Large owl territories as a planning tool for vertebrate fauna conservation in the forests and woodlands of eastern Australia

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ABSTRACT

The spatial patterns of Sooty Owl *Tyto tenebricosa* and Barking Owl *Ninox connivens* records, obtained from large owl surveys in the Victorian Central Highlands and the Pilliga Scrub in New South Wales respectively, allow the suggestion to be made that these species select territories with particular sets of habitat attributes. Estimated Sooty and Barking Owl territories in the Mountain Ash *Eucalyptus regnans* forests of the Central Highlands and the cypress pine *Callitris* spp-ironbark *Eucalyptus* spp forests and woodlands of the Pilliga Scrub were concentrated in areas with abundant tree hollows and other old-growth attributes and less frequent fires. Higher soil nutrients and plant productivity also appeared to be important attributes in the Pilliga Scrub. Territories of the large owls in both survey areas contained most of the sites where the highest nocturnal bird and arboreal marsupial species richness and abundance were recorded, enabling the proposal to be advanced that Sooty and Barking Owls could serve as indicators of high quality habitat for a range of forest and woodland-dependent vertebrates. In particular, they appear able to function as indicators for hollow-dependent and other specialised species disadvantaged by disturbances such as intensive logging and frequent fire. Territories of these large owls form a pattern that provides a natural planning template ideal for map-based reserve selection aimed at maximising biodiversity conservation in the forests and woodlands of eastern Australia.

Key words: large owls, spatial distribution patterns, territory selection, old-growth forest, soil nutrients, fire frequency, indicators of high quality habitat, reserve selection.

Introduction

The potential for large owls to serve as indicators of high levels of arboreal marsupial and other vertebrate species diversity, or "umbrella species" (Simberloff 1998), in the forests and woodlands of eastern Australia has provoked considerable discussion over the past few decades (*e.g.* Kavanagh 2002, Kavanagh and Bamkin 1994, Loyn *et al.* 1980, 2001, 2002, Milledge *et al.* 1991). Recent planning for the conservation of large owls has been based on habitat modelling (Loyn *et al.* 2001, 2002, McIntyre and Henry 2002), although the capacity of modelled owl habitat to cater for other species has not been clearly demonstrated. This chapter explores the approach of conserving known territories of large owls by examining data from two surveys of large owls conducted on different sides of the Great Dividing Range. The findings are presented as a framework for reserve selection to assist in achieving optimum biodiversity conservation outcomes in landscapes where competing land uses are now reducing options for formal reservation.

Neither sufficient data, nor exhaustive analyses of data from these two surveys, are available to unequivocally demonstrate relationships between large owl territories, habitats and other vertebrate species, but the findings are presented here to inform current conservation planning[1]. This decision was made because there will be little satisfaction in presenting, in another decade or so, a paper entitled: "Being wise after the event …", *i.e.* when it has been firmly established that large owls do exhibit a pattern of habitat selection that is ideal for map-based reserve design, but the opportunity to apply this knowledge has been lost.

In 1989 when I was invited to contribute to the first edition of *Conservation of Australia's Forest Fauna* (Lunney 1991), my colleagues and I had just completed a survey of large owls in the tall, wet Mountain Ash *Eucalyptus regnans* forests of Victoria's

[1] A note of caution needs to be sounded here when taking the leap from survey data to presenting the results as a contribution to the conservation debate. The publication of the Mountain Ash survey results and their extrapolation to predicting logging effects on large owls and gliders in the first edition of *Conservation of Australia's Forest Fauna* (Milledge *et al.* 1991) generated a perplexing series of misquotes and misinterpretations. Despite the chapter clearly indicating that survey sites were located in *unlogged* forests regrown following wildfires and that *twice* as many Sooty Owl site records were obtained from old-growth stands as from young stands, it has been claimed that the results showed "similar rates of occurrence of Sooty Owls in forest which had been logged 50 to 80 years previously and in forests older than 165 years" (Fanning 1993) and that "the density of the Sooty Owl *Tyto tenebricosa* was generally lower in clearfallen areas" (Countrywide Ecological Services 1995). Other publications have stated that the survey "found no difference between the number of sites where Sooty Owls were reported in forest 50-80 years old and forest in excess of 165 years developmental age" (York and Shields 1992), that "no difference was found in the number of sites where Sooty Owls were reported in forest 50-80 years old, and in forest in excess of 165 years development" (Mount King Ecological Surveys 1992) and that it "found that the number of Yellow-bellied Gliders declined after clearfelling (Cann *et al.* 2002). Yet another document claimed that the survey had recorded the Greater Glider "as common and widespread in relatively intensively harvested Mountain Ash forest in Victoria, but the Sooty Owl and Yellow-bellied Glider were essentially excluded" (Margules Groome Poyry 1993). Whatever the reasons for this confusion, it is difficult to suggest a remedy apart from an iterative approach to writing and publishing corrections.

Pp 493 - 507 in the *Conservation of Australia's Forest Fauna* (second edition) 2004, edited by Daniel Lunney. Royal Zoological Society of New South Wales, Mosman, NSW, Australia.

Central Highlands as part of the State's Silvicultural Systems Project (Milledge *et al.* 1991). Although the results had only been subject to preliminary analysis, an interesting spatial pattern was evident in the distribution of records of the Sooty Owl *Tyto tenebricosa*, the only large owl species that we had consistently recorded at survey sites. We postulated that in extensive tracts of Mountain Ash forest, the highest quality habitat for the hollow-dependent Sooty Owl was provided by large patches of old-growth forest. We also proposed that Sooty Owl home ranges or territories could serve as indicators of the habitat essential for the conservation of other hollow-dependent vertebrates in Mountain Ash and similar timber-production forests, where the loss of hollow-bearing trees and stags was a major threat to the maintenance of biodiversity.

Subsequent modelling of the survey data indicated that optimum habitat for the Sooty Owl in Mountain Ash forests consisted of old-growth stands that contained a relatively high proportion of mature and younger-aged trees (Milledge 1994), or what is termed multi-aged forest (*e.g.* Mackey *et al.* 2000). An examination of Sooty Owl territories showed that they contained most of the sites where the highest diversity and abundance of owls and arboreal marsupials were recorded during the large owl survey (Milledge 1994). Sooty Owls appeared to be selecting territories containing the greatest diversity and abundance of the critical resources of food (prey species) and shelter (roost and nest hollows). This raised the question of whether large owls could serve more broadly as indicators of habitats that should be given priority for reservation or careful management. A test would be to examine survey results from a contrasting environment.

In 2001, with the assistance of other colleagues, I conducted a survey of large owls in a different area of eastern Australia, the dry cypress pine *Callitris* spp-ironbark *Eucalyptus* spp forests and woodlands of the central north west slopes and plains of New South Wales. This was undertaken for the Western Regional Assessment in the Brigalow Belt South bioregion (Thackway and Cresswell 1995) as part of the New South Wales Government's on-going regional assessment process (*e.g.* Beattie and Dangerfield 2000). Here, records of the Barking Owl *Ninox connivens* formed an interesting distribution pattern in the Pilliga Scrub where the survey was concentrated (Milledge 2002, Milledge and Soderquist *in prep.*). The hollow-nesting Barking Owl appeared to be selecting territories with relatively high plant productivity and many tree hollows, attributes likely to support increased densities of other forest and woodland vertebrates, including the Barking Owl's prey species.

Barking and Sooty Owls are slow-reproducing, sedentary species whose young remain dependent for up to 4-5 months after fledging (Higgins 1999). Their selection of territories can be seen as a strategy to maximise breeding success and overall survival by providing a constant and reliable supply of prey that allows switching of the prey base as population numbers of prey species fluctuate with environmental change. Foraging opportunism by the Sooty Owl has been interpreted as indicating that the species may not be adversely affected by disturbances, such as logging (Kavanagh and Bamkin 1994) and "may be more resilient....than formerly believed" (Debus 1994). This infers that the species may not be a good indicator for forest vertebrates that are sensitive to the loss of old-growth elements, and consequently it may not make a good choice as an "umbrella species" in forest planning.

