Bat activity 22 years after first-round intensive logging of alternate coupes near Eden, New South Wales

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Summary

Bat activity was recorded in eight paired coupes of unlogged forest and 22-year-old regrowth forest, near Eden in southern New South Wales. Regrowth coupes had been clearfelled in 1976, with no retention of habitat trees or riparian buffers on minor forest streams. Ultrasonic detectors (Anabat) positioned off-flyways recorded an average of 87 passes in the first two hours after dark in unlogged coupes compared to 36 passes in regrowth coupes. This difference was probably due to considerable 'clutter' in the regrowth compared to the open forest structure of unlogged coupes. The overall rate of feeding (feeding buzzes / total passes) was very low in this study (3% in unlogged, 0.9% in logged). Low activity in regrowth was consistent for less maneuverable bat species, although those with a large body size were too rare to be tested. Despite low activity in regrowth, trapping rate on tracks was high, although 20% less than in unlogged coupes. Across the logged / unlogged mosaic, 11 bats were caught per harp-trap night. Roads and tracks provide linear edge habitat that may be an important ameliorative measure allowing a range of bat species to exploit habitat otherwise too cluttered for foraging. A significant bias towards capturing more females in unlogged coupes suggests maternity roosts were located in such areas and emphasizes the importance of retaining roost trees (now a standard practice in buffer zones and as habitat trees within logged areas) for bats.

Keywords: wildlife, habitat, surveys, silvicultural systems, logging, bats

Introduction

Rigorous information on the responses of Australian bats to logging is scarce. It is well established that hollows in mature trees are preferred sites for diurnal roosting, and there is some evidence that a complex forest structure is favoured by foraging bats (see references in Law 1996). Studies comparing activity levels between logged and unlogged sites, however, have been hampered by inadequate replication of experimental treatments, high variability within treatments and a lack of reliable sampling methodology (e.g. reliance on harp-traps and the presence of good flight paths or flyways) (Law 1996). New technology allows bats to be sampled, and often identified to species level, by recording their ultrasonic calls (e.g. using Anabat detectors, de Oliveira 1999). Recording of a sufficient number of bat passes for meaningful statistical analyses is also possible through the use of Delay Switches (Titley Electronics), which download calls of bats to a cassette recorder as they are detected (Law *et al*. 1998). This remote system also allows simultaneous recording of activity levels between paired sites.

The present study compared bat activity levels in paired logged and unlogged coupes in Compartment 206 (Banksia Rd) of East Boyd State Forest, approximately 20 km south of Eden. This was the first (1976) area in the Eden District to have been subject to small (~15 ha) alternate-coupe logging. At the time of this logging, integrated harvesting in the Eden area involved intensive clearfelling for sawlogs and woodchips with little or no retention of habitat trees or riparian buffers on minor forest streams. Prescriptions to protect these features are now standard practice in New South Wales (NSW) State Forests (Anon. 1999). Our study blocks are therefore representative of intensive timber harvesting, a practice not currently employed in NSW.

Our study was designed to investigate the recovery of bat foraging habitat in regrowth coupes 22 years after intensive logging. It serves the purpose of both documenting an intensive disturbance event as well as providing base-line information prior to second round logging of the alternate coupes, scheduled for 2001. The area is also a long-term study site investigating the effects of logging on birds (Kavanagh *et al*. 1985). Thus there is potential for future comparisons of the response of these two faunal groups to logging at the one site. Kavanagh *et al*.'s (1985) study found fewer bird species and individuals in the logged coupes compared to unlogged coupes during the first few years after logging. As the vegetation regenerated, however, numbers increased, so that four years after logging 78% of species present in unlogged forest also occurred on the logged plots.

The specific aims of our study were to compare the number of bat passes recorded by ultrasonic detectors off flyways and the number of bats trapped on flyways between unlogged and logged coupes, the latter having regenerated naturally for 22 years after intensive logging. Where possible, the response of individual bat species is analysed.

