and *A. saussurii* (Fig 53 & 54).

4.10.1.1.6 Koyithatta Sree Dharma Sastha Kavuv - KZE06

The site KZE06, in 2021 showed only an abundant population of *A. saussurii* in the post monsoon period. In the pre-monsoon and monsoon period, no individuals of the species were collected (Fig 55). But in 2022, a few species were collected in the pre-monsoon period, and a higher number of them were collected in the following monsoon and the post monsoon period (Fig 56). In the post monsoon period, the species, *Siphonorchinus koyithattensis* **sp.nov** was collected which turned out to be new to science. The individuals of this species were obtained only once throughout the collection period and it can be inferred that only the favourable climate in the microhabitat can yield rare species to light.

4.10.1.1.7 Sree Malliyodan Kavuv - KZE07

In 2021, only a single specimen belonging to species *Trigoniulus corallinus* was collected from the study site KZE07, during monsoon season. No further observations were made during the pre-monsoon or the post-monsoon periods of the year (Fig 57). In 2022, *Silvestrus seminudis* stands out with the highest number of individuals observed during the Post Monsoon season (around 20), indicating its dominance in the site during that period (Fig 58). It also appears in smaller numbers during the Monsoon and Pre-Monsoon seasons. Another notable species is *T. corallinus*, which was recorded only in the Post Monsoon season with a moderate count. This abundance pattern also highlights a strong post-monsoon surge in the population of select species like *S. seminudis*, possibly due to favorable environmental conditions during that time, while the overall species richness remains low.

4.10.1.2 Seasonal occurrence of millipede fauna in sacred groves of Kannur district.

During the study period of January 2021 - January 2023, a total of 5 sacred groves were surveyed in 2021 and 2022 respectively. The year is divided into 3 periods, Pre-monsoon, Monsoon and Post monsoon. The site wise occurrence of millipede fauna is given as follows:

4.10.1.2.1 Thazhe Kavu - KNN01

The 2021 survey resulted in the reporting of *Klimakodesmus bilobocaudatus* **sp.nov.** in abundance during the post-monsoon season (9 individuals) (Fig 59). A single specimen of *Rhinotus purpureus* was also collected during this period. In 2022, *K. bilobocaudatus* **sp.nov.** was collected yearlong with a small population in monsoon (3 individuals) and a sudden surge towards the post-monsoon season (33 individuals) (Fig 60). Least abundance of species was observed during monsoon period. The abundance pattern shows that the species find less humid and more dry conditions for their survival. On the other hand, the abundance pattern of *R. purpureus* shows minimal abundance (1 individual) in the monsoon period followed by an escalation in abundance in the post-monsoon period (14 individuals). The species is observed to be absent in the pre-monsoon period.

4.10.1.2.3 Madayi Kavu-KNN02

KNN02 is a species rich site which resulted in 3 species in 2021 survey (Fig 61). *A.saussurii* was the most abundant species with around 30 individuals. It is also observed in smaller numbers during the Pre-Monsoon and Monsoon periods. *S. insularis*, appears only in the post- monsoon period with a count of 8 individuals, indicating seasonal emergence. *P. malabarica* **sp.nov.** is found across all three seasons in low numbers, with a slight peak in the post-monsoon period. In the subsequent survey of 2022 (Fig 62), *A. saussurii* exhibited the highest abundance, with numbers rising from 3 individuals in the pre-monsoon to 14 in the monsoon and peaking at 25 individuals in the post-monsoon. *S. insularis* also showed a notable increase across seasons, with 10 individuals in the monsoon and a maximum of 16 in the post-monsoon. A similar trend was followed by *T. corallinus* by increasing the number steadily from 3 individuals in the pre-monsoon to 8 in the post-monsoon. *P. malabarica* was observed in low but consistent numbers, with a slight rise during the

post-monsoon. Overall, the graph indicates a clear increase in species abundance during the post-monsoon period, suggesting favorable ecological conditions following the monsoon rains.

4.10.1.2.3 Neeliyarkottam -KNN03

The survey of the site KNN03 in 2021 recorded two species, *S. insularis* and *X. carnifex* in small numbers. *S. insularis* was most abundant in post-monsoon with 29 individuals and 10 individuals in the monsoon period (Fig 63). No individuals of the species were collected in pre-monsoon period. *X. carnifex* was seen in a small margin of 4 individuals in monsoon. Seasonal abundance of the site in the year 2022 was recorded with *A. saussurii* showing the highest abundance, increasing from 12 individuals in the pre-monsoon to 22 during the monsoon, and with the highest number at 37 in the post-monsoon, indicating its strong post-monsoon dominance. *S. insularis* followed a similar trend, rising from 4 individuals in the pre-monsoon to 9 in the monsoon and reaching 27 in the post-monsoon. *T. corallinus* showed moderate abundance with a gradual increase across the seasons. Interestingly, *P. falcata* sp.nov. and *C. palmauts* were absent in the pre- and monsoon seasons but appeared in significant numbers (33 and 13, respectively) in the post-monsoon, indicating their seasonal specificity (Fig 64).

4.10.1.2.4 Chaamakavu-KNN04

The survey of 2021 reported least number of species and individuals from the study site KNN04. Only 2 individuals were collected from the site during monsoon period and no individuals were observed during pre and post monsoon periods. In the year 2022, 3 species were recorded from the study site. *A. saussurii* recorded, with only 1 individual in the pre-monsoon, rising to 11 during the monsoon, and surging to 42 in the post-monsoon, making it the most dominant species at this site. *T. corallinus* was moderately represented, showing a slight increase from 3 individuals in the pre-monsoon to 5 in the post-monsoon. Other species such as *C. palmauts* were completely absent in the pre-monsoon but showed moderate presence during monsoon and post-monsoon, peaking at 5 individuals. The post-monsoon season displayed a significant spike in abundance.

4.10.1.2.5 Poongottukavu-KNN05

KZE05 shows a highly restricted species distribution, with *A. saussurii* being the only species recorded across all three seasons (Fig 67). The abundance pattern indicates a narrow species representation, with only *A. saussurii* recorded across all three seasons. This species showed its highest abundance during the monsoon with 3 individuals, followed by 2 in the post-monsoon and a single occurrence in the pre-monsoon. Its abundance pattern in number peaked during the monsoon with 7 individuals, followed by a reduced count of 3 in the post-monsoon and just 1 in the pre-monsoon in the year 2022 (Fig 68). No other species were observed at this site during any of the seasons, indicating a strongly monodominant pattern.

4.10.1.3 Seasonal occurrence of millipede fauna in sacred groves of Kozhikode district.

During the study period of January 2021 - January 2023, a total of 3 sacred groves were surveyed in 2021 and 2022 respectively. The year is divided into 3 periods, Pre-monsoon, Monsoon and Post monsoon. The site wise occurrence of millipede fauna is given as follows:

4.10.1.3.1 Muchukunnu Kavu-CLT01

In the 2021 survey, 2 species were recorded, *C. kelaarti* and *A. saussurii* with 2 and 3 individuals respectively in the pre-monsoon period (Fig 69). A slight spike is observed for *A. saussurii* with 2 to 9 individuals in the monsoon period whereas a slight elevation from 3 to 4 individuals in the case of *C. kelaarti*. In the post-monsoon period, a rapid rise in individuals is observed for both the species rising up to 31 and 36 individuals. The graph plotting for the survey of 2022 (Fig. 70) suggests that the Post Monsoon season supports a higher abundance of certain species compared to the other two seasons. *P. sulcifer* exhibited the highest number of individuals, peaking with 75 individuals during the Post Monsoon. This was followed by *C. kelaarti* with around 35 individuals and *P. malabarica* **sp.nov.** with approximately 15 individuals. A moderate number of individuals were also observed for *Lophoturus muchukunnensis* **sp.nov.** and *S. muchukunnensis* **sp.nov.** during the same season and least number was counted for *T. badaga* in contrast, the Pre Monsoon and Monsoon seasons showed consistently low numbers across most species, with only slight

increases in the populations of *A. saussurii*, *C. kelaarti*, and *P. sulcifer* during the Monsoon.

4.10.1.3.2 Poyilkavu - CLT02

In 2021, only 3 individuals of *A. saussurii* were collected from the site CLT02 (Fig 71). The individuals were obtained in the post monsoon period. No other species or individuals were collected in pre-monsoon or post-monsoon of that year. In 2022 (Fig 72), the abundance of *A. saussurii* follows the same pattern as of 2021 with a remarkable spike during the post-monsoon period with around 26 individuals, preceded by 14 individuals and 4 individuals in monsoon and pre-monsoon periods respectively. Also, during the post monsoon period around 10 individuals of *Orthomorpha coarctata* were collected and were not obtained in any other season.

4.10.1.3.3 Vallikattukavu-CLT03

The 2021 (Fig 73) survey shows that species abundance in this site is generally very low across all seasons. Notably, *A. saussurii* was the only species observed during the Pre Monsoon (with just one individual) and also showed a slight increase during the Post Monsoon, reaching a maximum count of three individuals. In 2022 (Fig 74), only *A. graveyi* showed any notable activity and *A. saussurii* was not collected across the seasons. This species was recorded in small numbers during the Pre Monsoon and Monsoon, with a count of around 2 and 10 individuals respectively. Its population peaked during the Post Monsoon season, reaching approximately 20 individuals. The absence of other species across seasons may reflect limited habitat suitability or sampling constraints within the Vallikattukavu site.

4.10.1.4 Seasonal occurrence of millipede fauna in sacred groves of Wayanad district.

During the study period of January 2021 - January 2023, a total of 3 sacred groves were surveyed in 2021 and 2022 respectively. The year is divided into 3 periods, Pre-monsoon, Monsoon and Post monsoon. The site wise occurrence of millipede fauna in the 3 selected sacred groves of Wayanad district is given as follows:

4.10.1.4.1 Manikavu-WYN01

In the surveys conducted throughout the study period, only two species were reported from the grove; *A. saussurii* and *P. malabarica* **sp.nov.** In 2021 survey (Fig 75), *A. saussurii* showed the highest abundance, with 11 individuals recorded during the monsoon period and 10 in the post-monsoon period, but only one individual in the pre-monsoon period. On the other hand, *P. malabarica* **sp.nov.** was observed exclusively in the post-monsoon season, with the abundance of six individuals. A similar pattern of abundance was observed in 2022 (Fig 76) survey also with a gradual rise in individual number is observed starting from pre-monsoon period to post monsoon period and a rapid rise in population in post monsoon period with 2, 5 and 19 individuals respectively in the case of *A. saussurii*. In the case of *P. malabarica* **sp.nov.**, a few individuals of around 2 numbers were collected in the monsoon with a rapid spike towards 12 individuals in the post-monsoon period. The sharp increase in millipede activity during and after the monsoon points to the importance of rainfall-driven habitat changes in influencing faunal patterns.

4.10.1.4.2 Valliyurkavu - WYN02

The site WYN-02 is a species rich site as it lies in close proximity of the Western Ghats range. In 2021 (fig 77) survey, three species were recorded with varying seasonal abundance. The species *A. saussurii* and *C. kelaarti* were the most dominant, with notable increases during the Monsoon and Post-Monsoon periods. *A. saussurii* showed peak abundance in the post-monsoon with 18 individuals, followed by Monsoon 12, and a comparatively lower count during Pre-Monsoon 2 individuals. Similarly, *C. kelaarti* showed a strong seasonal trend with 9 individuals during Monsoon and 12 during Post Monsoon, while only 2 individuals were recorded in the Pre Monsoon. *A. aurocincta* was collected during monsoon and post-monsoon period in very small numbers of 1 and 2 respectively having the least abundance in the site. In 2022 (Fig. 78), a total of six species were recorded across three seasons. Among them, *A. saussurii*, and *C. kelaarti* exhibited pronounced seasonal variation. *A. saussurii* was highly abundant during the Post Monsoon (14 individuals), with reduced presence during the Monsoon (2) and no record in Pre Monsoon. Similarly, *C. kelaarti* showed an increasing trend from Monsoon (8 and 10 individuals respectively) to Post Monsoon (9 and 14 respectively), while absent in the Pre Monsoon. While *A. aurocincta* showed higher abundance in the monsoon period with

7 individuals and a slight decrease in the post-monsoon period with only 3 individuals, *H. prasadani* exhibited a fairly good abundance only during the post-monsoon period being absent in the other two periods. Similar to that, a single individual of *H. hyatti* was also collected during the post-monsoon period. This suggests that these species are likely to be seasonally active and their populations possibly peak in response to post-rainfall (except *A. aurocinta*) conditions such as increased moisture, litter decomposition, and favorable microclimatic conditions.

4.10.1.4.3 Anoth Kavu-WYN03

Only 2 species were recorded in 2021 (Fig 79) in the site WYN-03. *P. malabarica* **sp.nov.** is the most abundant species recorded with 4 individuals in the pre-monsoon and 7 in post-monsoon period. A small population of *A. aurocinta* with the abundance of 1 individual was collected in the pre-monsoon with absence in monsoon and post-monsoon on contrary to which they were collected in post-monsoon period of 2022 survey also with a small population consisting of 3 individuals. In 2022 (Fig. 80) survey also, the abundant species of this site was *P. malabarica* **sp.nov.** with 6 and 11 individuals in monsoon and post monsoon periods. The dominance of post-monsoon records suggests that this site, like others in the region, experiences a surge in millipede activity following the monsoon, possibly due to increased detritus availability and suitable microhabitats.

Environmental Influence on Diversity

Spearman correlation analysis indicated a positive relationship between relative humidity and Shannon diversity, as well as between relative humidity and abundance (Fig 89, 90 & Table 6,7). In contrast, temperature exhibited a weak negative association or non-significant effect, suggesting that higher temperatures may limit diversity, likely due to increased desiccation stress. Temperature, although an important environmental variable, appears to act more as a limiting factor during dry periods rather than a primary driver of community structure.

Multiple regression analysis (OLS) further demonstrated that relative humidity had a stronger influence on Shannon diversity compared to temperature. The model indicated that increasing humidity levels promote higher diversity, whereas elevated temperatures may impose constraints on species activity.

Table 6. Spearman correlation between environmental variables and millipede diversity metrics.

Response	Variable	Spearman_r	p_value
Shannon	Temp	0.011	0.9264
Shannon	RH	0.299	0.0127
Richness	Temp	0.06	0.6215
Richness	RH	0.341	0.0041
Abundance	Temp	0.136	0.2641
Abundance	RH	0.403	0.0006

Spearman's rank correlation coefficients (r) and corresponding p-values are presented for relationships between temperature, relative humidity, and diversity metrics (Shannon, richness, and abundance).

Table 7. Multiple regression analysis of environmental variables influencing millipede diversity.

Response	Predictor	Coefficient	p_value	R_squared
Shannon	Temp	0.0034	0.8692	0.0975
Shannon	RH	0.0203	0.0011	0.0975
Richness	Temp	0.046	0.5151	0.1186
Richness	RH	0.0748	0.0004	0.1186
Abundance	Temp	2.0621	0.1104	0.0546
Abundance	RH	0.6536	0.0825	0.0546

Regression coefficients represent the effect of temperature and relative humidity (RH) on diversity metrics. Statistical significance is indicated by p-values.

Summary of Seasonal Trends in Millipede Communities

Seasonal variation had a strong influence on the structure of millipede communities across the study sites. Diversity and evenness were highest during the monsoon season, indicating more favourable conditions for species coexistence. In contrast, total abundance reached its peak during the post-monsoon period. These observed patterns suggest that a combination of moisture availability, temperature, and habitat conditions plays a key role in determining the distribution and composition of millipede assemblages.

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4.11 Parasitic interactions in millipede

4.11.1 Endoparasite in Spirobolid Millipede

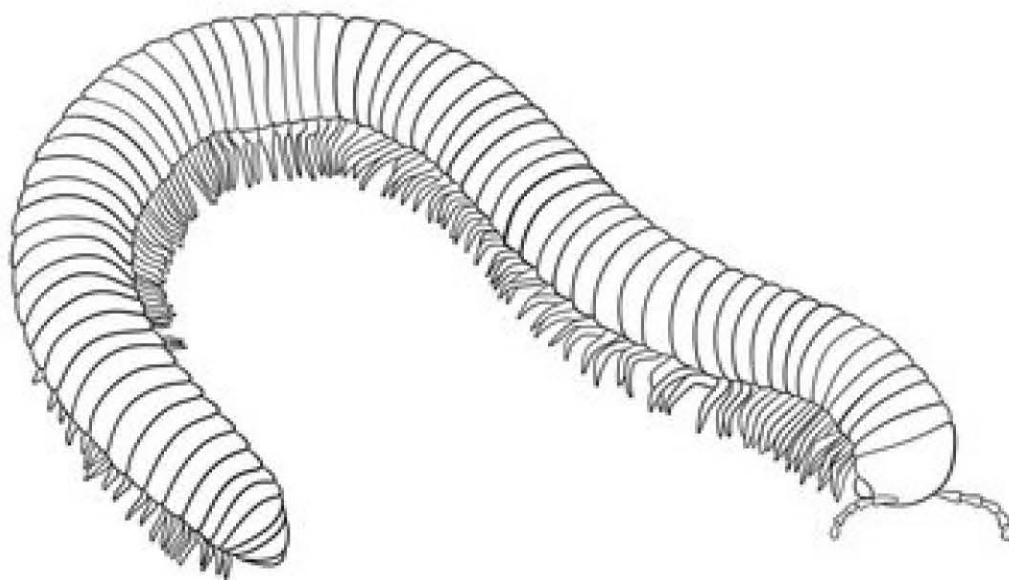
An endoparasite was obtained from the coelomic cavity of a female *Stenobolus insularis*, specimen. A total of 7 individuals were collected from Payyankulam Kavu (KZE03), during the post monsoon season of 2022. A single subadult female specimen among them, carried the nematode belonging to family Mermithidae in the coelomic cavity. All other specimens collected from the location were free of nematode infestation.

The mermithids are nematodes grouped under family Mermithidae and comprises over 50 extant genera. They are specialised invertebrate parasites, especially in insects (Poinar-Jr. 2015). The life cycle of mermithids consists of five stages: egg, second-stage juvenile (pre parasitic infective juvenile), parasitic third-stage juvenile, mature third-stage post parasitic juvenile, and the final transition into adulthood through two molts (Poinar-Jr. 1983; Kosulic & Masova 2019). In the case of nematodes targeting terrestrial insects, eggs containing juvenile forms are laid beneath leaves, where they are ingested by insects as food. Once inside, the eggs hatch, releasing juveniles that migrate to the host's hemolymph (Dolinski 2006). The parasitic nematodes usually complete their growth inside the host body and then emerge by forcing their way through the body wall to enter the soil (Martins et al., 2020). They kill the host and emerge into the soil and they molt into the adult stage to complete the cycle (Poinar-Jr. 1979).

The millipede specimen with infestation tends to have least effect on its morphology as there were no observable malformations or external abnormality but any internal or physiological impairment is unknown. This is the first report of finding an endoparasitic nematode from a common tropical millipede species and from species in India.

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CHAPTER 5 *DISCUSSION*

DISCUSSION

Millipedes are amongst the macro arthropods of the soil ecosystem. They are present all across the globe except Antarctica. Although they inhabit most regions of the world, species diversification is particularly prominent in tropical and subtropical zones. As a tropical country with diverse and vegetated landscapes, India is expected to host a rich diversity of millipedes. To date, over 270 species from 12 taxonomic orders of Diplopoda have been recorded from India (Golovatch & Wesener, 2016). Significant efforts were made to document Indian diplopods before the country gained independence in 1947, but post-independence, only a limited number of taxonomic studies have been conducted on this remarkable group. This study was undertaken to document the millipede diversity of Kerala, a coastal state on India's southwestern frontier. The study resulted in elevating the number of species from around 57 nominal species to 70 species. The study also resulted in updating the outdated taxonomic keys and redescribed the erstwhile under described species or taxa as a whole. The study revealed 9 species new to science and few state and regional reports for some species. Given the absence of comprehensive taxonomic research on Indian millipedes, this study serves as a pioneering effort and a foundational reference for future research. When compared with other neighbouring states of Tamil Nadu, Kerala has only less than half the number of millipede diversity with nominal numbers of around 127 and 57 species respectively. Based on recent studies, some of the accepted species were synonymised, and some were deleted from the Indian checklist due to lack of evidence (Sankaran & Sebastian, 2017; 2020).

Except for the 9 new species reported in this study, several species included in this study are widely distributed. The species, *Trigoniulus corallinus* shows a wide distribution throughout the Indo - Malayan region, South Asia, Africa and Americas. Being their origin to be traced into the Indo-Malayan region, the remaining distribution is considered as introduced species (Shelley et al., 2006). This species was also reported from Kew gardens in England (Pocock, 1902). The species *Stenobolus insularis* has a distribution all over India as well as in Maldives (Carl, 1918). The species *Xenobolus carnifex*, even though the type locality is in India, the species also shows distribution in Brazil and Australia (Fabricius, 1775; Hoffman et

al., 2002; Newport 1844). *Anoplodesmus saussurii*, the most common species in India also has the distribution across Mascarene Islands in the Indian Ocean, Singapore and Fiji Island and Sri Lanka its type locality (Humbert, 1865; Nguyen & Sierwald, 2013; Chamberlin, 1920; Rannavre et al., 2024). *Orthomorpha coarctata* on the other hand have much wider distribution all across the tropics (Likhitrakarn et al., 2019). The Polyzonid species *Rhinotus purpureus* called as common tramp species is frequently found in green houses and other synanthropic habitats from many different parts of the world including Kew Gardens in England (Read 2008), green houses in Germany (Decker et al. 2014), Central America and Southern USA (Mauriès 1980), Comoro Islands, Madagascar and Indian Ocean Islands (Vandenspiegel & Golovatch 2007) and recently in India (Aswathy & Sudhikumar, 2023). Other accepted species such as *Aulacobolus graveyi*, *Aulacobolus newtoni*, *Eucentobolus maindroni*, *Telodrepanum badaga*, *Chondromorpha kelaarti*, *Pagodesmus sulcifer*, *Carlogonus palmatus*, *Fageostreptus hyatti*, *Harpurostreptus prasadani* and *Silvestrus seminudus* have only the distribution in India and are considered as endemic species. The new species reported in this study are also considered endemic to India and Kerala. The validity of endemism is yet to be assessed by extensive surveys in the neighbouring countries as well. Many millipede species mentioned in this study are rare to stumble upon. Their population is relatively small and their conservation status is still unknown. The group on the whole is quite overlooked that not even a single species has been included in the IUCN (International Union for Conservation of Nature) red list across the world. The lack of taxonomic studies might be the reason for this and an elaborate and extensive survey and taxonomic documenting would unravel the mysterious life and diversity of this group.

5.1 Taxonomic Contributions from the Study: New Species and Distributional Records

Biodiversity exploration remains a keystone for taxonomic research, particularly in understudied and overlooked ecosystems. This study, conducted in the sacred groves of North Kerala, represents a pioneering effort in documenting the diversity of millipede fauna in these unique habitats. Through extensive fieldwork and taxonomic investigation, approximately 9 species new to science, along with several new state and regional records (Tables X, Y, & Z). These findings highlight the importance of

continued documentation and conservation efforts. The presence of species previously unrecorded from the state or region further emphasizes the role of sacred groves as refugia for unique and often overlooked taxa.

This chapter presents a detailed account of the newly discovered species, along with species recorded for the first time in Kerala. As one of the first comprehensive studies of its kind in the sacred groves of Kerala, these findings contribute to the growing body of knowledge on invertebrate diversity in sacred groves of North Kerala and reinforce the need for continued exploration in biologically rich but scientifically underexplored habitats.

This study documented the occurrence of *Rhinotus purpureus* for the first time. Additionally, 1 species was reported from Kerala for the first time (*Pagodesmus sulcifer*), while 8 species were newly recorded at the regional level (North Kerala) as a result of this research. Among the regional records, the presence of *Arthrosphaera aurocinta*, collected from Wayanad and originally described from its type locality in Parambikulam—situated within the Palakkad Gap (10° 20' N to 10° 26' N and 76° 35' E to 76° 50' E)—supports the hypothesis that these animals dispersed well before the formation of the Palakkad Gap, approximately 500 million years ago, driven by a combination of shearing and erosion (Biswas & Praveen, 2021). Conversely, *Arthrosphaera Kammadamensis* **sp.nov.**, which exhibits significant morphological resemblance to *Arthrosphaera craspedota* (Type locality: Parambikulam), may represent a case of speciation that occurred after the gap's formation. A comprehensive molecular study of this genus itself is essential to confirm its taxonomic status, genetic relationships, and phylogenetic connections.

Table. 2. The species discovered to be new to science obtained from the sacred groves of North Kerala.

Sl.No	Species Name
1	<i>Pseudosphaeroparia malabaricus</i> sp.nov
2	<i>Pseudosphaeroparia falcata</i> sp.nov
3	<i>Klimakodesmus bilobocaudatus</i> sp.nov

4	<i>Propyrgodesmus bulbogonopus</i> sp.nov
5	<i>Delarthum anomalans</i> sp.nov
6	<i>Lophoturus muchukunnensis</i> sp.nov
7	<i>Arthrosphaera kammadamensis</i> sp.nov
8	<i>Siphonorhinus muchukunnensis</i> sp.nov
9	<i>Siphonorhinus koyithattensis</i> sp.nov

Table 3. Species with first report from India

Sl. No.	Species Name
1	<i>Rhinotus purpureus</i>

Table 4. Species with first report from Kerala

Sl. No.	Species Name
1	<i>Pagodesmus sulcifer</i>

5.2 Seasonality in Millipedes

The population dynamics and activity period of millipedes depend on the climatic conditions in its microhabitat. It is closely linked with temperature, humidity and soil moisture content. In the countries of the tropical and subtropical regions, millipedes are found having their peak activity time during the months of June to November which falls in the Monsoon and Post monsoon periods (Kadamannaya et al., 2009). And during the dry season, they tend to burrow down to deep soil layers and enter into a dormancy stage (Golovatch & Kime, 2009). Similar trends are observed in African tropical forests, where millipedes are most active during the rainy season and

retreat underground during dry spells (Dangerfield & Telford, 1991). In other parts of the world having temperate climate, the peak activity period for millipedes is during spring (March to May) and autumn (September to November) as in the case of European species. This is because temperate countries have bimodal seasonal patterns (David & Handa, 2010). Based on the result of this study, the activity period of millipedes in the sacred groves of North Kerala falls mainly in the mid monsoon and post monsoon period (June - November). This knowledge on the seasonality of millipedes in this particular region proves plausible for future references and extensive research in the field of diplopodology.

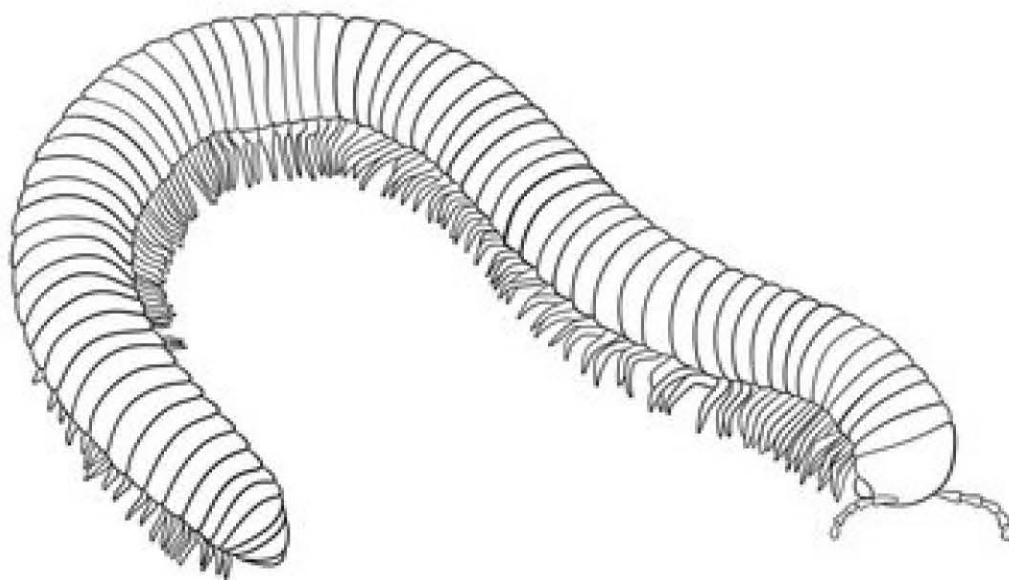
5.3 Endoparasite in Millipedes:

Being soil dwelling organisms, millipedes are ought to have some kinds of endoparasites in their alimentary canal or in their coelomic cavity. The discovery of mermithid nematode from the coelomic cavity of a millipede in this study is the first ever report from India. Usually, Mermithid species are reported from soil arthropods such as termites and grasshoppers from different parts of the globe such as Viet Nam and Argentina. No reports from the Indian Subcontinent have yet been produced in the context of millipedes. In a recent study, a spirobolid millipede was reported to be infested by a nematomorph worm (commonly called as horsehair worm) and was discovered to be a new addition to science (Chiu et al., 2020). Such nematode infestation in millipedes can result in reduced fecundity and life expectancy in individuals. In some cases, such infestations may also lead to the decreased mobility and foraging capacity eventually leading to death of the organism, while in some other cases the nematode and host co-exist as a symbiotic entity (Nagae et al., 2021). These associations need to be deeply explored to understand the effect of such endoparasitic nematodes on millipede populations.

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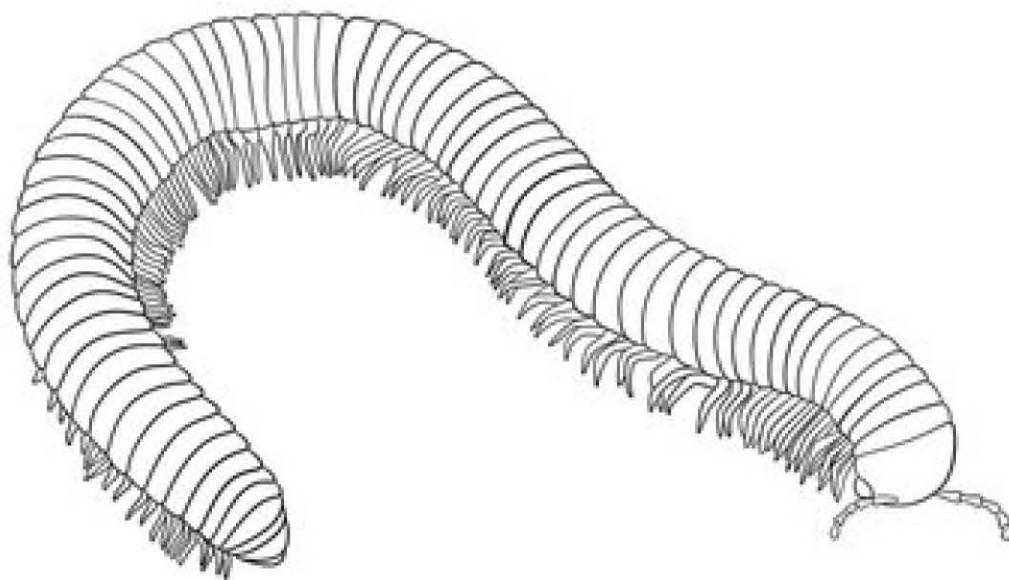
CHAPTER 6
CONCLUSION

CONCLUSION

The initial stage in biological conservation is the documentation of fauna. It is crucial to have a fundamental understanding of the biodiversity in many ecosystems and habitats, whether the goal is to conserve a specific group of creatures or a vast group of animals as a result of safeguarding a focus organism. This study has significantly contributed to the knowledge on millipedes in the sacred groves of North Kerala. Through extensive field surveys for 3 years, and taxonomic approaches, **9 new species** were discovered to science, along with several new state and regional records. These findings highlight the remarkable yet understudied diversity of millipedes in the region, reinforcing the importance of continued exploration and documentation of invertebrate fauna.

The findings from this study provides significant insights on the biogeographical distribution of several species of millipedes and accentuates the importance of undisturbed habitats, such as sacred groves, and highaltitude regions of Western Ghats as vital refuges for rare and endemic millipede species. During this study several inevitable challenges also occurred in terms of limited sampling coverage during different seasons and the need for a panoptic ecological and behavioural data. Cultural barriers posed significant challenges during field surveys, as many study sites were traditionally and culturally protected. Strict entry restrictions, including complete prohibitions and limitations on female access, hindered effective sampling and data collection. In some instances, substantial portions of the sacred groves had to be excluded from the survey due to these restrictions. The increasing anthropogenic pressures on forest ecosystems is crucial to integrate millipede taxonomy with conservation efforts to protect these ecologically significant but often overlooked arthropods.

In total, this study lays the groundwork for future research on millipedes in every aspect, ie., systematics, diversity, ecology, behaviour and biogeography in India. The study also substantiates the inevitability of monitoring, preserving and restoring the existing or lost vegetation and elevating the status of soil invertebrates and bringing about policy - level recognition. This study reinstates the wider understanding of diplopods of sacred groves of North Kerala and also reinforces the Western Ghats' status as a global biodiversity hotspot deserving of sustained scientific attention and conservation initiatives.



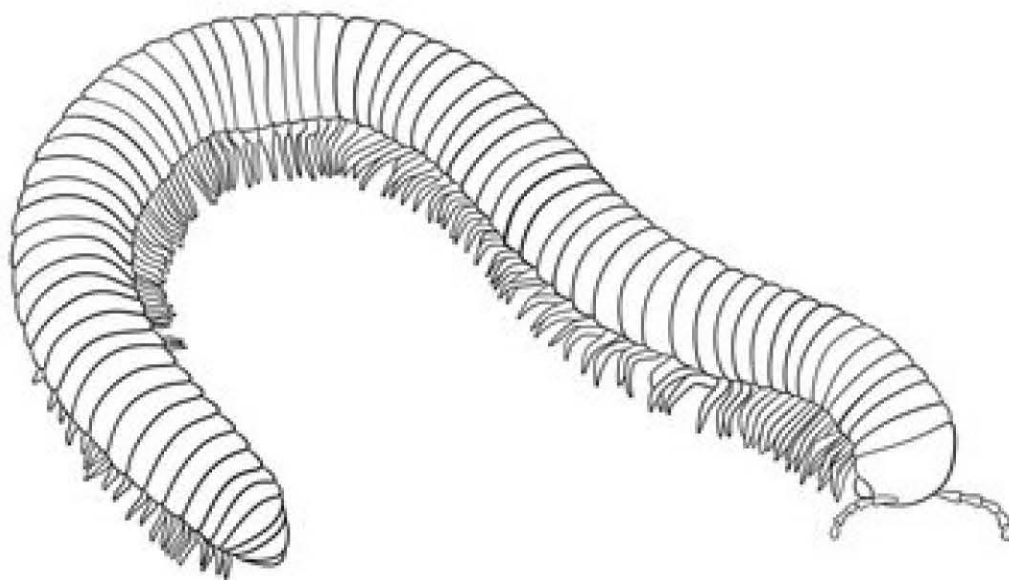
CHAPTER 7

RECOMMENDATIONS

RECOMMENDATIONS

The current study is a pioneer effort to study and document the millipedes of sacred groves of North Kerala. The following recommendations can be suggested post completion of this study;

- This study focused on a special ecosystem (Sacred groves) to document millipedes. Studies should also be conducted in different naturally existing habitats such as mangrove ecosystems, riparian habitats, shola forests etc., and manmade habitats such as urban gardens and Urban forests such as Miyawaki forests of Kerala.
- This study was also conducted in the northern side of Kerala and more studies need to be conducted in central and south Kerala on this account.
- Meticulous studies on ecology and diversity of millipedes of Kerala.
- Evaluation of endemism and conservation status of millipedes of Kerala according to IUCN protocols.
- Study the phylogenetic relatedness and genetic reassessment of species from Kerala.
- Revise the understudied and chaotic taxa and fill the knowledge gap within the group.
- Investigate the ozadenes across various taxa to analyze their chemical compositions and explore the potential applications of these compounds.
- Digitization of Indian millipede specimens deposited in various national and international repositories.



PLATES

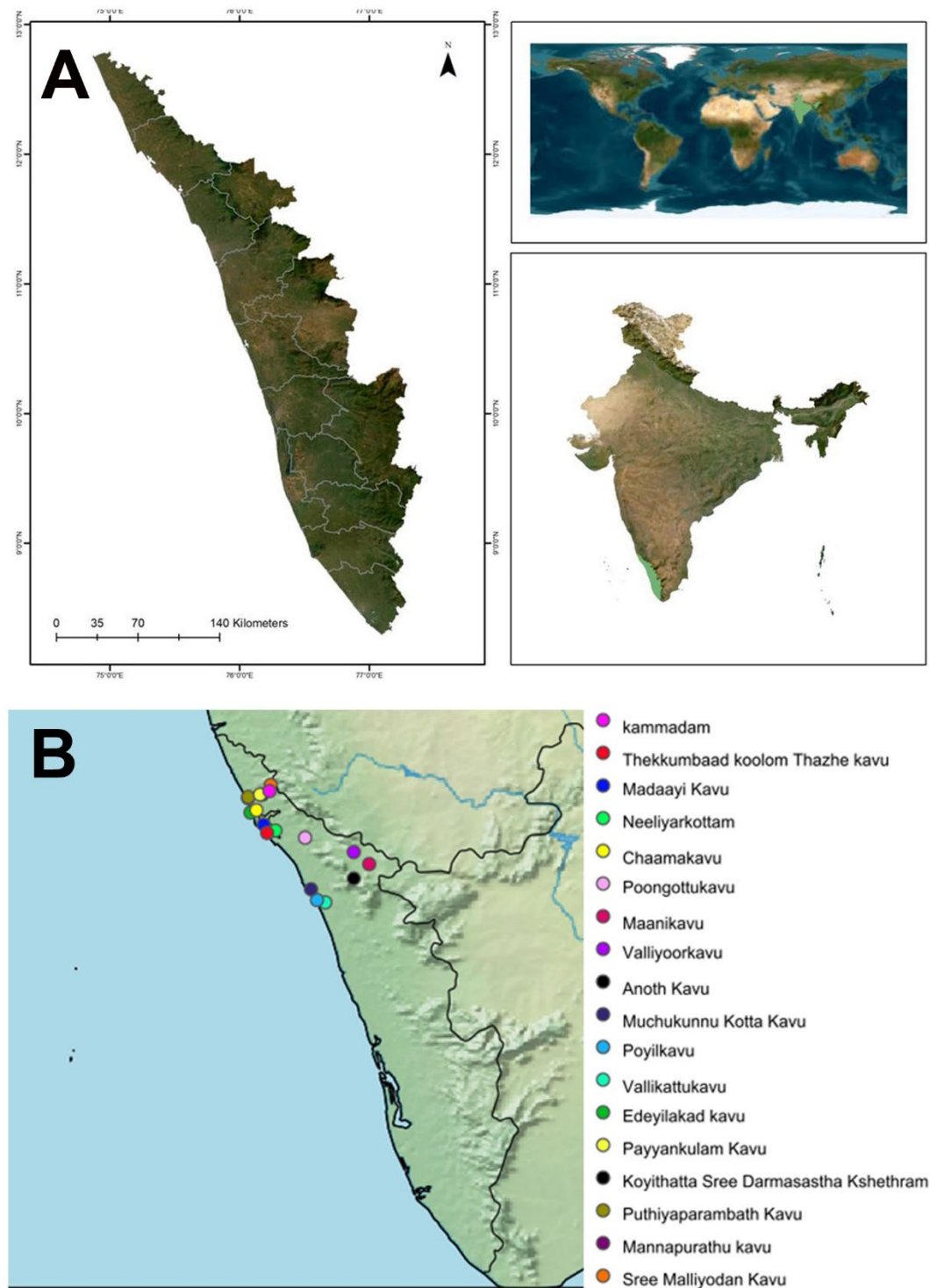


FIGURE 1. A. Map showing the location of study area in the political map of India.,
B. Map showing the location of study site (the sacred groves) s in the northern Kerala.

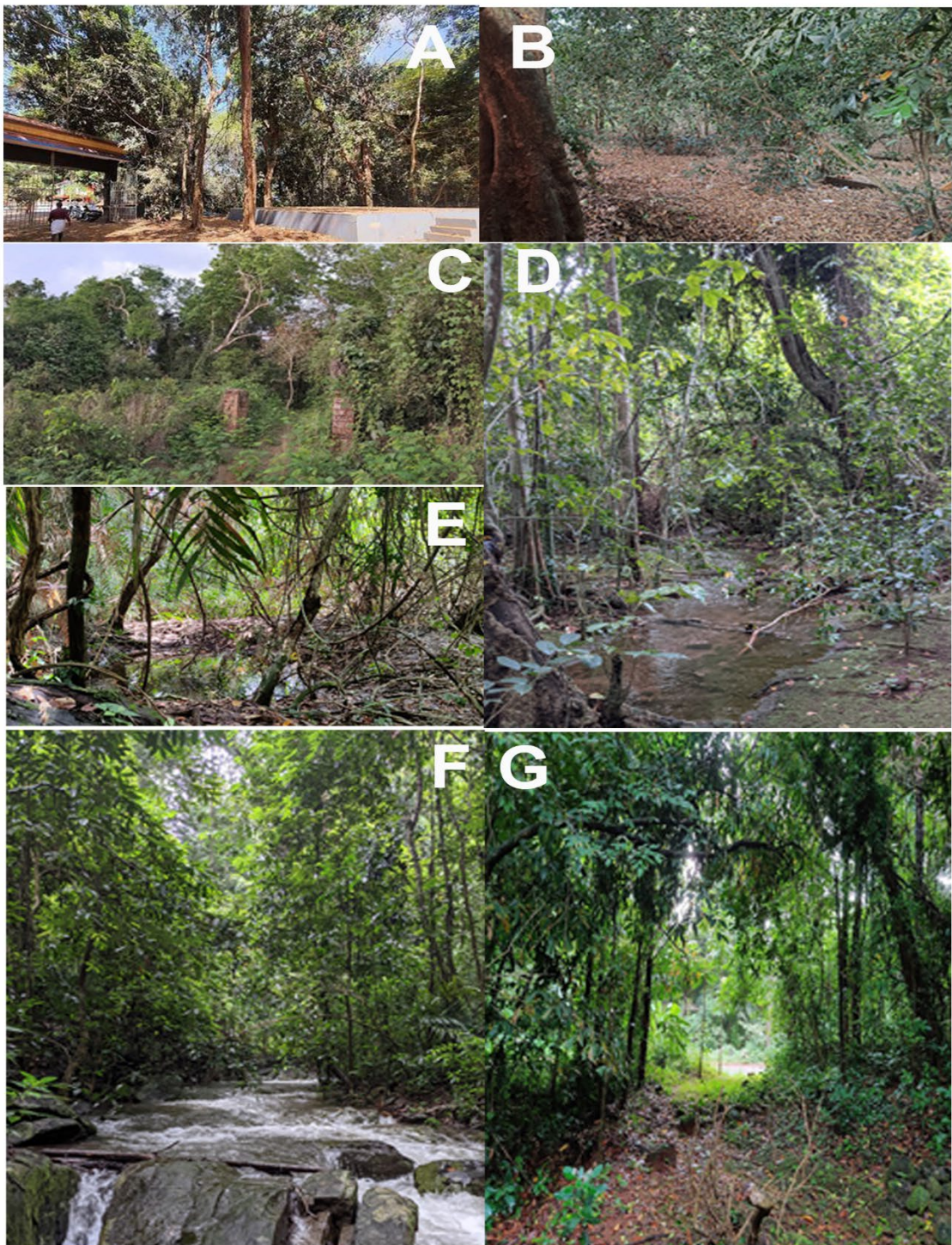


FIGURE 2. Study sites in Kasaragod district., **A.** Puthiyaparambath Kavu (KZE04), **B.** Mannampurathu Kavu (KZE05), **C.** Koyithatta Sree Dharma Sastha Kavu (KZE06), **D.** Payyankulam Kavu (KZE03), **E.** Edeyilakad Kavu (KZE01), **F.** Kammadam Kavu (KZE02), **G.** Sree Malliyodan Kavu (KZE07).