However, there are other interpretations and in my view, and that of others (*e.g.* Loyn *et al.* 2001, 2002), the evidence points to the value of the Sooty, Barking and possibly other large owl species as indicators of habitat most suitable for a range of forest and woodland-dependent species. This is particularly the case for those species with requirements for such old-growth attributes as tree hollows, as well as large home ranges. To examine this view in more detail, I present and interpret data on the occurrence of Sooty and Barking Owls and associated nocturnal vertebrates collected during both the Victorian Mountain Ash and New South Wales cypress pine-ironbark surveys.

The Sooty Owl in Mountain Ash forests in Victoria

A compressed version of the survey for large owls in Mountain Ash forests (reported in Milledge *et al.* 1991 and Milledge 1994) is provided here to establish the concept of large owl territories as indicators of forest attributes at the centre of the forest debate, namely old-growth forest, tree hollows, arboreal marsupials and top-order predators.

Large owls were surveyed in the Victorian Central Highlands at 130 sites, stratified across four different age classes of unlogged Mountain Ash forest. Age classes ranged from 50 to 250+ year old stands that had established following wildfires. The younger stands were dominated by trees too young to have developed hollows, while older stands were dominated by mature and senescent trees that provided abundant hollows and other old-growth attributes used by vertebrates. Sites, spaced approximately 1.0 km apart along vehicular tracks, were surveyed twice using owl call playback and spotlighting during the autumn, winter and early spring of 1989, with Sooty Owls recorded at 22 sites (17%). Most records were clustered in and about stands of old-growth forest (165 and 250+ year-old stands) characterised by central areas that were greater than 1.0 km^2. Records in young forest (50 and 63-80 year-old stands) that were more than 1.0 km from these large old-growth patches were made in areas containing scattered old trees, high densities of stags (standing dead trees) or riparian habitat. Logistic regression was used to model the probability of finding a Sooty Owl at a site using 16 broad scale (context) and 23 small scale (site-specific) habitat variables considered likely to influence Sooty Owl occurrence (Table 1). The chance of a Sooty Owl occurring at a site was found to increase with an increase in the proportion of old-growth forest about the site, but decreased with an increase in the proportion of senescent trees (trees with dead tops, Fig. 1).

Table 1. Broad and small scale habitat variables used in logistic regression analysis (from Milledge 1994)

Broad scale (context) variables

- altitude
- aspect
- landform
- distance from closest minor stream
- distance from closest major stream
- site (stand) age class
- % cover of site age class within site core area (area defined by circle of radius = distance to 12th closest tree)
- +/- mixed aged stand
- % cover of old-growth within site core
- distance from closest old-growth stand
- distance from closest old-growth stand with core area>1.0km²
- % cover of *Nothofagus* within site core
- distance from closest *Nothofagus* stand
- % cover of mixed-species *Eucalyptus* within site core
- distance from closest mixed-species *Eucalyptus* stand
- % cover of *Eucalyptus nitens* within site core

Small scale (site-specific) variables

- canopy foliage cover
- site (stand) height
- canopy tree density
- large canopy tree (dbh>/=1.5m) density
- canopy tree basal area
- large canopy tree basal area
- % of trees with dead tops
- % of trees with fire damage
- stag height range
- stag density
- large stag (dbh>/=1.0m) density
- stag basal area
- large stag basal area
- % *Eucalyptus regnans* in canopy
- % *Eucalyptus nitens* in canopy
- % *Eucalyptus delegatensis* in canopy
- % mixed-species *Eucalyptus* in canopy
- floristic sub-community
- tall understorey foliage cover
- tall understorey height
- +/- *Nothofagus* as tall understorey dominant/co-dominant
- +/- *Acacia* spp as tall understorey dominants/co-dominants
- +/- *Pomaderris* as tall understorey dominant/co-dominant

Sooty Owl territories were estimated by fitting a polygon of about 500 ha (mean of territory size range given by Schodde and Mason 1980) around clusters of survey records and other non-systematic records. The presence and numbers of all species of owls and scansorial and

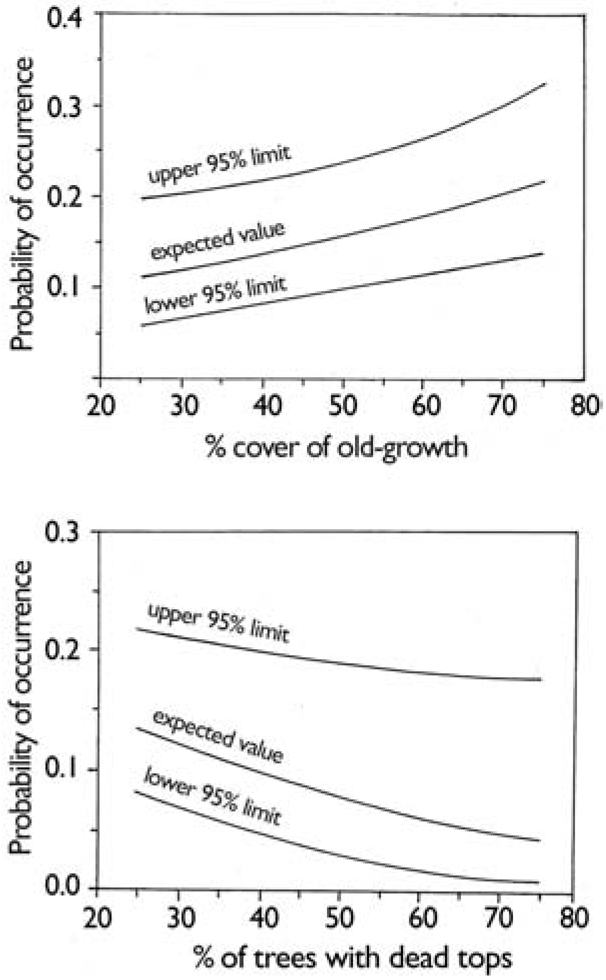

Figure 1. The upper and lower limits of confidence intervals for predicted values in the logistic regression model for the occurrence of the Sooty Owl *Tyto tenebricosa* in the Victorian Central Highlands survey area.

arboreal marsupials recorded during the survey (Table 2) were examined to determine whether the Sooty Owl territories contained a higher diversity of these species than surrounding areas of forest. The data obtained for 7 of the 12 owl and arboreal marsupial species were adequate for analysis (Table 2). The highest number of species recorded at sites ranged from 3 to 4, and the highest cumulative number of individuals ranged from 6 to 10. When overlaid on the map of Sooty Owl territories, it was apparent that 17 of the 20 sites (85%) where three or four species were recorded and 11 of the 12 sites (92%) where 6 to 10 individuals were recorded fell within Sooty Owl territories (Fig. 2). All but one (9 out of 10) of the richest sites for owls and arboreal marsupials (3 or 4 species plus 6 to 10 individuals) were located within the Sooty Owl territories (Fig. 2). Sooty Owl territories also contained a high proportion of records of the two arboreal marsupial species considered likely to be the most sensitive to timber harvesting in Mountain Ash forests. Twenty-four of the 31 sites (77%) where Yellow-bellied Gliders *Petaurus australis* were recorded, and 33 of the 47 sites (70%) where Greater Gliders *Petauroides volans* were recorded, fell within Sooty Owl territories (Fig. 3).