Methods

Study site

The study area was located in open forest on ridges and upper slopes dominated by silvertop ash *Eucalyptus sieberi*, blue-leaved stringybark *E. agglomerata* and white stringybark *E. globoidea* (see Kavanagh *et al*. 1985 for more detailed

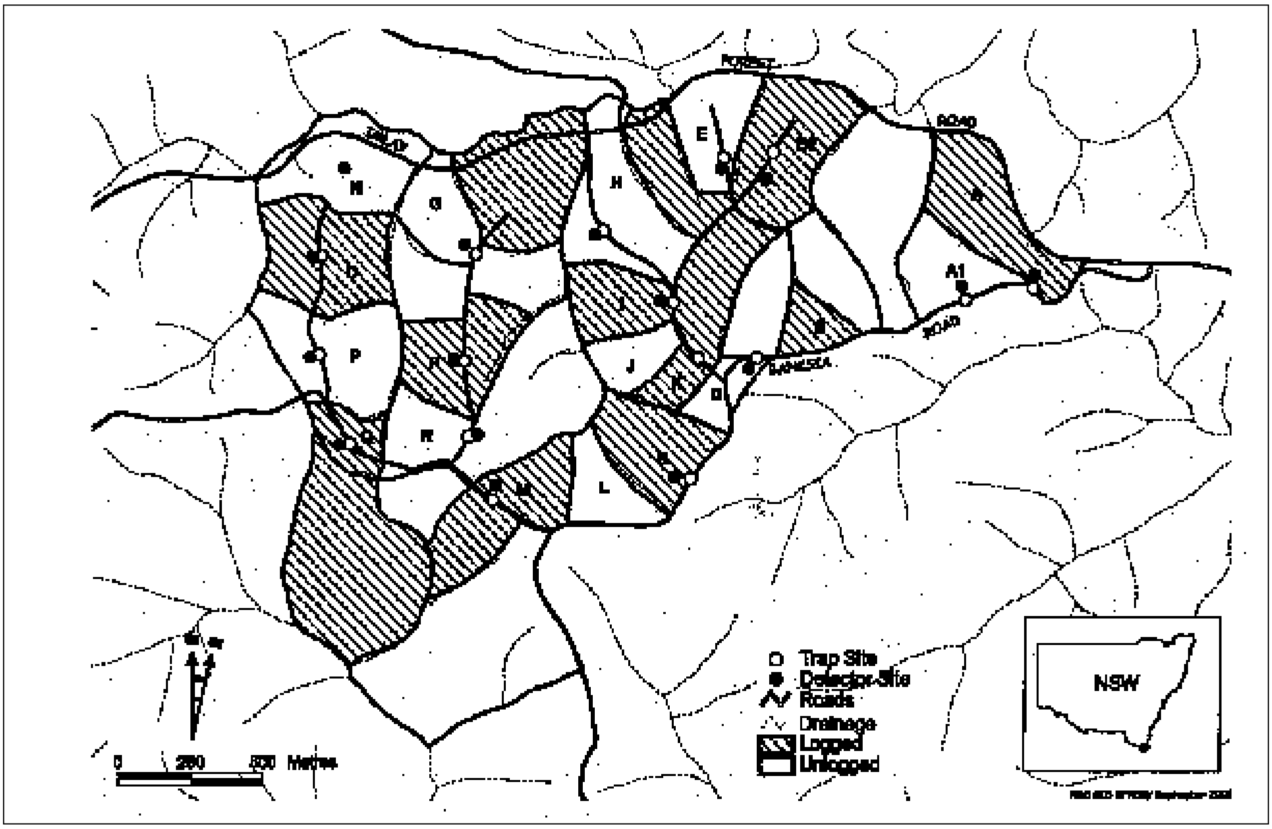

Figure 1. The layout of logged and unlogged coupes and sampling locations for bats at Banskia Road, Eden. East Boyd State Forest surrounding the Banksia Road site has also been subjected to alternate-coupe logging.

descriptions). Coupes averaged 15 ha in size and logging took place in 1976. Most coupes sampled were the same as those used by Kavanagh *et al.* (1985), but some additions and deletions were necessary to facilitate positioning of harp traps on trails (Fig. 1). All were located within a relatively small area (one compartment) in an effort to minimize variation potentially caused by differences in parent geology, forest type and landscape context.

