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COMMUNICATION

Diversity of scorpions (Arachnida: Scorpiones) in Polonnaruwa Archaeological Reserve, Sri Lanka

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Abstract: Sri Lanka harbours 20 scorpion species belonging to four families, of which 15 are endemic. The distribution and ecology of scorpion fauna in Sri Lanka is poorly known. In this study, we surveyed the diversity of scorpions in the Polonnaruwa Archaeological Reserve in the dry zone of Sri Lanka. Microhabitats were thoroughly observed using the direct visual encounter method and UV lights from July to November 2018 for about seven hours (19.00–02.00 h) by two to three observers. Species, abundance, age/sex, and microhabitat features were recorded. Diversity indices, including α-diversity and β-diversity, were calculated. *Heterometrus swammerdami* was the most abundant species recorded, while *Isometrus thwaitesi* was the rarest. *Reddyanus loebli* and *R. besucheti* were common in both open and forest habitat types. *Charmus laneus* was recorded for the first time in Polonnaruwa. The highest Shannon Index and Margalef Diversity Index values were recorded in open habitats, but species evenness was low compared to forest habitats. Sørensen index values showed a 58% species similarity between two habitats. The results presented here contribute to the knowledge of the diversity of scorpions in these historically significant sites. This can serve as a basis for future research on the impact of habitat modification and fragmentation on populations, distribution and ecology of scorpions.

Keywords: Buthidae, diversity, dry zone, microhabitat, Scorpionidae.

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Author contribution: KBW did the field work and prepared the manuscript, LSW did the statistical analysis and prepared the manuscript and KBR prepared the manuscript.

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INTRODUCTION

Sri Lanka supports a high level of biodiversity, and hence Sri Lanka together with Western Ghats of India is considered a global biodiversity hotspot (Mayer 2000; Mittermeier et al. 2011). Most of the biodiversity research in Sri Lanka concerns charismatic, flagship fauna (Fernando et al. 2011; Nijman 2012; Kittle et al. 2017), paying less attention to small sized and enigmatic species. Invertebrates are among the poorly investigated taxa. A few published work available for butterflies (van der Poorten & van der Poorten 2016), bees (Karunaratne & Edirisinghe 2008), dragonflies (Bedjanič 2004), theraphosid spiders (Samarawckrama et al. 2005), land snails (Naggs et al. 2005) and freshwater crabs (Bahir et al. 2005) represent significant attempts to characterize little-known invertebrate fauna (Ranawana et al. 2013). Among invertebrate taxa, studies of scorpions have gained attention owing to their economic (Kularatne et al. 2015) and ecological importance. Recently, Kovařík et al. (2016, 2018, 2019) summarized 20 known scorpion species of Sri Lanka belonging to four families: Buthidae (13 species), Scorpionidae (five species) Hormuridae (one species), and Chaerilidae (one species), of which 15 species (75%) are endemic to the island.

The spatial distribution of scorpions is influenced by a range of climatic and environmental variables such as temperature, rainfall, elevation, slope, soil properties, vegetation type and land cover (Polis 1990; Prendini 2005). Sri Lanka has distinct types of habitats, including rain forest, dry mixed evergreen forest, montane forest, and shrub forest, which support scorpions (Ashton et al. 1997). Most scorpion species are distributed through the dry zone, and few are found in the wet zone of Sri Lanka (Kovařík et al. 2016). The objective of this study was to assess the diversity of scorpions in an archaeological reserve located in the ancient city of Polonnaruwa, in North-central Province, Sri Lanka, as a conservation initiative for scorpions. Additionally, the study aimed to provide important information on population structure (age/sex ratio), microhabitat preference, and community-level characteristics (species richness and diversity in two selected habitats). Since Polonnaruwa is a well-preserved historic site and tourist attraction, this study is relevant to the impact of tourism on the conservation of biological diversity.

MATERIALS AND METHOD

Study site

This study was carried out in the archaeological reserve in Polonnaruwa ancient city (7.9584N & 81.0027E) located in North-central Province, Sri Lanka, from early July to late November 2018. The selected study site with an area of 7.9km^2 was an isolated secondary forest patch consisting ancient monuments dating back to King Parakramabahu in the 12th Century, and surrounded by human settlements. We have divided the study area into two habitat types: open habitat and secondary forest (Image 1). Open habitat predominantly consists of ancient monuments maintained by the Central Cultural Fund, Sri Lanka, with scattered trees. Some parts of the open habitat encompass exposed bedrock with boulders, and the soil type is sand to gravel particle-sized soil with low/no leaf litter (Image 2a). Secondary forest habitat consists of a dry mixed evergreen forest dominating by *Cassia marginata* (Fabaceae), *Manilkara hexandra* (Sapotaceae), *Drypetes sepiaria* (Putranjivaceae), and *Ficus* sp. (Fabaceae), tree species (Abeynayake et al. 1993) and scattered amidst shrubs and herbs (Image 2b).

