CANOPY INVERTEBRATE COMMUNITIES IN WOODLANDS - A COMPARISON OF MORNING AND AFTERNOON SAMPLES BY CHEMICAL KNOCKDOWN

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ABSTRACT

Chemical knockdown procedures were used to sample invertebrate communities during the morning and afternoon on four species of eucalypts (*Eucalyptus capillosa, E. loxophleba, E. erythronema* and *E. yilgarnensis*) and Jam Wattle (*Acacia acuminata*) in the wheatbelt of Western Australia. There were differences between morning and afternoon samples on the wattle and bulked *Eucalyptus* trees for individual taxa of invertebrates. Some taxa were significantly more abundant in morning samples (Collembola and Coleoptera - larvae) while others were significantly more abundant in those taken during the afternoon (Araneae, Hemiptera - others, Thysanoptera, Coleoptera - adults, Diptera - adults and Hymenoptera - others). The results show the importance of standardising sampling to set times of day. In comparing samples collected at the same time of day, temperature, wind speed and cloud cover conditions should be as similar as possible.

INTRODUCTION

The distribution and behaviour of terrestrial invertebrates differs throughout the day as temperature, light intensity, wind speed and humidity change with time of day and weather conditions (Southwood 1966). Thus, standardisation of invertebrate samples by time of day and weather conditions is important, if reliable estimates are to be made of invertebrate densities.

In our studies of *Eucalyptus* canopy invertebrates we standardise procedures by restricting sampling to early morning (0700 - 1000 h) and by not sampling when it is windy or there is rain (Majer & Recher 1988, Majer *et al.* 1990). In this paper we present the results of an experiment using chemical knockdown procedures in which we took equal numbers of samples during early morning, following our normal practice, and in late afternoon, when wind intensities were similar to those encountered during the morning, but temperatures were higher. These data are useful for the evaluation of precise stopping and starting rules for invertebrate sampling methods.

METHODS

Invertebrates were sampled between September 4 and 13, 1987 in East Yorkrakine and Durokoppin Reserves near the town of Kellerberrin in the central wheatbelt of Western Australia. Five tree species were sampled; Jam Wattle (*Acacia acuminata*), Wandoo (*Eucalyptus capillosa*), York Gum (*E. loxophleba*), and two species of mallee, *E. erythronema* and *E. yilgarnensis*. The vegetation is described by Muir (1978, 1980).

Ten patches of each species were selected. Five patches were designated for morning and five for afternoon sampling. Ten 0.5 m^2 circular nets were placed in each patch at a height of 0.5 - 2.5 m above the ground, taking care that there was no overlap between adjacent nets. Nets for the morning sample were placed in position the previous evening and those for the afternoon sample were positioned from mid to late morning. Knockdowns were performed between 0630 and 0830 h in the morning and 1600 and 1730 h in the afternoon. Knockdowns were restricted to times when wind speed was less than 8 - 10 km h^{-1} which sometimes prevented samples from being taken on consecutive days. Daily meteorological data and also temperature, wind speed and cloud cover during each sample period are presented in Table 1.

The canopy above each net was fogged with 0.5% pyrethrin insecticide synergised with piperonyl butoxide using a motorised knapsack mistblower. The insecticide reached an approximate height of 7 m. After fogging, the nets were left in position for approximately 30 minutes to allow the affected animals to drop from the vegetation. At the end of this time, the canopy was shaken to dislodge any remaining animals. All animals on the nets were collected and preserved in 70% ethanol. For this particular investigation we combined the invertebrates from the ten nets from each patch. The specimens were divided into broad taxonomic groups (Order or Family) and counted. The samples were placed in filter paper funnels for 12 hours and then weighed for an approximation of the live wet weight.

The data for the four *Eucalyptus* spp. were combined and analysed for the effect of tree species and time of day by two-way analysis of variance (ANOVA). The data for *A. acuminata*, which exhibited different trends from those for the eucalypts, were treated separately by an unpaired student's t-test. In both instances, we only performed tests on taxa which were present in the majority of samples.

TABLE 1. Weather data measured by the Bureau of Meteorology at Merredin during the period of canopy invertebrate sampling at Durokoppin and Yorkrakine Nature Reserves. Merredin is the closest weather recording site to these reserves (A). The temperature, percentage cloud cover and wind speed measured on-site at the time of sampling is also shown (B).

(A)	September 1987											
DATE	3	4	5	6	7	8	9	10	11	12	13	14
Max temp °C	16	19	20	18	19	23	24	28	23	25	26*	28
Min temp °C	3	3	6	7	4	8	10	8	11	12	12	-+
Rainfall	NIL											
(B)	September 1987											
DATE	3	4	5	6	7	8	9	10	11	12	13	14
0800												
Temp °C		10	11		10	12					14	
% Cloud cover		50	80		0	0					0	
Wind speed (kmh-1)		3-5	0		3-5	3					3-5	
1600												
Temp °C		20	20		20	26		28				
% Cloud cover		30	50		0	0		0				
Wind speed (kmh-1)		3-5	3-5		3	3		3				

* Maximum temperature not available and calculated as mean of previous and following day's maximum temperature.

