A ready reckoner of fertilizer doses has been prepared considering different yield targets at different fertility status of the soils (Table 4) which will be useful for extension officers, scientists and farmers alike in balanced fertilization of crop for targeted yield. These equations will be useful in red, laterite and yellow soils (Inceptisols and Alfisols) which constitute 84% of the total geographical area of Odisha.

1. Sivaprakash, K. R., Prashanth, S. R., Mohanty, B. P. and Parida, A., Genetic diversity of black gram (*Vigna mungo*) landraces as evaluated by amplified fragment length polymorphism markers. *Curr. Sci.*, 2004, **86**(10), 1411–1416.
2. Dixit, S., Impact of bio-fertilization on morphological parameters of *Vigna mungo* (L.) Hepper. *Int. J. Res. Plant Sci.*, 2013, **3**(1), 10–13.
3. Chatterjee, B. N. and Bhattacharya, K. K., *Principles and Practices of Grain Legume Production*, Oxford and IBH Publication Co, New Delhi, 1994, pp. 434.
4. Vavilov, N. I., Origin variation, immunity of cultivated plants. *Chronica Bot*., 1926, **13**, 364.
5. Poehlman, J. M., History, description, classification and origin. In *The Mungbean* (ed. Poehlman, J. M.), West View, Boulder, 1991, pp. 6–21.
6. Gour, Y. D., Microbiology, physiology and agronomy of nitrogen fixation: Legume-Rhizobium symbiosis. *Proc. Indian Nat. Sci. Acad. Ser. B*, 1993, **59**, 333–358.
7. Ali, M., Gupta, S., Singh, B. B. and Kumar, S., Role of plant introductions in varietal development of pulses in India. *Indian J. Plant Genet. Resour.*, 2006, **19**, 346–352.
8. Rathi, B. K., Jain, A. K., Kumar, S. and Panwar, J. D. S., Response of Rhizobium inoculation with sulphur and micronutrients on yield and yield attributes of black gram. *Legume Res.*, 2009, **32**, 62–64.
9. Pandey, N., Gupta, B. and Pathak, G. C., Foliar application of zinc at flowering stage improves plants performance, yield and yield attributes of black gram. *Indian J. Exp. Biol.*, 2013, **5**, 548–555.
10. Khaliq, A., Abbasi, M. K. and Hussain, T., Effect of integrated use of organic and inorganic nutrient sources with effective microorganisms (EM) on seed cotton yield in Pakistan. *Bioresour. Technol.*, 2006, **97**, 697–972.
11. Sharma, U. and Chauhan, J. K., Influence of integrated use of inorganic and organic sources of nutrients on growth and production of pea. *J. Farm Sci.*, 2011, **1**(1), 14–18.
12. Kanwar, J. S., Soil fertility evaluation. In *Proc. Int. Symp. Soil fertility Evaluation*, New Delhi, 1971, 1(1), 103–113,
13. Troug E., Fifty years of soil testing. Trans. 7th International Congress Soil Science, Wiscansin, USA, Part-III and IV, 1960, pp. 36–45.
14. Ramamoorty, B., Narasimhan, R. L. and Dinesh, R., Fertilizer application for specific yield targets of Sonera-64 (Wheat). *Ind. Fmg*., 1967, **17**, 43–45.
15. Pradhan, N. K., Mishra, A., Padhy, G. P. and Jena, B., Soil test based fertilizer recommendation for targeted yield of groundnut (*Arachis hypogaea*) under rice–groundnut cropping system in an *Inceptisol* of Orissa. *Environ. Ecol.*, 2007, **25**(2), 478–480.
16. Mishra, A., Pradhan, N. K., Nanda, S. K. and Jena, B., Soil test based fertilizer recommendation for targeted yield of sesamum (*Sesamum indicum*) under rice–sesamum cropping system in an *Inceptisol* of Orissa. *Environ. Ecol.*, 2008, **26**(4A), 1756–1758.
17. Mishra, A., Nanda, S. K., Pradhan, N. K., Jena, B. and Mukhi, S. K., Soil test based fertilizer recommendation for targeted yield of rice (*Oryza sativa*) under rice-rice cropping system in an *Inceptisol* of Orissa. Extended summaries-symposium on resource management in corps and cropping systems under changing climate, ISA and OUAT, Bhubaneswar, 7–8 May 2009.
18. Mishra, A., Dash, B. B., Nanda, S. K., Das, D., Sarangi, J., Panda, N. and Mishra, H. T., Study of soil taxonomy as a basis for extrapolation of fertilizer prescription equations for targeted yield of crops to different Areas – a case study in a *Vertic Ustochrept* of Orissa. *J. Res. Orissa Univ. Agric. Tech. Spec. Issue*, 2011, **1**(1), 207–214.
19. Gogoi, A., Mishra, A. and Jena, B., Soil test-based fertilizer recommendation for targeted yield of pumpkin (*Cucurbita moschata*) under rice-pumpkin cropping system in an *Inceptisol* of Orissa. *Environ. Ecol.*, 2011, **29**(2), 574–576.
20. Mishra, A., Dash, B. B., Nanda, S. K. and Das, D., Soil test based fertilizer recommendation for targeted yield of lady's finger (*Abelmoschus esculentus*) under rice–lady's finger cropping system in an *Ustochrept* of Orissa. *Environ. Ecol.*, 2013, **31**(1), 58–61.
21. Mishra, A., Dash, B. B., Nanda, S. K., Das, D. and Dey, P., Soil test based fertilizer recommendation for targeted yield of tomato (*Lycopersicon esculentum*) under rice–tomato cropping system in an *Ustochrept* of Odisha. *Environ. Ecol.*, 2013, **31**(2A), 655–658.
22. Jackson, M. L., *Soil Chemical Analysis*, Prentice Hall, New Delhi, 1973, p. 497.

