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STUDIES ON THE PRODUCTIVITY OF SOIL ANIMALS IN PASOH FOREST RESERVE, WEST MALAYSIA

V. SEASONAL CHANGE IN THE DENSITY AND BIOMASS OF SOIL MACROFAUNA: OLIGOCHAETA, HIRUDINEA AND ARTHROPODA[1)]

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1. INTRODUCTION

The ecological studies on soil macrofauna in tropical rain forests have been carried out by many soil zoologists. There were, however, generally limited to the results of the survey for short term or for the limited taxa. Density and biomass of soil macrofauna in tropical rain forests in Southeast Asia were only studied by DAMMERMAN (1925 and 1937), KIKUZAWA *et al.* (1965) and WATANABE *et al.* (1966, 1967). Therefore, there remained some difficulties in estimating the secondary productivity of soil macrofauna in tropical rain forests.

In order to estimate the mean density and the mean biomass of soil macrofauna in a tropical lowland rain forest, the routine sampling of them were carried out by the authors in Pasoh Forest Reserve, Negeri Sembilan, West Malaysia, during the period from April 1971 to August 1972, as a part of the Joint Malaysia/Japan/UK IBP Project.

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2. MATERIALS AND METHODS

Site descriptions for IBP Pasoh Study Area have been generally made by SOEPADOMO (1973), YODA (1974) and KIRA (1976). Moreover, the detailed description for Plot 1 of the study area was given in the first paper of this series (CHIBA *et al.* 1975). Routine sampling were performed at Plot 1, namely 66 sub-quadrates (4m x 4m square) in the five quadrates of Nos. 29, 32, 39, 57 and 58. Two supplemental samples from Plot 2 and Plot 3 were included in future discussion. A pit of 50cm square and 20cm in depth was examined in each sub-quadrate for detection of soil animals. Five pits (sometimes 2 pits) were exhausted in a month. The soil sample of each pit was examined by the hand sorting at the out side of the Plot. All animals larger than 1mm in body length were picked off from the soil and preserved in ethanole solution of 70 percent. The surface soil which contained rich fauna was reexamined by Tullgren's funnel in the laboratory, at Kuala Pilah about 38km far from Pasoh Forest. The extracted animals for 24 hours by the funnel were jointed to the animals obtained by hand sorting. As soil macrofauna, the following taxa were treated: Oligochaeta, Hirudinea, Scorpiones, Opiliones, Araneida, Isopoda, Diplopoda, Chilopoda, Thysanura, Blattoidea, Orthoptera, Hemiptera, larvae of Lepidoptera, larvae of Diptera, adults and larvae of Coleoptera, Hymenoptera and others. Isopoda was excluded as an other group studied independently.

The wet animals preserved in ethanole solution were weighed by using a Metler's balance (0.05mg per scale) and a torsion balance (0.1mg per scale).

The maps of 24 sub-quadrates were made on the litter distribution covering the soil surface and on the rotten wood for further discussions (4 Plates in Appendix). The list of the individual number and of their biomass per pit are also given in Table A and B in Appendix.

3. RESULTS

A list of macrofauna obtained is given in Table A (in Appendix), together with their individual number per pit. The data of their biomasses per pit are given in Table B (in Appendix).

3-1. Mean density, mean biomass and faunal makeup

The mean density of each taxon derived from 68 pits was given in Table 1, with percentage of total density of soil macrofauna. The majority of the studied soil macrofauna was Hymenoptera, being 1624.18 animals per m^2, which made up 85.37 percent of the whole soil macrofauna, and is mostly composed of Formicidae. The second abundant taxon was the adult of Coleoptera, being 77.65 animals per m^2 (4.08%), the third was Araneida being 48.18 animals per m^2 (2.53%), and the larvae of Coleoptera, Oligochaeta, Chilopoda and the larvae of Diptera followed their abundance, being 30.29 animals (1.59%), 25.47 animals (1.34%), 24.41 animals (1.28%) and 21.94 animals (1.15%), respectively.

On the biomass, the majority was also Hymenoptera, being 818.8 mg•wet-wt./m^2, made up 26.64 percent. The second taxon was also the adult of Coleoptera, being 596.0 mg•wet-wt./m^2 (19.36%), the third was the larvae of Coleoptera, being 425.2 mg•wet-wt./m^2 (13.83%), the fourth was Araneida being 322.4 mg•wet-wt./m^2 (10.49%), and Oligochaeta and Blattoidea follow their biomass bieng 176.4 mg•wet-wt./m^2 (5.74%) and 160.4 mg•wet-wt./m^2 (5.22%), respectively (Table 2).

The major taxon Formicidae consists of so many kinds of ants which make special aggregation called "colony". For thier aggregative behavior, the ordinary sampling method is inadequate to estimate the Formicidae density. The similar situation is also adoptable to Isoptera which was studied in the same area independently by ABE (1979). Then the density of total macrofauna must be corrected by using reasonably estimated density of Formicidae and must be added by the independently estimated density of Isoptera, as in discussion of this paper.

In above orderliness of the density and the biomass, the major taxa of the soil macrofauna in tropical lowland rain forest seem to be Hymenoptera (or Formicidae), Isoptera, adult and larvae of Coleoptera, larvae of Diptera, Blattoidea, Araneina and Oligochaeta.

Table 1 Mean density per pit with standard deviation, derived mean density per m^2 with standerd error, and percentile composition of soil macrofauna at Plot 1 of Pasoh Forest Reserve, West Malaysia, surveyed from April 1971 to August 1972 (L): larvae, (A): adults, —— no available data

Taxon	Mean density per pit	Standard deviation per pit	Mean density per m^2	Standard error per m^2	Percentile composition %
Oligochaeta	6.3676 ±	7.0454	25.47 ±	3.42	1.34
Hirudinea	0.0588 ±	0.2370	0.24 ±	0.11	0.01
Scorpiones	0.1765 ±	0.4869	0.71 ±	0.24	0.04
Opiliones	1.2941 ±	2.6489	5.18 ±	1.28	0.27
Araneida	12.0441 ±	8.2650	48.18 ±	4.01	2.53
Isopoda	1.5735 ±	2.4207	6.29 ±	1.17	0.33
Diplopoda	1.7059 ±	1.9929	6.82 ±	0.97	0.36
Chilopoda	6.1029 ±	5.6992	24.41 ±	2.76	1.28
Thysanura	0.8676 ±	2.7960	3.47 ±	1.36	0.18
Blattoidea	1.5882 ±	1.7554	6.35 ±	0.85	0.33
Orthoptera	1.2059 ±	1.6166	4.82 ±	0.78	0.25
Hemiptera	2.3676 ±	2.8226	9.47 ±	1.37	0.50
Lepidoptera (L)	0.9118 ±	1.2898	3.65 ±	0.63	0.19
Diptera (L)	5.4853 ±	14.8208	21.94 ±	7.19	1.15
Coleoptera (A)	19.4118 ±	11.4386	77.65 ±	5.55	4.08
Coleoptera (L)	7.5735 ±	5.5699	30.29 ±	2.70	1.59
Hymenoptera	406.0441 ±	639.0228	1624.18 ±	309.98	85.37
Others	0.8529	——	3.41	——	0.18
Total	475.6324 ±	653.9954	1902.53 ±	317.23	99.98

Table 2 Mean biomass per pit with standard deviation, derived mean biomass per m^2 with standerd error, and percentile composition of soil macrofauna at Plot 1 of Pasoh Forest Reserve, West Malaysia, surveyed from April 1971 to August 1972 —— no available data

Taxon	Mean biomass mg·wet-wt. per pit		Standard deviation mg·wet-wt. per pit	Mean biomass mg·wet-wt. per m^2		Standard error mg·wet-wt. per m^2	Percentile composition %
Oligochaeta	44.1	±	152.3	176.4	±	74.0	5.74
Hirudinea	1.1	±	10.0	4.4	±	4.8	0.14
Scorpiones	4.7	±	30.0	18.8	±	14.4	0.61
Opiliones	4.4	±	24.4	17.6	±	12.0	0.57
Araneida	80.6	±	117.0	322.4	±	56.8	10.49
Isopoda	5.1	±	22.3	20.4	±	10.8	0.66
Diplopoda	—		—	—		—	—
Chilopoda	—		—	—		—	—
Thysanura	0.4		—	1.6		—	0.05
Blattoidea	40.1	±	108.1	160.4	±	52.4	5.22
Orthoptera	7.0		31.6	28.0		15.2	0.91
Hemiptera	0.8	±	—	3.2		—	0.10
Lepidoptera (L)	1.8	±	10.0	7.2	±	4.8	0.23
Diptera (L)	2.6	±	10.0	10.4	±	4.8	0.34
Coleoptera (A)	149.0	±	779.5	596.0	±	378.0	19.39
Coleoptera (L)	106.3	±	315.2	425.2	±	152.8	13.83
Hymenoptera	204.7	±	209.7	818.8	±	101.6	26.64
Others	56.1	±	111.8	224.4	±	54.4	7.30
Total	768.5	±	991.3	3074.0	±	480.8	—

3-2. Seasonal change

The seasonal variation in the density and biomass of total soil macrofauna are shown in Fig. 1. The fluctuation of the density of total soil macrofauna corresponded with that of Hymenoptera which was the greatest component (Fig. 2). The peak of maximal density appeared during the months from June to August and then it fell steeply and kept fluctuations of low density. On the other hand, the peak of maximal biomass appeared corresponding with that of adults and larvae of Coleoptera which showed prominent increase of the biomass in July 1972 (Figs. 3 and 5). The density of Araneida fluctuated from 14 to 86 animals per m^2 and all pits contained one or more animals (Fig. 4). These diagrams mean that no seasonal regularity in body size is detected. Oligochaeta showed the prominence of the density and the biomass from April to July and in October (Fig. 6). Other taxa were too low in their density and biomass to draw the diagram.

