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RESEARCH ARTICLE

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Assemblage and distribution of pill millipedes and earthworms in relation to soil edaphic features in the Western Ghats and the west coast of India

Abstract Abundance and biomass of pill millipedes (*Arthrosphaera*) and earthworms in the forests and plantations of nine study sites in the southwestern India (Western Ghats, foothill of the Western Ghats and the west coast) were surveyed. Out of 10 morphospecies of pill millipedes (*Arthrosphaera*) recovered, four were identified, and the rest did not match with morphological and taxonomic descriptions. A maximum of five species of *Arthrosphaera* were recovered from the Western Ghat forests. In forests, the biomass of pill millipedes was higher than earthworms but lower in abundance. In plantations, both biomass and abundance of millipedes were higher than those of earthworms. None of the 12 soil edaphic features (moisture, bulk density, water-holding capacity, temperature, pH, conductivity, organic carbon, P, K, Ca, Mg and litter depth) significantly correlated with millipede biomass in the Western Ghat forests, nor were any soil features correlated with earthworm biomass in the west coast plantations. While all, except for soil moisture, were significantly correlated with earthworm biomass in the Western Ghat forests. In the Western Ghat plantations, the biomass of millipedes was significantly correlated with soil moisture, pH, organic carbon and minerals (P, K and Ca). In the west coast plantations, the biomass of millipedes was significantly correlated with moisture, water-holding capacity, organic carbon, Ca, and Mg, while, in the foothill plantations, only with temperature.

Keywords pill millipedes, *Arthrosphaera*, earthworms, Western Ghats, forests, plantations, biomass, abundance

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1 Introduction

Millipedes are the major saprophagous fauna widely distributed in diverse habitats of temperate and tropical regions (Lawrence, 1984; Blower, 1985; Sierwald and Bond, 2007). They are involved in mechanical fragmentation, redistribution and mineralization of organic matter and release essential elements (Wallwork, 1976; Hopkin and Read, 1992; Dangerfield and Milner, 1996; Kadamannaya and Sridhar, 2009). Besides supporting microbial decomposition and nutrient turnover, saprophagous activities of millipedes improve the soil-water relationships as well as soil structure (Swift et al., 1979; Hopkin and Read, 1992). Although millipedes contribute only about 10% of detritus decomposition in soil ecosystem, their feeding activities enhance the microbial function and, in turn, are responsible for up to 90% of total detritus breakdown (Anderson and Bignall, 1980). Although millipedes have a wide range of lifestyles, they are vulnerable to narrow fluctuations in edaphic factors and become suitable indicators to evaluate the status of different natural and disturbed ecosystems (Dangerfield and Telford, 1991; Kime and Golovatch, 2000).

According to Attems (1936), among 92 genera of millipedes in India, about 70% are endemic, and the rest (30%) occur in other regions. Diplopods of the Indian Peninsula encompass a high number of endemic pill millipedes (Sphaerotheriidae) (Attems, 1936). Surveys carried out in Southern India reveal a restricted and patchy distribution of the genus *Arthrosphaera* (Sphaerotheriidae) (Chowdaiah, 1969; Achar, 1986, 1987; Ashwini and Sridhar, 2008). Among 45 species of *Arthrosphaera*

endemic to southern India and Sri Lanka, about 82% are confined to southern India (Sridhar et al., 2009).

The Western Ghats has a long ecological history with heterogeneous landscapes and biodiversity at about 2000-m altitudinal range and receiving rainfall between 100 and 600 cm per annum (Chandran, 1997). The vegetation cover of the Western Ghats mainly constitutes grassland, shola, scrub, deciduous forests, and mixed-evergreen/semi-evergreen to evergreen forests. The climatic conditions, vegetation pattern and soil properties differ drastically from the high altitudes to the west coastal locations. In the recent past, ecosystems of the Western Ghats have been influenced by human interference such as agricultural and plantation activities, including exploitation of forest products. In view of an inadequate survey of pill millipedes in Western Ghats, the present study aims at understanding the distribution, biomass and abundance of pill millipedes that belong to the genus *Arthrosphaera* in comparison with earthworms (as they occur commonly with millipedes) in forests and plantations of the Western Ghats and west coast locations in relation to soil edaphic features.