Received 2 September 2015; revised accepted 28 February 2017

doi: 10.18520/cs/v113/i02/314-317

Ants indicate urbanization pressure in sacred groves of southwest India: A pilot study

T. P. Rajesh, U. Prashanth Ballullaya, Parvathy Surendran and Palatty Allesh Sinu*

Ecology and Evolutionary Biology Laboratory,
Department of Animal Science, Central University of Kerala,
Padannakad 671 314, India

Sacred groves may contain remnants of pristine and primary forests outside the state-owned protected area system. As they are small fragments and located in the neighbourhood of human settlements, towns, and cities, they are likely to be affected by urbanization. We studied the effect of urbanization on the ecosystem health of sacred groves of Kerala using litter-dwelling ants as the indicator taxa. Ants were pitfall-trapped (10–12 traps/sacred grove) from three rural and two urban sacred groves, and identified to species. Overall, 1,119 ants of 32 species and 6 subfamilies (Aenictinae, Dolichoderinae, Ectatomminae, Formicinae, Myrmicinae and Ponerinae) were collected. This corresponds to 76.54% of the estimated

*For correspondence. (e-mail: sinu@cukerala.ac.in)

species richness. Urbanization had little impact on the species diversity of ants. Abundance was remarkably high in urban sacred groves, mainly due to higher abundance of generalist and invasive species. The effect of urbanization was indicated by different ant assemblages. Rural sacred groves had nine species and three subfamilies exclusive to them as against the five exclusive species of urban sacred groves. Urban sacred groves were characterized by high abundance of *Anoplolepis gracilipes*, a globally important invasive species. Sacred groves were clustered based on the rural–urban gradient as hypothesized by the study.

Keywords: Biodiversity, urbanization, sacred grove, ants, *Anoplolepis gracilipes*, invasive species, Western Ghats, biotic invasion.

THE sacred groves of India would be the last few relics of the pristine and primary forests that stand outside the state-owned protected area system in rural and urban areas[1–4]. According to Hindu religion[1], these groves are created for worshipping God. However, they are now globally renowned Indigenous Community Conserved Areas of IUCN[4]. These groves have historical existence from the pre-agricultural era and most of these groves conserve pristine vegetation[1]. As they are seen in all altitudes and latitudes in the Western Ghats and beyond, in the highly populated plains including coastal plains, in Tamil Nadu, Kerala, Karnataka and Maharashtra, their existence is vital for sustaining local and regional biodiversity and maintaining ecosystem functions, such as water security[1–3,5]. Cultural beliefs were the major driving force behind the conservation of these forests even today[4,6]. As sacred groves are fragments of small forests distributed in the mosaic of human-influenced landscape, they are likely to be affected by anthropogenic disturbance and urbanization. According to recent government records, more than 90% of the sacred groves of Kerala have lost the forest cover[6]. Today Kerala has about 1200 sacred groves, that are mostly seen in coastal plains of Alappuzha district and in north Malabar region[6]. Unlike the rich knowledge available on plant biodiversity of the sacred groves[3,7], little is known about the animal biodiversity of sacred groves[8] and how environmental degradation is affecting its biodiversity.

