A Comparative Study of the Ant Fauna in a Primary and Secondary Forest in Sabah, Malaysia

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ABSTRACT. The diversity and ecology of ants in a primary and secondary selectively logged forest was compared over a 12 month period at Danum Valley, Sabah, Malaysia. Species richness and diversity were higher in the primary forest. A total of 192 species from seven subfamilies were recorded. The Myrmicinae was the most common subfamily in species and abundance, for both habitats. Rainfall had some negative effects on subterranean fauna in primary and secondary forest while high temperature diminished the number of arboreal species collected in the primary forest.

KEY WORDS: ant diversity, ecology, Myrmicinae, Formicinae, Ponerinae.

INTRODUCTION

Ants are extremely abundant, species-rich, and ecologically important in tropical lowland rain forests (Atkin & Proctor 1988, Burghouts *et al.* 1992, Levings 1983). Measurements suggest that about one third of the entire animal biomass of the Amazonian *terra firme* rain forest is composed of ants and termites, with each hectare of soil containing in excess of eight million ants and one million termites (Fittkau & Klinge 1973). These insects, along with bees and wasps, account for more than 75 percent of the total insect biomass in that forest. The diversity of ants is substantial, far exceeding that of other social insects and reflecting the manner in which ant species have evolved to saturate a wide range of feeding niches in soil and vegetation (Holldobler & Wilson 1990). In a lowland rain forest in Papua New Guinea, Wilson (1959) collected 172 species of ants belonging to 59 genera in an area of about one square mile (2.6 km^2). Olson (1991) recorded 41 genera and 122 species from three primary forest sites in Costa Rica, while Levings (1983) collected 49 genera and 127 species in a tropical moist forest in Panama. Bolton (in Room 1971) recorded 219 species in 63 genera in a square mile of a cocoa plantation and forest in Ghana.

Tropical rain forests are the richest ecosystems that the world has ever known (Marshall 1992). However, it has been estimated that 11 million hectares of mature tropical forests, of which 7.5 million hectares are rain forests, are converted each year to other uses. The great majority is changed to non-forest uses, only 600,000 hectares becoming timber plantations (Gomez-Pompa & Burley, in Marshall 1992), resulting in a loss of global biodiversity. Ants, one of the most diverse and abundant group of organisms in the rainforest, have great potential as indicator species for studying the effects of deforestation. The aims of this research were to describe the ant fauna in the rain forest, to study the effects of logging and to look at the effects of biotic and abiotic factors on the diversity and ecology of ants.

Study Area and the Environment

A 12-month study was conducted in Danum Valley Conservation Area, Sabah, Malaysia (4^0 58' N and 117^0 48' E), which comprises 43,800 hectares of tropical lowland evergreen

D. S. Edwards et al. (eds.), Tropical Rainforest Research – Current Issues, 357–366.

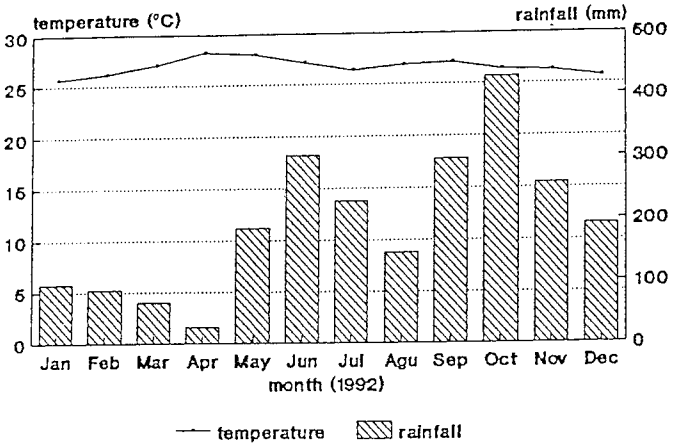

Figure 1. Mean temperature and monthly rainfall in Danum Valley Field Centre (1992).

dipterocarp rain forest. This area is situated in eastern Sabah at the upper reaches of the Segama River, approximately 70 km from the coast.

The total rainfall recorded at Danum Valley Field Centre (DVFC) for 1992 was 2314 mm, which was lower than the annual rainfall average of 2822 mm (based on 5 years of records). It was dry at the beginning of the year until April and two rainfall peaks in June (302.7 mm) and October (428.1 mm) were observed. This pattern (Figure 1) is influenced by the edge effects of two monsoons; the wetter northeast monsoon from November to March and the drier but more consistent southwestern monsoon in June and July (Marsh & Greer 1992). Mean annual temperature at DVFC in 1992 was 26.7°C. The highest mean monthly temperature recorded was 28.3°C in April, and the lowest was 25.6°C in December.