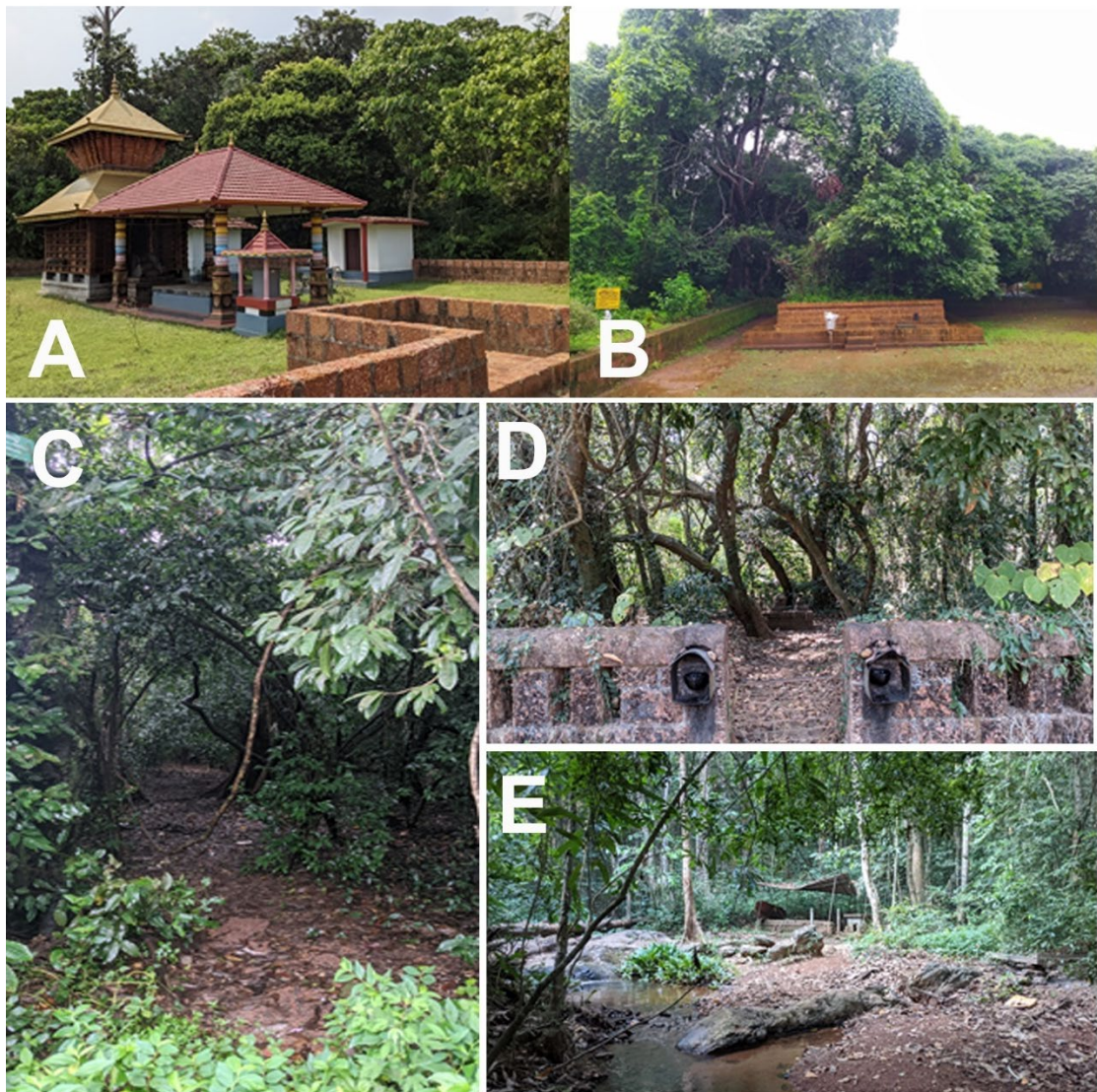


FIGURE 3. Study sites in Kannur District, **A.** Thekkummbaad koolom Thaazhe kavu (KNN01), **B.** Neeliyar Kottam (KNN03), **C.** Madayi Kav (KNN02), **D.** Chaamakavu (KNN04), **E.** Poongottukavu (KNN05).



FIGURE 4. Study sites in Kozhikode District, **A.** Muchukunnu Kotta Kavay (CLT01), **B.** Vallikattukavu (CLT03), **C.** Poyilkavu (CLT02).

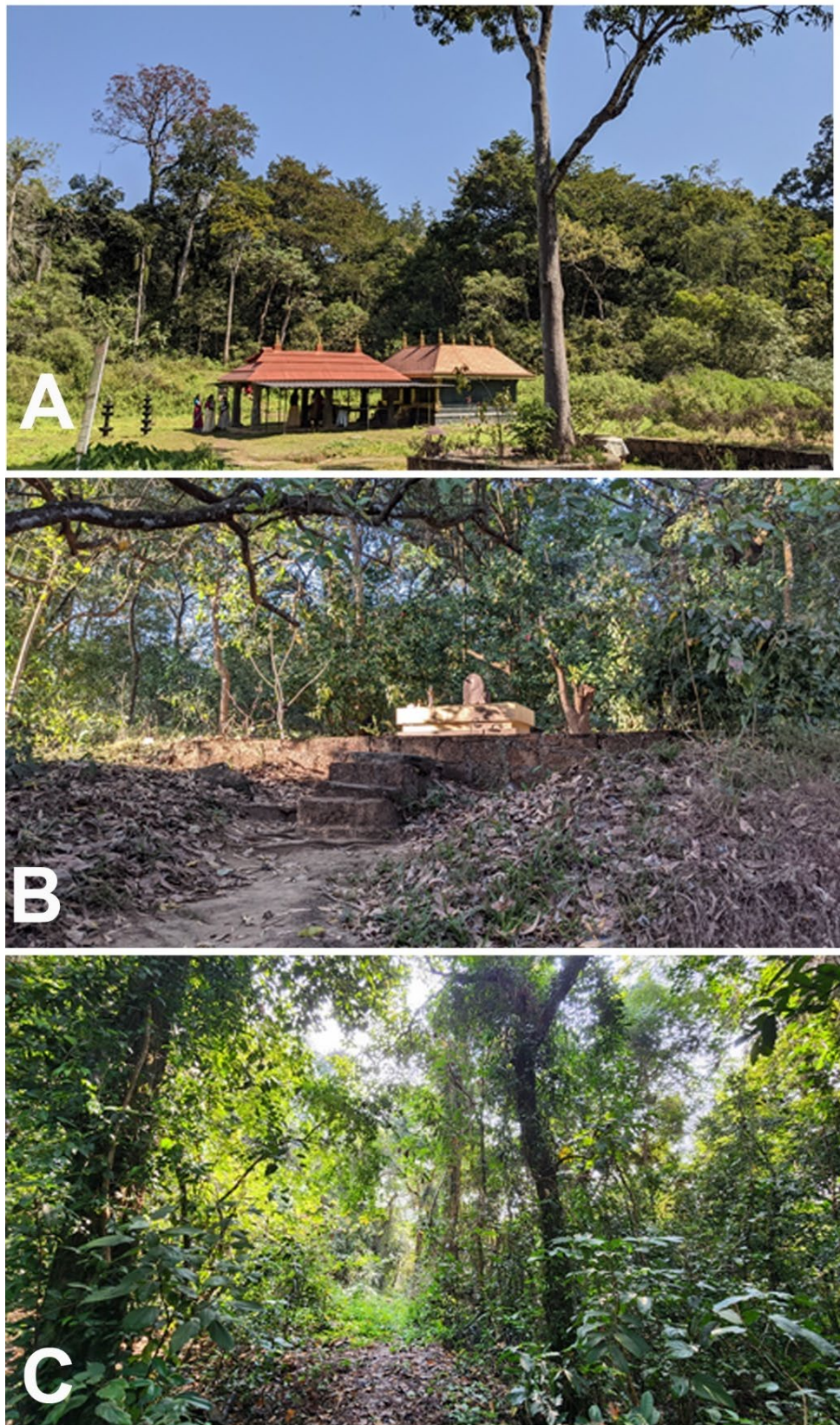


FIGURE 5. Study sites in Wayanad District, **A.** Maanikavu (WYN01), **B.** Valliyoorkavu (WYN02), **C.** Anoth Kavv (WYN03).



FIGURE 6. Sampling equipment used in field surveys **A.** sampling tray, **B.** Gloves, **C.** Thermo-humidity meter, **D.** Rechargeable head torch, **E.** forceps, **F.** Zip lock bags, **G.** Rake, **H.** Hand shovel, **I.** Hand lens, **J.** Collection vials of different capacities, **K.** Mobile phone with in-built GPS, **L.** Ice box, **M.** Ethyl Alcohol, **N.** Camel hair painting brush, Graphite pencils, permanent markers and field note book, **O.** Digital camera.



FIGURE 7. Sampling Techniques, **A.** Hand picking method, **B.** Leaf Litter sampling, **C.** Berlese-Tullgren extraction.

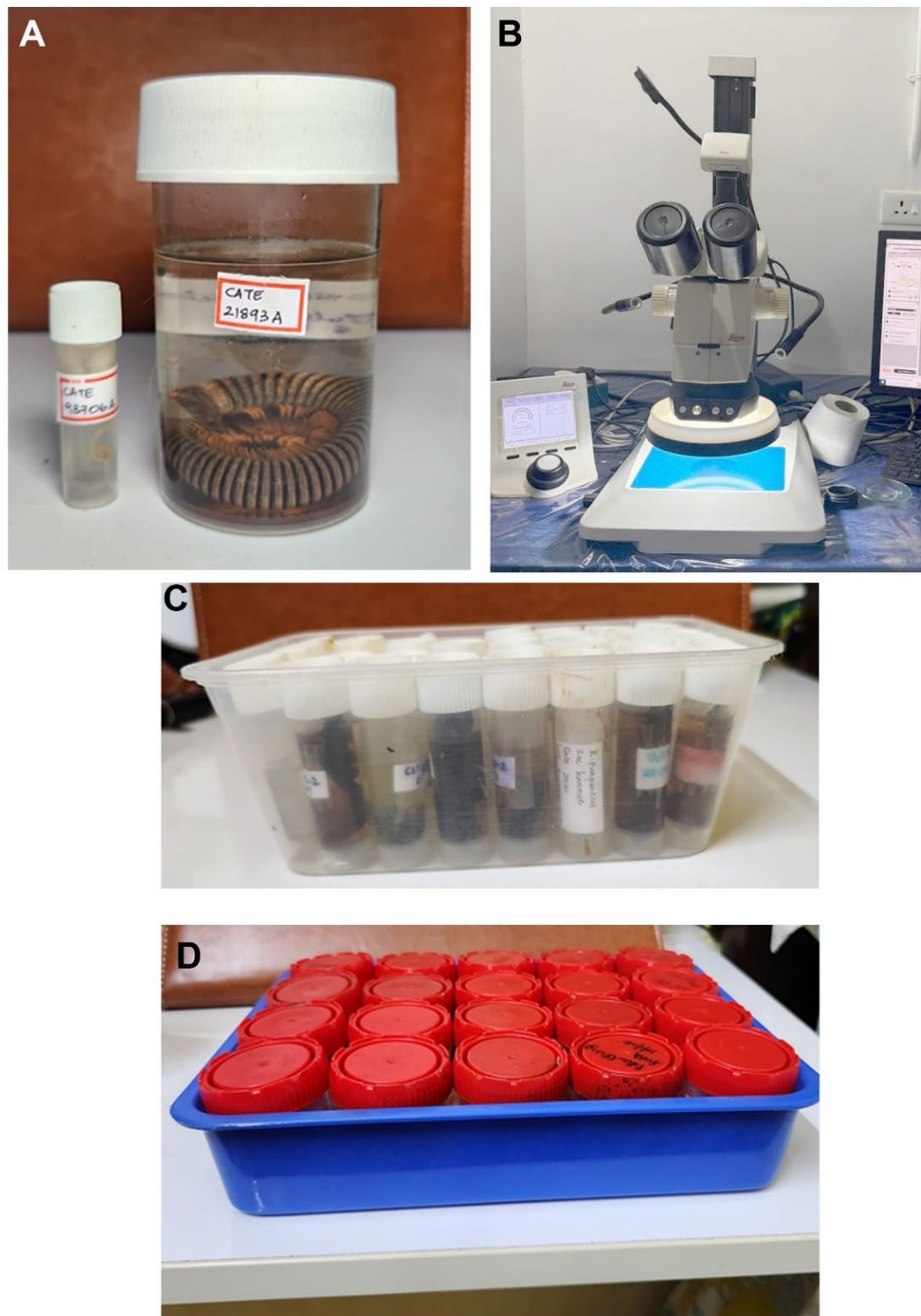


FIGURE 8. Storing, preservation and Identification, **A, C and D.** preservation of collected and identified specimens, **B.** Microscope used for imaging.

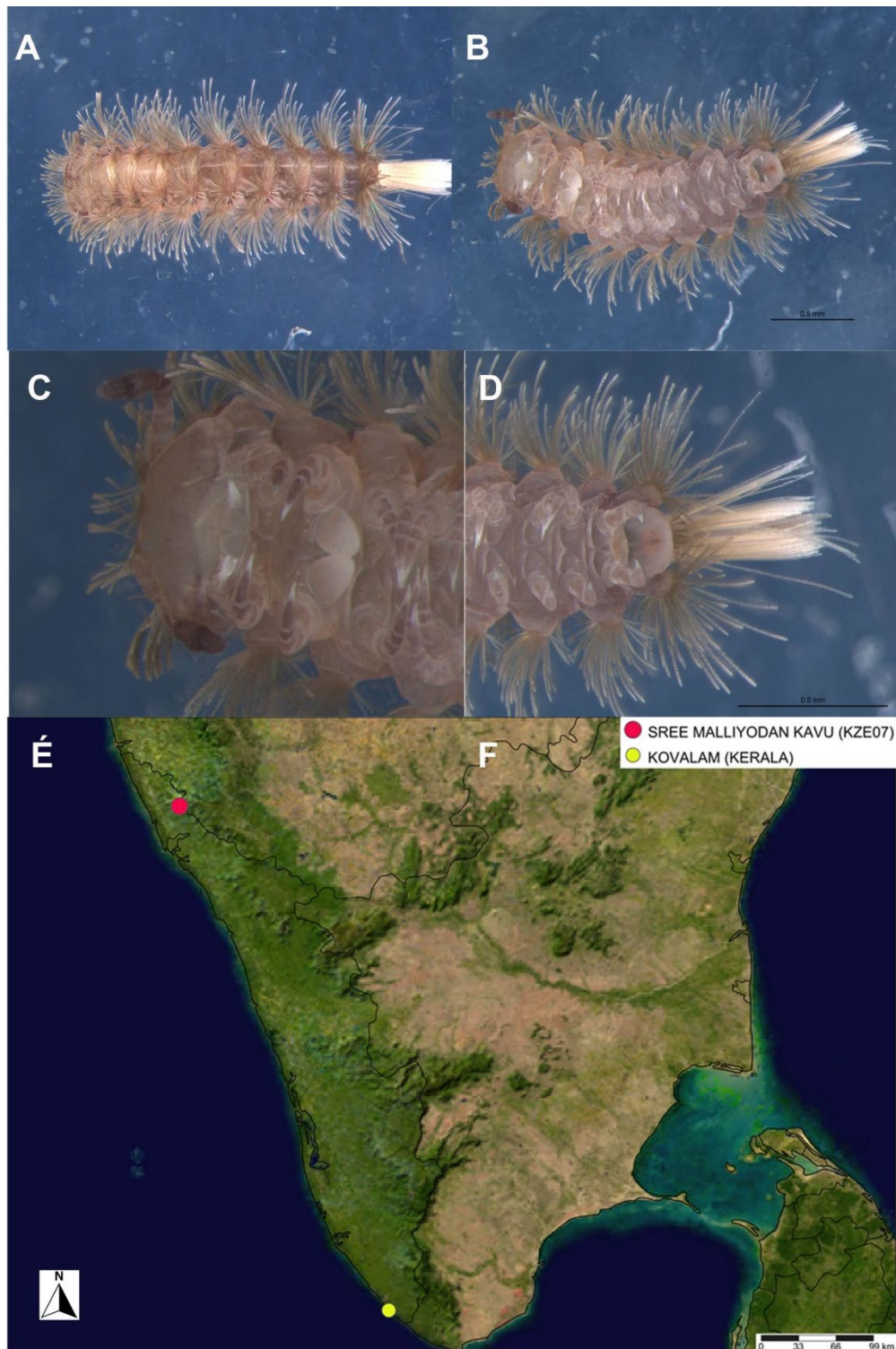


FIGURE 9. *Silvestrus seminudus* Jones, 1937, **A.** Male Habitus, dorsal, **B.** Male habitus, Ventral, **C.** Male Anterior region, Ventral, **D.** Male posterior, Ventral, **E.** Map showing overall distribution of the species.

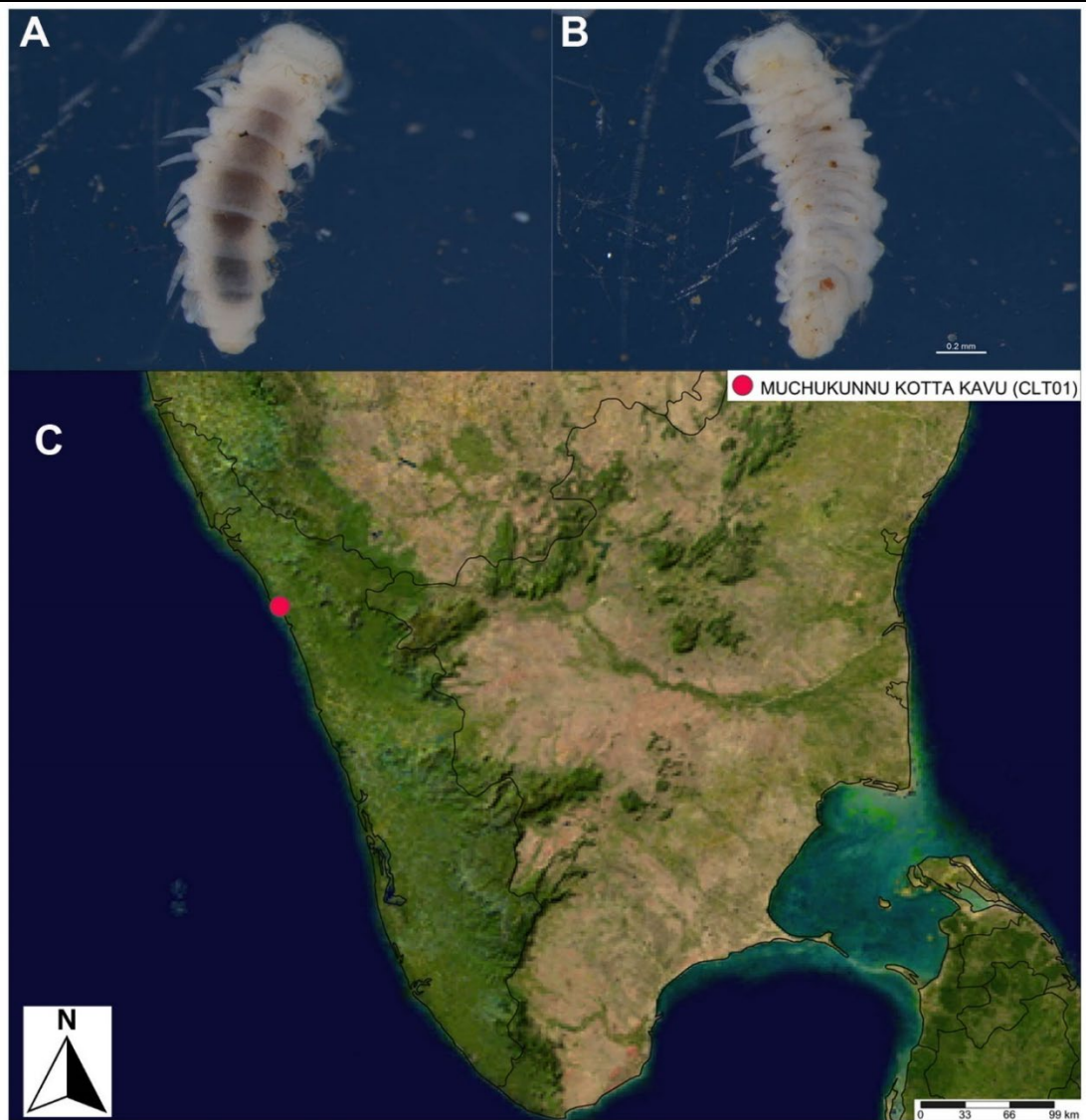


FIGURE 10. *Lophoturus muchukunnesnsis* sp. n., **A.** Male Habitus, dorsal, **B.** Male habitus, Ventral, **C.** Map showing overall distribution of the species.

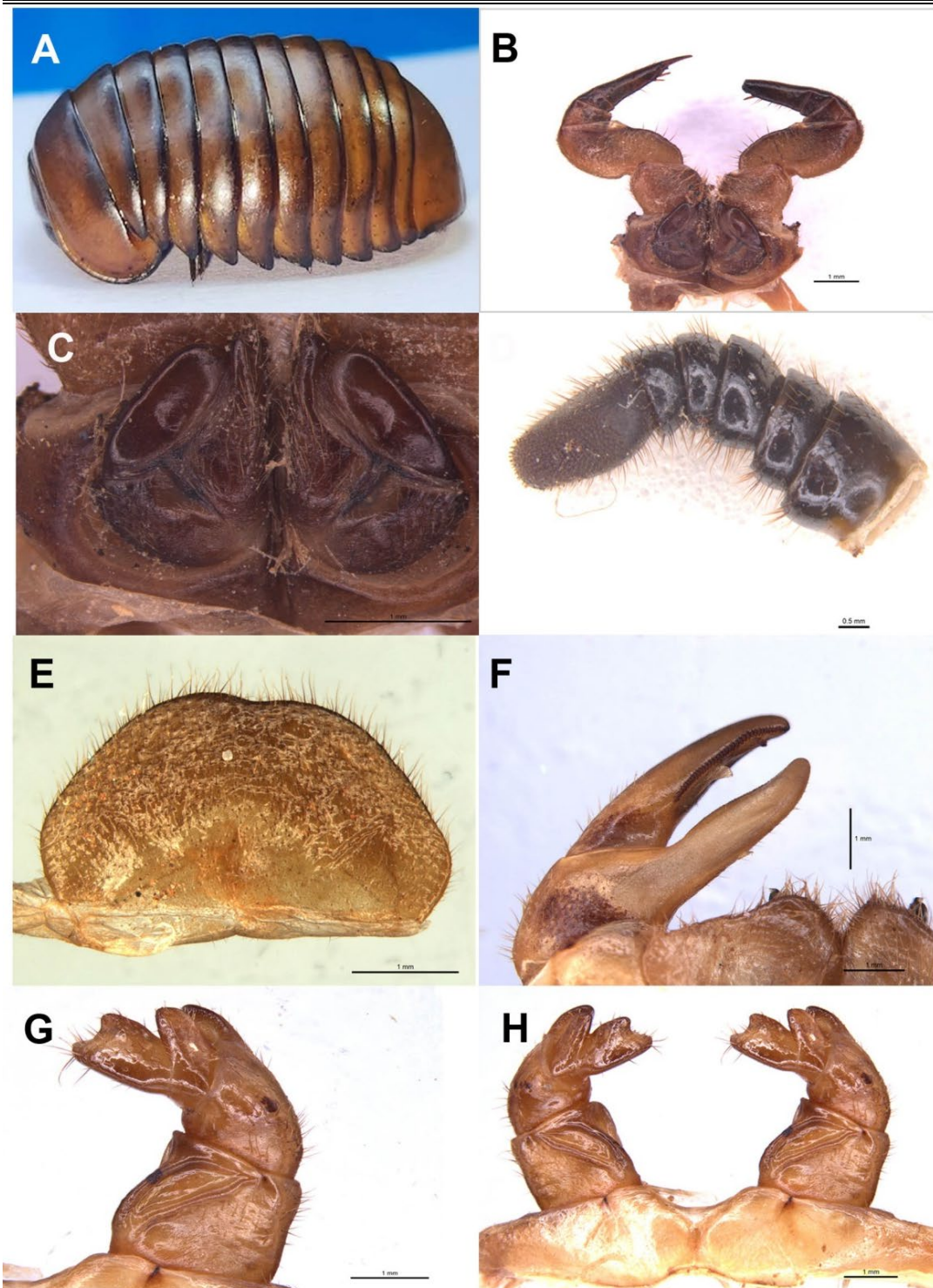


FIGURE 11. *Arthrosphaera aurocincta* Pocock, 1899, **A.** Male Habitus, **B.** Female leg pair 2, **C.** Female vulva **D.** Antenna **E.** Washboard, **F.** Posterior telopodite, **G&H.** Anterior telopodite.

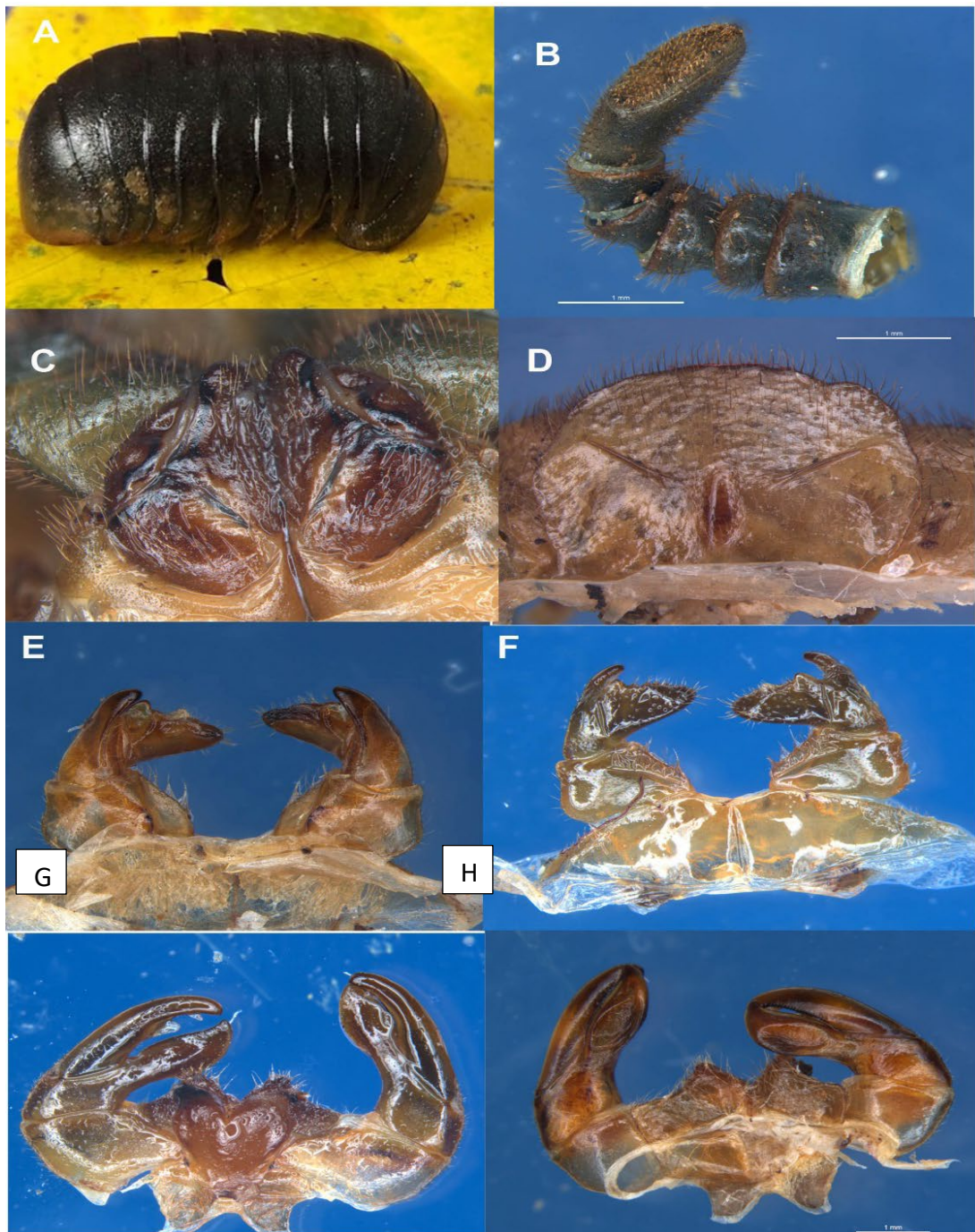


FIGURE 12. *Arthrosphaera kammadamensis* sp.n., **A.** Male Habitus, **B.** Antenna **C.** Female vulva **D.** Washboard **E.** Anterior telopodite, Dorsolateral view **F.** Anterior telopodite, ventrolateral view, **G&H.** Posterior telopodite, dorsolateral and ventrolateral view.

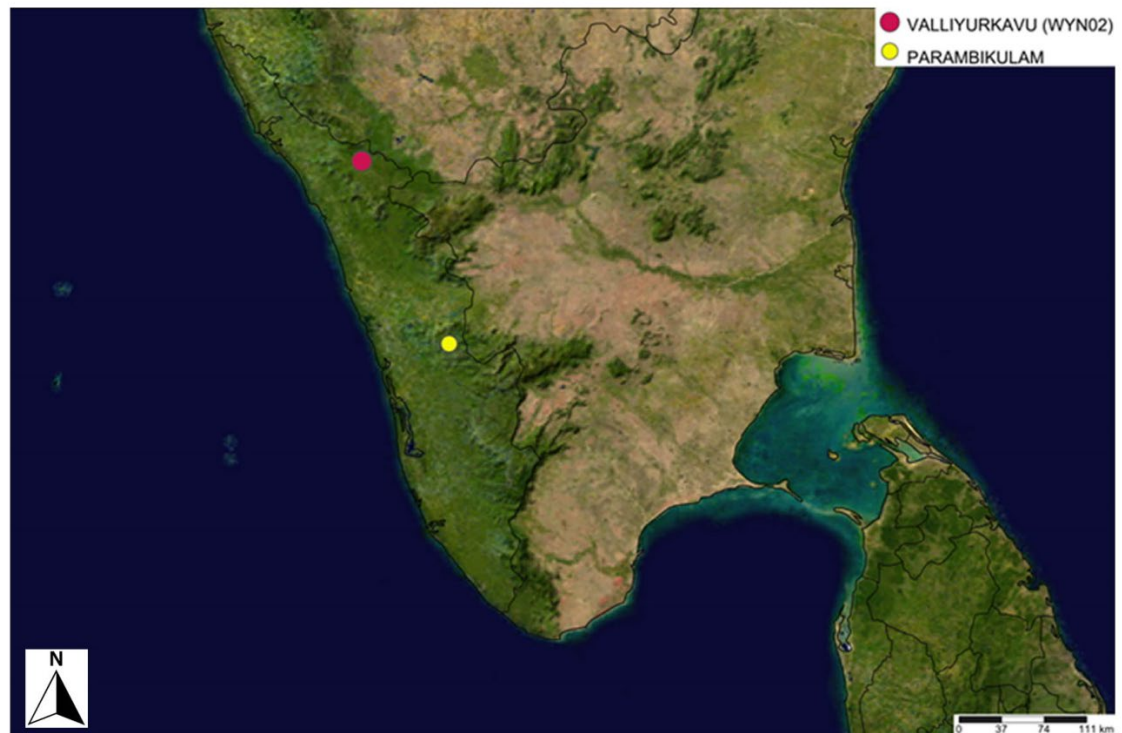


FIGURE 11. *Arthrosphaera aurocincta* Pocock, 1899 A. Map showing the cite of collection of the species (Red dot) and other distribution (Yellow dot).

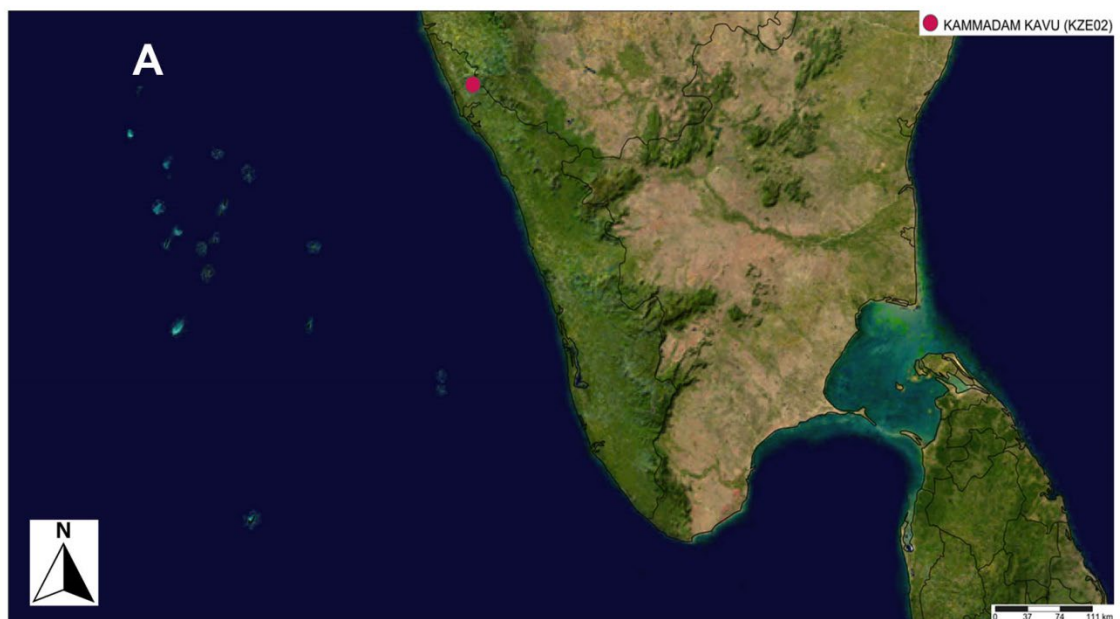


FIGURE 12.1 *Arthrosphaera kammadamensis* sp.n., A. Map showing the distribution of the species in the sacred groves of northern Kerala.

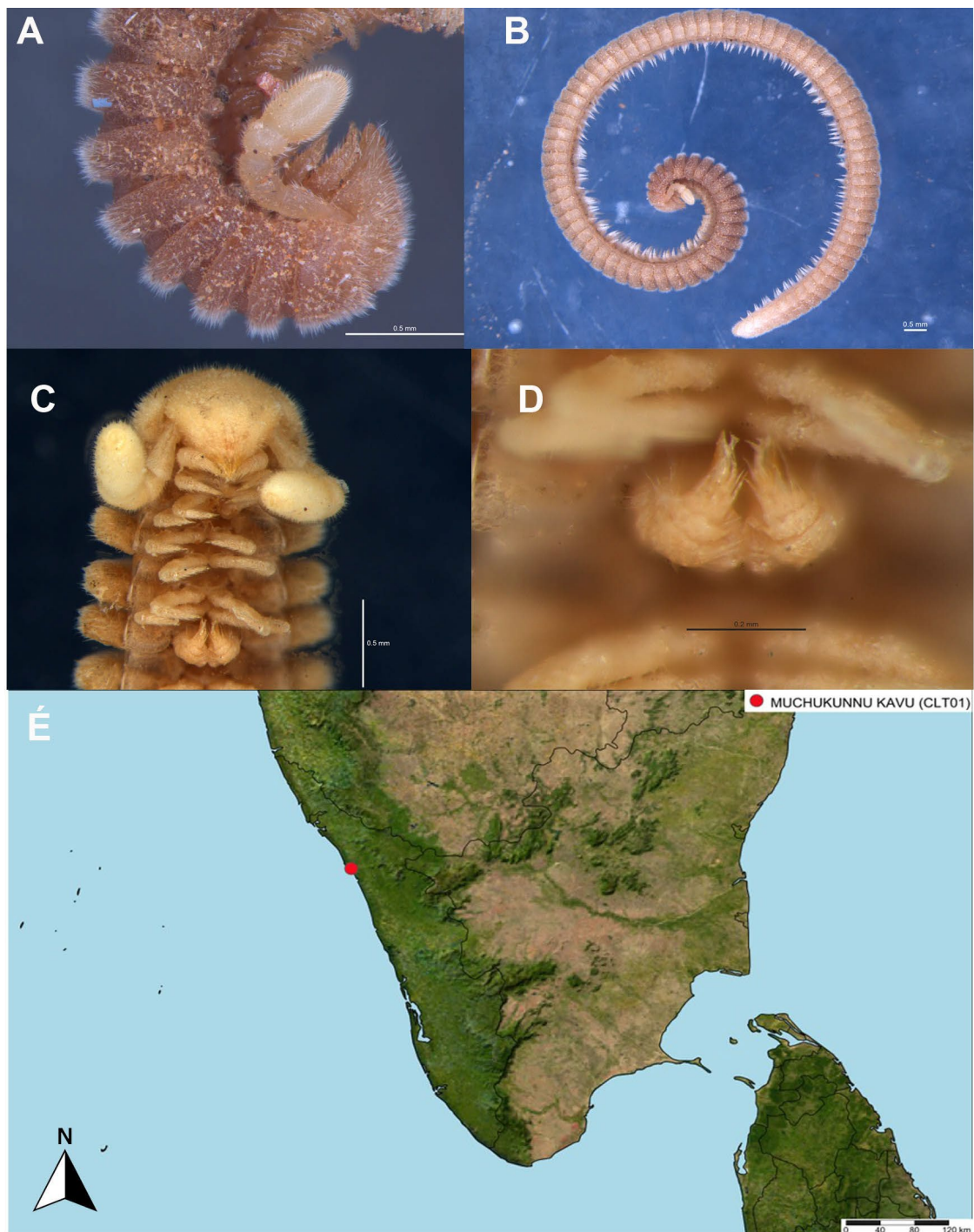


FIGURE 13. *Siphonorhinus muchukennensis* sp. n, **A.** Male Anterior, Lateral view **B.** Male habitus, **C.** Male anterior, ventral view **D.** Gonopod (in-situ) **E.** Map showing the distribution the species in the sacred groves of northern Kerala.

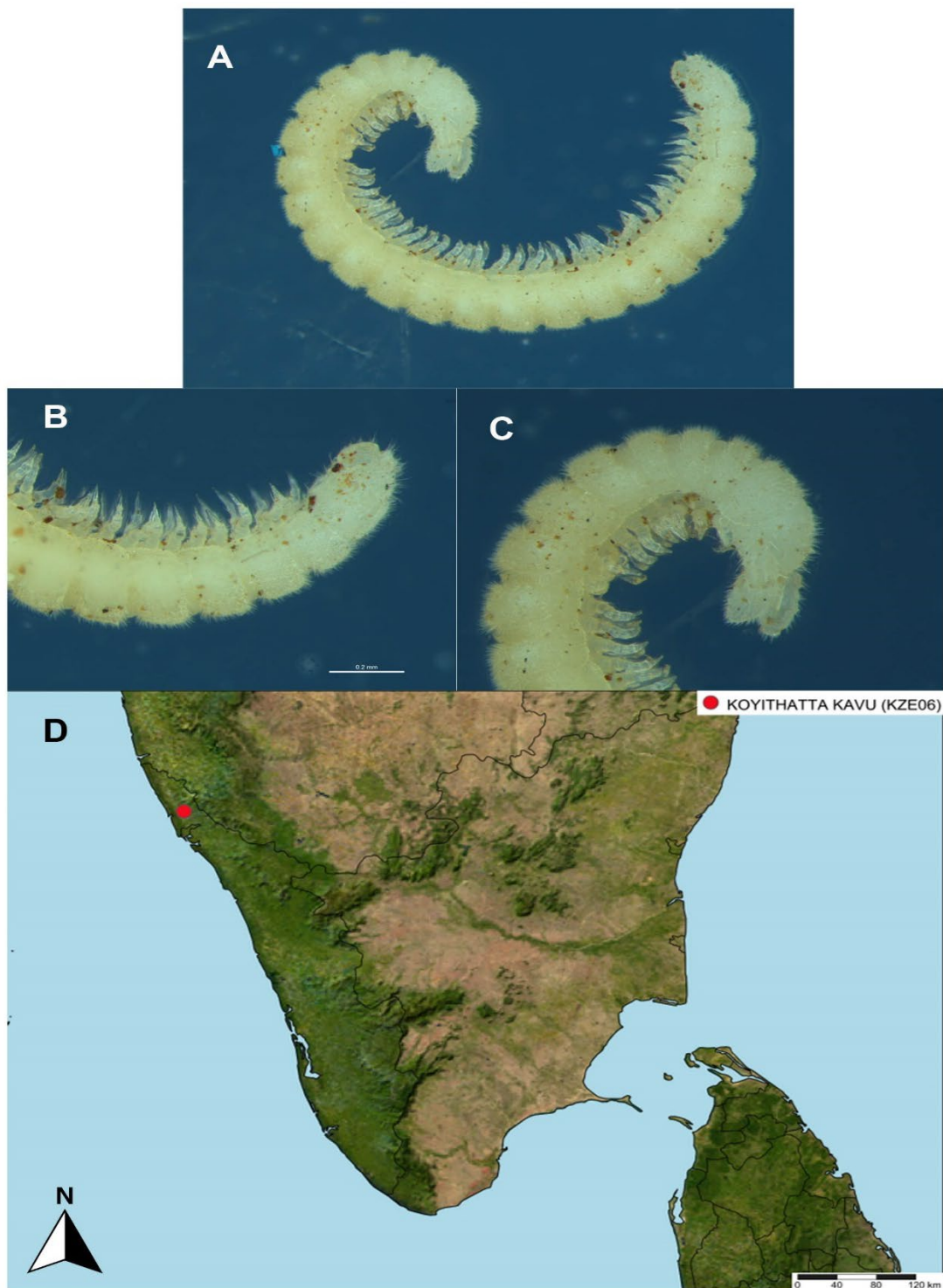


FIGURE 14. *Siphonorhinus koyithattensis* sp. n, A. Male Habitus, Lateral view B. Male posterior, lateral view, C. Male anterior, ventral view D. Map showing the distribution the species in the sacred groves of northern Kerala.

