Optimum sampling effort for study of tropical ground beetles (Carabidae: Coleoptera) using pitfall traps

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Optimum number of pitfall traps needed to study species-abundance distribution of ground beetles (Carabidae: Coleoptera) in an agroforest was determined over a sampling period of four months using sampling numbers of 15, 25, 35 and 50 pitfall traps within a sample area of 15,000 sq m. Analysis based on the qualitative and quantitative community structure of carabids indicated the use of either 25 or 35 pitfall traps as optimum for assessing their diversity depending on the type of investigation. This study pointed out the variations in sampling numbers to be adopted over geographic regions for the precise estimate of carabid species distribution.

GROUND beetles, also called as carabid beetles, form a distinct taxon of Adephaga, a suborder of Coleoptera. Ground beetles, one of the major groups of soil fauna are important members of agrocoenoses with respect to both energy flow and predation on agricultural pests, and as pedobiological indicators. Efforts in the conservation of ground beetle communities as potential indicators of environment and as economic bioagents can only succeed, if we know a great deal about their structure and function over diverse habitats. Since conclusions based on samples are used to make hypotheses about populations as a whole, sampling procedure must be standardized to provide maximum information, within the experimental constraints of time, finance and manpower.

Pitfall trapping is one of the approaches to sampling epigeic fauna[1] as proved to be useful in the study of carabids in assessing their species abundance[2–5], daily and seasonal dynamics of activity[6], occurrence of proportion of sexes[7] and for collecting them for ecomorpho-physiological research[8]. Since the trap catch measures 'activity-density' of carabids[9], a sampling programme with high sampling efficiency is needed. In this study, we fixed up the optimum sampling numbers required to check out the species-abundance distribution of carabids by comparing the effects of increased sampling numbers in an agroforest ecosystem.

Four sampling areas of an agroforest 15,000 sq m, each, with similar ecological parameters were selected. The agroforest habitat with its origin under social forestry had the ecological traits of low crop biomass, high energy flow, complex food chain, large total organic matter, high structural and species diversity, large plant size, long life cycle and high stability. Sampling numbers consisted of 15, 25, 35 and 50 pitfall traps. As the species diversity is expected to be more under tropical situations, widely varying sampling numbers were adopted. Each pitfall trap consisted of a 11 cm × 6 cm glass jar filled with 50 ml of 4% formalin. Pitfall traps were sunk into the soil with their rims flush with the soil surface in each sampling area in a grid pattern with multiples of five. Sampling was done for a period of four months (May–August, 1991) with trap collections done at fortnightly intervals. Species of carabids were separated at the end of each fortnight in the laboratory using the method of mechanical sieving and hand sorting. Specimens of ground beetles were identified based on the standard collection maintained at the Soil Biology Laboratory of University of Agricultural Sciences, Bangalore. Composition of carabid species in terms of richness and abundance from the four sampling areas with differing sampling numbers was recorded separately. Comparison of catches among sampling numbers was done by calculation of the following statistics, indices and measures:

(a) overall qualitative analysis based on the presence and/or absence of a species among sampling efforts using Cochran's Q statistic[10];

(b) overall quantitative analysis of carabid abundance among sampling numbers using F statistics after log $(X + 1)$ transformation;

(c) qualitative similarity index of Sorensen[1] for species richness between sampling numbers;

(d) quantitative similarity index of Pianka[12] and;

(e) expected species richness for 100 individuals by method of rarefactions[13] for each of the sampling numbers.