Bat sampling

Field work from 19 to 24 October 1998 coincided with the early stage of the bat maternity season (females heavily pregnant). The short time-frame of the field work minimized seasonal variation in the activity of bats and their prey. Eight paired alternate coupes (logged vs unlogged) were sampled for bats using Anabat detectors and delay switches (total of 16 sites). Eight detector units were used simultaneously, allowing four paired coupes to be sampled per night. Each site was sampled for two consecutive nights. Detectors were angled at 45^{o} from the ground, away from trails and flyways, near the centre of each coupe. Bat activity was expressed for each species or taxa as the number of passes, averaged for the two nights of sampling.

Bat passes were identified using Anabat 6 software and reference calls collected at the study site and nearby areas (see Law *et al*. 1998 for more details). Species were categorized from reference calls on the basis of pulse characteristic frequency and shape (see Reinhold *et al.* 2001). Identification of calls to species level is strongly determined by call quality. Calls of poor quality or short duration were grouped as unidentified bat passes and incorporated into measures of total bat activity. Moreover, some species have calls that are difficult to distinguish using Anabat software. No attempt was made to distinguish *Nyctophilus gouldi* from *N. geoffroyi* on the basis of calls as they are considered indistinguishable. Some overlap occurred in the calls of V*espadelus darlingtoni* and *V. regulus* and as a result they have been grouped as a *V. darlingtoni*/ *regulus* complex. The presence of feeding attempts (feeding buzz) was assessed by listening to replays of calls and inspecting call characteristics such as increased pulse rates.

One harp trap was also set in each coupe for two consecutive nights. Harp traps provide crude information of species abundance, and more importantly, yield data on sex ratio, neither of which is provided by bat detectors. The need to position traps on trails reduced our trapping comparison to seven logged coupes and seven unlogged coupes. Because dense regrowth in logged coupes provided more restricted flyways than those in unlogged coupes, comparisons of the number of bats caught between logged and unlogged coupes must be interpreted with caution.

Vegetation structure

Understorey habitat complexity has been successfully described and related to ground mammal abundance with a simple scoring system (Catling and Burt 1995). We modified this to estimate structural complexity for bats in logged and unlogged coupes by scoring (0 = nil to 3=extensive) cover for each of the following- 1. Canopy and/or emergent eucalypts, 2. Regrowth eucalypts, 3. Shrub layer, 4. Ground vegetation and 5. Litter, logs and rocks. A simple soil moisture rating was also assigned to each site.

Estimates were made in a 50 m by 20 m area in the direction that the Anabat microphone was pointed. Given the extensive foraging ranges of bats, these measures record 3-dimensional 'microhabitat'structure for bats at each sampling site.

Analysis

We used the non-parametric Mann-Whitney *U*-test to compare the number of passes between logged and unlogged coupes, because data were not normally distributed and variances were very heterogeneous. Chi-square tests were used to compare the total numbers of bats caught for each species between logged and unlogged coupes rather than treating coupes as equal replicates because of the differing quality of flyways.

Results

Structural attributes of vegetation

The two forest age classes differed most obviously in the amount of cover provided by either young eucalypt or older canopy trees (Table 1). Logged coupes had extensive cover of regrowth eucalypts to a height of about 14-18 m, with emergent trees generally being absent. Often the shrub layer was poorly developed in these situations. In comparison, unlogged coupes had more well-spaced, large stems, a canopy to a height of 22-27 m and a moderate shrub layer. The canopy was well separated from the shrub layer and horizontal gaps between crowns of canopy trees were also extensive. Cover provided by ground vegetation, logs and litter as well as soil moisture was similar between the two treatments (Table 1).

Table 1. Mean scores (0-3, i.e. nil to extensive) for structural attributes of logged (n=8) and unlogged (n=8) coupes at Banksia Rd, Eden

Attribute	Logged	Unlogged
Canopy/emergent cover	0.2	0.7
Regrowth cover	1.3	0.6
Shrub cover	0.9	1.2
Ground cover	0.3	0.3
Litter, log, rock cover	1.8	1.9
Moisture	0	0

Ultrasonic detection

Ultrasonic detectors recorded a total of 2257 bat passes from 11 taxa. Three species of *Vespadelus* were the most frequently recorded of all bats (Table 2). Larger species (>8 g) were rare in the study area (Table 2). Thirty-two per cent of passes could not be identified to species due to the poor quality of recordings and/or brief sequences. Total activity at unlogged coupes was very high and limited recordings on cassettes to an average of 4 hours per night compared to an average of 8 hours per night for logged coupes. Despite reduced sampling in unlogged coupes, they contributed 65% of all passes. Therefore, because of unequal sampling, comparisons of bat activity between logged and unlogged coupes were restricted to the minimum time period recorded in both treatments (the first two hours after dark).