2 Study area and methods

2.1 Study area

The locations chosen for survey were forests and plantations distributed in three biomes: (1) Western Ghats, (2) foothill of Western Ghats, and (3) the west coast. The mixed-evergreen to evergreen forests of Western Ghats: Madikeri (1147 m asl), Agumbe (657 m asl) and Ulvi (647 m asl), have characteristic cool and humid climatic conditions. These locations receive rainfall between 400 and 600 cm annually, and the temperature ranges between 10–12°C (minimum) and 30–32°C (maximum). Common genera of tree species in these locations consists of *Acacia*, *Ailanthus*, *Albizzia*, *Alstonia*, *Artocarpus*, *Butea*, *Calamus*, *Calophyllum*, *Carallia*, *Careya*, *Cinnamomum*, *Flacuortia*, *Holigarna*, *Hopea*, *Lagerstroemia*, *Macaranga*, *Mimusops*, *Ochlandra*, *Pterocarpus*, *Syzygium* and *Terminalia*. The Western Ghat plantations: Basrikallu (1387 m asl), Horanadu (804 m asl) and Geejagaru (604 m asl), possess common plantation crops (e.g. *Areca*, *Cocoa*, *Coffea*, *Musa* and *Piper*) cultivated along with native tree species.

The Western Ghat foothill locations consist of mixed-evergreen to semi-evergreen forests: Kadaba (124 m asl), Adoor (113 m asl) and Adyanadka (91 m asl), and receive rainfall about 250–400 cm annually, and the temperature ranges between 21–22°C (minimum) and 34–36°C (maximum). The common tree species in these locations encompass *Acacia*, *Ailanthus*, *Albizzia*, *Alstonia*, *Aporosa*, *Artocarpus*, *Butea*, *Calamus*, *Calophyllum*, *Carallia*, *Cinnamomum*, *Dalbergia*, *Ficus*, *Flacuortia*, *Holigarna*, *Hopea*, *Lantana*, *Lagerstroemia*, *Mangifera*, *Mimusops*, *Ochlandra*, *Pterocarpus*, *Syzygium*, *Tectona*, *Terminalia* and *Zizypus*. All three foothill locations possess plantations of *Areca*, *Cocos*, *Coffea*, *Musa*, *Piper*, *Syzygium* and *Theobroma* grown along with the native tree species.

Three dry humid west coast plantations: Uppala (22 m asl), Kasaragod (22 m asl) and Kotekar (9 m asl), are situated about 2–8 km away from the Arabian Sea. They receive rainfall up to 200–380 cm annually, and the temperature fluctuates between 22–26°C (minimum) and 36–38°C (maximum). These regions are highly fragmented mainly due to the cultivated lands and road ways. The common vegetation and plantation crops belonged to *Acacia*, *Adenanthera*, *Anacardium*, *Areca*, *Artocarpus*, *Calophyllum*, *Carallia*, *Careya*, *Caryota*, *Casuarina*, *Cinnamomum*, *Cocos*, *Eucalyptus*, *Glyricidia*, *Hopea, Macaranga*, *Mangifera*, *Mimusops*, *Musa* and *Syzygium*.

2.2 Sampling and survey

The survey was performed during the post-monsoon season (October, 2005). In a 200-m transect of each location, four sampling points were marked at a distance of 50 m, and the plant litter depth was determined. Initially, pill millipedes and earthworms in litter and soil surface of 30 cm × 30 cm area of each sampling point were collected. Later, soil was excavated up to 10-cm depth to gather pill millipedes and earthworms. Biomass (fresh weight) and number of pill millipedes and earthworms were calculated from 9 m^3 of soil volume. About 3 kg of composite soil per sampling point was collected and transferred to the laboratory in airtight polythene bags for analysis.

The dimensions of pill millipedes (length, breadth and diameter on conglobation) of adult millipedes were recorded using dial calipers. A few adult individuals were immobilized using ethyl acetate and preserved in 70% ethanol for morphological analysis, and the rest of the animals were released at the respective sampling locations. Morphological features of each morphospecies were assessed using low-power microscopy. Further details such as antennae, mandibles, gnathochilarium, endotergam, second leg pair in females and males, ninth pair of legs in females and males, subanal plates with wash board in females, and anterior and posterior pairs of telopods were also evaluated. Details of each morphospecies were compared with taxonomic keys by Pocock (1899), Attems (1936) and Jeekel (1974) for identification.