Two permanent 100 x 150 m plots were used to study the ant fauna; one each in a primary and secondary forest. The altitude of the plots was 180-230 m. In both plots, three line transects (150 m in length and 50 m apart) were established to collect ants. The primary forest plot was located at 0.6 km from DVFC, and was composed primarily of dipterocarps with a high canopy at about 40 m. The secondary forest plot was located within a three year old selectively logged forest, 2.0 km from DVFC.

MATERIAL AND METHODS

Sampling was done once a month along the transects in each plot. Three methods were used to collect ants at the arboreal, terrestrial and subterranean levels.

Manual Sampling

A sweep net, an aspirator and forceps were used to collect arboreal ants. The maximum height that could be reached using this method was about 3 m above the ground. Sampling was carried out in the morning (0830-1130 hrs), by collecting ants found on vegetation along the transects.

Baited Pitfall Sampling

Plastic cups with a diameter of 7 cm and a depth of 12 cm were planted in the soil, every 15 m along the transects. Eleven pitfall traps were set up in each transect, resulting in a total of 33 for one plot. Tuna flakes in oil were used as bait. The bait was wrapped in a piece of

cloth which was hung across the cup with a small stick. The traps were 1/8-filled with water and liquid detergent was added to reduce water tension. They were left overnight in the forest and emptied the following day. This method was used for collecting nocturnal and terrestrial ants.

Winkler's Sampling

Leaf litter and soil to about 5 cm depth were collected and sifted from eleven 0.25 m^2 quadrats chosen at random along one transect. The sifted litter and soil were transferred to debris bags in the field. When the bags were brought back to DVFC, the contents were transferred to several flat mesh bags which were hung inside an outer cloth sack (Winkler's bag). Soil organisms worked their way out of the litter and dropped into a container which was placed at the base of the Winkler's bag. Specimens were collected and sorted the next day.

Sorting and Identification of Ants

Most of the ants were identified to generic level using Bolton (1990) and Murphy (1973). Specimens are deposited with the Entomology Section, Universiti Kebangsaan Malaysia, Sabah Campus.

Statistical Analysis

For the analyses of data, the Wilcoxon paired-sample test, which is a non parametric analogue to the paired sample t-test, was used as the data was not normally distributed.

Shannon's Index (H') was used to evaluate species diversity. This provides the average degree of uncertainty in predicting what species an individual chosen at random from a sample will belong to. Hutcheson 't' test was applied to test for the difference between two diversity indices in each month (Zar 1984).

Hill's Modified Index (E5) was used to calculate the degree of evenness of ant species distribution. The value approaches zero as a single species becomes more and more dominant in a community. This index was recommended as it is the least ambiguous and easiest to interpret. It does not require an estimate of the number of species in the community, a feature which is affected by sample size (Ludwig & Reynolds 1988).

Multiple correlation was used to detect relationships among variables throughout the year. The variables were number of species and individuals collected with different methods, total species, abundance, diversity, evenness, rainfall and temperature.

RESULTS AND DISCUSSION

Species Richness

A total of 192 ant species from more than 50 genera and seven subfamilies were recorded (see Appendix). However, some taxa were identified only to subfamily level. The percentage of species and abundance recorded for each subfamily in the primary and secondary plot are shown in Figure 2(i) and (ii). Myrmicinae was the most abundant and diverse subfamily in both plots, followed by Formicinae and Ponerinae. Percentage of species and abundance of the myrmicine ants were relatively higher in the secondary plot. The abundance of formicine and ponerine ants were higher in the primary plot. Dorylinae, Pseudomyrmecinae and Leptanillinae were represented by very few species and individuals in both plots.

Throughout the year, species richness was higher in the primary plot (Wilcoxon test, $P<0.01$). 164 (86%) species (out of the total of 192) were recorded in the primary plot, while 155 (81%) species were found in the secondary plot. 19.3% of the total species were found exclusively in the primary plot and 14.6% were recorded exclusively in the secondary plot. The monthly overlap of species was 33-44%. The annual overlap of species was 66%.

