Eucalypt forest birds: the role of nesting and foraging resources in conservation and management

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ABSTRACT

Forest wildlife management in Australian eucalypt forests emphasizes the retention of tree hollows for fauna requiring hollows for nesting or denning. This overlooks the requirements of birds in eucalypt forests for a variety of resources for nesting and foraging other than tree hollows. Some birds nest only on vertical or horizontal dead branches, while others require shrubs or dense ground vegetation. There are significant differences between plant species in the foraging resources available to birds. For example, bark type and the associated arthropod fauna differ between tree species, as do the arthropods found in the canopy. This complex array of resources is not necessarily provided by management plans which emphasize the conservation of trees with hollows. Not all eucalypts readily form hollows and those that do differ in bark type, epiphytes, canopy arthropods and nectar production from those that do not. Comparable differences occur among types and species of shrubs and ground vegetation. Additionally, logs, coarse woody debris and litter, and their associated biota, are important components of forest ecosystems and provide essential resources for forest birds. If the full complement of forest birds is to be conserved, each of these resources must be managed across the entire forest estate and not just where logging is taking place. It is equally important to manage the impacts of fuel reduction burns. The availability of foliage, seeds, fruits, nectar, lerp, arthropods and vertebrates used by forest birds as food changes seasonally and from year to year within and between forest areas and the pattern of resource abundance, which is partly a consequence of fire history, must be part of all plans of management. If the goal is the conservation of forest birds in perpetuity, then site and industry specific management protocols are inadequate. Instead, management must be regional and involve all land tenures with close co-ordination of conservation programs between regions at a continental scale. Rehabilitation, conservation and tree planting programs in urban and agricultural areas must be integrated with the management of birds on state forests, conservation reserves and private lands.

Key words: birds, Eucalypt Forest, Forest Wildlife Management, Conservation, Nesting Resources, Foraging Resources, Australia

Introduction

The management of wildlife in Australia has always been different from America. Until the passage of endangered species legislation in the United States, wildlife management in America was synonymous with the management of wildlife (fauna) for sport (game), fur and pest control. It was a science of exploitation with the principles of management summarized in the provision of 'food, cover and water', the control of predators, stocking of game fish and birds, and the regulation of the take by setting open and closed seasons, and bag and size limits (Leopold 1933). To provide food, cover and water, habitats were manipulated, food crops planted and water levels regulated. These were simple but effective procedures which were supported by the detailed knowledge of the life histories and requirements of the relatively small number of species that were socially and economically important. In the process of 'game management', many non-game species also benefitted.

Apart from fish, Australia has few native species which qualify as game and for most of the 20th Century these were protected from hunting (Frith 1973). Hunting in Australia is presently restricted to waterfowl (ducks) and quail, native pests (kangaroos, parrots) and feral animals (deer, goats, rabbits, pigs), although indigenous people are able to take a wider range of native fauna for food. With the growing and mis-guided opposition to hunting and the possession of firearms even the limited hunting presently allowed non-indigenous Australians may soon cease. The absence of game animals and a hunting tradition in Australia is unfortunate as it has deprived wildlife conservation of the rich source of funds and political support which supported nature conservation in America long before much thought was given to non-game species.

Until the mid-1970s, the management of wildlife in Australia was synonymous with the prohibition of taking native wildlife, the establishment of conservation reserves, and the control of agricultural pests (Frith 1973). Habitat manipulation, the provision of 'food, cover and water' and the control of predators on native wildlife are not part of the Australian tradition. It is only since the 1990s, with the advent of 'threatened species' management programs, that these tools have become a significant part of wildlife conservation and management in Australia. Just as there was no tradition of 'game management' in Australia, there was little support, political or financial, for nature conservation outside the growing of a reserve system established primarily for recreation and almost entirely restricted to public lands with no other perceived value (Recher 2002a,b).

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Wildlife management in 21st Century America is now different. Although the traditions of game management and pest control continue, there is an expectation that non-game, non-pest species will also be conserved and managed (Stockwell 1990). It would not be extreme to suggest that the emphasis in America is now on the management of threatened species and that these have achieved the social, political and economic importance of game species. To some extent, changes in wildlife management in Australia during the latter half of the 20th Century paralleled those in the United States, with greater public interest in wildlife in general and threatened species in particular.

In the 1960s, the advent of intensive forestry, the adoption of broad area hazard reduction burning, and an expansion of land clearing for agriculture and plantation establishment coincided with the growing awareness of the need for environmental conservation by the Australian public. Demands from the public that all forms of wildlife be protected against exploitation and inadvertent destruction added new dimensions to the management of Australian wildlife. Emphasis remained on preservation through reserves and prohibitions on the taking of wildlife, but by the late 1970s management protocols for wildlife conservation were being widely adopted as an integral part of forestry practices in eucalypt forests used for wood production (Christensen 1974; Recher *et al.* 1980; Davey 1989; Dobbyns and Ryan 1983; Loyn 1985; Newsome 1985; Shaw 1983; Recher 1996).