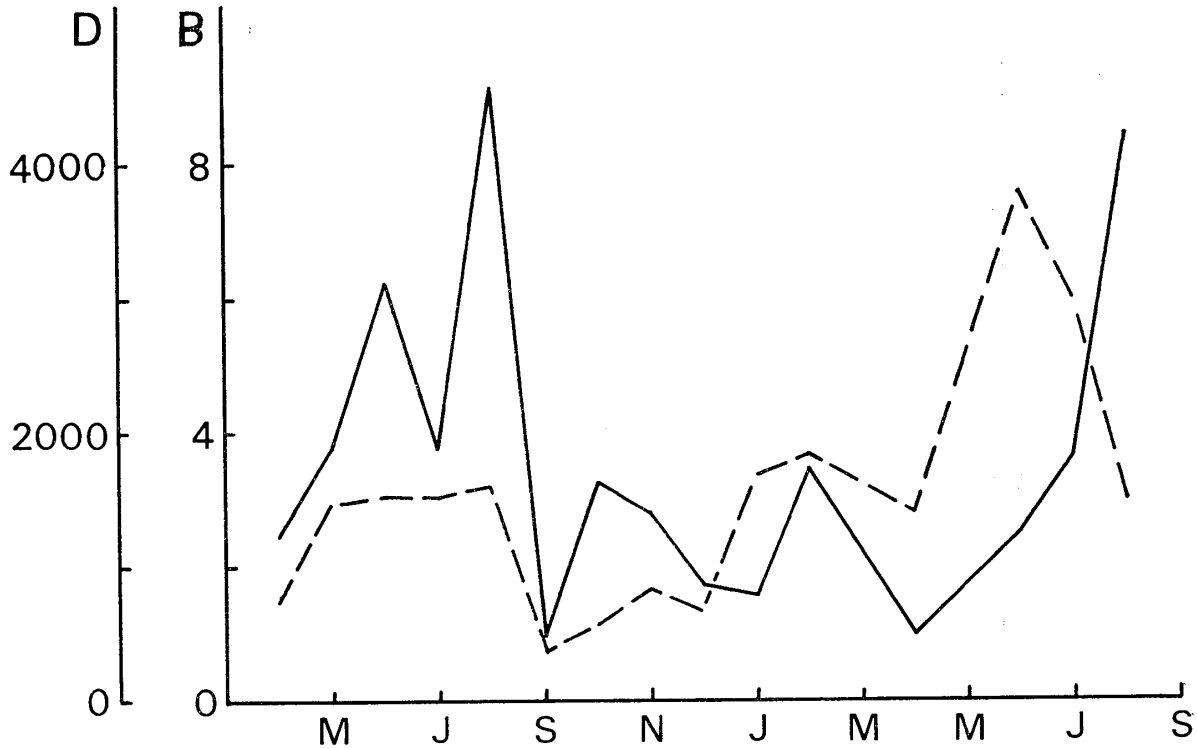

Fig. 1 Seasonal changes in density and biomass per square meter of all soil macrofauna of Plot 1 at Pasoh Forest Reserve, West Malaysia, surveyed from April 1971 to August 1972. A solid line shows density (No./m²) and a broken line shows biomass (g·wet-wt./m²). D means density and B means biomass.

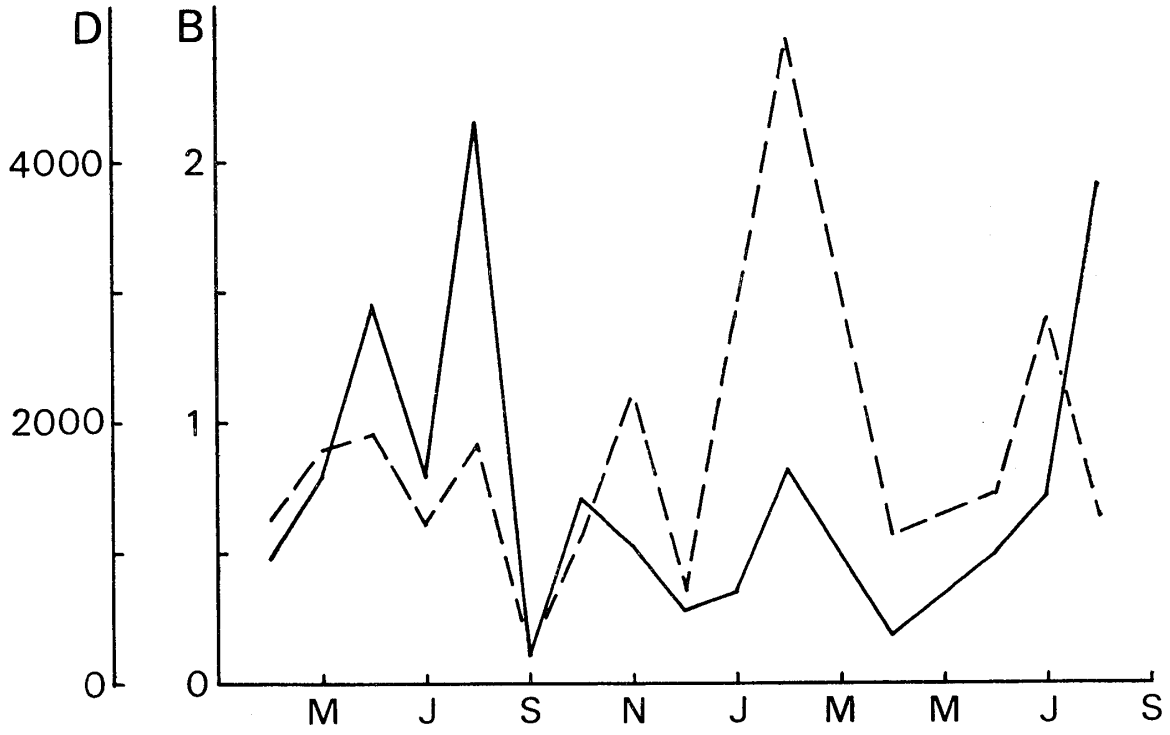

Fig. 2 Seasonal changes in density and biomass per square meter of Hymenoptera of Plot 1 at Pasoh Forest Reserve, West Malaysia, surveyed from April 1971 to August 1972. A solid line shows density (No./m²) and a broken line shows biomass (g·wet-wt./m²). D means density and B means biomass.

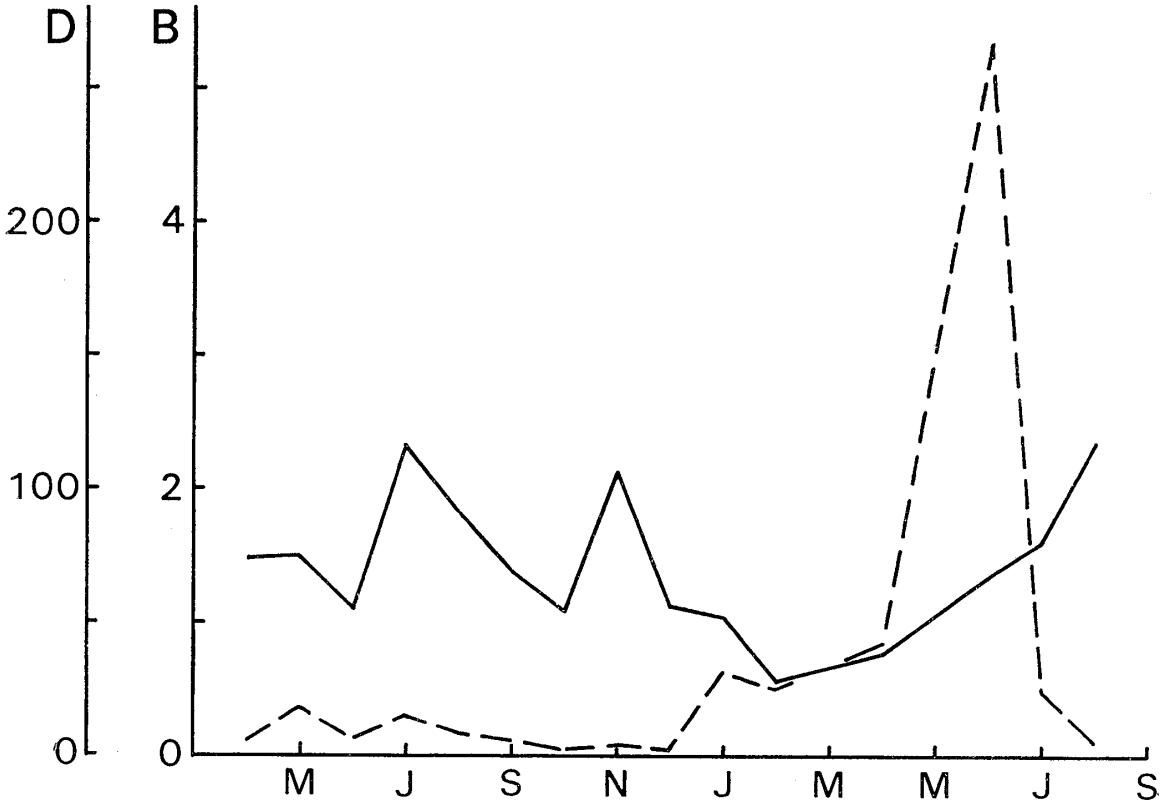

Fig. 3 Seasonal changes in density and biomass per square meter of Coleoptera (A) of Plot 1 at Pasoh Forest Reserve, West Malaysia, surveyed from April 1971 to August 1972. A solid line shows density (No./m²) and a broken line shows biomass (g·wet-wt./m²). D means density and B means biomass.

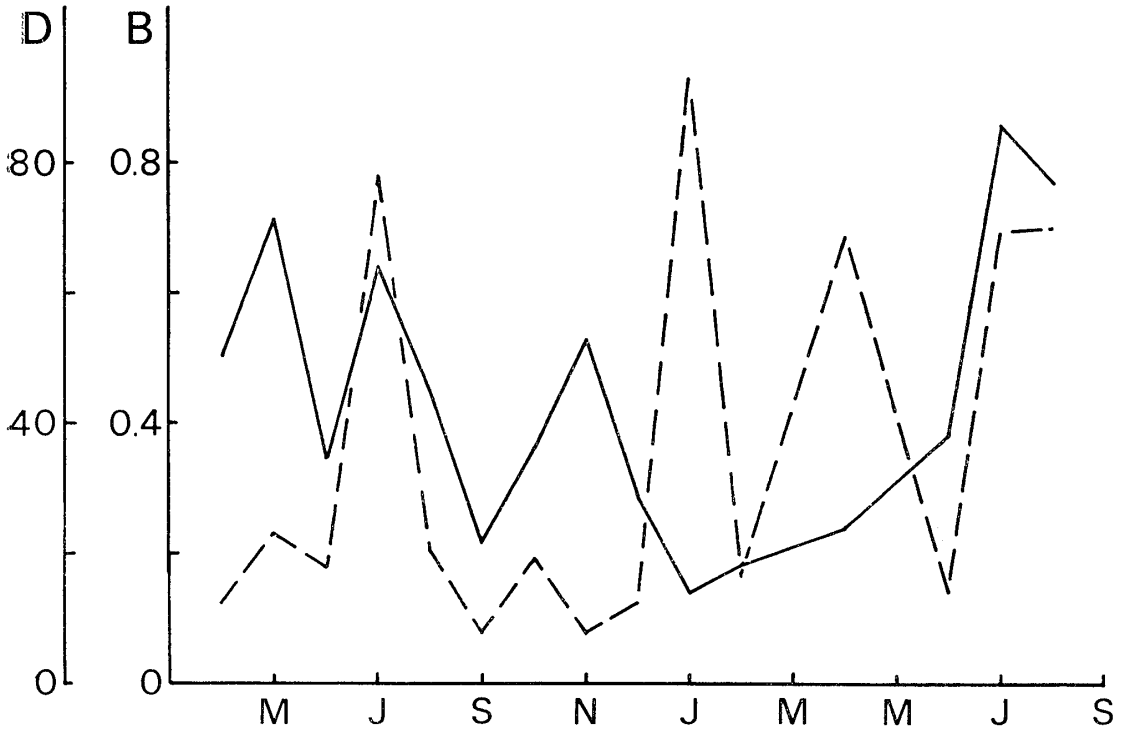

Fig. 4 Seasonal changes in density and biomass per square meter of Araneida of Plot 1 at Pasoh Forest Reserve, West Malaysia, surveyed from April 1971 to August 1972. A solid line shows density (No./m²) and a broken line shows biomass (g·wet-wt./m²). D means density and B means biomass.