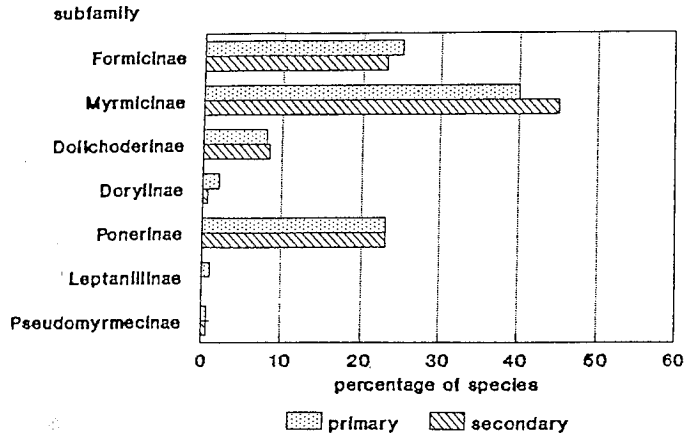

Figure 2 (i). Percentage of species in each subfamily, in primary and secondary plots.

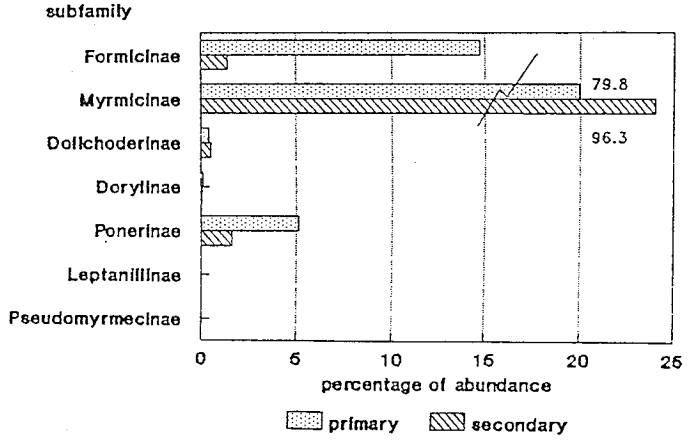

Figure 2 (ii). Percentage of ant abundance in each subfamily, in primary and secondary plots.

Diversity

The Shannon's diversity indices were significantly higher in the primary plot with the ratio of 10:2 for the 12 months' sampling (Hutcheson 't' test, $P<0.05$). The average value of Shannon's index (formula based on ln) was 1.83 (SD=0.48), compared to 1.47 (SD=0.37) in the secondary plot. The higher value in diversity index suggests that either one or both species richness and evenness were higher in the primary plot because diversity indices incorporate species richness and evenness into a single value.

Evenness

The average value of the evenness index (E5) was fairly low; 0.40 (SD=0.08) in the primary plot and 0.39 (SD=0.08) in the secondary plot. This suggests that dominance of certain ant species occurred in both plots and different ant-species had very different colony sizes. It also showed that higher diversity in the primary plot was due to species richness and the low value of evenness had indirectly affected the diversity values in both plots.

Table 1. Mean total number of species and individuals (±SD) collected each month with different methods in primary and secondary plots throughout the year.

	Pitfall	Manual	Winkler's
Species			
primary plot	21.5±3.5	20.8±3.1	33.9±3.8
secondary plot	20.7±2.6	22.6±2.6	23.8±3.4
Individuals			
primary plot	5498±2682	131±34	337±147
secondary plot	6818±3445	156±29	218±67

Table 2. Ant species that achieved more than 5% in the total abundance in respective plots throughout the year.

Species	code	% of abundance
Primary plot		
Pheidole sp.	DV83	49.0
Euprenolepis sp.	DV121	8.3
Pheidologiton sp.	DV45	7.8
Pheidole sp.	DV14	6.5
Secondary plot		
Pheidole sp.	DV83	66.0
Pheidologiton sp.	DV45	8.6

Abundance

Although more ants were collected from the secondary plot, the difference was not significant. Abundance in both plots varied and fluctuated throughout the year. The inconsistency in ant abundance may be the result of the methods used to collect ants. Baited pitfall sampling collected the most ants (Table 1), thus it was this method that primarily affected the total abundance of ants collected. At times, thousands of ants from one species were found in one pitfall trap because the trap was placed within the foraging trail of the species. Catches of any ant species depends on the size and abundance of its foraging population, the dispersion of colonies, levels of activity, the size of individual ants, and the thoroughness with which foragers cover their territory (Southwood 1966). The abundances in both plots were dominated by a myrmicine species, *Pheidole* sp. (DV83), large colonies of which were collected, mainly by pitfall sampling. Table 2 shows that four ant species from the primary plot and only two from the secondary plot achieved more than 5% of the total abundance in the respective plots.

Frequency of Occurrence

The number of individuals collected in an area is not a good indication of how common a species is, because of differences in foraging behaviour of different ant species (e.g, solitary or in colonies). The frequency of occurrence seems to give a more comprehensive picture. In this context, 'common' refers to the chances of being encountered. Figure 3 shows the frequency of occurrence of ant species at 12 sampling times. High percentages of species that occurred once only throughout the year in both plots suggests that a large number of ant species migrate from one place to another for food and shelter. 9.1% of the ant species in the primary plot and 8.4% in the secondary plot achieved 100% occurrence (Table 3).