Survey

A pilot study was carried for two days in early July for habitat selection and species identification before the survey. All possible microhabitats, including both terrestrial and arboreal, were thoroughly observed using the direct visual encounter method with the aid of UV lights. Sampling was carried out by two to three observers and lasted for about seven hours (19.00–02.00 h). A total of 78 human hours were spent equally for open and forest habitats (39 human hours per each habitat). Abundance and age-sex classes were recorded as male, female, or juvenile. But burrowing scorpions were not classified into age/sex categories due to difficulties in excavating their burrows and habitat disruptions. Tree barks were observed up to 3m in height from the ground level. Tree heights were categorized into five height classes as 1: 0–60 cm, 2: 61–120 cm, 3: 121–180 cm, 4: 181–240 cm and 5: 241–300 cm. Tree diameter at breast height (DBH) was measured using a DBH tape. Tree DBH measures were categorized into five classes as 1: 0–120 cm, 2: 121–240 cm, 3: 241–360 cm, 4: 361–480 cm and 5: 481–600 cm. Photographs were taken using a Canon 750D camera with Canon EF 100mm f/2.8L Macro IS USM lens with an external flashlight. Identifications of the species were based on Kovařík et al. (2016).

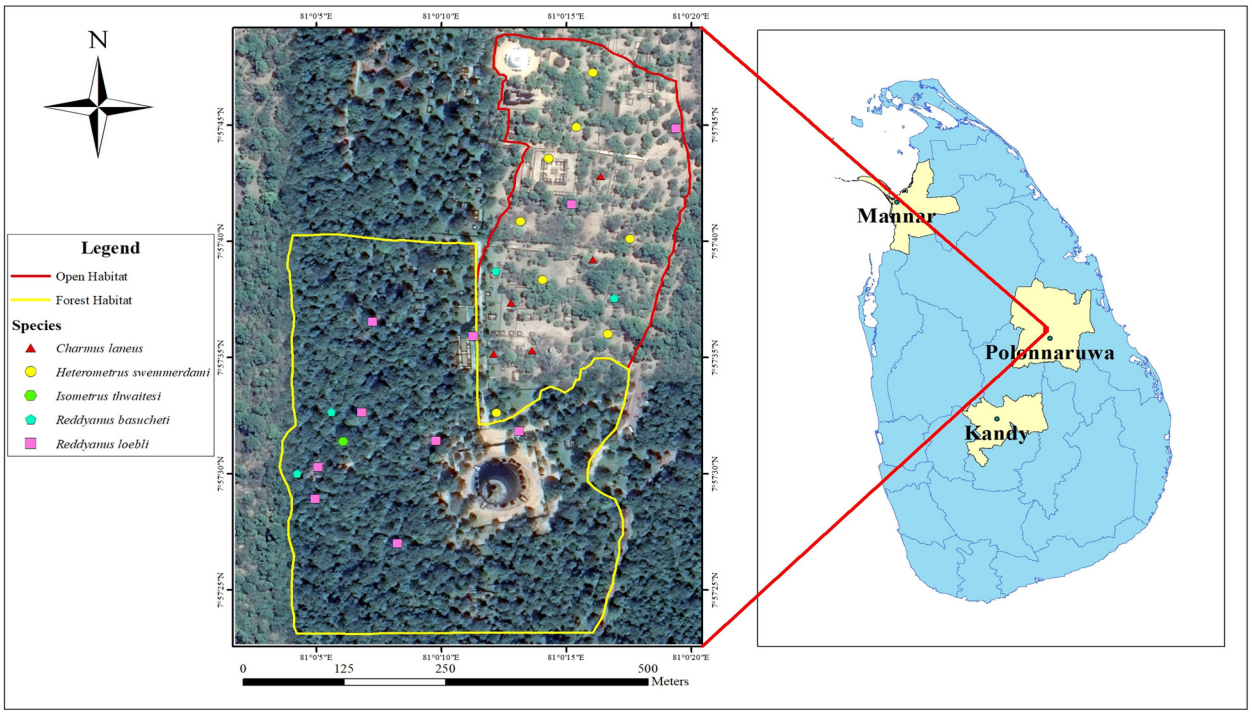

Image 1. Study site, Polonnaruwa Archaeological Reserve, Sri Lanka.

Image 2. Habitat types in Polonnaruwa Archaeological Reserve: a—open habitat | b—forest habitat. © Kumudu B WIjesooriya.

Statistical analysis

The α-diversity of scorpion species across open and forest habitat was calculated using the Shannon diversity index (H') separately for two habitats (Magurran 1988). Shannon evenness (E) was calculated to analyse the evenness of species across the forest and open habitats (Magurran 1988). Margalef's species richness index (D_{Mg}) was used to compare species richness across microhabitats (Magurran 1988). Bootstrap sampling using the means of each data set was carried out to assess 95% confidence intervals of Shannon Index (H'), Shannon Evenness (E) and Margalef Diversity Index (D_{Mg}) using R version 6.3.

The β-diversity, which represents unshared species, was measured by finding similarity or overlap between scorpion species composition across microhabitats, using Sørensen index. We employed chi-squared tests of independence to test the significant difference in the microhabitat preference (height and DBH) of scorpions between open and forest habitat types.