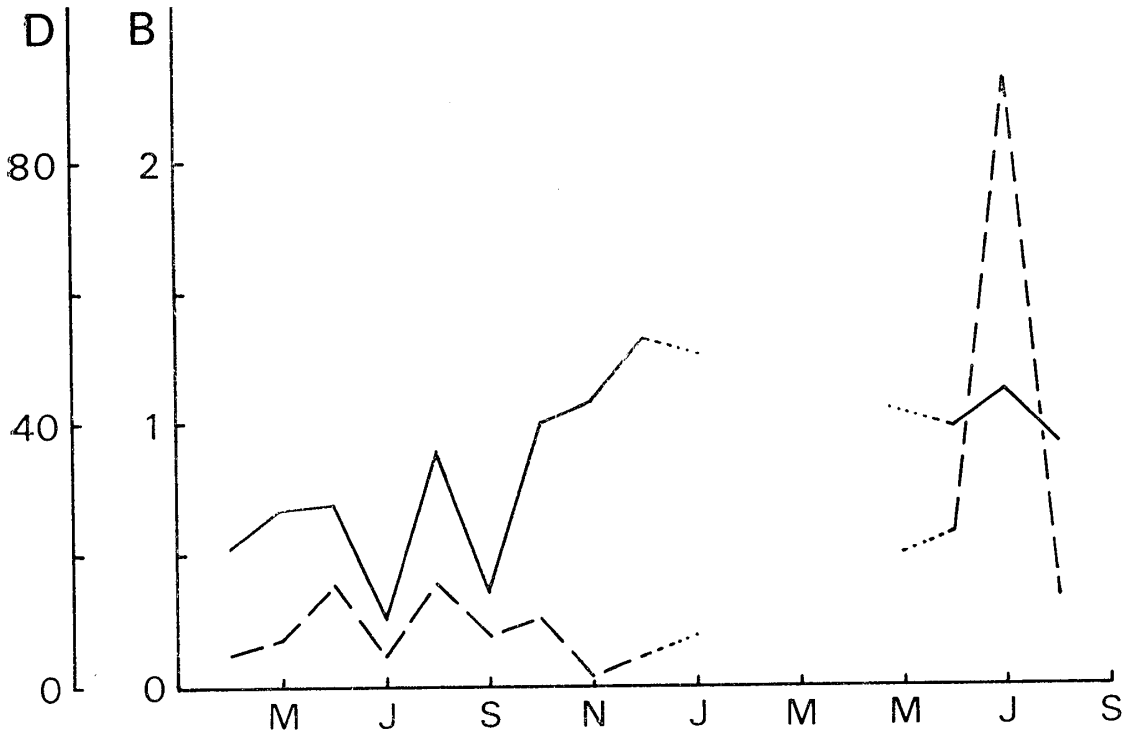

Fig. 5 Seasonal changes in density and biomass per square meter of Coleoptera (L) of Plot 1 at Pasoh Forest Reserve, West Malaysia, surveyed from April 1971 to August 1972. A solid line shows density (No./m²) and a broken line shows biomass (g·wet-wt./m²). D means density and B means biomass.

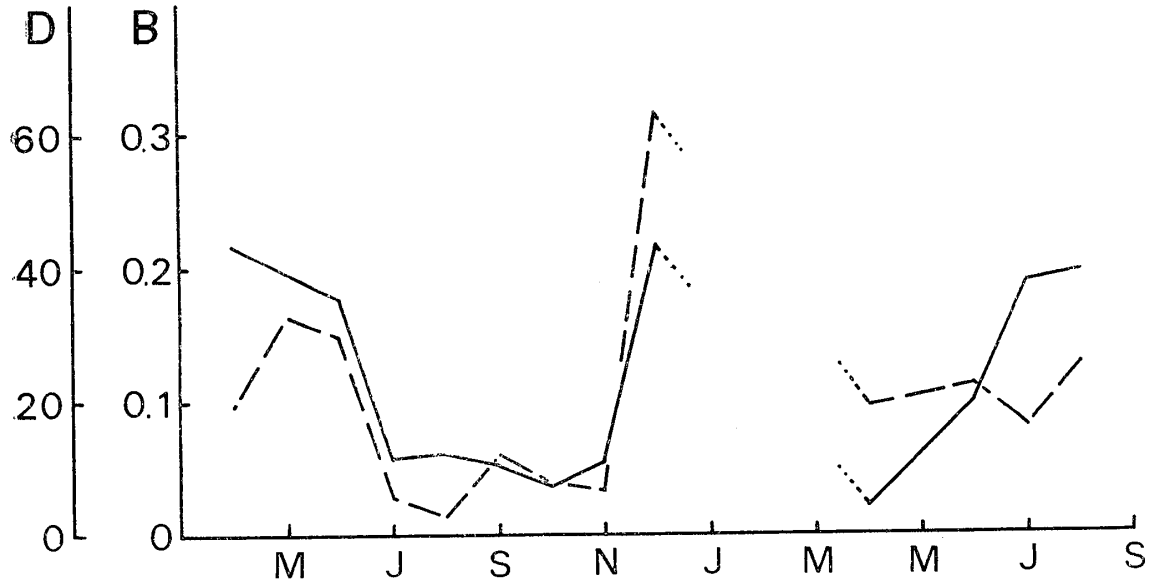

Fig. 6 Seasonal changes in density and biomass per square meter of Oligochaeta of Plot 1 at Pasoh Forest Reserve, West Malaysia, surveyed from April 1971 to August 1972. A solid line shows density (No./m²) and a broken line shows biomass (g·wet-wt./m²). D means density and B means biomass.

3-3 Heterogeneity and sampling problems

Sixty-eight samples in Pasho Forest Reserve were dealt for estimating the mean density and the mean biomass of the soil macrofauna in this field. This sample size as thought to be too small to analyze the density and biomass in every kind of habitat and of monthly fluctuation statistically.

For the analysis of density heterogeneity of each taxon in this forest, above 68 samples were computed on the assumption that all samples were in the same situation or the same statistical population. By this assumption, mean density, standard error of the mean (S. E.), coefficient of variation (C. V.) and I_δ-index (MORISITA, 1959) were computed of each taxon, and minimum sample size was determined by devised formula after TSUMURA (1956).

$$\text{minimum sample size} \geqq \frac{(C.V.)^2/P^2}{1+(C.V.)^2/N\cdot P^2}$$

where N is total estimating area shown by unit size and P is the allowance of estimate for mean density by using the proportion of mean density. If N is large enough, this formula is rewritten as

$$\text{minimum sample size} \geqq (C.V.)^2/P^2 .$$

Tables 3 and 4 show the above-mentioned minimum sample size of the density and biomass, respectively.

The taxa of which I_δ-indices were 0 to 1.0, were Hirudinea and Scorpiones. These two taxa seemed to be distributed homogeneously. But, the densities were too low to estimate accurately (**** in Table 3). Hirudinea was found in four samples of sixty-eight of 50cm × 50cm quadrate pit with one animal. Therefore, the samples are necessary to be taken more than 1602 pits for estimating the density with the accuracy within ten percent of the estimate. Scorpiones was found in two samples with two animals and six samples with one animal of sixty-eight of the same quadrate pits. The minimum sample size was computed as 750 for estimating the density with the accuracy within ten percent of the estimate.

The taxa, of which I_δ-index were 1.0 to 2.0 were Oligochaeta, Hemiptera, Orthoptera, larvae of Lepidoptera, Diplopoda, Chilopoda, Blattoidea, adults and larvae of Coleoptera and Araneida. Animals of these taxa distributed randomly or somewhat aggregate. The accuracy of the estimated mean density of Coleoptera (adults and larvae) and Araneida were within ten percent of the estimate (* in Table 3). Our sampling size may be adequate size of these taxa. Other seven taxa of 1.0 to 2.0 class of I_δ-index show the accuracy of the estimated mean density being ten percent to twenty percent of them (** in Table 3). The sample sizes, of which the accuracy of the estimated mean density are expected within ten percent of them, are more than 272 samples which are four times of our samples. Isopoda, Hymenoptera (mainly of Formicidae), Opiliones, the

larvae of Diptera and Thysanura took higher value of I_δ-index which means remarkably aggregate distribution. The accuracy of the estimated mean density of these taxa ranged from twenty to fourty percent of the average. Then, if we want to get the accuracy within ten percent of the estimate, we must take four to sixteen times as many as of our sample size. This result suggests that we must take other approach to get better estimates of these taxa. The mean density of whole soil animals was 1903 animals per m^2, of which accuracy was within twenty percent of the estimate. This suggests that four times of sampling effort is necessary to get the accuracy within ten percent of the estimate.

By the same way, the biomass of each taxon was estimated and computed the standard error of the mean (S. E.), coefficient of variation (C. V.) and I_w-index which was the same function of I_δ-index, but the number was continuous (Table 4). Of this data, major taxa, such as Hymenoptera and Araneida, and the total soil macrofauna showed the estimated mean biomass within the accuracy of twenty percent of them. These results suggest that four times of sampling effort is necessary to get the accuracy within ten percent of the estimate.