Table 3. Ant species that were present throughout the year in primary and secondary plot.

Primary plot		Secondary plot	
Species	code	Species	code
Odontoponera sp.	DV1	*Odontoponera* sp.	DV1
Camponotus gigas	DV3	*Camponotus gigas*	DV3
Diacamma rugosum	DV10	*Diacamma rugosum*	DV10
Pheidole sp.	DV14	*Pheidole* sp.	DV14
Pheidole sp.	DV83	*Pheidole* sp.	DV83
Ponera sp.	DV23	*Ponera* sp.	DV23
Hypoponera sp.	DV87	*Hypoponera* sp.	DV87
Odontomachus rixosus	DV11	*Polyrhachis* sp.	DV7
Pheidole sp.	DV20	*Crematogaster* sp.	DV18
Pheidole sp.	DV118	*Polyrhachis ypsilon*	DV32
Tapinoma sp.	DV21	*Pheidologiton* sp.	DV45
Colobopsis sp.	DV30	*Strumigenys* sp.	DV48
Polyrhachis bihamata	DV31	*Pheidole* sp.	DV113
Discothyrea sp.	DV74		
Euprenolepis sp.	DV121		

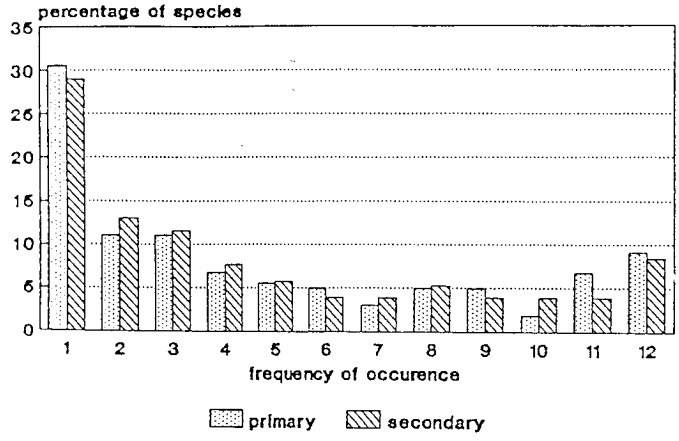

Figure 3. Frequency of occurrence in primary and secondary plots throughout the year.

Comparison of Species and Individuals Collected with Different Methods in Primary and Secondary Forest

Table 1 shows the mean total number of species and individuals collected each month. Number of species (Wilcoxon test, $P<0.001$) and number of individuals ($P<0.05$) collected with the Winkler's method were significantly lower in the secondary plot. Korthals (1990), in his research in Danum Valley, reported that the soil in the secondary forest contained more sand, less clay and seemed to be more compact than the primary forest. Conductivity, percentage of carbon, nitrogen, cation exchange capacity, and total and soluble phosphorus were lower in the secondary forest. The soil in the primary forest is less disturbed and has a higher nutrient status, thus making it more suitable for the soil fauna.

The number of individuals collected by manual sampling were higher (Wilcoxon test, $P<0.05$) in the secondary plot. Manual sampling collected mainly arboreal ants. In general,

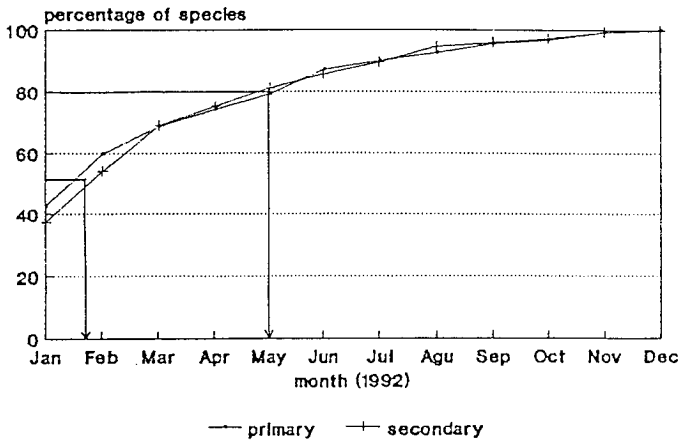

Figure 4. Cumulative percentage of species in both plots throughout the year.

trees in the secondary forest are lower with their canopy not as dense as those in the primary forest. Consequently, more light reaches the lower strata of the forest, resulting in an undergrowth which is relatively dense in certain parts of the plot. Climbers and shrubs like *Eupatorium, Jacquemontia, Callicarpa* and *Merremia* are abundant in such vegetation. Many of these plants produce extrafloral nectaries and food bodies which are a source of food for the ants. In return, the ants protect the plant from herbivore attack. Some plants, such as *Macaranga hypoleuca* and *Korthalsia furtadoana*, also provide shelter for ants. Ants stay in the stem and branch cavities of *M. hypoleuca* and in the ochreas (apical leaf sheath) of *K. furtadoana*. In primary forest, ground vegetation is scarce and most of the arboreal ants are found in the canopy (Fittkau & Klinge 1973) which was beyond the limit of the manual sampling.

