Australian Journal of Ecology (1996) **21**, 229–234

Short note

Branchlet shaking: A method for sampling tree canopy arthropods under windy conditions

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Abstract Chemical knockdown is a commonly used method for sampling canopy arthropods. The procedure is susceptible to high winds and in certain conditions may be virtually unusable. Here we introduce a new procedure, branchlet shaking, and compare it with chemical knockdown. Samples produced by branchlet shaking yield fewer arthropods per tree and tend to miss some larger (>1.0 cm) and some smaller (<0.2 cm) animals. However, the two procedures generally produce data which can portray similar information about the canopy fauna. It is concluded that although chemical knockdown is a superior sampling procedure, branchlet shaking is a possible alternative for situations where chemical knockdown is impractical. Interpretation of the data must, however, take into account the limitations of the branchlet shaking procedure.

Key words: arthropods, canopy, *Eucalyptus*, sampling, wind.

INTRODUCTION

In keeping with the current world-wide interest in the biology of tree canopies (Nadkarni & Parker 1994), canopy arthropods are being investigated in Australian forests and woodlands (e.g. Majer & Recher 1988, Abbott *et al.* 1992), mallee (e.g. Yen 1989) and rainforests (e.g. Basset & Arthington 1992, Kitching *et al.* 1993). A number of approaches to sampling the foliage-associated fauna have been tried, including branch clipping (Woinarski & Cullen 1984, Majer & Recher 1988, Abbott *et al.* 1992), restricted canopy fogging of bagged branches (e.g. Basset 1990), and chemical knockdown onto sheets (e.g. Majer & Recher 1988) or nets suspended beneath the foliage (Kitching *et al.* 1993, Recher *et al.* 1996).

Branch clipping is advantageous in that the leaves from the sample can be counted and weighed, thus permitting the arthropod count to be expressed as a function of foliage surface area or weight (Majer & Recher 1988). Its ability to produce statistically usable data is restricted by the low numbers of arthropods per clip and the resulting high number of zeros in the data-set. Restricted canopy fogging can sample larger volumes of canopy, thus yielding larger numbers of animals that can still be expressed on a foliage area or weight basis (Basset & Arthington 1992). However, the procedure is labour intensive, thus restricting the number of samples that can be taken in a short time. There is also the risk that animals may move off the branch when it is encased in the plastic enclosure. Chemical knockdown, using pesticides to rapidly knock animals down onto sheets placed on the ground, produces large amounts of material. Although the resulting data are statistically robust (Majer & Recher 1988), the method does not distinguish foliage strata from which the animals were obtained and, in the case of tall trees, may fail to obtain material which does not fall vertically beneath the tree. In response to these two problems, Majer *et al.* (1990) and Kitching *et al.* (1993) used 0.5 m^2 nets hung immediately beneath the stratum of foliage to be sampled. The resulting data are statistically robust (e.g. see Kitching *et al.* 1993) and, in forested areas, the procedure is not adversely affected by wind speeds up to 10 km h^{-1}.

In 1993 we initiated a study in the Western Australian wheatbelt and the New England tablelands of New South Wales on the effect of habitat fragmentation on canopy arthropods. Both areas have been extensively affected by agriculture In the wheatbelt, more than 90% of the original vegetation has been cleared, with the original trees only remaining in the few nature reserves, remnants of uncleared vegetation, along roads or as individual trees isolated in otherwise cleared fields or paddocks. About half the original vegetation on the tablelands has been cleared, but the extent of habitat

Accepted for publication September 1995.

fragmentation is less pronounced than in the wheatbelt. McIntyre and Barrett (1992) describe the remaining native vegetation on the tablelands as 'variegated', meaning that remnants are linked by numerous corridors and paddocks with a sparse but continuous tree cover.

Our 1993 study involved selecting trees in the centre and at the edge of intact blocks of native vegetation, and also along road verge corridors and within paddocks. We intended to sample trees by chemical knockdown onto suspended nets in order to see how progressive habitat alteration and fragmentation affect the canopy arthropod fauna. Our efforts to sample trees in both States were thwarted by wind, the effect of which was worsened in cleared areas by the lack of buffering from adjacent trees. Even on calm days when ground wind speeds were 5 km h^{-1}, this value increased to 15 km h^{-1} in the upper canopy (>7 m) with the result that nets blew off the trees or turned over. We first attempted to circumvent this problem by sampling before 08.00 h when conditions are generally less windy. However, we found that the window of wind-free conditions was unreliable and too short to complete the sampling. We subsequently tried weighing the nets down by suspending 500 g water-filled balloons from their undersides. This also proved to be ineffective. In this paper we report on branchlet shaking as an alternative method of sampling trees and compare it with chemical knockdown sampling.

