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SEMI-QUANTITATIVE SAMPLING OF TERRESTRIAL ARTHROPODS OCCURRING IN THE AIR OVER SOUTH AUSTRALIA

By **T. C. R. White**[1]

Abstract: Arthropods collected in 41 samples, 30 at 152 m and 11 at 305 m, using a net towed by a light aircraft, are tabulated. Each sample was of 15 minutes duration. Catches ranged from 16 to many more than 500 individuals per sample. Small thrips made up the bulk of all the samples. Conservative estimates of the likely volume of air sifted by these samples indicated that from 430 to 213,000 individuals of a single species may be present in the air over a hectare of land to 152 m and 860—426,000 to a height of 305 m. These estimates support the hypothesis that large numbers of many species are widely dispersed as aerial plankton.

Introduction: An attempt to demonstrate the presence of adults of a particular species of insect in the air at considerable heights above the trees on which they had developed (White 1973) provided an opportunity to collect many other arthropods at the same time. The results of these collections and their interpretation are presented here.

Material and Methods: Details of the design and construction of the drogue-net used to collect these samples and the methods of operating were described previously (White 1970). The nets were mounted on a steel ring 38 cm in diameter and were towed from the wing of a Cessna 172 aeroplane. Each net was released when the aeroplane had levelled off at the required height and was cruising at 121—131 km/hr. The net was well clear of the fusilage and wash from the propellor, and below the trailing edge of the wing. In early trials it remained stable and in the same position relative to the aircraft during a variety of manoeuvres. Height and speed were maintained as accurately as possible for the duration of each sample. All samples were of 15 minutes duration and made over a relatively small area between Keith and Willalooka in the southeast of South Australia (White 1970, fig. 2). The first 30 were taken at 152 m above the ground; the remaining 11 at 305 m.

All nets were kept sealed in plastic bags until immediately before being used. At the completion of each sample a knot was tied in the net before it was detached from the ring and resealed in a plastic bag. All bags were returned to the laboratory before being opened and the nets immersed in 70% alcohol before the knots were untied.

Results: Table 1 shows the number of each major group captured in each sample, and Table 2 lists the numbers of each species of arthropod collected at the two altitudes.

Although many specimens were badly smashed when struck by the net, very many

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Table 1. The numbers, by major groups, caught in each sample