Figure 4 estimates that to obtain 50% of the ant species recorded in this study, sampling using the three different methods should be carried out twice; to obtain 80% of the species, sampling should be carried out five times (sampling once a month).

Effects of Rainfall and Temperature

The number of species collected with the Winkler's method in the secondary plot and the number of individuals in the primary plot, collected by the same method, showed negative correlation with monthly rainfall ($P<0.05$). In the rain forest, 80.7% of the annual rainfall in 1990 reached the forest floor as throughfall and 1.9% as stemflow, giving an interception loss of 17.4% (Sinun *et al.* 1992). This percentage of throughfall affected the soil fauna. Rainfall reduced population density in the primary forest but did not affect the population density in the secondary forest. However, it caused a reduction in the number of species observed in the secondary forest, suggesting that while some species were disappearing, the remaining species were thriving after rainfall.

Ant species collected by manual sampling in the primary plot correlated negatively with high monthly mean temperature ($P<0.001$) and high daily temperature ($P<0.05$) (temperature taken at 0800hrs of the sampling day) whereas no correlation was detected in the secondary plot. This suggests that arboreal ant species in the primary forest have a lower tolerance towards high temperatures, compared with those of the secondary forest. Possibly temperature affected only the arboreal ants because microhabitats of arboreal ants are more exposed to changes of temperature, when compared to terrestrial and subterranean species.

Terrestrial and subterranean microhabitats are often surrounded by soil and leaf litter where the humidity is constantly high. Torres (1984), in his research on upland tropical forest, grassland and agricultural land in Puerto Rico, reported that forest ants had a lower tolerance to high temperatures than ants from non-forested areas.

ACKNOWLEDGEMENTS

We would like to thank Danum Valley Management Committee for permission to work at DVFC. We are grateful to the Danum researchers, especially Dr. J. Willot, Dr. P.M. Costa and R. Nussbaum, for comments on an earlier version of this manuscript. This study was funded by a M.Sc. Scholarship from Sabah Shell and partly from IRPA grant 04-07-03-07, and supported by the Royal Society, UK.

LITERATURE CITED

ATKIN, L. & PROCTOR, J. 1988. Invertebrates in the litter and soil on Volcan Barva, Costa Rica. *Journal of Tropical Ecology* 4:307-310.

BOLTON, B. 1990. Key to the ant genera of Oriental region. Pp. 46-53 in Holldobler, B. & Wilson E.O. (eds). *The ants*. Belknap Press of Harvard University Press, Cambridge, Massachusetts.

BURGHOUTS, T., KORTHALS, G. & VRIES, T.D. 1992. Litterfall, leaf litter decomposition and litter invertebrates in primary and selectively logged dipterocarp forest in Sabah, Malaysia. Pp. 407-416 in Marshall, A.G. & Swaine, M.D. (eds). *Tropical rain forest: disturbance and recovery*. The Royal Society, London.

FITTKAU, E.J. & KLINGE, H. 1973. On biomass and trophic structure of the Central Amazonian rain forest ecosystem. *Biotropica* 5:2-14.

HOLLDOBLER, B. & WILSON, E.O. 1990. *The ants*. Belknap Press of Harvard University Press, Cambridge, Massachusetts. 732 pp.

KORTHALS, G.W. 1990. *A description of the litter dwelling arthropod fauna in a primary and a secondary rain forest in North-East Borneo*. Ph.D. Thesis, Free University, Amsterdam.

LEVINGS, S.C. 1983. Seasonal, annual and among site variation in the ground ant community of a deciduous tropical forest: some causes of patchy species distributions. *Ecological Monographs* 53:435-455.

LUDWIG, J.A. & REYNOLDS, J.F. 1988. *Statistical ecology*. John Wiley & sons, Inc. New York. 337 pp.

MARSH, C.W. & GREER, A.G. 1992. Forest land-use in Sabah, Malaysia: an introduction to Danum Valley. Pp. 331-340 in Marshall, A.G. & Swaine, M.D. (eds). *Tropical rain forest: disturbance and recovery*. The Royal Society, London.