Table 2. Number of sites where owl and scansorial and arboreal marsupial species were recorded, and numbers of individuals recorded at sites, following two surveys of 130 sites in the Mountain Ash forests of the Victorian Central Highlands

Species	Number of sites where species recorded after 2 surveys			Number of individuals recorded at sites after 2 surveys		
	Sites in young forest (50, 63-80yrs)	Sites in old-growth forest (165, 250+yrs)	Total sites	Sites in young forest (50, 63-80yrs)	Sites in old-growth forest (165, 250+yrs)	**Total numbers**
Powerful Owl *Ninox strenua*	2	3	**5**	2	3	**5**
Southern Boobook *Ninox novaeseelandiae*	9	9	**18**	12	11	**23**
Sooty Owl *Tyto tenebricosa*	7	15	**22**	8	18	**26**
Tawny Frogmouth *Podargus strigoides*	1	1	2	1	1	2
Australian Owlet-nightjar *Aegotheles cristatus*	2	1	3	3	2	5
Brown Antechinus *Antechinus stuartii*	-	1	1	-	1	1
Yellow-bellied Glider *Petaurus australis*	5	31	**36**	8	73	**81**
Sugar Glider *Petaurus breviceps*	3	2	**5**	3	2	**5**
Greater Glider *Petauroides volans*	12	35	**47**	19	55	**74**
Leadbeater's Possum *Gymnobelideus leadbeateri*	2	2	4	2	3	5
Mountain Brushtail Possum *Trichosurus caninus*	9	16	**25**	10	21	**31**
Feathertail Glider *Acrobates pygmaeus*	-	1	1	-	1	1

Data from Milledge 1994, species used in analysis in **bold**

The conclusion drawn was that the Sooty Owl would perform well as an indicator of habitat quality for forest-dependent species in Mountain Ash and similar forests used for timber production in eastern Australia. In addition, it could also function as an indicator for hollow-dependent vertebrates in such forests. However, because the latter conclusion is based on data obtained from surveys in unlogged stands, and the Sooty Owl is known to be able to change its prey base (*e.g.* Loyn *et al.* 1986, Lundie-Jenkins 1993, Debus 1994), more research will be required before the species' credentials in this regard can be confirmed.

The Barking Owl in cypress pine-ironbark forests and woodlands in NSW

A summary of the survey for large owls in the Pilliga Scrub within the New South Wales section of the Brigalow Belt South bioregion (described in Milledge 2002 and Milledge and Soderquist *in prep.*) is presented here to support the idea of large owl territories as indicators of habitat quality for forest and woodland-dependent vertebrates. The survey for large owls in the Pilliga Scrub was conducted at 510 sites selected to give comprehensive coverage of the major blocks of forest and woodland in the area. These blocks were mostly contained within State Forests and the Pilliga Nature Reserve. The sites were stratified to sample the main vegetation types present, together with riparian habitats, and forest and woodland edges with agricultural land. Sites were spaced 1.5-2.0 km apart along minor roads and vehicular tracks. They were surveyed once, using owl call playback, and the survey was conducted during the autumn-winter of 2001.

Barking Owls were recorded at 92 sites (18%) with the records concentrated in State Forests in the north and west of the survey area (Fig. 4). The majority of records (54%) were from the forest and woodland interior, or more than 1.0 m from edges, and only a few (5%) were from riparian habitat along major drainage lines (Fig. 4). The pattern of records closely followed the distribution of the non-commercial box *Eucalyptus albens, E. pilligaensis*, *E. populnea* forests and woodlands (Fig. 5), which are mainly restricted to the extensive clay and sand flats that characterise landscapes in the western and northern Pilliga. These are areas of higher soil nutrient status and increased plant productivity compared with the low sandstone ridges of the eastern and southern Pilliga. Research elsewhere has demonstrated that soils of higher nutrient status support higher densities of possums and gliders (*e.g.* Braithwaite 1983, Braithwaite *et al.* 1984), some of which comprise the prey of the Barking Owl. Further, the box and co-occuring non-commercial eucalypt species contain abundant tree hollows. Both these factors are likely to benefit Barking Owls and their most important prey species.

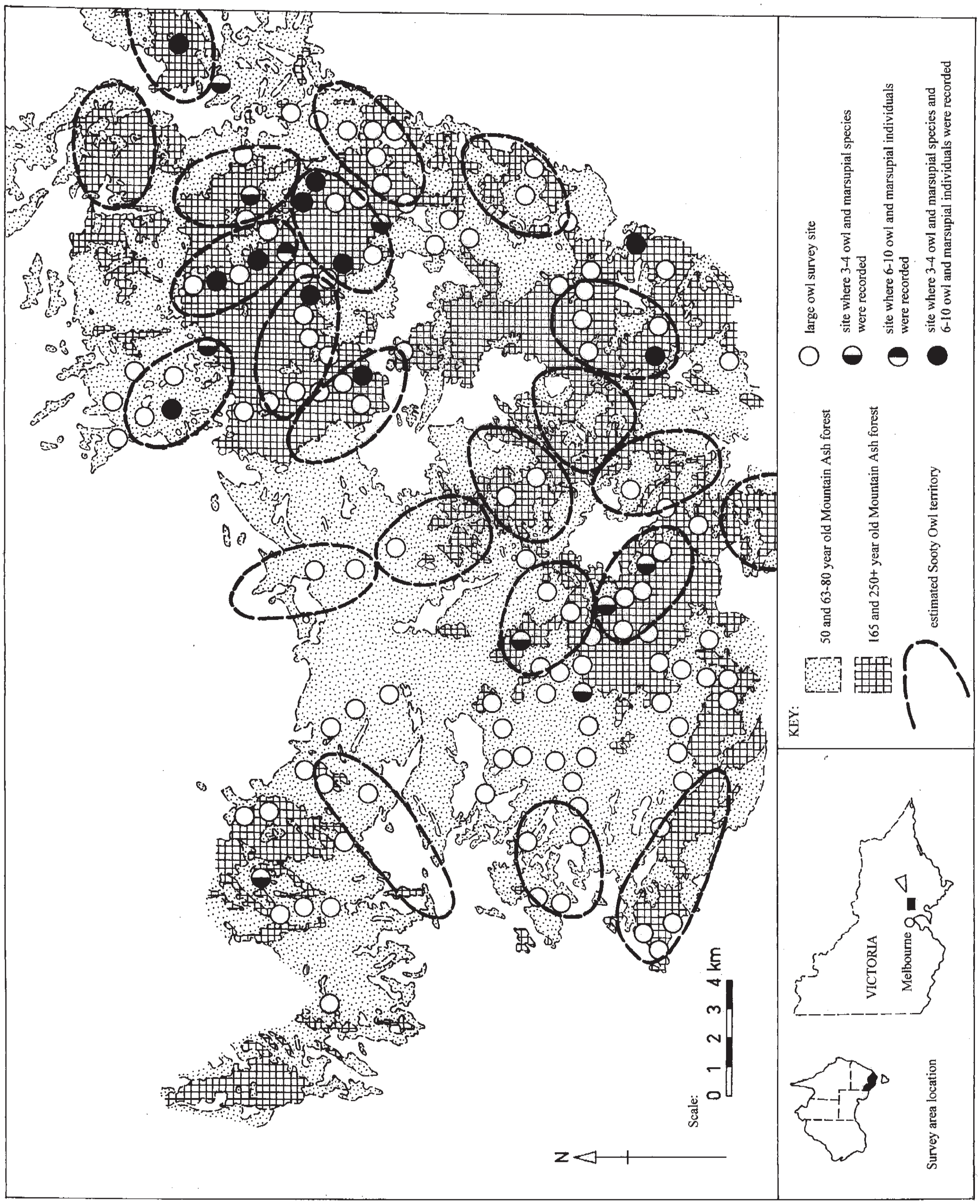

Figure 2. Sites where the highest values for owl and arboreal marsupial species richness and abundance were recorded during the large owl survey in the Victorian Central Highlands, showing the relationship between the sites and estimated Sooty Owl *Tyto tenebricosa* territories.

The pattern of Barking Owl records was also associated with areas unburnt by the frequent wildfires that occur in the Pilliga, where forest management is focused on excluding fire in the more productive and valuable western and northern areas (R. Kavanagh, State Forests of NSW, *pers. comm.*). Areas most frequently burnt over the past 50 years are concentrated in the east and south (Fig. 6) and it is reasonable to postulate that the higher fire frequency there further reduced productivity and habitat diversity for the Barking Owl and its prey. Interestingly, the distribution pattern of the Koala *Phascolarctos cinereus* in the Pilliga is broadly similar to that obtained for the Barking Owl (Kavanagh and Barrott 2001). Koalas are sensitive to fire and foliage nutrient status and the issues of fire frequency and plant productivity both warrant further investigation in these forests and woodlands.