Ground insects, particularly ants, owing to their ubiquitous nature, greater species diversity and functional diversity, dominance, and ability to respond to even subtle changes in the environment are considered as prime indicator of different ecosystem processes and changes. Land use change, forest disturbance, fragmentation, climate change and urbanization are affecting biodiversity and ecosystem functions[8–16]. We used litter-dwelling ant community to study the impact of urbanization on leaf sacred groves with the working hypothesis that urbanization affects ant diversity and ant assemblage of the sacred groves.

The present study was made in the sacred groves of Malabar region in Kannur and Kasaragod districts during November 2013–May 2014. Five sacred groves were selected (Table 1); two (Mannampurathu kavu and Puthiyaparampathu kavu) located in urbanized towns (hereafter, urban sacred groves) and three (Kammadam kavu, Konnakadu kavu and Edyilakad kavu) located in rural village environment in Bheemanadi, Konnakadu and Valiya paramba villages (hereinafter, rural sacred groves). The average distance between the study locations was about 20 km. These sacred groves in the urban–rural scale are located as follows: Mannampurathu kavu > Puthiyparampathu kavu > Edayilakadu kavu > Konnakadu kavu > Kammadam kavu (Table 1). Regardless of the location, all sacred groves contain thick and dense semi-evergreen forests dominated by *Hopea ponga*, *Syzygium travancoricum*, *Tabernaemontana heyneana*, *Dalbergia horrida*, *Holigarna arnottiana*, *Cinnamomum malabatrum*, *Diospyros* sp., *Flacourtia montana*, *Hydnocarpus pendandra*, *Ficus beddomie*, *Lagerstroemia microcarpa*, *Hopea parviflora*, *Syzygium cumini*, *Memecylon* sp., *Myristica fatua*, *Myristica malabarica* (pers. observ.).

We used pitfall traps to sample the litter-dwelling ants, which are known to generate relative abundance of litter-dwelling ants from fragmented forests[9,13,17]. In each sacred grove, 10–12 pitfall traps were used to sample the ants. The traps were placed in a 100 or 120 m long line transect, which was placed 100 m inside the forest from the edge to reduce the edge effect. The inter-trap distance of 10 m was kept constant in all study sites. The pitfall trap is a plastic container (12 cm depth × 10 cm radius) flushed inside the ground, with trap mouth level intact with soil surface. Ethanol (25 ml of 70%) was used as a preservative in the pitfall traps. The traps were operated for five continuous days before retrieval. Ants were then sorted out from the mixture of other insects and debris from each pitfall trap and preserved in 90% ethanol. Ants were identified to species. Voucher specimens were mounted and the remaining individuals were preserved in 90% ethanol in the natural history museum of the Central University of Kerala.

Ant species richness and abundance were considered as primary measures of diversity of the sacred groves. Jackknife 1 was considered as a measure of estimated species richness[18]. Shannon diversity and Simpson's evenness were considered as the estimated diversity measures. Sacred groves were compared based on mean ant species richness and mean ant abundance per pitfall trap; one-way ANOVA test was used for the comparison. Ant abundances were transformed into a 6-order standard ordinal scale: 1, 1 ant; 2, 2–5 ants; 3, 6–10 ants; 4, 11–20 ants; 5, 21–50 ants; 6, >50 ants[15,19]. We calculated mean ant species richness and mean ant abundance per sacred grove on pooled pitfalls, and mean species richness and abundance per trap per sacred grove to compare ant diversity between rural and urban sacred groves; Student's

Table 1. Details of the study locations

Location	Geographical coordinates	Forest area (ha)	Canopy height (m)	GBH (mean ± SD) (cm)	Tree density/ 50 sq. m	Canopy cover (%)	Litter bed size (cm)
Mannampurathu kavu	12°15.463′N, 75°07.935′E	7	34	59.47 ± 84.53	55	80	4.8
Puthiyaparampathu kavu	12°15.825′N, 75°08.186′E	8	21.5	71.46 ± 48	41	70	5.3
Edayilakad kavu	12°08.141′N, 75°09.392′E	11	24.6	48 ± 24.67	181	80	5.5
Kammadam kavu	12°18.681′N, 75°18.956′E	24	45	202 ± 64.76	76	87	6.4
Konnakadu kavu	12°17.940′N, 75°18.126′E	20	40	141 ± 34.54	87	90	6

Table 2. Ant fauna collected from the sacred groves of North Malabar region of Kerala state, India