METHODS

Site description and sampling

The pilot study was performed in and around the Amery Reserve, near Dowerin (31°09'S, 117°05'E) in Western Australia. It was repeated at the Newholme research station (30°26'S, 151°36'E) in New South Wales, although we only report on these findings where they differ from those at Amery. At each site we selected 20 trees in the centre and edge of the woodland reserve and a similar number of trees scattered throughout paddocks. We sampled Wandoo (*Eucalyptus wandoo*) in Western Australia and Yellow Box (*Eucalyptus melliodora*) in New South Wales. The 20 trees from each of the reserve centre, edge and paddock were then stratified so that equal numbers were sampled by chemical knockdown and by branchlet shaking. The upper canopies of trees (>7 m) were accessed by an aerial work platform in order to carry out sampling. Sampling was respectively performed between 16 and 27 September 1993 at Amery and 22 and 30 November 1993 at Newholme. All samples were taken between 08.00 and 12.00 h and 13.00 and 17.00 h.

Ten cotton, funnel-shaped nets with a sampling area of 0.5 m^2 were used to collect the chemical knockdown samples from each tree. Nets were suspended about 60–70 cm below the canopy foliage and each was fitted with a centre sleeve that held a 100 mL plastic tube. The canopy above the nets was sprayed with two litres of 0.2% alphamethrin using a motorized knapsack mistblower. Trees were then left for 30 min to allow silk-attached invertebrates to drop into nets. The canopy was then shaken to dislodge remaining invertebrates and specimens were brushed into the collecting tubes.

Branchlet shaking was performed at the same height as the chemical knockdown samples. Thirty centimetre long branchlets were grabbed and vigorously shaken into a 30 cm^2 calico net mounted on a metal frame, which was positioned so that the prevailing wind would blow the dislodged animals into the net. A total of 60 branchlets were sampled per tree in a 15 min period. In order to separate the arthropods from the large amount of plant material in the bags, the contents were tipped onto a calico sheet and the animals picked up with forceps and placed in a vial of 70% alcohol. Due to the windy conditions this operation was undertaken inside a vehicle.

Data analysis

Material from both sampling methods was sorted and counted at the ordinal level. Samples from the 10 knockdown nets from each tree were pooled to produce data which were comparable with that obtained by branchlet shaking and the data sets were each subjected to the following analysis. For the reserve centre, edge and paddock separately, the ordinal totals for each tree were compared between the two sampling methods by unpaired Student's *t*-test. Following this, the data were transformed to $\log_{10}$ (1 + number of animals) in order to stabilize the variance and justify normality. Then, for the knockdown and shake data separately, the individual taxa were compared between reserve centre, edge and paddock by one-way ANOVA.

Finally, 10 knockdown and 10 shake samples were randomly selected from the three tree locations and the length of each animal was recorded by means of a stereo microscope and graticule. Numbers of individuals in each size category were compared between the two sampling methods by Student's *t*-test.

RESULTS

Chemical knockdown produced a mean of 225 invertebrates per tree, while the branchlet shaking sampled considerably fewer animals (mean = 91). Although present in some samples, certain taxa were considered too rare to provide ecologically meaningful data. Consequently, these taxa were eliminated from the data set, leaving 19 ordinal taxa. Branchlet shaking yielded lower numbers of the majority of taxa from all three tree locations, although between six and seven of the 19 taxa were most abundant in the shake samples (Table 1). The generally low numbers of animals on the trees, and the high number of

zeros in the data, resulted in few statistical differences between methods.

For each taxon, the ranking of invertebrate means and the statistical difference between tree location in terms of either knockdown or shake samples demonstrated that in general the lowest level of animals was found in the reserve centre, most in the paddocks, and intermediate levels occurred at the reserve edge (Table 2). The two methods produced reasonable agreement on ranks of each taxon (total agreement for eight taxa) and they produced the same overall best rank. The knockdown procedure produced data which revealed a greater number of statistical differences between tree location than did branchlet shaking (5 *vs* 2).

From the numbers of invertebrates in each size class obtained by knockdown and shake samples it is evident that there is considerable variation in the numbers of animals in different size categories sampled by the two procedures (Fig. 1). Of particular interest, there appears to be a tendency for knockdowns to sample more animals than shaking in the smallest (<0.2 cm) and largest (>1.0 cm) size classes. Numbers in the shake samples were significantly lower in three of the larger size categories, although differences were not significant in the smallest size category, probably due to the low numbers of individuals involved. We can not explain the significantly higher numbers in the 0.3–0.39 cm size category shake samples, although the failure to sample the <0.2 cm sized animals explains the small numbers of Collembola and Thysanura collected by branchlet shaking (Table 1).