During this period, 1406 bat passes from 10 taxa were recorded. Eight taxa were recorded in unlogged coupes compared to seven in logged coupes. *Scotorepens orion* and *Falsistrellus tasmaniensis* were missing from logged coupes, while

Table 2. Mean (+ standard error) number of passes recorded in logged (n=8) and unlogged (n=8) coupes for the first two hours after dark. Comparisons were limited to this period because high activity at some sites used up cassettes before the end of the night. Calls not identifiable to a particular taxon are included in the total. Significant differences (Mann-Whitney U-test, P<0.05) are highlighted in bold. Species with few passes (<1 per two hours) were not tested.

Species	Logged	Unlogged
Vespadelus darlingtoni/regulus	**13 + 11**	**40 + 20**
Vespadelus vulturnus	10 + 7	14 + 6
Chalinolobus morio	4 + 2	5 + 3
Nyctophilus spp.	1 + 0.7	1 + 0.6
Miniopterus schreibersii	0.1 + 0.1	0.4 + 0.4
Scotorepens orion	0	0.3 + 0.3
Falsistrellus tasmaniensis	0	0.3 + 0.3
Chalinolobus gouldii	0	0.3 + 0.2
Mormopterus sp1	0.1 + 0.1	0
Tadarida australis	0.1 + 0.1	0
Total	**36 + 22**	**87 + 26**

Mormopterus sp. 1 was missing from unlogged coupes (Table 2). In the first 2 hours after dark, a mean of 87 passes was recorded in unlogged coupes compared to 36 passes in logged sites (Mann-Whitney U=10, P = 0.04). This pattern of greater activity in unlogged coupes was consistent at a species level for *V. darlingtoni/ regulus* (U=10, P=0.04) and as a strong trend for *V. vulturnus* (U=12, P=0.06). No difference in activity levels between logged and unlogged coupes was recorded for *C. morio* (U=23.5, P=0.6) nor for *Nyctophilus* spp. (U=47, P=0.3), although few passes were recorded for the latter (Table 2). There were insufficient passes to test the remaining species.

Despite these clear, overall trends, the relatively large standard errors in Table 2 indicate that bat activity was patchy. For instance, activity was unusually high at one logged coupe (B2), with the cassette being used up within 3.5 hours on the first night and 2 hours on the second night (mean = 152 passes). Conversely, two unlogged coupes recorded unusually low bat activity. A mean of 35 passes was recorded from two full nights of sampling at Coupe E and 34 passes in a full night at coupe H.

An index of foraging activity for each coupe was calculated by dividing the number of feeding buzzes by the total number of bat passes (i.e. full data set). Foraging activity did not differ between logged and unlogged sites (U=17, P=0.12). Three per cent of passes in unlogged coupes had feeding buzzes compared to 0.9% in logged coupes.

Trapping

A total of 317 bats from 10 species were captured in 28 harp trap-nights. *Vespadelus darlingtoni*, *V. vulturnus* and *V. regulus* were the species most frequently caught (Table 3), constituting 74% of all captures. More bats were trapped on trails in unlogged coupes (177) than on trails in logged coupes (140) (χ^2 = 3.0, P=0.08). For individual species, there were significantly more captures in unlogged coupes for *V. darlingtoni* and *V. regulus* (χ^2 tests, Table 3). Interestingly, the distribution of sexes differed across logging treatment. The ratio of males to females captured did not differ from parity (59:78; χ^2 = 2.6, P = 0.11) in logged coupes, but captures were significantly female-biased in unlogged coupes (46:131; χ^2 = 40.8, P<0.001).