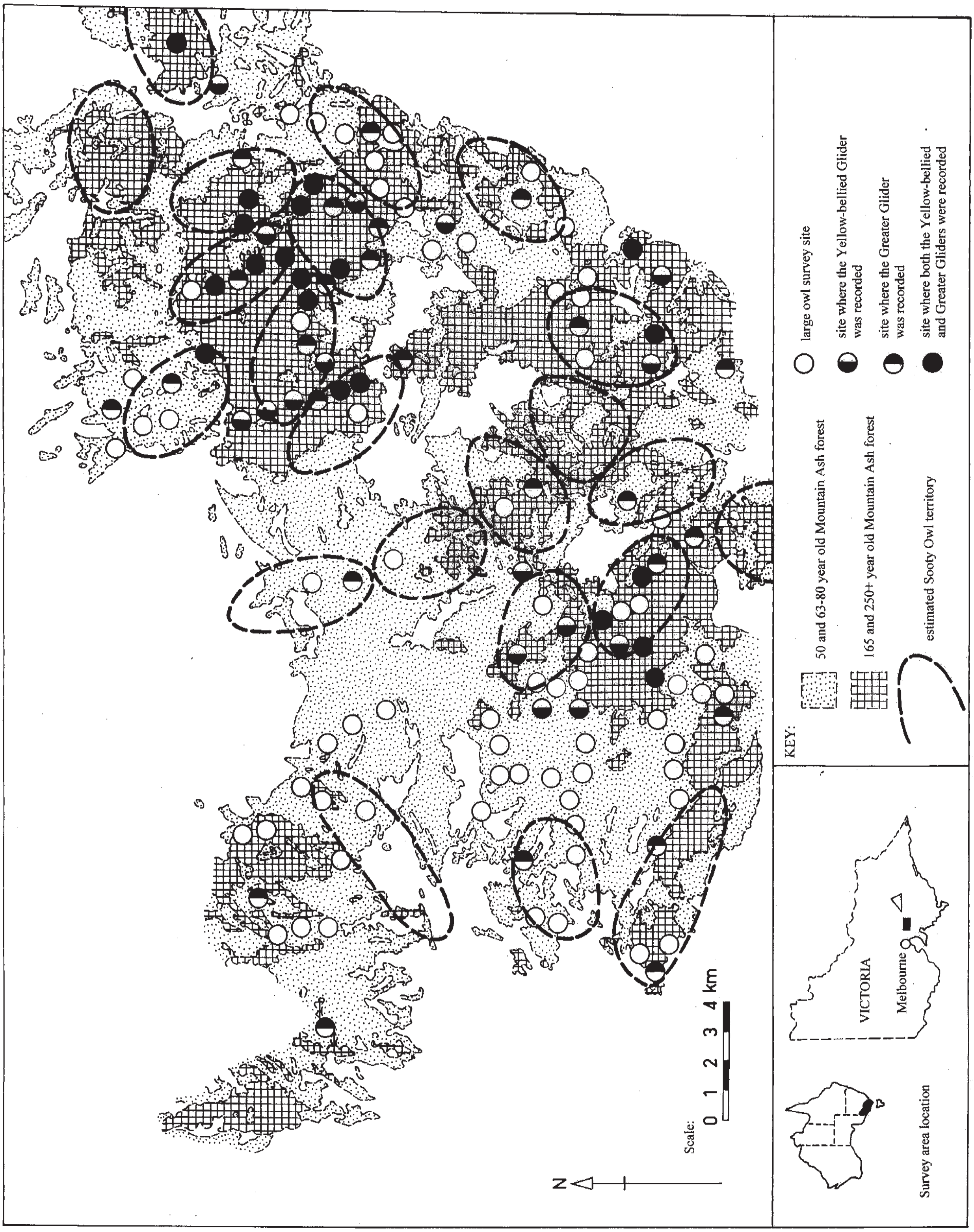

Figure 3. Sites where the Yellow-bellied Glider *Petaurus australis* and Greater Glider *Petauroides volans* were recorded during the large owl survey in the Victorian Central Highlands, showing the relationship between the sites and estimated Sooty Owl *Tyto tenebricosa* territories.

Barking Owl territories in the Pilliga were estimated by fitting a polygon of about 6000 ha (based on Schedvin *et al.* 2001) around clusters of survey records to take into account the response intensity of a pair or individual to call playback, the initial direction of response, the abatement of response if the pair or individual followed the surveyor between sites, and surrounding suitable habitat. This approach makes a number of assumptions, but is consistent with current knowledge of Barking Owl home range size in similar forests and woodlands and it represents a reasonable estimate for supporting the argument that forms the basis for this chapter.

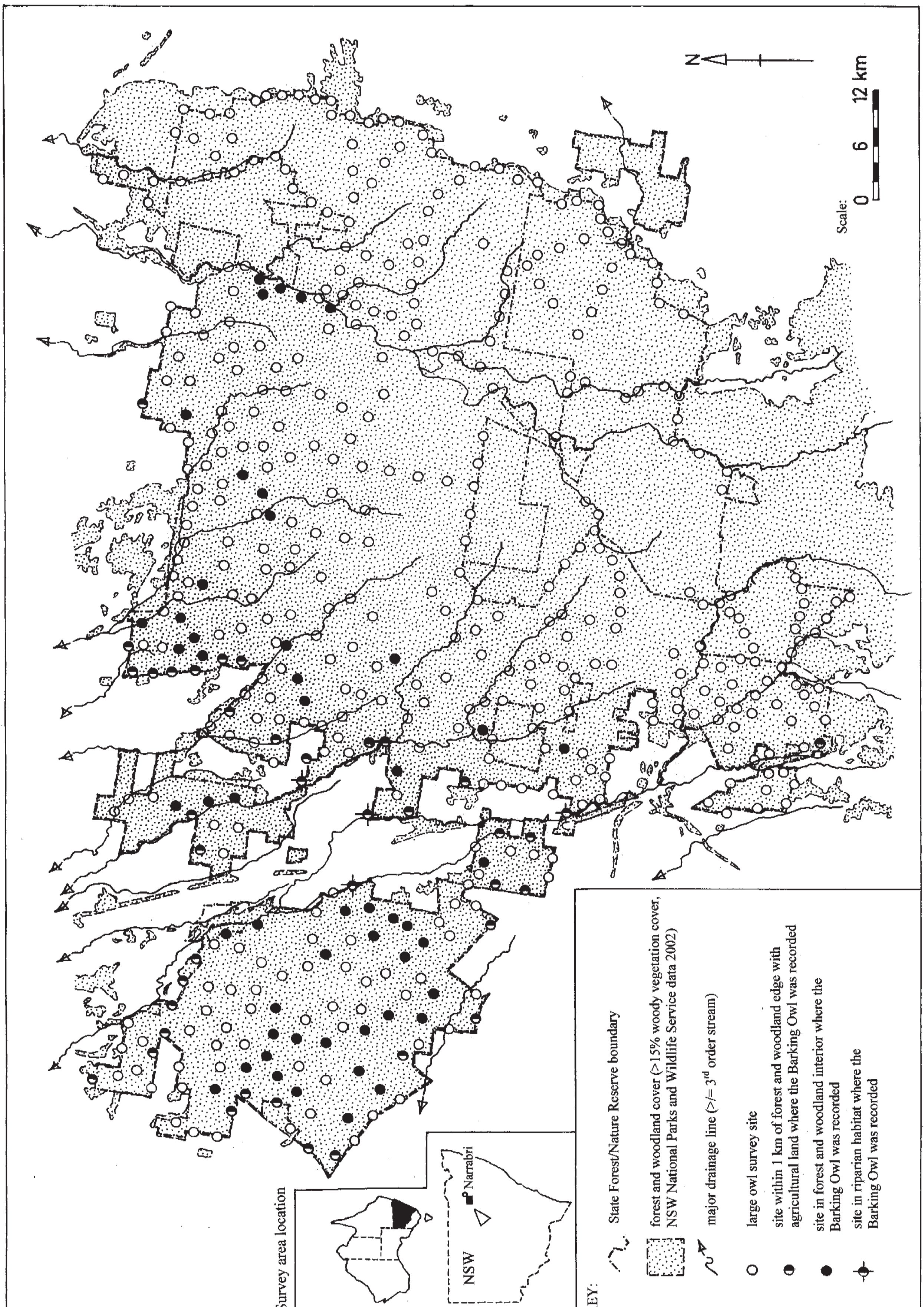

Figure 4. Sites where the Barking Owl *Ninox connivens* was recorded during the large owl survey in the Pilliga Scrub of New South Wales, showing the relationship between the sites and forest and woodland edges with agricultural land, and major drainage lines (3rd and larger order streams).