Table 3 Mean density per m^2 (M. D.), standard error (S. E.), coefficient of variation (C. V.), I_δ-index and minimum sample size of each soil macrofauna at Plot 1 of Pasoh Forest Reserve, West Malaysia, surveyed form April 1971 to August 1972. * shows the accuracy of the estimated mean density (* within ten percent, ** within twenty percent, *** within thirty percent, **** within forty percent) —— no available data

Taxon	M.D.	S.E.	C.V.	I_δ	Minimum sample size	accuracy
Thysanura	3.47	1.36	3.1989	10.2537	1024	****
Diptera (L)	21.94	7.19	2.6820	8.0322	720	****
Opiliones	5.18	1.28	2.0318	4.4054	413	***
Hymenoptera	1624.18	309.98	1.5622	3.4380	245	****
Isopoda	6.29	1.17	1.5271	2.7219	234	**
Oligochaeta	25.47	3.42	1.0983	2.0539	121	**
Hemiptera	9.47	1.37	1.1834	1.9904	140	**
Orthoptera	4.82	0.78	1.3307	1.9657	177	**
Lepidoptera (L)	3.65	0.63	1.4041	1.9059	187	**
Diplopoda	6.82	0.97	1.1596	1.7739	155	**
Chilopoda	24.41	2.76	0.9270	1.6995	86	**
Blattoidea	6.35	0.85	1.0971	1.5888	121	**
Coleoptera (L)	30.29	2.70	0.7300	1.4036	54	*
Araneida	48.18	4.01	0.6812	1.3827	47	*
Coleoptera (A)	77.65	5.55	0.5849	1.2916	35	*
Scorpiones	0.71	0.24	2.7382	3.0909	750	****
Hirudinea	0.24	0.11	4.0017	0.0000	1602	****
Others	3.41	——	——	——	——	
Total	1902.53	317.23	1.3649	2.8608	187	**

Table 4 Mean biomass per m^2 (M. B.), standard error (S. E.). coefficient of variation (C. V.), I_w-index and minimum sample size of each soil macrofauna at Plot 1 of Pasoh Forest Reserve, West Malaysia, surveyed from April 1971 to August 1972. * shows the accuracy of the estimated mean bipmass (* within ten percent, ** within twenty percent, *** within thirty percent, **** within forty percent) —— no available data

Taxon	M. B. g•wet-wt.	S.E.	C.V.	I_w	Minimum sample size	accuracy
Thysanura	0.0016	——	——	34.0000	——	****
Diptera (L)	0.0104	0.0048	3.8462	16.0129	1480	****
Opiliones	0.0176	0.0120	5.5455	30.3223	3076	****
Hymenoptera	0.8188	0.1016	1.0176	2.0359	104	**
Isopoda	0.0204	0.0108	3.9216	18.4514	1538	****
Oligochaeta	0.1764	0.0740	3.4308	12.7776	1178	****
Hemiptera	0.0032	——	——	18.7586	——	****
Orthoptera	0.0280	0.0152	4.5143	20.8035	2038	****
Lepidoptera (L)	0.0072	0.0048	5.5556	20.0274	3087	****
Diplopoda	——	——	——	——	——	****
Chilopoda	——	——	——	——	——	****
Blattoidea	0.1604	0.0524	2.6733	8.1667	715	****
Coleoptera (L)	0.4252	0.1528	2.9426	9.6633	866	****
Araneida	0.3224	0.0568	1.4404	3.0863	208	**
Coleoptera (A)	0.5960	0.3780	5.1926	27.9800	2697	****
Scorpiones	0.0188	0.0144	6.3830	42.9652	4075	****
Hirudinea	0.0044	0.0048	9.0909	68.0000	8263	****
Others	0.2244	0.0544	1.9768	——	——	
Total	3.0740	0.4808	1.2803	2.6393	163	**

3-4. Effect of litter covering on density

The differences of the densities of 24 pits are examined between litter-covered ground and naked ground as shown in Plates (in Appendix) and in Table 5. There are no differences in density of Orthoptera and the larvae of Lepidoptera between two types of ground. Opiliones, Oligochaeta, the adults and the larvae of Coleoptera and Araneida have also no differences of I_δ-index which shows a degree of aggregation, but the density at the litter-covered ground was higher than that at naked ground. On the other hand, Thysanura is also no difference in a degree of aggregation, but the density at the naked ground was higher than that at litter-covered ground. Diptera and Hymenoptera (mainly Formicidae) show higher value of I_δ-index which means high aggregation, at the litter-covered ground than naked ground.

Mean density of total soil macrofauna at litter-covered ground was three times as much as that at naked ground. Litter-covered ground accounted for 72.45 percent of total ground in 24 subquadrates. Then, the mean density weighed with the percentages of litter-covered ground and naked ground was computed as 1673.69 animals per m^2. This mean density is lower than above-mentioned mean density.

Table 5 Mean density, standard error, coefficient of variation (C. V.) and I_δ- index, of the litter-covered stand and naked stand of Plot 1 of Pasoh Forest Reserve, surveyed from April 1971 to August 1972 —— no available data

Taxon	Mean density ± Standard error				C. V.		I_δ	
	covered		naked		covered	naked	covered	naked
Thysanura	3.25 ±	1.75 <	14.00 ±	10.41	2.0967 =	1.9691	4.5128 =	4.7619
Diptera (L)	50.00 ±	29.55 >	17.50 ±	4.46	2.2896 >	0.6755	6.1934 >	1.2634
Opiliones	9.00 ±	3.39 >	4.00 ±	2.72	0.6837 =	0.7946	1.3885 =	1.5197
Hymenoptera	1713.50 ±	753.91 >	524.00 ±	140.64	1.7040 >	0.7101	3.9020 >	1.4980
Isopoda	8.00 ±	2.28 >	1.50 ±	1.05	1.1040 <	1.8557	1.7742 <	2.6667
Oligochaeta	14.75 ±	4.60 ≧	10.50 ±	3.99	1.2079 =	1.0068	2.2256 >	1.7143
Hemiptera	13.75 ±	3.28 >	4.50 ±	2.66	0.9255 <	1.5674	1.5946 <	2.8889
Orthoptera	4.75 ±	1.64 =	3.50 ±	1.91	1.3387 =	1.4498	2.0585 =	2.2875
Lepidoptera (L)	5.25 ±	1.70 =	5.00 ±	3.00	1.2553 =	1.5874	1.9048 <	3.0222
Diplopoda	8.50 ±	2.36 >	3.50 ±	1.18	1.0766 =	0.8921	1.7398 >	0.7619
Chilopoda	21.25 ±	5.73 >	12.50 ±	10.56	1.0453 <	2.1729	1.9272 <	5.6267
Blattoidea	5.50 ±	1.25 >	2.00 ±	0.07	0.8860 =	1.0000	1.1082	–
Coleoptera (L)	37.00 ±	5.56 >	23.50 ±	6.25	0.5828 =	0.7041	1.2399 =	1.3543
Araneida	46.25 ±	8.16 >	29.00 ±	8.70	0.6837 =	0.7946	1.3885 =	1.5197
Coleoptera (A)	82.75 ±	13.08 ≧	69.50 ±	16.57	0.6123 =	0.6311	1.3306 =	1.3504
Scorpiones	–	–	0.50 ±	0.50	–	2.6456	–	–
Hirudinea	–	–	–	–	–	–	–	–
Total	2029.50 ±	762.39 >	738.00 ±	150.36	1.4549 >	0.5391	3.1152 >	1.2860

4. DISCUSSION

The mean annual density of soil macrofauna excluding termites was 1903 animals/m^2 with standard error of 317 animals/m^2, at Plot 1 in Pasoh Forest Reserve, West Malaysia. The mean annual biomass and the standard error of them were 3.08 g·wet-wt./m^2 and 0.48 g·wet-wt./m^2. In Pasoh Forest, ABE (1979) estimated the mean annual density and mean annual biomass of termites to be 3160-3810 animals/m^2 and 8.69-10.13 g·wet-wt./m^2. Therefore, the mean annual density and biomass of soil macrofauna including termites were 5000-5700 animals/m^2 and 11.8-13.2 g·wet-wt./m^2, respectively.

WATANABE *et al.* (1966) showed that the mean biomass of soil macrofauna was 4.6-20.8 g·wet-wt./m^2 during the period from November 1963 to January 1964 at tropical evergreen forest at Khao Chong in southern Thailand. These biomasses are similar to that of Pasoh Forest. However, their estimation on density of 44-154 animals/m^2 was lower than that of our estimation. At present, it is not clear that this difference is due to the faunistic difference or quantitative difference betweeen two study site. As already described, Formicidae contributed largely to the density of the soil macrofauna of Pasoh Forest. If the soil macrofauna excluding Formicidae and Isoptera at Pasho Forest would be compared with that of Khao Chong and all known data on soil macrofauna at tropical evergreen forest including that of Pasoh Forest seems to be smililar.

In Japan, the biomass of 14.2 g·wet-wt./m^2 of soil macrofauna was recorded at an artificial forest of Meiji-Jingu in Tokyo (SAITO *et al.* 1979). And at a *Castanopsis* forest of Iriomote Island, the biomass of soil macrofauna based on the average biomass in October and February was estimated at 39.1 g·wet-wt./m^2 (SAITO *et al.* 1979). In comparison with these results, the biomass at Pasoh Forest is similar to smaller biomass of soil macrofauna in Japanese forests.

Increase in density for animal population or community is related to reproduction and immigration of individuals, and decrease in density is due to death and emigration of individual, when all habitats in the area concerned were examined. It is not clear that the fluctuation in density related to reproduction and death, to immigration and emigration of individual, to aggregation and dispersal at restricted habitat, or not. Mean body weight of a species generally shows it's mean developmental stage. However, as the concerning taxa contained the species of different body size, it is difficult to detect seasonal change of the body weight through their life history. In Pasoh Forest Reserve, seasonal change in density and biomass of these macrofauna were not remarkable, unlike those of the soil macrofauna in Japan (*e.g.* WATANABE and SHIDEI 1963, KITAZAWA *et al.* 1964, NAKAMURA *et al.* 1970, TANAKA *et al.* 1978).

Breeding habit of the invertebrates in tropics may be different from that of these animals in temperate zone. In regard to snail, BERRY and CHAN (1968) showed that breeding was found throughout the year in Malayan *Achatina fulica* and the cycle of reproductive activity was related to rainfall. On the other hand, BELFIELD (1956) pointed out the similar relation between increasing density of soil macrofauna and rainfall in African pastures. Unfortunately it is not clear the relation between seasonal change in density and biomass of soil macrofauna in Pasoh Forest Reserve and that of rainfall.