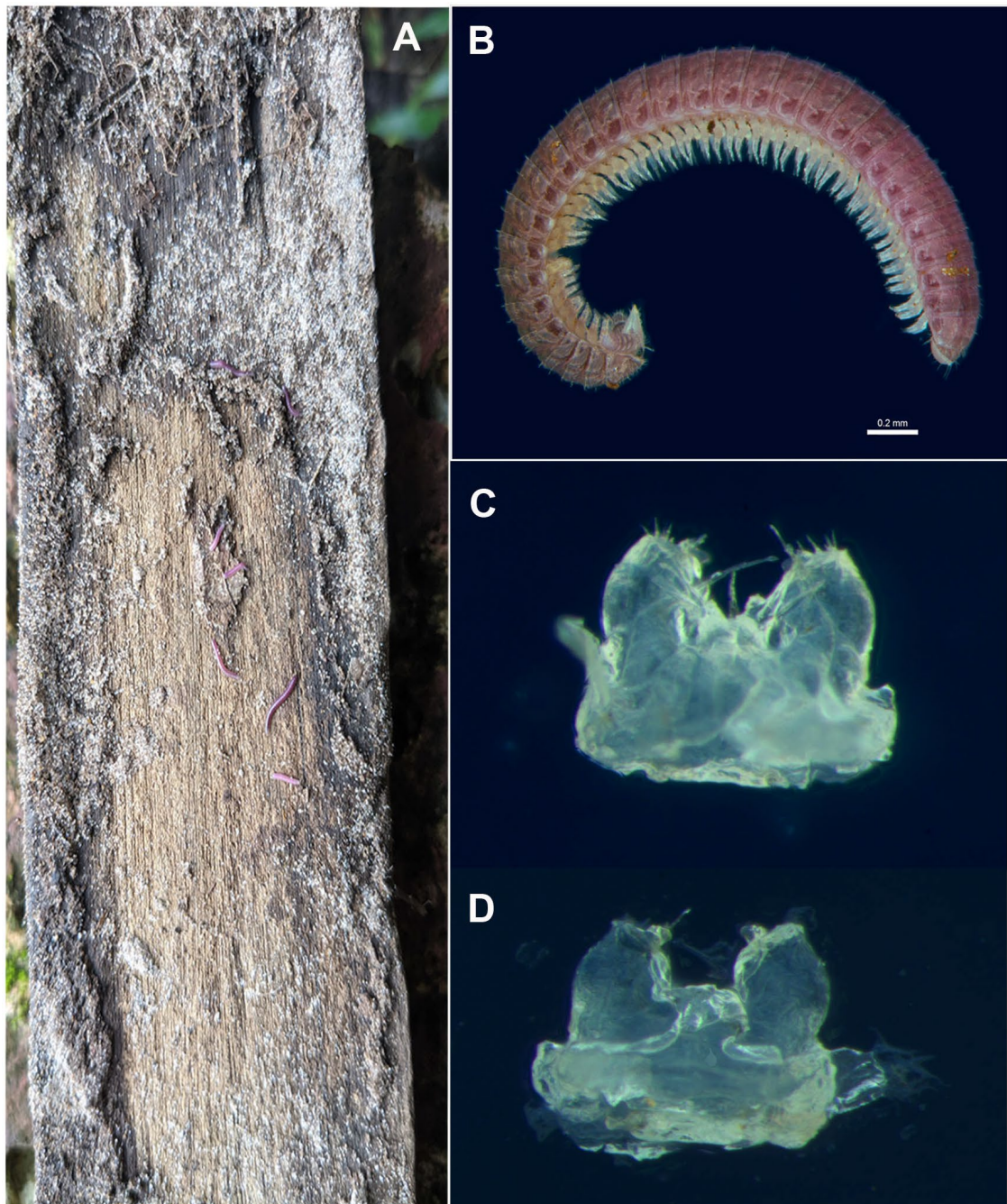


FIGURE 15. *Rhinotus purpureus* (Pocock, 1894), A. Live specimens in their natural habitat, B. Male habitus, lateral view, C. & D. gonopods, mesal view.

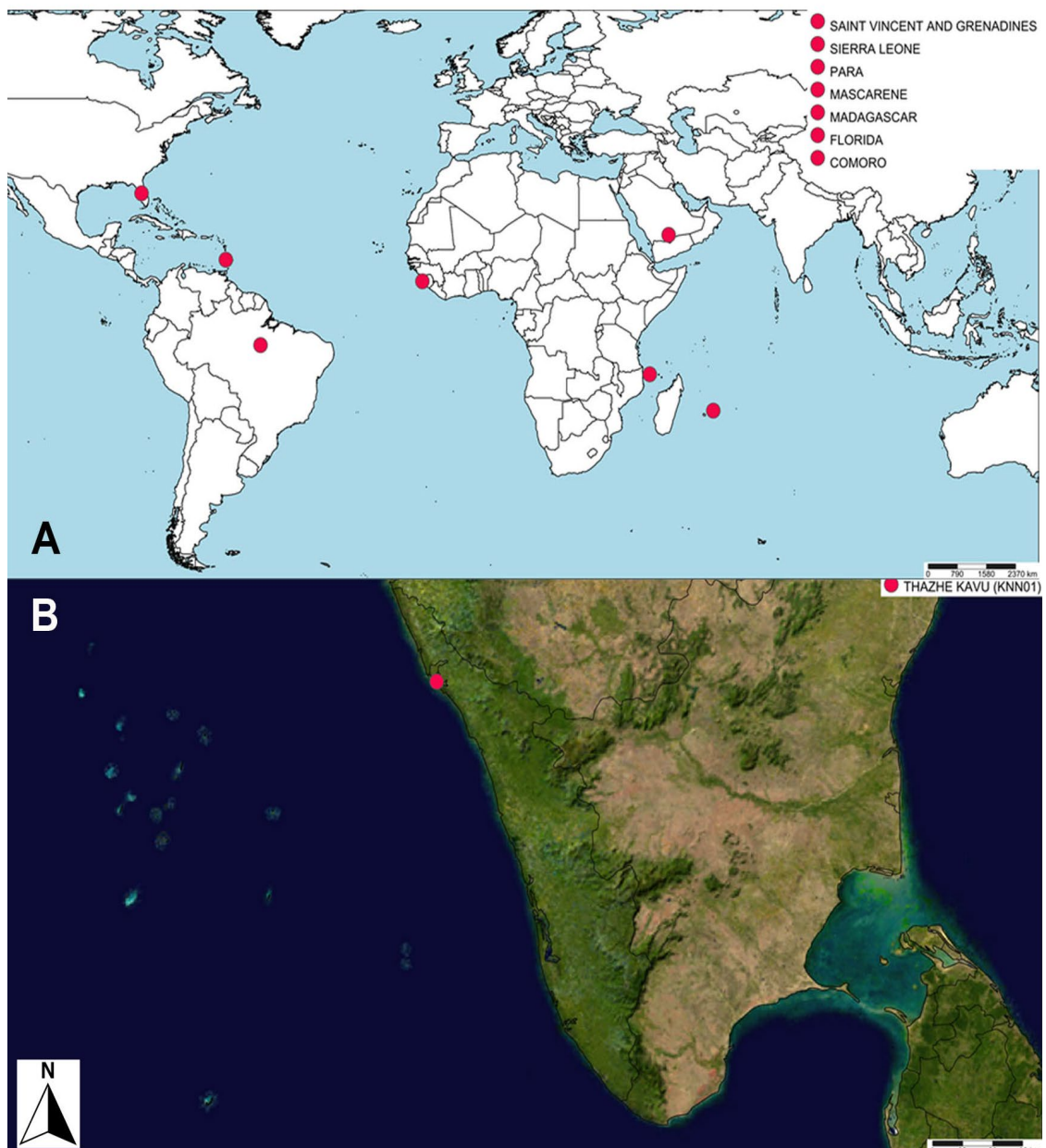


FIGURE 16. *Rhinotus purpureus* (Pocock, 1894), distribution. A. Map showing the distribution the species, B. Map showing the distribution the species in the sacred groves of northern Kerala.

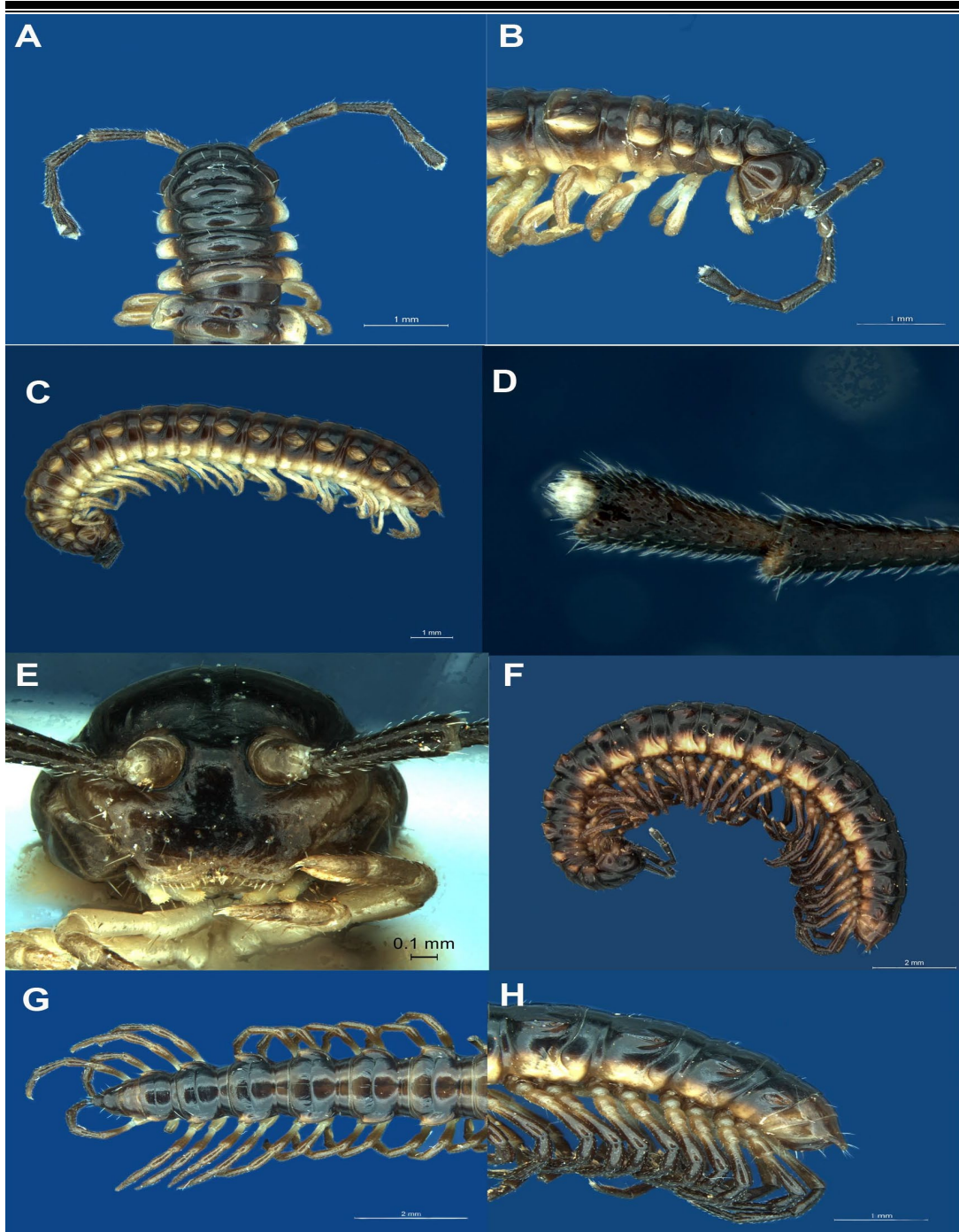


FIGURE 17. *Delarthrum anomalans* sp. n. (Golovatch et al., 2022)), A. Male anterior, dorsal view, B. Male anterior, lateral view, C. & F. Female and male habitus, lateral. D. 6th Antennomere, E. Head, G & H. Male posterior dorsal and lateral.

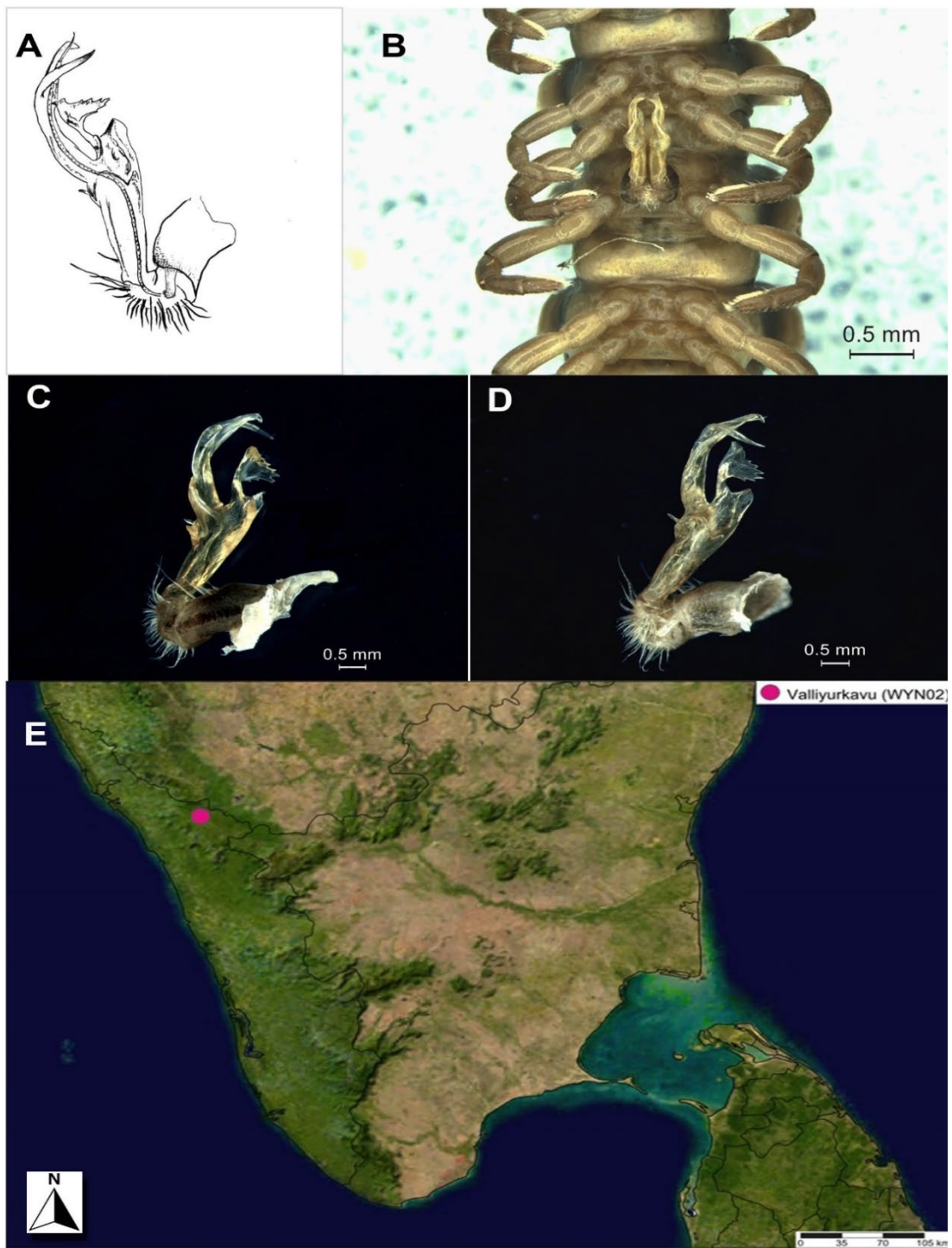


FIGURE 18. *Delarthrum anomalans* sp. n. (Golovatch et al., 2022), **A.** Gonopod, mesal view, **B.** Gonopod, in-situ view, **C.** & **D.** Female and male habitus, lateral, **E.** Map showing the collection site and distribution of the species.

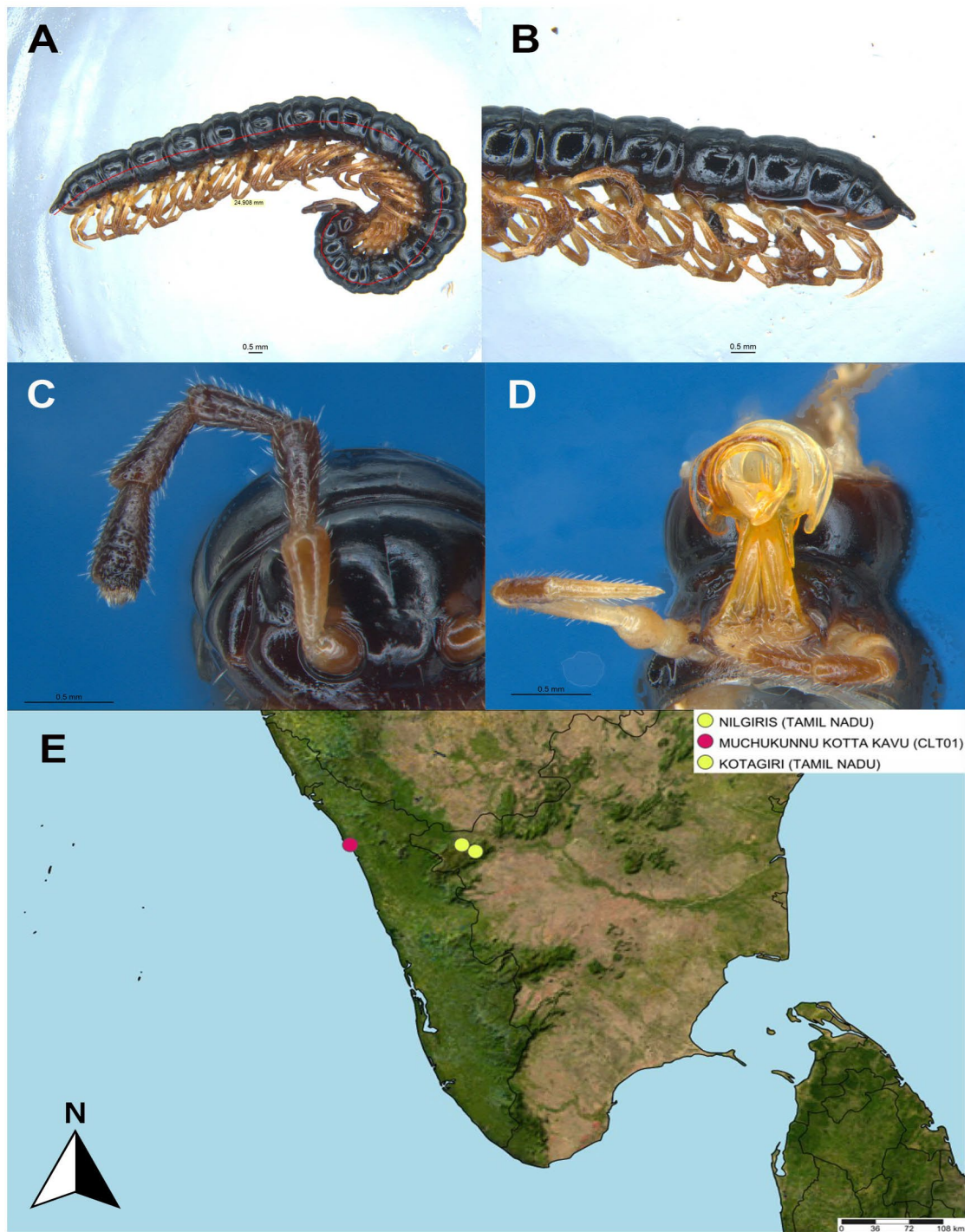


FIGURE 19. *Telodrepanum badaga* Carl, 1932. **A.** Male habitus, lateral view, **B.** Male posterior, lateral view, **C.** Left Antenna. **D.** Gonopods, insitu view **E.** Map showing the site of collection (red dot) and other distribution (yellow dots).

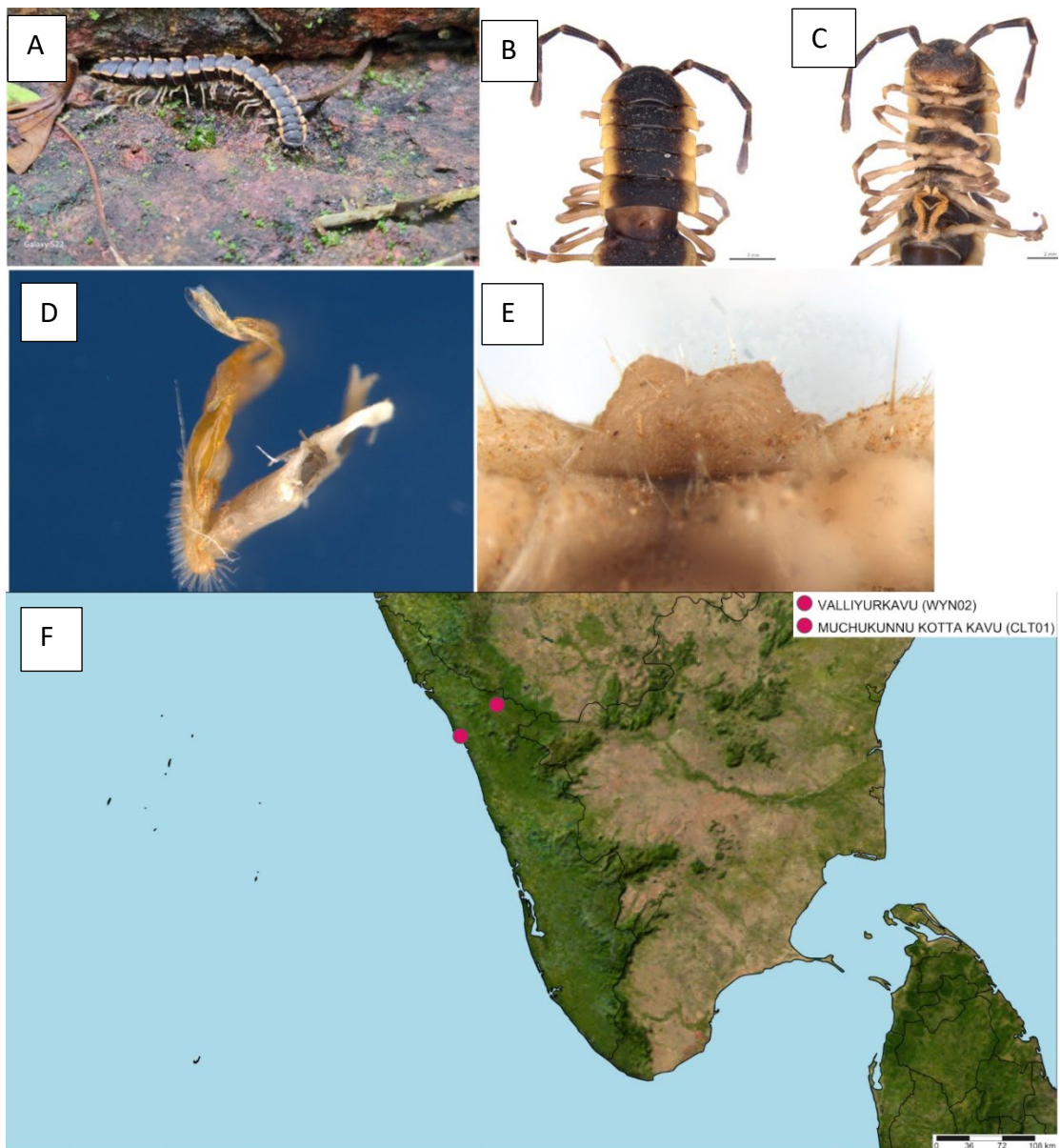


FIGURE 20. *Chondromorpha kelaarti* Humbert, 1865. **A.** Male habitus, live animal view, **B.** Male anterior, dorsall view, **C.** Male anterior, ventral view, **D.** Gonopods, mesal view, **E.** Sternal lobe, **F.** Map showing the site of collection (red dot) .



FIGURE 21. *Anoplodesmus saussurii* (Humbert, 1865). **A.** Male anterior lateral view, **B.** Male posterior, ventral view, **C. & D.** Male habitus of live specimens, **E.** Gonopods, in-situ.

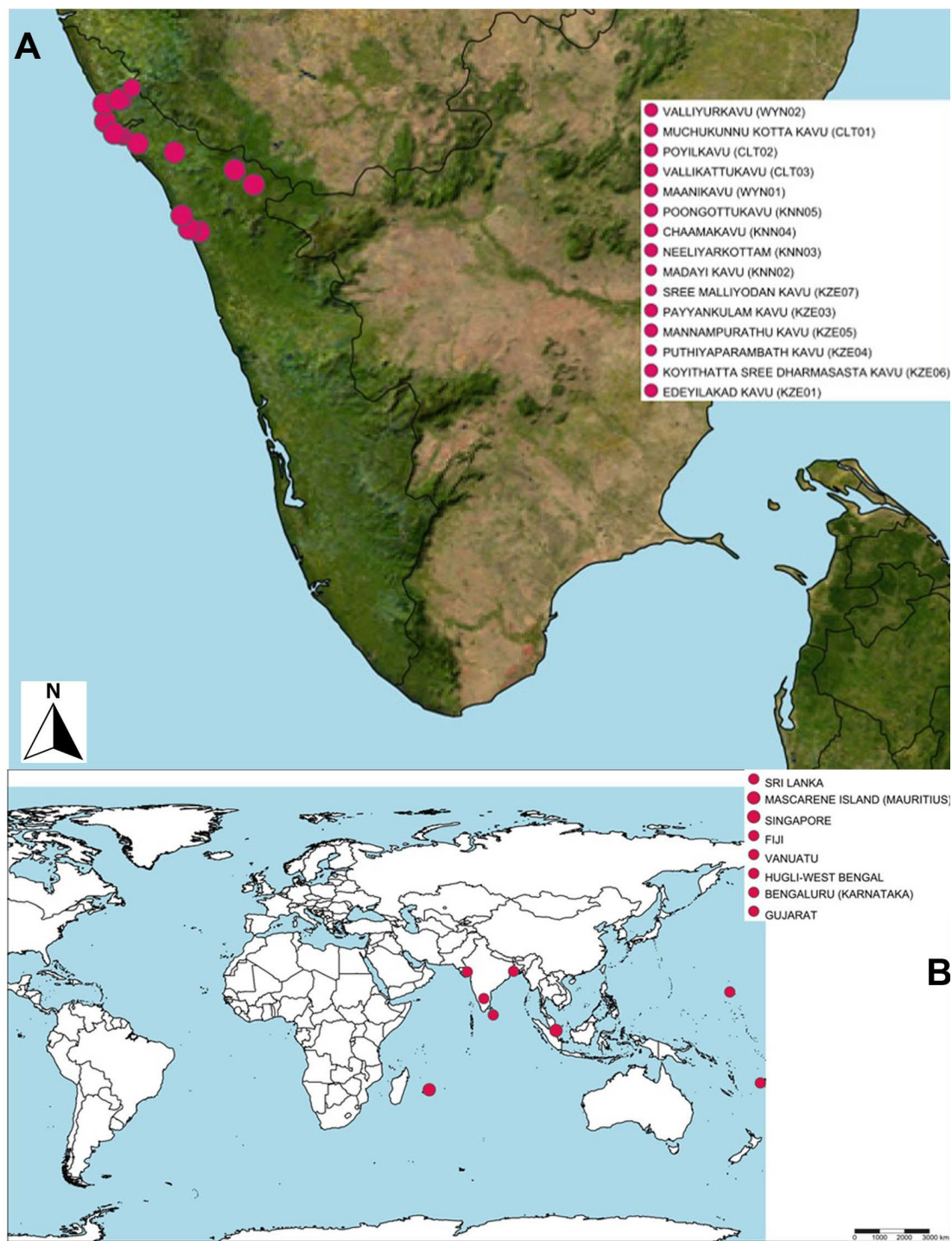


FIGURE 22. *Anoplodesmus saussurii* (Humbert, 1865). **A.** Map showing the collection sites of the species. **B.** Map showing the worldwide distribution of the same.

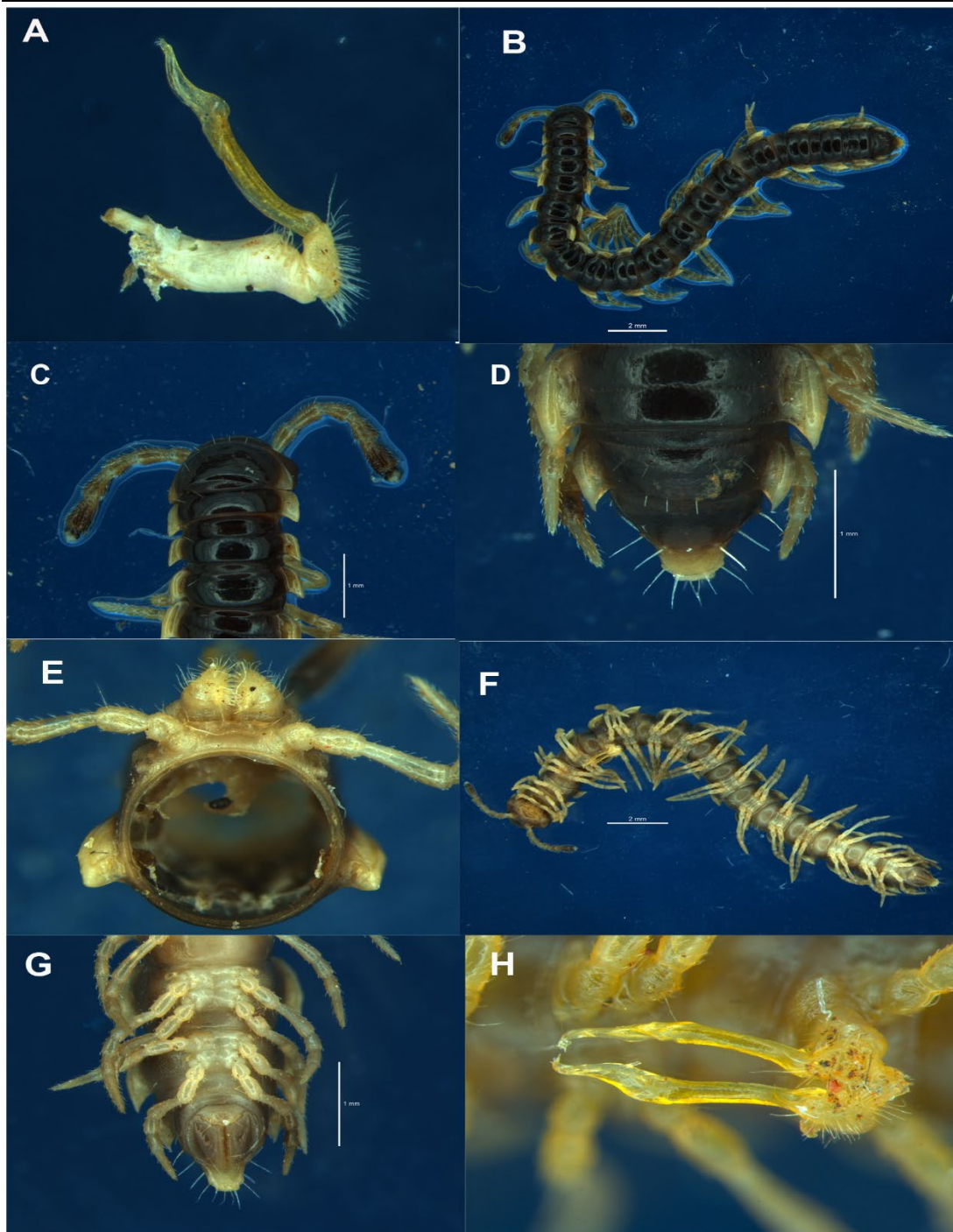


FIGURE 23. *Orthomorpha coarctata* (de Saussure, 1860). **A.** Gonopod, mesal view **B.** Male habitus, dorsal view, **C.** Male anterior, dorsal view **D.** Male posterior, dorsal view, **E.** Sternal lobes, **F.** Male habitus, ventral view, **G.** Male posterior, ventral view, **H.** Gonopods in-situ view.

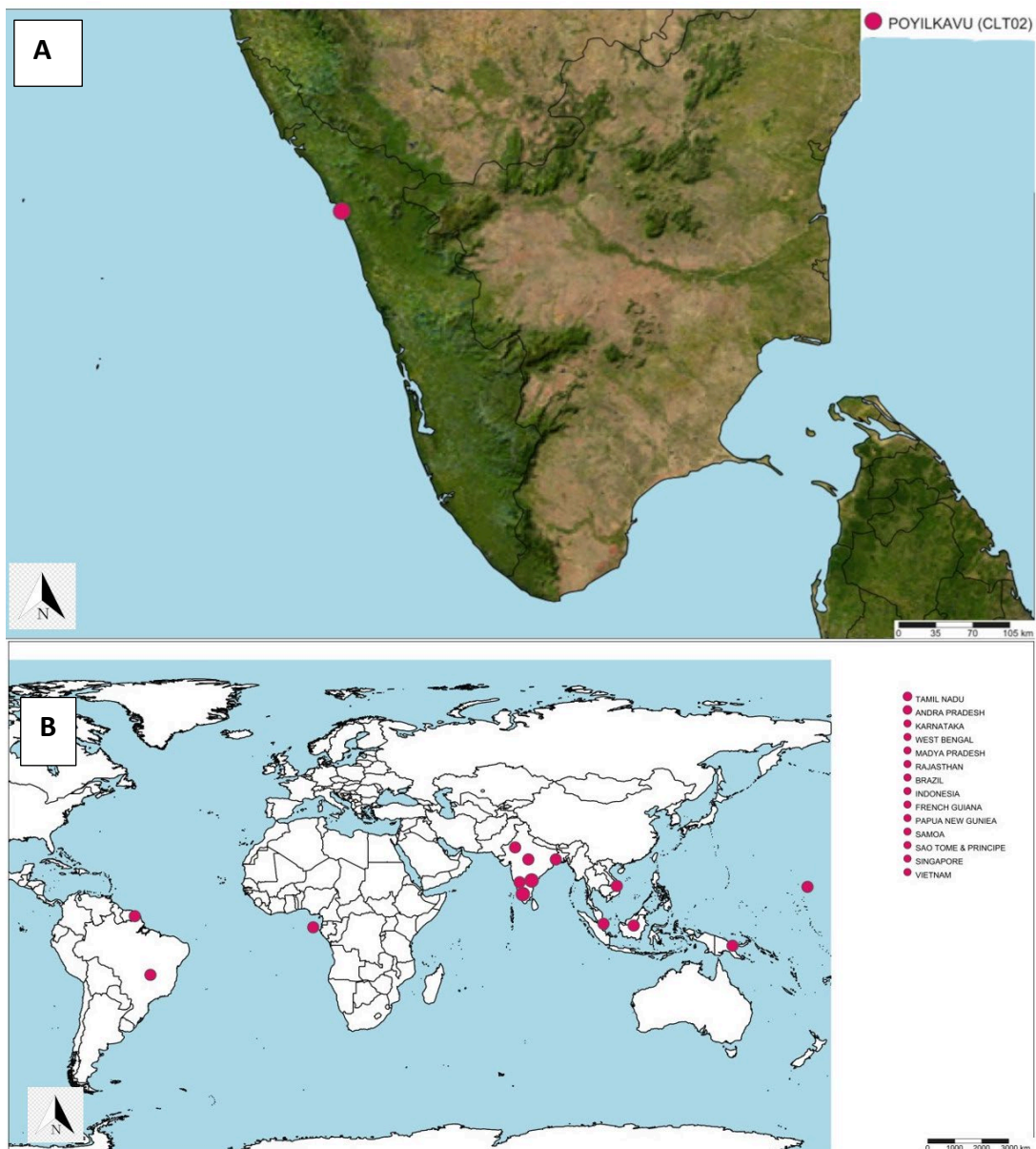


FIGURE 24. *Orthomorpha coarctata* (de Saussure, 1860) distribution. **A.** Map showing the collection sites of the species. **B.** Map showing the worldwide distribution of the same.

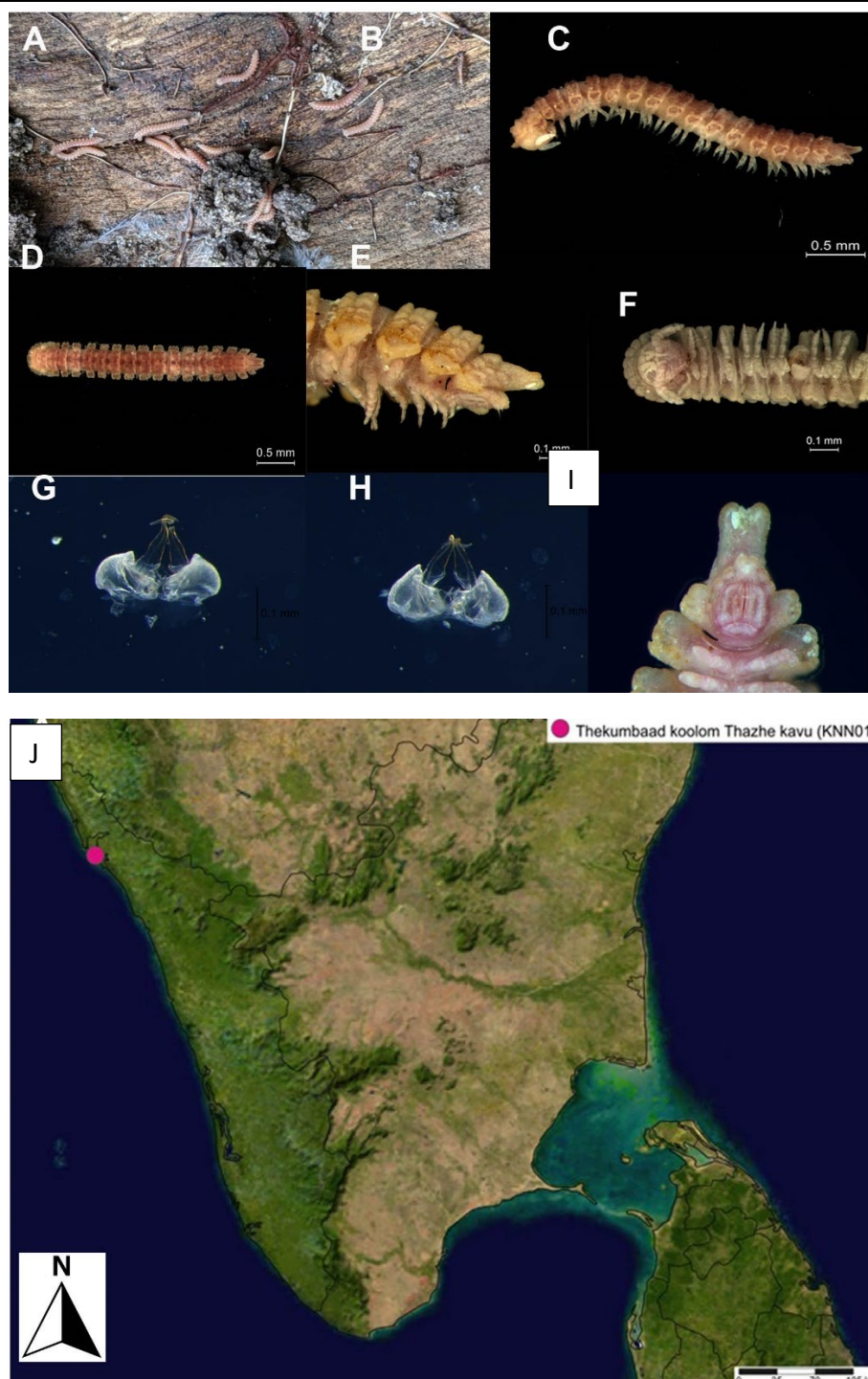


FIGURE 25. *Klimakodesmus bilobocaudatus* sp. n. (Aswathy et al., 2021). **A.** Habitus of live animals **B.** Male habitus, lateral view, **C.** Male anterior, dorsal view **D.** Male posterior, lateral view, **F.** Male habitus, ventral view, **G. & H.** Gonopods mesal view, **I.** Male telson, ventral view, **J.** Map showing the collection site of the species.

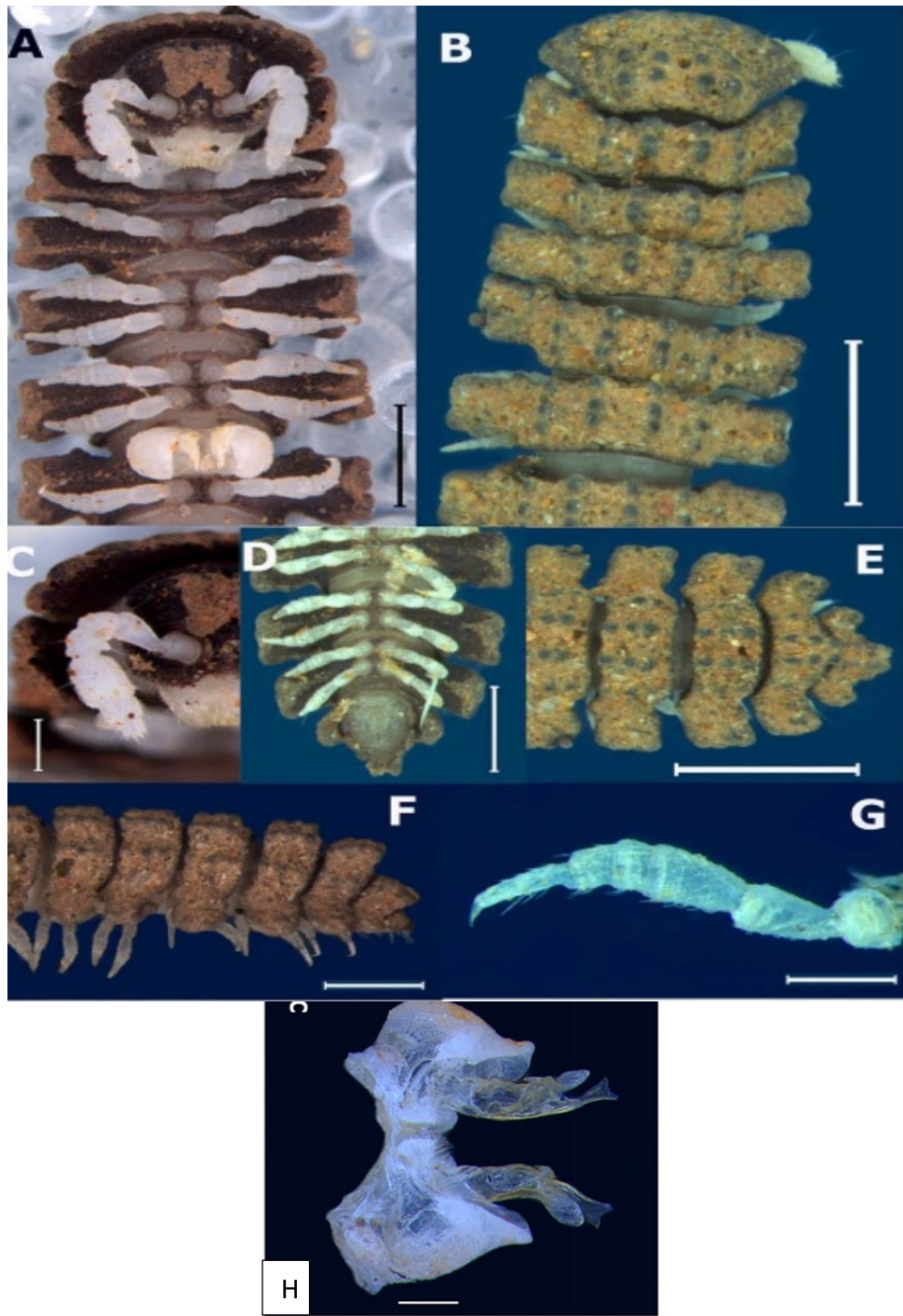


FIGURE 26. *Propyrgodesmus bulbogonopus* sp. n. (Aswathy & Sudhikumar, 2022). **A.** Male anterior, ventral, **B.** Male anterior, dorsal view, **C.** Antenna **D.** Male posterior, ventral view, **E.** Male posterior, dorsal view, **F.** Mid body anterior leg, **G.** Mid body posterior leg, **H.** Gonopods mesal view.