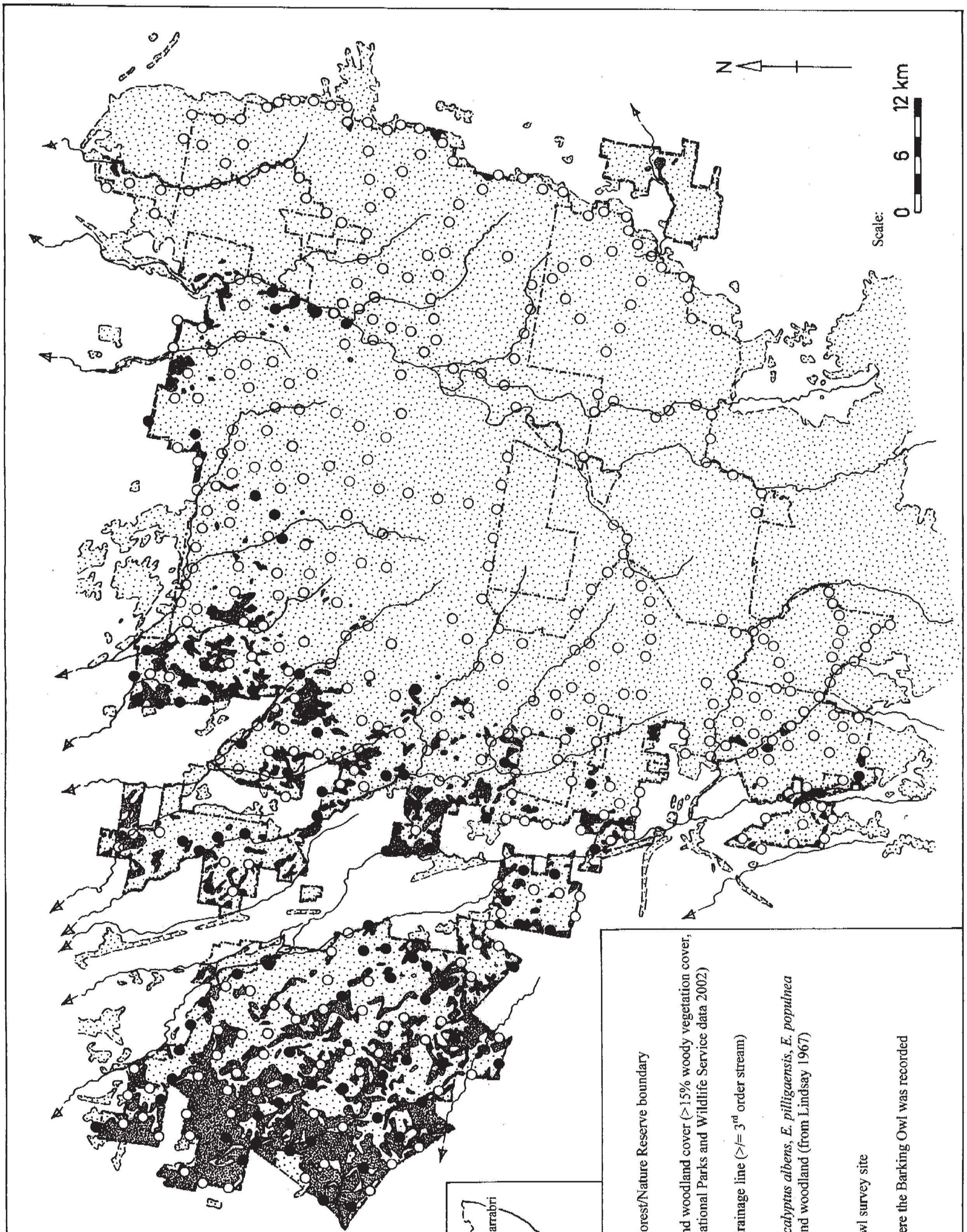

Figure 5. Sites where the Barking Owl *Ninox connivens* was recorded during the large owl survey in the Pilliga Scrub of New South Wales, showing the relationship between the pattern of sites and the distribution of box *Eucalyptus albens, E. pillagaensis, E. populnea* forests and woodlands.

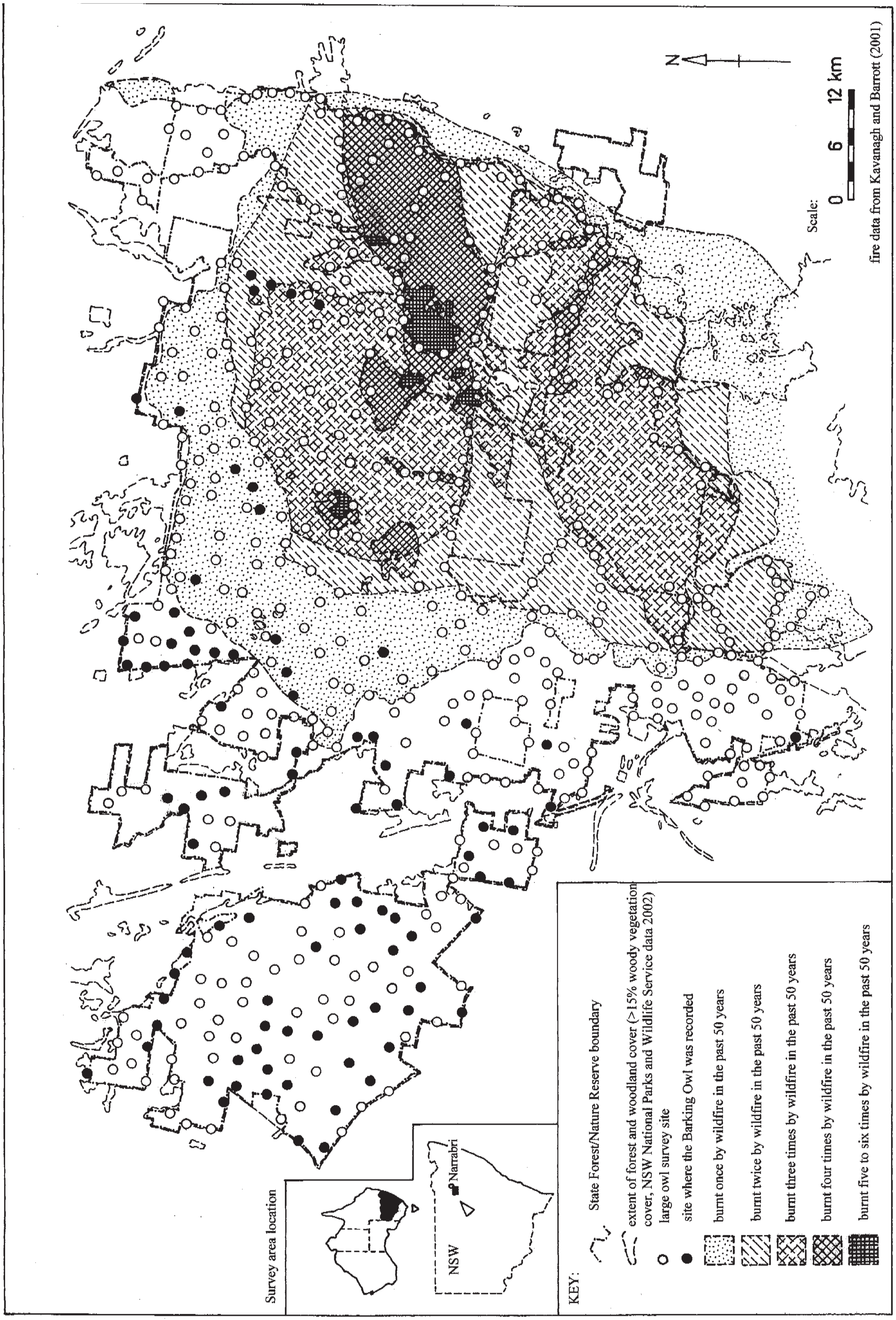

Figure 6. Sites where the Barking Owl *Ninox connivens* was recorded during the large owl survey in the Pilliga Scrub of New South Wales, showing the relationship between the pattern of sites and wildfire frequency over the past 50 years.