2.3 Soil analysis

Temperature, pH and conductivity of soil samples were assessed at the sampling sites. Soil temperature was determined using a mercury thermometer at a depth of 10 cm. Composite samples of soil were mixed with distilled water (1∶2.5 w/v), shaken for 10 min, and pH

(Systronics, India; Model 335) and conductivity (Systronics, India; Model 304) were determined. Other soil parameters such as moisture, texture, bulk density and water-holding capacity were determined in the laboratory based on the methods outlined by Chopra and Kanwar (1982). Soil organic carbon (Walkley and Black's rapid titration), available phosphorus (spectrophotometric; Systronics, India; Model 106), available potassium (flame emission photometry; Systronics, India; Model MK1/MK3), and exchangeable calcium and magnesium (titrimetric) were assessed according to the procedures outlined by Jackson (1973).

2.4 Statistical analysis

As the Western Ghat forests and plantations are in close proximity, one-way ANOVA was employed to determine the difference in soil edaphic features, biomass of millipedes and earthworms between forests and plantations using Statistica, Version 8, (StatSoft Inc., 2008). Pearson correlation was employed using GraphPad Prism version 4.0 b for Macintosh, GraphPad Software, San Diego, California, USA (www.graphpad.com), to determine the relationship between the biomass of pill millipedes and earthworms vs. soil edaphic features (parameters: *P* values, two tailed; confidence intervals, 95%).

3 Results

Out of 10 species of *Arthrosphaera* recovered from this survey, four have been identified up to species (*Arthrosphaera dalyi*, *A. davisoni*, *A. fumosa*, and *A. magna*), and the other six morphospecies that did not match with the morphological and taxonomic descriptions are designated as *Arthrosphaera* sp. 1–6 and most likely belong to undescribed species. A maximum of five species were found at the Western Ghat forests (Table 1), while in the Western Ghat plantations and foothill forests/plantations, we found only two species each, and only one species was confined to the plantations of the west coast. None of the sampling points possessed more than one species of *Arthrosphaera*. However, locations Ulvi and Agumbe encompassed three and two species, respectively, in different transects of same location. Overall, biomass and abundance of pill millipedes were higher in plantations than forests, and also at the foothill than Western Ghat and west coast locations (Fig. 1). The earthworm biomass was lower than pill millipedes in forests, but higher in abundance. In plantations, biomass as well as abundance of earthworms was lower than pill millipedes. Except for one location (Uppala), the coastal plantations were devoid of pill millipedes, while earthworms were prominent.

The texture of soils was loamy sand, sandy to loamy sand and sandy in Western Ghats, foothill and west coast, respectively. From high to low altitude, the soil moisture, water-holding capacity, minerals (K, Ca and Mg) and pill millipede biomass declined, but the soil temperature rose from high to low altitude. Between high-altitude forests and plantations, soil bulk density, water-holding capacity, pill millipede biomass and abundance differed significantly (Table 2). Most soil edaphic features, pill millipede biomass and abundance significantly differed between forest and plantation locations of foothills.

The biomass of pill millipedes was not correlated with any soil edaphic features assessed in forests of Western Ghats, but showed a negative correlation with organic carbon ($P < 0.01$, $r = -0.744$) and Ca ($P < 0.05$, $r = -0.5966$) in the foothill forests (Table 3). Pill millipede biomass in the Western Ghat plantations exhibited a negative correlation with moisture ($P < 0.01$; $r = -0.7694$) and a positive correlation with pH ($P < 0.05$; $r = 0.5838$), organic carbon ($P < 0.01$; $r = 0.8001$), P ($P < 0.01$; $r = 0.7161$), K ($P < 0.001$; $r = 0.8391$) and Ca ($P < 0.05$; $r =$

Table 1 *Arthrosphaera* species recovered in the Western Ghats, foothill and west coast locations

species	Western Ghats		foothill		west coast
	forest[a]	plantation[b]	forest[c]	plantation[d]	plantation[e]
Arthrosphaera dalyi	–	–	Kadaba	Kadaba	–
Arthrosphaera davisoni	–	Basrikallu	–	–	–
Arthrosphaera fumosa	Madikeri	–	–	–	–
Arthrosphaera magna	–	–	Adyanadka	Adyanadka and Adoor	–
Arthrosphaera sp. 1	–	–	–	–	Uppala
Arthrosphaera sp. 2	Agumbe	–	–	–	–
Arthrosphaera sp. 3	Ulvi	–	–	–	–
Arthrosphaera sp. 4	–	Geejagaru and Horanadu	–	–	–
Arthrosphaera sp. 5	Ulvi	–	–	–	–
Arthrosphaera sp. 6	Agumbe and Ulvi	–	–	–	–
total species	5	2	2	2	1

Note: [a]Madikeri (1147 m asl), Agumbe (657 m asl), Ulvi (647 m asl); [b]Basrikallu (1387 m asl), Geejagaru (604 m asl), Horanadu (804 m asl); [c]Kadaba (124 m asl), Adyanadka (91 m asl); [d]Adoor (113 m asl); [e]Uppala (22 m asl).