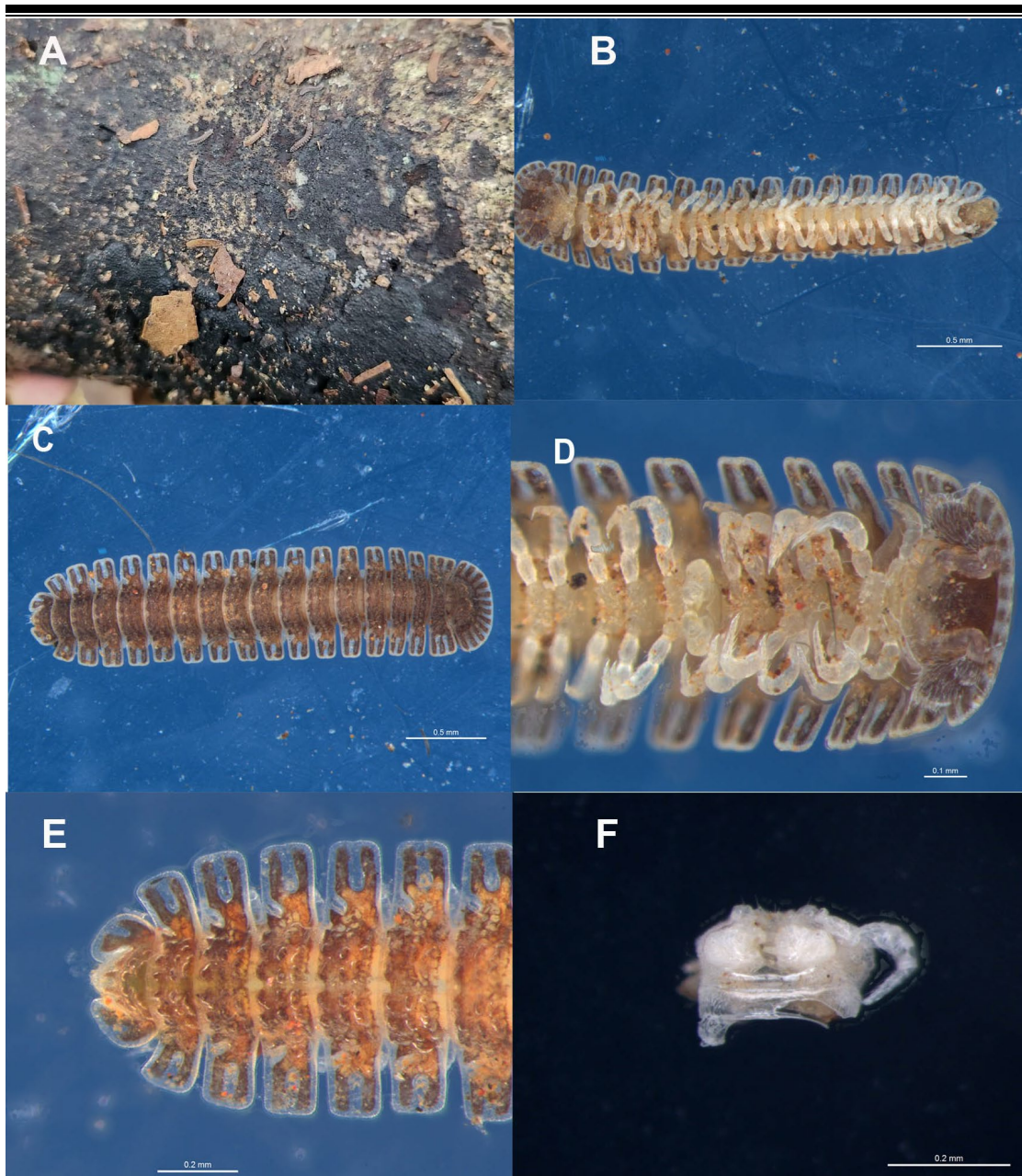


FIGURE 27. *Propyrgodesmus bulbogonopus* sp. n. (Aswathy & Sudhikumar, 2022). **A.** Individuals in their natural habitat **B.** Male habitus, ventral view, **C.** Male habitus, dorsal view, **D.** Male anterior, ventral view, **E.** Male posterior, dorsal view **F.** Gonopods in situ view.

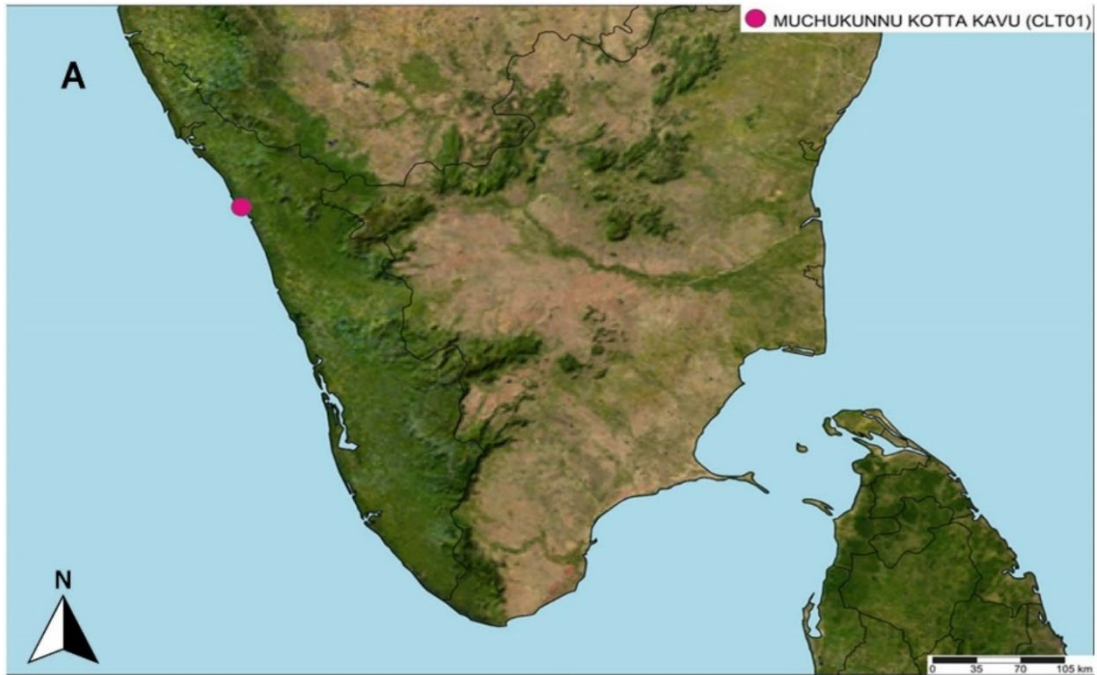


FIGURE 28. *Propyrgodesmus bulbogonopus* sp. n. (Aswathy & Sudhikumar, 2022) and *Pagodesmus sulcifer* distribution.

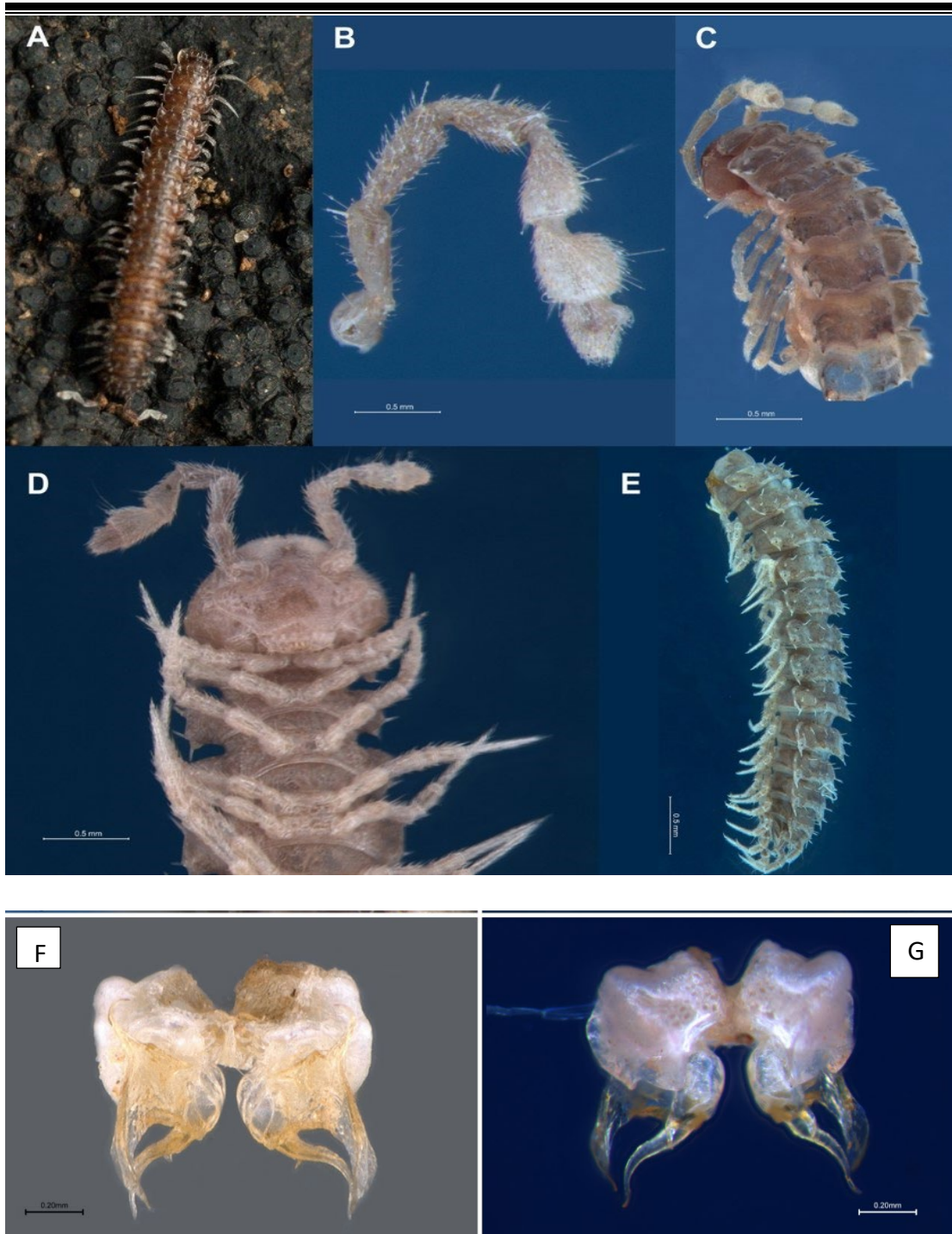


FIGURE 29. *Pseudosphaeroparia malabarica* sp. n. **A.** Natural microhabitat. **B.** Antenna. **C.** Adult male, anterior portion, dorsolateral view. **D.** Adult male, anterior portion, ventral view. **E.** Adult male, posterior portion, mesolateral view. **F & G.** Gonopods, caudal view.

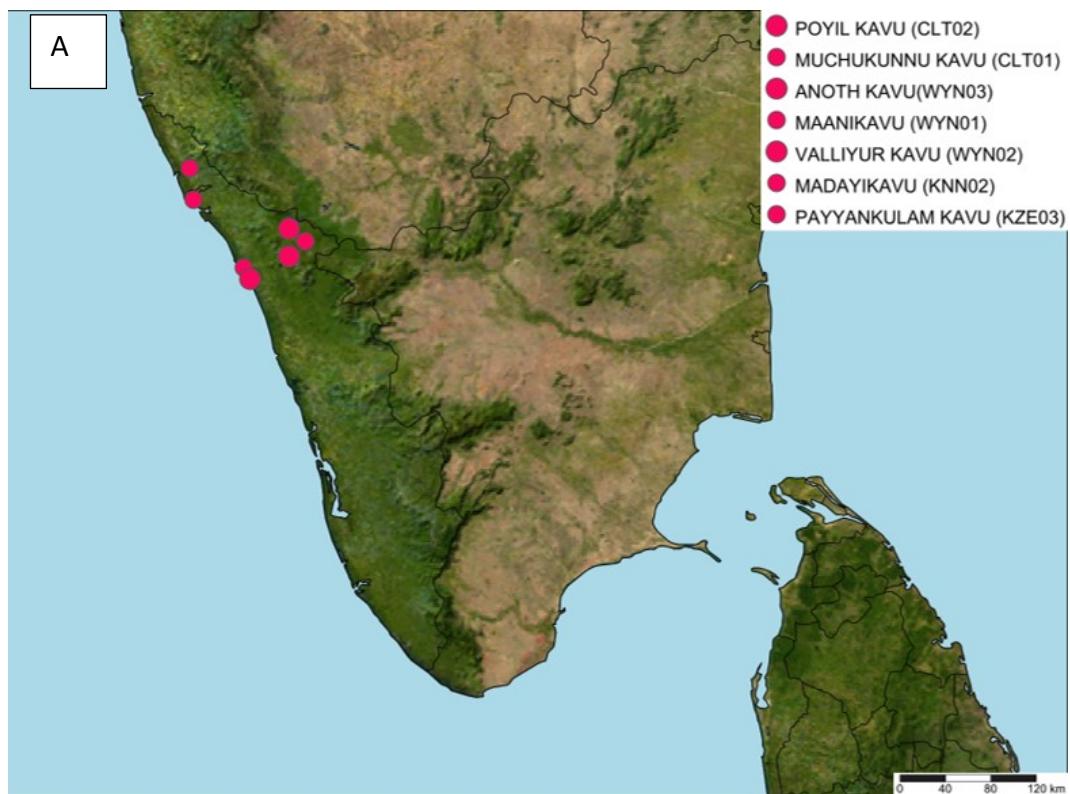


FIGURE 30. *Pseudosphaeroparia malabarica* sp. n. A. Map showing the sites of collection of the species from different sacred groves of northern Kerala.

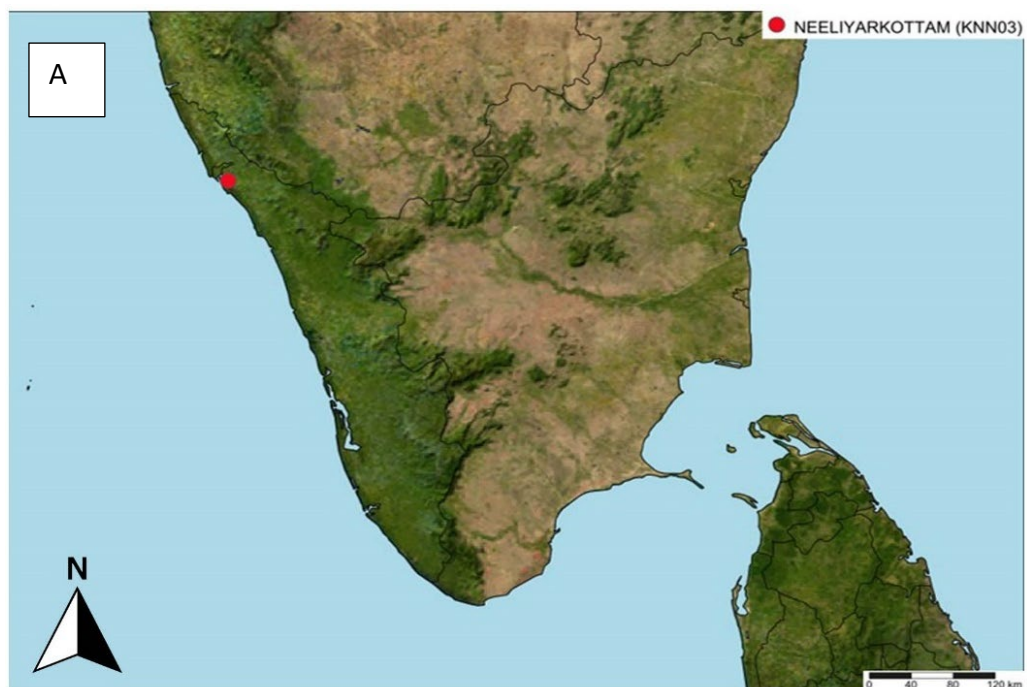


FIGURE 31. *Pseudosphaeroparia falcata* sp. n. A. Map showing the site of collection of the specimens from the sacred groves of northern Kerala.

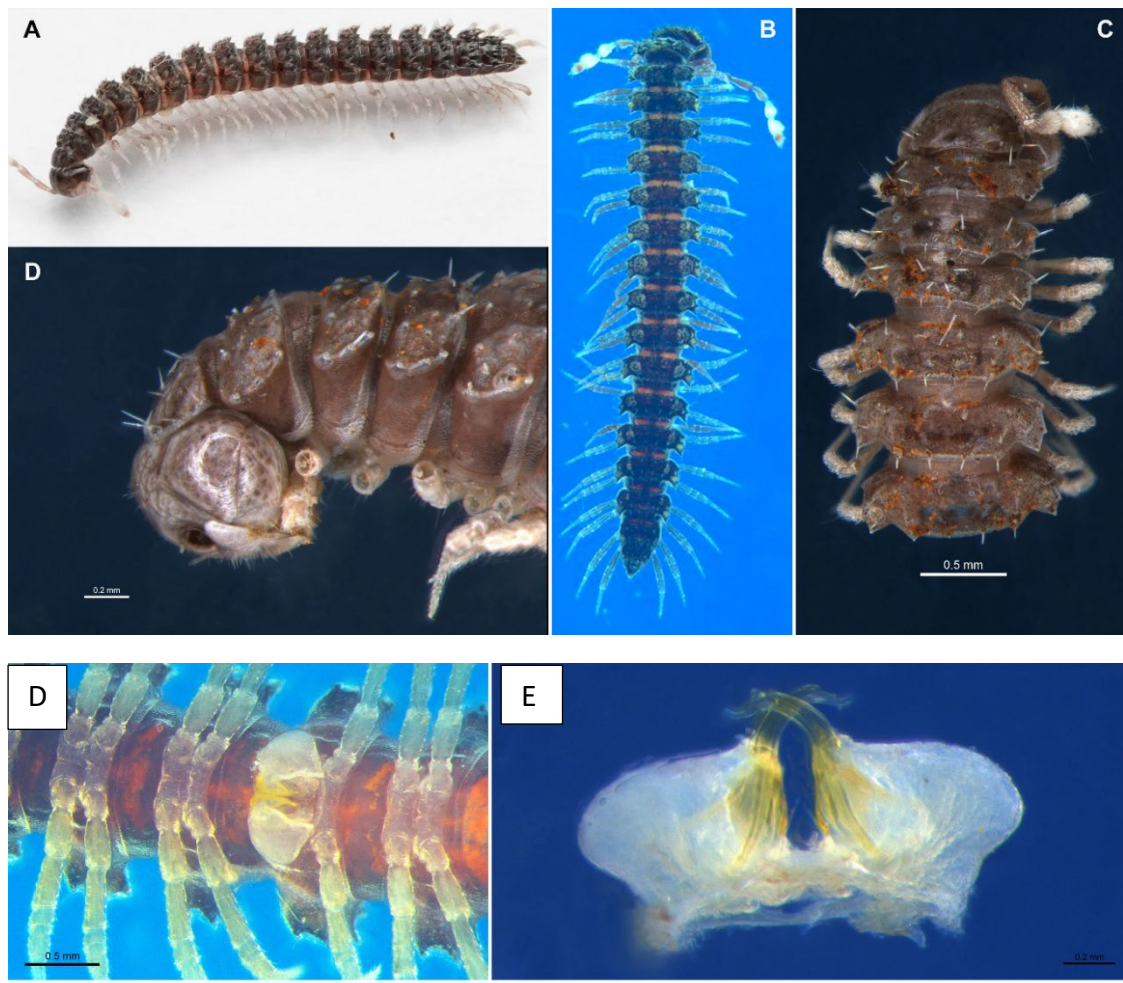


FIGURE 32. *Pseudosphaeroparia falcata* sp. n. **A.** Natural microhabitat. **B.** Habitus, dorsal view, **C.** Adult male, anterior portion, dorsolateral view. **D.** Gonopod in-situ view. **E.** Gonopods, caudal view.

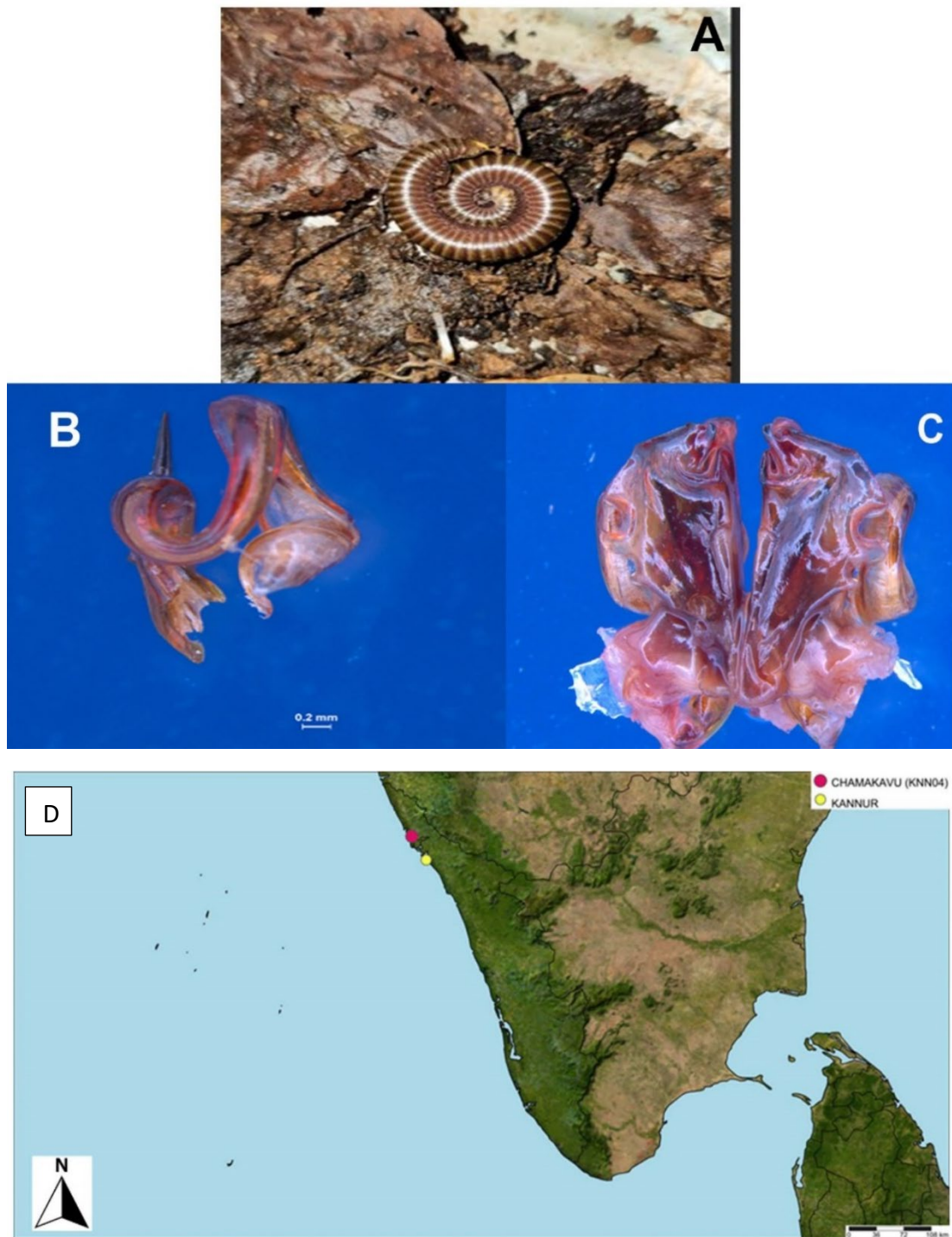


FIGURE 33. *Carlogonus palmatus* Demange, 1977A. Natural microhabitat. **B.** Telopodite, aboral view, **C.** Gonopod oral view. **D** Map showing the site of collection of species (Red dot) from the sacred groves of northern Kerala and the distribution of the same (Yellow dot).

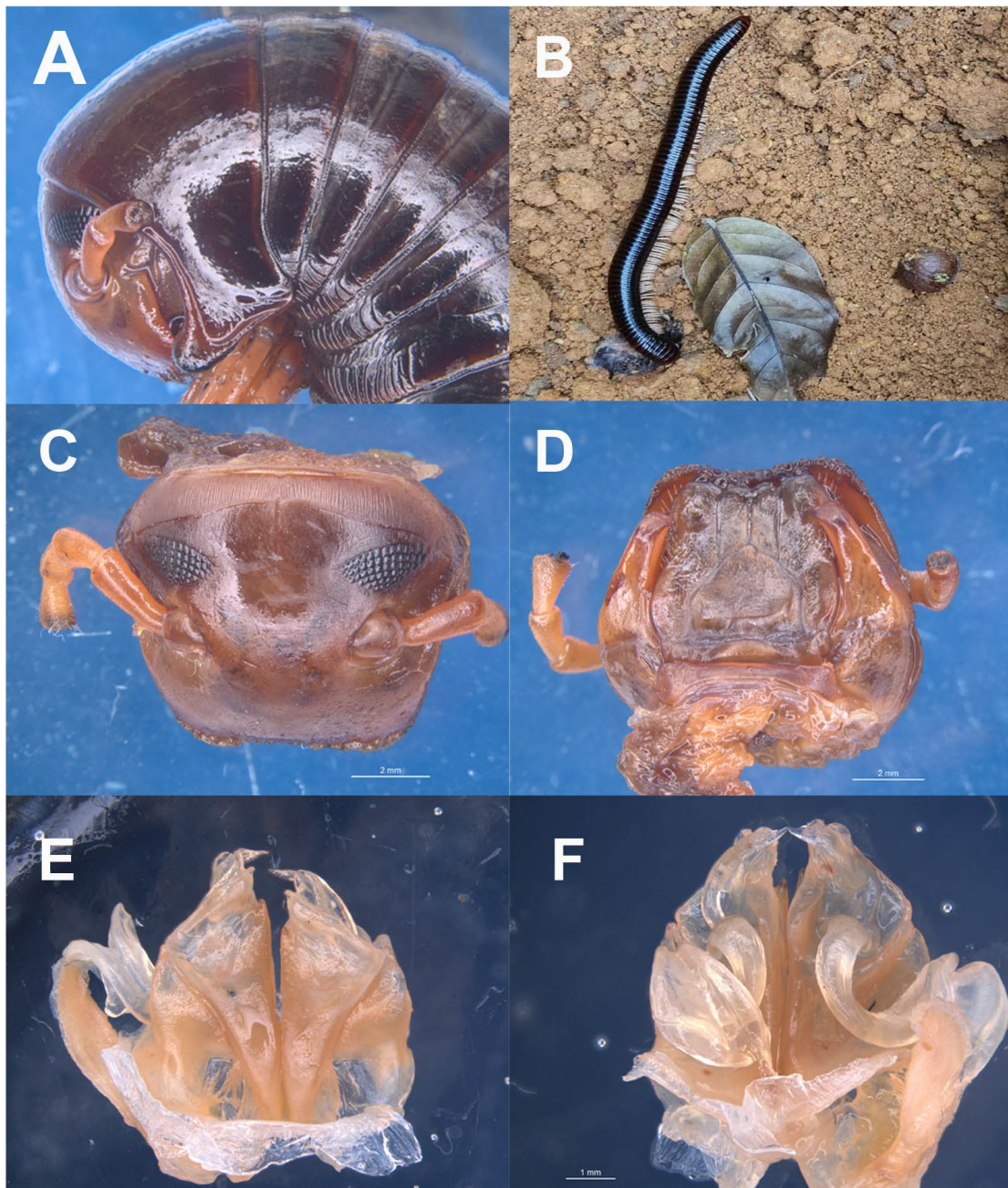


FIGURE 34. *Fageostreptus hyatti* Demange, 1961. **A.** Male anterior, lateral view **B.** Natural microhabitat, **C.** Head, dorsal view. **D** Ganathochilarium, **E.** Gonopod, oral view, **F.** Gonopod, aboral view.

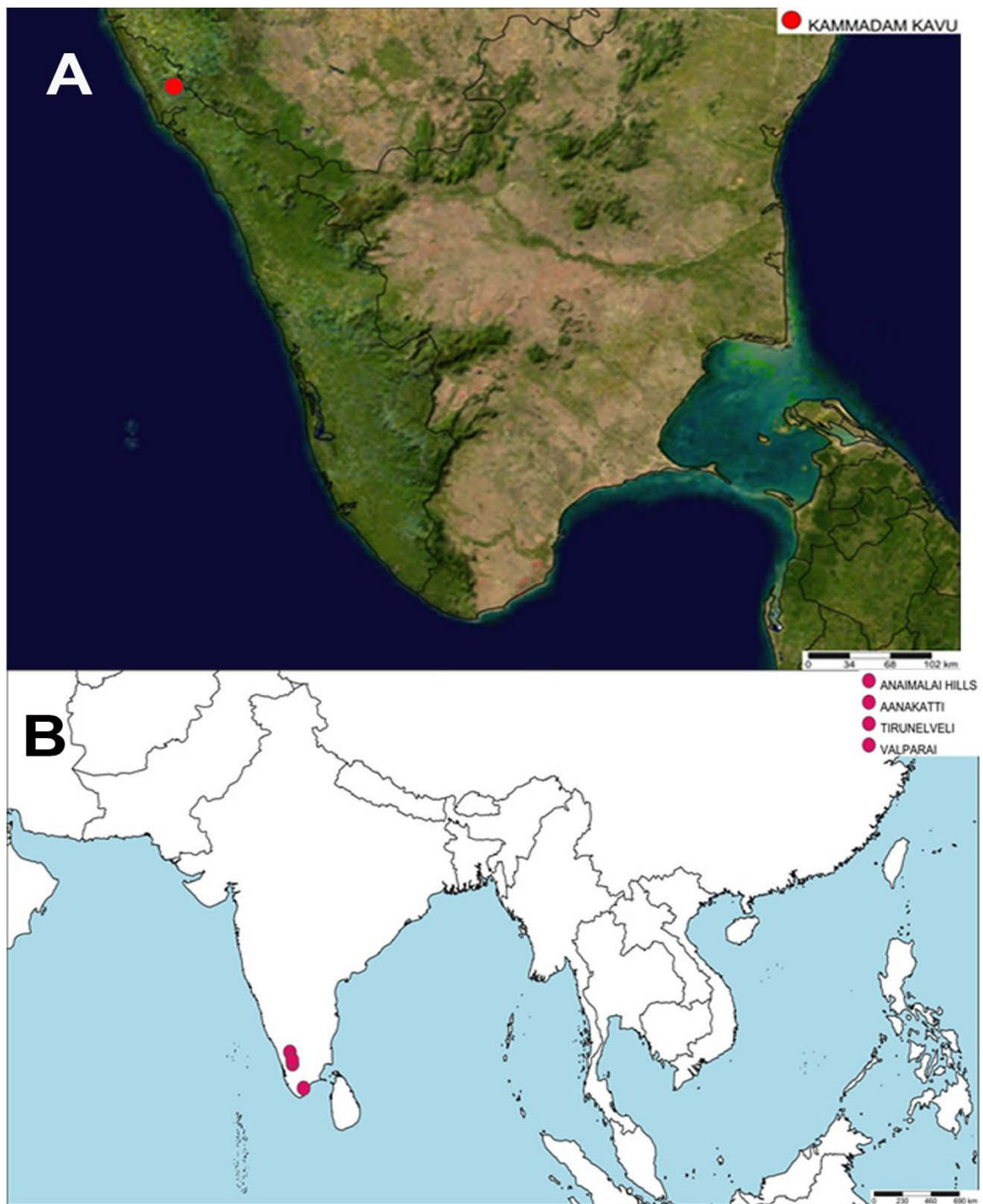


FIGURE 35. *Fageostreptus hyatti* Demange, 1961 distribution. A. Map showing the collection site of the specimen from the sacred groves of northern Kerala B. Map showing the worldwide distribution of the species.

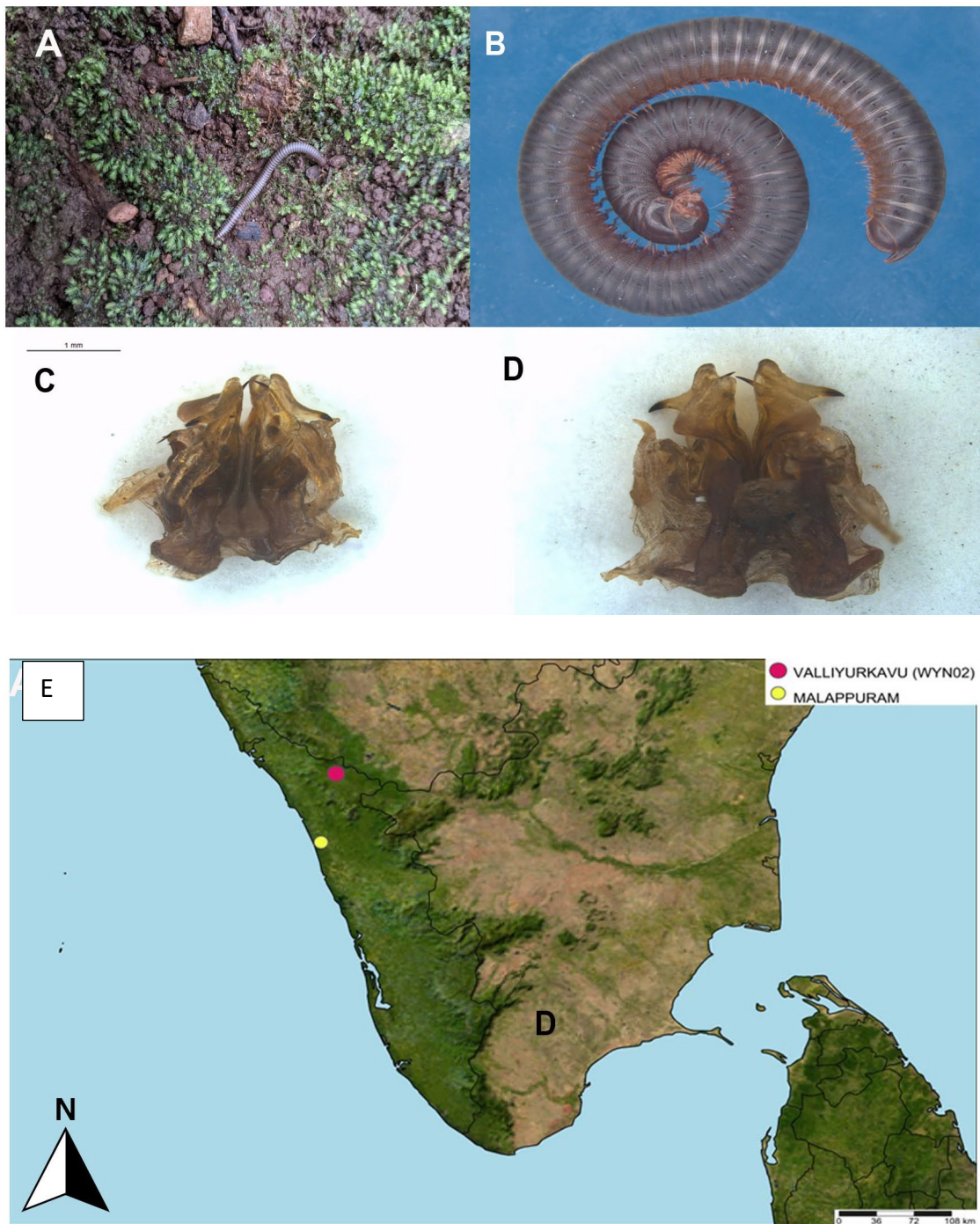


FIGURE 36. *Harpurostreptus prasadani* Demange, 1989. **A.** Natural microhabitat, **B.** Male habitus, **C.** Gonopod oral view. **D.** Gonopod, aboral view, **E.** Map showing the collection site of the species from sacred groves of northern Kerala (Red dot) and other places of distribution (Yellow dot).

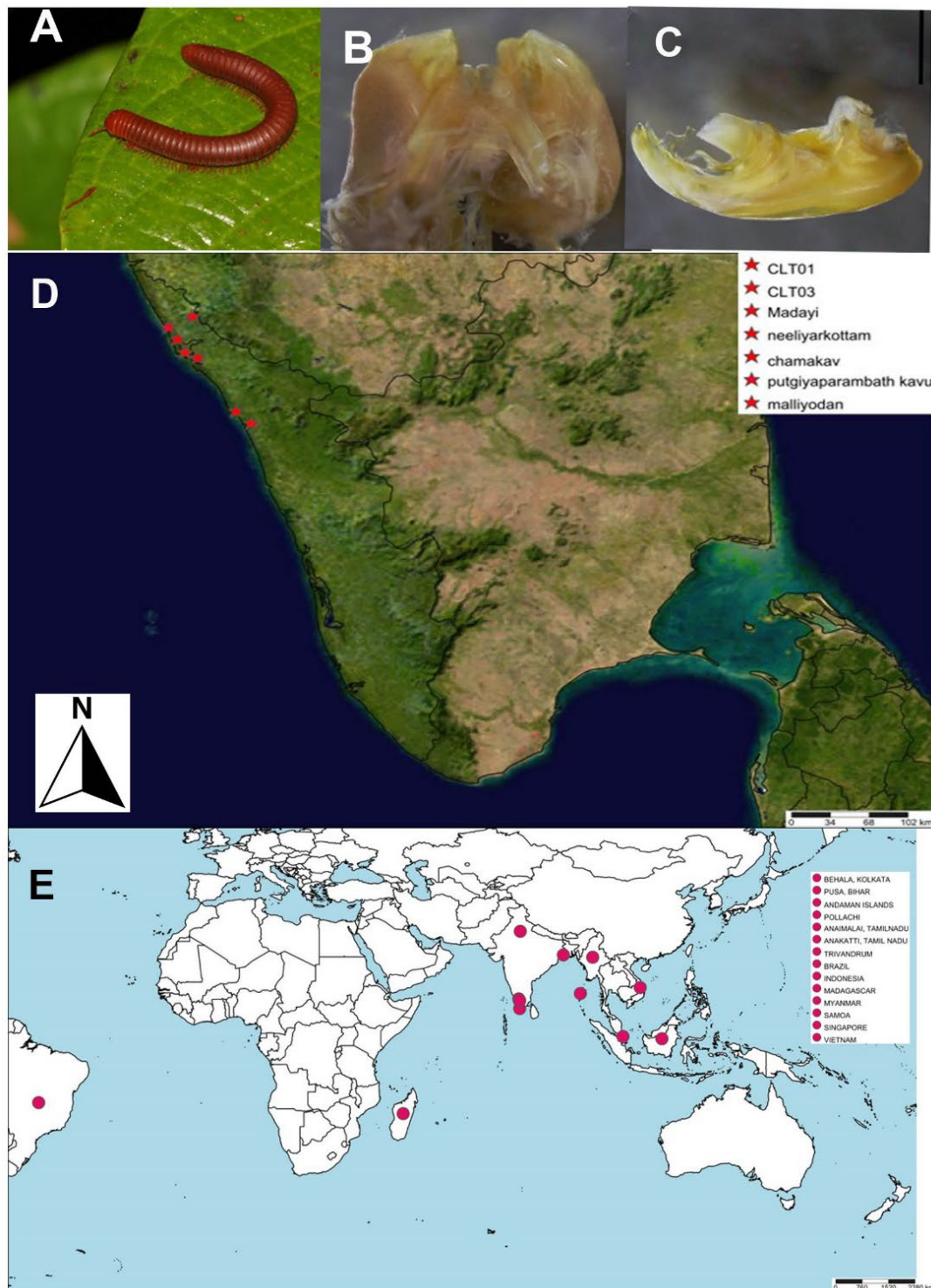


FIGURE 37. *Trioniulus corallinus* (Gervais, 1847). **A.** Natural microhabitat, **B** Anterior gonopods, **C.** Posterior gonopods, **D.** Map showing the collection site of the species from sacred groves of northern Kerala (Red dot) **E.** Map showing the worldwide distribution of the species.