Subfamily species	Abundance
Aenictinae	2
Aenictus aitkeni Forel	1
Aenictus brevicornis (Mayr)	1
Dolichoderinae	41
Dolichorus sp.	10
Irridomyrmex sp.	1
Tapinoma melonocephalum (Fabricius)	30
Ectatomminae	1
Gnamptogenys coxalis (Roger)	1
Formicinae	306
Acropyga acutiventris Roger	3
Anoplolepis gracilipes (Smith)	275
Camponotus irritans (Smith)	4
Camponotus paria Emery	2
Nylanderia sp.	1
Oechophylla smarigdina (Fabrcius)	4
Paratrechina longicornis (Lactaralle)	3
Prenolepis sp.	13
Myrmicinae	680
Crematogaster sp. 2	2
Crematogaster sp. 1	19
Lophomyrmex quadrispionosus (Jerdon)	2
Monomorium floricula (Jerdon)	156
Monomorium latinode (Mayr)	3
Monomorium sp.	89
Oligomyrmex sp.	47
Pheidole sp.	232
Pheidole sp. 1	5
Strumigenys sp.	1
Tetramorium coonoorense Forel	124
Ponerinae	89
Anochetus graeffei Mayr	3
Diacamma rugosum (LeGuiilou)	43
Hypoponera sp.	3
Odontomachus haematodus (Linnaeus)	25
Pachycondylla annamitus (Andre)	1
Pachycondyla leeuwenhoeki (Forel)	5
Pachycondylla rufipes (Jerdon)	10

t-test was used for the comparison. The ant abundance data was log-transformed before using it in parametric analysis. Individual-based rarefied species richness was calculated to account for the difference in the number of sampling plots used between rural and urban sacred groves. Estimated species richness (Jack-knife 1) was used to understand the percentage of species captured in the present sampling effort. Rank abundance curves were used to understand whether the dominant ant species shifted between the urban and rural sacred groves. Mean ant abundance per pitfall trap per sacred grove was used to construct the rank abundance curves to account for the plausible extreme variation in ant abundance among pitfall traps and sacred groves. Mean ant abundance per trap took care of distortions in an ant abundances of a few species in few pitfall traps, possibly caused by accidental placement of the trap close to an ant nest. It also gives a clear estimate of ant fauna based on their daily activity on the ground. The ant species assemblage (presence–absence; Sorensen similarity index) data was used to examine similarity of sacred groves. All analyses were performed in R[20] and EstimateS9.0 (ref. 21).

We collected 1119 ants of 32 species and 6 subfamilies, viz. Aenictinae, Dolichoderinae, Ectatomminae, Formicinae, Myrmicinae and Ponerinae (Table 2). *Anoplolepis gracilipes* (Formincinae), *Tapinoma melanocephalum* (Dolichoderinae), *Pheidole* sp., *Monomorium floricula* and *Tetramorium coonoorense* (Myrmicinae), *Diacamma rugosum* and *Odontomachus haematodus* were characteristic (generalistic) species of respective subfamilies by their abundance.

Based on the estimated species richness (Jack-knife 1 = 41.81), we captured 76.54% of species in the litter stratum of the sacred groves. This varied between 63% and 83% of the species estimated for individual sacred groves (Table 3). We captured 73.58% ($S_{obs} = 27$ versus $S_{Jack\text{-}knife1} = 36.69$) and 73.09% ($S_{obs} = 23$ versus $S_{Jack\text{-}knife1} = 31.55$) of the species estimated for rural and urban sacred groves respectively (Figure 1). Species richness and species diversity were highest in Kammadam sacred grove, the most rural sacred grove in the present study. Estimated species diversity and evenness were lowest in Mannampurathukavu, the most urbanized sacred grove (Table 2). Individual-based rarefaction predicted 26.97 ($S_{obs} = 27$) and 21.04 ($S_{obs} = 23$) species respectively, for rural and urban sacred groves for 481 ants. The mean abundance of ants per pitfall trap was significantly higher in urban sacred groves when compared to the rural sacred groves (Student's *t*-test: $t = -2.91$, $df = 41.37$, $P = 0.005$). However, the mean species richness per pitfall trap did

Table 3. Details of the species diversity of litter-dwelling ants of sacred groves of rural and urban areas

System	Sacred forest	Number of pitfall traps	S_{obs} (%)*	Shannon	Evenness (Simpsons)	Jack-knife 1	Abundance
Rural		32	27 (73.59)	2.4	0.94	36.69	483
	Edayilakad	10	15 (77)	2.11	0.83	19.5	163
	Kammadam	12	21 (70)	2.24	0.83	30.17	207
	Konnakad	10	12 (73)	1.66	0.63	16.5	113
Urban		20	23 (72.90)	1.76	0.96	31.55	636
	Mann.kavu	10	17 (63)	1.28	0.55	26.9	377
	Puthiya.kavu	10	17 (83)	1.84	0.91	20.6	259

*Percentage of species captured in the study is based on estimated species richness, Jack–Knife 1 is indicated in the parentheses.