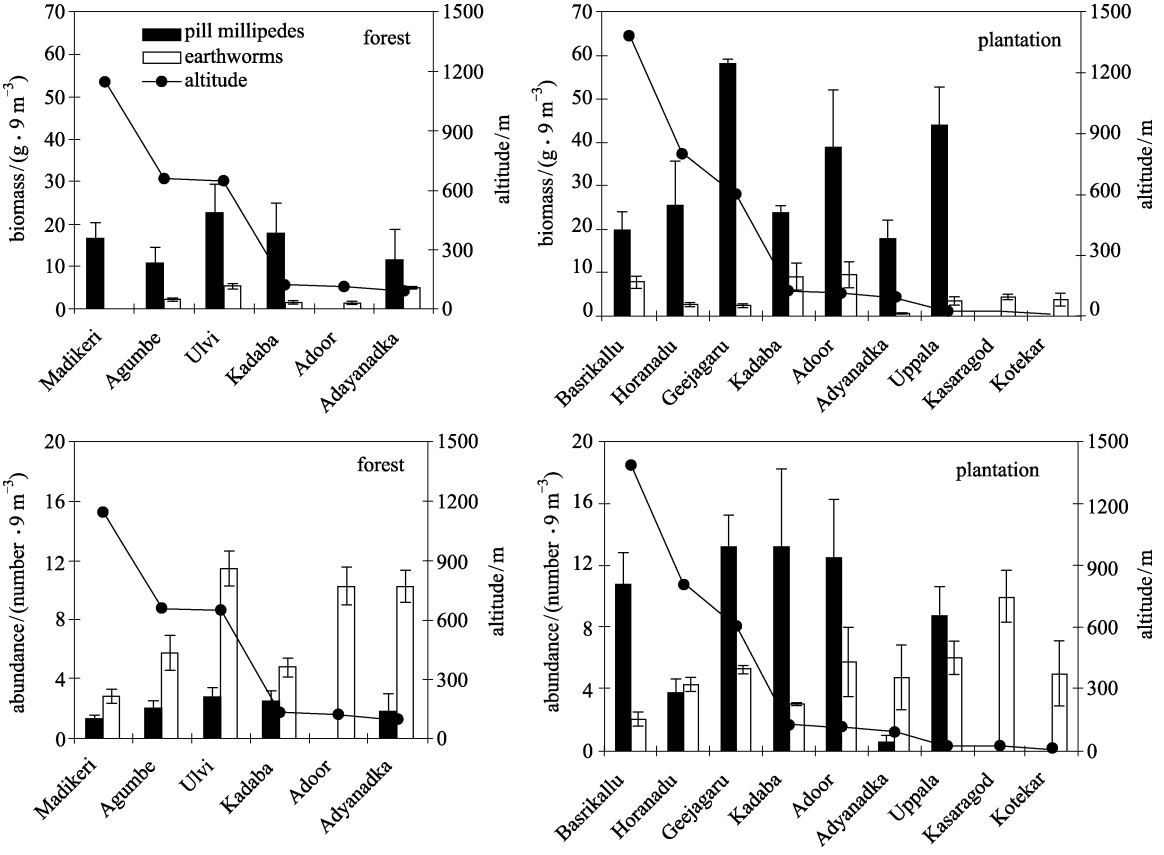

Fig. 1 Altitude-wise biomass and abundance of pill millipedes (*Arthrosphaera*) and earthworms in forests and plantations of the Western Ghats, foothill and west coast locations.