Table 3. Total numbers of bats caught in logged and unlogged coupes on Banskia Rd, Eden. Results of χ^2 tests are shown with significant differences (P<0.05) highlighted in bold. Species with low capture numbers were not tested.

Species	Logged	Unlogged	χ^2
Vespadelus darlingtoni	**42**	**65**	**4.9**
Vespadelus vulturnus	47	38	1.0
Vespadelus regulus	**15**	**28**	**3.9**
Chalinolobus morio	16	12	0.6
Nyctophilus geoffroyii	12	15	0.3
Nyctophilus gouldi	5	13	3.6
Chalinolobus gouldii	1	3	-
Miniopterus schreibersii	1	1	-
Falsitrellus tasmaniensis	1	1	-
Scotorepens orion	0	1	-
Total trapped	140	177	3.0
Number of trap-nights	14	14	

Discussion

Data were not collected prior to the first round of logging of the alternate coupes (pre-1976), which means that we cannot describe the full impact that this disturbance may have had on bat populations. Our primary finding, however, is that after 22 years of regrowth, bat detectors positioned away from flyways clearly recorded greater bat activity in unlogged coupes compared to adjacent regrowth. Low bat activity in young forests is consistent with other studies that have recorded total activity away from flyways (Thomas 1988; Brown *et al*. 1997; Humes *et al.* 1999). Regrowth coupes had a lower canopy height and were structurally more cluttered than unlogged coupes. *Eucalyptus sieberi* is very slow to self-thin; for example 20 years after logging 4000-7000 stems ha^{-1} can be expected in densely stocked regrowth stands (Florence 1996).

The difference in bat activity between the logged and unlogged coupes is probably not food related. Although insect diversity is usually greater in forests with complex structure (Recher *et al*. 1996), a greater abundance of flying insects was found in recently logged forest compared to unlogged forest at Eden, and numbers of insects per understorey leaf were similar (Recher *et al*. 1985). This suggests that prey availability may not be the critical factor explaining the patterns of bat activity. Indeed, foraging rates were not significantly higher in unlogged coupes (3%) than regrowth coupes (0.9%). Rather, our results are consistent with the idea that habitat structure and clutter are key features determining the use of forests by bats with different wing shapes (Crome and Richards 1988; Brigham *et al*. 1997a; Brown *et al*. 1997; Humes *et al*. 1999). However, some patchiness in activity patterns in the logged/unlogged mosaic indicates either that vegetation structure was variable within logging treatments or that other, unmeasured factors also influenced bat activity.

Our study also provides data on the activity of individual species in regrowth, which is an aspect lacking in other studies of logging in eucalypt forests (e.g. Kutt 1995; Brown *et al.* 1997; see also Law 1996). Ecomorphology predicts that species with long slender wings (high aspect ratio) are less maneuverable than those with short broad wings (low aspect ratio) and are therefore restricted to open habitats (Findley 1993). Our results are limited to a sub-set of species that have a small body size, because only they had sample sizes sufficient for statistical testing. The species grouping, *V. darlingtoni/ regulus*, was recorded less often in cluttered regrowth coupes. The aspect ratio of these two species (5.92, 5.66 respectively – O'Neill and Taylor 1986) and observations of flight, such as flying with considerably more speed than *Nyctophilus* species (O'Neill and Taylor 1986), suggest that they are clutter-sensitive species unsuited to flying in regrowth. *Vespadelus vulturnus* has a lower aspect ratio (5.46 - O'Neill and Taylor 1986), indicating greater maneuverability and more tolerance of clutter. Activity for this species was higher in unlogged coupes (P=0.06), but the lack of statistical significance indicates that logged coupes are also regularly used.

Chalinolobus morio does not avoid regrowth as both the number of passes and the number trapped did not differ across management treatment. Previous studies, based on wing shape and direct flight observations (aspect ratio = 5.5 – O'Neill and Taylor 1986; Dwyer 1965), indicate that it is relatively maneuverable. Together with the capacity for formulating high-resolution images derived from its high frequency call (characteristic frequency = 50 kHz) (Law and Chidel, unpubl. data), it appears to able to operate within clutter.