\+ Minimum temperature not available.

RESULTS

Twenty-two categories of invertebrate taxa were recorded from the five species of tree (Table 2). At the ordinal level, faunal diversity was greatest on York Gum, with 21 taxa, and least on Wandoo, with 18 taxa. Numbers of invertebrates were lowest on Wandoo and greatest on Jam Wattle. The latter was in part accounted for by the high numbers of psyllids on the wattle. However, when the psyllids were excluded, the overall daily count was still highest on the wattle.

On the wattle, there was a tendency for taxa to be more numerous in the afternoon samples than in those from the morning (14 vs 3 taxa respectively) (Table 2). The tendency for taxa to be favoured by time of day statistically differs from that which could be expected by chance ($p<0.01$ using the 50% probability test [Langley 1970]). Six taxa (Araneae, Hemiptera - others, Thysanoptera, Coleoptera - adults, Diptera - adults and Hymenoptera - others) were significantly more abundant in the afternoon samples, as was the total invertebrate biomass (Table 2).

The time-trends were less clear on the eucalypts, with more taxa being abundant in the morning samples on the mallee species, more taxa being abundant in the afternoon on the Wandoo and no difference evident on the York Gum (Table 2). Using the ANOVA, three taxa exhibited statistically different time-trends; Collembola and Coleoptera - larvae were more abundant in morning samples and Coleoptera - adults were more abundant in the afternoon samples (Table 2). These trends were consistent over all four *Eucalyptus* spp. We did not perform tests on taxa on individual tree species in view of the relatively low numbers of individuals and the high variance between samples.

TABLE 2: Morning and afternoon numbers and biomass of invertebrates collected in pyrethrin knockdown samples of Eucalyptus and Acacia species in Durokoppin and East Yorkrakine Reserves during September 1987. Numbers shown are mean and standard deviation with level of significance between morning and afternoon samples.