Commencing in the 1990s, the decade of Landcare, extensive tree plantings were undertaken in Australia's agricultural areas. The primary reason for planting trees was to rehabilitate land and water degraded by excessive clearing, poor farming practices and over grazing beginning in the latter part of the 19th Century and accelerating from the 1940s onward. Planting trees is necessary to achieve agricultural sustainability, but an added benefit of Landcare plantings was seen as the provision of habitat for wildlife and the conservation of biodiversity. More recently, Landcare plantings have been extended to urban areas with the view of restoring amenity values, encouraging wildlife, and improving water quality in urban streams and rivers. In both urban and rural environments, land carers have been encouraged to establish corridors linking remnants of native vegetation (e.g., Hobbs and Hopkins 1991; Recher 1993; Majer and Recher 1994; Bennett 1999). Remnants, in turn, are fenced to exclude grazing and allow natural restoration to occur.

In the 1980s, the concept of biodiversity conservation gained ascendancy. By the end of the 20th Century, land managers were seen as having an obligation to protect native fauna and the advent of Landcare gave rise to an expectation that not only should native wildlife be protected on private land, but that it could be restored to agricultural lands as part of the move to achieve agricultural sustainability. This does not mean that all wildlife is protected against the impacts of development or that all land is managed sympathetically according to the principles of biodiversity conservation. To the contrary, there is abundant evidence that the majority of wildlife in Australia's eucalypt forests and woodlands are under greater threat than ever and that Australia's efforts to conserve continental biodiversity are inappropriate and inadequate (Recher and Lim 1990; Recher 1999; 2002a,b).

This chapter is a revision of one I wrote in 1990 (Recher 1991) and published in *Conservation of Australia's Forest Fauna* (Lunney 1991). That chapter emphasized the resource requirements of birds in eucalypt forests and was primarily concerned with mitigating the impacts of logging and other management activities in production forests. I have retained almost all of the original material bar some which in the course of time and further research seems less important. In addition, the scope of the chapter is expanded to include a wider range of land tenures. This has been done for the simple reason that the conservation of eucalypt forest birds requires the integration of management across all public and private lands in Australia, but the emphasis remains on the resources required by birds for foraging and nesting. Although the emphasis in this chapter is on forests, forest birds and forest management, all that I write applies equally to eucalypt woodlands and agricultural landscapes, including the pastoral zone.

Conservation and resources for forest birds

In my original chapter, I concluded that the management of wildlife in eucalypt forests affected by logging had emphasized the retention of mature and overmature trees for animals dependent on tree hollows for nesting and denning. This was achieved in a variety of ways, including the retention of habitat trees[1] within logging coupes and excluding patches and strips of mature forest from logging to provide both habitat and movement corridors for fauna. Recher (1996) provides an account of wildlife management practices in Australian eucalypt forests in the early 1990s, while Lindenmayer and Franklin (2002) provide a more recent review of forest wildlife management on a global scale.

Logging affects forest structure in a variety of ways, but a conspicuous outcome is the reduction in the proportion of older, larger trees, and an increase in the proportion of younger, smaller trees. These changes occur progressively throughout the logging cycle with the rate of change dependent upon the intensity of logging. An inevitable consequence is the reduction of the number and distribution of hollows available for forest animals. The emphasis in forest wildlife management on hollow-dependent fauna and on fauna requiring mature trees was therefore understandable, but it did not provide the full range of resources required by forest birds. The objectives of the original chapter were therefore to identify these 'other resources' and describe the ways in which birds were dependent on them.

[1] Habitat trees are virtually synonymous with 'trees with hollows'. Thus, they tend to be large and old, but may be small. Most large habitat trees have multiple hollows, an abundance of dead wood and large amounts of loose and decorticating bark. They therefore provide a multiplicity of nesting and foraging resources for birds and are an important component of eucalypt forest and woodland ecosystems.

Resources that are important for birds and which were rarely, if ever, considered in plans of forest management included nest sites other than hollows, nest materials, such as spider web, foraging substrates and types of prey or food. I cannot find evidence that management consideration of the resources required by forest birds changed significantly during the 1990s; although wildlife managers in production forests employ a variety of techniques to mitigate the impacts of logging (Recher 1996; Abbott and Whitford 2002; Lindenmayer and Franklin 2002), the emphasis remains on habitat trees and hollow-dependent fauna. Moreover, I can now add to the array of resources which need to be managed for the conservation of forest birds. In particular, the need to accommodate temporal and spatial variation in resource abundances adds a dimension to the conservation of forest birds that is not yet applied in the design of reserve systems nor in the conservation and management of forest wildlife.