DATE	SAMPLE NO.	ARANEIDA	ACARINA	PSOCOPTERA	THYSANOPTERA*	NEUROPTERA	HEMIPTERA	COLEOPTERA	HYMENOPTERA	DIPTERA	TOTAL (With Minute Thysanoptera)	TIME (Mid-sample)	
1/XI/71	1	2	—	—	50—75	—	2	—	4	24	82	9.52	a.m.
	2	2	1	—	75—100	—	2	2	8	15	105	10.13	,,
	3	4	1	1	100—150	—	7	—	6	11	130	11.09	,,
	4	—	2	1	50—75	—	5	1	8	21	88	11.27	,,
	5	1	—	1	75—100	—	7	2	11	32	129	11.45	,,
	6	1	—	1	25—50	—	5	—	5	15	52	12.02	p.m.
	7	4	—	—	75—100	—	3	2	6	14	104	12.20	,,
	8	3	—	—	50—75	—	2	—	5	14	74	1.09	,,
	9	2	—	—	25—50	—	1	2	7	11	48	1.36	,,
	10	—	—	—	25—50	—	1	—	3	5	34	1.53	,,
	11	1	—	—	5—25	—	2	—	1	7	16	2.12	,,
2/XI/71	12	—	—	3	>500	1	17	3	16	15	555	12.41	p.m.
	13	1	—	—	300—400	—	15	1	11	13	341	12.58	,,
	14	2	—	1	200—300	—	7	—	7	12	229	1.17	,,
	15	1	—	—	150—200	—	4	1	7	11	174	1.34	,,
	16	4	—	—	100—150	—	13	4	3	4	128	1.52	,,
	17	2	—	1	200—300	—	5	—	9	6	223	2.09	,,
	18	1	—	—	150—200	—	2	1	8	4	166	2.26	,,
3/XI/71	19	—	—	—	26—50	—	7	1	4	2	39	11.54	a.m.
	20	—	—	—	75—100	—	4	—	3	4	86	12.11	p.m.
	21	—	—	—	150—200	—	6	—	5	3	164	12.29	,,
	22	—	—	—	100—150	—	10	2	4	1	117	12.47	,,
	23	—	—	—	200—300	—	7	—	1	2	210	1.04	,,
	24	1	—	1	200—300	—	4	—	2	4	212	1.21	,,
	25	—	—	—	100—150	1	2	—	4	2	109	1.39	,,
	26	—	—	—	75—100	—	3	—	2	1	81	1.57	,,
11/XI/71	27	—	—	—	200—300	—	10	2	13	11	236	11.54	a.m.
	28	1	1	—	>>500	—	20	3	8	54	587	12.11	p.m.
	29	1	3	—	>>500	—	6	4	11	74	599	12.28	,,
	30	—	1	—	>500	—	7	3	5	80	596	12.48	,,
	31	—	—	—	200—300	—	6	3	7	45	261	1.02	,,
	32	—	1	—	150—200	—	8	1	3	36	199	1.19	,,
	33	—	—	—	100—150	—	5	—	3	21	129	1.36	,,
	34	—	—	—	200—300	—	4	1	1	23	229	1.53	,,
12/XI/71	35	—	—	—	50—75	—	3	—	1	12	66	12.15	p.m.
	36	—	—	—	25—50	—	7	—	—	6	38	13.32	,,
	37	—	—	—	200—300	—	8	1	4	29	242	12.49	,,
	38	—	—	—	200—300	—	6	—	4	27	237	1.06	,,
	39	—	—	—	75—100	—	2	—	1	19	97	1.22	,,
	40	—	—	—	25—50	—	3	—	1	5	34	2.11	,,
	41	—	—	—	75—100	—	2	—	—	16	93	2.27	,,
Total		34	10	10	6080—8675	2	239	40	212	711	7338	—	

*T. *imaginis* made up the bulk of this order. Their large numbers and the fact that many would have passed through the mesh of the nets, made accurate counting pointless. Instead they were graded as 5 to 25, 25 to 50, 50 to 75, 75 to 100, 100 to 150, 150 to 200 and then in hundreds up to 500, judging the numbers by counting out a group of 25 in each sample and estimating the total from this. All estimates are conservative.

survived and were observed crawling around in the nets after these had been placed in plastic bags. The freshness and moistness of the broken individuals suggested that these too were alive prior to capture.

Discussion: In general the presence of this variety and number of arthropods at these heights lends considerable support to the hypothesis that the general (and efficient) mode of long distance dispersal for such animals is by way of admixture and widespread dissemination in aerial currents. With most insects it is the winged adult stage of the life cycle which is dispersed in this way. With spiders this process is often facilitated by their behavior of spinning a web to act as a "parachute". With others — as the presence of the first instar coccid in sample 30 illustrates — it is the newly hatched young which are so dispersed. The chance of finding such a small animal in nets is not great; and most would at any rate have passed through the mesh. The capture of this single individual lends strong support to the hypothesis that scale insects may be spread over great distances — not just from one tree to another — by aerial dispersal of the first instar nymphs.

Except for the ants which were all males, females predominated in those groups where the sex of individuals could be determined (Araneida 14 : 8; Acarina all female; Psocoptera 6 : 3; ***Isoneurothrips*** 203 : 10; ***Cardiaspina*** 28 : 22). There is no point in speculating on this apparent predominance of females without knowing the sex ratios of the populations from which they came. But sufficient males were caught to indicate that both sexes may be dispersed in this way. All the male ants were caught between 12.30 and 2.30 p.m. on the second day. There must have been mating flights on that day, and the failure to capture females probably reflects the behaviour of these insects. Many males tend to remain in the air for long periods, flying up and down in swarms which rise and fall and move to and fro with the movement of the air. The larger and heavier females fly directly up into these swarms, are quickly grasped by a male, and immediately fall back to earth. The probability of a male being carried up out of a swarm would therefore be far greater than for a female.