RESULTS

During the survey, five species of scorpions belonging to four genera in two families were recorded (Image 3). Of which, 28% of individuals belonged to family Buthidae, and 72% of individuals belonged to family Scorpionidae (Table 1). Observed four species of scorpions were terrestrial, and only one species, *Reddyanus loebli*, was arboreal. *Heterometrus swammerdami* (271 individuals) was abundant across the archaeological site, but its distribution was only confined to the open habitat. *Charmus laneus* was the second most abundant species (37 individuals) in open habitat. *Reddyanus loebli* (45 individuals) was the most abundant species in forest habitat. The least abundant species of the open and forest habitats were *Reddyanus besucheti* (nine individuals) and *Isometrus thwaitesi* (three individuals), respectively.

The highest number of individuals was recorded in open habitat (327 individuals) compared to forest habitat (52 individuals). Highest Shannon index (H') was recorded in open habitat but, species evenness was low compared to the forest habitat. Sørensen index was 0.5882 (or 58.82%), where *Reddyanus loebli* and *R. besucheti* were the common species recorded from both habitats (Table 2).

Tree height and DBH preference of arboreal *R. loebli* were varied. The highest occurrence height was recorded as 300 cm in a *Manilkara hexandra* tree, whereas the lowest occurrence height was 15 cm in a *Drypetes sepiaria* tree. Importantly, the highest number of individuals was recorded in height class 3, while the lowest number of individuals was recorded in height class 5 (Figure 1a). The average DBH was recorded as 330cm. The highest number of individuals was recorded in DBH class 4, whereas, at least was recorded in DBH class 2 (Figure 1b). However, there was no significant difference among tree height preference and habitats (χ^2= 2.947, DF = 4, p= 0.5667). Nevertheless, there was a significant difference in DBH preference and habitat type (χ^2= 18.041, DF = 4, p= 0.0012).

Table 1. Scorpion species found in Polonnaruwa Archaeological Reserve, Sri Lanka in 2018.

Family	Species
Buthidae (28%)	*Charmus laneus*
	Isometrus thwaitesi
	Reddyanus besucheti
	Reddyanus loebli
Scorpionidae (72%)	*Heterometrus swammerdami*

Table 2. Species diversity indices in Polonnaruwa Archaeological Reserve, Sri Lanka.

Diversity index	Open habitat	Forest habitat
No. of species (S)	4	3
Total number of individuals recorded (N)	327	52
Shannon Index (H')	0.6011	0.4869
Shannon Evenness (E)	0.4336	0.4432
Margalef Diversity Index (D_{Mg})	0.5181	0.5062
Sørensen index between open and forest habitat	0.5882	

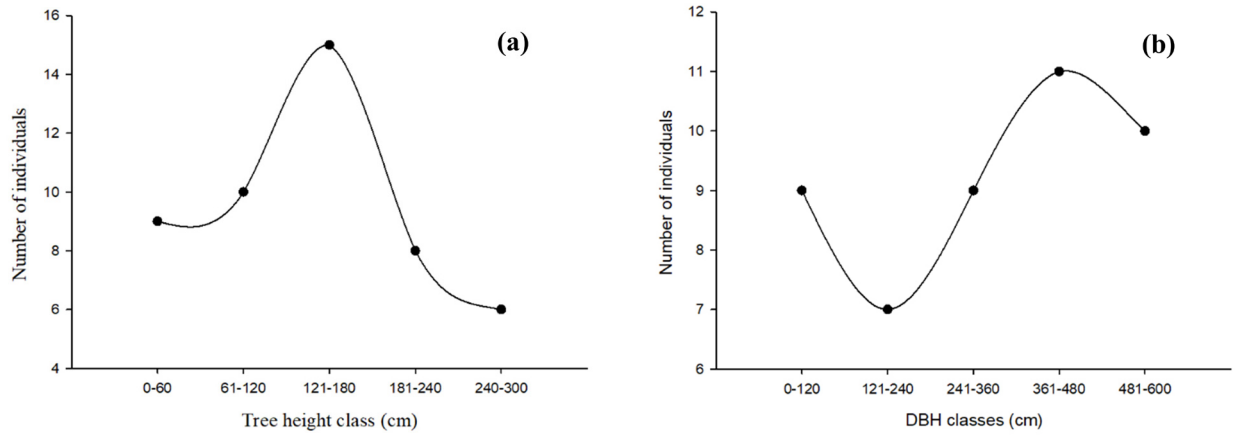

Figure 1. a—tree height preference of arboreal *Reddyanus loebli* | b—tree DBH preference of arboreal *Reddyanus loebli*.

DISCUSSION

The equatorial location of Sri Lanka and the complex topography of the island produce several distinct climatic zones and diversified habitats. The dry zone (60% of the island), intermediate zone (15%), and the wet zone (25%) are the major climatic zones. Though climatic and environmental factors and vegetation vary among these climatic zones, scorpion species are not confined to specific zones (Kovařík et al. 2016). Their distributions overlap, and only a few species are restricted to specific habitats, like *Hottentotta tamulus* from Jaffna peninsula, Sri Lanka (Ranawana et al. 2013). We recorded five species, of which four are endemic to Sri Lanka. In the present study, *Heterometrus swammerdami* was the most abundant species, whereas *Isometrus thwaitesi* was the rarest. *Reddyanus loebli* and *R. besucheti* are the only two species sharing both habitat types. Importantly, *Charmus laneus* was recorded for the first time in Polonnaruwa.