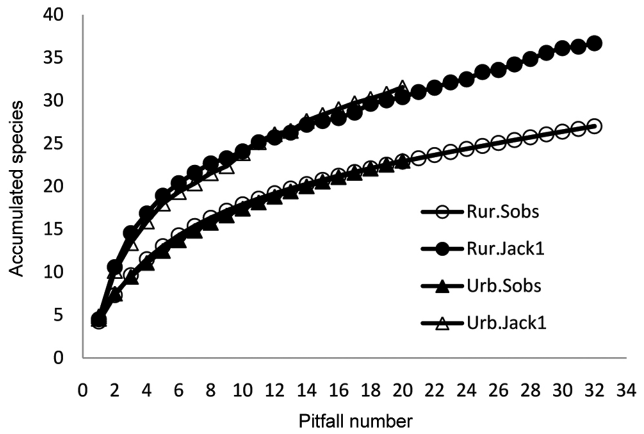

Figure 1. Species accumulation curves show the observed (S_{obs}) and estimated (Jack–Knife 1) species richness against the sampling effort in rural and urban sacred groves.

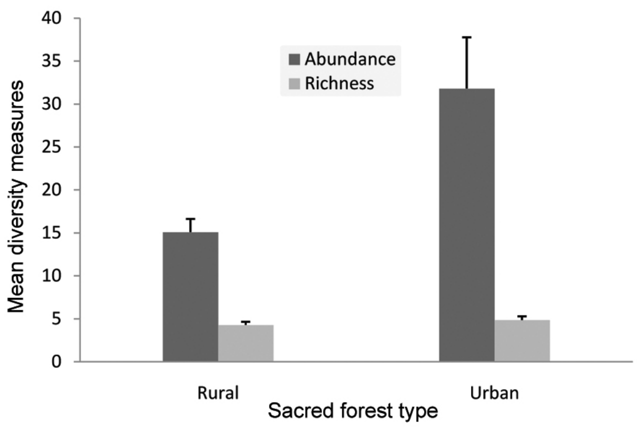

Figure 2. Mean (± 1 SEM) species richness and abundance of ants per pitfall trap per sacred grove in rural and urban areas.

not differ between sacred groves of the two types (t = –1.03, df = 41.18, P = 0.31) (Figure 2). When the pitfall traps were pooled, both rural and urban sacred groves maintained same species diversity (abundance: 318 ± 59 (urban) versus 161 ± 21.15 (rural); t test: $t_{\text{log–abundance}}$ = –2.694, df = 2.547, P = 0.08) (species richness: 16 ± 2.64 (urban) versus 17 ± 0.0 (rural); t test: t = –0.378, df = 2, P = 0.74).

Rank-abundance curves clearly illustrated a shift in dominant species as well as abundance of dominant species in rural and urban sacred groves (Figure 3). *Anoplolepis gracilipes* was the dominant species in urban sacred groves; an average of 15.56 (±25.05 SD) ants per pitfall trap was counted in urban sacred groves. *Tetramorium coonoorense* was the dominant species in rural sacred groves; an average of 6.47 (±6.82 SD) ants per pitfall trap was counted in rural sacred groves. Interestingly, the rural and urban sacred groves clustered on two different branches of the cluster diagram (Figure 4).

Based on the overall ant species composition (Sorensen similarity index), the rural and urban sacred groves were 56.3% similar. Eighteen out of thirty-two species were commonly collected in the sacred groves of two landscape types. The urban sacred forests had five species exclusive to them. Out of the five species, four were 'rare' species (*Lophomyrmex quadrispionosus*, *Nyladeria* sp., *Pachycondyla leeuwenhoeki*, *Strumigenys* sp. (Mustaq Ali, pers. commun.). The rural sacred groves had two subfamilies (Aenictinae and Ectatominae) and nine species exclusive to them. Another subfamily, Dolichoderinae, with its three species (*Dolichorus* sp., *Irridiomyrmex* sp. and *Tapinoma melanocephalum*), also had a clear majority in rural sacred groves; about 83% of the total ant abundance from these three species were captured from the rural sacred groves.