The presence of the odd cast skin (10 psyllid, 10 spider) emphasises the essentially passive nature of aerial dispersal. Once a small arthropod has been launched from the substrate (by whatever means) its eventual destination is determined largely by the movement of the air. If this movement is upwards (as it is as the land warms each morning) then it is inevitable that the animal will be taken up; and often carrried a considerable distance before again falling to earth as the air cools in the evening.

This mechanism was perhaps most dramatically illustrated by the large number of ***Thrips imaginis*** captured. At the time the mallee eucalypts in the area were flowering profusely and their leaves and flowers were literally crawling with this species. Most of them were unharmed when captured, and could be seen crawling around in the nets. Very many of them must have been widely dispersed. Just how many can be judged by considering the following.

Assuming that the air through which the nets passed was chosen at random (a fairly safe assumption) then the average number present per cubic metre of the air ***actually sifted at the height sampled*** can be calculated.

A net with a diameter of 38 cm pulled through the air at a mean speed of 126 km/hr would sift 3575 cubic metres in a 15 minute sample. But because of the "cushion" of air formed in front of the net it is improbable that this volume of air would have passed through the net. Much of it would have been deflected around the sides of the net. No attempt was made to assess the "effective" diameter of the nets — it may well have been no more than 2.5 cm to 5 cm. But the smaller the effective diameter of the net the smaller the real volume of air sampled. An effective diameter of 23 cm for example, would mean only 1309 cubic metres of air had been sifted in 15 minutes. The calculated density of thrips from a sample containing 500 of them would be one per 7.2 cubic metres and one per 2.6 cubic metres respectively for the 38 cm and 23 cm diameters — $2^3/_4$ times as dense with the smaller diameter. Thus assuming the full diameter of the net to be the effective diameter will give an estimate of the ***minimum*** number of animals present ***in the air sampled.***

It is ***not*** safe to assume that the animals were distributed at random throughout a block of air over any particular area of land. Horizontally the distribution would tend to be patchy. Thermals, wind speed, time of day and ambient temperature at the time of sampling would all contribute to this patchiness. Previous evidence would suggest that the density of animals decreases with increasing altitude. But again the variables mentioned would influence this. In particular it may not be true later in the day when thermal uplift has ceased, the air is cooling, and animals earlier carried aloft are falling back to earth.

During a 15 minute flight, however, it might be expected that a fair range of densely and thinly "populated" patches of air would have been traversed in an unbiased way; and except in the late afternoons it is likely that the air below the sampling height contained more animals per cubic metre than the air sifted by the net.

On this basis, and again assuming the full diameter of the net to be the effective diameter, a conservative estimate of the number of animals that were present in a given volume of air ***at the time of sampling*** can be calculated.

A 152 metre high block of air above a hectare of land contains 1,520,000 cubic metres of air; at 305 metres, 3,050,000 cubic metres. This means that the single first instar coccid caught in sample number 30 represented approximately 430 in the air up to 152 metres above a hectare of land; the 500 thrips 213,000 in the same volume of air. At 305 metres the same captures would represent 860 and 426,000 individuals above a hectare of land.

Table 2. List of spiders, mites and insects captured

Order, family, genus, species			Number collected at indicated altitude		
			152 m	305 m	Total
ARANEIDA			**34**	—	**34**
	Indet. spp.		5	—	5
	Linyphiidae:	Indet. spp.	5	—	5
	(Erigoninae):	Indet. spp.	2	—	2
		Erigone sp. A.	14	—	14
		Erigone sp. B.	1	—	1
	(Linyphiinae):	*Bathyphantes* sp.	5	—	5
	Lycosidae				
	(Lycosinae):	*Arctosa* sp. (near *A. funerea* Hentz)	1	—	1
		Lycosa sp.	1	—	1

Table 2 (cont'd)