DISCUSSION

At Amery, WA, branchlet shaking yielded fewer animals per tree in the smallest and largest size classes than the chemical knockdowns. A similar trend was observed at Newholme, NSW, with the tendency to miss the smaller size classes even more pronounced. The lower numbers

Table 1. Number (mean + SE; $n = 10$) of invertebrates sampled by chemical knockdown and branchlet of *Eucalyptus wandoo* trees at Amery, Western Australia

Taxon	Location of Trees: Reserve Centre					Reserve Edge					Paddock				
	Chemical		Shaking			Chemical		Shaking			Chemical		Shaking		
	Mean	SE	Mean	SE	Trend	Mean	SE	Mean	SE	Trend	Mean	SE	Mean	SE	Trend
Acarina	9.2	2.9	0	0	−*	7.2	2.7	0	0	−	18	6.8	0	0	−*
Araneae	0.2	0.2	2.9	0.5	+*	6.8	2.8	18	11	+	3.9	1.2	8.8	3.2	+
Collembola	1.4	0.7	0	0	−	0.8	0.6	0	0	−	7	4.8	0	0	−
Blattodea	0	0	0	0	=	0.8	0.4	0	0	−	0	0	0	0	=
Orthoptera	0	0	0	0	=	0	0	0.1	0.1	+	0.2	0.5	0	0	−
Psocoptera	6.2	1.5	11	4.6	+	11	2.5	4	1.1	−	19	9.2	9.1	3.2	−*
Hemiptera															
Homoptera	12	3.4	28	6.7	+*	15	3.7	31	4.5	+*	27	17	43	7	+
Heteroptera	2.6	0.9	3.6	1.2	+	4	0.5	1.1	0.3	−	7	9.1	7.3	2.7	+
Thysanoptera	19	6.3	0.7	0.4	−	5.6	2.3	1.1	0.3	−	31	63	0.8	0.3	−*
Neuroptera															
Adults	0	0	0	0	=	0	0	0.5	0.3	+	0	0	0	0	=
Larva	0	0	0.1	0.1	+	0.2	0.2	0.1	0.1	−	0	0	0	0	=
Coleoptera															
Adults	10.4	6	2.4	0.7	−	3	0.9	1.7	0.6	−	13	19	6.2	1.9	−
Larva	0.6	0.6	0.5	0.2	−	1	0.8	0.9	0.5	−	2.6	2	3.2	1.6	+
Diptera															
Adults	2.8	1.4	1.2	1.4	−	17	4.1	2.8	1.2	−*	39	49	17	7.7	−
Larva	1.2	0.8	0	0	−	0.2	0.2	0	0	−	0.2	0.5	0	0	−
Lepidoptera															
Adults	0.2	0.2	0	0	−	0.2	0.2	0	0	−	0	0	0.2	0.1	+
Larva	0.2	0.2	2.7	1.2	+	1.6	0.7	13	5.3	+	1.2	1.1	15	10	+
Hymenoptera															
Ants	4.8	3.2	4.8	2.3	=	4	0.7	1.1	0.3	−*	10	18	6.2	4.3	−
Other	2.2	1	4.3	1.6	+	2.6	0.6	7.7	2	+*	5.2	4	7.1	1.7	+
Shake < knockdown					8					13					9
Shake > knockdown					7					6					7
Shake = knockdown					4					0					3

Means are shown separately for reserve centre, edge and paddock trees and the direction of the difference between knockdown and shaking is shown (− and + respectively indicate least or most animals in shake samples).

*Knockdown and shaking means are significantly different ($P<0.05$; unpaired Student's t-test).

of animals obtained by shaking result, in part, from the volume of canopy being smaller than that sampled by chemical knockdown; 60 branchlets *vs* the entire canopy above a 5 m^2 catchment. Another possibility is that physical disturbance may dislodge fewer animals than does pesticide action. Larger animals may be better equipped to fly away (e.g. some Coleoptera and Diptera) or hang on to the substrate when disturbed (e.g. ants), thus resulting in the undersampling of these size classes in the shake samples. Surprisingly, some taxa were consistently more abundant in the shake samples (e.g. Araneae, Homoptera, Lepidoptera larvae and small Hymenoptera); shaking may be more efficient at dislodging silk-attached spiders and larvae and some of the sessile homopterans.