Heterometrus swammerdami was the only burrowing species in this study. They prefer to burrow in termite mounds, though they are not constructing burrows. They displayed sit and wait behaviour expecting possible prey with extended pedipalp and open chela. Most of the time, one adult can be seen in the opening of the termite mound burrow, and sometimes several juveniles can be observed with their mother. Due to their burrowing behaviour it is difficult to observe them closely to determine age and sex. Higher opportunities to access resources might account for their higher abundance. *Isometrus thwaitesi* is known as an arboreal species. Kovařík et al. (2016) found *I. thwaitesi* running on branches and trunks of trees, and also sitting on leaves 1–4 m in height. In this study, however, all three individuals were observed on the ground near a wood debris pile among leaf litter, and they were only observed in forest habitat. The presence of a higher stratum in the forest habitat compared to open habitat could be influencing scorpion abundance by providing better foraging areas where moonlight cannot reach easily (Nime et al. 2013).

Reddyanus loebli is a tree-dwelling species. Most dry zone trees have fissured barks as an adaptation for harsh weather conditions, and this gives a suitable microhabitat. They were mostly (93.2%) observed in *Manilkara hexandra*, *Drypetes sepiaria*, and *Ficus* sp. trees among and under the scales, within the cracks in the bark. Most of the observed individuals displayed sit and wait behaviour under the scales of the tree bark, with extended pedipalp and open chela, remaining 6.8% individuals observed in brick walls of ruins. All juvenile individuals were observed in forest habitat. Vegetation cover in the forest provides a safe habitat from predators for these tree-dwelling scorpions. *Reddyanus besucheti* is a terrestrial species that is also found in both habitats. In the forest habitat, 55.6% of individuals were observed on the leaf litter, whereas 44.4% were observed in open habitat on sand.

Charmus laneus was the second most abundant scorpion species observed only in the open habitat. Lourenço (2002) recorded this species from Mannar District and in Wilpattu National Park (Northwestern part of Sri Lanka) and Kovařík et al. (2016) recorded this species from Puttalam District and Eluwankulama (western part of Sri Lanka). Therefore, this is the first record of *C. laneus* from the Polonnaruwa District (eastern part of the island), which is about 200km away from Mannar District. Their distribution was confined to the surrounding of exposed bedrock in an open area. Unlike *H. swammerdami,* they were very active and observed running among small grasses near to exposed bedrock on open land. None of the individuals was observed in the open grassy plains or among leaf litter.

The total Shannon diversity index was calculated as 1.0880 for both open and forest habitat. Since the normal range of the Shannon index is 1.5–3.5 (Magurran 1988), this value for the entire site indicates shallow species diversity compared to other taxa. This low alpha diversity is common among predators like scorpions because they are well known for their restricted movement, cannibalism, predation by nocturnal predators, habitat specificity, food size specificity, extreme climate adaptability, and adaptive radiation (Newlands 1972; Polis 1990; Pande et al. 2004). Together with a longer life span than many invertebrates, these factors may act as constraining factors as far as species diversity is a concern (Pande et al. 2012). Since, the 95% confidence intervals of Shannon index values are not overlapped, the Shannon index value for open habitat is significantly different than the forest habitat (Figure 3a). This reflects open habitat has higher scorpion diversity compared to the forest habitat, because open habitat contains scattered boulders. Crevices under boulders are a preferred habitat for scorpions to spend the day time.

The number of species reflects the species richness. Species richness is strongly dependent on sampling size and effort (Help et al. 1998). The species abundance is often a more sensitive measure of a diversity parameter than species richness alone (Kempton 1979). To overcome this problem, the Margalef index was used. Since, the 95% confidence intervals for the Margalef