Order, family, genus species			Number collected at indicated altitude		
			152 m	305 m	Total
ACARINA			**9**	**1**	**10**
	Macrochelidae	*Macrocheles mykytowyczi* Womersley	9	1	10
PSOCOPTERA			**10**	—	**10**
	Caeciliidae:	*Caecilius* sp.	4	—	4
	Elipsocidae:	? *Propsocus* sp.	1	—	1
		Propsocus pulchripennis (Perkins)	2	—	2
	Peripsocidae:	*Ectopsocus* sp.	2	—	2
		Peripsocus sp.	1	—	1
THYSANOPTERA			**2239**	**7092**	**9331**
	Aelothripidae:	*Andrewarthaia kellyana* (Bagnall)	1	—	1
	Phlaeothripidae:	*Adelothrips* sp. nov.	1	—	1
		Haplothrips sp. (mostly *H. robustus* Bagnall, but a few *H. victoriensis* Bagnall)	88	12	100
		Idolothrips spectrum Haliday	1	—	1
	Thripidae:	*Australothrips bicolor* Bagnall	—	1	1
		Isoneurothrips australis Bagnall	137	76	213
		Limnothrips cerealium Haliday	11	3	14
		Thrips imaginis Bagnall	approx. 1000 to 2000	approx. 5000 to 7000	approx. 6000 to 9000
NEUROPTERA			**2**	—	**2**
	Hemerobiidae:	*Micromus* sp.	2	—	2
HOMOPTERA			**151**	**39**	**190**
	Aphididae:	*Aphis craccivora* Koch	4	3	7
		Myzus persicae (Sulz.)	3	—	3
		Rhopalosiphum padi (L.)	9	—	9
	Cicadellidae:	Indet. sp.	4	—	4
	(Austroagalloidinae):	*Austroagalloides wrighti* Evans	3	—	3
	(Deltocephalinae):	Indet. spp.	14	6	20
	(Typhlocybinae):	Indet. sp. (near *Pettya*)	2	—	2
		Erythroneura ix Myers	2	5	7
		Orosius argentatus (Evans)	19	5	24
		? *Pettya* sp.	14	1	15
	Eriococcidae:	First Instar Nymph	1	—	1
	Psyllidae:	*Cardiaspina densitexta* Taylor	43	17	60
		Ctenarytaina sp.	2	—	2
		Eucalyptolyma sp.	2	—	2
		Psylla sp. (?)	6	—	6
		Psylla sp. A (possibly a mixture of species)	20	—	20
		Psylla sp. B	1	—	1
		Psylla sp. C	1	—	1
		Psylla sp. D	1	—	1
		Psylla sp. E	—	1	1
		Indet. (gen. et sp. nov.)	—	1	1

Table 2 (cont'd)

Order, family, genus, species			Number collected at indicated altitude		
			152 m	305 m	Total
HETEROPTERA			**35**	**13**	**48**
	Lygaeidae:				
	(Cryptorhamphinae):	*Cryptorhamphus orbus* Stal	1	—	1
	(Orsillinae):	*Nysius vinitor* Bergroth	23	12	35
	(Rhyparochrominae):	Indet. sp.	1	—	1
		Brentiscerus putoni (White) [=*Isopeltus australis* (Bergroth)]	4	1	5
	Miridae:				
	(Phylinae):	Indet. sp.	6	—	6
COLEOPTERA			**34**	**6**	**40**
	Carabidae:				
	(Harpalinae):	*Amblystomus gracilis* Blkb.	1	—	1
		Hypharpax inornatus Germar	5	—	5
		Hypharpax sp.	1	—	1
	Chrysomelidae:				
	(Eumolpinae):	*Colaspoides* sp.	1	—	1
	Curculionidae:				
	(Brachyderinae):	*Sitonia humeralis* Steph.	2	—	2
	(Erirrhininae):	Indet. sp.	2	—	2
		Misophrice sp.	3	—	3
	Dytiscidae:	*Allodessus bistrigatus* (Clk.)	1	—	1
		Corticaria adelaidae Blkb.	8	5	13
	Lathridiidae:	*Corticaria* sp.	1	—	1
	Melyridae:	*Laius bellulus* Guerin	1	—	1
	Staphylinidae:	*Atheta* sp.	7	1	8
		Philonthus sp.	1	—	1
HYMENOPTERA			**187**	**25**	**212**
	Bethylidae:	Indet. sp.	1	1	2
	Braconidae:	Indet. sp.	1	—	1
		Indet. sp. A	1	—	1
		,, ,, B	1	—	1
		,, ,, C	1	—	1
	(Alysiinae):	Indet. sp.	2	1	3
	(Aphidiinae)	Indet. sp.	24	3	27
	? Chalcidoidea:	Indet. sp.	45	4	49
	Cynipidae:				
	(Eucoilinae):	Indet. sp. A	3	—	3
		,, ,, B	1	—	1
	Diapriidae:	Indet. sp. A	2	—	2
		,, ,, B	9	1	10
	Encyrtidae:	Indet. sp. A	3	—	3
		,, ,, B	1	—	1
		Psyllaephagus sp.	1	—	1
	Eulophidae:	Indet. sp. A	8	—	8
		,, ,, B	1	—	1