The resources I discuss are mentioned in the literature; I am not the first to recognize them. However, unless an observation is attributed to another source, the information presented here is based upon or verified by my own observations and those of my co-researchers and students, not all of which have been published. A particular resource may be individually important to certain species of birds, but more importantly it represents a suite of resources on which the integrity of the avifauna depends.

Ecological relationships within forest ecosystems are complex and no single prescription or management formula satisfies all wildlife conservation objectives. Although not everyone will agree with me, it is my opinion based on 35 years contact with Australian conservation and land management authorities, that the holistic approach to wildlife management represented in this chapter is lacking in Australia's conservation programmes. The narrow approach taken to conservation of biodiversity in Australia, and in particular to the management of forest fauna, was the original stimulus for putting my views in print. It is for the same reason that I agreed to revise this chapter.

Nest sites

All birds have specific nesting requirements with no two species selecting the same nest sites. Species differ in the height of nests, proximity to the center of the tree or shrub in which it is located and the species of plant or type of vegetation (or debris) within which the nest is built (Recher unpubl. data). The choice of nest sites may differ between habitats accordingly to the availability and location of suitable substrates and plant species. Although most eucalypt forest birds nest in spring, species' breeding seasons are staggered, rather than synchronous, further allocating the use of nesting resources among species (Marchant 1981, 1992; Recher *et al.* 1983; Recher and Holmes 1985; McLean *et al.* ms).

Hollow-nesters

About a third of eucalypt forest birds place their nest in a tree hollow or cavity. The choice of nest hollows/cavities is highly specific and differs even among closely related species. For example, within the Climacteridae, the White-throated Treecreeper *Cormobates leucophaea* nests mainly in tree trunks (knotholes), while the co-occurring Red-browed Treecreeper *Climacteris erythrops* selects an upward sloping, hollow spout (Noske 1985; Stokes *et al.* ms). As a result, White-throated Treecreepers have a greater number of potential nest sites than Red-browed Treecreepers and are less affected by logging and other forms of forest management which reduce the abundance of large, old trees.

Hollow-nesting birds require different sized hollows, according to the size of the bird, and may prefer to nest in particular species of trees or at different heights above the ground, although data are lacking on these points. Selection of hollows may also be influenced by aspect and shelter from the weather, orientation of the hollow (vertical or horizontal) and its opening (upwards or downwards facing), and ease of entry. Hole-nesters prefer hollows where the perimeter of the entry is healed or smooth, as opposed to being rough or with protruding wood (Recher unpubl. data). Birds may rework the entry to remove obstructions and sharp edges. They also abandon or do not use hollows with foreign substances, including nests of other birds. For example, Carnaby's Cockatoo *Calyptorhynchus latirostris* will not nest in hollows containing duck feathers, despite using the hollow for nesting prior to its use by ducks (P. Mawson pers comm.). A consequence of the criteria applied by birds in selecting a nest hollow is that the number of hollows in a forest suitable for hollow-nesting species is likely to be significantly fewer than the total number of hollows available (see Gibbons 1999; Abbott and Whitford 2002 for alternative views).

Not all hole-nesters require a tree or branch hollow. Many species place their nests in open cavities (e.g., Grey Shrike-thrush *Colluricincla harmonica*, Scarlet Robin *Petroica multicolor*, White-fronted Honeyeater *Phylidonyris albifrons*, Dusky Woodswallow *Artamus cyanopterus*), behind loose bark (e.g., Grey Shrike-thrush , Dusky Woodswallow, Buff-rumped *Acanthiza reguloides* and Western *A. inornata* Thornbills) or in cracks (splits) (e.g., Chestnut-rumped Thornbill *A. uropygialis*, Southern Whiteface *Aphelocephala leucopsis*). Nests in concealed positions, such as hollows and cavities, are usually more successful than those placed in the open (Ricklefs 1969; Martin and Roper 1988; McLean *et al.* ms). Hollows and cavities are also important as nocturnal roosting sites offering important thermoregulatory advantages overnight and during inclement weather (Ricklefs 1969). Some birds build dome shaped nests which are used for roosting with or without having been previously used for nesting (e.g., babblers *Pomatostomus* spp., Red-browed Finch *Neochmia temporalis*, Zebra Finch *Taeniopygia guttata*).