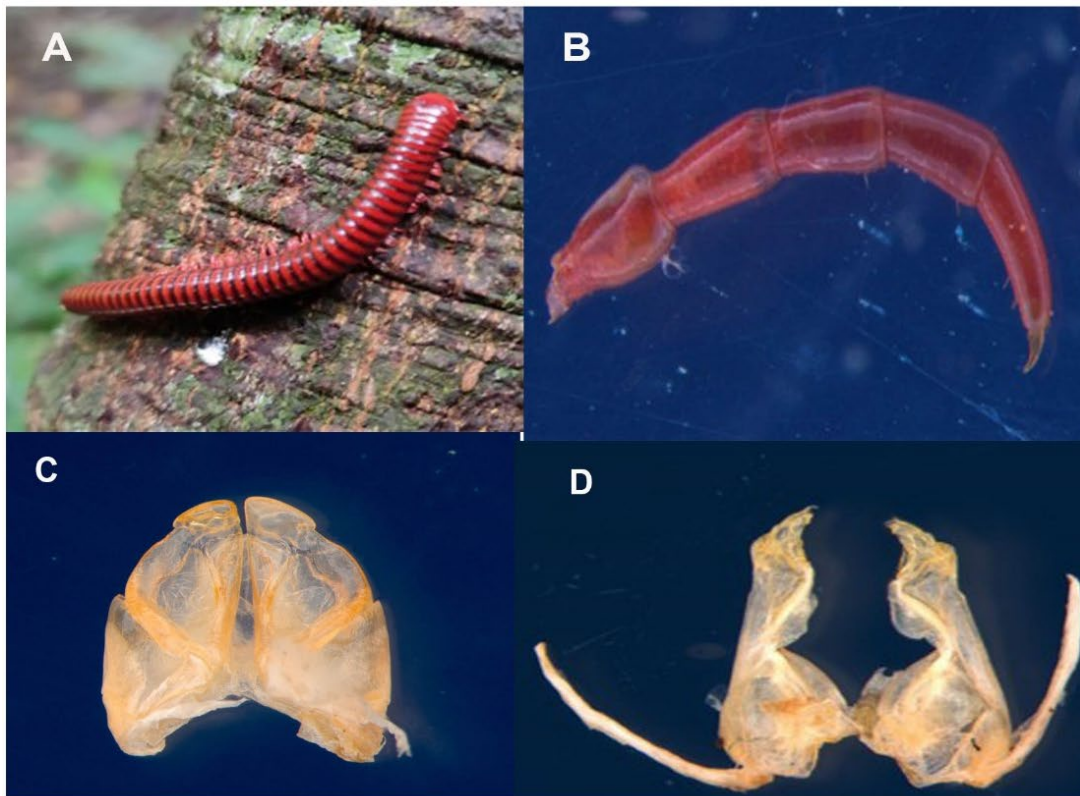


FIGURE 38. *Stenobolus insularis* Carl, 1918. **A.** Natural microhabitat, **B.** Mid body leg **C.** Gonopod Anterior. **D** Gonopod, posterior.

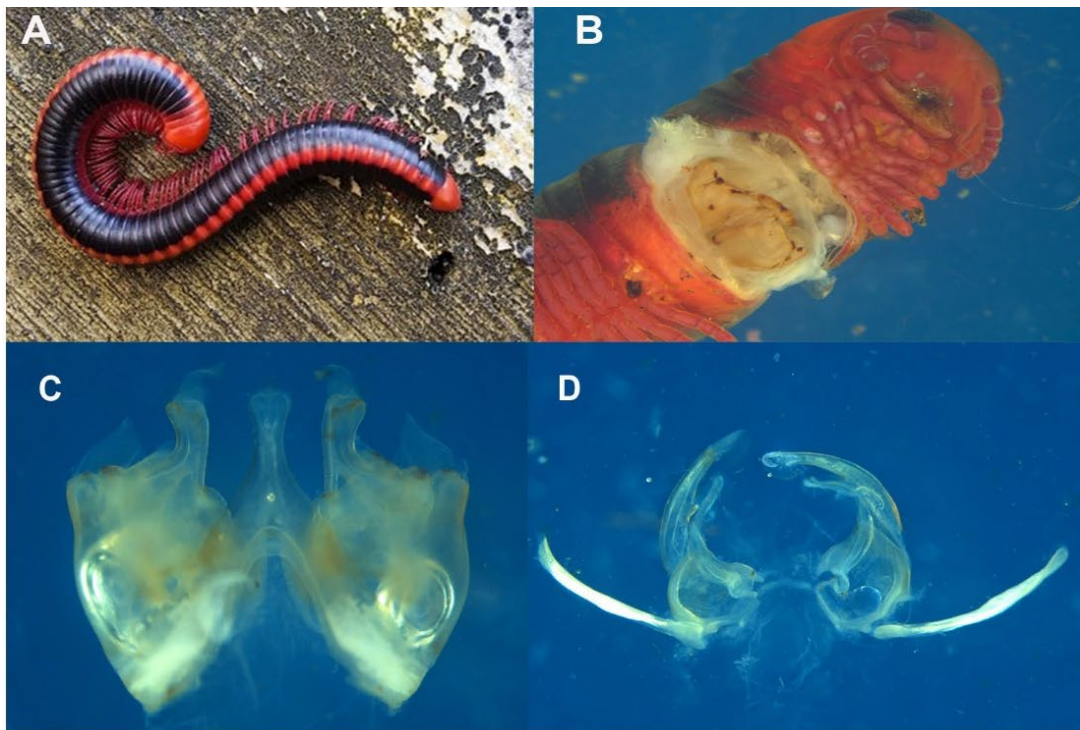


FIGURE 39. *Xenobolus carnifex* Carl, 1919. **A.** Natural microhabitat, **B.** Gonopod, in-situ **C.** Gonopod Anterior. **D** Gonopod, posterior

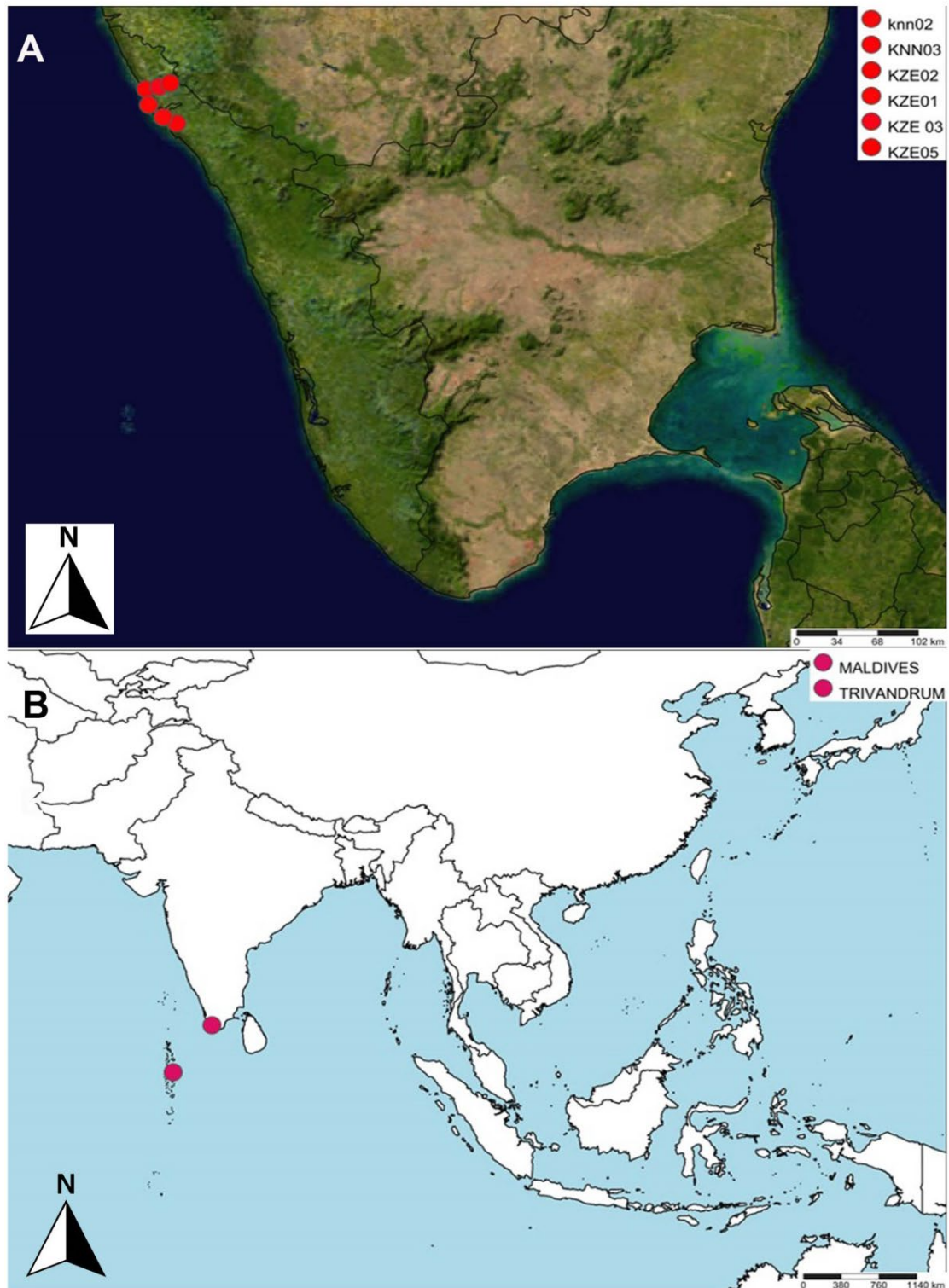


FIGURE 40. *Xenobolus carnifex* Carl, 1919. **A.** Map showing the collection sites of the specimens from the sacred groves of northern Kerala. **B.** Map showing the worldwide distribution of the species.

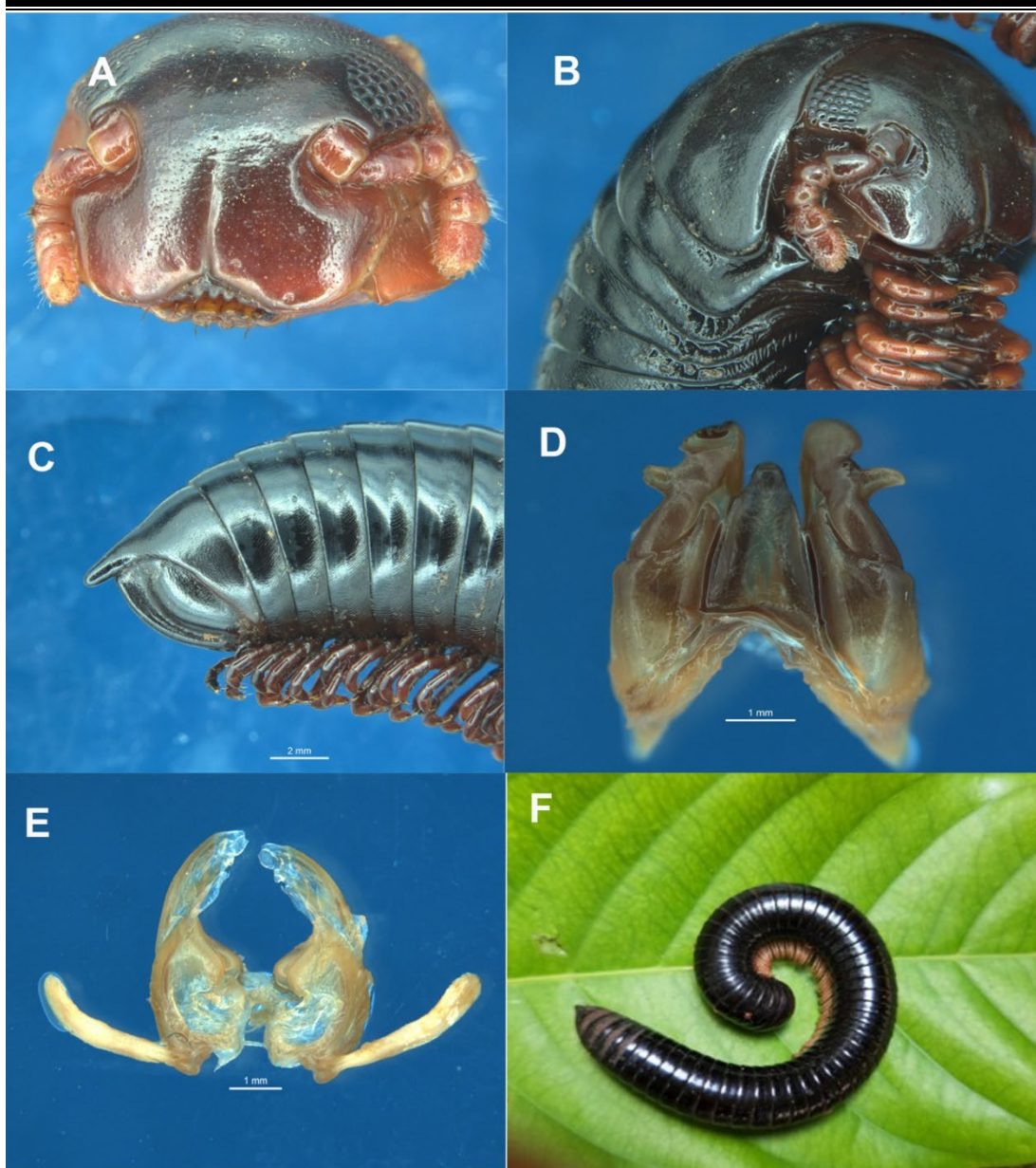


FIGURE 41. *Aulacobolus graveyi* Silvestri, 1916. **A.** Head, mesal view **B.** Male anterior meso- lateral view, **C.** Male posterior, lateral view **D** Gonopod, anterior, **E.** Gonopod, posterior, **F.** Natural microhabitat.

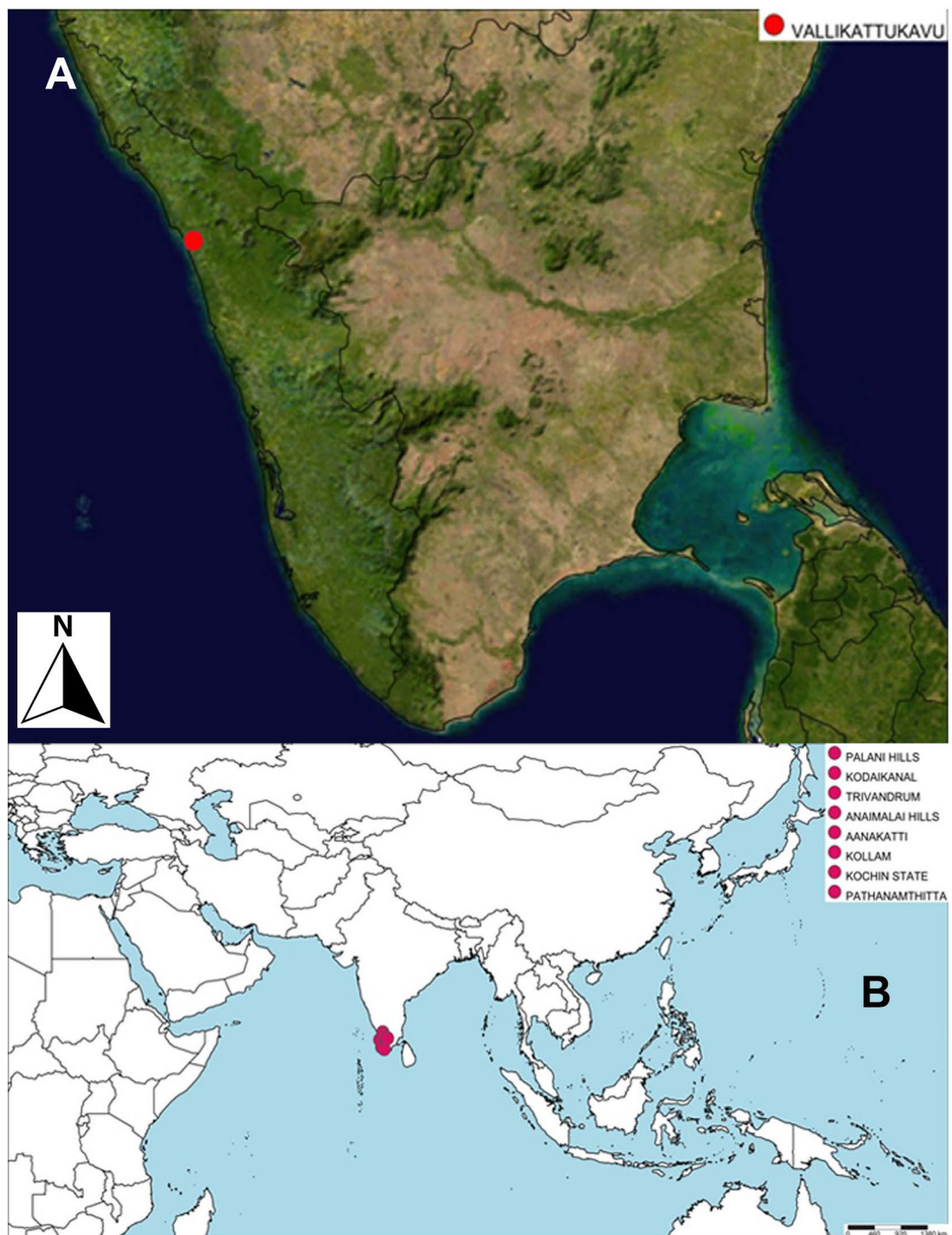


FIGURE 42. *Aulacobolus gravelyi* Silvestri, 1916. **A.** Map showing the collection sites of the specimens from the sacred groves of northern Kerala. **B.** Map showing the worldwide distribution of the species.

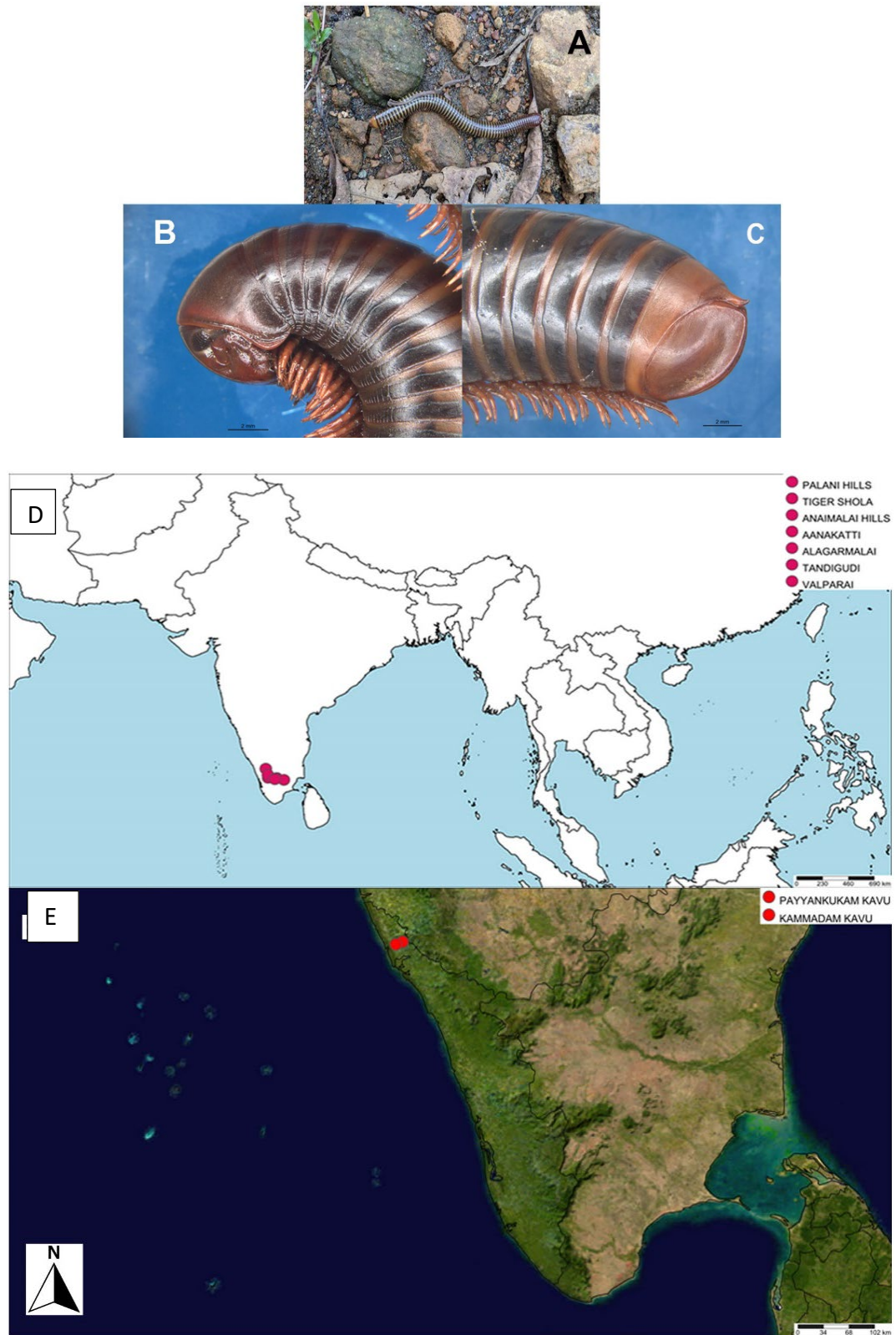


FIGURE 43. *Aulacobolus newtoni* Silvestri, 1916. A. Natural microhabitat B. Female anterior, lateral view, C. Female posterior, lateral view D. Map showing the collection sites of the specimens from the sacred groves of northern Kerala, E. Map showing the worldwide distribution of the species.

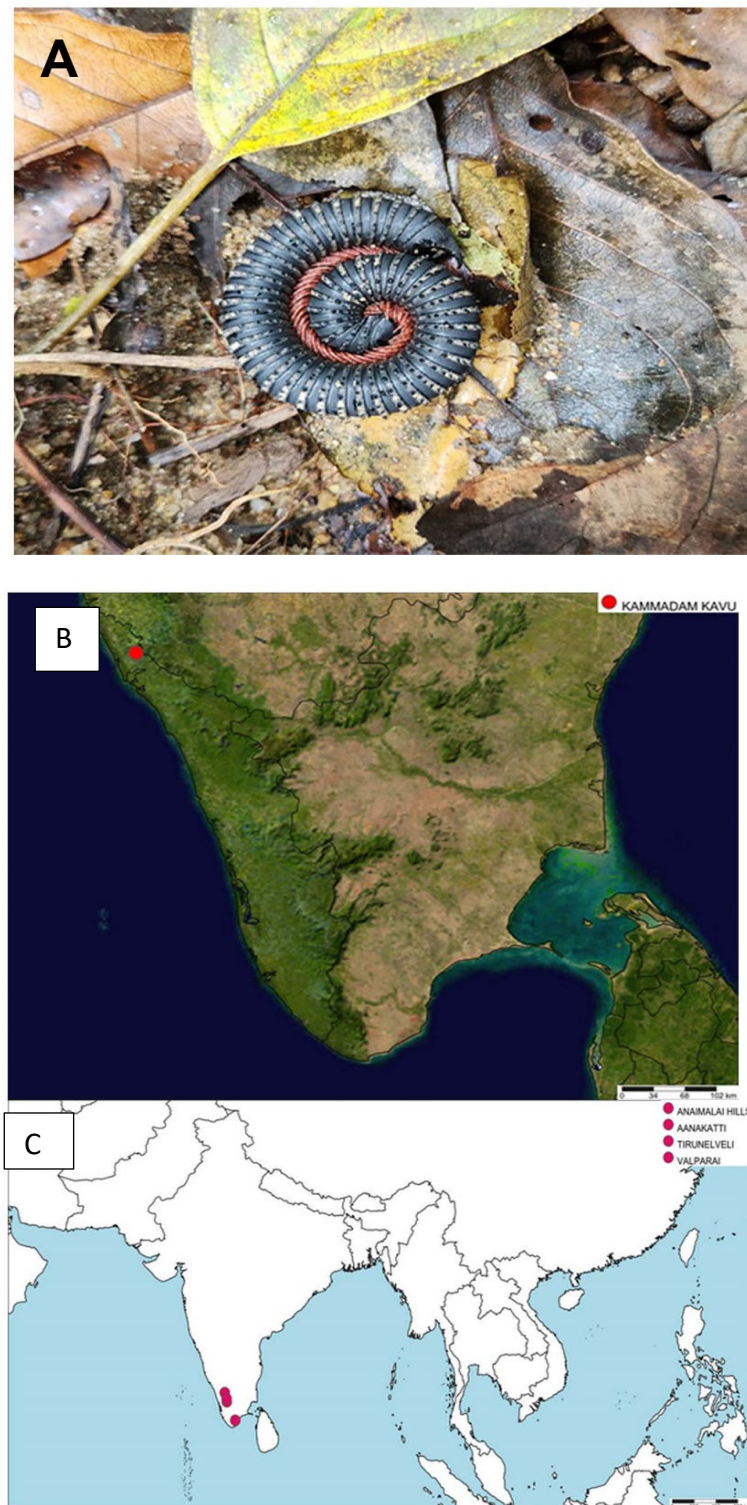
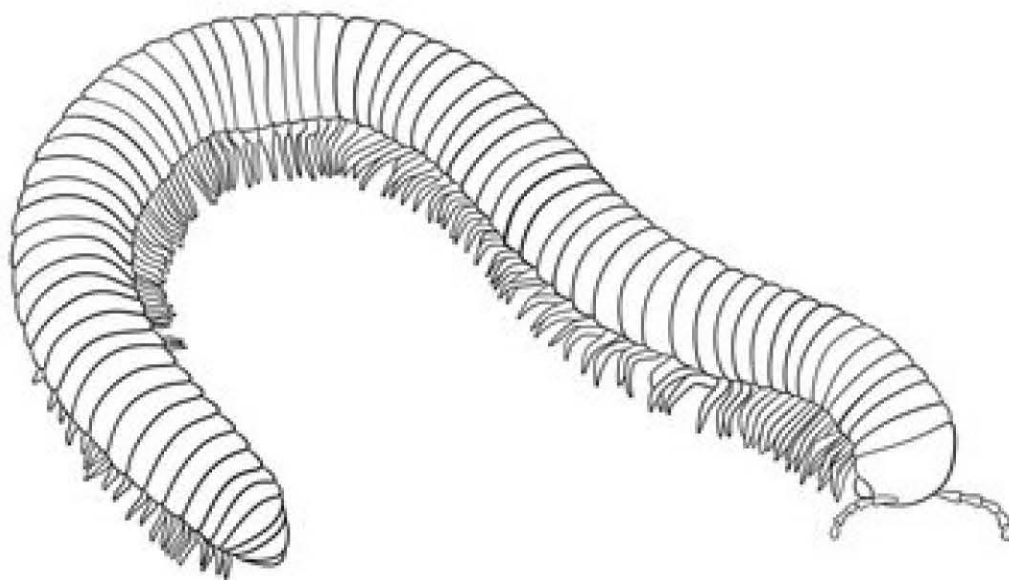


FIGURE 44. *Eucentrobolus maindroni* (Bouvier, 1903). **A.** Natural microhabitat. **B.** Map showing the collection sites of the specimens from the sacred groves of northern Kerala. **C.** Map showing the worldwide distribution of the species.



GRAPHS

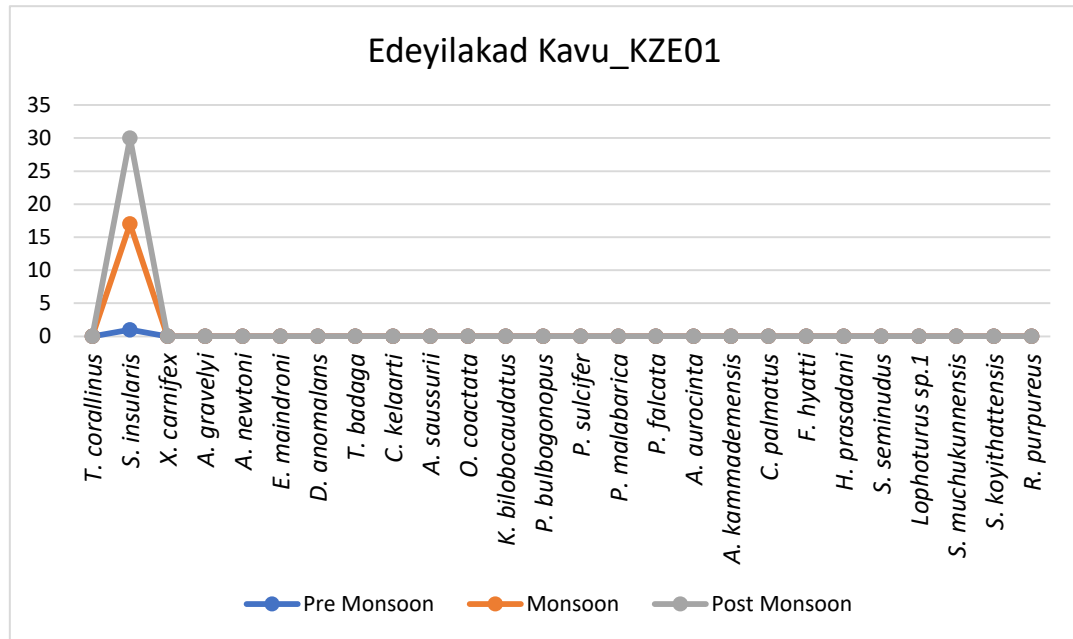


FIGURE 45. Graph showing the seasonal abundance of millipedes for the sacred grove Edeyilakkad Kav (KZE01) in the year 2021.

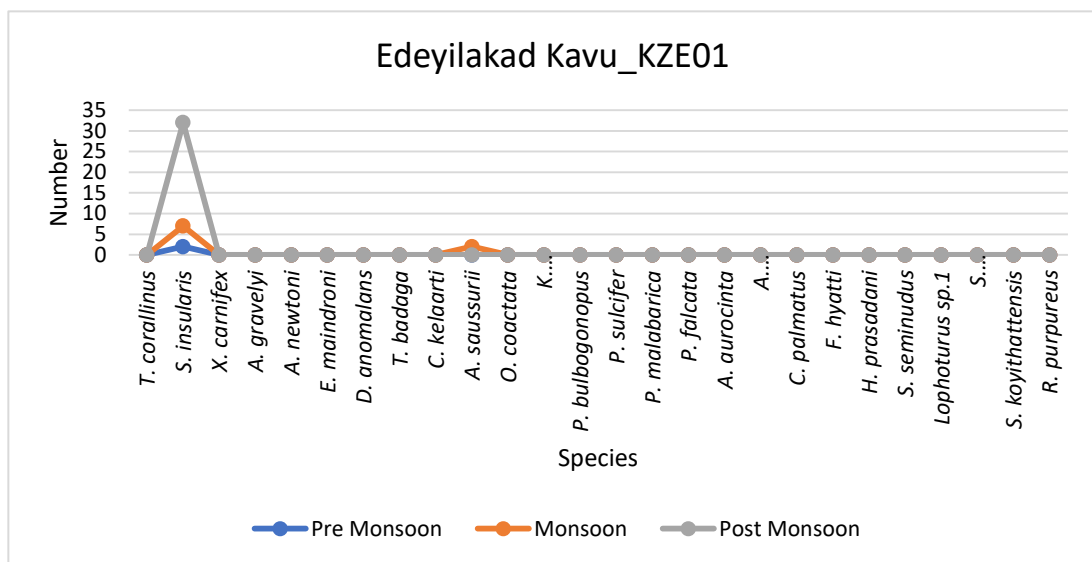


FIGURE 46. Graph showing the seasonal abundance of millipedes for the sacred grove Edeyilakkad Kav (KZE01) in the year 2022.

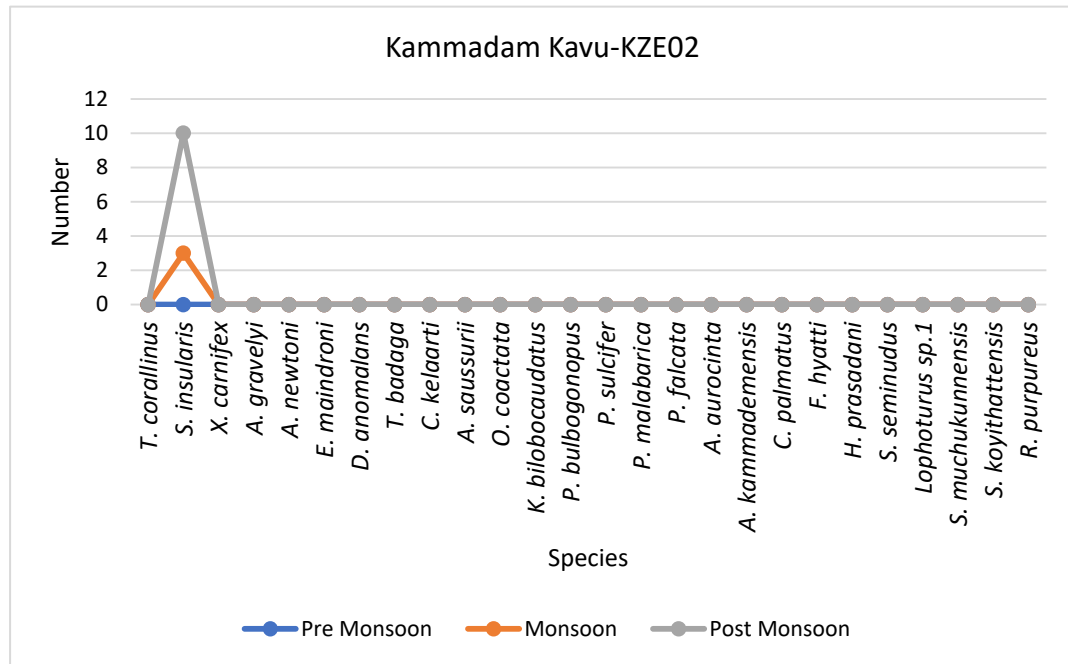


FIGURE 47. Graph showing the seasonal abundance of millipedes for the sacred grove Kammadam Kavuv (KZE02) in the year 2021.

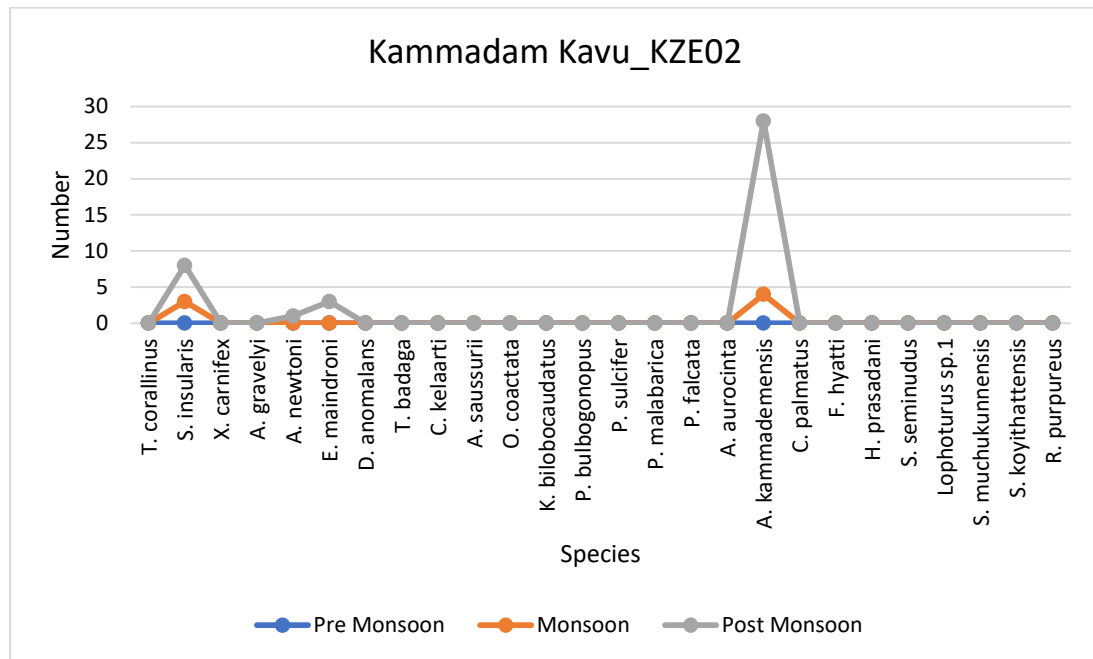


FIGURE 48. Graph showing the seasonal abundance of millipedes for the sacred grove Kammadam Kavuv (KZE02) in the year 2022.

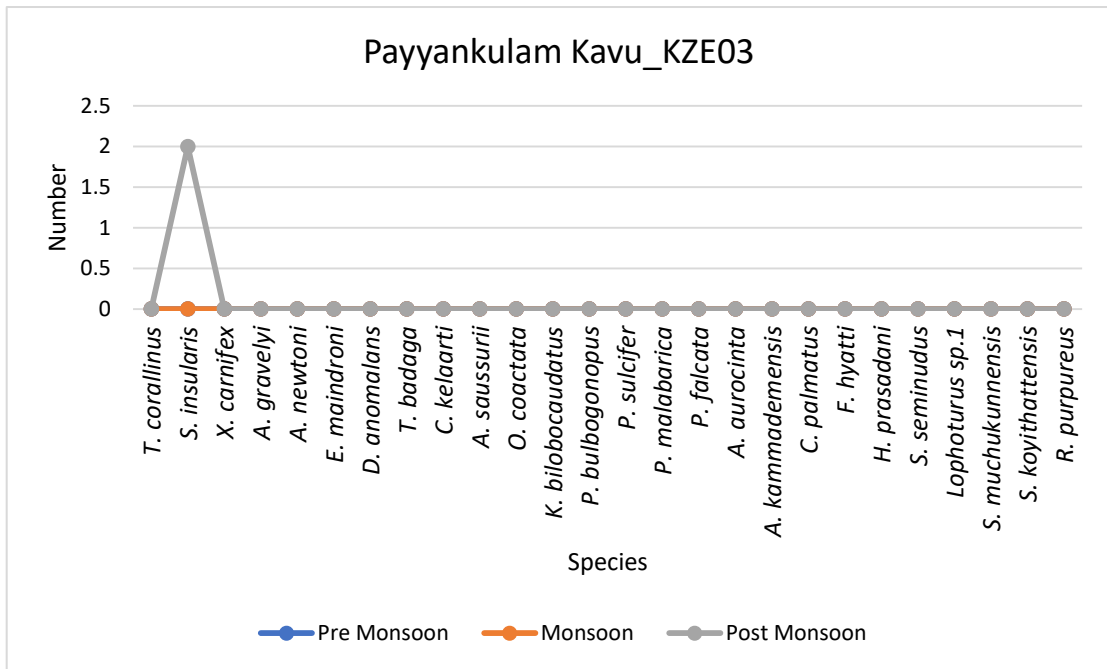


FIGURE 49. Graph showing the seasonal abundance of millipedes for the sacred grove Payyankulam KavU (KZE03) in the year 2021.

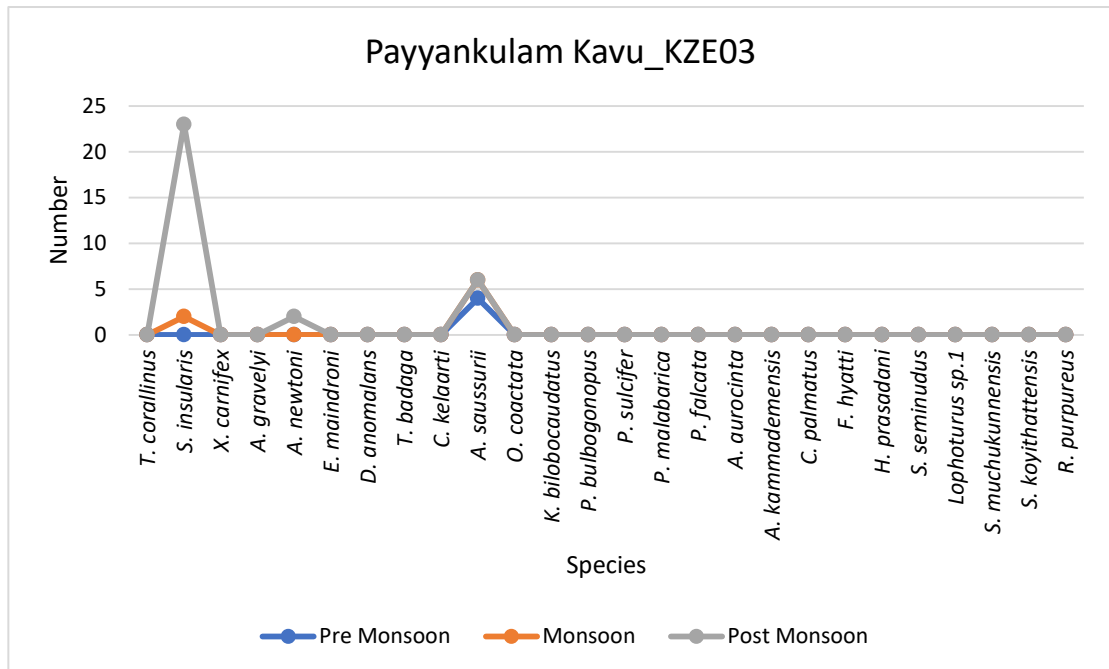


FIGURE 50. Graph showing the seasonal abundance of millipedes for the sacred grove Payyankulam KavU (KZE03) in the year 2022.

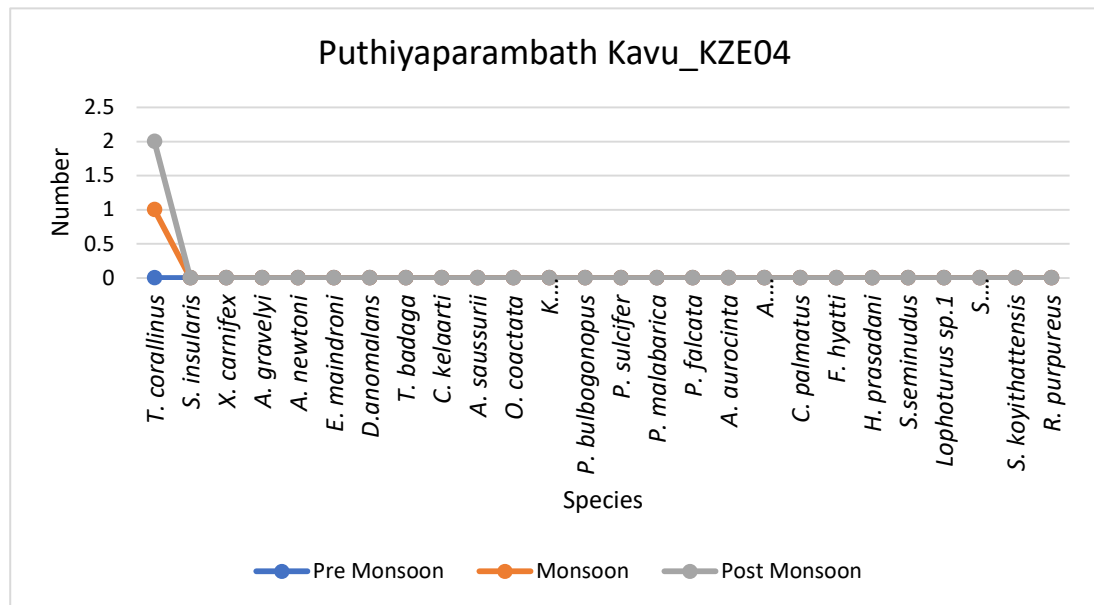


FIGURE 51. Graph showing the seasonal abundance of millipedes for the sacred grove Puthiyaparambath Kav_u (KZE04) in the year 2021.