Table 2 (cont'd)

Order, family, genus, species			Number collected at indicated altitude		
			152 m	305 m	Total
		„ „ C	1	—	1
		„ „ D	1	—	1
		„ „ E	—	1	1
		„ „ F	—	1	1
		Elasmus sp. A	2	—	2
		„ „ B	5	—	5
	Eurytomidae:	Indet. sp.	1	—	1
	Formicidae:				
	(Dolichoderinae):	*Iridomyrmex* sp.	7	—	7
	(Formicinae):	*Camponotus* sp.	2	—	2
	Ichneumonidae:	Indet. sp.	—	1	1
	Mymaridae:	Indet. sp. A	10	2	12
		„ „ B	3	—	3
		„ „ C	1	—	1
		„ „ D	1	—	1
	Proctotrupoidea:	? Indet. sp.	3	—	3
	Proctotrupidae:	Indet. sp.	1	—	1
	Pteromalidae:	Indet. sp. A	2	—	2
		„ „ B	3	—	3
		„ „ C	2	2	4
		„ „ D	2	—	2
		„ „ E	2	—	2
		„ „ F	1	—	1
		„ „ G	1	—	1
		„ „ H	1	1	2
		„ „ I	2	—	2
		„ „ J	2	—	2
		„ „ K	1	—	1
		„ „ L	1	—	1
		„ „ M	1	—	1
		„ „ N	—	1	1
		„ „ O	—	2	2
		„ „ P	—	1	1
		„ „ Q	—	1	1
	Scelionidae:	Indet. sp. A	1	—	1
		„ „ B	13	2	15
		„ „ C	1	—	1
		„ „ D	1	—	1
		„ „ E	1	—	1
	Torymidae:	Indet. sp. A	5	—	5
		„ „ B	1	—	1
DIPTERA			**474**	**237**	**711**
	Agromyzidae:	*Liriomyza caulophaga* (Kleinschms)	1	—	1
	Calliphoridae:	*Aphyssura* sp. [prob. *minuta* (Mall.)]	1	—	1
		Aphyssura sp.	2	—	2

Table 2 (cont'd)