Species in our study with the lowest aspect ratio, and which are maneuverable enough to forage within clutter, as well as in open areas, include *N. gouldi* and *N. geoffroyi* (Brigham *et al.* 1997b). As predicted by ecomorphology (aspect ratio = 5.13 for *N. geoffroy*i – O'Neill and Taylor 1986), the number of passes of *Nyctophilus* spp. did not differ between logged and unlogged coupes, but these species emit low-intensity ultrasonic calls (Grant 1991) and are not recorded efficiently by bat detectors. Trapping also revealed similar numbers on trails in logged and unlogged coupes for *N. geoffroyi* and *N. gouldi.*

Where suitable roost trees are available, individuals of small *Vespadelus* spp. have been found to forage and breed in regrowth forest (Law and Anderson 2000). How do bats achieve this if they are inefficient at foraging in clutter? Our harp trap results indicate that large numbers of bats used (commuting, foraging or otherwise) roads as openings within the regrowth coupes. Indeed, capture rates were higher across the logged/unlogged mosaic of Banksia Rd (11 bats / trap-night) than those reported in other studies from south-eastern Australia (reviewed in Young and Ford 2000). Roads provide long linear edges, which studies outside Australia have demonstrated to be important habitat for many bat species (Limpens and Kapteyn 1991; Crampton and Barclay 1996; Walsh and Harris 1996a,b; Grindal and Brigham 1999). In State Forests of the south-west slopes, Law *et al.* (1998) found greater foraging rates on tracks compared to off-tracks. Thus, roads may act as an important ameliorative measure in regrowth forest for less maneuverable bats. To properly quantify the ameliorative influence of roads, future studies should position detectors on and off flyways. The upper canopy surface of logged and unlogged forest might also be used by bats as edge habitat, as suggested by studies on bats in Canada (Kalcounis *et al*. 1999).

Our trapping revealed female-biased sex ratios in unlogged coupes. Such a bias is probably due to the location of maternity roosts (females only) in hollow-bearing trees in unlogged coupes at the time of the study (late October). As with birds (Kavanagh *et al*. 1985), the close proximity of unlogged forest (all logged and unlogged coupes were paired) would be a major contributor to the presence of bats on logged coupes. Clearly, the retention of roost trees is critical for the successful management of bats in these production forests (Lunney *et al*. 1988; Taylor and Savva 1988; Law 1996) and this is now standard practice in NSW.

Larger bat species (*T. australis, F. tasmaniensis, Miniopterus schreibersii, C. gouldii, S. orion* and *Mormopterus* sp.1) were rarely recorded by either detectors or traps. Although it is likely that they often fly above trap height, each possesses a call that is recorded easily and is usually distinctive (B. Law and M. Chidel, *pers. obs*.). The rarity of large bat species suggests that ridge-top vegetation dominated by *E. sieberi*, a species indicative of low-nutrient soil (Braithwaite *et al*. 1984, 1988), represents poor habitat for these bats. Indeed, open forest dominated by *E. sieberi* supports fewer flying insects than tall open forest that is adjacent and located on better soil (Recher *et al.* 1985). Positive associations between nutrient-rich soil and high bird species richness (Braithwaite *et al*. 1989), as well as arboreal marsupial abundance (Braithwaite *et al.* 1984), also occur in southern NSW. The low productivity of the Banskia Rd site may provide a partial explanation for the low rate of feeding off-tracks (0.9%-3% of passes) compared to other published values (14% - Law *et al*. 1998; 9% - Law and Anderson 1999). However, total bat captures on tracks, particularly for small species, were very high. The positioning of detectors may be important here, as the rates of feeding can be higher for detectors placed on tracks (Law *et al*. 1998). In support of the importance of soil fertility to large bats, high activity of a range of large bat species was recorded in northern NSW in remnant vegetation on productive farmland, but not in forests on less fertile, surrounding hills (Law *et al*. 2000).