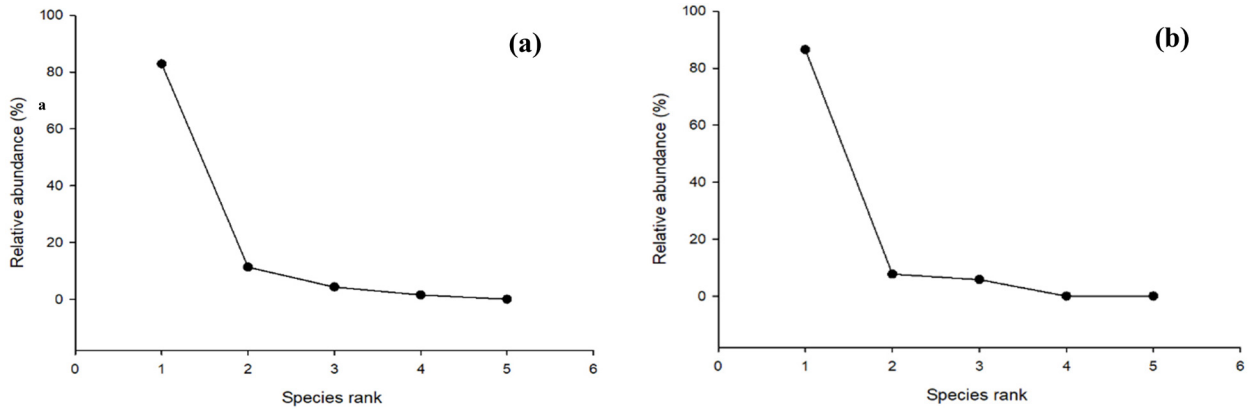

Figure 2. a—Whittaker plot for open habitat Rank 1: *H. swammerdami*, 2: *C. laneus*, 3: *R. loebli*, 4: *R. besucheti*, 5: *I. thwaitesi* | b—Whittaker plot for forest habitat Rank 1: *R. loebli*, 2: *R. besucheti*, 3: *I. thwaitesi*, 4/5: *C. laneus*, *H. swammerdami*.

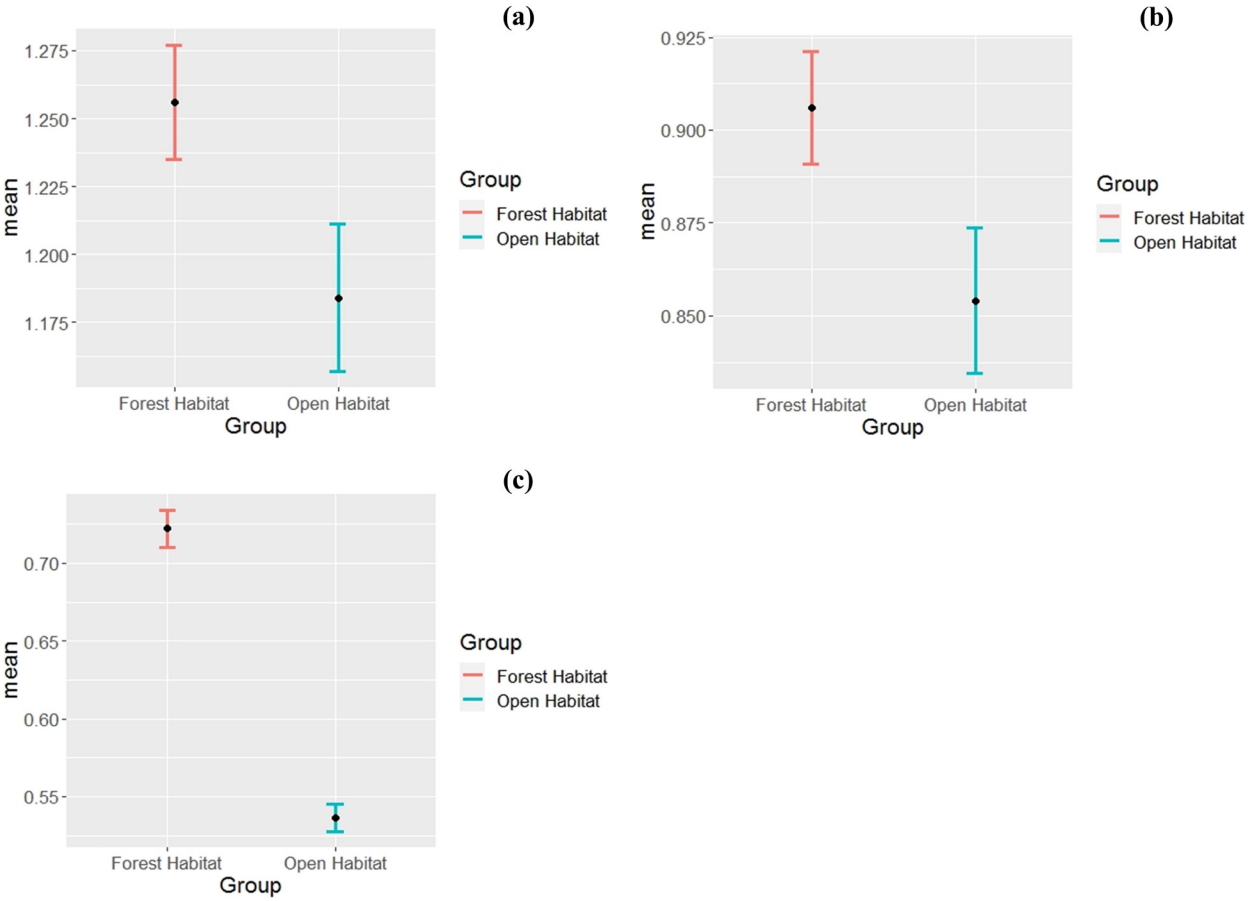

Figure 3. 95% confident intervals of a—Shannon index (H') | b—Shannon evenness (E) | c—Margalef diversity Index (D_{Mg}) for forest and open habitat.

index values in two habitats are not overlapped with each other, the Margalef index value for open habitat is significantly different from forest habitat (Figure 3.c). This index reflects two habitats have almost similar in species richness. Species evenness is a measure of how similar species are equally abundant (Lloyd & Ghelardi 1964; Magurran 2004). Evenness value range from 0.0-1.0. When the species are equally abundant, evenness value is greater. When the few species are dominant in the community, evenness is less (Magurran 2004). Since