Order, family, genus, species		Number collected at indicated altitude 152 m	305 m	Total
Cecidomyiidae:	Indet. spp. (prob. all one sp.)	9	17	26
	Indet. sp.	2	—	2
Ceratopogonidae:	Indet. sp.	6	—	6
Chamaemyiidae:	? *Leucopis* sp.	—	1	1
Chironomidae:				
(Chironominae):	Indet. spp. (2 species)	2	2	4
	Chironomus tepperi Skuse	5	—	5
	Chironomus sp. (prob. *C. tepperi*)	14	7	21
	Procladius paludicola Skuse	10	4	14
	Tanytarsus sp.	3	—	3
Chloropidae:	Indet. sp.	3	—	3
	Botanobia sp.	1	1	2
Dolichopodidae:	Indet. sp.	1	—	1
	Indet. sp. (poss. *X. pudicum*)	2	1	3
	Hydrophorus sp.	—	1	1
	Xiphandrium pudicum Par.	1	2	3
Drosophilidae:	*Scaptomyza* aff. *australis* Mall.	82	61	143
Empididae:				
(Tachydromiinae):	Indet. sp. A	15	2	17
(Hemerodrominae):	Indet. (gen. et sp. nov.)	1	—	1
Ephydridae:	? Indet. sp.	3	—	3
	Indet. sp. A	2	2	4
	Indet. sp. B	1	—	1
	Indet. sp. C	1	—	1
	Hyadina pullipes Cress.	6	7	13
	Hydrellia tritici Coq.	15	15	30
	Hydrellia victoria Cress.	11	8	19
	Nostima duosetosa Cress.	15	8	23
	? *Psilopa* sp.	1	—	1
	Scatella australiae Mall	4	3	7
	Scatella nitidithorax Mall.	15	5	20
	Scatella sp.	1	—	1
Fergusoninidae:	*Fergusonina* sp.	3	—	3
Lauxaniidae:	Indet. sp.	1	1	2
	Poecilohetaerus schineri Hend.	6	9	15
Muscidae:	*Coenosia* sp.	10	2	12
	Limnophora sp.	—	1	1
Phoridae:	Indet. spp.	10	14	24
Platystomatidae:	*Rivellia* sp.	3	—	3
Psychodidae:	Indet. sp.	2	1	3
	Psychoda sp.	3	—	3
Sciaridae:	Indet. sp.	14	1	15
Simulidae:	*Simulium ornatipes* Sk.	1	—	1
Sphaeroceridae:	*Leptocera* "sp. A" (may be a mixture)	70	57	127
	Leptocera "sp. B" (prob. homogeneous)	12	2	14

Table 2 (cont'd)

Order, family, genus, species		Number collected at indicated altitude		
		152 m	305 m	Total
Syrphidae:	*Melangyna collatus* (Walk.) [=*M. viridiceps* of previous report (White 1970)]	4	—	4
	Melanostoma sp.	1	—	1
	Simosyrphus grandicornis (Macq.) [=*Ischiodon grandicornis* of previous report (White 1970)]	1	—	1
Tachinidae:	Indet. sp.	1	—	1
	Anagonia sp.	1	—	1
	Hyalomyia sp.	3	—	3
Tephritidae:	*Spathulina* sp.	2	2	4
	Trupanea sp.	1	—	1
Tipulidae:	Indet. sp.	1	—	1

Conclusion: It is unrealistic to attempt to use these results to calculate precise densities of arthropods in the air sampled. There are too many unknown variables. But it would seem reasonable to assume that conservative, if not minimum, estimates of densities can be made from them.

On the basis of such estimates it would seem likely that very large numbers of a great many species are widely and passively dispersed as aerial plankton.

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WAU ECOLOGY INSTITUTE

Wau Ecology Institute was incorporated in Papua New Guinea in late 1971. Earlier it was the B. P. Bishop Museum New Guinea Field Station (1961–1971).

The Institute is situated at 1200 m in Wau Valley, on the lower slopes of Mt Kaindi (Morobe District, NE New Guinea). The grounds cover over 60 hectares, with large areas of research arboreta and some natural forest. Nearby are ***Araucaria*** mixed rainforest, oak forest, ***Nothofagus*** semi-mossforest and other types of rainforest, as well as ***Banksia*** savanna, kunai, etc. There is road access to most types of New Guinea environments, with extensive alpine grassland and tundra in 2 days' climb.

There is a branch station at 2300 m at the summit of Mt Kaindi, 45 minutes drive from Wau, with furnished cabins. Also a camp at 2600 m near the upper end of the main transect, a day's walk south of Edie Creek (1 hour drive from Wau), above which the moss forest is richly developed. The lower end of the transect extends to sea level near Lae, at 3 hours drive from Wau.

Visitors are welcome by pre-arrangement. Charge is A$4.00 per adult per night, with bedding and cooking facilities (but not food) supplied, with discounts for longer periods and for groups. 4-wheel drive vehicles are usually available for rent.

Address: Secretary, Wau Ecology Institute, Box 77, Wau, Papua New Guinea.