5. ACKNOWLEDGEMENTS

We wish to express our sincere thanks to Prof. T. KIRA, the Project Leader, Drs. H. OGAWA, K. HOZUMI and K. YODA, the Senior Members of the Japanese Team of Joint Malaysia/Japan/UK IBP Research Project, for their leaderships throughout our study in Pasoh Forest Reserve.

We are also grateful to Mr. K. D. MENON, Dr. J. A. BULLOCK, Dr. E. SOEPADMO and other Malaysian members of the same Project for their help and kind co-operation in the course of our study.

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西マレーシア・パソー保護林における土壌動物の生産力に関する研究

V　土壌大形動物（貧毛類・ヒル類・節足類）の密度と現存量の季節変化

近藤正樹・渡辺弘之・千葉滋男
・安部琢哉・芝　実・斉藤晋

要　　旨

本報は，ＩＢＰ(国際生物学事業計画)のひとつとして，マレーシア・日本・イギリスが共同で研究した熱帯多雨林の研究のひとつで，土壌動物に関する一連の報告のひとつである。

1971年４月から1972年８月までの間に，毎月５個，計68個の土壌塊を検査し，次の結果を得た。検査された土壌塊は，面積50cm×50cm，深さ20cmを単位とするものである。

1. 個体数が最も多いのは，アリを含む膜翅類の動物で全体の85.4%を占め，第２位は鞘翅類の幼虫の4.1%であった。現存量では膜翅類の26.6%，鞘翅類の成虫19.4%となった。
2. 全土壌大形動物の平均密度は1903個体/m^2，同現存量は3.1 g/m^2であった。
3. 季節変化はすべての生物群について見られる共通点は明瞭ではないが，密度は６～８月に高く，現存量はむしろ７月に高くなっていた。
4. Iδ-indexを用いた検討によると，ヒル類・サソリ類が少いが均等に分布し，貧毛類・半翅類・直翅類・鱗翅類・ヤスデ類・ムカデ類・ゴキブリ類についてはいくぶんかたまり気味であったが，かなり分散していることがわかった。アリを含む膜翅類とシロアリ（等翅類）はともに強い集合性を示していた。
5. 落葉が堆積している場所と，落葉がない場所との密度や現存量を比較してみたが，直翅類や鱗翅類幼虫については差が認められ難く，メクラグモ類・貧毛類・鞘翅類の幼虫と成虫・クモ類は集合性には差がなかったが，落葉のある土壌の方が高密度であった。双翅類の幼虫やアリを含む膜翅類は落葉の多い土壌の方が高い集合性を示した。
6. これらの資料とABE(1979)のシロアリの密度や現存量の資料を加えて，この地域の土壌大形動物の密度は5000～5700個体/m^2同現存量は11.8～13.2 g/m^2（湿重量）と推定することができる。ここに推定された密度は，今迄の報告にくらべて大きい値をとっているが，アリ・シロアリ以外の動物群のみを比較するとWATANBE *et al.*（1966）のタイにおける値とほぼ同様になる。

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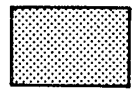
APPENDIX

(Four Plates and two Tables)

Explanation of plates

Maps of the ground surface of 24 sub-quadrate of Plot I at Pasoh Forest Reserve, West Malaysia, surveyed from April 1971 to August 1972. Number of sub-quadrate is explained in the first report of this studies (CHIBA *et al.* 1975). The size of the sub-quadrate is 4 m × 4 m, in which sample pit of 50 cm × 50 cm was settled.


litter covered ground


naked ground


50 cm × 50 cm pit for sampling


tree


buttressed tree and root above the ground

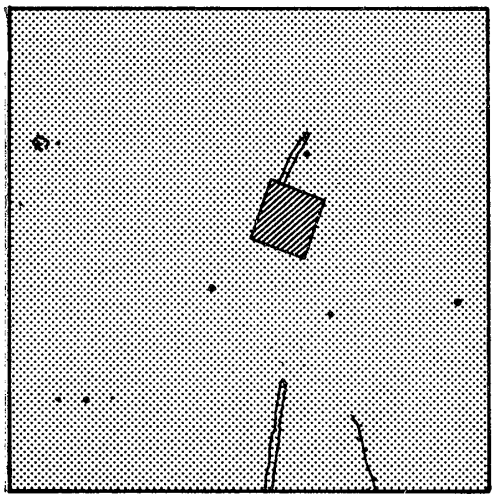

palm


rattan


fallen tree


mound of termite

29-30



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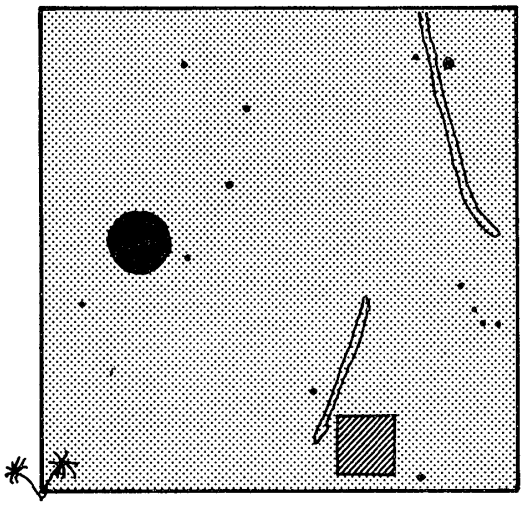

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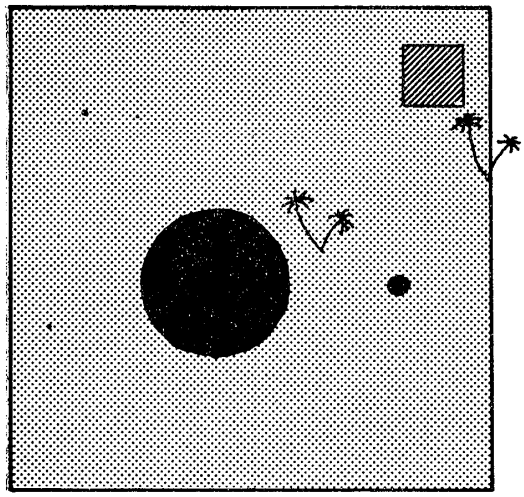

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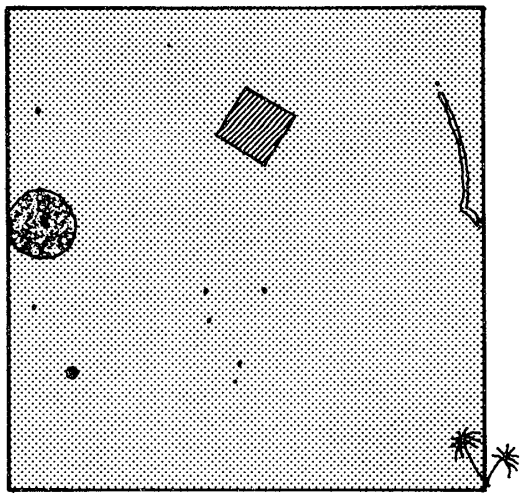

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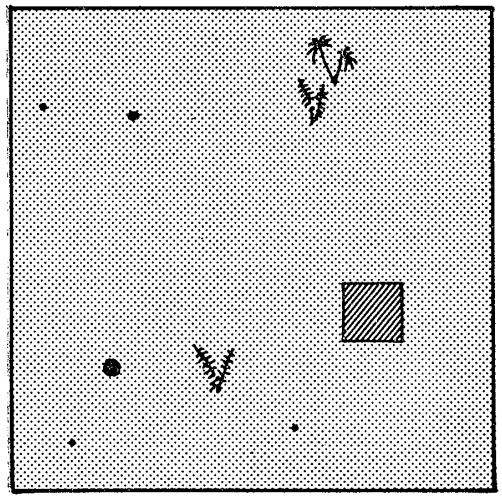

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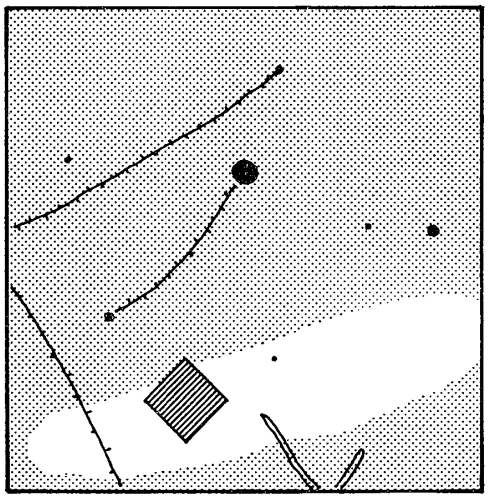
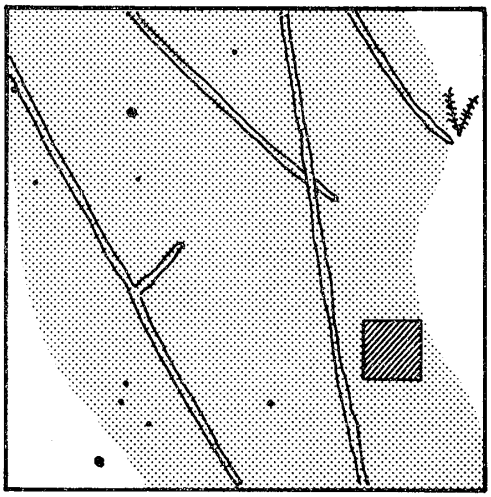
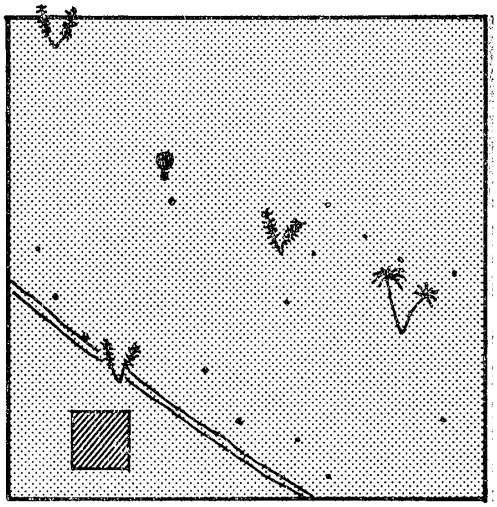


