Journal of the Royal Society of Western Australia, 80:281-286, 1997

Abundance of arthropods in tree canopies of *Banksia* woodland on the Swan Coastal Plain

R A Tassone[1,2] & J D Majer[2]

[1]Entomology Section, Agriculture Western Australia, South Perth WA 6151
[2]School of Environmental Biology, Curtin University of Technology, Kent Street, Bentley, WA 6845
email: imajerj@info.curtin.edu.au

Manuscript received January 1997, accepted May 1997.

Abstract

Canopy arthropods and foliar nutrients were quantified during summer for *Banksia menziesii*, *B. attenuata*, *B. ilicifolia* and *Nuytsia floribunda* within a low woodland site at Jandakot Airport on the Swan Coastal Plain, Western Australia. Foliar nutrients were higher for *N. floribunda* than any of the *Banksia* species. *B. ilicifolia* differed from the other two banksias in having lower nitrogen and phosphorus but higher potassium. Invertebrate densities were also higher for *N. floribunda* than any of the *Banksia* species, while densities on the three *Banksia* species were relatively similar, albeit with a few predominantly phytophagous taxa having a higher density on *B. ilicifolia*. These trends provide evidence that, as in other ecosystems where this has been studied, differing arthropod loads between tree species are related to variation in foliar nutrient levels. Tree usage by predominantly insectivorous birds may reflect the relatively low difference in arthropod loads between the three *Banksia* species and an uneconomic strategy of seeking out low-density *N. floribunda* trees.

Introduction

Invertebrates are an ubiquitous component of most terrestrial ecosystems and a key element in the energy flow and nutrient turnover within a community. Arboreal invertebrates may function as major herbivores, pollinators, parasites and predators (Majer & Recher 1988), and are themselves an important food resource for vertebrates. The dynamics of bird communities are closely linked to the abundance and diversity of invertebrates, with insectivorous avifauna responding to variations in the abundance of prey (Recher *et al.* 1991). Studies in open eucalypt forests of New South Wales by Recher & Majer (1994) showed that the abundance and biomass of invertebrates on eucalypts selected by birds were greater than on less preferred species. Similar invertebrate-driven preferences in tree usage by birds exist in wandoo (*Eucalyptus wandoo* Blakely) woodland (Majer & Recher 1988) and jarrah (*E. marginata* Donn ex Smith) forest (Recher *et al.* 1996) in Western Australia.

In south-western Australia there is a distinct seasonality of climatic patterns and there are also considerable differences in weather patterns between years. These variations, coupled with soil nutrients, moisture and the effects of fire, result in the local vegetation having variable levels of invertebrates. Recher *et al.* (1996) described these forests and woodlands as fluctuating environments, which possess significant temporal and spatial variation in invertebrates.

Another variable influencing invertebrates in tree canopies is vegetation type. This study provides data for invertebrate densities on tree canopies of *Banksia* woodland at Jandakot Airport on the Swan Coastal Plain. It complements data on canopy arthropods in other Western Australian ecosystems, ranging from mallee (Recher *et al.* 1993) to wandoo woodland (Majer & Recher 1988, Majer *et al.* 1996) to jarrah forests (Majer *et al.* 1990, 1994).

At present, natural bushland covers approximately 237 ha of Jandakot Airport and most of this is in a relatively undisturbed state (Milewski & Davidge 1981). In 1993, a draft environmental impact statement for additional development of aviation facilities, extraction of silica sand, and construction of a commercial estate (Anon 1993) proposed that 96 ha (40.5%). of the airport bushland be conserved. The significance of urban bushland remnants to vertebrate fauna has been noted by How & Dell (1994) who have conducted surveys in this region. In view of this, it is important to gather information on how the area caters for the feeding requirements of insectivorous vertebrates, such as birds.

Methods

Study site

The study was undertaken at Jandakot Airport (32 °6 'S, 115 °53 'E), 18 km south of the centre of Perth and 9.5 km east of the coast, in the City of Cockburn. The vegetation of this region of the Swan Coastal Plain is broadly classified as "low woodland" over "heath" and the airport has mainly mixed woodlands of the Proteaceae, *Banksia menziesii* R Br, *B. attenuata* R Br and *B. ilicifolia* R Br (Milewski & Davidge 1981). These banksias can be co-dominant, but vary widely in relative abundance. The study site is located within the Bassendean Dune system in a swale that retains high soil moisture throughout winter. This grey soil is a heavily leached sesquioxide podsol and is acidic (McArthur & Bettenay 1960). The mean annual rainfall at Jandakot

Airport is 802 mm, with most rain falling between May and August.