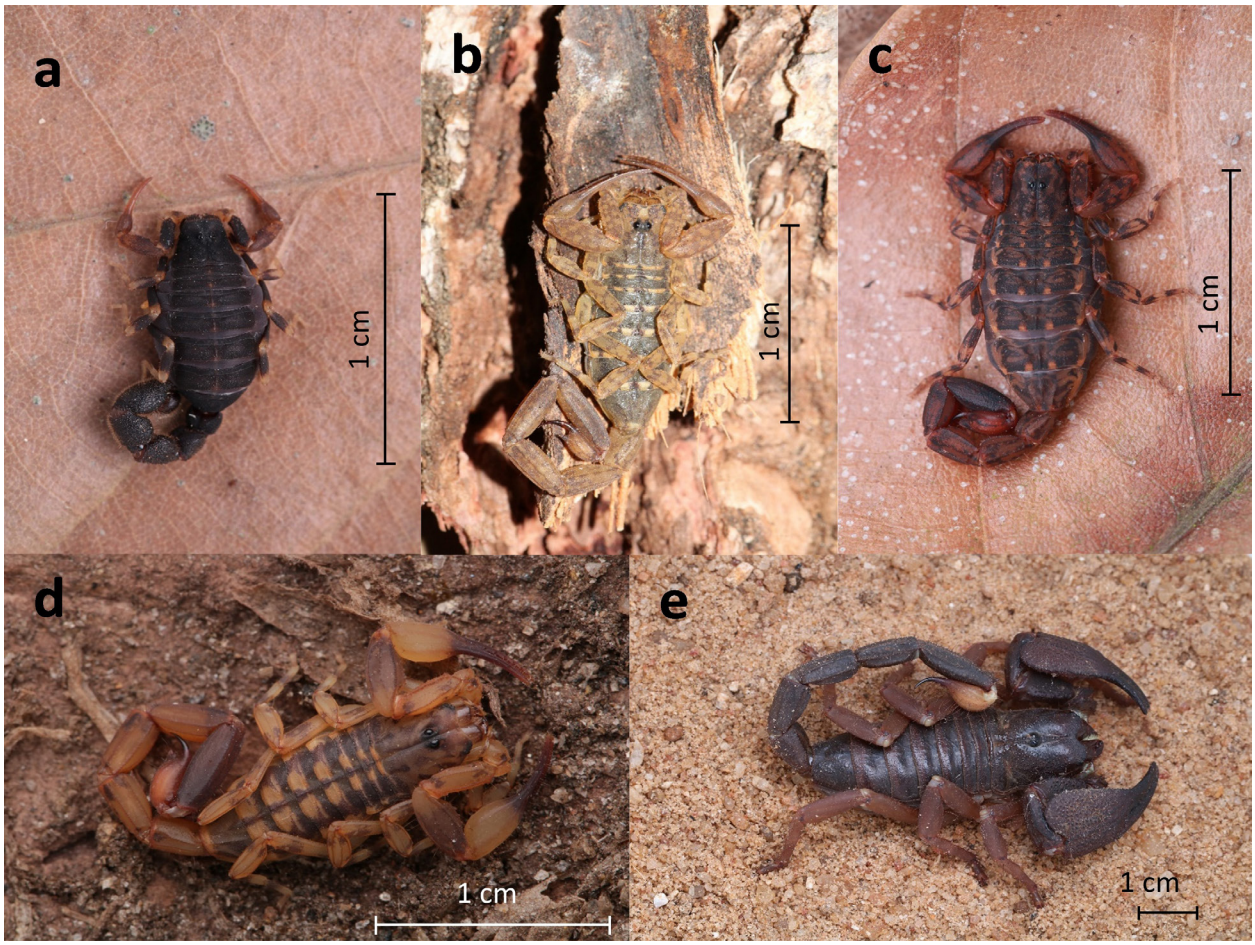

Image 3. Scorpion species found in Polonnaruwa Archaeological Reserve, Sri Lanka: a—*Charmus laneus* female | b—*Isometrus thwaitesi* female | c—*Reddyanus besucheti* female | d—*Reddyanus loebli* female | e—*Heterometrus swammerdami* female. © Kumudu B Wijesooriya

the 95% confidence intervals for the Shannon evenness values of two habitats are not overlapped, the Shannon evenness values are significantly different in the forest and open habitats (Figure 3b). The higher Shannon evenness value of forest habitat explains that scorpions found in forest habitat were more equally abundant than the open habitat due to the high dominance of *H. swammerdami* in open habitats (Figure 2a). Similarly, forest habitat has evenness value below 0.5, which is due to the high dominance of *R. loebli* in forest habitat (Figure 2b). Beta diversity of habitats compares the species similarity between the two habitats (Magurran 2004). To compare the similarity between two habitats, which was calculated as 0.5882 in Sørensen index in a way reflecting a more than 50% shared species between two habitats. Similar results were observed in previous studies as intra-specific and inter-specific coexistence in several species of scorpions (Kaltsas et al. 2009; Shehab et al. 2011; Lira et al. 2013). Thus, species might either co-occur in the same habitat or co-occur in the same shelter (Warburg 2000).