32-51



32-52



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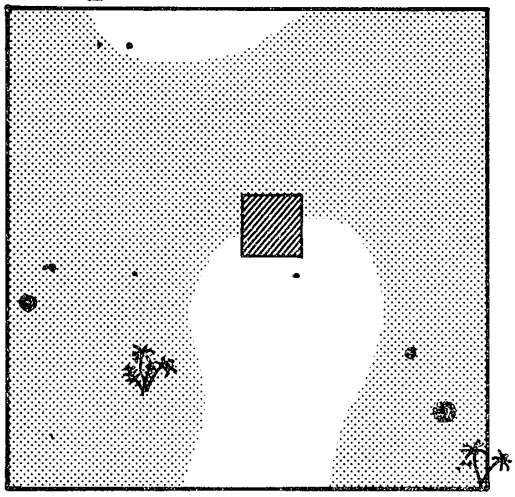

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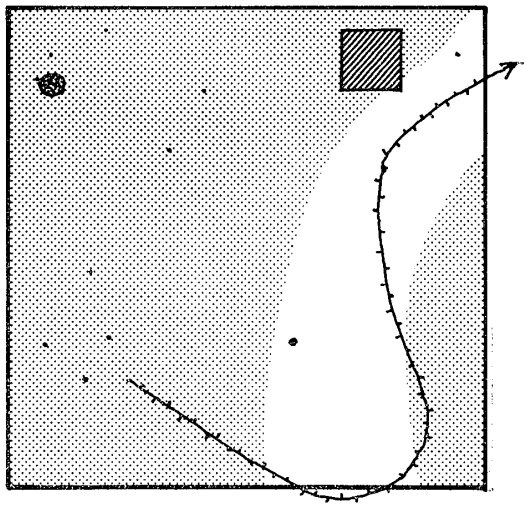

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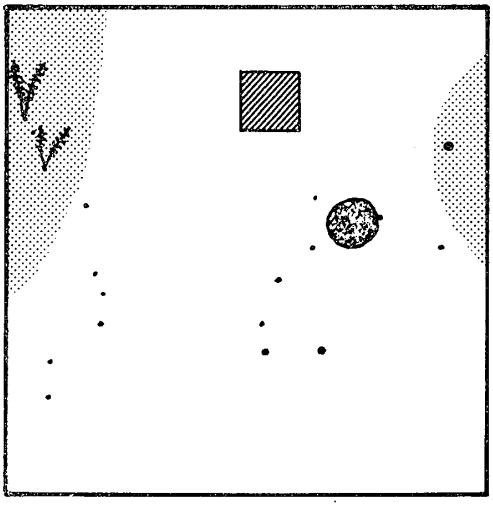

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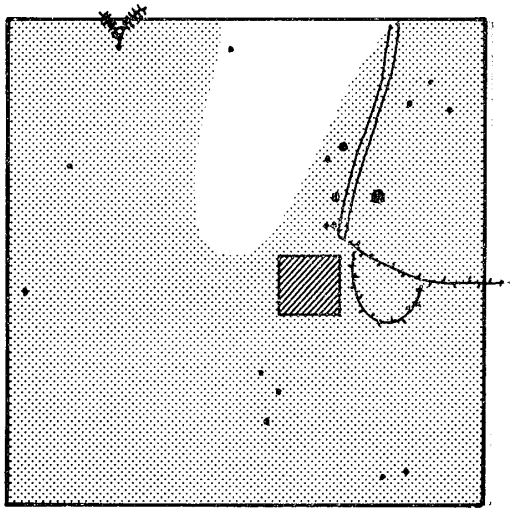

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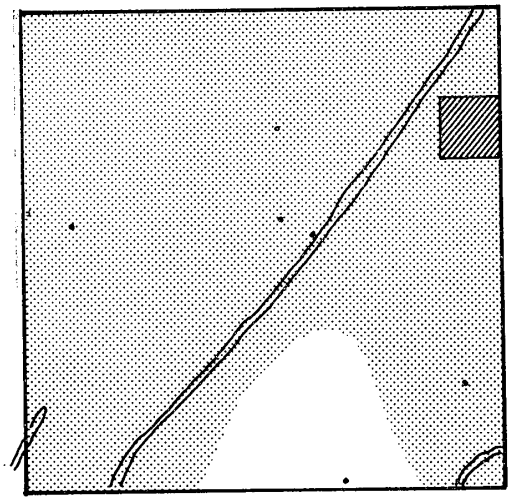

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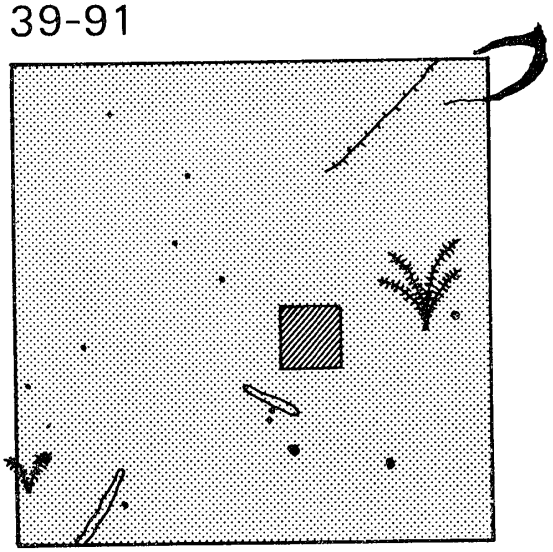

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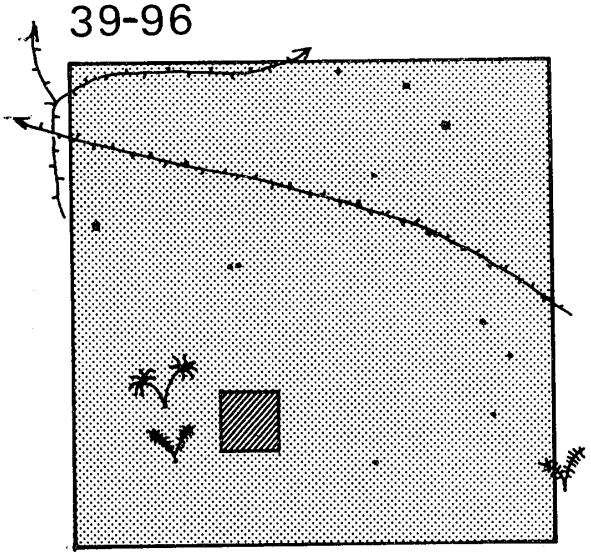

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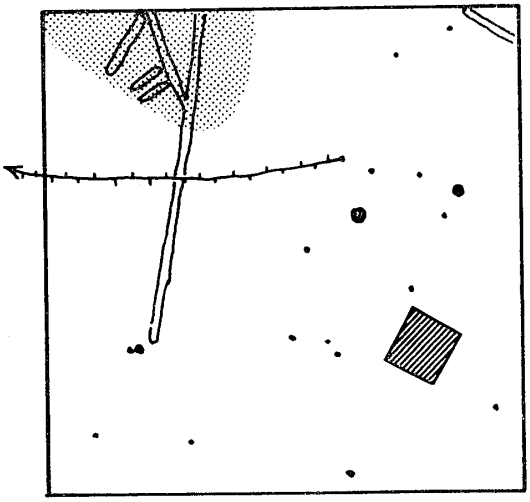

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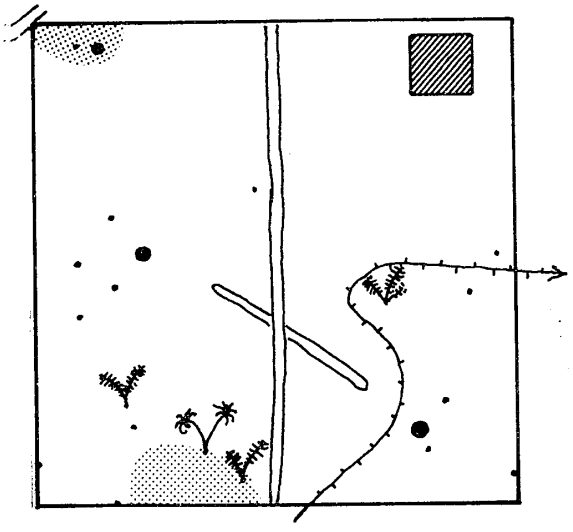

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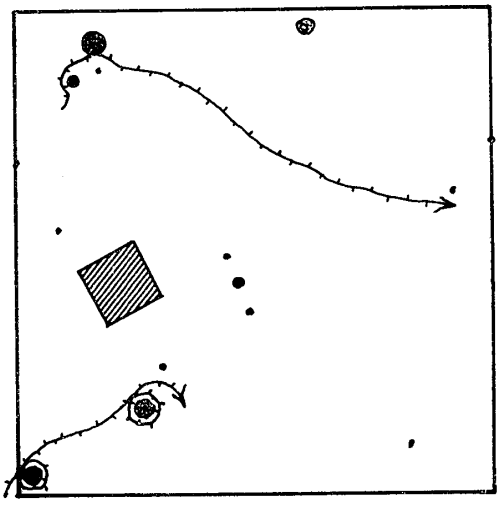

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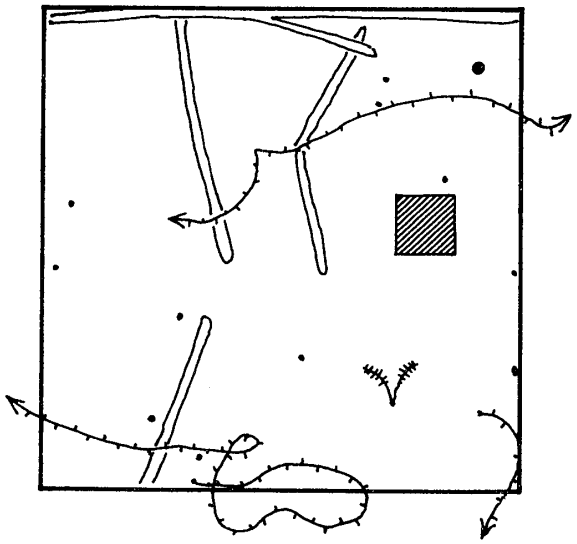

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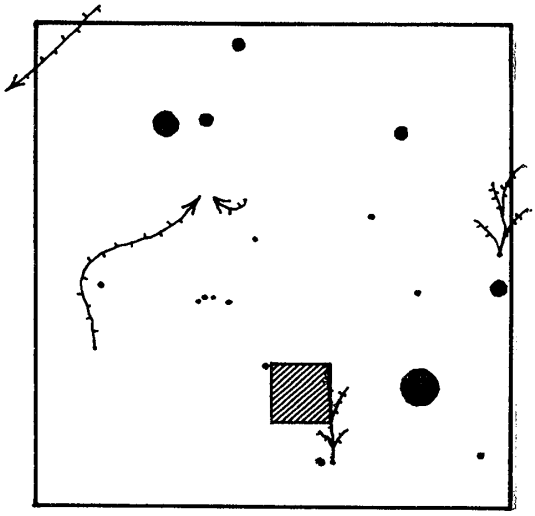