Sampling was carried out within a woodland area measuring 100 m by 130 m. The site was 15 m from the edge of the woodland, and had a 1.5 m sand bank between this edge and an access road. The area was adjacent to the study site used by the Western Australian Museum (R A How & J Dell, *pers comm*) for determining the significance of remnant urban bushland to reptile and other fauna. We sampled the three *Banksia* species and also *Nuytsia floribunda* (Labill) R Br ex Fenzl (Loranthaceae), which was scarce and contributed less than 2% to the tree cover. Tree canopy cover was 47%, and averaged 6 - 7 m in height. The dense understorey was dominated by the 2 m tall shrub, *Regelia ciliata* Schauer (Myrtaceae), which had a patchy distribution throughout the study site, and also by grass trees, *Xanthorrhoea preissii* Endl (Xanthorrhoeaceae). The ground cover consisted of undershrubs and perennial herbs. An additional tree species, *Eucalyptus todtiana* F Muell (Myrtaceae), was also present, but was so sparsely distributed that it was not included in this study.

All three *Banksia* species can be trees up to 10 m in height. The leaves of *B. menziesii* are dull green and very rigid, 10 - 40 mm wide and 80 - 250 mm long (Marchant *et al.* 1987). The conspicuous flower heads (held above the foliage) are usually pink or red, occurring mainly in February to August. The leaves of *B. attenuata* are more crowded than *B. menziesii* and much narrower, being 5 - 15 mm wide, 40 - 270 mm long, and strongly serrated. The conspicuous flower heads are bright yellow, appearing from September to December. The common name holly-leaved banksia aptly describes *B. ilicifolia*, with its dark green leaves; they are 20 - 40 mm wide and 30 - 90 mm long, elliptical with an undulating edge, and the leaves are slightly serrated with each tooth possessing a spine. The flower heads are cream, turning deep pink with age. The flowers appear throughout the year, but peak in spring. *N. floribunda* is a tree up to 10 m high, that parasitises the roots of surrounding plants. The glabrous leaves are long (40 - 100 mm), narrow (3 - 8 mm) and thick. This tree has masses of orange flowers, which occur from October to January. To touch, the leaves of *N. floribunda* are much less sclerophyllous than the leathery *Banksia* leaves. When bent, *B. menziesii* and *B. attenuata* leaves crack and split, unlike *B. ilicifolia* whose leaves are more supple.

Sampling

The proportional composition of tree species within the canopy was assessed above 400 vertical sighting points taken at regular distances along transects throughout the study site.

Arthropods were sampled from the canopy of the three *Banksia* and *N. floribunda* during early summer (December 1994). We sampled trees which were not in flower, since we were primarily interested in foliage-associated arthropods. The number of trees sampled was dictated by their availability in the study site. Consequently, 20 each of *B. menziesii* and *B. attenuata*, 10 of *B. ilicifolia* and four of *N. floribunda* were sampled. The height and crown diameter was recorded for each tree. Mature foliage was collected from 10 individuals of each species for subsequent analysis of nutrients. Leaf material was dried at 60 °C for 48 hours and ground to a fine powder prior to analysis.

Cotton, funnel-shaped nets with a sampling area of 0.5 m^2 were used to collect the chemical knockdown samples. Each net was fitted with a sleeve that held a 100 ml plastic tube. Within a given tree, five nets were suspended at different heights below the canopy foliage. Net positions were selected to equalize the amount of foliage (determined by visual inspection) in the column directly above the nets. Nets were positioned in the morning (0800 h), one hour prior to spraying, to allow disturbed invertebrates to return.

The canopy above each net was sprayed with synthetic pyrethrin pesticide, synergised with piperonyl butoxide, using a motorized-knapsack mist-blower. Spraying was done only during dry and calm conditions. Two litres of diluted (0.2%) pesticide was used per tree, and trees were left for at least 30 minutes 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 and preserved in 70% ethanol prior to sorting and counting to ordinal level.