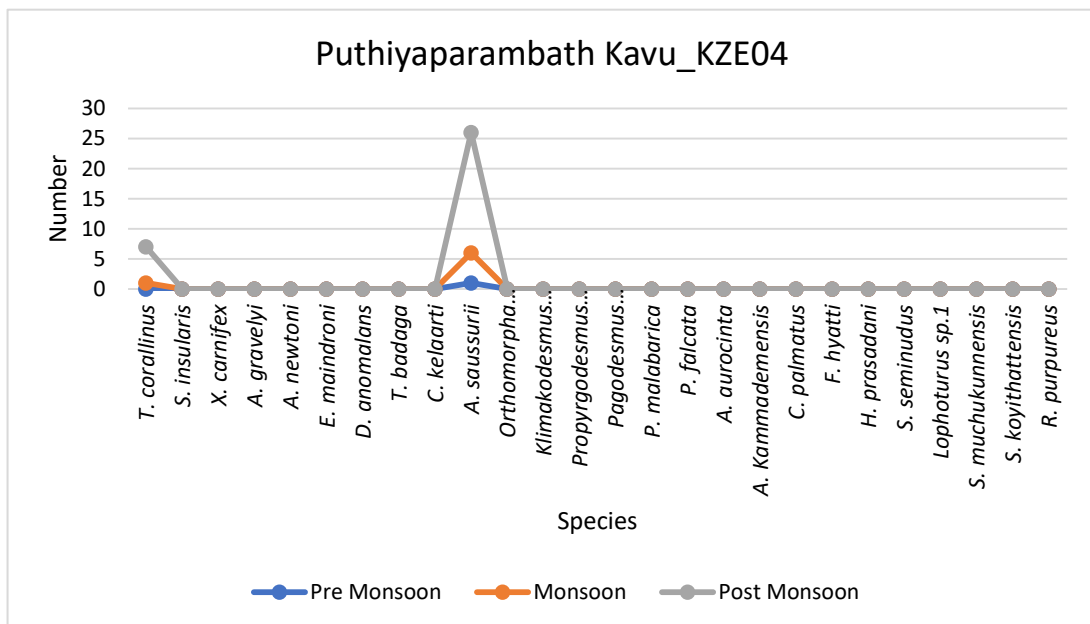


FIGURE 52. Graph showing the seasonal abundance of millipedes for the sacred grove Puthiyaparambath Kav_u (KZE04) in the year 2022.

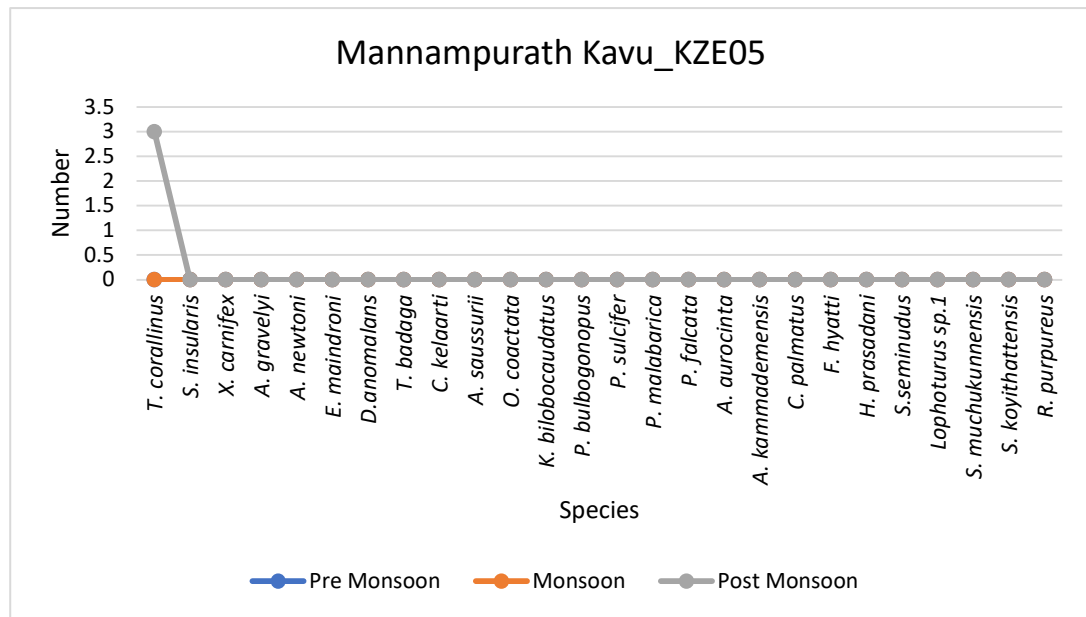


FIGURE 53. Graph showing the seasonal abundance of millipedes for the sacred grove Mannampurath Kav_u (KZE05) in the year 2021.

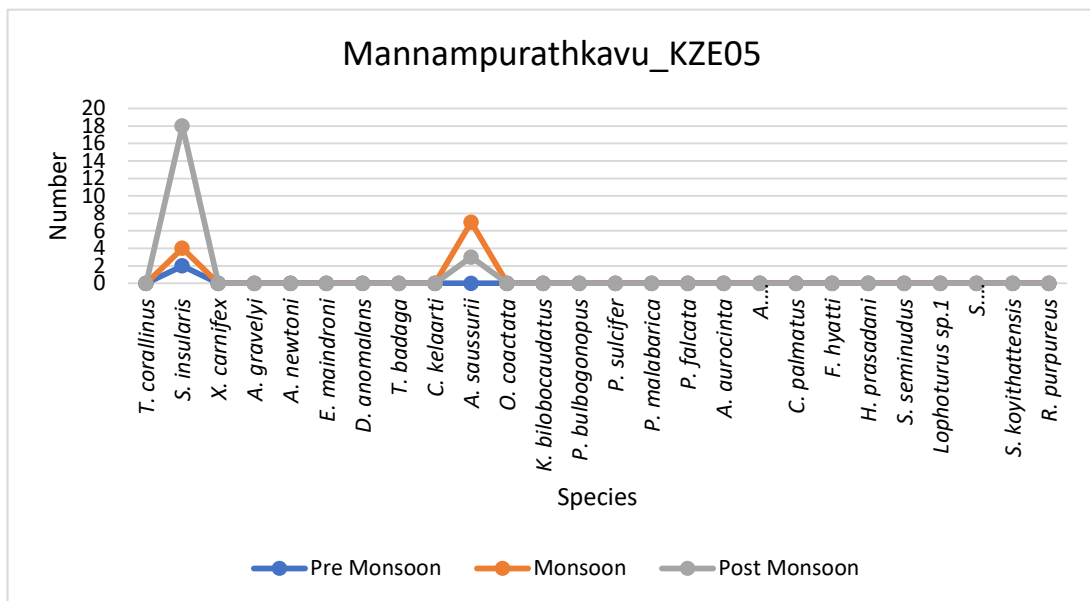


FIGURE 54. Graph showing the seasonal abundance of millipedes for the sacred grove Mannampurath Kav_u (KZE05) in the year 2022.

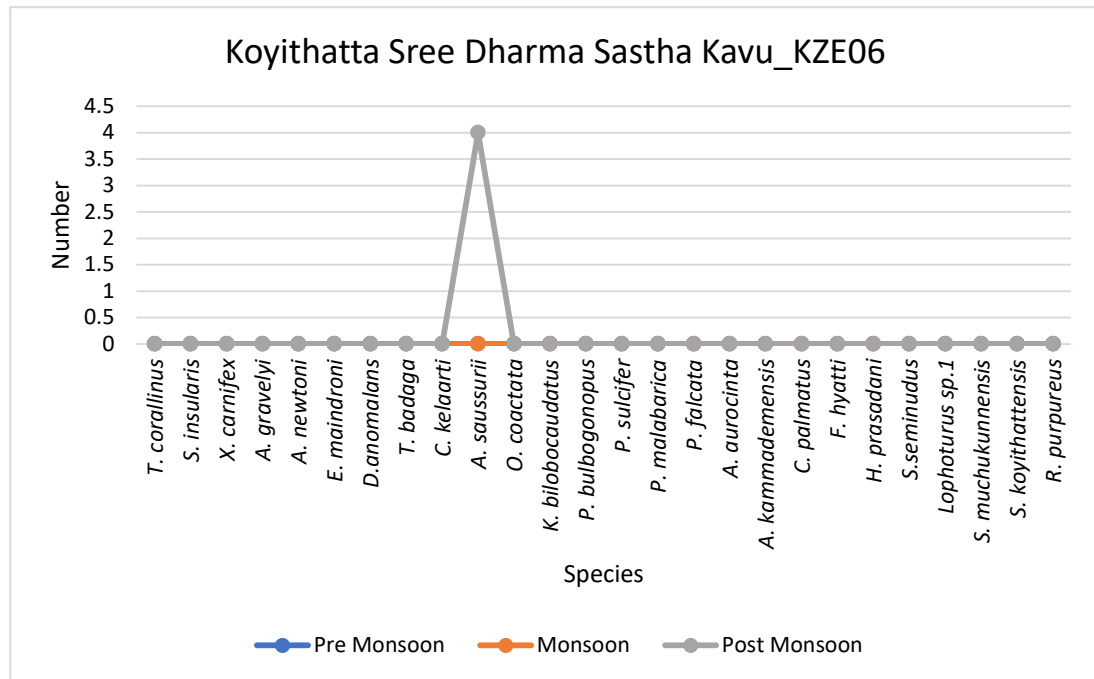


FIGURE 55. Graph showing the seasonal abundance of millipedes for the sacred grove Koyithatta Sree Dharma Sastha Kavay (KZE06) in the year 2021.

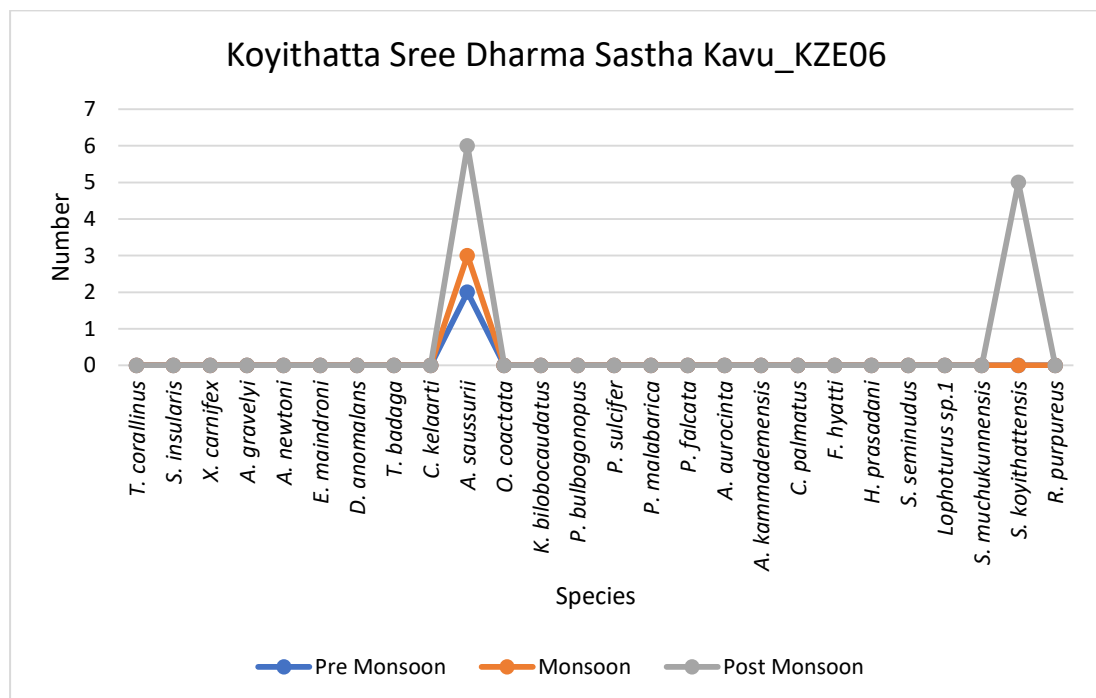


FIGURE 56. Graph showing the seasonal abundance of millipedes for the sacred grove Koyithatta Sree Dharma Sastha Kavay (KZE06) in the year 2022.

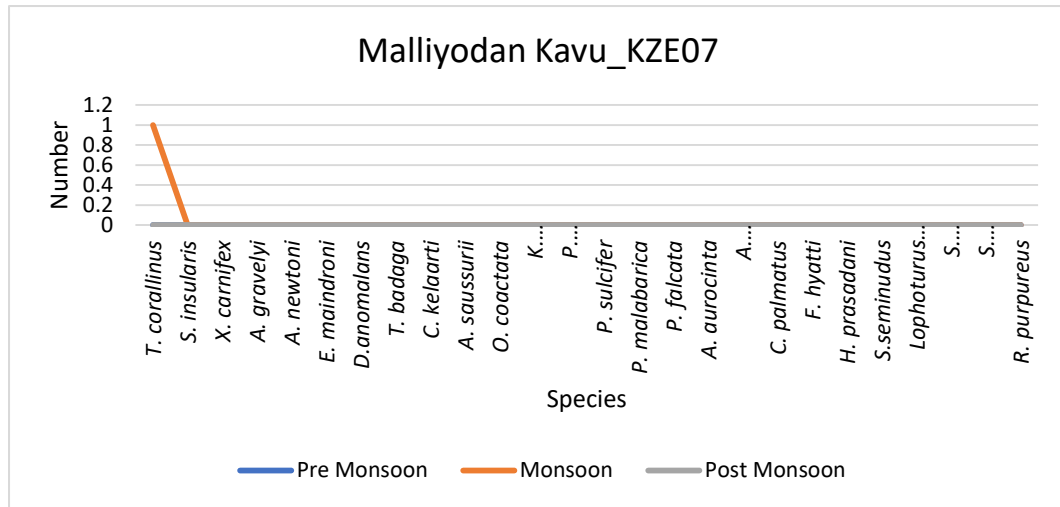


FIGURE 57. Graph showing the seasonal abundance of millipedes for the sacred grove Malliyodan Kavu (KZE07) in the year 2021.

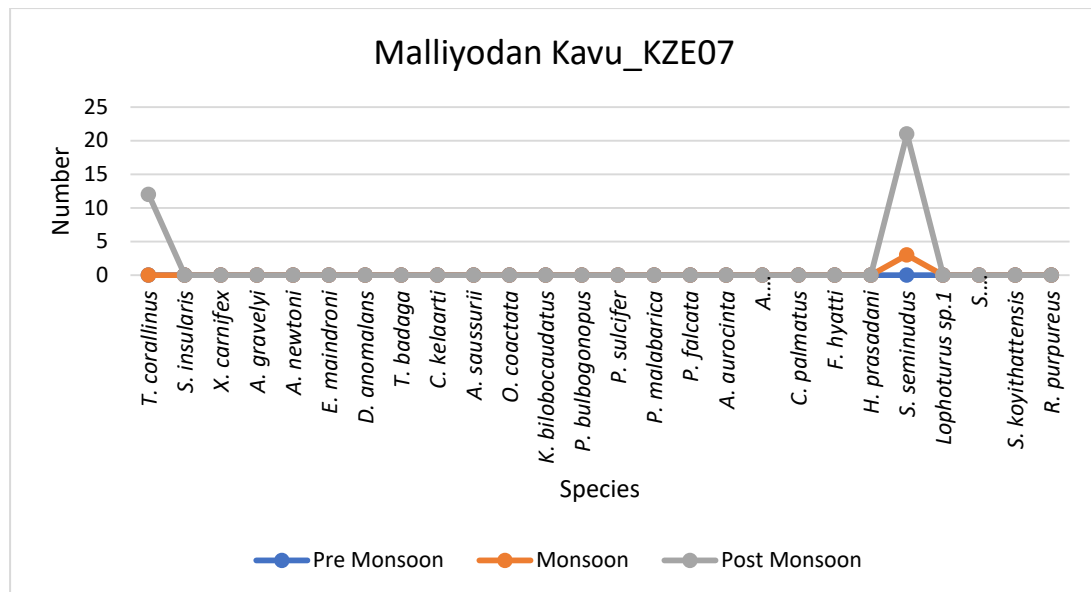


FIGURE 58. Graph showing the seasonal abundance of millipedes for the sacred grove Malliyodan Kavu (KZE07) in the year 2022.

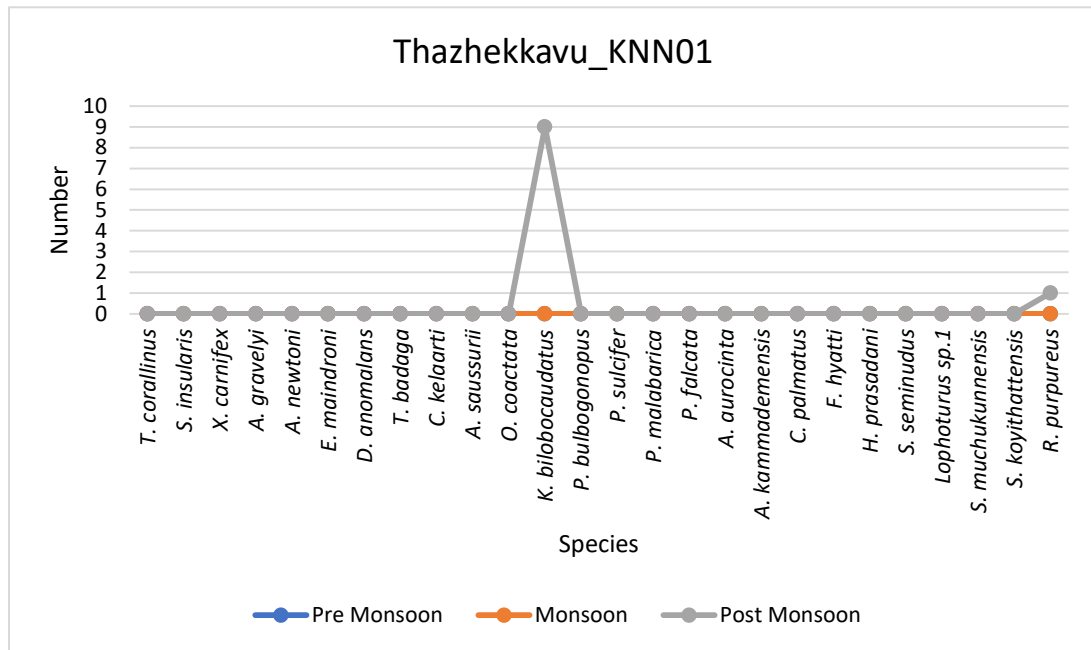


FIGURE 59. Graph showing the seasonal abundance of millipedes for the sacred grove Thazhe Kavvu (KNN01) in the year 2021.

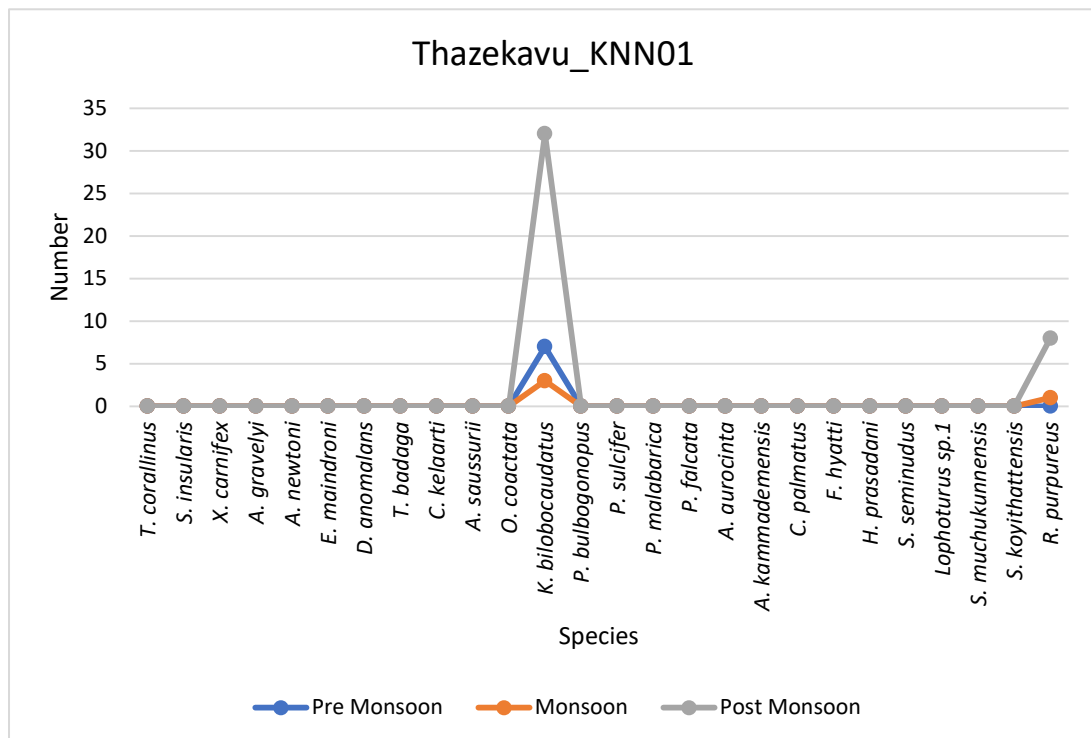


FIGURE 60. Graph showing the seasonal abundance of millipedes for the sacred grove Thazhe Kavvu (KNN01) in the year 2022.

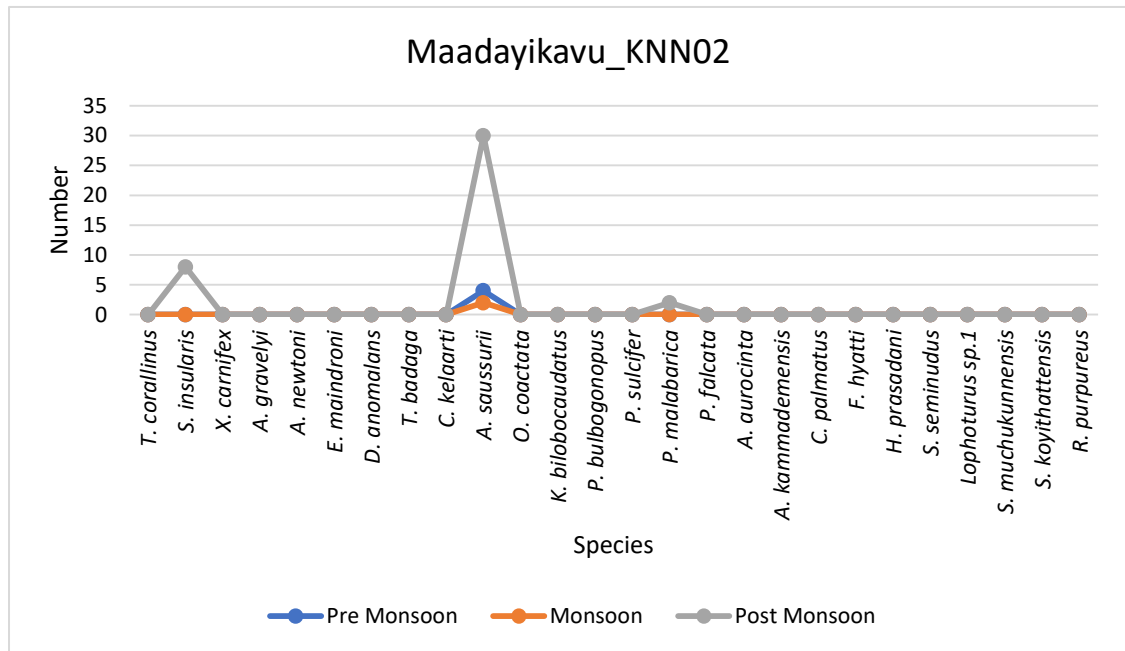


FIGURE 61. Graph showing the seasonal abundance of millipedes for the sacred grove Madayi Kavuv (KNN02) in the year 2021.

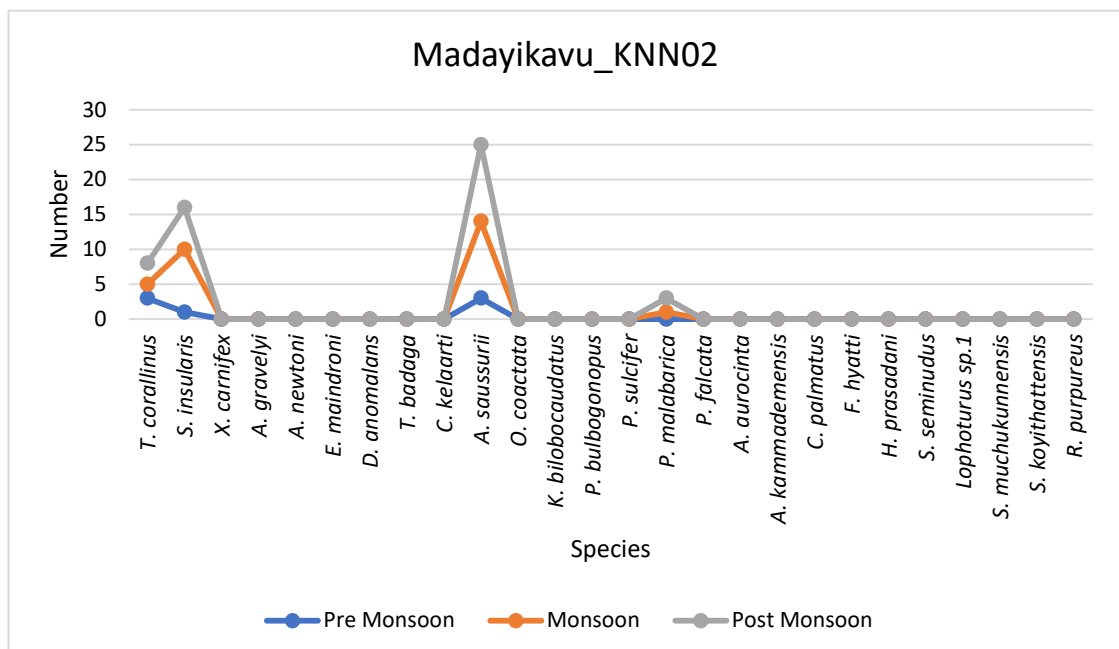


FIGURE 62. Graph showing the seasonal abundance of millipedes for the sacred grove Madayi Kavuv (KNN02) in the year 2022.

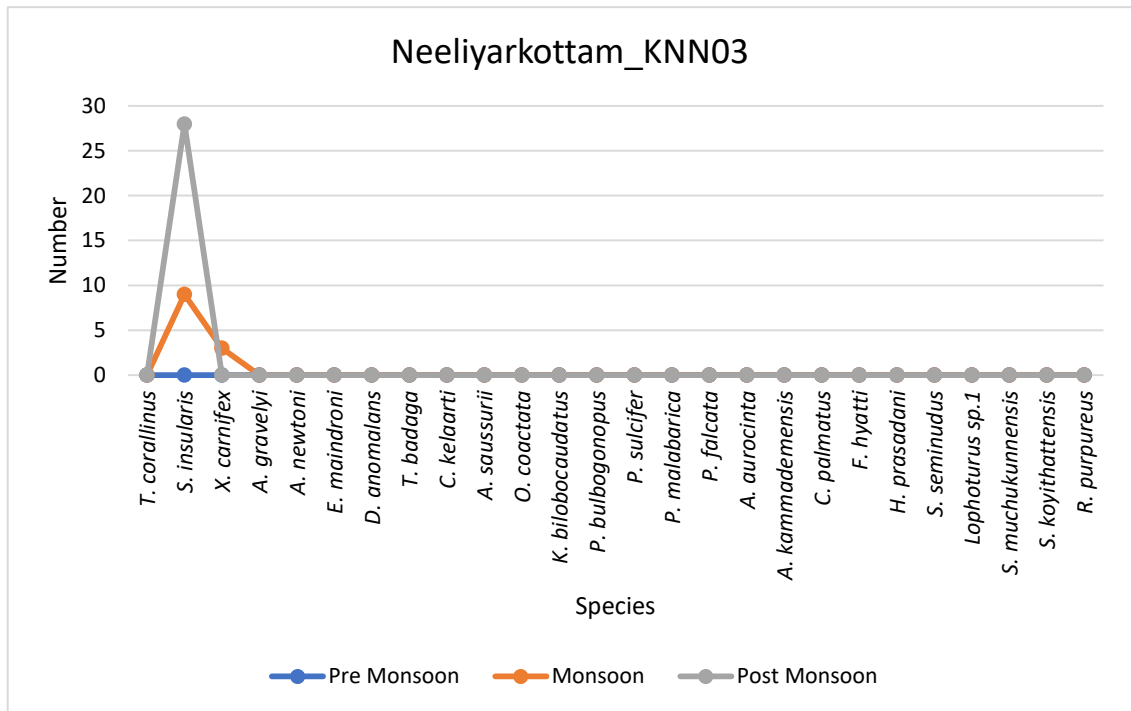


FIGURE 63. Graph showing the seasonal abundance of millipedes for the sacred grove Neeliyar Kottam (KNN03) in the year 2021.

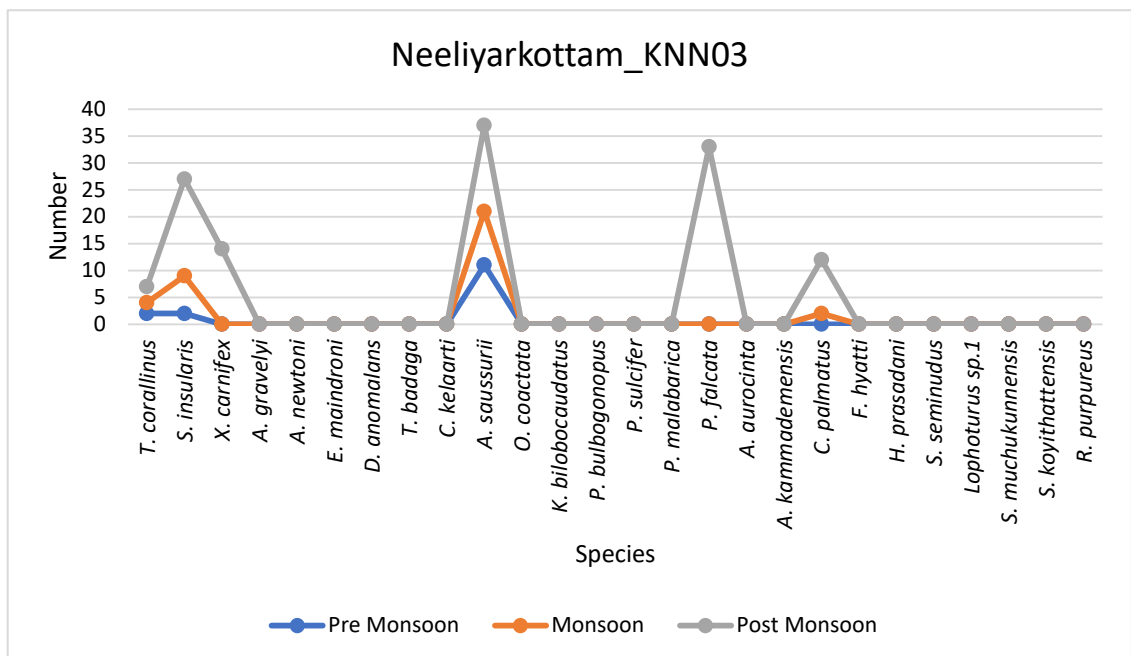


FIGURE 64. Graph showing the seasonal abundance of millipedes for the sacred grove Neeliyar Kottam (KNN03) in the year 2022.

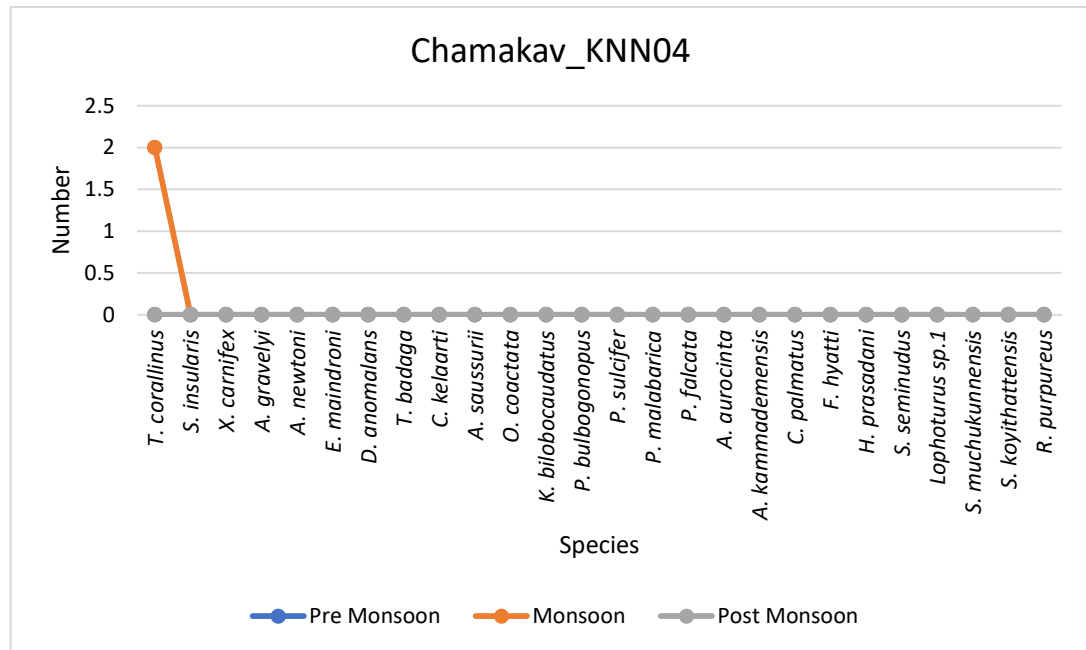


FIGURE 65. Graph showing the seasonal abundance of millipedes for the sacred grove Chamakavu (KNN04) in the year 2021.

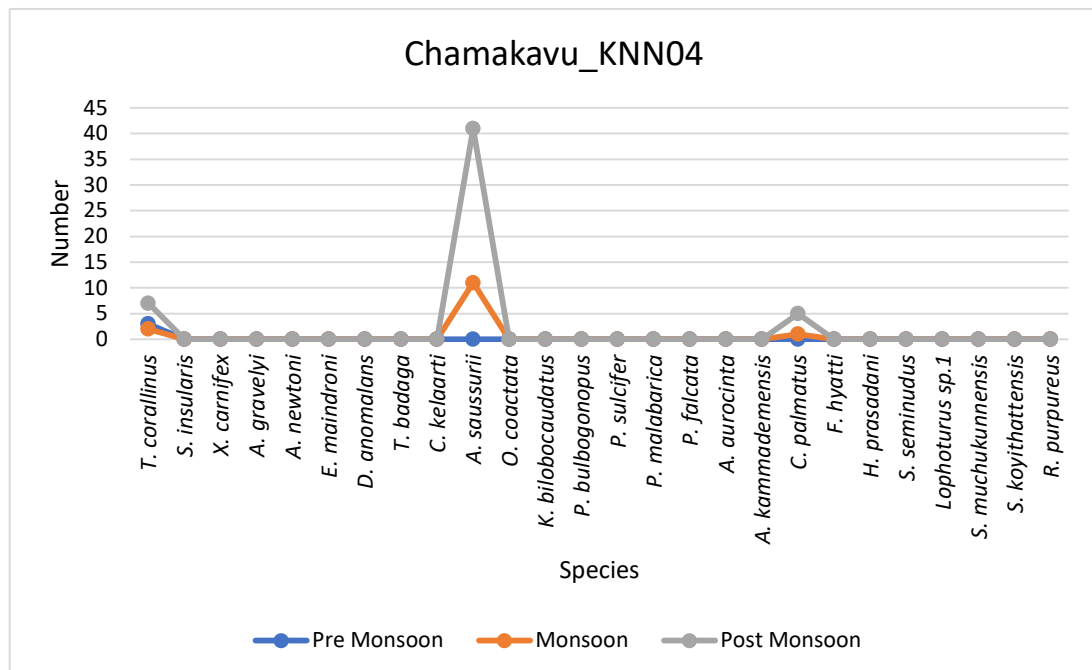


FIGURE 66. Graph showing the seasonal abundance of millipedes for the sacred grove Chamakavu (KNN04) in the year 2022.

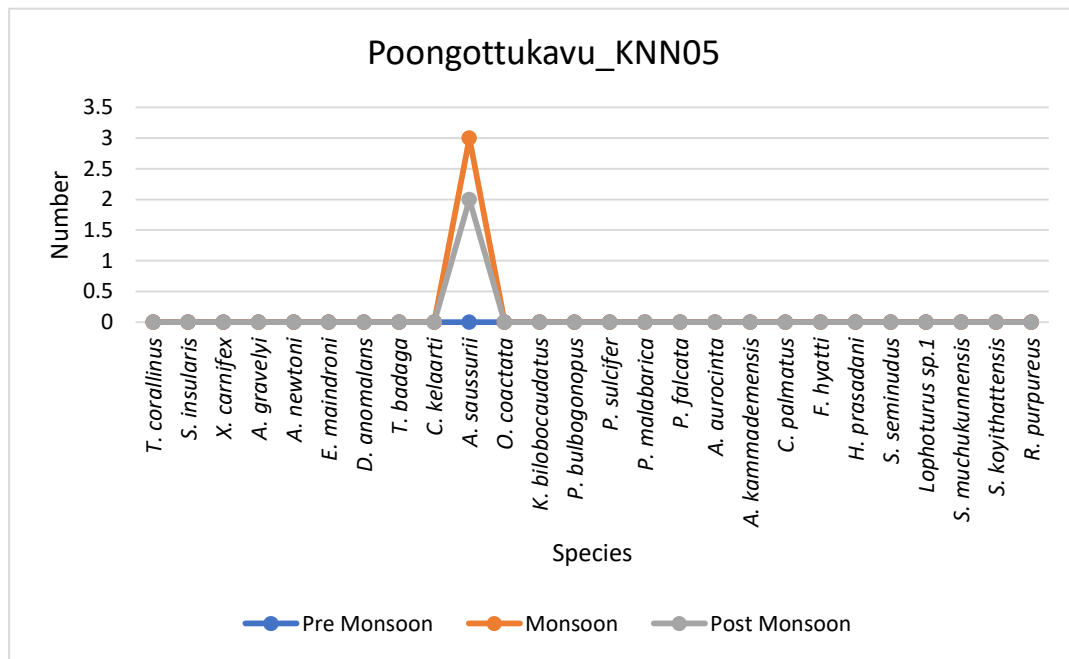


FIGURE 67. Graph showing the seasonal abundance of millipedes for the sacred grove Poongottukavu (KNN05) in the year 2021.

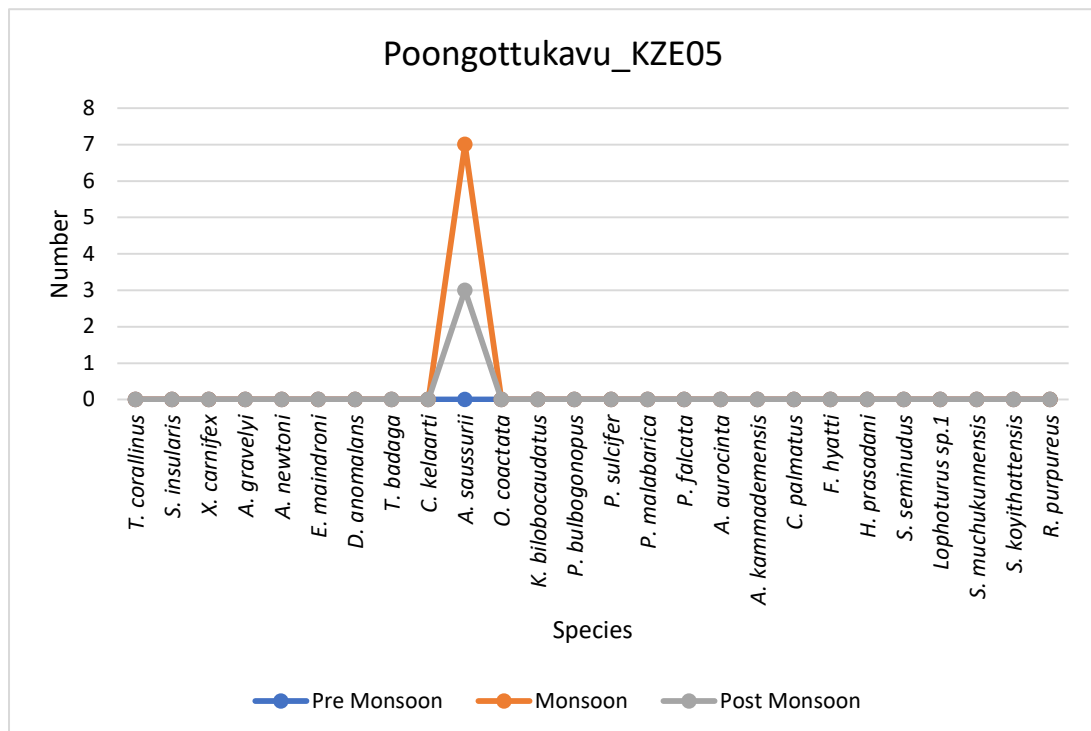


FIGURE 68. Graph showing the seasonal abundance of millipedes for the sacred grove Poongottukavu (KNN05) in the year 2022.

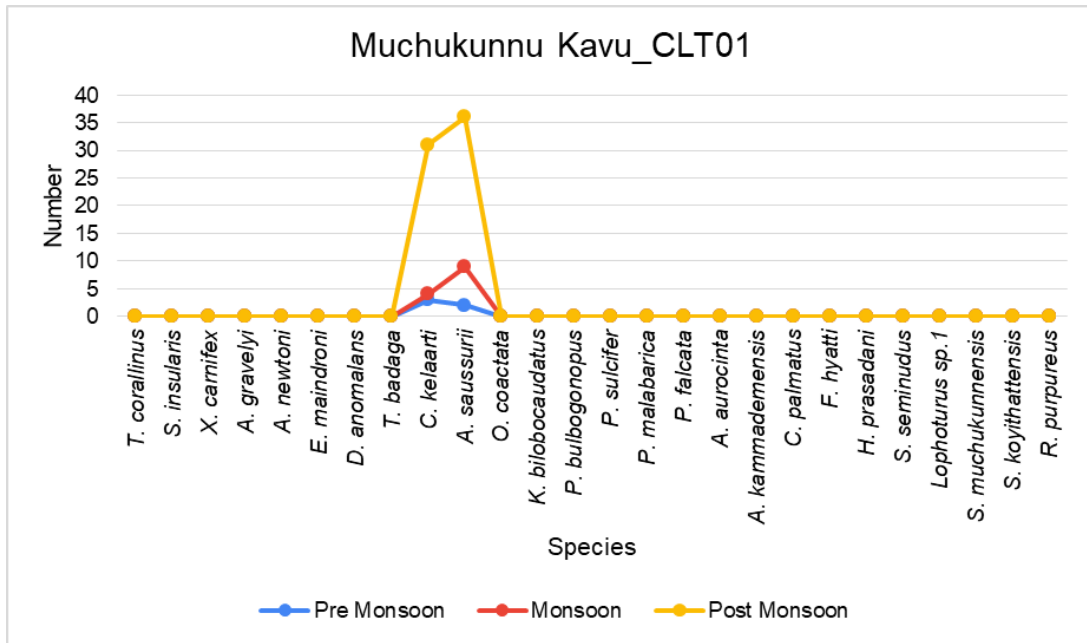


FIGURE 69. Graph showing the seasonal abundance of millipedes for the sacred grove Muchukunnu Kav (CLT01) in the year 2021.