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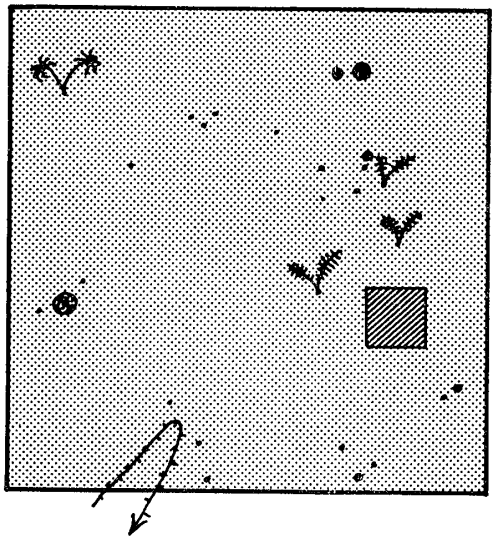

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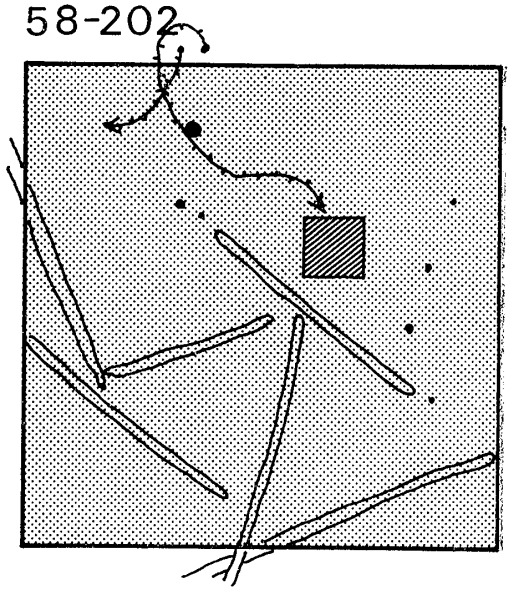

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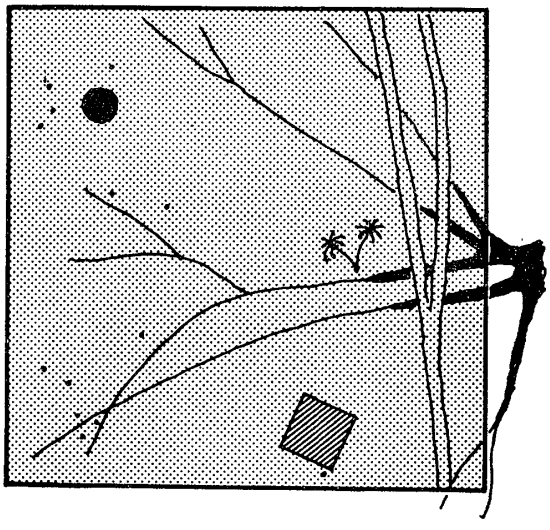

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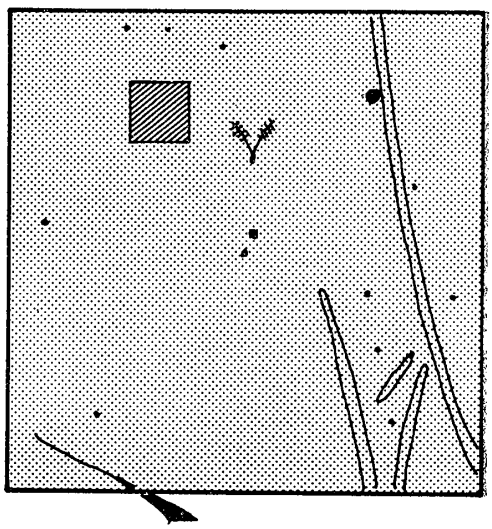

Table A Individual number of soil macrofauna from each pit, at Plot 1 of Pasoh Forest Reserve, West Malaysia, surveyed from April 1971 to August 1972

Date	April 1971					May 1971					June 1971					July 1971					August 1971				
	A-14	A-15	A-19	A-21	A-26	M-10	M-12	M-15	M-17	M-19	J-08	J-10	J-12	J-14	J-16	J-06	J-08	J-10	J-12	J-14	A-07	A-09	A-11	A-13	A-16
Number of sub-quadrate	32-60	29-27	57-195	58-222	39-79	29-28	32-65	39-78	57-190	58-223	29-29	32-70	39-77	57-185	58-224	29-30	32-75	39-76	57-180	58-225	29-35	32-54	39-81	56-175	58-216
Oligochaeta	4	13	17	14	6	24	8	1	14	2	7	9	4	22	2	1	5	0	8	0	3	6	3	2	1
Hirudinea	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scorpiones	0	0	0	0	0	1	0	0	1	0	0	0	0	2	0	0	0	1	0	1	0	0	0	0	0
Opiliones	1	2	0	0	0	1	0	0	0	0	0	0	0	0	0	9	0	0	0	0	1	2	0	0	0
Araneida	7	9	6	30	11	23	15	9	13	29	12	4	5	6	16	18	11	16	17	18	10	17	9	5	15
Isopoda	0	0	0	3	0	0	3	0	1	0	2	2	1	3	3	3	1	1	0	6	1	3	0	0	6
Diplopoda	4	0	1	2	0	1	1	3	2	3	0	2	0	4	1	3	1	1	0	1	0	4	3	1	1
Chilopoda	4	10	13	6	2	3	11	2	1	12	5	0	3	5	10	5	5	11	5	8	2	8	17	2	4
Thysanura	1	0	0	3	0	1	0	0	0	4	0	0	0	0	0	0	0	1	0	2	1	1	0	0	0
Blattoidea	0	0	1	3	1	0	2	1	2	3	0	1	3	0	1	1	4	1	1	3	2	2	3	2	2
Orthoptera	0	0	0	2	2	0	0	0	1	0	1	2	0	0	1	6	1	4	1	1	2	3	0	0	2
Hemiptera	12	6	0	5	2	0	7	0	1	6	5	3	1	0	8	0	3	5	3	1	2	7	2	0	0
Lepidoptera (L)	0	0	0	1	2	1	0	0	0	2	0	2	0	0	0	1	1	2	0	2	1	3	0	0	1
Diptera (L)	6	2	4	0	4	0	6	4	1	2	1	0	2	4	0	0	0	2	1	0	0	2	0	0	1
Coleoptera (A)	33	7	13	19	19	20	31	11	13	18	22	10	11	11	14	20	39	25	38	23	26	37	9	15	27
Coleoptera (L)	5	6	4	7	4	3	8	7	7	9	5	6	7	9	8	1	1	0	7	4	6	10	15	8	6
Hymenoptera	155	257	216	405	148	991	126	78	180	623	218	358	979	260	1821	352	425	155	140	908	458	3050	198	243	1425
Others	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	232	312	275	500	201	1069	218	116	238	713	278	399	1016	326	1885	420	497	225	221	978	515	3155	259	278	1491

(Table A continued)

Date	September 1971					October 1971					November 1971					December 1971					January 1972		February 1972	
	S-26	S-28	S-30	O-02	O-04	O-23	O-25	O-27/28	O-30	N-01	N-23	N-35	N-27	N-29	D-01	D-19	D-23	D-27	D-29	D-31	J-11	J-12	F-20	F-26
Number of sub-quadrate	29-40	32-53	39-86	57-179	58-211	29-45	32-52	39-91	57-178	58-206	29-50	32-51	39-96	57-177	58-201	29-31	32-56	39-97	57-176	58-202	29-36	29-41	32-66	39-99
Oligochaeta	0	6	0	1	6	2	3	0	2	2	1	1	6	1	5	19	30	1	2	2	0	0	0	0
Hirudinea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scorpiones	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Opiliones	0	0	0	0	0	12	2	1	0	1	5	2	3	3	0	2	0	1	0	1	0	0	0	0
Araneida	0	5	1	3	18	10	11	6	3	15	9	20	32	1	4	7	9	8	4	7	4	3	3	6
Isopoda	0	0	0	0	1	0	1	3	0	3	0	1	8	2	1	6	1	0	0	1	0	0	0	0
Diplopoda	0	0	0	1	1	1	6	1	0	0	1	7	5	2	3	0	2	8	2	0	0	0	0	0
Chilopoda	0	4	0	4	5	0	4	7	1	0	1	16	14	1	4	2	4	14	4	1	2	1	3	0
Thysanura	0	0	0	0	1	1	2	0	0	7	21	0	0	6	0	0	1	1	0	0	0	0	0	0
Blattoidea	0	1	0	0	5	1	1	1	0	1	1	2	1	0	1	0	1	0	0	1	0	0	0	0
Orthoptera	1	0	0	0	0	0	0	1	0	0	1	1	1	1	3	1	1	0	0	0	0	0	0	1
Hemiptera	11	1	7	0	2	0	3	1	0	1	0	8	0	0	5	4	2	7	0	2	0	0	0	0
Lepidoptera (L)	0	0	0	0	0	6	1	1	0	1	0	2	4	2	0	0	0	0	6	1	2	0	0	0
Diptera (L)	11	8	122	4	0	6	4	5	5	8	2	11	15	3	9	5	12	8	10	2	0	0	0	0
Coleoptera (A)	6	19	9	25	28	13	24	11	3	16	12	36	51	5	29	8	21	21	12	8	18	8	6	8
Coleoptera (L)	0	6	1	3	8	7	19	9	6	9	15	9	13	3	14	10	16	16	7	17	0	0	0	0
Hymenoptera	0	206	15	20	18	130	1178	236	14	203	235	396	308	253	111	110	225	242	25	91	38	310	168	665
Others	1	1	0	2	5	0	0	14	0	0	0	0	0	1	0	4	7	1	16	0	0	1	2	0
Total	30	257	155	63	98	189	1259	297	34	267	304	512	461	284	189	178	332	328	88	134	64	323	182	680

(Table A continued)