The numbers of invertebrates caught could be influenced by the amount of foliage above each net. To obtain a measure of this, we cut three 1 m long branches (measured from growing tip backwards) from each tree species and counted the number of leaves on each branch. Twenty leaves of each species were then removed and their surface area measured using a computer-based planimeter. This enabled a measure of the area of foliage on a 1 m branch to be calculated.

Data analysis

Following sorting, the number of animals within each taxon was summed for the five nets placed within each tree. Mean and standard error of the numbers of each invertebrate taxon on each tree species were then calculated. Three comparisons were made; (1) between the three *Banksia* species for each invertebrate taxon; (2) between the three *Banksia* species for all taxa that were significantly different; and (3) between the four sampled tree species for each invertebrate taxon. Analyses were restricted to the common invertebrate taxa, those occurring in >65% of the samples. *N. floribunda* was excluded from comparisons (1) and (2) because of the low number of trees sampled. Comparison (1) was performed by univariate analysis of variance (ANOVA) and those means which differed significantly were detected using Tukey's pairwise comparisons ($P < 0.05$). Comparison of *Banksia* species for each invertebrate taxon required natural log transformations of the data due to the high degree of variability or the presence of zeros. Comparisons (2) and (3) involved ranking the invertebrate taxa and comparing these ranks using Kendall's coefficient of concordance.

Foliar samples from each tree were analysed for total nitrogen, phosphorus and potassium (see Majer *et al.* 1992 for methodology). The variation in nutrient levels between the four sampled tree species was analysed by univariate analysis of variance (ANOVA) and those means which significantly differed were detected using Tukey's pairwise comparisons ($P < 0.05$). Standard deviations were relatively homogeneous, indicating that transformations were unnecessary.

Results

In terms of cover, *B. attenuata* was the most dominant species (70% of projected foliage cover), followed by *B. menziesii* (20% of projected foliage cover) and *B. ilicifolia* with 7% of projected foliage cover (Table 1). Table 1 also indicates that *B. ilicifolia* was the smallest tree species sampled, having up to a 2 m crown diameter. The single main stem of this species had many branchlets that formed a cover of dense foliage around its stem. The large crown diameter of *N. floribunda* was in part associated with the tendency of this species to have more than one main stem. *B. attenuata* and *B. menziesii* had similar canopy structure, with the diameter (3.0 - 3.5 m) and height above the ground (6.5 - 7.0 m) of their crowns being similar. The area formed by the crown of *N. floribunda* (17.3 m^2) was twice as large as *B. menziesii* (7.3 m^2) and *B. attenuata* (9.5 m^2), and approximately six times larger than *B. ilicifolia* (3.2 m^2). *N. floribunda* supported by far the most leaves per metre of branch, followed by *B. attenuata*; *B. menzesii* branches had the lowest number of leaves (Table 1). When leaf area was taken into account, *N. floribunda* branches supported the least foliage, *B. attenuata* the most, while the other two banksias were intermediate.

There were generally significantly higher levels of nitrogen, phosphorus and potassium within the leaves of *N. floribunda* than in the *Banksia* species (Table 2). Nitrogen and phosphorus are generally mobile nutrients within the plant, and their within-plant concentrations are usually correlated (Majer *et al.* 1992). This is a probable explanation for the assayed leaves showing identical patterns of significance for nitrogen and phosphorus. *B. ilicifolia* had significantly lower levels of nitrogen and phosphorus but higher levels of potassium than the two other *Banksia* species. *B. menziesii* and *B. attenuata* exhibited no significant difference between their levels of nitrogen, phosphorus or potassium.

A total of 7 105 individual arthropods was obtained from the 54 tree canopies sampled. The invertebrate count was higher on *N. floribunda* than on any of the *Banksia* species (collected arthropods averaged 216 from *N. floribunda*, 182 from *B. ilicifolia,* and only 107 - 114 from *B. menziesii* and *B. attenuata* respectively). The F ratios for univariate ANOVA comparisons of the three *Banksia* species, together with means and standard errors for the data, are presented in Table 3. It is evident that the densities of only a few invertebrate taxa differ significantly between sampled *Banksia* species within woodland at Jandakot. These invertebrates are Acarina (mites), Blattodea (cockroaches), Homoptera (sucking bugs), Thysanoptera (thrips) and Neuroptera (lacewings) larvae. In almost all significant differences, numbers were significantly higher on *B. ilicifolia* than *B. menziesii* and *B. attenuata*. The exception was for Blattodea, where *B. ilicifolia* and *B. attenuata* had similar but higher densities than *B. menziesii*. Levels of the various invertebrate taxa generally did not significantly differ between *B. attenuata* or *B. menziesii,* although Acarina were significantly more abundant on *B. menziesii* and, as mentioned, Blattodea were significantly more abundant on *B. attenuata.*