0.6534), while only with temperature ($P < 0.05$; r = 0.5791) in the foothill plantations. In the west coast plantations, the biomass was positively correlated with soil moisture ($P < 0.05$; r = 0.6385), water-holding capacity ($P < 0.01$; $r = 0.7962$), organic carbon ($P < 0.05$; $r = 6654$) and Ca ($P < 0.01$; r = 0.7195) and negatively with Mg ($P < 0.05$; r = −0.6263). Unlike pill millipedes, the biomass of earthworms was significantly correlated with all soil edaphic factors except for moisture and organic carbon in the Western Ghat forests (Table 3). However, the biomass showed a significant negative correlation with Ca at the Western Ghat plantations. In the foothill forests, it showed a significant positive correlation with moisture, bulk density and temperature, while a negative one with conductivity and litter depth. The earthworm biomass showed a significant negative correlation with soil pH, P and Ca in the foothill plantations.

4 Discussion

The Western Ghats and its foothill locations are mainly composed of loamy sand characterized by lower temperature and higher edaphic features (e.g. moisture, water-holding capacity, organic carbon, K and Mg) than the west coast locations. Unlike the west coast, plantation vegetation in Western Ghats has not entirely replaced native tree species, and in plantations, native tree species have been retained for shade, green manure and organic matter. Biomass and/or abundance of pill millipedes was significantly higher at the Western Ghat and foothill plantations mainly due to the higher water-holding capacity and lower bulk density of soil than forest locations. An earlier study on the pill millipedes of the Western Ghats and west coast locations has also revealed the importance of soil temperature, water-holding capacity, bulk density and organic carbon (Ashwini and Sridhar, 2008). High millipede diversity was found in calcareous soils of Belgium (Branquart et al., 1995). Similarly, the millipede richness was the highest in mixed forests of Australia consisting of calcareous soils (Erwin and Andreas, 1997). Millipede cuticular structures are heavily encrusted with calcium carbonate (or magnesium carbonate) (Enghoff, 1990) and serve Ca turnover in soil (Crossley, 1996). In our study, the biomass of pill millipedes of the Western Ghat plantations was positively correlated with organic carbon, P, K and Ca. In the Kadaba plantation (foothill of Western Ghats), also during the post-

Table 2 Soil edaphic features, biomass and abundance of pill millipedes and earthworms in the Western Ghats, foothill and west coast locations (n = 12; mean ± SE)

parameters	Western Ghats		foothill		west coast plantation
	forest	plantation	forest	plantation	
soil edaphic features					
moisture/%	32.27 ± 4.16[a]	33.37 ± 1.96[a]	26.19 ± 1.58[a]	27.01 ± 1.09[a]	22.66 ± 0.52
bulk density/(g·cc^{-1})	1.06 ± 0.05[a]	0.92 ± 0.01[b]**	1.46 ± 0.07[a]	1.24 ± 0.08[b]*	1.36 ± 0.09
water-holding capacity/%	57.19 ± 2.65[a]	65.34 ± 0.58[b]**	49.95 ± 0.26[a]	51.43 ± 1.70[a]	36.64 ± 0.69
temperature/°C	23.06 ± 0.67[a]	21.79 ± 0.29[a]	26.04 ± 0.29[a]	26.29 ± 0.32[a]	28.83 ± 0.23
pH	5.71 ± 0.32[a]	5.40 ± 0.21[a]	5.31 ± 0.12[a]	5.98 ± 0.17[b]**	5.36 ± 0.10
conductivity/(mmhos·cm^{-1})	0.31 ± 0.04[a]	0.35 ± 0.02[a]	0.86 ± 0.14[a]	0.65 ± 0.10[b]***	0.38 ± 0.04
organic carbon/%	3.75 ± 0.10[a]	3.48 ± 0.26[a]	4.36 ± 0.26[a]	3.97 ± 0.23[a]	2.63 ± 0.26
total phosphorus/(μg·g^{-1})	33.85 ± 5.13[a]	25.36 ± 5.98[a]	12.00 ± 1.73[a]	30.37 ± 8.47[b]*	41.65 ± 6.10
potassium/(μg·g^{-1})	136.10 ± 23.2[a]	134.26 ± 7.15[a]	90.10 ± 6.96[a]	167.15 ± 19.1[b]***	82.41 ± 7.81
calcium/(μg·g^{-1})	2.20 ± 0.36[a]	2.37 ± 0.26[a]	1.72 ± 0.19[a]	2.58 ± 0.49[a]	1.85 ± 0.15
magnesium/(μg·g^{-1})	1.50 ± 0.33[a]	0.94 ± 0.06[a]	0.72 ± 0.12[a]	0.69 ± 0.08[a]	0.72 ± 0.07
litter depth/cm	5.71 ± 0.38[a]	6.46 ± 0.41[a]	6.00 ± 0.54[a]	4.50 ± 1.04[a]	6.83 ± 0.43
biomass/(g·9m^{-3})					
pill millipedes	16.79 ± 2.90[a]	34.58 ± 6.41[b]*	9.80 ± 3.77[a]	26.96 ± 5.32[b]*	14.68 ± 6.82
earthworms	2.57 ± 0.69[a]	4.32 ± 0.89[b]*	2.67 ± 0.52[a]	6.34 ± 1.82[b]*	3.96 ± 0.54
abundance/(number·9m^{-3})					
pill millipedes	2.00 ± 0.30[a]	3.83 ± 0.46[b]**	1.42 ± 0.51[a]	5.83 ± 0.48[b]*	2.00 ± 0.91
earthworms	6.67 ± 1.22[a]	9.25 ± 1.52[b]*	8.42 ± 0.95a	8.75 ± 2.59[a]	7.92 ± 1.17