The present study examined the impact of urbanization on the biodiversity of sacred groves; litter-dwelling ants were used as the indicator taxon to examine the impact. Though we used only 3 rural and 2 urban sacred groves for the comparison, it brought out some evidences of the ill-effects of urbanization on the sacred groves. Greater abundance of *Anoplolepis gracilipes*, the third globally important invasive ant species[22], in almost all the pitfall traps of the two urban sacred groves indicates that aggression of the invasive species may be a major ill effect of urbanization on the sacred groves. The observed species diversity measures, such as abundance and species richness did not vary between the sacred groves of urban and rural environments. However, the species composition turned over between landscape types, which might be a crucial indicator of environmental change. In fact, the abundance of ants was high in pitfall traps of urban sacred groves, which was due to the large and even catches of *A. gracilipes* in 18 out of 20 pitfall traps in the two sacred groves, which together contributed to 90.54% of the total *A. gracilipes* catches of the present study. In contrast, 70–90% of the pitfall traps of each of the rural sacred groves did not capture a single *A. gracilipes* during the sampling. Also, no dominant ant species was captured in the pitfall traps of rural environment. All these results suggest that the sacred groves in rural environment may be less disturbed and possibly support greater amount of native biodiversity. We also found that the urban and rural sacred groves clustered in different branches on the ant species composition. All these results suggest that litter ants might be good ecological indicators of ecosystem health. Only 18 out of the 32 species were common between the sacred groves of two landscape types. Interestingly, the rural sacred groves contained several exclusive ant sub-families and a larger number of exclusive ant species when compared to the sacred groves of urban environment. This result suggests that urbanization may have an impact not only at a species-level but also at a higher taxonomic level. Though the present study suggests that sacred groves of urban areas may face anthropogenic pressures, such as urbanization (for instance, the biotic invasion[23] and biotic homogenization)[24], the results need to be interpreted with caution as it is still a preliminary study. Future studies should monitor the population and community structure of ants from different strata of the forest in different seasons to draw a firm conclusion on this.

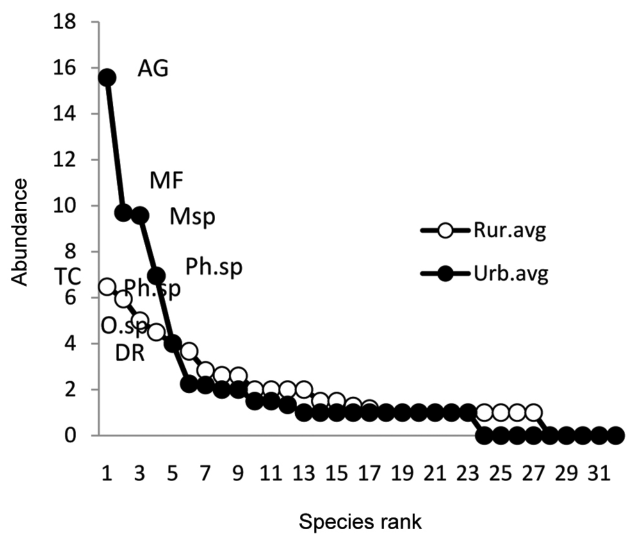

Figure 3. Rank-abundance plots show the dominant ant species in rural and urban sacred groves; mean abundance of ants per pitfall trap was used to construct the curves. AG, *Anoplolepis gracilipes*; Ph.sp, *Pheidole* sp; MF, *Monomorium floricula*; Msp, *Monomorium* sp.; Osp, *Oligomyrmex* sp.; DR, *Diacamma rugosum*).

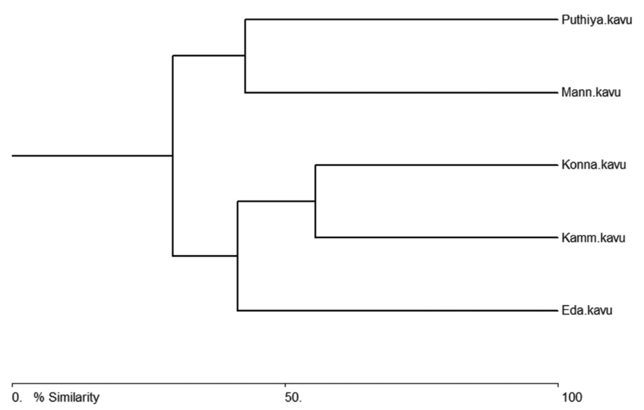

Figure 4. Dendrogram based on the Sorensen similarity index showing the similarity of sacred groves based on the litter-dwelling ant composition data.