Despite these abundance differences, almost the same variety of taxa were found on the four tree species. Overall, arthropods from 20 orders of insects (Heteroptera and

Table 1

Crown diameter and height (n = 10), the proportional composition of the overstorey, mean leaf area (n = 20), and the number and area of leaves along 1 m branches (n = 3) of sampled tree species in the *Banksia* woodland study site at Jandakot Airport during December 1994. Values are mean (± se).

Species	Crown diameter m	Tree height m	Percentage canopy (%)	Leaf area cm^2	Number of leaves on 1 m branch	Leaf area on 1 m branch (cm^2)
Banksia attenuata	3.5 ± 0.2	7.0 ± 0.2	69.9	9.4 ± 0.4	979.7 ± 7.7	9256.9
Banksia menziesii	3.0 ± 0.2	6.7 ± 0.2	19.9	25.6 ± 0.6	274.3 ± 5.3	7021.9
Banksia ilicifolia	2.0 ± 0.3	6.4 ± 0.4	6.8	14.5 ± 0.4	490.7 ± 6.7	7124.0
Nuytsia floribunda	4.5 ± 0.4	6.7 ± 0.4	1.7	2.1 ± 0.2	2023.7 ± 15.8	4236.3
Others	-	-	1.7	-	-	-

Table 2

Nutrient levels (μg g^{-1}) within tree foliage (n = 10) from *Banksia* woodland at Jandakot Airport during December 1994. The means (± se) of are shown with level of significance (P) between tree species; different superscript letters indicate that means differ significantly using univariate analysis of variance (ANOVA)

Total nutrient	Species				Nutrient comparison	
	B. menziesii	*B. attenuata*	*B. ilicifolia*	*N. floribunda*	F Value	P
Nitrogen	5353.0 ± 6.6^b	5540.0 ± 6.4^b	3914.0 ± 8.3^c	6746.0 ± 9.3^a	34.5	< 0.05
Phosphorus	209.5 ± 1.7^b	200.5 ± 1.7^b	157.5 ± 1.8^c	434.5 ± 2.0^a	141.2	< 0.05
Potassium	1680.0 ± 6.2^b	2065.5 ± 4.0^b	2602.5 ± 7.2^a	2471.0 ± 7.5^a	9.2	< 0.05

Table 3

Numbers of invertebrates per tree, sampled by pyrethrin knockdown of *Banksia* woodland canopy at Jandakot Airport during December 1994. The number of invertebrates per tree was based on five 0.5 m^2 nets within the canopy. Best ranks are assigned to all taxa and also the five taxa where significant differences occurred. Means (± se) for the three *Banksia* species were compared where possible using a univariate analysis of variance (ANOVA) and those means which differ significantly are indicated by different superscript letters. Taxa with significant differences between banksia species are indicated in bold. Ranks compared using Kendall's Coefficient of concordance. NS = not significant.