Arboreal scorpion *R. loebli* prefers to occupy around heights of 121–180 cm range. This might be mainly due to foraging opportunities and predator pressure. They are considered efficient predators of Isoptera, Hymenoptera, Diptera, Hemiptera, while civets, mongoose, land monitors, and lizards are the predators of them (personal observation). Thus, *R. loebli* might prefer to forage in this favourable height range without being consumed by another predator. On the other hand, *R. loebli* prefers to inhabit around DBH of 361–480 cm range, which is above the average DBH level. The diameter of a tree considered as contemplate of a niche area for an arboreal scorpion. Thus, they favour occupying a much larger niche for obtaining more resources like prey, sites to rest and hide from predators.

In conclusion, the five species reported in the Archaeological site of Polonnaruwa suggest high scorpion

richness in this area. This highlights the importance of conservation of historic ruins and forest patches of the archaeological site to maintain scorpion fauna. Thus, the results presented here contribute to the knowledge of the diversity of scorpions in these historically significant sites that can serve as a basis for future research on the impact of habitat modification and fragmentation on the population, distribution, and ecology of scorpions.

REFERENCES

Abeynayake, K., R.N. de Fonseka & R. Sandhya (1993). A Survey of the vegetation of Damila Mahasaya in Polonnaruwa. *Journal of the Royal Asiatic Society of Sri Lanka* 38: 127–140.

Ashton, M.S., S. Gunatilleke, N. de Zoysa, M.D. Dassanayake, N. Gunatilleke & S. Wijesundera (1997). *A Field Guide to the Common Trees and Shrubs of Sri Lanka.* Wildlife Heritage Trust Publications (Pvt.) Ltd, Colombo, 430pp.

Bahir, M.M., P.K.L. Ng, K. Crandall & R. Pethiyagoda (2005). A conservation assessment of the freshwater crabs of Sri Lanka. *The Raffles Bulletin of Zoology* 12: 121–126.

Bedjanič, M. (2004). Odonata fauna of Sri Lanka: Research state and threat status. *International Journal of Odonatology* 7(2): 279–294. https://doi.org/10.1080/13887890.2004.9748216

Fernando, P., J. Jayewardene, T. Prasad, W. Hendavitharana & J. Pastorini (2011). Current status of Asian elephants in Sri Lanka. *Gajah* 35: 93–103. https://doi.org/10.18987/jjwrs.37.0_37

Help, C.H.R., P.M.J. Herman & K. Soetaert (1998). Indices of diversity and evenness. *Oceanis* 24: 61–87.

Kaltsas, D., I. Stathi & M. Mylonas (2009). Intraspecific differentiation of social behavior and shelter selection in *Mesobuthus gibbosus* (Brullé, 1832) (Scorpiones: Buthidae). *Journal of Ethology* 27: 467–473. https://doi.org/10.1007/s10164-008-0144-6

Karunaratne, I.W.A.P. & J.P. Edirisinghe (2008). Keys for the identification of common bees of Sri Lanka. *Journal of the National Science Foundation of Sri Lanka* 36(1): 69–89. https://doi.org/10.4038/jnsfsr.v36i1.134

Kempton, R. (1979). The Structure of Species Abundance and Measurement of Diversity. *Biometrics* 35: 307–321.

Kittle, A.M., A.C. Watson & T.S.P. Fernando (2017). The ecology and behaviour of a protected area Sri Lankan leopard (*Panthera pardus kotiya*) population. *Tropical Ecology* 58(1): 71–86.

Kovařík, F., G. Lowe, K.B. Ranawana, D. Hoferek, V.A.S. Jayarathne, J. Plíšková & F. Šťáhlavský (2016). Scorpions of Sri Lanka (Scorpiones: Buthidae, Chaerilidae, Scorpionidae) with description of four new species of the genera Charmus Karsch, 1879 and Reddyanus Vachon, 1972, stat. n. *Euscorpius* 220: 1–133.

Kovařík, F., K.B. Ranawana, V.A.S. Jayarathne, D. Hoferek & f. Šťáhlavský (2019). Scorpions of Sri Lanka (Arachnida: Scorpiones). Part III. *Heterometrus yaleensis* sp. n. (Scorpionidae). *Euscorpius* 283: 1–13.

Kovařík, F., K.B. Ranawana, V.A.S. Jayarathne, S. Karunarathna & A. Ullrich (2018). Scorpions of Sri Lanka (Arachnida: Scorpiones). Part II. family Hormuridae *Euscorpius* 258: 1-8. http://www.science.marshall.edu/fet/euscorpius/example.pdf

Kularatne, S.A.M., N.P. Dinamithra, S. Sivansuthan, K.G.A.D. Weerakoon, B.Thillaimpalam, V. Kalyanasundram & K.B. Ranawana (2015). Clinico-epidemiology of stings and envenoming of *Hottentotta tamulus* (Scorpiones: Buthidae), the Indian red scorpion from Jaffna Peninsula in northern Sri Lanka. *Toxicon* 93: 85–89. https://doi.org/10.1016/j.toxicon.2014.11.225