Date	April 1972		June 1972					July 1972					August 1972						
	A-23	A-30	J-03	J-04	J-05	J-06	J-07	J-02	J-03	J-04	J-05	J-06	A-01	A-02	A-03	A-04	A-05	A-26	S-03
Number of sub-quadrate	23-46	30-71	29-47	32-72	39-100	57-181	58-203	29-48	32-73	39-95	57-186	58-204	29-49	32-74	39-90	57-191	58-205	Plot 2	Plot 3
Oligochaeta	1	1	1	2	9	2	11	13	2	14	7	11	16	3	12	10	8	26	18
Hirudinea	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
Scorpiones	0	0	0	0	0	0	0	1	2	0	2	0	0	1	0	0	0	0	0
Opiliones	1	0	2	2	0	0	1	6	0	0	4	12	1	0	1	0	9	0	0
Araneida	6	6	8	7	15	11	7	23	19	15	12	38	10	13	23	15	35	21	15
Isopoda	2	0	5	0	6	0	1	1	0	0	1	14	1	0	1	1	5	1	1
Diplopoda	0	0	0	4	4	1	1	3	3	2	0	3	0	1	2	2	9	2	0
Chilopoda	2	3	14	5	14	3	8	3	8	9	9	17	8	2	6	12	32	13	1
Thysanura	0	2	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
Blattoidea	0	0	7	0	2	0	4	3	6	4	1	6	1	1	2	2	7	2	4
Orthoptera	5	2	0	0	1	0	0	3	0	0	3	4	4	2	7	3	5	1	1
Hemiptera	0	0	2	1	0	4	1	3	1	3	1	1	2	1	2	0	4	0	2
Lepidoptera (L)	0	0	1	0	0	0	0	1	1	2	2	1	2	1	2	2	2	0	0
Diptera (L)	0	0	2	1	1	3	1	14	4	8	4	6	9	2	4	4	7	4	7
Coleoptera (A)	9	10	47	15	13	6	8	28	15	18	17	23	22	9	38	23	55	32	24
Coleoptera (L)	0	0	8	6	8	14	13	4	23	5	11	13	3	5	8	19	11	22	1
Hymenoptera	142	45	390	121	557	94	75	281	140	481	202	657	151	198	411	108	3904	254	34
Others	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	170	70	488	165	630	138	131	387	225	562	276	807	230	239	519	201	4094	378	108

Table B Biomass (mg·wet-wt./m²) of soil macrofauna from each pit which was preserved in 70% ethanole, at Plot of Pasoh Forest Reserve, West Malaysia, surveyed from April 1971 to August 1972

Date	April 1971					May 1971					June 1971					July 1971					August 1971				
	A-14	A-15	A-19	A-21	A-26	M-10	M-12	M-15	M-17	M-19	J-08	J-10	J-12	J-14	J-16	J-06	J-08	J-10	J-12	J-14	A-07	A-09	A-11	A-13	A-16
Number of sub-quadrate	32-60	29-27	57-195	58-222	39-79	29-28	32-65	39-78	57-190	58-223	29-29	32-70	39-77	57-185	58-224	29-30	32-75	39-76	57-180	58-225	29-35	32-54	39-81	56-175	58-216
Oligochaeta	8	45	52	8	+	71	71	16	42	6	7	34	26	118	+	+	+	–	33	–	+	15	+	+	+
Hirudinea	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Scorpiones	–	–	–	–	–	+	–	–	+	–	–	–	–	+	–	–	–	+	–	+	–	–	–	–	–
Opiliones	+	24	+	–	–	+	–	–	–	–	–	–	–	–	–	+	–	–	–	–	+	+	–	–	–
Araneida	11	12	23	80	26	55	19	29	21	159	85	59	4	34	38	290	+	141	51	497	54	26	128	2	41
Isopoda	–	–	–	71	–	–	+	–	–	–	+	+	+	+	+	+	+	+	–	+	+	112	–	–	8
Diplopoda	+	–	53	8	–	+	24	328	12	132	–	83	–	821	97	+	+	+	–	23	–	747	5	29	6
Chilopoda	+	20			+	+					+	–	+			–	–	–	2		+				
Thysanura	+	–	–	+	–	+	–	–	–	+	–	–	–	–	–	–	–	+	–	+	+	+	–	–	–
Blattoidea	–	–	+	+	+	–	+	+	+	+	–	+	+	–	+	+	+	+	+	+	+	111	80	46	384
Orthoptera	–	–	–	+	+	–	–	–	+	–	+	+	–	–	+	+	+	+	+	+	161	+	–	–	+
Hemiptera	+	+	–	+	+	–	+	–	+	+	+	+	+	–	+	–	+	+	+	+	+	+	+	–	–
Lepidoptera (L)	–	+	–	+	+	+	–	–	–	+	–	+	–	–	–	+	+	+	–	+	+	46	–	–	+
Diptera (L)	+	+	+	–	+	–	+	+	+	+	+	–	+	+	–	–	–	+	+	–	–	+	–	–	+
Coleoptera (A)	7	8	99	13	+	163	32	9	4	226	50	4	10	66	20	+	+	+	332	25	26	108	4	38	12
Coleoptera (L)	26	19	24	83	+	+	41	16	31	129	155	17	20	139	109	+	+	–	128	2	37	133	32	205	88
Hymenoptera	83	208	302	142	42	687	99	26	116	176	83	201	88	325	487	175	182	26	58	314	304	173	104	152	415
Others	18	20	10	250	27	27	18	12	817	46	19	22	34	79	471	151	306	446	20	574	52	26	6	8	5
Total	153	356	563	655	95	1003	304	436	1043	874	399	420	182	1582	1222	616	488	613	624	1435	634	1497	359	480	959

(Table B continued)

Date	September 1971					October 1971					November 1971					December 1971					January 1972		February 1972	
	S-26	S-28	S-30	O-02	O-04	O-23	O-25	O-27/28	O-30	N-01	N-23	N-35	N-27	N-29	D-01	D-19	D-23	D-27	D-29	D-31	J-11	J-12	F-20	F-26
Number of sub-quadrate	29-40	32-53	39-86	57-179	58-211	29-45	32-52	39-91	57-178	58-206	29-50	32-51	39-96	57-177	58-201	29-31	32-56	39-97	57-176	58-202	29-36	29-41	32-66	39-99
Oligochaeta	–	56	–	1	16	13	17	–	8	8	2	+	3	+	37	144	232	1	16	3	–	–	–	–
Hirudinea	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Scorpiones	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Opiliones	–	–	–	–	–	+	13	15	–	1	+	2	+	+	–	10	–	1	–	2	–	–	–	–
Araneida	–	58	1	2	35	49	58	38	2	91	37	44	2	+	12	8	91	28	14	16	59	408	9	72
Isopoda	–	–	–	–	+	–	1	1	–	+	–	1	5	+	1	1	3	–	–	5	–	–	–	–
Diplopoda	–	–	–	+	+	+	3	–	+	–	+	1	1	+	+	–	37	1	3	–	–	–	–	–
Chilopoda	–	21	–	1	+	–	4	15	+	–	+	24	+	+	+	36	14	1	1	2	61	98	55	–
Thysanura	–	–	–	–	1	+	+	–	–	+	+	–	–	+	–	–	+	+	–	–	–	–	–	–
Blattoidea	–	42	–	–	+	10	1	+	–	+	67	226	+	–	15	–	281	–	–	+	–	–	–	–
Orthoptera	7	–	–	–	–	–	–	+	–	–	6	1	+	+	47	+	1	–	–	–	–	–	–	200
Hemiptera	2	16	19	–	2	–	+	+	–	+	–	+	–	–	+	+	11	4	–	+	–	–	–	–
Lepidoptera (L)	–	–	–	–	–	+	11	+	–	+	–	+	14	+	–	–	–	–	6	+	44	–	–	–
Diptera (L)	5	25	69	1	–	+	+	+	+	+	1	1	36	+	+	3	24	6	5	+	–	–	–	–
Coleoptera (A)	2	9	61	9	48	2	5	11	12	1	5	15	20	+	25	17	19	4	1	1	104	209	28	218
Coleoptera (L)	–	8	5	56	173	1	48	1	264	1	6	8	25	+	6	39	31	57	3	6	–	–	–	–
Hymenoptera	–	82	4	25	13	34	412	132	29	97	135	228	853	145	15	154	73	132	54	32	56	643	174	1058
Others	+	13	–	+	+	–	–	+	–	–	–	–	–	+	–	+	+	+	+	–	–	1	5	–
Total	16	330	159	95	288	109	573	213	315	199	259	551	959	145	158	412	817	235	103	67	324	1359	271	1548

(Table B continued)

Date	April 1972		June 1972					July 1972					August 1972						
	A-23	A-30	J-03	J-04	J-05	J-06	J-07	J-02	J-03	J-04	J-05	J-06	A-01	A-02	A-03	A-04	A-05	A-26	S-03
Number of sub-quadrate	23-46	30-71	29-47	32-72	39-100	57-181	58-203	29-48	32-73	39-95	57-186	58-204	29-49	32-74	39-90	57-191	58-205	Plot 2	Plot 3
Oligochaeta	9	38	12	5	57	+	67	54	+	45	+	+	60	+	40	42	20	212	1228
Hirudinea	–	–	72	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Scorpiones	–	–	–	–	–	–	–	30	40	–	247	–	–	–	–	–	–	–	–
Opiliones	2	–	+	36	–	–	+	+	–	–	+	195	+	–	+	–	+	–	–
Araneida	324	19	27	6	50	82	10	46	52	283	49	436	38	212	70	53	501	32	170
Isopoda	10	–	5	–	+	–	+	+	–	–	+	120	+	–	+	+	+	+	+
Diplopoda	–	–	–	+	+	14	30	+	+	+	–	+	–	+	+	178	42	+	–
Chilopoda	6	85	+	+	195	+	34	–	–	–	–	–	+	+	+	+	+	+	+
Thysanura	–	2	–	9	–	–	–	–	–	13	–	–	–	–	–	–	–	–	–
Blattoidea	–	–	302	–	16	–	16	35	44	42	+	109	16	6	58	+	682	79	60
Orthoptera	33	21	–	–	+	–	–	+	–	–	+	+	+	+	+	+	+	+	+
Hemiptera	–	–	+	+	–	+	+	+	+	+	+	+	+	+	+	–	+	–	+
Lepidoptera (L)	–	–	+	–	–	–	–	+	+	+	+	+	+	+	+	+	+	–	–
Diptera (L)	–	–	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Coleoptera (A)	383	37	6434	64	13	8	156	12	55	497	+	14	37	+	+	45	42	251	+
Coleoptera (L)	–	–	29	10	55	349	294	259	183	–	2408	65	22	26	59	216	98	985	–
Hymenoptera	167	121	348	76	274	90	116	192	163	272	541	575	90	89	277	87	238	625	29
Others	2	146	35	15	22	25	14	82	75	25	73	117	85	35	90	35	163	72	22
Total	936	469	7264	221	682	568	737	710	612	1177	3318	1631	348	368	594	656	1786	2256	1509