			Species				Tree comparison	
			B. menziesii	*B. attenuata*	*B. ilicifolia*	*N. floribunda*		
Class	Taxon		n = 20	n = 20	n = 10	n = 4	F Value	P
Arachnida	Pseudoscorpionida		0.2 ± 0.2	0.3 ± 0.2	0.1 ± 0.2	4.8 ± 0.9		-
	Acarina		**23.7 ± 1.1^b**	**11.5 ± 0.7^c**	**74.8 ± 2.5^a**	22.8 ± 2.2	15.4	< 0.05
	Araneae		8.0 ± 0.5	12.1 ± 0.6	10.0 ± 0.8	22.0 ± 1.8		NS
Crustacea	Isopoda		0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0		-
Collembola			0.5 ± 0.2	0.2 ± 0.1	1.1 ± 0.5	0.3 ± 0.4		-
Insecta	Thysanura		0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	3.0 ± 0.6		-
	Blattodea		**0.2 ± 0.1^b**	**1.2 ± 0.3^a**	**1.1 ± 0.3^a**	1.8 ± 0.6	5.1	< 0.05
	Plecoptera		0.1 ± 0.1	0.3 ± 0.2	0.2 ± 0.2	1.0 ± 0.6		-
	Mantodea		0.2 ± 0.1	0.2 ± 0.1	0.1 ± 0.2	0.5 ± 0.4		-
	Isoptera		0.5 ± 0.2	0.4 ± 0.2	0.8 ± 0.4	2.5 ± 0.9		-
	Orthoptera		0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.2	0.3 ± 0.4		-
	Pscoptera		3.0 ± 0.4	2.2 ± 0.3	5.6 ± 0.7	54.0 ± 2.3		NS
	Hemiptera	Homoptera	**2.7 ± 0.4^b**	**4.4 ± 0.4^b**	**9.1 ± 1.1^a**	12.5 ± 1.6	4.2	< 0.05
		Heteroptera	5.7 ± 0.6	4.7 ± 0.5	8.6 ± 0.8	3.3 ± 1.0		NS
	Thysanoptera		**9.2 ± 0.5^b**	**12.8 ± 0.7^b**	**24.6 ± 1.4^a**	8.5 ± 1.7	3.3	< 0.05
	Neuroptera	adults	0.1 ± 0.1	0.5 ± 0.3	0.3 ± 0.3	0.5 ± 0.5		-
		larvae	**1.0 ± 0.3^b**	**1.0 ± 0.3^b**	**2.6 ± 0.4^a**	7.3 ± 1.6	6.7	< 0.05
	Coleoptera	adults	12.1 ± 0.6	18.3 ± 0.7	14.5 ± 1.2	37.0 ± 3.6		NS
		larvae	12.3 ± 0.7	11.3 ± 0.6	6.8 ± 0.6	3.0 ± 1.1		NS
	Mecoptera		0.5 ± 0.3	0.6 ± 0.3	0.0 ± 0.0	0.0 ± 0.0		-
	Diptera	adults	1.8 ± 0.3	1.8 ± 0.3	3.2 ± 0.6	6.5 ± 1.0		NS
		larvae	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0		-
	Lepidoptera	adults	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.8 ± 0.5		-
		larvae	1.1 ± 0.3	1.0 ± 0.3	0.2 ± 0.2	0.0 ± 0.0		NS
	Hymenoptera	ants	16.6 ± 0.9	17.9 ± 1.1	7.5 ± 1.2	7.8 ± 1.4		NS
		others	7.5 ± 0.4	11.9 ± 0.8	10.7 ± 0.8	16.5 ± 1.3		NS
Total inverterbrates			106.7	114.4	182.0	216.3		
Best rank (All taxa)			4	2	3	1		
Arachnida	Acarina		2	3	1	-		
Insecta	Blattodea		3	1.5	1.5	-		
	Hemiptera	Homoptera	2.5	2.5	1	-		
	Thysanoptera		2.5	2.5	1	-		
	Neuroptera	larvae	2.5	2.5	1	-		
Best rank (Significant taxa)			3	2	1	-		

Homoptera counted as one order), arachnids, crustaceans and collembolans were collected, with 18 sampled on *N. floribunda*, 17 on *B. attenuata* and *B. ilicifolia*, and 20 on *B. menziesii*. The most abundant invertebrate order on the four tree species was Acarina, with over 1540 individuals recovered (22% of total). Along with Acarina, Coleoptera (beetles) and Hymenoptera (ants, wasps, sawflies and bees) dominated the numbers of invertebrates collected from Jandakot. Of the 20 orders sampled, these three composed 61% of the total number of invertebrates.