While the lower yield of material in shake samples could be remedied by shaking a larger quantity of branchlets, the disparity in the proportions of different sizes and kinds of animals would persist. The paucity of smaller animals in the shake samples is undoubtedly associated with the ability of the observer to see and pick small animals from among the large amount of plant material which had fallen into the net. One way to overcome this would be to observe the material under a stereo-microscope, although experience indicates that this is time consuming and impractical in the field. In conclusion, for various reasons the ordinal profile of arthropods sampled by the two methods is dissimilar. However, both techniques have inherent biases and these should be considered when interpreting the data.

The results initially suggest that chemical knockdown should be used as the preferred sampling method. Under ideal conditions, a team of four workers can sample 10 trees per day, which is the same as the quantity of trees that can be sampled by branchlet shaking. Unfortunately, knockdown is not a viable option in open, windy environments. During the two week sampling periods at both locations we were unable to use knockdowns on about half of the days. When we were able to spray, material from about half of the trees was lost due to unexpected gusts overturning the nets. One suggestion would be to arrange sampling during wind-free conditions. However,

Table 2. Ranking of invertebrate abundance per tree at Amery using data obtained by chemical knockdown and branchlet shaking (for each taxon: 1 = highest numbers; 3 = lowest numbers)

Taxon	Chemical knockdown				Branchlet shaking			
	Reserve Centre	Reserve Edge	Paddock	Significant Difference	Reserve Centre	Reserve Edge	Paddock	Significant Difference
Acarina	2	3	1	No	—	—	—	ND
Araneae	3	1	2	No	3	1	2	Yes
Collembola	2	3	1	No	—	—	—	ND
Protura	—	—	—	ND	—	—	—	ND
Plecoptera	—	—	—	ND	—	—	—	ND
Blattodea	3	1	2	ND	—	—	—	ND
Orthoptera	2.5	2.5	1	ND	2.5	1	2.5	ND
Psocoptera	3	2	1	Yes	3	2	1	No
Hemiptera								
Homoptera	3	2	1	No	3	2	1	No
Heteroptera	3	2	1	No	2	3	1	No
Thysanoptera	2	—	1	No	3	1	2	No
Neuroptera								
Adults	—	—	—	ND	—	—	—	ND
Larvae	2.5	1	2.5	No	1.5	1.5	3	No
Coleoptera								
Adults	2	3	1	No	2	3	1	No
Larvae	3	2	1	Yes	3	2	1	No
Diptera								
Adults	3	2	1	Yes	3	2	1	Yes
Larvae	1	2	3	No	—	—	—	ND
Lepidoptera								
Adults	2.5	2.5	1	ND	2.5	2.5	1	ND
Larvae	3	1	2	No	3	2	1	No
Hymenoptera								
Ants	2	3	1	Yes	2	3	1	No
Others	3	2	1	Yes	3	1	2	No
Best rank	3	2	1		3	2	1	

The means for each taxon have been compared between the three locations by one-way ANOVA. ND signifies that analysis was not performed due to insufficient data.

such conditions are unpredictable and, in the Western Australian wheatbelt, infrequent. Also, the need to pre-book machinery and personnel for chemical knockdown sampling means that this is seldom a viable option.

How useful then is branchlet shaking? Clearly, without a substantial additional investment of time, it is not suitable for surveying smaller arthropods such as Acarina, Collembola and Thysanoptera. As the thrust of our study was to measure how arthropods are affected by fragmentation of vegetation, the failure to sample the smaller arthropods has not necessarily compromised this objective. At Amery, other orders showed trends in abundance in relation to the spatial distribution of vegetation (e.g. edge *vs* paddock trees; cf. Table 1). These trends provide an adequate basis for interpreting the impact of habitat fragmentation on arthropods. Neither branchlet shaking nor chemical knockdown is a suitable procedure for sampling galls, leaf miners, leaf mites or even psyllids. For these groups, it is necessary to conduct visual counts (H. F. Recher unpubl. data), or to use a branch clipping procedure (Majer & Recher 1988). However, while branchlet shaking at Amery detected spatial trends in arthropod abundance, this was not always the case at Newholme. Patterns of arthropod distribution and abundance between edge, centre and paddock vegetation at Newholme were less obvious. This may be associated with the distinction between reserve edge, centre and paddock locations being less clear cut in this mosaic of land uses than at Amery, where clearing has been almost complete.