We do not have any long-term monitoring of less-charismatic fauna, such as insects in our native habitats, although this information may be useful to predict the ecosystem health[8]. Ants have been used as an important proxy taxa in the world to study the impacts of several ecosystem processes and changes[13,16,19] including biotic invasion[25–27]. The taxonomy of ants is stable when compared to other litter insects, which qualify them as a popular indicator taxon[13]. The study suggests that monitoring the population structure of *A. gracilipes* and other litter-dwelling insects might help predict whether this ant species has some ecological significance, such as displacing our native biodiversity in our native habitats[27]. Sacred groves are the last refugia of wildlife in the rural and urban environments outside the protected area network. Our study showed that the sacred groves still conserve some data-deficient and rare species in our neighbourhood[8]. We recommend increased local participation from local communities, village authorities, temple trusts, and forest departments to conserve sacred groves of India as a living natural and cultural heritage of India[4].

1. Gadgil, M. and Vartak, V. D., Sacred forests of India: a plea for continued conservation. *J. Bombay Nat. Hist. Soc.*, 1975, **72**, 313–320.
2. Bhagwat, S. A. and Rutte, C., Sacred groves: potential for biodiversity management. *Front. Ecol. Environ.*, 2006, **4**, 519–524.
3. Chandrashekara, U. M. and Sankar, S., Ecology and management of sacred groves in Kerala, India. *For. Ecol. Manage.*, 1998, **112**, 165–177.
4. Lowman, M. D. and Sinu, P. A., Can the spiritual values of forests inspire effective conservation? *BioScience*, 2017, online early; doi:10.1093/biosci/bix057.
5. Khan, M. L., Khumbongmayum, A. D. and Tripathi, R. S., The sacred groves and their significance in conserving biodiversity an overview. *Int. J. Ecol. Env. Sci.*, 2008, **34**, 277–291.
6. Suchitra, M. Sacred groves of Kerala: from 10000 to 1200. *Down to Earth*, 2015; http://www.downtoearth.org.in/news/sacred-groves-of-kerala-down-from-10000-to-1200-49070 (accessed on 5 December 2016).
7. Rajendraprasad, M., Krishnan, P. N. and Pushpangadan, P., Vegetations characterization and litter dynamics of the sacred groves of Kerala, southwest India. *J. Trop. For. Sci.*, 2000, **12**, 320–335.