To conclude, our results demonstrate significantly lower bat activity in regrowth coupes, 22 years after intensive logging, versus unlogged coupes. Given that these coupes represent an 'extreme' form of logging, which is no longer practiced, these results also provide support for the recent shift towards more ecologically sustainable forms of logging. Integrated harvesting at Eden now includes prescriptions that retain undisturbed habitat in riparian strips and in between-catchment corridors, as well as retaining habitat trees in the net logging area. Such prescriptions have the dual benefit of providing roost trees (Lunney *et al.* 1988; Law and Anderson 2000) as well as patches of forest/clumps of retained mature trees that would increase gaps and edges apparently required by many species of bats for successful foraging. The success of this approach will require measuring after the second round of alternate coupe logging, which is scheduled for the next few years.

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References

Anon. (1999). **http://www.racac.nsw.gov.au/rfa/pdf/npws_tsl_licence.pdf**

Braithwaite, L.W., Turner, J. and Kelly, J. (1984) Studies on the arboreal marsupial fauna of eucalypt forests being harvested for woodpulp at Eden, NSW. III. Relationships between faunal densities, eucalypt occurrence and foliage nutrients, and soil parent materials. *Australian Wildlife Research* **11,** 41-48.

Braithwaite, L.W., Binns, D.L. and Nowlan, R.D. (1988) The distribution of arboreal marsupials in relation to eucalypt forest types in the Eden (NSW) woodchip concession area. *Australian Wildlife Research* **15,** 363-373.

Braithwaite, L.W., Austin, M.P., Clayton, M., Turner, J. and Nicholls, A.O. (1989) On predicting the presence of birds in *Eucalyptus* forest types. *Biological Conservation* **50,** 33-50.

Brigham, R.M., Grindal, S.D., Firman, M.C. and Morissette, J.L. (1997a) The influence of structural clutter on activity patterns of insectivorous bats. *Canadian Journal of Zoology* **75,** 131-136.

Brigham, R.M., Francis, R.L. and Hamdorf, S. (1997b) Microhabitat use by two species of *Nyctophilus* bats: a test of ecomorphology theory. *Australian Journal of Zoology* **45,** 553-560.

Brown, G.W., Nelson, J.L. and Cherry, K.A. (1997) The influence of habitat structure on insectivorous bat activity in montane ash forests of the central Highlands, Victoria. *Australian Forestry* **60,** 138-146.

Catling, P.C. and Burt, R.J. (1995) Studies of the ground-dwelling mammals of eucalypt forests in south-eastern New South Wales: the effect of habitat variables on distribution and abundance. *Australian Wildlife Research* **22,** 271-288.

Crampton, L.H. and Barclay, R.M.R. (1996) Habitat selection by bats in fragmented and unfragmented aspen mixedwood stands of different ages. In: Barclay, R.M.R. and Brigham, R.M. (eds). *Bats and Forests Symposium, October 19-21, 1995, Victoria, British Columbia, Canada.* Research Brranch, BC Ministry of Forestry, Victoria, British Columbia. Work. Pap. 23/1996, pp. 238-259.

Crome, F.H.J. and Richards, G.C. (1988) Bats and gaps: Microchiropteran community structure in a Queensland rainforest. *Ecology* **69,** 1960-1969.

de Oliveira, M.C. (1998) Anabat System Practical Guide. Department of Natural Resources, Queensland.

Dwyer, P.D. (1965) Flight patterns of some eastern Australian bats. *Victorian Naturalist* **82,** 36-41.

Findley, J.S. (1993) *Bats: A Community Perspective.* Cambridge University Press, Cambridge, UK.

Florence, R.G. (1996) *Ecology and Silviculture of Eucalypt Forests.* CSIRO Publishing, Victoria.

Grant, J.D.A. (1991) Prey location by two Australian long-eared bats, *Nyctophilus gouldi* and *N. geoffroyi. Australian Journal of Zoology* **39,** 45-56.

Grindal, S.D. and Brigham, R.M. (1999) Impacts of forest harvesting on habitat use by foraging insectivorous bats at different spatial scales. *Ecoscience* **6,** 25-34.

Humes, M.L., Hayes, J.P. and Collopy, M.W. (1999) Bat activity in thinned, unthinned, and old-growth forests in western Oregon. *Journal of Wildlife Management* **63,** 553-561.

Kalcounis, M.C., Hobson, K.A., Brigham, R.M. and Hecker, K.R. (1999) Bat activity in the boreal forest: importance of stand type and vertical strata. *Journal of Mammalogy* **80,** 673-682.