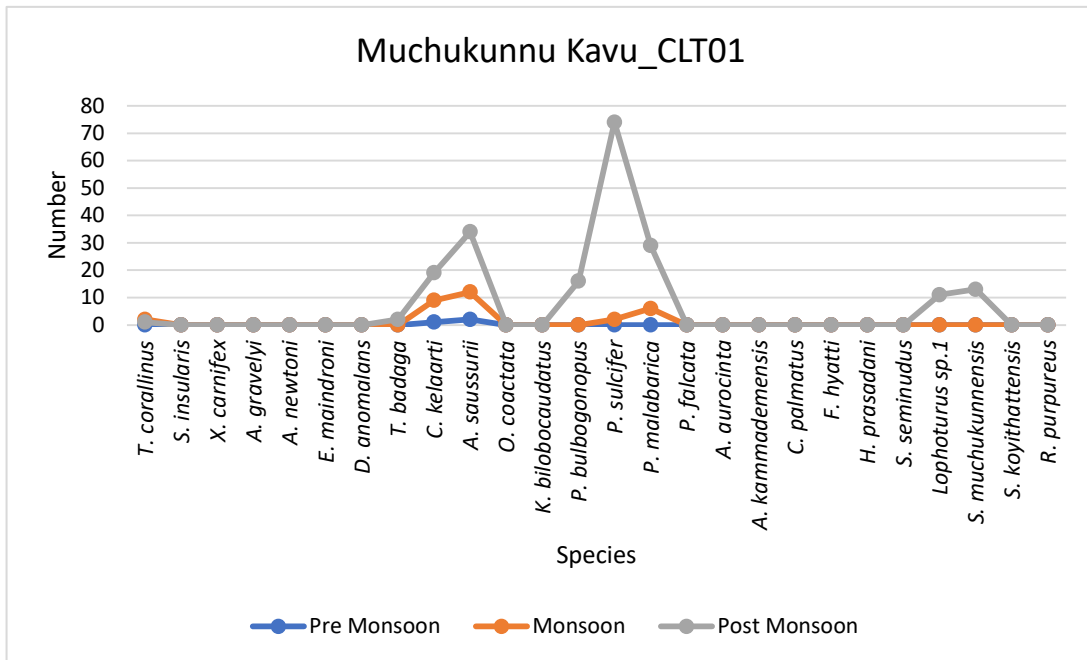


FIGURE 70. Graph showing the seasonal abundance of millipedes for the sacred grove Muchukunnu Kav (CLT01) in the year 2022

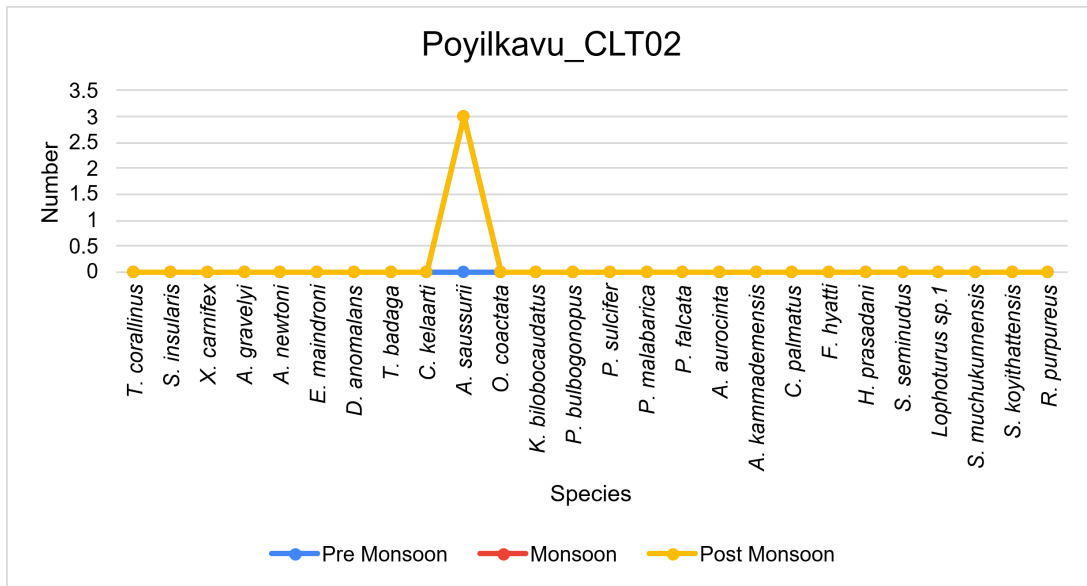


FIGURE 71. Graph showing the seasonal abundance of millipedes for the sacred grove Poyilkavu (CLT02) in the year 2021.

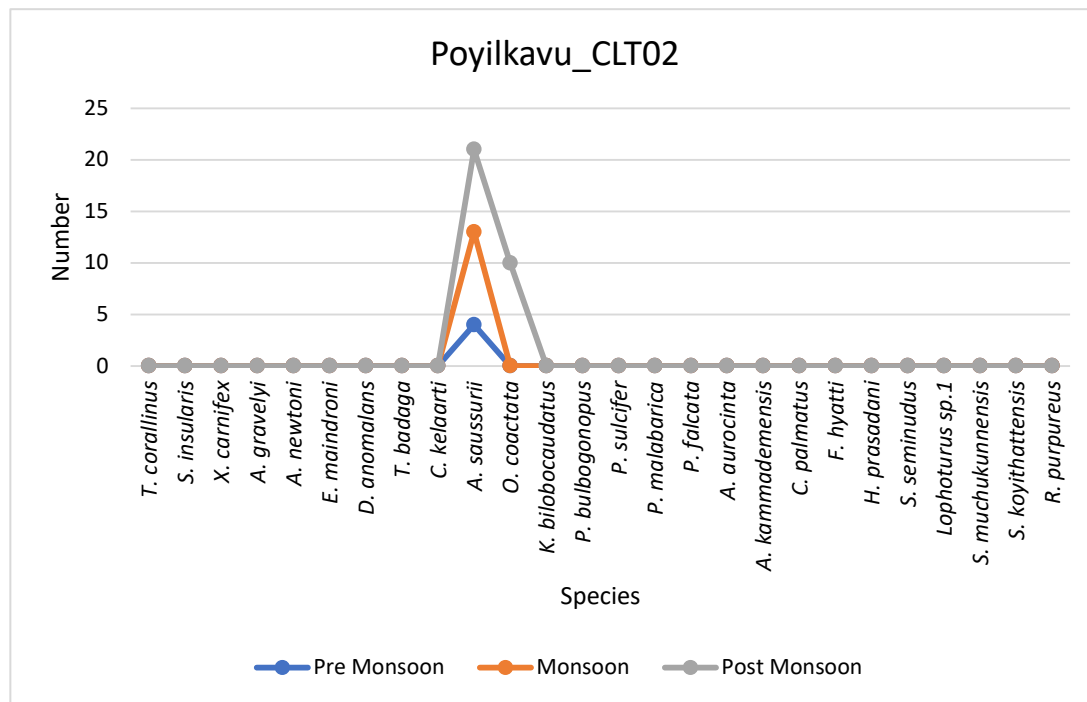


FIGURE 72. Graph showing the seasonal abundance of millipedes for the sacred grove Poyilkavu (CLT02) in the year 2022.

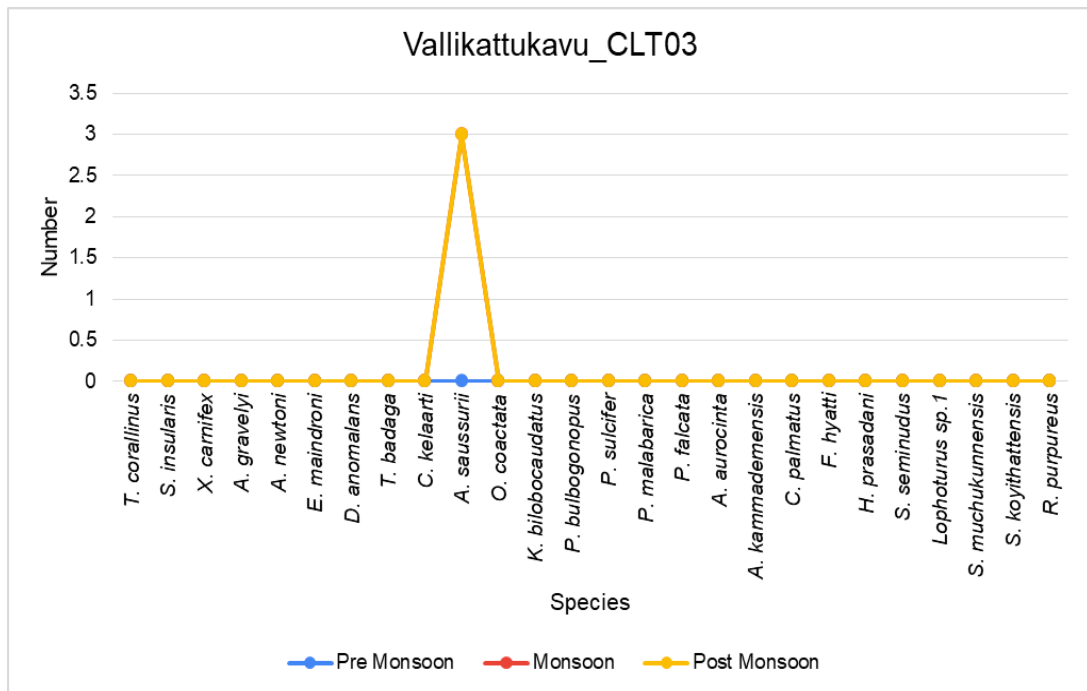


FIGURE 73. Graph showing the seasonal abundance of millipedes for the sacred grove Vallikattukavu (CLT03) in the year 2021.

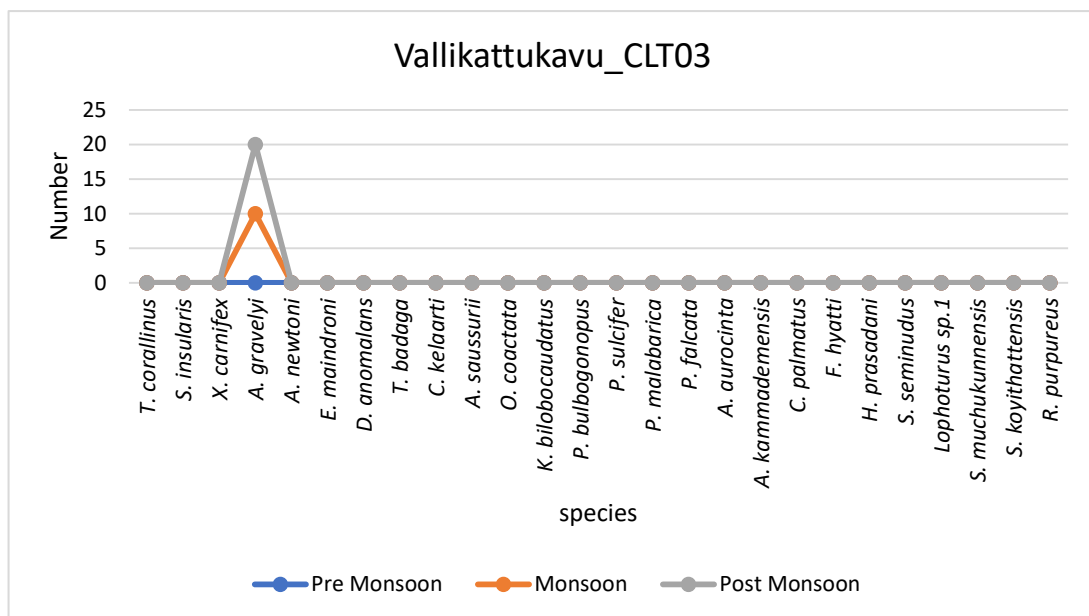


FIGURE 74. Graph showing the seasonal abundance of millipedes for the sacred grove Vallikattukavu (CLT03) in the year 2022.

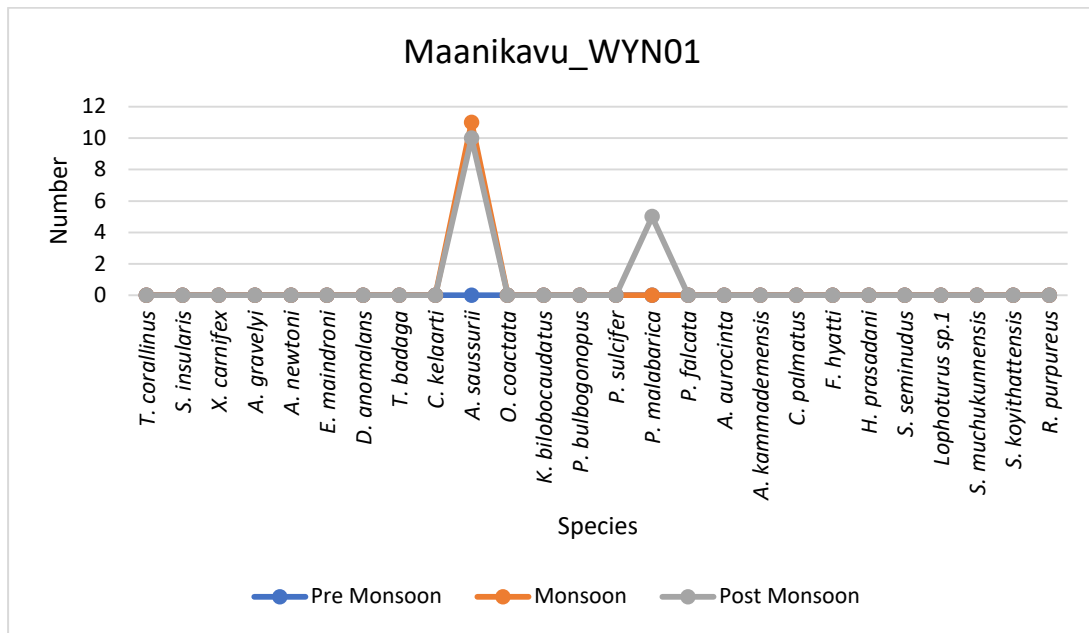


FIGURE 74. Graph showing the seasonal abundance of millipedes for the sacred grove Maanikavu (WYN01) in the year 2021.

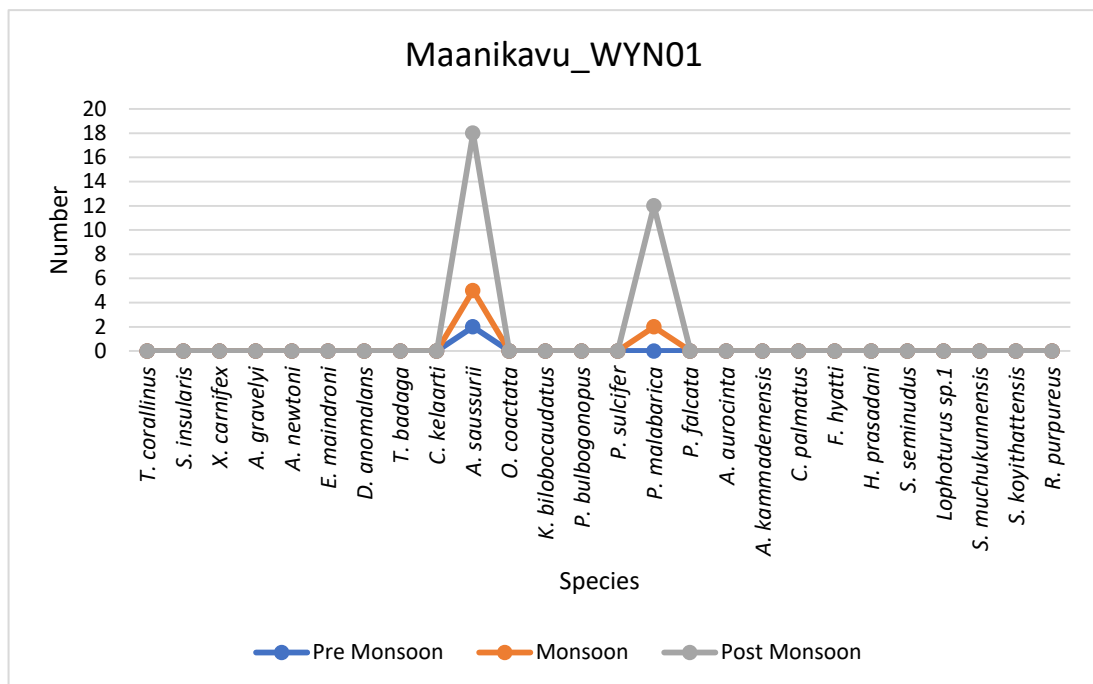


FIGURE 76. Graph showing the seasonal abundance of millipedes for the sacred grove Maanikavu (WYN01) in the year 2021.

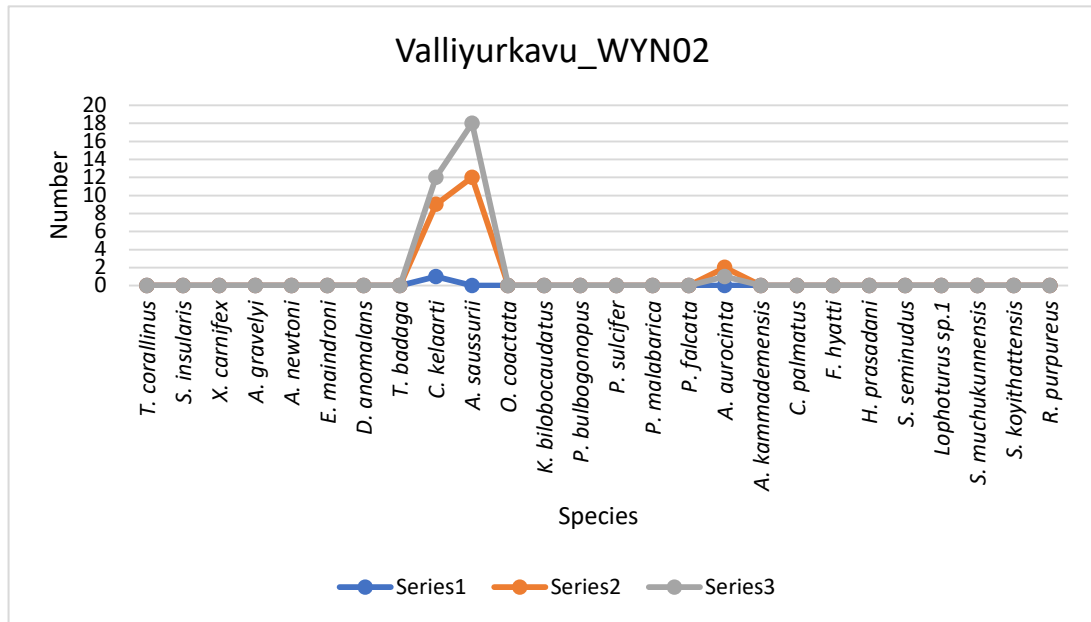


FIGURE 77. Graph showing the seasonal abundance of millipedes for the sacred grove Valliyurkavu (WYN02) in the year 2021.

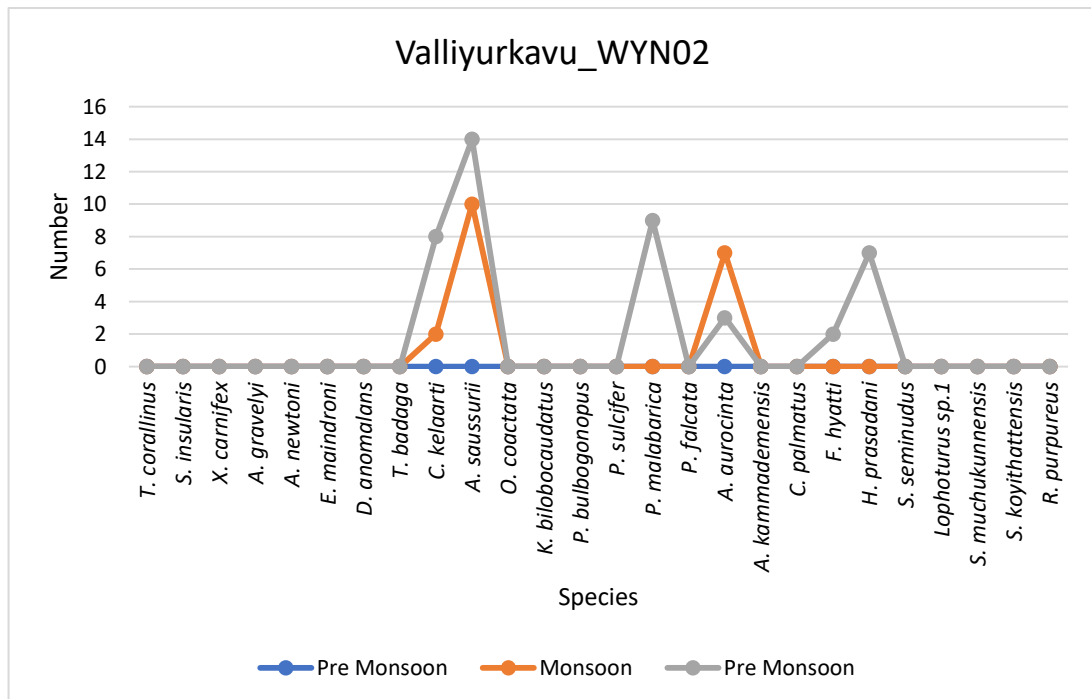


FIGURE 78. Graph showing the seasonal abundance of millipedes for the sacred grove Valliyurkavu (WYN02) in the year 2022.

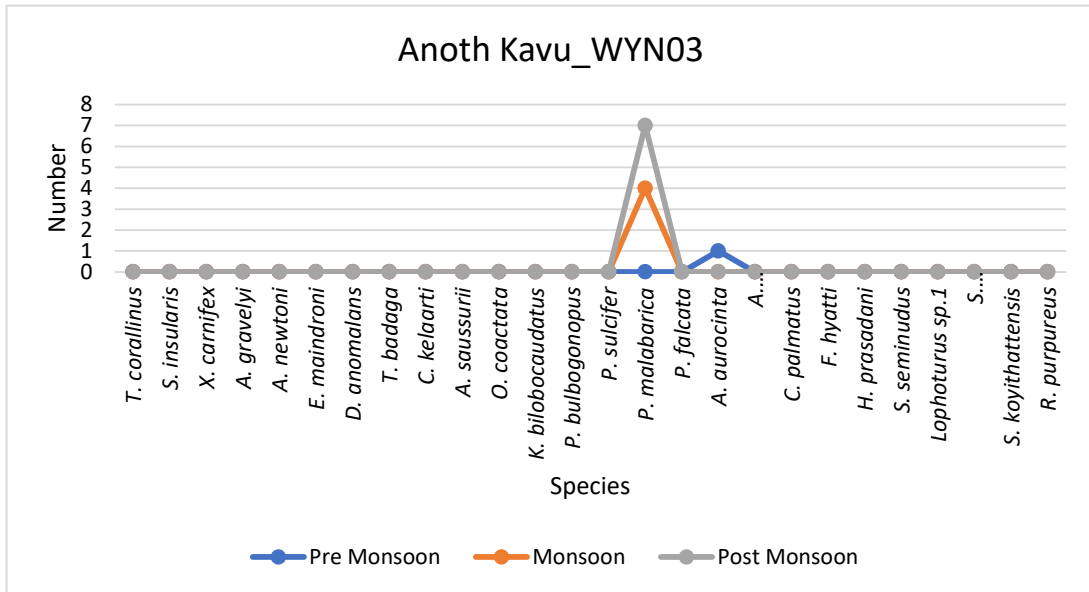


FIGURE 79. Graph showing the seasonal abundance of millipedes for the sacred grove Anoth Kau (WYN03) in the year 2021.

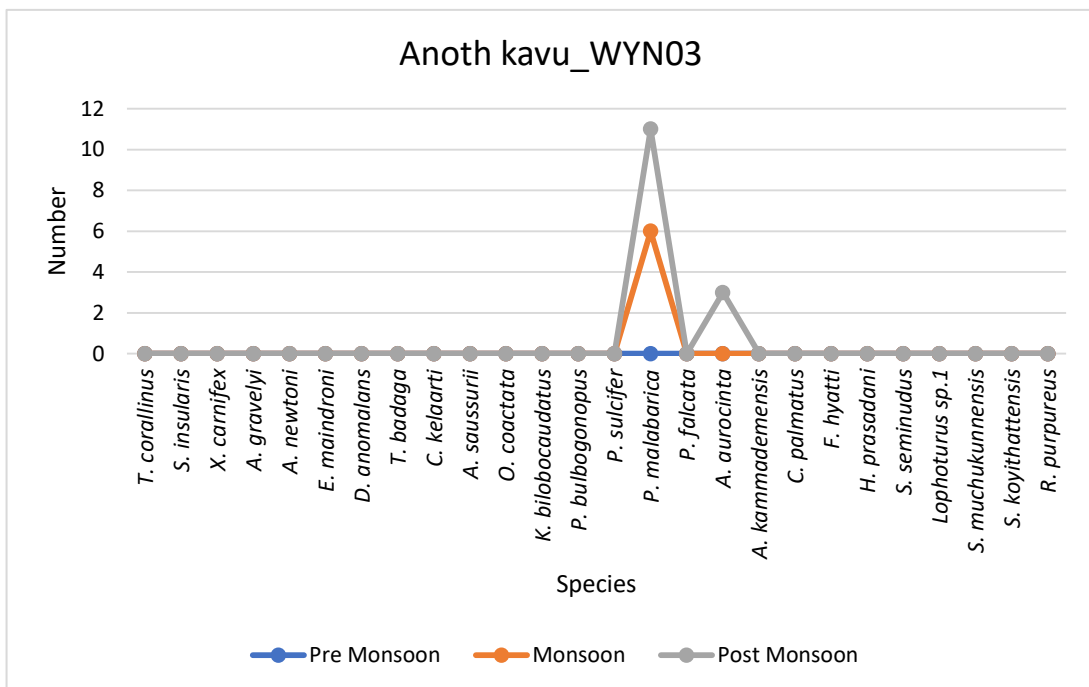


FIGURE 80. Graph showing the seasonal abundance of millipedes for the sacred grove Anoth Kau (WYN03) in the year 2022.

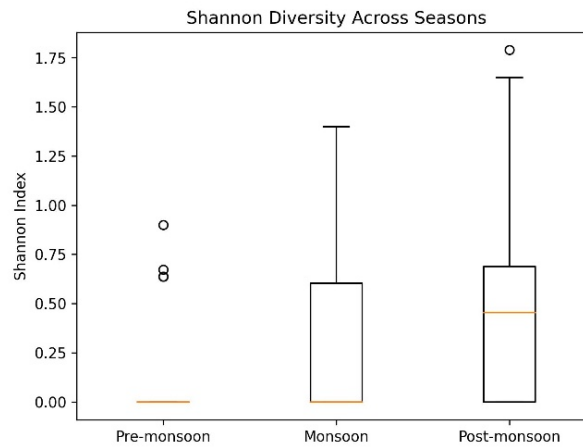


FIGURE 81. Seasonal variation in Shannon diversity (H') of millipede assemblages across study sites

Shannon–Wiener diversity index (H') calculated for each site across pre-monsoon, monsoon, and post-monsoon seasons (site $\times$ year replicates). Boxplots represent median, interquartile range, and variability among sampling units.

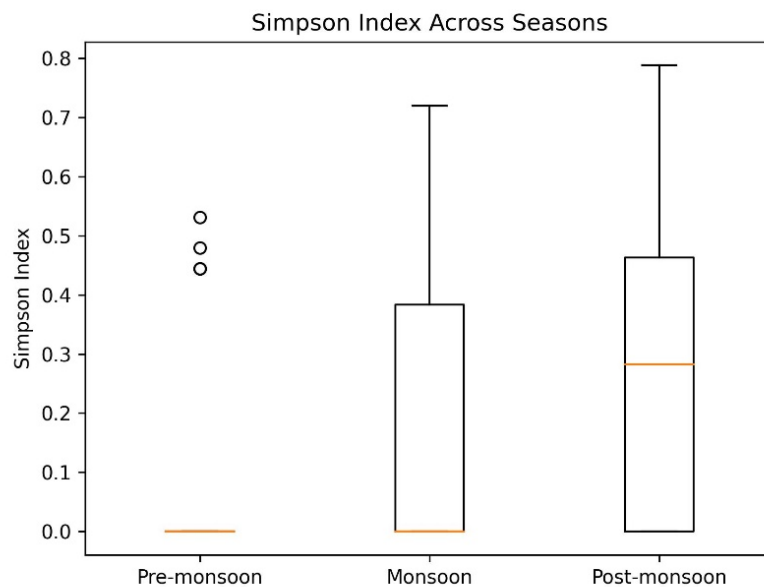


FIGURE 82. Seasonal variation in Simpson diversity index ($1-D$) of millipede communities

Simpson index ($1-D$) indicating diversity and dominance patterns across seasons. Higher values represent greater diversity and reduced dominance.

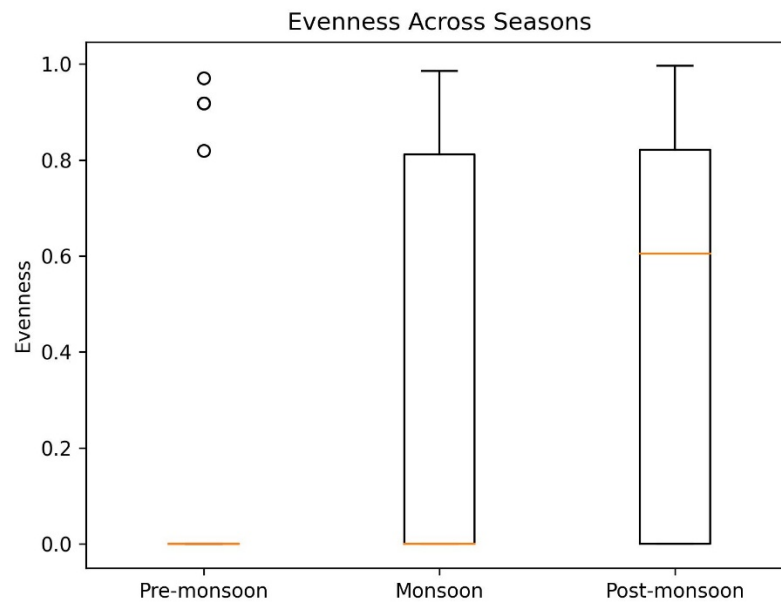


FIGURE 83. Seasonal variation in Pielou's evenness (J') of millipede assemblages. Evenness (J') reflects the distribution of individuals among species, with values closer to 1 indicating a more uniform community structure.

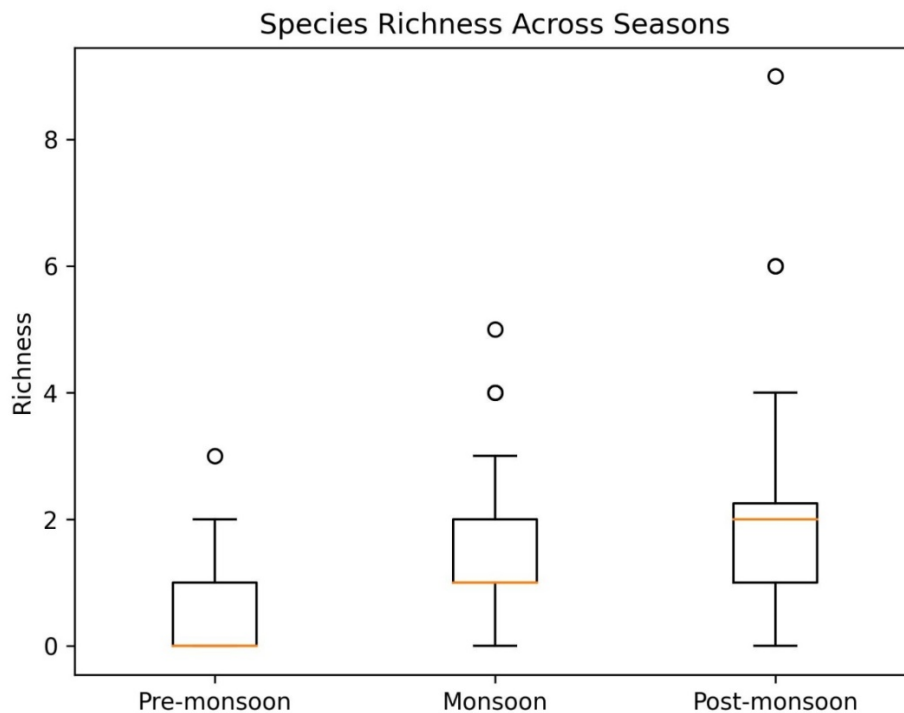


FIGURE 84. Seasonal variation in species richness of millipedes across study sites. Species richness represents the total number of species recorded per site-year-season combination.

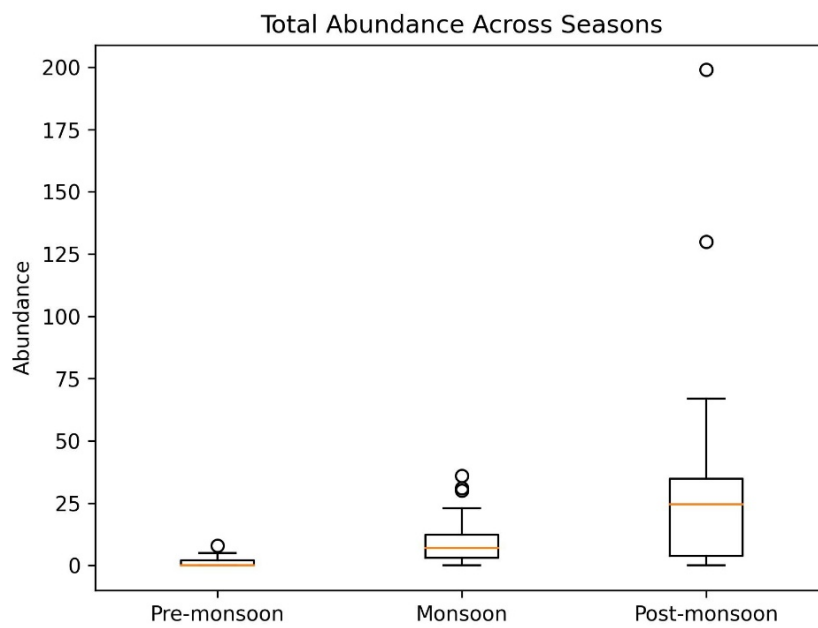


FIGURE 85. Seasonal variation in total abundance of millipedes across study sites
Total abundance represents the number of individuals recorded per sampling unit (site
× year × season).

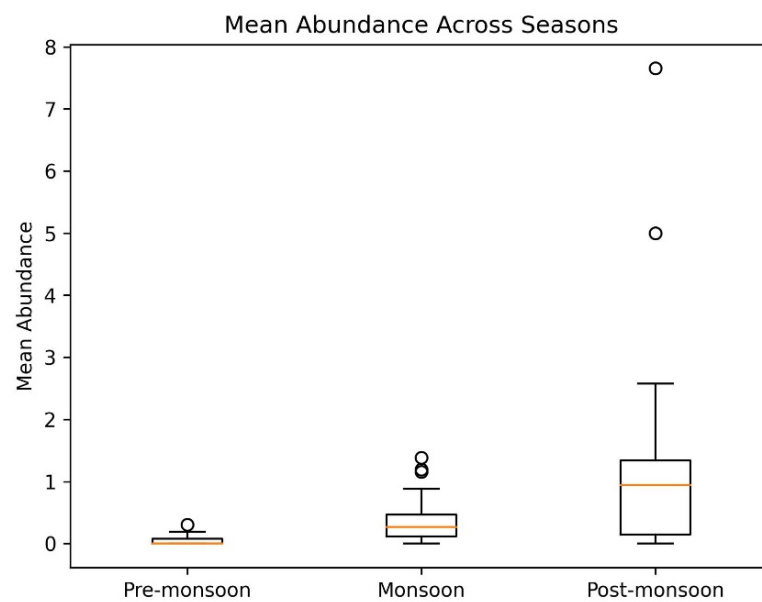


FIGURE 86. Seasonal variation in mean abundance per species of millipedes
Mean abundance calculated as the average number of individuals per species within
each sampling unit.

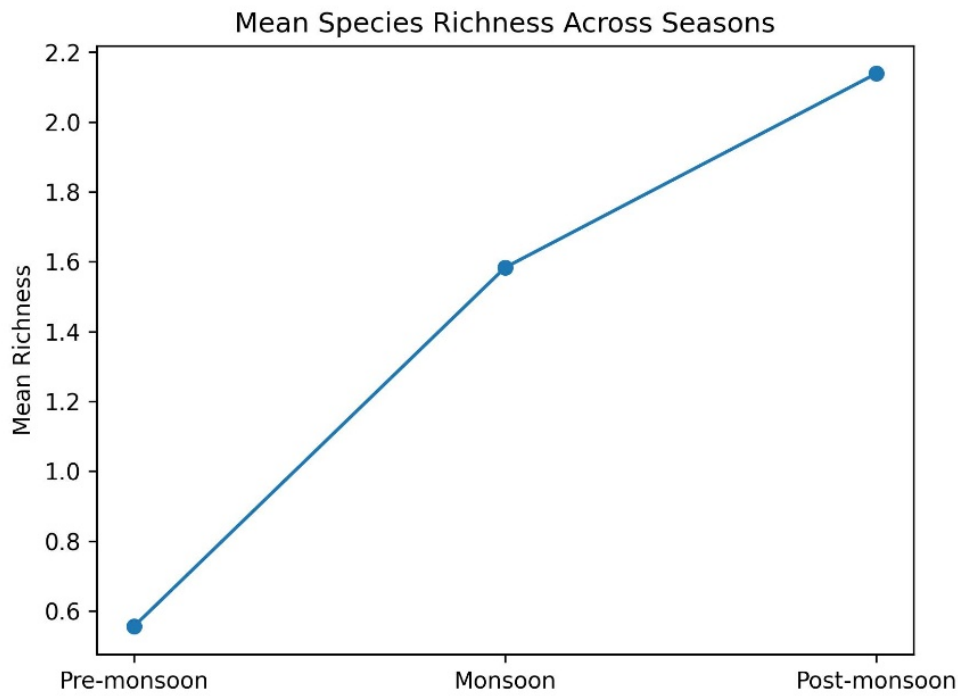


FIGURE 87. Seasonal trend in mean species richness of millipedes

Line plot showing average species richness across seasons. Points represent mean values, and the line indicates seasonal trends.

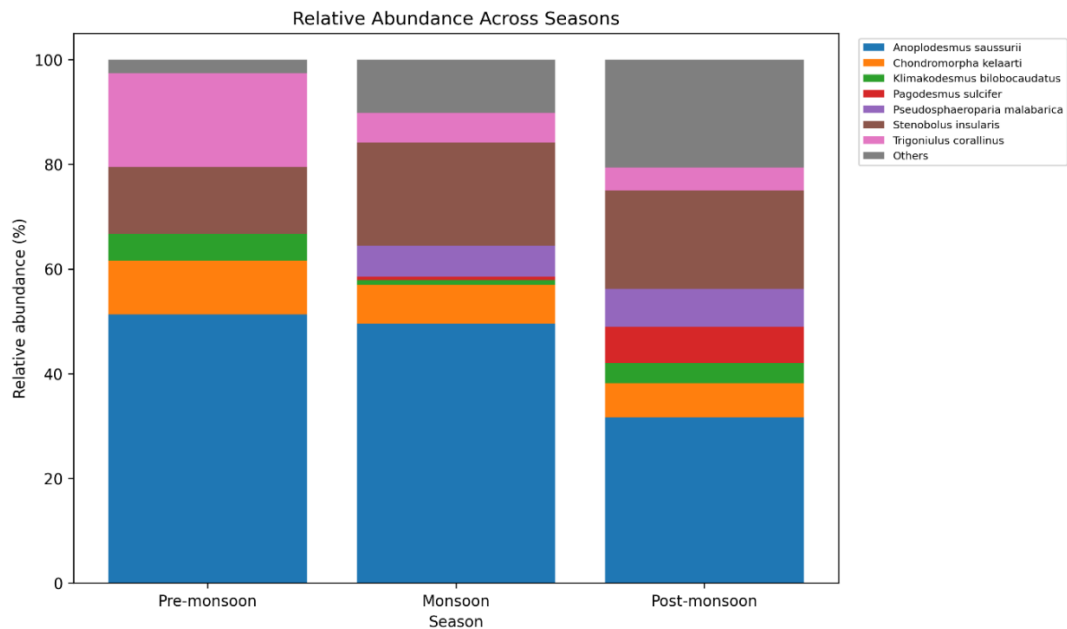


FIGURE 88. Relative abundance (%) of millipede species across seasons

Stacked bar plot showing proportional contribution of species to total abundance across seasons. Rare species are grouped as "Others" for clarity.

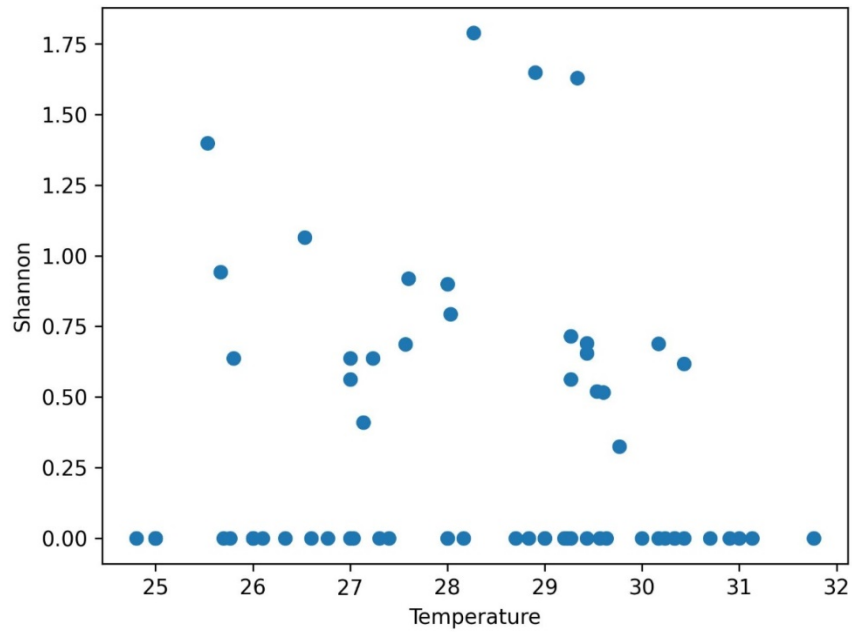


FIGURE 89. Relationship between temperature and Shannon diversity of millipedes
Scatter plot showing the relationship between temperature (°C) and Shannon diversity (H'). Each point represents a site–year–season observation.