MARSHALL, A.G. 1992. The Royal Society's South-east Asia rain forest research programme: an introduction. Pp. 327-330 in Marshall, A.G. & Swaine, M.D. (eds). *Tropical rain forest: disturbance and recovery*. The Royal Society, London.

MURPHY, D.H. 1973. Preliminary key to genera of Malaysian ants, based on workers. *Bukit Timah Survey: Supplement 1*.

OLSON, D.M. 1991. A comparison of the efficacy of litter and pitfall traps for sampling leaf litter ants (Hymenoptera: Formicidae) in a tropical wet forest, Costa Rica. *Biotropica* 23:166-172.

ROOM, P.M. 1971. The relative distributions of ants species in Ghana's cocoa farms. *Journal of Animal Ecology* 40:735-751.

SINUN, W., WONG, W.M., DOUGLAS, I. & SPENCER, T. 1992. Throughfall, stemflow, overland flow and throughflow in the Ulu Segama rain forest, Sabah, Malaysia. Pp. 389-396 in Marshall, A.G. & Swaine, M.D. (eds). *Tropical rain forest: disturbance and recovery*. The Royal Society, London.

SOUTHWOOD, T.R.E. 1966. *Ecological methods, with particular reference to the study of insect populations*. Chapman & Hall, London. 542 pp.

WILSON, E.O. 1959. Some ecological characteristics of ants in New Guinea rain forests. *Ecology* 40:437-447.

ZAR, J.H. 1984. *Biostatistical analysis*. Prentice Hall, New Jersey. 718 pp.

Appendix. Ant species recorded in Danum Valley Conservation Area (1972). Species not in italics are identified to subfamily. sf (Subfamily) - Myrmicinae (M.), Formicinae (F), Ponerinae (P), Dolicherodinae (D), Dorylinae (DO), Pseudomyrmicinae (PS), Leptanillinae (L). Size in mm. Method - Manual (M), Pitfall (P), Winkler (W).