Species richness and abundance of ground beetles in the pitfall traps with varying sampling numbers are given in Table 1. The species richness among sampling numbers differed significantly (Cochran's $Q = 13.2$, $P \leq 0.01$). Only seven species of ground beetles could be recorded using the minimum sampling number of 15. However, a maximum of fifteen species was obtained with 50 pitfall traps. The species richness was 13 with either of the sampling numbers, namely 25 and 35. Abundance of carabids was 90, 225, 280 and 290 among the sampling numbers 15, 25, 35 and 50, respectively, and the differences were nonsignificant ($F_{(3,43)} = 0.202^{ns}$). Values of Sorensen's qualitative similarity index based on species richness and of Pianka's quantitative similarity index based on species proportion between sampling numbers (Table 2) showed

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Table 1. Species richness and abundance of carabids in pitfall traps with different sampling numbers

Species	Species abundance among sampling numbers			
	15	25	35	50
Abacetus dejeani	8	13	18	21
Abacetus placidulus	10	20	24	26
Abacetus sp.	**	**	**	2
Anthracus horni	**	1	3	4
Chlaenius malachinus	**	3	6	8
Chlaenius panagaeoides	21	70	82	69
Clivina tranquebarica	6	20	26	28
Clivina sp.	**	**	**	2
Crasepedophorus angulatus	1	2	4	4
Dioryche colombensis	**	1	2	3
Microcosmus flavopilosus	**	4	6	7
Microlestes inconspicuus	**	3	2	1
Omphra pilosa	41	78	92	101
Tachys poecilopterus	**	2	2	**
Zuphium olens	**	**	**	1
Total species abundance	89	225	280	290
Total species richness	7	13	13	15

**Indicates the absence of species.

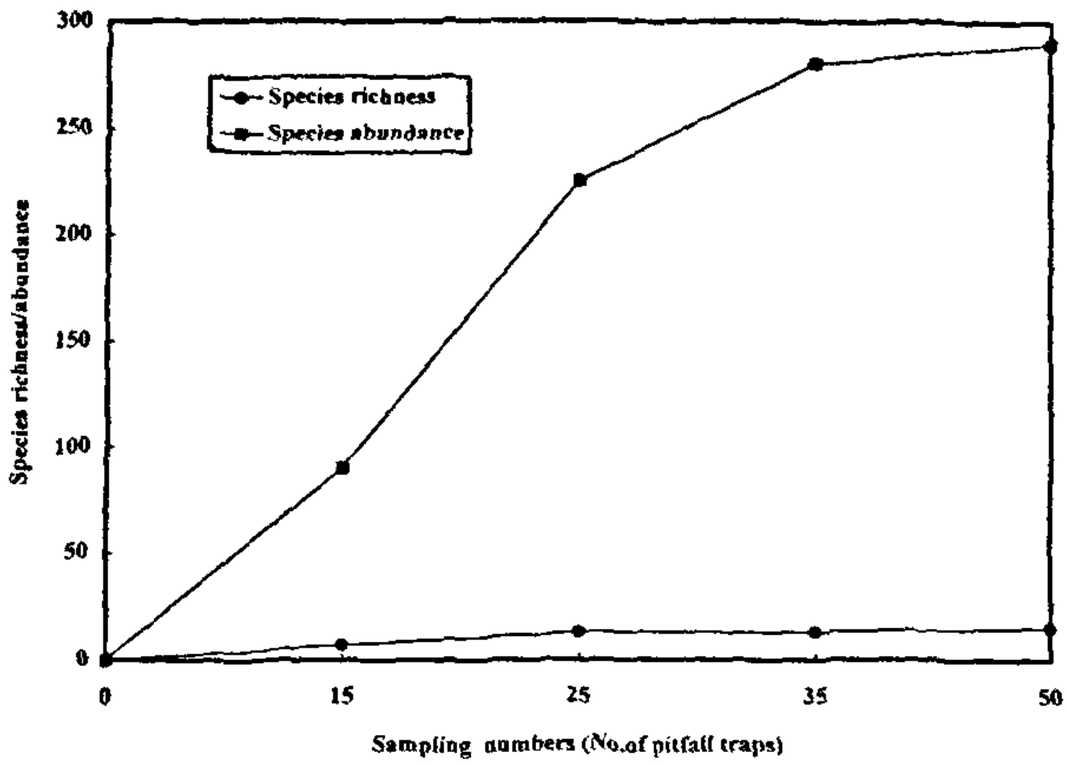

Figure 1. Cumulative collector curves of species richness and species abundance based on increasing sampling numbers.