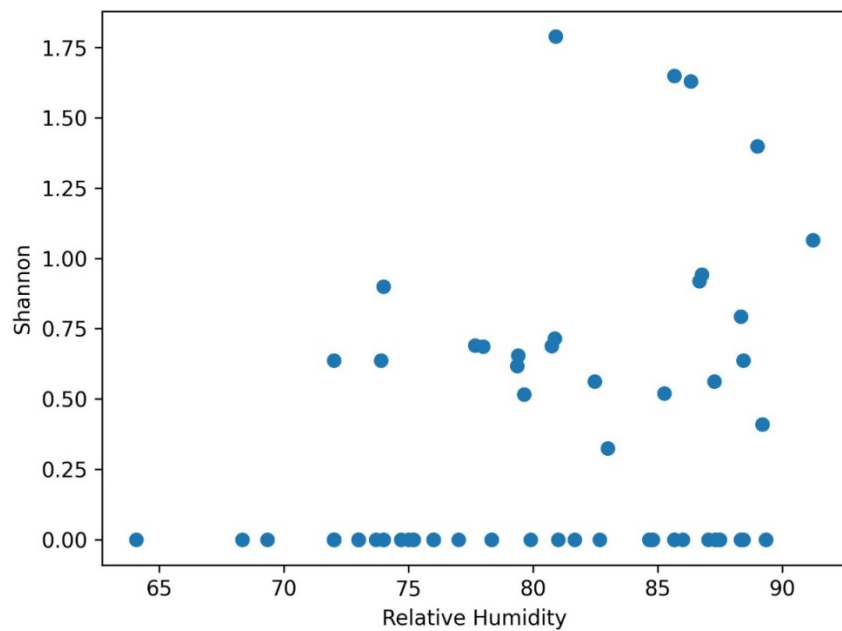
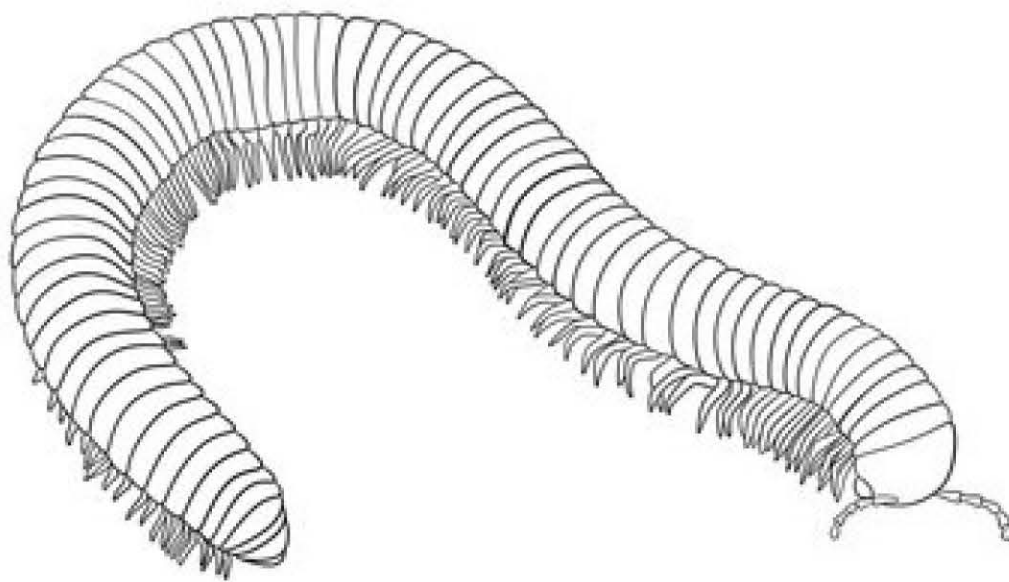


FIGURE 90. Relationship between relative humidity and Shannon diversity of millipedes

Scatter plot showing the relationship between relative humidity (%) and Shannon diversity (H'). A positive trend indicates the influence of moisture on diversity.



PUBLICATION

The millipede genus *Klimakodesmus* Carl, 1932, with the description of a new species from Kerala state, southern India (Diplopoda, Polydesmida, Pyrgodesmidae)

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Abstract

Klimakodesmus Carl, 1932 is briefly redescribed, rediagnosed, and shown to be an oligotypic genus endemic to southern India and distinct from the particularly similar genus *Pyrgodesmus* Pocock, 1892, monobasic and endemic to Sri Lanka, by several important features of peripheral and, especially, gonopodal structure. A new species, *Klimakodesmus bilobocaudatus* sp. nov., is described from Kerala state, India, differing from the sole accepted, and type species *K. gravelyi* Carl, 1932, from Tamil Nadu state, primarily by the laterally trilobate paraterga, the caudally more deeply bilobate mid-dorsal keel on ring 19, and certain minor details of the gonopodal structure.

Key words: *Klimakodesmus*, *Pyrgodesmus*, taxonomy, new species, India, Sri Lanka

Introduction

At present, the millipede fauna of India, however insufficiently studied, comprises 270+ nominate species or subspecies in at least 90 genera, 25 families and 11 orders (Golovatch & Wesener 2016). Of them, the large and mostly tropical family Pyrgodesmidae contains some 14 species in seven genera, including *Klimakodesmus* Carl, 1932.

The taxonomy of Pyrgodesmidae is long known to be particularly badly confused and chaotic globally, with more than 170 genera, largely monotypic, and nearly 400 species all over the tropics, marginally in Southern Europe, North Africa, southern U.S.A., Japan, Taiwan and central China (Enghoff *et al.* 2015). Progress is strongly hampered by the small size of the animals (typically 3–16 mm long), as well as the outstandingly diverse and often complex structures, both peripheral and gonopodal, which are often difficult to see, let alone describe and depict. Numerous pyrgodesmid genera remain monotypic, often based only on female or even juvenile material, and delimited using solely such somatic features as the number of body segments/rings, the shape, distribution and location of ozopores and tergal ornamentations, the structure of the paraterga etc.

Klimakodesmus was originally described based on a single, and type species, *K. gravelyi* Carl, 1932, originating from near Coonoor and Mudumalai, both in Tamil Nadu state, Western Ghats, southern India (Carl 1932). Verhoeff (1939) promoted *Klimakodesmus* to the rank of a monobasic subfamily, Klimakodesminae Verhoeff, 1939, but presently it is considered as a strict junior subjective synonym of Pyrgodesmidae (Hoffman 1980; https://www.fieldmuseum.org/sites/default/files/taxon_table_5.pdf).

Carl (1932), when erecting his *Klimakodesmus*, compared it to *Pyrgodesmus* Pocock, 1892, the type genus of Pyrgodesmidae and also monobasic (Pocock 1892), because both genera shared numerous somatic features. He paid special attention to the identity of *Pyrgodesmus obscurus* Pocock, 1892, the type species of *Pyrgodesmus*, described from two male syntypes from Pundaluoya, Sri Lanka. Carl (1932) compared the original, rather superficial description and few schematic drawings of *P. obscurus* as given by Pocock (1892) to the excellent and richly illustrated

redescription of that species as presented by Silvestri (1920), based on a male syntype from Pundaluoya and two additional males from Paradenyia, Sri Lanka. Carl noted differences between both descriptions in tergal ornamentation, antennae, leg thickness, and gonopodal conformation. In particular, the gonopods of *P. obscurus* were verbally described as showing unusually hypertrophied coxites and blade-like telopodites (Pocock 1892), vs. moderately enlarged and squarish coxites with strongly curved and ribbon-shaped telopodites as depicted by Silvestri (1920). As a result, Carl (1932) considered Silvestri's (1920) record and most detailed redescription of *P. obscurus* as a misidentification, suggesting to give it a new name different from *P. obscurus*, and emphasizing that neither species belonged to *Klimakodesmus*. He also expressed the need for a new revision of the *P. obscurus* syntypes, both presumably kept in the London Museum (Pocock 1892).

On the other hand, according to Silvestri (1920), the tegument of at least some of the *Pyrgodesmus obscurus* samples he studied was so heavily coated with earth that only after it had been thoroughly cleansed did it show the necessary details of the underlying, real tergal structure and sculpture. Moreover, both bodies, one coated with earth and the other clean, were very beautifully and artistically illustrated, albeit neither was properly labeled as to its provenance! So we can only adhere to Carl's (1932) appeal to revise at least one of the male syntypes of *P. obscurus*, since the task is to simply check the gonopodal structure and to compare it to Silvestri's (1920) account and illustrations. Only this could finally reveal the species' identity.

It was Attems (1940) who took action following Carl's (1932) investigation and suggestions. He proposed *Klimakodesmus permutatus* Attems, 1940 as a replacement name for *Pyrgodesmus obscurus* in the sense of Silvestri (1920), but, contrary to Carl's opinion, he assigned it to *Klimakodesmus*. It is since then that formally the genus *Klimakodesmus* has hitherto contained two species: *K. gravelyi* Carl, 1932, from southern India (Golovatch & Wesener 2016), and *K. permutatus* Attems, 1940, from Sri Lanka (De Zoysa *et al.* 2016). Moreover, strangely enough, Attems (1940: 271) retypified *Klimakodesmus* through selecting *K. permutatus* Attems, 1940 as the type species, a completely invalid action (Jeekel 1971).

The present paper puts on record a second, new species of *Klimakodesmus*, also clarifying the similarities to and differences from *Pyrgodesmus*. We follow Carl (1932) in treating both these genera as distinct and, pending a revision of *P. obscurus*, we remove *K. permutatus* from the scope of *Klimakodesmus* (see the reasons in Carl (1932) and below).

Materials and methods

The material underlying the present contribution was hand-collected in a sacred grove of Kannur district, Kerala, India. The local name of the grove is Thekkumbadu Koolom—Thazhekkavu, located on an inland island bordered by thick mangroves. The samples were collected in January 2021 (winter season) and preserved in absolute ethanol. The holotype and most of the paratypes are deposited in the collection of the Centre for Animal Taxonomy and Ecology, Christ College, Irinjalakuda, Kerala, India (CATE), with the holotype ID=CATE-5302, and paratypes ID=CATE-5302B–CATE-5302I. A few paratypes have been lent for further studies to the Zoological Museum, State University of Moscow (ZMUM), Russia, as indicated below.

Photographs in the field were taken with a Canon EOS 5D Mark-III camera using a Canon EF 100 mm f/2.8 Macro USM Lens and a Canon MT-24EX Macro Twin Lite Flash. Multifocal photographs of specimens were taken in the lab with a Leica DMC4500 digital camera mounted on a Leica M205 C stereo microscope. Photographs were stacked, and the measurements (in mm) taken, using Leica Application Suite (LAS) version 4.3.0 software. The final images were processed with Adobe Photoshop CC software. The map was executed using both Google Earth and Simple Mappr software.

In the following morphological accounts, we use Hoffman's (1976) formula for describing the most typical ornamentation pattern of the metaterga in Pyrgodesmidae, in which:

PM stands for paramedian,

DL for dorsolateral tubercles/lobes,

i for intercalary series of grains,

Am for anteromarginal,

Cm for caudomarginal lobulations.

Taxonomic part

Order Polydesmida Latreille, 1802/03

Family Pyrgodesmidae Silvestri, 1896

Genus *Klimakodesmus* Carl, 1932

Type-species: *Klimakodesmus gravelyi* Carl, 1932, by monotypy.

Other species included: *Klimakodesmus bilobocaudatus* **sp. nov.**

Brief description. This genus shows a body shape and an ornamentation pattern typical of Pyrgodesmidae, characterized by 20 segments/rings (19+T) both in the male and female; a flabellate collum is strongly domed and tuberculate, completely covering the head from above, with 5+5 distinct, equal, clearly incised and rounded lobulations at a subhorizontal anterior margin; the antennae are short, two basal antennomeres of each antenna being sunken inside a distinct transverse groove, and antennomere 5 being much longer and thicker than the 6th; a cerotegument crust with microvilli covers most of the dorsal surface of the collum and following metaterga, the limbus being microlobulate and microspiculate caudally; body rings are strongly arched dorsally, each with 2+2 longitudinal rows of basically 2+2 or 3+3 larger and fused tubercles/lobes (paramedian, PM, and dorsolateral, DL), both rows largely representing higher bilobed keels mostly slightly inclined either forward or caudad, but PM always being higher than DL. PM of only ring 19 is abruptly and unusually strongly elongate and more or less clearly bilobate caudally, conspicuously overhanging and concealing a short epiproct from above (Figs 2–4, 8–10). Neither intercalary (i) series of grains nor antero- (Am), nor truly caudomarginal lobulations (Cm) are distinguished. The pore formula is normal: ozopores 5, 7, 9, 10, 12, 13, 15 and 16 are borne on distinct porosteles, vs. 17, 18 and 19 which open flush on the surface. The paraterga are set low (at about half the height of midbody metazonae), slightly declivous to subhorizontal, leaving the dorsum very convex, moderately bi- or trilobate laterally regardless of a cylindrical porostele or ozopore located just before or upon the ultimate lobulation, respectively. The legs are short and stout, rather sparsely setose, the prefemur bearing a particularly strong seta distomesally, the tibia a distodorsal one.

The gonopods are fairly simple, *in situ* either slightly diverging or distally crossing each other; each coxite is moderately enlarged, hemispherical or squarish, microgranulate and microsetose laterally, and concave medially, the gonocoel thus being moderately deep; the cannula is as usual, simple, moderately long and strongly unciform. The telopodite is simple, slender, unipartite, represented by a very strong, moderately long, but mostly exposed, gradually attenuating and acuminate solenomere.

Diagnosis. *Klimakodesmus* seems to be particularly similar to *Pyrgodesmus* in most somatic characters, as correctly noted by Carl (1932), but both genera are distinct primarily in gonopodal structure: clearly hypertrophied gonocoxites and “blade-like” telopodites (Pocock 1892) vs. moderately incrassate, apparently smaller, subspherical or squarish gonocoxites, each of which supports a strong and unipartite telopodite represented solely by a slender, strongly exposed, increasingly attenuating and acuminate solenomere. In addition, PM crests, including the one on the penultimate ring that overhangs and fully conceals the epiproct from above, are much higher and stronger, whereas DL reduced, in *Pyrgodesmus* compared to *Klimakodesmus* species.

A similar, remarkably strong, massive and largely exposed solenomere taking up most of the gonopod telopodite is also observed in the genus *Pseudocatapyrgodesmus* Miyosi, 1957, with *P. glaucus* Miyosi, 1957, the type species from Honshu, Japan (Miyosi 1957), and *P. pulcher* Golovatch, Semenyuk, VandenSpiegel & Anichkin. 2011, from southern Vietnam (Golovatch *et al.* 2011). Yet their gonopods are considerably more elaborate and clearly branched, vs. relatively very simple and unipartite in *Klimakodesmus*. They are the gonopods of *P. pulcher* that seem to be especially similar to those of *Klimakodesmus* (Golovatch *et al.* 2011).

The strong, flattened, dorsal crest PM on the penultimate ring that overhangs and conceals the epiproct from above, however conspicuous, is unique to neither *Klimakodesmus* nor *Pyrgodesmus* species. For instance, several, but not all of the Afrotropical species of the genera *Monachodesmus* Silvestri, 1927 or *Udodesmus* Cook, 1896 show the same or very similar conditions (Golovatch *et al.* 2015, 2017).

Species description

Klimakodesmus bilobocaudatus sp. nov.

Figs 1–15

Material examined. Adult male holotype (CATE-5302), 2 adult male and 6 subadult female paratypes (CATE-5302B–CATE-5302I), 1 adult male and 2 subadult female paratypes (ZMUM), India, Kerala state, Kannur district, N11°58'2.5", E75°17'46.6", 5 m a.s.l., 27/01/2021, M.D. Aswathy leg.

Name. To emphasize a caudally relatively deeply bilobed dorsal keel (PM) on ring 19 in the new species; adjective.

Diagnosis. The new species differs clearly from *K. gravelyi*, the only other congener to be accepted (Carl 1932), by the more regularly tuberculate collum (cf. Figs 5 and 16), the lower PM and DL which are mostly inclined caudad (vs. inclined forward until ring 16, cf. Figs 7, 8 and 17), the caudally more deeply bilobed dorsal keel (PM) on ring 19 (vs. indistinctly bilobulate, cf. Figs 9, 10 and 18), the laterally bi- (rings 3 and 4) or trilobate (remaining postcollum rings) paraterga (vs. mostly bilobate, trilobate only on ring 2, cf. Figs 5, 8, 9 and 17–19), and the gonopods showing subspherical coxites (vs. squarish) and subcontiguous, apically subunciform and crossing each other (vs. divergent and suberect) telopodites, each of the latter additionally reinforced with a mesobasally thickened wall (vs. a laterobasal lobe, cf. Figs 12–15 and 20 & 21).

Description. Length ca. 3.68 mm, width of midbody segments 0.10 and 0.14 mm on pro- and metazonae, respectively (holotype). Length of adult male paratypes ca. 3.0–3.8 mm, that of subadult female paratypes 3.2–3.5 mm. Width of adult male paratypes ca. 0.40–0.45 mm, that of subadult female paratypes 0.44–0.48 mm. Live colouration generally pink; antennae, legs and venter translucent, lighter than dorsum (Figs 1, 7 & 9). Colouration in alcohol after 2 months of preservation pale brown to pinkish brown, legs and antennae faded to translucent (Figs 2–6, 8 & 10). No earth crust visible on body.

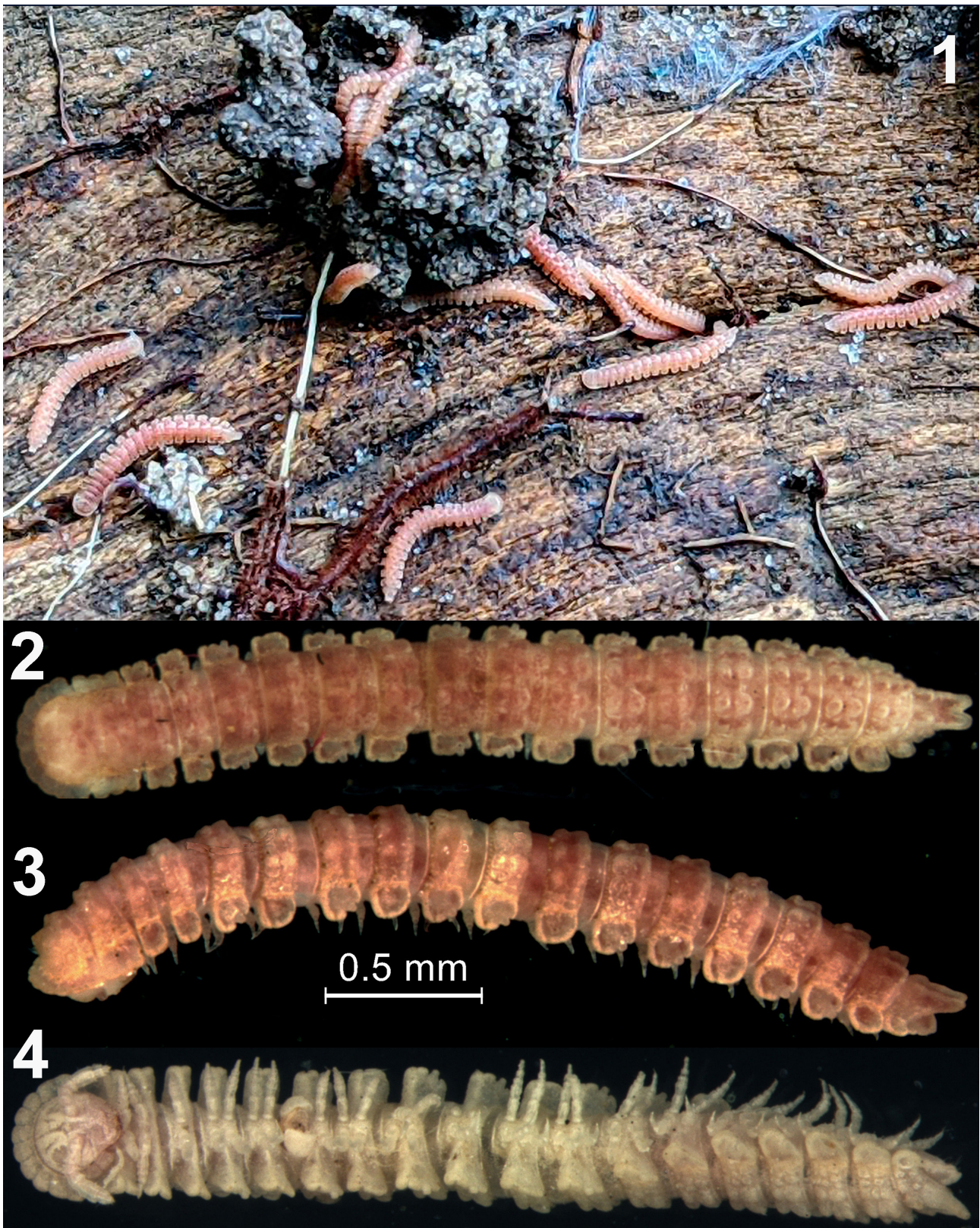
Most characters as in the generic description above, except as follows.

Body with 20 segments (likely in both sexes, see below) (Figs 2 & 4). In width, head << collum < segment 2=3 < 4–6 < 7–9 < 10–15, body gradually tapering towards telson thereafter. Head circular, labral region moderately setose, epicranial suture rather deep, vertex microgranulate (Fig. 6). Interantennal isthmus nearly as wide as diameter of antennal socket. Antennae short, weakly clavate, *in situ* reaching body segment/ring 3 when stretched ventrolaterally. In length, antennomere 7<3<1<6<4<2<<5; antennomeres 5–7 each with a more or less compact apicodorsal group of bacilliform sensilla (Figs 6 & 7). Collum flabellate, completely covering the head from above; anterior margin with 5+5 distinct, equal, moderately incised and rounded lobulations; central part domed, with 2+2 and 3+3 prominent and rounded tubercles arranged in two transverse rows (Figs 2–7). Paraterga set low (at about half of midbody height), subhorizontal to faintly declivous. Dorsum strongly arched, its outline smoothly extending onto paraterga (Figs 3 & 7). Prozonae, as well as deep and thin strictures between pro- and metazonae finely alveolate. Postcollum metaterga with strongly differentiated dorsal tuberculations: 2+2 longitudinal crests/rows of mostly 2+2 fused tubercles, those before ring 19 slightly inclined caudad, but PM on ring 19 abruptly modified into a mid-dorsal, strongly elongate, conspicuous and caudally clearly bilobate ridge overhanging and concealing a short epiproct (Figs 2–4, 8–10). Paraterga broad, thin, rather irregularly tuberculate near bases and clearly lobulated laterally, with three rounded and moderately incised lobulations on rings 2–19, regardless of cylindrical porosteles located between the 2nd and 3rd lobulations on rings 5, 7, 9, 10, 12, 13, 15 and 16 (Figs 2–10); only paraterga 3 and 4 with last lobulation in a clearly caudolateral position (Figs 5–7). Epiproct (Fig. 10) finger-shaped, tip bent down and divided into two round bulbs. Hypoproct (Fig. 10) semi-circular, with 1+1 strong setae borne on minute, caudal, paramedian knobs.

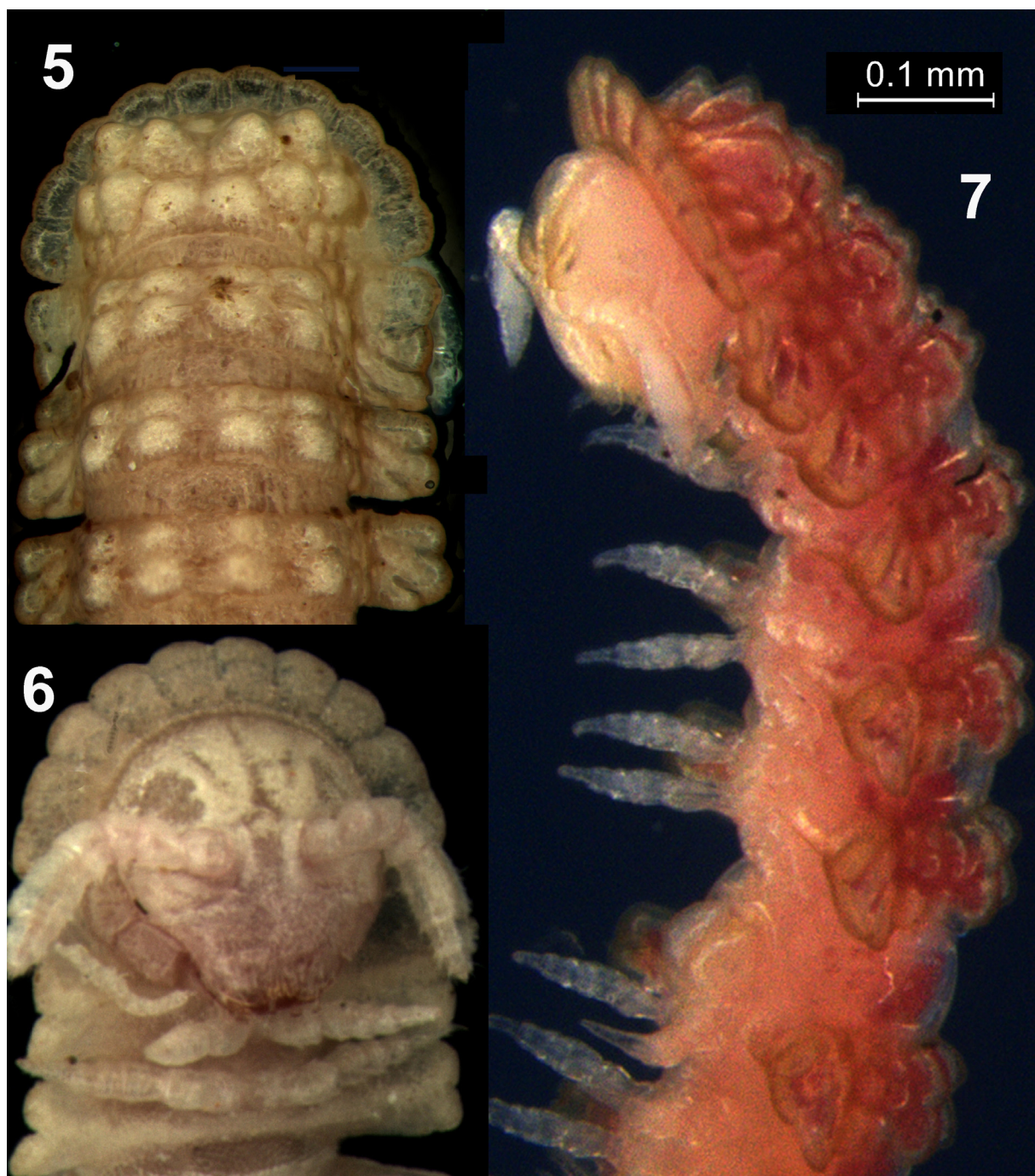
Legs with neither adenostyles nor tarsal brushes (Fig. 11). In length, tarsi > femora > prefemora > tibiae > coxae > postfemora; claws simple, slightly curved ventrally.

Gonopods (Figs 12–15) relatively simple, placed inside a transversely oblong-oval gonopodal aperture, the latter with thin and slightly elevated caudal and lateral margins; *in situ*, both gonopods strongly exposed, held mostly parallel to one another, with only tips crossing each other. Coxites (cx) voluminous, but moderately enlarged, gonocoel thus being relatively shallow; cannulae simple. Telopodites directed caudally, each unipartite and subtriangular, long and slender, gradually attenuating distad and acuminate apically, each represented solely by a solenomere (sl) and supporting a seminal groove running along lateral margin to the end of a laterally directed and unciform apical

part, and additionally reinforced basally through a distinctly thickened caudomesal wall of a prominent, membranous, mesal lobe (lo); prefemorite as usual, relatively short, densely and strongly setose.



FIGURES 1–4. *Klimakodesmus bilobocaudatus* **sp. nov.** 1. Natural microhabitat (rotting wood with a colony on the surface, photographed not to scale). 2. Adult male paratype, dorsal view. 3. Subadult female paratype, lateral view. 4. Adult male paratype, ventral view.

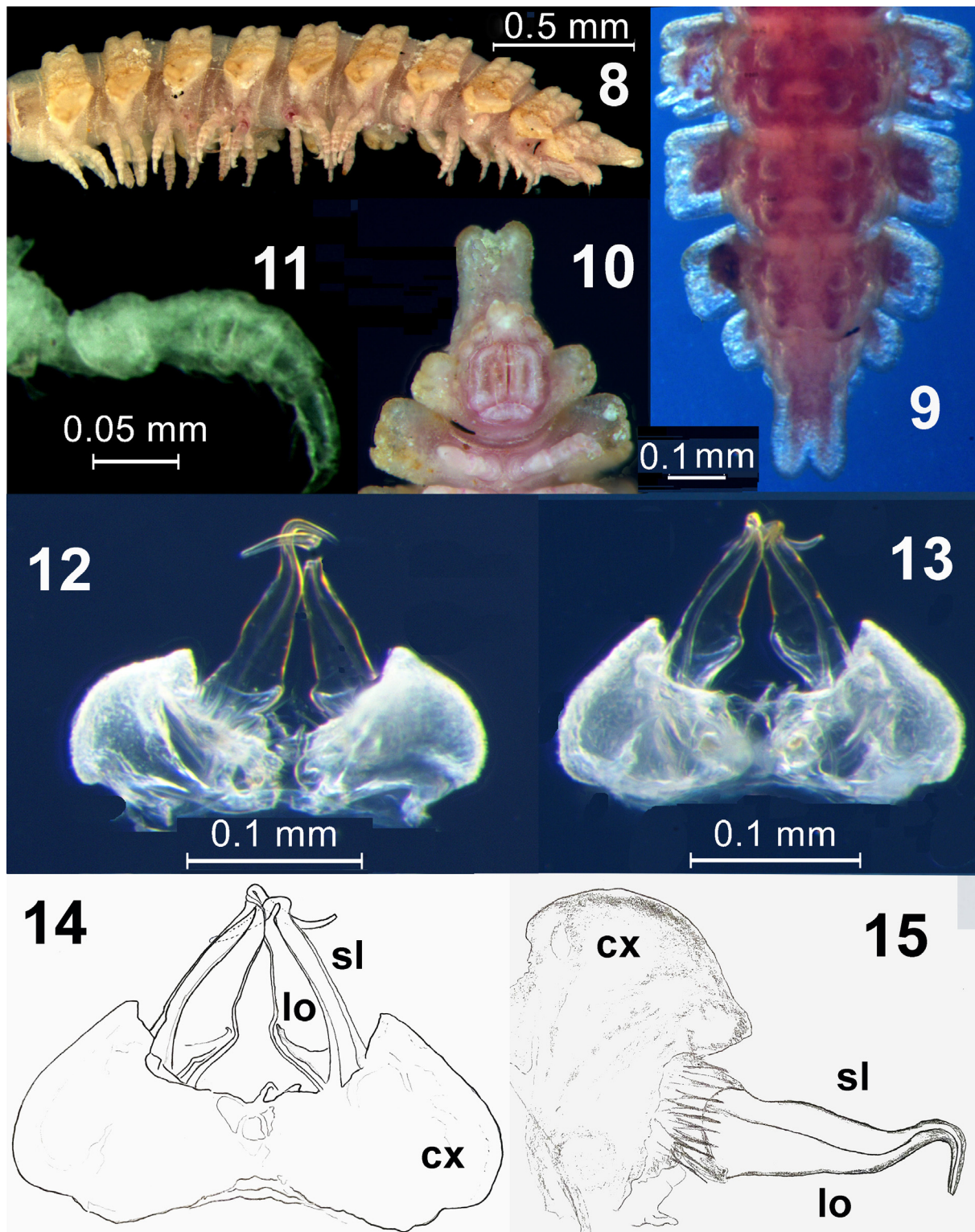


FIGURES 5–7. *Klimakodesmus bilobocaudatus* sp. nov. Anterior parts of body, dorsal, ventral and lateral views, respectively.

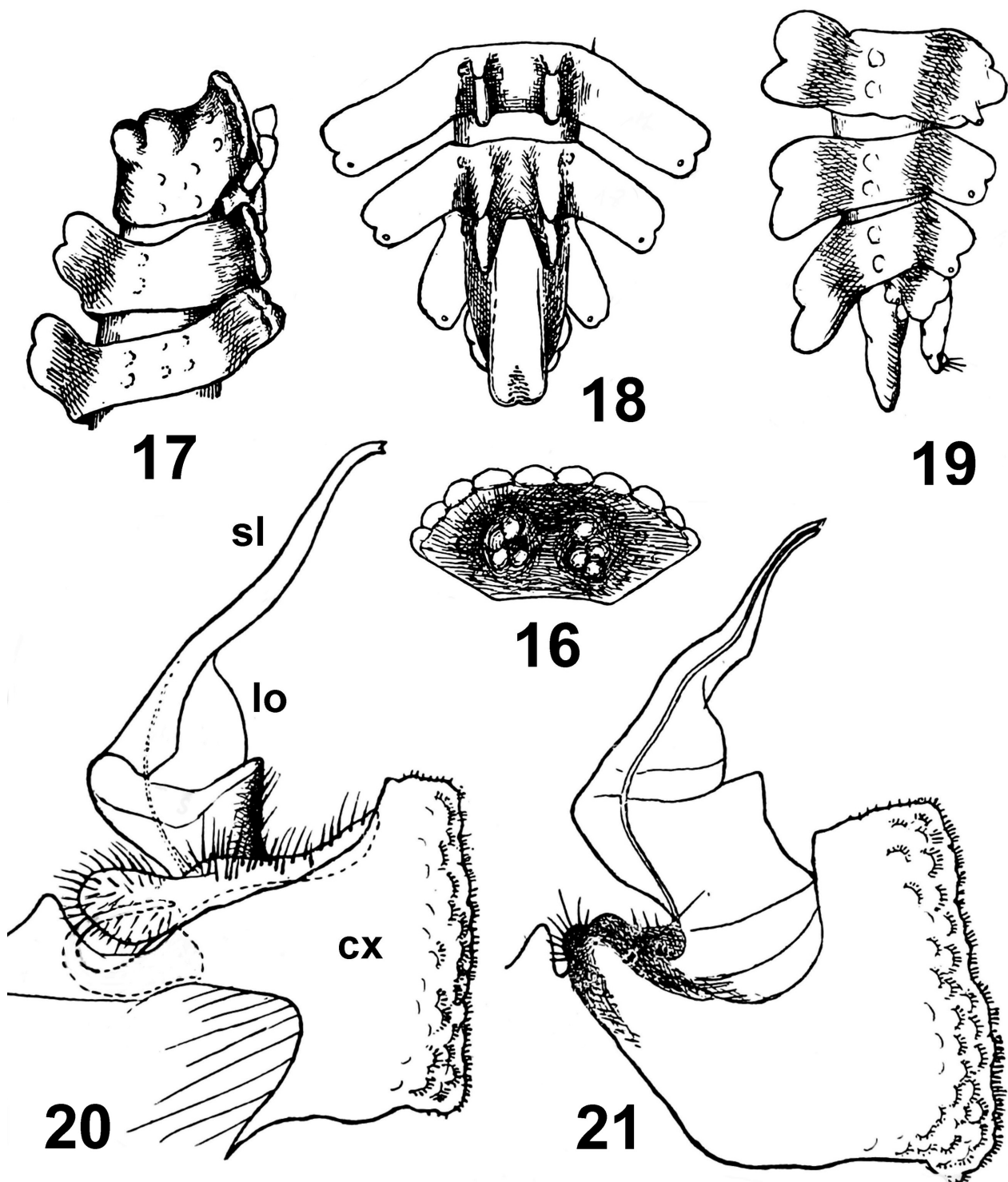
Ecological notes. This new species was found under rotting wood near a lowland swamp overgrown with *Myristica* forest in the Kannur district, northern Kerala, India. The habitat area of approximately 20 ha is a sacred grove protected by local people. In contrast, *K. graveleyi* came from high-altitude areas (1000–1600 m a.s.l.) in the state of Tamil Nadu (Carl 1932), Western Ghats, southern India (Fig. 22).

It seems noteworthy that all females collected at the type locality in January appear to be subadults, each with 19 body segments. This has been proven by dissecting the vulvae which have always been found underdeveloped (amorphous ovoid clods devoid of setae), and an anterior, ventral, transverse, marginal ridge on ring 3 missing. This agrees well with the common wisdom that only adult males in Polydesmida, but never adult females, can be composed of a lesser number of body rings. Usually, in the course of teloanamorphosis characteristic of the order Polydesmida, both the males and females of Polydesmida show the same number of body rings, either 20 or 19,

more rarely 18, exceptionally up to 40 (Shear *et al.* 2016). When there is a difference in polydesmidan body segment counts, the adult males typically have one segment less and nearly always remain stable per sex (Enghoff *et al.* 2015). Only exceptionally, as is the case of *Ammodesmus granum* Cook, 1896 and *A. congoensis* VandenSpiegel & Golovatch, 2015 (Ammodesmidae), from western or central Africa, respectively, can both sexes vary in the number (18 or 19) of body rings (VandenSpiegel & Golovatch 2012, 2015).



FIGURES 8–15. *Klimakodesmus bilobocaudatus* sp. nov. 8. Posterior half of body (subadult female paratype), lateral view. 9 & 10. Posterior part of body (adult male paratype), dorsal and ventral views, respectively. 11. Midbody leg (adult male paratype), lateral view. 12–14. Both gonopods (adult male paratype), caudal, oral and caudal views, respectively. 15. Right gonopod, caudal view. **Abbreviations:** cx, coxite; lo, mesal lobe; sl, solenomere. **NB:** Figures 14 & 15 drawn not to scale.



FIGURES 16–21. *Klimakodesmus graveleyi* Carl, 1932, male holotype, after Carl (1932). **16.** Collum, dorsal view. **17.** Anterior part of body, lateral view. **18 & 19.** Posterior part of body, dorsal and lateral views, respectively. **20 & 21.** Left and right gonopods, caudal and oral views, respectively. **Abbreviations:** cx, coxite; lo, lateral lobe; sl, solenomere. Drawn not to scale.

In *Klimakodesmus* species, however, the situation is ordinary, as both sexes (must) equally have 20 body segments. The absence of adult females in the type series seems best to be accounted for by seasonal factors alone.

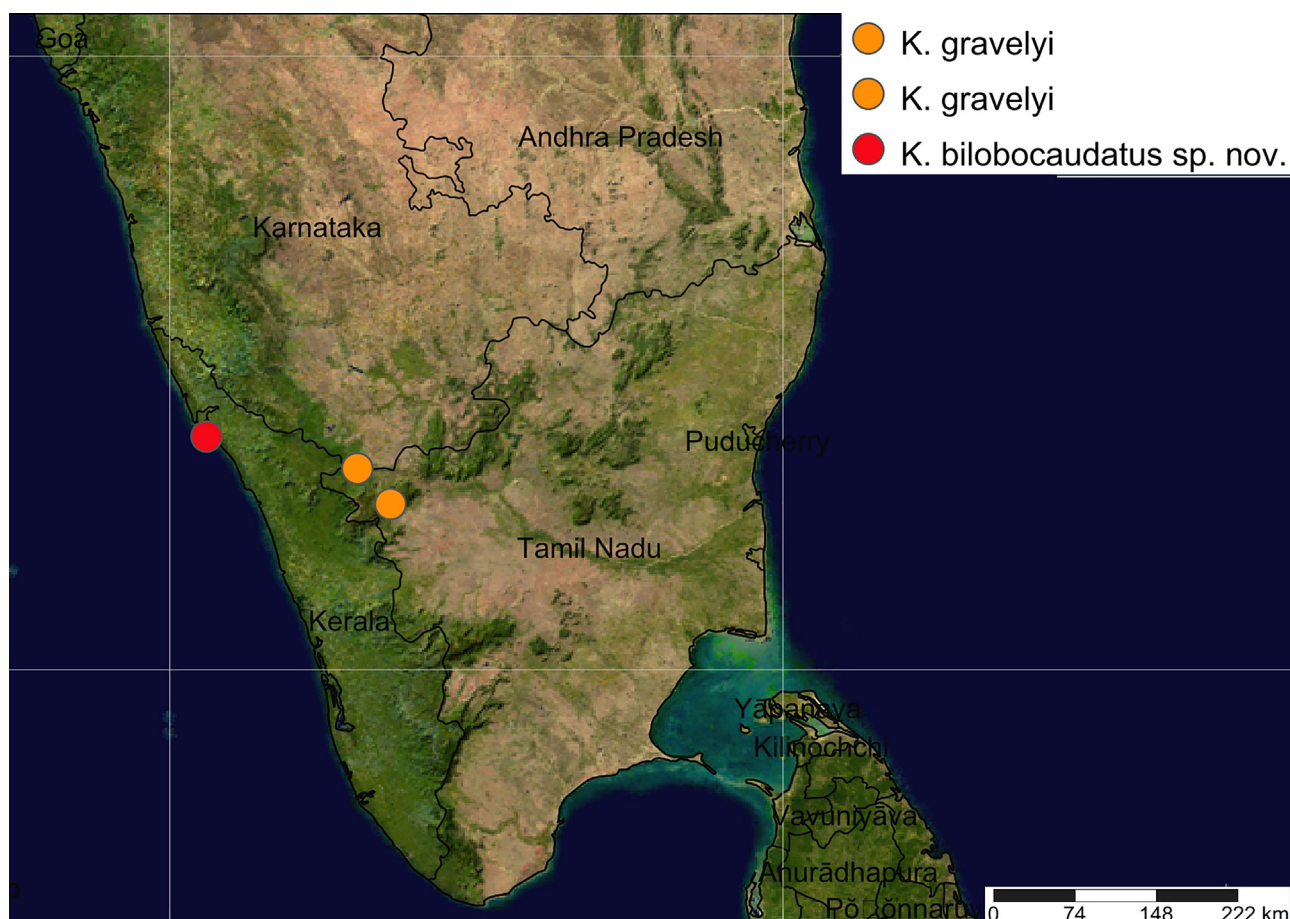


FIGURE 22. Distribution of the genus *Klimakodesmus*: *K. graveyi* in Tamil Nadu state (orange dots), and *K. bilobocaudatus* sp. nov. in Kerala state (red dot).

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