Data on the 12 nocturnal birds and arboreal marsupials recorded (Table 3) were then examined in a similar analysis to that undertaken for the Mountain Ash survey results. The objective was to compare species richness and abundance in Barking Owl territories with that in contiguous forest and woodland. Data for five species were considered sufficient for analysis (Table 3), with the highest number of species at a site varying from two to three (with four species at one site) and the highest number of individuals varying from three to four. These were lower totals than those obtained during the Mountain Ash survey (where four species were recorded at 10 separate sites), although sites in the latter survey were surveyed twice whereas the Pilliga sites were only surveyed once. More importantly, the substantial differences between the survey areas in forest type, rainfall pattern, fire frequency and soil nutrient status were probably responsible for the differences in bird and marsupial diversity. Further, the Yellow-bellied and Greater Gliders, considered to be the species (other than large owls) most effectively surveyed by the call playback and spotlighting method, were absent from the cypress pine-ironbark forests and woodlands.

Overlaying sites with the highest number of species and individuals on the map of estimated Barking Owl territories showed that 29 of the 37 sites (78%) where two to four species were recorded, and all of the 23 sites where three to four individuals were recorded, fell within territory boundaries (Fig. 7). All of the 22 richest sites for nocturnal bird and arboreal marsupial species (two to three species plus three to four individuals) were located within the Barking Owl territories (Fig. 7). This mirrors the result obtained for the Mountain Ash forests, where sites with the highest owl and arboreal marsupial species richness were concentrated in Sooty Owl territories. Together with the evidence of selection of territories in areas of higher plant productivity and abundant tree hollows, the conclusion can be drawn that the Barking Owl is an indicator of habitat quality for this specialist group of species, and probably for a wider range of vertebrates, in cypress pine-ironbark and similar forests and woodlands.

The leap from survey results to planning for forest and woodland fauna conservation

The call for systematically obtained data on forest fauna during the 1970s, 1980s and early 1990s lead to fauna survey becoming a central platform of the Comprehensive Regional Assessment (CRA) for the New South Wales Upper and Lower North East regions (as part of the RFA process). Most of the results of these surveys remain in databases and unpublished reports, yet the information provided the framework for reserve selection in the Upper and Lower North East CRAs (e.g. Brown *et al.* 2000). The design and application of fauna survey methods, together with the raw data obtained from the surveys, typically provided a conceptual basis for ideas about the distributions, associations and requirements of the target species. These were invaluable in generating hypotheses, although they did not necessarily prove relationships or demonstrate the existence of causal links.

The distribution pattern of large owls, their prey and associated vertebrate species in the Pilliga forests and woodlands of New South Wales formed a remarkably similar pattern to that obtained from the survey in the Victorian Central Highlands. There is a leap from survey data to conservation planning, but if we wait for the definitive studies to be conducted and published, many crucial opportunities to conserve remaining fauna populations will have slipped away. Not only are large owls worthy of conservation in their own right, but their territories form a spatial pattern that provides a natural planning template. It is this pattern that that is the focus of this chapter. Further surveys and species-specific studies are required to confirm the conclusions drawn, or to provide other ideas, but the compelling patterns from these surveys are too powerful to ignore. Further, they are presented here to provide a stimulus for better informed fauna input to conservation planning and for sustained research into the assumptions

Table 3. Number of sites where nocturnal bird and arboreal marsupial species were recorded, and numbers of individuals recorded at sites, after a survey of 510 sites in the cypress pine-ironbark forests and woodlands of the Pilliga Scrub.

Species	Number of sites where species recorded	Number of individuals recorded at sites
Bush Stone-curlew *Burhinus grallarius*	1	1
Barking Owl *Ninox connivens*	**92**	**148***
Southern Boobook *Ninox novaeseelandiae*	6	6
Barn Owl *Tyto alba*	1	1
Spotted Nightjar *Eurostopodus argus*	3	3
Australian Owlet-nightjar *Aegotheles cristatus*	**66**	**68**
Tawny Frogmouth *Podargus strigoides*	2	2
Koala *Phascolarctos cinereus*	**26**	**26**
Sugar Glider *Petaurus breviceps*	**38**	**40**
Squirrel Glider *Petaurus norfolcensis*	1	1
Common Ringtail Possum *Pseudocheirus peregrinus*	7	7
Common Brushtail Possum *Trichosurus vulpecula*	**15**	**16**

Data from Milledge 2002. Species used in analysis in **bold**
*considered to represent greater than actual total due to individuals following the surveyor between sites