8. Manoj, K., Rajesh, T. P., Prashanth Ballullaya, U., Meharabi, K. M., Shibil, V. K., Rajmohana, K. and Sinu, P. A., Diversity of Platygastridae in leaf litter and understory layers of tropical rainforests of the Western Ghats biodiversity hotspot, India. *Environ. Entomol.*, 2017, **46**, 685–692.
9. Andersen, A. N., Ants as indicators of restoration success at a uranium mine in tropical Australia. *Restoration Ecol.*, 1993, **1**, 156–167.
10. Gibb, H. and Hochuli, D. F., Colonisation by a dominant ant facilitated by anthropogenic disturbance: effects on an ant assemblage composition, biomass and resource use. *Oikos*, 2003, **103**, 469–478.
11. Alonso, L. E., Ants as indicators of diversity. In Ants. *Standard Methods for Measuring and Monitoring Biodiversity* (eds Agosti, D. *et al.*), Smithsonian Institution Press, Washington, DC, USA, 2000, pp. 80–88.
12. Belshaw, R. and Bolton, B., The effect of forest disturbance on the leaf litter ant fauna in Ghana. *Biodiv. Conserv.*, 1993, **2**, 656–666.
13. Underwood, E. C. and Fisher, B. L., The role of ants in conservation monitoring: if, when, and how. *Biol. Conserv.*, 2006, **132**, 166–182.
14. Menke, S. B., Guénard, B., Sexton, J. O., Weiser, M. D., Dunn, R. R. and Silverman, J., Urban areas may serve as habitat and corridors for dry-adapted, heat tolerant species; an example from ants. *Urban Ecosyst.*, 2011, **14**, 135–163.
15. Sanford, M. P., Manley, P. N. and Murphy, D. D., Effects of urban development on ant communities: implications for ecosystem services and management. *Conserv. Biol.*, 2009, **23**, 131–141.
16. Lessard, J. P. and Buddle, C. M. The effects of urbanization on ant assemblages (Hymenoptera: Formicidae) associated with the Molson Nature Reserve, Quebec. *Can. Entomol.*, 2005, **137**, 215–225.
17. King, J. R. and Porter, S. D., Evaluation of sampling methods and species richness estimators for ants in upland ecosystems in Florida. *Environ. Entomol.*, 2005, **34**, 1566–1578.
18. Colwell, R. K. and Coddington, J. A., Estimating terrestrial biodiversity through extrapolation. *Philos. T. R. Soc. London B*, 1994, **345**, 101–118.
19. Andersen, A. N., Using ants as bioindicators: multiscale issues in ant community ecology. *Conserv. Ecol.*, 1997, **1**, 1–17.
20. R Core Team R: A language and environment for statistical computing. R Foundation for statistical computing, Vienna, Austria. http://www.R-project.org, 2014.
21. Colwell, R. K., EstimateS: statistical estimation of species richness and shared species from samples. Version5, http://viceroy.eeb.uconn.edu/estimates, 1997.
22. Wetterer, J. K., Worldwide distribution and potential spread of the long-legged ant, *Anoplolepis gracilipes* (Hymenoptera: Formicidae). *Sociobiology*, 2005, **45**, 1–21.
23. Mack, R. N., Simberloff, D., Lonsdale, W. M., Evans, H., Clout, M. and Bazzaz, F. A., Biotic invasions: causes, epidemiology, global consequences, and control. *Ecol. Appl.*, 2000, **10**, 689–710.
24. McKinney, M. L. Urbanization as a major cause of biotic homogenization. *Biol. Conserv.*, 2006, **127**, 247–260.
25. Holway, D. A. and Suarez, A. V., Homogenization of ant communities in Mediterranean California: the effects of urbanization and invasion. *Biol. Conserv.*, 2006, **127**, 319–326.
26. Forys, E. A., Allen, C. R. and Wojcik, D. P., Distribution of the red imported fire ant in the Lower Florida Keys: effects of human development and roads and spatial overlap with vulnerable rare species. *Biol. Conserv.*, 2002, **108**, 27–33.
27. Sinu, P. A., Sibisha, V. C., Nikhila Reshmi, M. V., Reshmi, K. S., Jasna, T. V., Aswathi, K. and Megha, P. P., Invasive ant (*Anoplolepis gracilipes*) disrupts pollination in pumpkin. *Biol. Invasions*, 2017, online early; doi:10.1007/s10530-017-1470-9.

ACKNOWLEDGEMENTS. We thank Prof. Mustaq Ali (GKVK Bangalore) for determining the ants collected in the study to the species. P.B.U. thanks Kerala State Council for Science Technology and Environment (KSCSTE) for a Ph D fellowship; The project was supported by National Geographic Society's Conservation Research and Exploration award to P.A.S. He also thanks the University Grants Commission's start-up grant for funding the research. We also thank two anonymous reviewers for their constructive comments on the manuscript, which helped improve the overall style of the manuscript.

Received 20 May 2016; revised accepted 17 February 2017

doi: 10.18520/cs/v113/i02/317-322

Species diversity of white grubs (Coleoptera: Scarabaeidae) in the sub-Himalayan and northern plains of India

K. Sreedevi[1,*], Sakshi Tyagi[1] and Veena Sharma[2]

[1]Division of Entomology, ICAR-Indian Agricultural Research Institute, Pusa, New Delhi 110 012, India
[2]Department of Bioscience and Biotechnology, Banasthali University, Banasthali 304 022, India

White grubs belonging to subfamilies Melolonthinae and Rutelinae of Scarabaeidae (Coleoptera) are ubiquitous pests. Studies during 2013 and 2014 document the species diversity of white grubs in the sub-Himalayan and northern plains of India. Surveys conducted in four states, viz. Himachal Pradesh, Uttarakhand, Uttar Pradesh and Rajasthan revealed high species diversity representing 65 species under 16 genera. The species richness, evenness and composition varied among the states. Higher species diversity was recorded in Uttarakhand and Himachal Pradesh of the sub-Himalayan region when compared to Uttar Pradesh and Rajasthan of the northern plains. The species abundance distribution followed log normal distribution in all places except Uttarakhand, where the curve skewed to the left due to overweight of species with low abundance. The species dominance and abundance patterns in different regions are presented. The new distributional records, *Anomala pictipes* Arrow and *Popillia macclellandi* Hope from Uttarakhand, *Anomala propinqua* Arrow and *Popillia marginicollis* Hope from Himachal Pradesh and *Anomala stenodera* Arrow from Uttar Pradesh are provided.

Keywords: Abundance models, Melolonthinae, Rutelinae, species diversity, white grub.

*For correspondence. (e-mail: kolla.sreedevi@gmail.com)