TREE GENUS		*Eucalyptus*								AM/PM Comparison		*Acacia*		AM/PM Comparison	
TREE SPECIES		*capillosa*		*erythronema*		*yilgarnensis*		*loxophleba*				*acuminata*			
DAY / TIME OF DAY		4th AM	5th PM	7th AM	8th PM	8th AM	7th PM	5th AM	4th PM	F Value	Sig.	13th AM	10th PM	t Value	Sig.
Arachnida	Acarina	1.2±0.8	2.6±3.6	3.8±4.7	1.2±1.8	3.0±1.2	4.2±5.0	1.8±0.8	1.6±1.8		ns*	11.2±9.4	63.6±50.9		ns
Arachnida	Araneae	4.0±1.6	6.4±3.4	7.2±2.9	7.2±4.3	6.4±0.5	8.2±4.7	9.2±5.8	5.6±2.7		ns	7.0±3.7	12.4±3.6	-2.33	<.05
Crustacea	Isopoda	-	-	-	-	-	-	-	0.2±0.4		nt*	-	-		nt
Collembola		7.6±4.5	1.2±0.8	42.2±23.8	4.6±1.1	44.8±19.6	11.6±10.3	6.8±7.5	0.2±0.4	30.91	<.05	1.2±1.3	0.4±0.9		nt
Insecta	Thysanura	-	-	-	0.8±1.8	-	0.4±0.9	0.2±0.4	-		nt	-	0.6±1.3		nt
Insecta	Blattodea	0.2±0.4	0.2±0.4	0.2±0.4	-	-	-	0.2±0.4	0.6±1.3		nt	-	0.2±0.4		nt
Insecta	Mantodea	-	-	-	0.2±0.4	-	-	-	-		nt	-	-		nt
Insecta	Orthoptera	-	-	-	-	0.2±0.4	0.2±0.4	-	0.2±0.4		nt	-	-		nt
Insecta	Psocoptera	20.4±23.3	44.8±35.3	11.2±8.2	5.6±5.2	4.2±2.7	3.4±1.1	6.8±7.0	19.2±24.0		ns	7.6±3.8	12.6±4.3		ns
Insecta	Hemiptera psyllids	3.6±1.1	23.0±22.1	14.2±9.5	10.6±5.7	21.6±13.5	10.2±8.4	46.6±27.7	21.0±15.7		ns	2679±2038	5014±3810		ns
Insecta	Hemiptera others	27.0±13.4	25.0±15.7	45.4±17.7	46.2±22.7	60.2±16.6	72.6±21.4	22.2±7.0	23.4±24.0		ns	11.0±2.8	18.0±6.1	-2.33	<.05
Insecta	Thysanoptera	5.0±4.2	12.0±9.7	29.4±19.2	14.2±6.1	35.2±27.1	15.4±9.7	47.0±76.3	28.2±31.5		ns	16.0±6.4	44.2±16.9	-3.48	<.01
Insecta	Neuroptera adults	1.0±0.7	0.6±0.9	1.4±1.7	-	0.6±0.9	0.4±0.9	0.8±0.4	0.4±0.5		ns	0.4±0.5	0.4±0.9		nt
Insecta	Neuroptera larvae	-	1.4±1.3	-	0.2±0.4	0.8±0.8	-	0.2±0.4	0.2±0.4		nt	0.4±0.5	0.4±0.9		nt
Insecta	Coleoptera adults	38.8±13.2	51.2±32.2	42.6±22.5	76.8±17.8	35.8±13.6	35.8±21.0	29.4±17.8	54.8±17.2	7.90	<.05	24.6±10.0	91.6±33.6	-4.28	<.005
Insecta	Coleoptera larvae	9.8±3.6	3.0±2.1	7.4±3.4	5.2±3.5	8.0±3.2	1.8±1.3	4.0±3.0	3.2±1.3	20.13	<.05	13.2±7.8	11.2±6.5		ns
Insecta	Diptera adults	36.2±10.7	15.0±6.2	37.6±11.6	10.0±4.6	24.0±16.6	22.8±28.8	38.8±9.5	50.0±20.4		ns	19.8±10.0	100.2±49.1	-3.59	<.01
Insecta	Diptera larvae	1.2±1.3	-	1.0±0.7	0.2±0.4	0.4±0.5	-	1.0±1.0	-		nt	7.4±4.7	5.4±4.8		ns
Insecta	Lepidoptera adults	1.2±0.4	0.2±0.4	1.8±1.5	1.0±1.0	1.4±1.5	1.6±2.1	0.6±1.3	0.2±0.4		nt	0.6±1.3	1.0±1.0		nt
Insecta	Lepidoptera larvae	2.0±2.2	3.6±2.9	5.6±3.0	4.6±2.3	6.6±3.3	3.8±4.7	2.2±1.5	5.4±4.2		ns	17.0±5.6	18.8±7.5		ns
Insecta	Hymenoptera ants	5.6±5.3	10.0±12.6	22.4±18.3	36.4±26.1	20.0±6.0	9.4±5.0	9.4±11.5	26.8±25.1		ns	59.2±32.0	126.4±127.2		ns
Insecta	Hymenoptera others	16.4±7.7	20.8±8.1	21.6±6.9	11.4±9.1	18.6±12.7	19.2±9.8	24.2±10.9	36.4±12.6		ns	18.0±9.7	88.8±51.6	-3.02	<.05
Total Invertebrates		181.2±52.2	221.0±59.3	229.2±57.5	236.4±46.2	291.8±77.2	224.6±84.8	251.4±107.9	277.4±145.2		ns	2893±1998	5611±3780		ns
Biomass (g)		0.14±0.04	0.23±0.08	0.23±0.07	0.23±0.10	0.32±0.13	0.25±0.10	0.20±0.11	0.24±0.15		ns	0.36±0.11	0.93±0.47	-2.66	<.05

* nt = test not performed on this taxon
ns = not significant

DISCUSSION

There were detectable and sometimes significant differences in the abundances of invertebrates sampled during morning and afternoons.

Avoidance of high temperatures and desiccation (e.g. by springtails and larval beetles), increased activity with warmer temperatures (e.g. by adult flies and beetles), aggregation at food sources such as nectar or honeydew (e.g. by some wasps), and responses to diurnal changes in the physiology of the tree, are possible reasons for differences in the abundance of various taxa between morning and afternoon sampling periods. Movements between trees and/or the use of different kinds of substrates throughout the day may have also affected the kinds and numbers of invertebrates sampled at different times of the day. The different patterns of abundance observed for different taxa and the differences between tree species in the numbers, biomass and kinds of invertebrates sampled suggests that there is no simple explanation for the differences between morning and afternoon samples.

Samples of invertebrates within and between trees obtained by branch clips, chemical knockdown and visual counts are highly variable, even when taken in a standardised manner at the same time of day and during fine weather conditions (Majer & Recher 1988, Majer *et al.* 1990, Recher & Gowing unpublished data). Variability of samples arising from these changes in the distribution and behaviour of invertebrates can only be controlled by standardised sampling procedures. Samples taken at different times of the day or under different physical conditions add additional, significant variability to the data and cannot be used to compare invertebrate communities on different species of plants or on the same species in different localities or seasons. Although costs are increased, we conclude that samples of invertebrate communities need to be rigorously controlled for time of day and, in so far as is possible, taken under similar weather conditions.

The need to standardise sampling times does not just apply to invertebrates. For instance, Rollfinke and Yahner (1990) have recently demonstrated that, although winter bird counts were similar between morning and midday, they were much lower in the afternoon. Thus, for studies of birds and their invertebrate food resources, the standardising of survey times for both groups of animals is critically important if reliable data are required.

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