Note: Soil edaphic features vs. biomass and abundance were compared between forest and plantation of the Western Ghats and foothill by one-way ANOVA. Figures across the forest and plantation columns of the Western Ghats and foothill with different letters significantly differ (*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$).

monsoon period, pill millipede biomass was positively correlated with Ca and Mg, while in the Kadaba forest, it was positively correlated with temperature and K (Kadamannaya et al., 2009). Organic farming practices in plantations seem mainly responsible for higher biomass and abundance of pill millipedes compared to forests. Based on the seasonal patterns of occurrence of *Arthrosphaera magna* in semi-evergreen forest and adjacent organically managed mixed plantation at the foothill of Western Ghats, Ashwini and Sridhar (2006) opined that these millipedes invaded the plantation from forest and reduced the risks of local extinction. On the contrary, in our study, the earthworm biomass was correlated with many edaphic factors (except for soil moisture) in forests, while only with Ca in plantations, indicating that they are not as sensitive as pill millipedes to soil edaphic factors. Unlike pill millipedes, certain earthworms have a wide distribution and occur throughout the year, and each species of earthworm may show specific adaptation to specific soil edaphic factor.

Elevated N, P, K and Ca in the litter layers of *Leucaena* plantations in Puerto Rico resulted in domination of millipedes (Warren and Zou, 2002). The areas possessing highest standing crop of litter and vegetation cover in British beechwood were also endowed with numerous millipedes (Phillipson and Meyer, 1984). It is evident that the species richness of millipedes was elevated with increased age of forest stands in South Africa (van Aarde et al., 1996). Ashwini and Sridhar (2008) emphasized the importance of evergreen to semi-evergreen forests of the Western Ghats on the occurrence of *Arthrosphaera*. In our study, although biomass of *Arthrosphaera* spp. was the highest in the Western Ghat plantations, the species richness was the highest in the Western Ghat forests. This may be due to the occurrence of heterogeneous plant litter on the forest lands than plantations. Meentenmeyer (1978) and Aerts (1997) were of the opinion that climatic conditions and litter chemistry are the most important factors in regulation of litter decomposition. As climatic variations are not too wide in humid tropics, the litter chemistry is significant in litter turn-over by invertebrates and microbes (Henegan et al., 1999; González and Seastedt, 2001; González et al., 2001). As millipedes are influenced by litter chemistry at narrow spatial scales (meters to decametres) of their habitat (Warren and Zou, 2002), they become reliable indicators of soil qualities. They are also known to be sensitive to a single edaphic factor (e.g. soil texture and litter thickness) despite whether overall ecological conditions are favourable, and these features qualify millipedes as authentic indicators of soil

Table 3 Pearson correlation coefficients between biomass of pill millipedes and earthworms vs. soil edaphic features in the Western Ghats, foothill and west coast locations