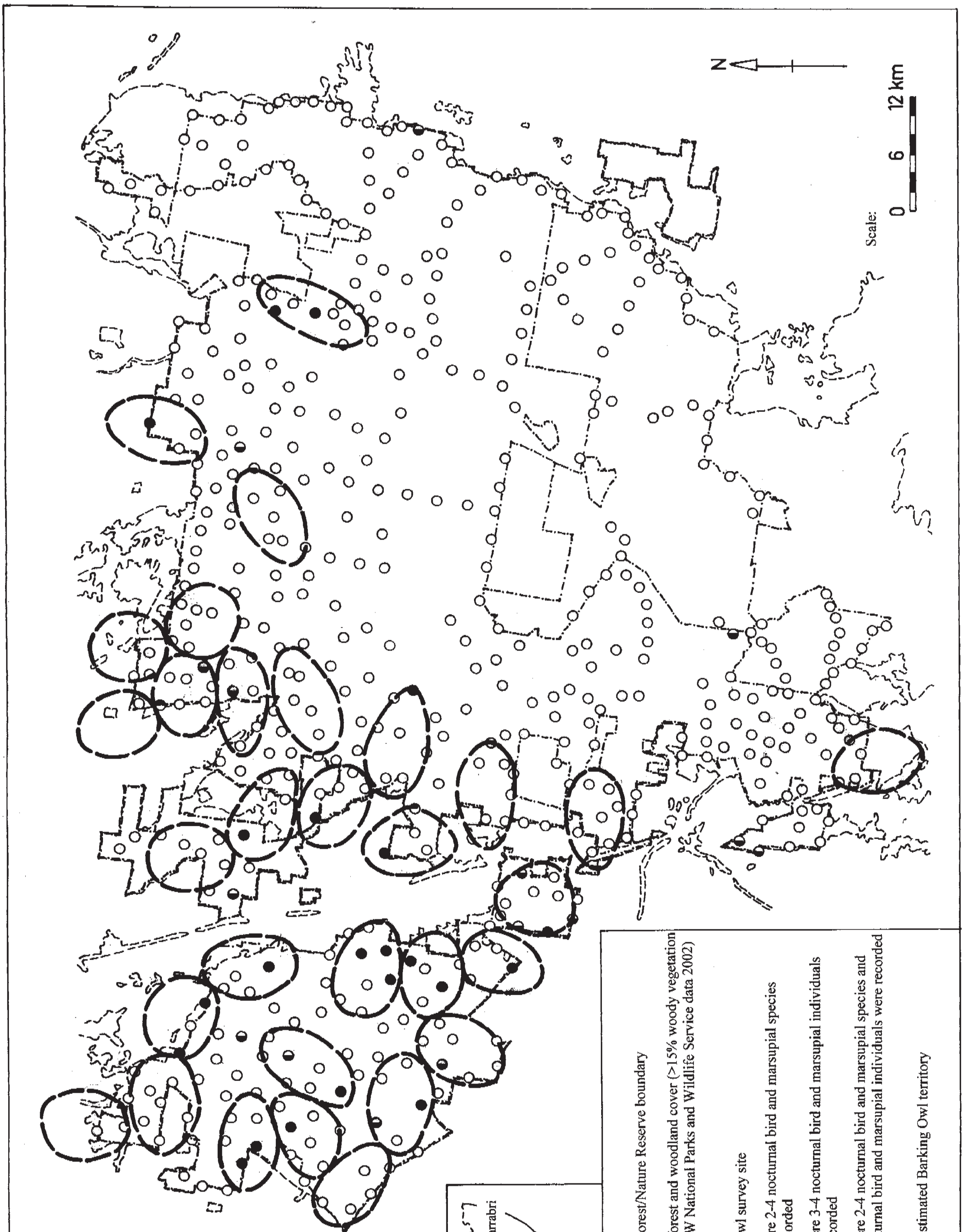

Figure 7. Sites where the highest values for nocturnal bird and arboreal marsupial species richness and abundance were recorded during the large owl survey in the Pilliga Scrub of New South Wales, showing the relationship between the sites and estimated Barking Owl *Ninox connivens* territories.

made and questions posed, particularly those relating to the links between large owls and their prey species, soil nutrients and forest disturbance history.

The conclusions drawn from these survey results should be regarded as preliminary because the surveys were designed to detect large owls, and the boundaries of the territories of large owls were only estimated. Further detailed research is required to measure the richness and abundance of a range of vertebrate species within and outside actual Sooty and Barking Owl territories, and those of other large owl species, so that the use of large owl territories can take a formal place in conservation planning, especially the computer-based planning exercises that are rich in layers of vegetation but relatively poor in spatial patterns that can be employed to define the richest faunal habitats.

Apart from identifying regionally important areas for conserving Sooty and Barking Owls (much of the Mountain Ash survey area in the Victorian Central Highlands has now been reserved in the Yarra Ranges National Park, Commonwealth of Australia 1997), the results of the large owl surveys are of wider value to conservation planning at the landscape scale. The concentration of territories in particular areas precisely defines those areas where reserves or management priority areas should be selected for large owls and their prey species, particularly arboreal marsupials. An approach of reserving or protecting clusters of large owl territories would maximise benefits for many other vertebrates as these areas appear to support the greatest local richness and abundance of a suite of other forest and woodland-dependent species. These include many species that are sensitive to such disturbances as logging and fire that reduce the structural and floristic diversity of forests and woodlands. Because of their large size (many hundred up to several thousand hectares, Schodde and Mason 1980, Higgins 1999, Schedvin *et al.* 2001, Schedvin 2003), large owl territories would include a mosaic of habitats and a series of environmental gradients. When centred on the most productive areas in the landscape, such areas should rank among the best suited to function as refugia and sources of colonists for lower quality habitat or areas recovering from disturbance. The use of territories of large owls as a basis for conservation planning will have particular value in regions where native vegetation cover has been greatly reduced, fragmented or highly modified. In such regions, where conservation options are usually limited, any large owl territories could represent the most cost-effective areas for conservation action.

Acknowledgements

The Victorian large owl survey was undertaken while I was employed by the former Victorian Department of Conservation and Environment (now Department of Sustainability and Environment) at the Arthur Rylah Institute and I am grateful for Departmental support in analysing and publishing the results of this work. I particularly wish to acknowledge the assistance of colleagues Keith Cherry, Ross Meggs, Jenny Nelson and Carol Palmer and officers of the former Victorian Board of Works in the field component of the survey. The original analysis and publication of results benefited from discussions with many additional colleagues and from comments provided by other researchers, and I especially wish to thank Ross Cunningham, Sandy Gilmore, David Lindenmayer, Richard Loyn and Harry Recher in this regard. The large owl survey in central western New South Wales was funded by the Threatened Species Unit, Western Region of the former New South Wales National Parks and Wildlife Service (now Department of Environment and Conservation). The Western Region also supported the analysis and publication of results and I am most grateful for the assistance of the Unit's Todd Soderquist in all aspects of the project. Harry Parnaby provided invaluable assistance with the field survey and the National Parks and Wildlife Service and State Forests of New South Wales provided permits necessary to undertake this work. Dan Lunney, Jack Baker, Richard Loyn, Todd Soderquist and an anonymous referee made many valuable suggestions that substantially improved early drafts of this manuscript. Finally, I would like to acknowledge my debt to the many wildlife ecologists and ornithologists who have generously contributed to my understanding of the biology of large owls over the years, particularly to Stephen Debus, Sandy Gilmore, David Hollands, Rod Kavanagh, Richard Loyn, Ed McNabb, Natasha Schedvin and Todd Soderquist.

References

Beattie, A.J. and Dangerfield, M. 2000. Expert workshop on Western Regional Assessment. Key Centre for Biodiversity, Macquarie University, Ryde, NSW.

Braithwaite, L.W. 1983. Studies on the arboreal marsupial fauna of eucalypt forests being harvested for woodpulp at Eden, NSW I. The species and distribution of animals. *Australian Wildlife Research* 10: 219-229.

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.

Brown, D.M., Hines, H.B., Ferrier, S., and MacKay, K. (eds). 2000. Establishment of a biological information base for regional planning in north-east New South Wales. NSW National Parks and Wildlife Service, Hurstville, NSW.

Cann, B., Williams, J. and Shields, J.M. 2002. Monitoring large forest owls and gliders after recent logging in production regrowth forests of the mid-north coastal region of New South Wales. Pp 255-264 in *Ecology and Conservation of Owls,* edited by I. Newton, R. Kavanagh, J. Olsen and I. Taylor. CSIRO Publishing, Collingwood, Victoria.

Commonwealth of Australia. 1997. *Central Highlands Comprehensive Regional Assessment.* Joint Commonwealth and Victorian Forest

Agreement (RFA) Steering Committee, Department of Natural Resources and Environment, Melbourne, Victoria.

Countrywide Ecological Services 1995. Draft FIS for the Dorrigo 3-year Forestry Management Area EIS. Countrywide Ecological Services, Cremorne, NSW.

Debus, S.J.S. 1994. The Sooty Owl *Tyto tenebricosa* in New South Wales. *Australian Birds* 28 (suppl.): 4-19.

Fanning, F.D. 1993. Native Fauna of the Tenterfield Management area. A report on the potential impacts of proposed timber harvesting operations on the native fauna. Gunninah Consultants, Greenwich, NSW.

Higgins, P.J. (ed.) 1999. *Handbook of Australian, New Zealand and Antarctic Birds. Vol. 4 Parrots to Dollarbird*. Oxford University Press, Melbourne, Victoria.

Kavanagh, R.P. 2002. Conservation and management of large forest owls in southeastern Australia. Pp 201-219 in *Ecology and Conservation of Owls,* edited by I. Newton, R. Kavanagh, J. Olsen and I. Taylor. CSIRO Publishing, Collingwood, Victoria.

Kavanagh, R.P. and Bamkin, K.L. 1994. Distribution of nocturnal forest birds and mammals in relation to the logging mosaic in south-eastern New South Wales, Australia. *Biological Conservation* 71: 41-53.

Kavanagh, R. and Barrott, E. 2001. Koala populations in the Pilliga forests. Pp 93-103 in *Perfumed Pineries: Environmental history of Australia's Callitris forests*, edited by J. Dargavel, D. Hart and B. Libbis. CRES, Australian National University, Canberra, ACT.