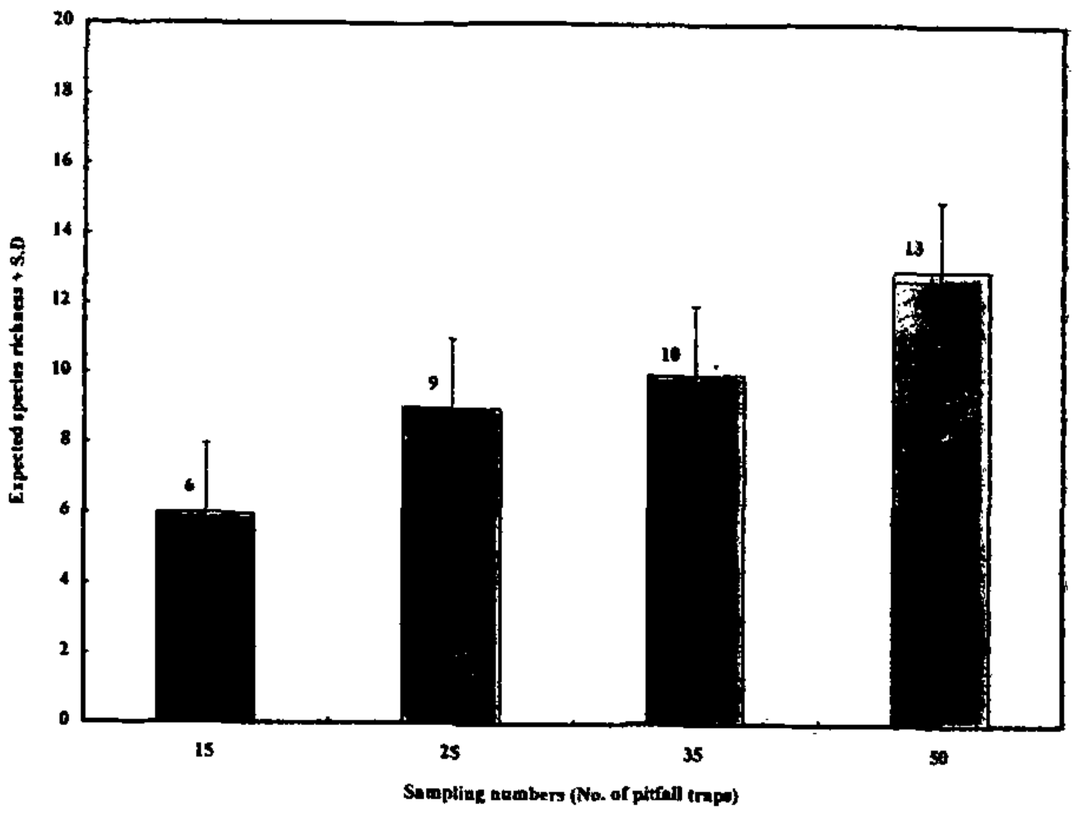

Figure 2. Rarefaction estimates of species richness for 100 individuals from differing sampling numbers.

Table 2. Qualitative similarity index of Sorensen and quantitative similarity index of Pianka between sampling numbers

Sampling numbers** (No. of pitfall traps)	15	25	35	50
15		0.736	0.736	0.636
25	*0.966*		0.916	0.889
35	*0.898*	*0.978*		0.898
50	*0.985*	*0.988*	*0.978*	

**Values in italics represent Pianka's index; underlined values represent Sorensen's index.

high sampling numbers to have more similarity for both species richness and abundance. The highest similarity index of 0.916 (91.6%) for species richness was between 25 and 35, while the indices for abundance were around 0.9 (90% and above) between any two sampling numbers. Cumulative catches of species richness and abundance increased with increased sampling numbers, with the latter showing steeper increase than species richness (Figure 1). While the difference in species richness between the sampling numbers 15 and 25 was only six, species abundance was 2.5 times higher in the sampling number 25 than 15. Rarefaction estimates of species richness standardized to an equal abundance of 100 individuals did not differ between sampling efforts of 25 and 35 (Figure 2).