The numbers of invertebrates in each taxon were ranked across tree species for all taxa and also for those taxa which exhibited significant differences (Table 3). In the first of these rankings, *N. floribunda* ranked as having the most abundant invertebrate fauna, followed by *B. attenuata*, *B. ilicifolia* and finally *B. menziesii*. This ranking was not significant (Kendall's coefficient of concordance; P > 0.05), although it was in partial agreement with the ordering of total invertebrate counts in that *N. floribunda* was ranked the highest and *B. menziesii* the lowest; the other two *Banksia* sp. were ranked as intermediate. When only those invertebrates with significant differences on *Banksia* species were ranked (on the basis of their ordering in the ANOVA analysis), *B. ilicifolia* had the most individuals, while *B. attenuata* was only marginally ranked higher than *B. menziesii.*

Discussion

The higher abundance of invertebrates on the canopy of *N. floribunda* than on that of the *Banksia* species supports the conclusions from other studies that invertebrate densities are higher in canopies of tree species with higher foliar nutrient levels (Majer *et al.* 1992), although it is not possible to test this statistically due to the low sample size. The possibility that higher invertebrate densities can be associated with greater amounts of foliage can here be eliminated as *N. floribunda* was the species with the lowest area of leaves above the sampling nets.

As with *N. floribunda*, the densities of invertebrates on the three *Banksia* species were unrelated to foliage area above the nets. The densities of invertebrates in canopies of the three *Banksia* species were all relatively similar. *B. menziesii* and *B. attenuata* had almost identical foliar nutrient levels, so it is consistent that the density of invertebrates on these two species was similar. The position of *B. ilicifolia* in the invertebrate rankings was equivocal, since its foliar nutrient levels were lower in nitrogen and phosphorus, but higher in potassium than those of the other two banksias. Usually it is the levels of nitrogen which correlate with invertebrate levels, particularly herbivores, presumably because this reflects the protein content of the diet (see references in White 1969; Morrow 1983). Phosphorus and potassium levels may also reflect some aspects of the nutritional quality of the foliage, so possibly the effects of higher potassium cancels out the effects of lower levels of the other two nutrients.

Certain taxa do exhibit significant differences between the *Banksia* species and four of these taxa (Acarina, Blattodea, Homoptera and Thysanoptera) contain species which derive their nutrients directly from live or decaying leaves. The fact that they reach greatest abundance on *B. ilicifolia* suggests that some taxa may be responding to the higher levels of potassium in leaves of this species. These trends therefore provide evidence supporting the fact that, as in other ecosystems where this has been studied, differing arthropod abundance's (Recher *et al.* 1996) and richness levels (Majer *et al.* 1994) between tree species may be related to foliar nutrient levels. An alternative possibility is that the higher foliage density on *B. ilicifolia* may create a more favourable microclimate for arthropods.

The other studies on canopy arthropods elsewhere in Australia (see Introduction) used identical procedures, with the exception that 10 nets were used to sample the overstorey trees. How do the levels of invertebrates compare with other trees in Western Australia? If values are expressed as mean number of invertebrates per net, then the *Banksia* species support similar levels of arthropods to *E. marginata* and *E. calophylla* Lindley (marri) trees sampled during the same season in the nearby jarrah forest (Recher *et al*. 1996). Levels of invertebrates on *N. floribunda* were considerably higher than those normally present on local *Eucalyptus* species. Arthropod levels on all tree species in the present study were higher than on trees in the more arid mallee (Recher *et al*. 1993) and wheatbelt woodland sites (Majer & Recher 1988, Majer *et al.* 1996), suggesting the possible existence of a gradient of canopy arthropod densities with increasing rainfall.

Tree usage by insectivorous birds was recorded in the same site during the period when invertebrates were sampled through until September 1995 (P Kirkpatrick, School of Environment Biology, Curtin University, *unpublished data*). When the proportion of feeding observations was assigned to the various tree species, it was found that values reflected the proportional composition of the overstorey for each tree species. Thus, insectivorous birds at Jandakot do not appear to be selecting particular tree species as foraging substrates, but rather use the various species of tree in a random manner. The absence of any apparent selection of tree species by insectivorous birds is consistent with the *Banksia* species supporting relatively similar invertebrate loads. The absence of any selection for *N. floribunda,* despite its higher nutrient loads and invertebrate numbers, is surprising. It is possible that its low density within this ecosystem means that birds do not find it economical to seek out this tree species. Another possibility is that birds may find it difficult to probe for invertebrates amongst the dense foliage of this species.