No.	Genus/Species	Code	s.f.	Size	Method	No.	Genus/Species	Code	s.f.	Size	Method
1	*Acanthomyrmex* A	DV 71	M	3	M,W	57	*Eurhopalothrix* A	DV 99	M	3	W
2	*Acanthomyrmex* B	DV 164	M	3	W	58	*Eurhopalothrix* B	DV 97	M	2	W
3	*Acropyga* A	DV 12	F	4	M	59	*Eurhopalothrix* C	DV 143	M	3	W
4	*Aenictus* A	DV 16	DO	4	M	60	Formicine A	DV 104	F	4	M
5	*Aenictus* B	DV 66	DO	4	M	61	Formicine B	DV 108	F	5	M
6	*Aenictus* C	DV 151	DO	3	M	62	Formicine C	DV 181	F	4	M
7	*Anochetus* A	DV 17	P	4	W	63	Formicine D	DV 187	F	3	P
8	*Anochetus* B	DV 95	P	2	W	64	Formicine E	DV 127	F	13	M
9	*Anochetus* C	DV 186	P	6	W	65	Formicine F	DV 169	F	1	W
10	*Bothroponera* A	DV 165	P	7	W	66	*Gnamptogenys* A	DV 57	P	6	M
11	*Calyptomyrmex* A	DV 50	M	3	W	67	*Gnamptogenys* B	DV 98	P	5	W
12	*Calyptomyrmex* B	DV 93	M	2	W	68	*Gnamptogenys* C	DV 100	P	3	W
13	*Camponotus* A	DV 70	F	5	M,P	69	*Gnamptogenys* D	DV 148	P	5	M
14	*Camponotus* B	DV 79	F	3	W	70	*Gnamptogenys* E	DV 177	P	2	W
15	*Camponotus* C	DV 107	F	12	M	71	*Hypoponera* A	DV 26	P	7	W
16	*Camponotus gigas*	DV 3	F	25	M,P	72	*Hypoponera* B	DV 73	P	2	W
17	*Camponotus variegatus*	DV 22	F	7	P,M	73	*Hypoponera* C	DV 75	P	1	W
18	*Cataulacus* A	DV 115	M	4	M	74	*Hypoponera* D	DV 87	P	3	W
19	*Ceraphachys* A	DV 135	P	2	W	75	*Hypoponera* D	DV 77	P	2	W
20	*Ceraphachys* B	DV 136	P	2	W	76	*Hypoponera* E	DV 176	P	6	W
21	*Colobopsis* A	DV 30	F	5	M	77	*Labidogenys* A	DV 49	M	2	W
22	*Colobopsis* B	DV 59	F	6	M	78	*Labidogenys* B	DV 142	M	2	W
23	*Colobopsis* C	DV 43	F	6	M	79	*Leptanilla* A	DV 91	L	2	W
24	*Colobopsis* D	DV 179	F	7	M	80	*Leptanilla* B?	DV 140	L	4	W
25	*Crematogaster* A	DV 5	M	4	M	81	*Leptogenys* A	DV 2	P	8	M,P,W
26	*Crematogaster* B	DV 18	M	2	M,P,W	82	*Leptogenys* B	DV 144	P	6	P
27	*Crematogaster* C	DV 34	M	4	M	83	*Leptogenys* C	DV 6	P	9	M,P,W
28	*Crematogaster* D	DV 62	M	3	M	84	*Leptogenys* D	DV 25	P	3	M
29	*Crematogaster difformis*	DV 28	M	5	M	85	*Liometopum* A?	DV 114	D	5	M
30	*Crematogaster* E	DV 102	M	2	M	86	*Liomyrmex* A?	DV 124	M	3	P
31	*Crematogaster* F	DV 184	M	2	M	87	*Mesoponera* A	DV 53	P	6	M
32	*Crematogaster* G	DV 105	M	2	M	88	*Mesoponera* B	DV 90	P	7	W
33	*Crematogaster* H	DV 156	M	2	W	89	*Monomorium* A	DV 68	M	1	M
34	*Crematogaster* I	DV 192	M	3	P	90	*Myrmicaria* A	DV 9	M	6	M,P
35	*Crematogaster inflata*	DV 33	M	5	M	91	*Myrmicaria* B	DV 110	M	5	M
36	*Diacamma* A	DV 162	P	9	M	92	*Myrmicaria* C	DV 155	M	5	M
37	*Diacamma rugosum*	DV 10	P	12	M,P	93	Myrmicine A	DV 188	M	2	W
38	*Discothyrea* A	DV 74	P	2	W	94	Myrmicine B	DV 191	M	1	W
39	*Discothyrea* B	DV 133	P	3	W	95	Myrmicine C	DV 63	M	4	M
40	Dolichoderine A	DV 55	D	2	P	96	Myrmicine D	DV 85	M	4	M,W
41	Dolichoderine B	DV 123	D	5	P	97	Myrmicine E	DV 86	M	3	W
42	Dolichoderine C	DV 152	D	5	M	98	Myrmicine F	DV 92	M	5	W
43	*Dolichoderus* A	DV 4	D	5	M	99	Myrmicine H	DV 96	M	1	W
44	*Dolichoderus* B	DV 38	D	4	M	100	Myrmicine I	DV 111	M	4	M
45	*Dolichoderus* C	DV 67	D	5	M	101	Myrmicine J	DV 119	M	2	P
46	*Dolichoderus* D	DV 167	D	3	M	102	Myrmicine K	DV 125	M	2	P
47	*Dolichoderus* E	DV 58	D	5	M	103	Myrmicine L	DV 131	M	5	W
48	*Dolichoderus* F	DV 126	D	8	P,M	104	Myrmicine M	DV 132	M	3	W
49	*Dolichoderus* G	DV 44	D	6	M	105	Myrmicine N	DV 145	M	3	P
50	*Dolichoderus* H	DV 64	D	6	M	106	Myrmicine O	DV 149	M	1	M
51	*Dolichoderus* I	DV 190	D	3	M	107	Myrmicine P	DV 157	M	3	W
52	*Dolichoderus thoracicus*	DV 60	D	4	M,P	108	Myrmicine Q	DV 158	M	1	W
53	*Echinopla* A	DV 35	F	6	M	109	Myrmicine R	DV 159	M	3	W
54	*Epitritus* A	DV 94	M	1	W	110	Myrmicine S	DV 160		3	W
55	*Euprenolepis* A	DV 121	F	5	P	111	Myrmicine T	DV 163		2	W
56	*Euprenolepis* B	DV 13	F	3	M,P	112	Myrmicine U	DV 171		3	P

Appendix (continued). Ant species recorded in Danum Valley Conservation area (1972). Species not in italics are identified to subfamily. s.f. (subfamily) - Myrmicinae (M), Formicinae (F), Ponerinae (P), Dorylinae (DO), Pseudomyrmicinae (PS), Leptanillinae (L). Size in mm. Method - Manual (M), Pitfall (P), Winkler (W).