parameters	Western Ghats		foothill		west coast plantation
	forest	plantation	forest	plantation	
pill millipedes					
moisture	−0.1666	−0.7694** (0.0034)	−0.2739	−0.2406	0.6385* (0.0255)
bulk density	−0.1151	−0.4197	0.3517	0.512	0.2912
water-holding capacity	0.107	−0.3572	0.295	−0.4265	0.7962** (0.0019)
temperature	−0.04779	0.2649	−0.3891	0.5791* (0.0485)	0.4905
pH	0.4371	0.5838* (0.0463)	−0.2839	−0.03602	0.2257
conductivity	−0.09308	−0.1227	−0.5298	0.5456	0.3753
organic carbon	−0.382	0.8001** (0.0018)	−0.744** (0.0055)	−0.1223	0.6654* (0.0182)
total phosphorus	0.2354	0.7161** (0.0088)	0.5161	−0.3859	0.5577
potassium	0.3423	0.8391*** (0.0006)	−0.5581	0.4657	0.296
calcium	−0.1796	0.6534* (0.0212)	−0.5966* (0.0406)	−0.3103	0.7195** (0.0083)
magnesium	−0.09643	0.02024	−0.5693	0.4281	−0.6263* (0.0293)
litter depth	−0.2894	−0.1572	−0.1642	−0.05721	0.01379
earthworms					
moisture	0.4263	0.4621	0.7425** (0.0057)	0.2489	−0.5206
bulk density	−0.8959*** (< 0.0001)	−0.1925	0.83*** (0.0008)	0.05621	0.06084
water-holding capacity	0.8738*** (0.0002)	−0.3649	0.2985	−0.4954	−0.2779
temperature	0.7106** (0.0096)	0.4211	0.5773* (0.0494)	−0.1487	−0.1024
pH	0.7794** (0.0028)	−0.2943	−0.4899	−0.5982* (0.0399)	0.01739
conductivity	–0.6719* (0.0167)	0.5231	−0.6412* (0.0246)	0.2713	0.1812
organic carbon	0.1147	−0.4585	−0.328	−0.3015	−0.174
total phosphorus	0.954*** (< 0.0001)	−0.1689	0.3821	−0.7051* (0.0104)	−0.2048
potassium	0.9447*** (< 0.0001)	−0.2176	−0.0208	0.1785	−0.1437
calcium	−0.9199*** (< 0.0001)	−0.605* (0.0371)	0.02986	−0.6615* (0.0191)	−0.1767
magnesium	−0.8732*** (0.0002)	−0.2885	−0.4117	0.2746	−0.3378
litter depth	−0.7167** (0.0087)	0.497	−0.593* (0.0421)	0.4743	−0.1109

Note: Significant P values are indicated with asterisk (*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$).

quality (Kime and Golavatch, 2000). However, they have been poorly employed as indicators compared to Lepidoptera and Coleoptera (David et al., 1993). As *Arthrosphaera* species are endemic to the Western Ghats, their habitat preservation through restoration of soil qualities and restricted human interference are the most

important factors in developing future conservation strategies in forest and plantation development.

South African millipedes have been classified into site endemics, local endemics and regional endemics by Hamer and Slotow (2002). Many giant millipedes recovered from Madagascar were also endemic (*Sphaeromimus, Zoosphaerium*) (Wesener and Sierwald, 2005a, 2005b). Investigations focused on pill millipede distribution in forests or plantations in India and Sri Lanka are scanty. As *Arthrosphaera* are endemic to narrow distributional ranges in Southern India and Sri Lanka (Attems, 1936), it is assumed that the soil edaphic features are highly suitable for their survival and activity. Ashwini and Sridhar (2008) found four species of *Arthrosphaera* endemic to the Western Ghat forests. *Arthrosphaera magna* was most abundant in foothill locations, *Arthrosphaera* sp. 1 at single location of the Western Ghats, and *Arthrosphaera* sp. 2 and 3 were distributed at the Western Ghats as well as foothill locations. Even though 70 samples from 14 locations of the Western Ghats were assessed, none of them consists of more than one species of *Arthrosphaera* (Ashwini and Sridhar, 2008). In our study, the endemic nature of *Arthrosphaera* was also evident. Out of 10 species recovered, not more than one species was found per sampling point. However, 2–3 species were recorded in different sampling points of 200-m transect of the Western Ghat forests and plantations (Table 1). Some of the foothill locations of Western Ghat forests have terrain covered with boulders and rocks (Ashwini and Sridhar, 2008). *Arthrosphaera magna* were abundant in such locations, and probably, the crevices of boulders and rocks consist of sufficient organic matter. Such natural landscapes should not be disturbed or ignored during rehabilitation or plantation development. Sholas (forests restricted to mountain valleys) of the Western Ghats accumulate high amounts of organic matter and need special attention to investigate the distribution and activity of pill millipedes. Specific ecological conditions and soil edaphic features of the forest or plantation possessing more than one species of pill millipedes deserve special attention in future investigations.

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