Lindsay, A.D. 1967. Forest Types of the N.S.W. Cypress Pine Zone. Forestry Commission of New South Wales Technical Paper No. 8. Forestry Commission of New South Wales, Sydney, NSW.

Loyn, R.H., Macfarlane, M.A., Chesterfield, E.A. and Harris, J.A. 1980. Forest utilisation and the forest flora and fauna in Boola Boola State Forest in south-eastern Victoria. Bulletin 2. Forests Commission Victoria, Melbourne, Victoria.

Loyn, R.H., Traill, B.J. and Triggs, B.E. 1986. Prey of Sooty Owls in East Gippsland before and after fire. *Victorian Naturalist* 103: 147-149.

Loyn, R.H., McNabb, E.G., Volodina, L. and Willig, R. 2001. Modelling landscape distributions of large forest owls as applied to managing forests in north-east Victoria, Australia. *Biological Conservation* 97: 361-376.

Loyn, R.H., McNabb, E.G., Volodina, L. and Willig, R. 2002. Modelling distributions of large owls as a conservation tool in forest management: a case study from Victoria, southeastern Australia. Pp 242-254 in *Ecology and Conservation of Owls,* edited by I. Newton, R. Kavanagh, J. Olsen and I. Taylor. CSIRO Publishing, Collingwood, Victoria.

Lundie-Jenkins, G. 1993. The diet of the Sooty Owl *Tyto tenebricosa* in the Blue Mountains, NSW. *Emu* 92: 124-127.

Lunney, D. (ed.) 1991. *Conservation of Australia's Forest Fauna*. Royal Zoological Society of NSW, Mosman, NSW.

Mackey, B.G., Lindenmayer, D.B., Gill, M.A. and McCarthy, M. 2000. The Central Highlands ecosystem study: wildfire, refugia, fire regimes and climate change. Unpubl. report to Australian Greenhouse Office. Australian National University, Canberra, ACT.

McIntyre, A D. and Henry, S.R. 2002. Large forest owl conservation in the East Gippsland Forest Management Area, Victoria. Pp 220-232 in *Ecology and Conservation of Owls,* edited by I. Newton, R. Kavanagh, J. Olsen and I. Taylor. CSIRO Publishing, Collingwood, Victoria.

Margules Groome Poyry. 1993. Draft EIS on the export by Sawmillers Exports Pty Ltd of woodchips produced from silvicultural operations in State Forests in northern NSW and from private property operations. Margules Groome Poyry Pty Ltd, Canberra, ACT.

Milledge, D.R. 1994. The distribution and ecology of the Sooty Owl *Tyto tenebricosa* in Mountain Ash *Eucalyptus regnans* forests of the Victorian Central Highlands. MRSc thesis. Department of Ecosystem Management. University of New England, Armidale, NSW.

Milledge, D.R. 2002. A survey of large owls in the cypress pine-ironbark forests and woodlands of central western NSW. Unpubl. report to Western Directorate, NSW National Parks and Wildlife Service. Landmark Ecological Services, Suffolk Park, NSW.

Milledge, D. and Soderquist, T. *in prep*. Distribution of a dense population of Barking Owls *Ninox connivens* in the Pilliga forests of New South Wales.

Milledge, D.R., Palmer, C.L. and Nelson, J.L. 1991. "Barometers of change": the distribution of large owls and gliders in Mountain Ash forests of the Victorian Central Highlands and their potential as management indicators. Pp 53-65 in *Conservation of Australia's Forest Fauna*, edited by D. Lunney. Royal Zoological Society of NSW, Mosman, NSW.

Mount King Ecological Surveys. 1992. Proposed Forestry Operations – Dorrigo Management Area. Fauna Impact Statement October 1992. Forestry Commission of NSW, Sydney, NSW.

Schedvin, N.K. 2003. Life on the edge – habitat requirements of the Barking Owl in southeastern Australia. Abstracts. Australasian Ornithological Conference 2003, Australian National University, Canberra, 10-13 December 2003.

Schedvin, N., Soderquist, T., Baker, J. and Taylor, I. 2001. One Barking Owl – 6000 ha of forest. Australian Wildlife Society poster (subsequently included in Price, C. and Baker, J. 2003. Wail and Bark. *Wingspan* 10: 10-15).

Schodde, R. and Mason, I.J. 1980. *Nocturnal Birds*. Landsdowne Editions, Melbourne, Victoria.

Simberloff, D. 1998. Flagships, umbrellas and keystones; is single species management passe in the landscape era? *Biological Conservation* 83: 247-257.

Thackway, R. and Cresswell, I. 1995. *An Interim Biogeographic Regionalisation for Australia; A framework for setting priorities in the national reserve system cooperative programme*. The Australian Nature Conservation Agency, Canberra, ACT.

York, A. and Shields, J.M. 1992. Fauna Survey, Wingham Management Area. Part 2: Birds. Forest Resources Series No. 20. Forestry Commission of NSW, Sydney, NSW.

APPENDIX I

The author on the NSW north-western slopes showing some of the equipment needed for winter surveys of large owls in extensive tracts of forest and woodland. This includes a 4wd vehicle with an efficient heater, portable CD player, CD of standard owl calls, transistorised horn speaker for broadcasting calls, proforma, 50 or 100w spotlight and binoculars. Not shown are other items needed to ward off cold and fatigue such as warm clothing including gloves, a flask of hot coffee and various small pieces of electronic equipment such as a digital thermometer, GPS and head-torch.

Photo: Hank Bower

Young (50 year old) Mountain Ash *Eucalyptus regnans* forest regenerated following wildfire in the former South Maroondah Catchment (now Yarra Ranges National Park) in the Victorian Central Highlands. The uniform canopy of young trees demonstrates how most trees are killed in Mountain Ash forest burnt by intense fires. Sooty Owls *Tyto tenebricosa* were only recorded sparsely in this age class in stands containing scattered old trees, in riparian areas or in stands with high densities of stags (standing dead trees) as shown on the upper slopes in the photograph.

Photo: David Milledge

Old-growth Mountain Ash *Eucalyptus regnans* forest not burnt by wildfire for more than 250 years in the former O'Shannassy Catchment (now Yarra Ranges National Park) in the Victorian Central Highlands. Old Mountain Ash trees provide abundant hollows, clumps of decorticated bark and other resources used by a range of arboreal marsupials that are preyed on by the Sooty Owl *Tyto tenebricosa.* Survey results indicated that Sooty Owls were strongly associated with large patches of old-growth forest and modelling of data showed that the probability of encountering a Sooty Owl at a site increased with an increase in the amount of old-growth about the site.

Photo: David Milledge

APPENDIX I

On the eastern edge of Pilliga East State Forest looking north east from Willala Mountain towards the Nandewar Range. No records of Barking Owls *Ninox connivens* were obtained from this broad area of cypress pine and ironbark eucalypt forest and woodland on low sandstone ridges, where plant productivity is relatively low and fires frequent. This was despite extensive edge habitat between the forest and woodland and agricultural land, habitat favoured by Barking Owls elsewhere throughout their range in south-eastern Australia.

Photo: David Milledge

Looking west from Panton's Lookout in Pilliga East State Forest towards Pilliga West State Forest where Barking Owl *Ninox connivens* survey records were concentrated. No records of Barking Owls were obtained from the area in the foreground or middle distance of the photograph. The unbroken expanse of the remaining large remnant of the Pilliga Scrub is clearly shown in the photograph although the east-west transition from lower to higher soil nutrient status, increased areas of box eucalypt forest and woodland and decreased fire frequency are less obvious.

Photo: David Milledge

Box eucalypt-dominated woodland in Merriwindi State Forest in the western Pilliga showing the relatively tall open structure, grassy ground cover and large old trees providing a high density of hollows. Five site records of Barking Owls *Ninox connivens* were obtained during the survey in this small State Forest and it is known to contain at least one breeding pair. Box eucalypt forests and woodlands appear to provide optimum habitat for the Barking Owl throughout the Pilliga Scrub as survey records were strongly associated with this vegetation type.

Photo: David Milledge