No.	Genus/Species	Code	s.f.	Size	Method
113	Myrmicine V	DV 180	M	2	W
114	*Myrmoteras* A	DV 27	F	4	W
115	*Myrmoteras* B	DV 134	F	4	W
116	*Mystrium* A	DV 84	M	4	W
117	*Odontomachus rixosus*	DV 11	P	12	M,P,W
118	*Odontoponera transversa*	DV 1	P	10	M,P,W
119	*Oligomyrmex* A?	DV 41	M	2	M
120	*Pachycondyla* A	DV 47	P	11	W
121	*Pachycondyla* B	DV 52	P	8	M,W
122	*Pachycondyla* C	DV 128	P	5	M
123	*Paratrechina* A	DV 15	F	3	M,P,W
124	*Paratrechina* B	DV 103	F	2	M
125	*Pheidole* A	DV 14	M	2	M,P,W
126	*Pheidole* B	DV 42	M	4	M
127	*Pheidole* C	DV 69	M	1	M,P
128	*Pheidole* D	DV 83	M	3	M,P,W
129	*Pheidole* E	DV 113	M	2	M
130	*Pheidole* F	DV 118	M	1	P
131	*Pheidole* G	DV 116	M	3	P
132	*Pheidole* H	DV 122	M	1	P
133	*Pheidole* I	DV 20	M	3	M,P
134	*Pheidole* J	DV 129	M	3	M
135	*Pheidole* K	DV 178	M	1	W
136	*Pheidologiton* A	DV 45	M	2	M,P
137	*Pheidologiton* B	DV 88	M	2	W
138	*Pheidologiton* C	DV 146	M	3	P
139	*Polyrhachis* A	DV 7	F	6	M
140	*Polyrhachis armata*	DV 39	F	7	M,P
141	*Polyrhachis* B	DV 8	F	4	M
142	*Polyrhachis bihamata*	DV 31	F	11	M
143	*Polyrhachis* C	DV 36	F	6	M
144	*Polyrhachis calybea*	DV 173	F	9	M
145	*Polyrhachis* D	DV 40	F	5	M
146	*Polyrhachis* E	DV 46	F	6	M
147	*Polyrhachis* F	DV 61	F	5	M
148	*Polyrhachis* G	DV 105	F	5	M
149	*Polyrhachis* H	DV 109	F	7	M
150	*Polyrhachis* I	DV 120	F	9	M
151	*Polyrhachis* J	DV 130	F	4	M
152	*Polyrhachis* K	DV 153	F	7	M
153	*Polyrhachis* L	DV 154	F	8	M
154	*Polyrhachis* M	DV 54	F	7	M
155	*Polyrhachis* N	DV 168	F	7	M
156	*Polyrhachis* O	DV 174	F	10	M
157	*Polyrhachis* P	DV 175	F	7	M
158	*Polyrhachis* Q	DV 182	F	5	M
159	*Polyrhachis rastellata*	DV 37	F	5	M
160	*Polyrhachis ypsilon*	DV 32	F	12	M
161	*Ponera* A	DV 23	P	3	P,W
162	Ponerine A	DV 138	P	2	W
163	Ponerine B	DV 172	P	6	M
164	Ponerine C	DV 183	P	2	W
165	Ponerine D	DV 189	P	4	M
166	*Proatta* A	DV 141	M	2	W
167	*Proceratium* A	DV 80	P	4	W
168	*Proceratium* B	DV 101	P	3	W
169	*Proceratium* C	DV 161	P	2	W
170	*Proceratium* D	DV 185	P	4	W
171	*Pseudolasius* A?	DV 139	F	3	W
172	*Smithistruma* A?	DV 56	M	2	P
173	*Strumigenys* A	DV 48	M	1	W
174	*Strumigenys* B	DV 76	M	1	W
175	*Strumigenys* C	DV 170	M	2	W
176	*Strumigenys* D	DV 24	M	3	W
177	*Strumigenys* E	DV 82	M	3	W
178	*Tapinoma* A	DV 166	F	2	M
179	*Tapinoma* B	DV 21	F	4	M,P,W
180	*Tapinoma* C	DV 29	F	1	M
181	*Tetramorium* A	DV 51	M	2	W
182	*Tetramorium* B	DV 72	M	4	M,P
183	*Tetramorium* C	DV 81	M	3	W
184	*Tetramorium* D	DV 89	M	1	W
185	*Tetramorium* E	DV 112	M	4	M
186	*Tetramorium* F	DV 117	M	2	P
187	*Tetramorium* G	DV 137	M	3	W
188	*Tetramorium* H	DV 150	M	2	M
189	*Tetramorium* I	DV 78	M	2	W
190	*Tetraponera* A	DV 147	PS	7	M
191	*Trigonogaster* A	DV 19	M	2	P
192	*Vollenhovia* A?	DV 65	M	4	M