In determining optimum sampling numbers for carabid studies, the selection of identical sample areas, the use of similar traps, and an equal sampling interval and sampling period allowed sampling efforts alone as a variable factor to be compared.

Cochran's Q test demonstrated the significant differences among sampling numbers for species richness, the number of species increasing with increasing sampling numbers. However, the species richness was the same between 25 and 35 pitfall traps. Though there was an increase in carabid abundance with increasing sampling numbers, differences were nonsignificant. Highest similarity of species richness (91.6%), abundance (97.8%) and a similar expected species richness when rarified to an equal abundance of 100 individuals suggested the use of 25 or 35 pitfall traps for assessing species-abundance distributions of carabids, in general. Since the cumulative collection curves reveal the differences between sampling numbers for species richness to be narrower than those for species abundance, the op-

tion of using less number of sampling units (minimum of 25 pitfall traps) would suffice for studies evaluating the qualitative structure of the carabid community. For quantitative studies, higher number of sampling numbers (minimum of 35 pitfall traps) should be used for precise population estimates.

Obrtel[14] suggested that 10–15 traps would be sufficient to capture all species of similar activity type in any part of the habitat – a recommendation based on studies at temperate situations. However, following such a procedure only six species could be recorded in the hitherto only study on carabid distribution in tropics, at forest sites of an area similar to the present study[15] in the same locality. This shows the emergence of an incomplete picture of carabid community structure of the tropics from the previous study because of insufficient sampling numbers. The present study indicates the need for using more number of traps for establishing community distribution in carabids more precisely and also suggests the variation in sampling numbers to be adopted over geographic regions.

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Differential responses to complete and corresponding skeleton photoperiods in male blackheaded bunting

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In male blackheaded bunting, we have investigated whether the action of the complete photoperiod (CP, single continuous long light pulse in a 24 h day) can be fully simulated by its corresponding skeleton photoperiod (SP, two short light pulses in a 24 h day). Birds were subjected to 12L:12D (CP) and 6L:5D:1L:12D (SP) daily or alternately interposed with constant darkness (12L:12D/DD, 6L:5D:1L:12D/DD) for a period of 21 weeks. There was a clear differential response to two photoperiods in the rate and magnitude of photoperiod-induced body fattening and gonadal growth. It appears that the action of a single long light pulse in the complete photoperiod, extending simultaneously to different phases, is different from that of two short light pulses in the skeleton photoperiod, falling discretely at two different phases of the circadian oscillator(s) regulating photoperiodic responses in the bunting.

IT is believed that the action of single long light pulse in the complete photoperiod (CP) is fully simulated by two short light pulses in the skeleton photoperiod (SP) when the duration of a single long light pulse in CP equals the interval between the beginning of the first and the end of the second light pulse in SP. The data from experiments on some insect species (e.g. *Drosophila*, *Sarcophaga* and *Calliphora*) partially support the hypothesis. Simulation by SP of the responses induced by CP is almost perfect for all photoperiods up to 11 h, but not > 12 h; skeleton of a 13 h photoperiod causes unstable entrainment[1,2].

In photoperiodic vertebrates, the implication of simulation by SP of CP-induced responses is that the entrainment to two photoperiods of circadian rhythm of photoperiodic photosensitivity, which mediates physiological responses to light[3–5], is similar and, so, the phase of inducibility (photoinducible phase, Φ_i) remains in the same position in both photoperiodic situations. If that is true, exposure to CP and its corresponding SP which enable identical illumination of Φ_i should result in similar photoperiodic induction. However, this has not been examined precisely in any photoperiodic species so far. It is not known how exactly the CRPP responds to complete and skeleton photoperiods and how well the physiological responses induced by two kinds of pho-

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