Kavanagh, R.P., Shields, J.M., Recher, H.F. and Rohan-Jones, W.G. (1985) Bird populations of a logged and unlogged forest mosaic at Eden, New South Wales. In: Keast, A., Recher, H.F., Ford, H. and Saunders, D. (eds). *Birds of Eucalypt Forests and Woodlands:*

Ecology, Conservation, Management. Ornithologists Union and Surrey Beatty and Sons, Sydney. Pp. 273-281.

Kutt, A.S. (1995) Activity and stratification of Microchiropteran bat communities in thinned, unthinned and old lowland regrowth forest, East Gippsland. *Victorian Naturalist* **112,** 86-93.

Law, B.S. (1996) The ecology of bats in south-east Australian forests and potential impacts of forestry practices: a review. *Pacific Conservation Biology* **2,** 363-374.

Law, B. and Anderson, J. (1999) A survey for the southern myotis *Myotis macropus* (Vespertilionidae) and other bat species in river red gum *Eucalyptus camaldulensis* forests of the Murray River, New South Wales. *Australian Zoologist* **31,** 166-174.

Law, B.S. and Anderson, J.A. (2000) Roost preferences and foraging ranges of the eastern forest bat *Vespadelus pumilus* under two disturbance histories in northern New South Wales, Australia. *Austral Ecology* **25,** 352-367.

Law, B.S., Anderson, J. and Chidel, M. (1998) A survey of bats on the south-west slopes region of NSW with suggestions of improvements for bat surveys. *Australian Zoologist* **30,** 467-479.

Law, B.S., Chidel, M. and Turner, G. (2000) The use by wildlife of paddock trees in farmland. *Pacific Conservation Biology* **6,** 130-143.

Limpens, H.J.G.A. and Kapteyn, K. (1991) Bats, their behaviour and linear landscape elements. *Myotis* **1991,** 39-47.

Lunney, D., Barker, J., Priddel, D. and O'Connell, M. (1988) Roost selection by Gould's long-eared bat, *Nyctophilus gouldi* Thomas (Chiroptera: Vespertilionidae), in logged forest on the south coast of New South Wales. *Australian Wildlife Research* **15,** 375-384.

O'Neill, M.G. and Taylor, R.J. (1986) Observations on flight patterns and foraging behaviour of Tasmanian bats. *Australian Wildlife Research* **13,** 427-432.

Recher, H.F., Allen, D. and Gowing, G. (1985) The impact of wildfire on birds in an intensively logged forest. In: Keast, A., Recher, H.F., Ford, H. and Saunders, D. (eds). *Birds of Eucalypt Forests and Woodlands: Ecology, Conservation, Management*. Ornithologists Union and Surrey Beatty and Sons, Sydney. Pp. 283-290.

Recher, H.F., Majer, J.D. and Ganesh, S. (1996) Eucalypts, birds and arthropods: on the relation between foliar nutrients and species richness. *Forest Ecology and Management* **85,** 177-195.

Reinhold, L., Law, B., Ford, G. and Pennay, M. (2001) *Key to the Bat Calls of South-East Queensland and North-East New South Wales.* Forest Ecosystem Research and Assessment Technical Paper 2001-07, Department of Natural Resources and Mines, Queensland.

Taylor, R.J. and Savva, N.M. (1988) Use of roost sites by four species of bats in State forest in southeastern Tasmania. *Australian Wildlife Research* **15,** 637-645.

Thomas, D.W. (1988) The distribution of bats in different ages of Douglas-fir forests. *Journal of Wildlife Management* **52,** 619-626.

Walsh, A.L. and Harris, S. (1996a) Foraging habitat preferences of vespertilionid bats in Britain. *Journal of Applied Ecology* **33,** 508-518.

Walsh, A.L. and Harris, S. (1996b) Factors determining the abundance of vespertilionid bats in Britain: geographical, land class and local habitat relationships. *Journal of Applied Ecology* **33,** 519-529.

Young, R.A. and Ford, G.I. (2000) Bat fauna of a semi-arid environment in central western Queensland, *Australia. Wildlife Research* **27,** 203-215.