These findings suggest that, on a unit area basis, *Banksia* woodland provides similar amounts of food for canopy-feeding insectivorous birds as does the jarrah forest in the Darling Ranges. Indications are that, in contrast to the jarrah forest, insectivorous bird richness is low at Jandakot Airport and that some species are no longer present (How & Dell 1993). Probably the fragmentation of the woodlands of the Swan Coastal Plain, and the reduction in area of this habitat, has reduced the available feeding areas for tree-dependent birds and this has resulted in the local extinction of some species. The presence of this array of invertebrates in the canopies of *Banksia* species and *N. floribunda* presents a compelling case for maintaining this sizeable remnant of native woodland at Jandakot Airport.

Acknowledgments: We would like to thank K Flecknell and the Federal Airports Corporation for permission to use the Jandakot Airport site and also P Kirkpatrick, R P Tassone and E Kostas who assisted with field work. N Keals and M J de Sousa Majer helped with sorting of arthropod material and K McGregor, J O'Neil and M Costigan of the Department of Ecosystem Management, University of New England, performed the nutrient analyses. P Groom assisted with the leaf area measurements and R How, B Lamont, J Scott and an anonymous referee kindly commented on an earlier draft of this paper.

References

Anon 1993 Proposed additional developments at Jandakot Airport. Environmental impact statement. Dames & Moore, Perth.

How R A & Dell J 1993 Vertebrate fauna of the Perth Metropolitan Region: Consequences of a changed environment. In: Urban Bushland Management (ed M Hipkins). Australian Institute of Urban Studies, Perth, 24-47.

How R A & Dell J 1994 The zoogeographic significance of urban bushland remnants to reptiles in the Perth region, Western Australia. Pacific Conservation Biology 1:132-140.

Majer J D & Recher H F 1988 Invertebrate communities on Western Australian eucalypts: A comparison of branch clipping and chemical knockdown procedures. Australian Journal of Ecology 13:269-278.

Majer J D, Recher H F & Ganeshanandam S 1992 Variation in foliar nutrients in *Eucalyptus* trees in eastern and Western Australia. Australian Journal of Ecology 17:383-393.

Majer J D, Recher H F & Keals N 1996 Branchlet shaking: A method for sampling tree canopy arthropods under windy conditions. Australian Journal of Ecology 21:229-234.

Majer J D, Recher H F, Perriman W S & Achuthan N 1990 Spatial variation of invertebrate abundance within the canopies of two Australian eucalypt forests. Studies in Avian Biology 13:65-72.

Majer J D, Recher H F & Postle A C 1994 Comparison of arthropod species richness in eastern and western Australian canopies: A contribution to the species number debate. Memoirs of the Queensland Museum 36:121-131.

Marchant N G, Wheeler J R, Rye B L, Bennett E M, Lander N S & MacFarlane T D 1987 Flora of the Perth region. Department of Agriculture, Perth.

McArthur W M & Bettenay E 1960 The development and distribution of the soils of the Swan Coastal Plain. CSIRO (Australia) Soil Publication 16. CSIRO, Canberra.

Milewski A V & Davidge C 1981 The physical environment, floristics and phenology of a *Banksia* woodland near Perth, Western Australia. Western Australian Herbarium Research Notes 5:29-48.

Morrow P A 1983 The role of sclerophyllous leaves in determining insect grazing damage. In: Mediterranean-Type Ecosystems (eds F J Kruger, D T Michael & J U Jarvis). Springer-Verlag, Berlin, 509-524.

Recher H F & Majer J D 1994 On the selection of tree species by Acanthizidae in open-forest near Sydney, New South Wales. Emu 94:1-7.

Recher H F, Majer J D & Ford H A 1991 Temporal and spatial variation in the abundance of eucalypt canopy invertebrates: The response of forest birds. Acta XX Congressus Internationalis Ornithologicii 20:1568-1575.

Recher H F, Majer J D & Ganesh S 1996 Eucalypts, arthropods and birds: On the relation between foliar nutrients and species richness. Forest Ecology and Management 85: 177-196.

Recher H F, Majer J D, Gowing G & Sarti N L 1993 Canopy invertebrate communities in woodlands - A comparison of morning and afternoon samples by chemical knockdown. Mulga Research Centre Journal 11:27-30.

White T C R 1969 Food and outbreaks of phytophagous insects, with special reference to *Cardiaspina densitexta* Taylor (Psyllidae, Homoptera) on *Eucalyptus fasciculosa* F.v.M. (Myrtaceae) in South Australia. PhD Thesis. University of Adelaide, Adelaide.