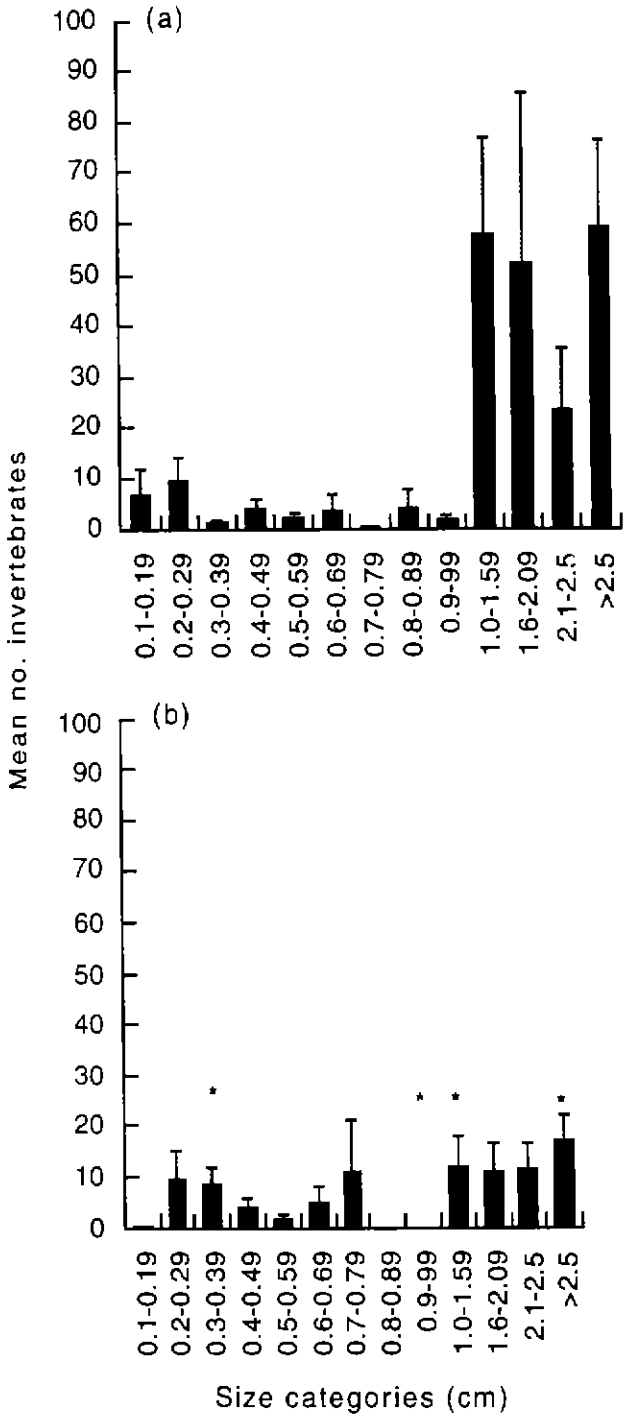

Fig. 1. Mean number ($n = 10$) of invertebrates (and standard error) in each size class obtained from *Eucalyptus wandoo* trees at Amery by (a) chemical knockdown and (b) branchlet shaking. Asterisks indicate those size categories where differences in numbers caught by the the two sampling methods were demonstrated ($P<0.05$; unpaired Student's t-test).

With respect to the comparative costs of the two procedures, the principal advantages of branchlet shaking are the saving of time when wind prevents chemical knockdowns from being completed, and the fact that each tree is visited only once. With chemical knockdowns, each tree is visited twice or even three times; first when the collecting nets are positioned, second when they are collected after spraying, and third if spraying is done at a different time to the positioning of the nets. The cost disadvantage of branchlet shaking is the time required to sort arthropods from the debris accumulated when the branchlets are vigorously shaken; knockdown samples are almost free of such material. Probably we could have improved the sampling of the smallest arthropods by further treatment of the debris collected by branchlet shaking. Not only was this not possible under the conditions in which we were working at Amery, but it would have imposed an additional (and unfunded) cost on the project in terms of time, staff and materials. By using two teams, one to sample material and the other to pick out the animals, we found that, in the time we had allocated to the project, we could sample about the same number of trees with the same number of people using branchlet shaking, as we had expected to use had chemical knockdowns been feasible. Had we not adopted branchlet shaking as an alternative procedure, the project could not have been completed.

ACKNOWLEDGEMENTS

We wish to thank Joannah Monahan, Kate McGregor, Bill Upjohn and Chris Norwood for assistance during the field work. The Western Australian branch of The

Men of the Trees and the University of New England kindly allowed us to use their facilities close to the sampling sites. The study was undertaken with the support of a grant from the Australian Research Council.

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