Lira, A.F.A., A.M. Souza, A.A.C. Silva Filho & C.M.R. Albuquerque (2013). Spatio-temporal microhabitat use by two co-occurring species of scorpions in Atlantic rainforest in Brazil. *Zoology* 116: 182–185. https://doi.org/10.1016/j.zool.2013.01.002

Lloyd, M. & R.J. Ghelardi (1964). A table for calculating theequitability'component of species diversity. *The Journal of Animal Ecology* 33: 217-225pp. https://doi.org/10.2307/2628

Lourenço, W.R. (2002). Further taxonomic considerations about the genus Charmus Karsch, 1879 (Scorpiones, Buthidae), with the description of a new species from Sri Lanka. *Entomologische Mitteilungen aus dem Zoologischen Museum Hamburg* 14(165): 17–25.

Magurran, A.E. (1988). *Ecological Diversity and its Measurement*. Princeton University Press, London, 168pp.

Magurran, A.E. (2004). *Measuring Biologica Diversity*. Blackwell Publishing, Victoria, 256pp.

Mayer, P. (2000). Hot Spot: Forest policy in Europe: achievements of the MCPFE and challenges ahead. *Forest Policy and Economics* 1: 177–185. https://doi.org/10.1016/s1389-9341(00)00018-6

Mittermeier, R.A., W.R. Turner, F.W. Larsen, T.M. Brooks & C. Gascon (2011). Global Biodiversity Conservation: The Critical Role of Hotspots, pp. 3–22. In: Zachos, F. & J. Habel (eds.). *Biodiversity Hotspots*. Springer, Berlin, Heidelberg, 565pp. https://doi.org/10.1007/978-3-642-20992-5

Naggs, F., D. Raheem, K.B. Ranawana & Y. Mapatuna (2005). The darwin initiative project on Sri Lankan land snails : patterns of diversity in Sri Lankan forests. *The Raffles Bulletin of Zoology* 12: 23–29.

Newlands, G. (1972). Ecological adaptations of Kruger National Park scorpionids (Arachnida: Scorpionides). *Koedoe* 15: 37–48. https://doi.org/10.4102/koedoe.v15i1.666

Nijman, V. (2012). Purple-faced langurs in human-modified environments feeding on cultivated fruits: a comment to Dela (2007, 2012). *International Journal of Primatology* 33: 743–748. https://doi.org/10.1007/s10764-012-9609-0

Nime, M.F., F. Casanoves, D.E. Vrech & C.I. Mattoni (2013). Relationship between environmental variables and surface activity of scorpions in the Arid Chaco ecoregion of Argentina. *Invertebrate Biology* 132(2): 1–11. https://doi.org/10.1111/ivb.12019

Pande, S., D. Bastawade, A. Padhye & A. Pawashe (2012). Diversity of scorpion fauna of Saswad-Jejuri, Pune District, Maharashtra, western India. *Journal of Threatened Taxa* 4(2): 2381–2389. https://doi.org/10.11609/jott.o2910.2381-9

Pande, S., A. Pawashe, D.B. Bastawade & P.P. Kulkarni (2004). Scorpions and molluscs: Some new dietary records for Spotted Owlet Athene brama in India. *Newsletter for Ornithologists* 1(5): 68–70.

Prendini, L. (2005). Scorpion diversity and distribution in southern Africa: Pattern and process, pp. 25–68. In: Huber, B.A., B.J. Sinclair & K.-H. Lampe (eds.) *African Biodiversity: Molecules, Organisms, Ecosystems*. Proceedings of the 5th International Symposium on Tropical Biology, Museum Alexander Koenig, Bonn. Springer, Verlag, New York, 68pp.

Polis, G.A. (1990). Life history. *The Biology of Scorpions*. Stanford University Press, Stanford, 293pp.

Ranawana, K.B., N.P. Dinamithra, S. Sivansuthan, I.I. Nagasena, F. Kovařík & S.A.M. Kularatne (2013). First report on *Hottentotta tamulus* (Scorpiones: Buthidae) from Sri Lanka, and its medical importance. *Euscorpius* 155: 1–10. https://doi.org/10.18590/euscorpius.2013.vol2013.iss155.1

Samarawckrama, V.A.M.P.K., M.D.B.G. Janananda, K.B. Ranawana & A. Smith (2005). Study of the distribution of the Genus *Poecilotheria* of the Family Theraphosidae in Sri Lanka. *Ceylone Journal of Science* 34: 75–86.

Shehab, A.H., Z.S. Amr & J.A. Lindsell (2011). Ecology and biology of scorpions in Palmyra, Syria. *Turkish Journal of Zoology* 35(3): 333–341. https://doi.org/10.3906/zoo-0904-19

van der Poorten, G.M. & N.E. van der Poorten (2016). *The Butterfly Fauna of Sri Lanka*. Lepodon Books, Torronto, 418pp.

Warburg, M.R. (2000). Intra- and interspecific cohabitation of scorpions in the field and the effect of density, food, and shelter on their interactions. *Journal of Ethology* 18: 59–63. https://doi.org/10.1007/s101640070026

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