Unlike other continents where woodpeckers (Picidae) excavate primary hollows in trees (Thomas 1979; Hunter 1990), Australian birds rely on hollows that develop through decay and insect attack. However, Laughing Kookaburra *Dacelo novaeguineae* and Sacred Kingfisher *Todiramphus sanctus* excavate hollows in rotten wood and arboreal termiteria. Pardalotes (Pardalotidae) will also excavate burrows in rotten wood and soft soil. This enables them to nest where suitable hollows may be otherwise unavailable. Parrots (Psittacidae) frequently enlarge, modify or open the entry to a hollow, but cannot, or will not, remove foreign substances, such as duck feathers. Thus, competition for large hollows becomes intense in remnants of native vegetation surrounded by agricultural land. Agriculture provides resources favouring a few species of parrots (e.g., Galah *Eolophus roseicapillus*, Port Lincoln Parrot *Barnardius zonarius*) and ducks (e.g., Mountain Duck *Tadorna tadornoides*, Wood Duck *Chenonetta jubata*), which by virtue of numbers, if for no other reason, pre-empt the majority of nest hollows to the detriment of other large, hollow-nesting birds (e.g., Carnaby's Cockatoo). Increased competition for nest hollows may also occur in wood production forests as the number of habitat trees is reduced.

Dead wood nesters

A number of open-nesting species require sites, which, like hollows, are associated with mature or overmature trees. These include birds which place their nests only or primarily on dead branches. Sittellas *Daphoenositta* spp., for example, are obligate dead wood nesters requiring a small vertical dead branch on which to build their nest. Leaden *Myiagra rubecula* and Satin *M. cyanoleuca* Flycatchers, Jacky Winter *Microeca fascinans*, Black-faced Cuckoo-shrike *Coracina novaehollandiae*, Cicadabird *C. tenuirostris*, and White-winged Triller *Lalage sueurii* commonly select a horizontal dead branch on which to build. All select a branch, with an appropriate fork for placing the nest, which is clear of surrounding vegetation, but not necessarily in an exposed position. Other species, such as Willie Wagtail *Rhipidura leucophrys,* most often nest on a horizontal branch, but do not select for dead branches. The preference of some species for dead branches may be for the camouflaging effect of placing a nest built from spider web, dry grass, and bark and wood fibers against a grey, weathered substrate. Whatever the reason they are selected, suitable sized and positioned dead branches are as necessary for the integrity of the forest avifauna as nest hollows.

Above ground foliage nesters

The majority of eucalypt forest birds place their nests among the foliage and small branches of trees and shrubs. Some species nest over a wide range of heights from less than a metre or two above ground to over 25 m in the canopy (e.g., Rufous Whistler *Pachycephala rufiventris*, Striated Thornbill *Acanthiza lineata*, Weebill *Smicrornis brevirostris*), but generally birds nest within a specific layer of vegetation (i.e., shrub, subcanopy or canopy) and each species has a narrow nesting height range (Martin and Roper 1988; Recher unpubl. data).

Choice of a nest site may be related to a variety of factors including foliage density, plant species, tree height, aspect, presence of conspecifics (i.e., territorial behaviour, colonial nesting), presence of other nesting species (e.g., Leaden Flycatcher and Noisy Friarbird *Philemon corniculatus* often nest in close proximity; Yellow-rumped Thornbill *A. chrysorrhoa* place nests in the nest structure of raptors) or some other feature, such as water (e.g., Noisy Friarbirds choose to nest over water, if it is available). Additionally, birds of different species appear to aggregate nests within a small area (Recher unpubl. data), perhaps for mutual protection against predators.

The absence of suitable vegetation and substrates affects the numbers and kinds of above ground foliage nesters as much as the absence of dead wood or hollows affects the numbers and kinds of dead wood and hollow-nesters. Open habitats with sparse foliage and few or small shrubs have fewer and different kinds of breeding birds from forests with a complex vegetation structure. Partly these differences are related to foraging resources, but the availability of suitable nest sites is also a factor. Factors excluding foliage nesting birds from structurally simple habitats include interference competition from other species and increased nest predation and parasitism. Birds which nest in dense ground vegetation and/or shrubs (e.g., Brown Thornbill *A. pusilla*, Superb Blue Wren *Malurus cyaneus*) are among the first species affected by changed fire regimes and grazing by domestic stock-processes which remove their preferred nest sites.

Ground nesters

Nests of ground-nesters are placed on the ground, either in the open (e.g., White-throated Nightjar *Eurostopodus mystacalis*), under low vegetation (e.g., Painted Button Quail *Turnix varia*; Spotted Quail-thrush *Cinclosoma punctatum*), or set into dense vegetation (e.g., Speckled Warbler *Chthonicola sagittata*, White-browed *Sericornis frontalis* and Spotted *S. maculatus* Scrubwrens). Spotted Pardalote *Pardalotus punctatus* and Rainbow Bee-eater *Merops ornatus* construct nesting burrows into the ground and must have a suitable moist and friable soil. Pardalotes require a vertical face, perhaps only a few centimeters in height, on which to commence their nest burrow. All ground-nesters are affected by changes in grazing and fire regimes and by weed invasion, which alter the mosaic of bare ground, litter and ground plants, as well as affecting soil structure.

Nest Materials

Although birds building nests can be flexible in their choice of nest materials and will incorporate an array of material of human origin into nests, including wool, plastic and wire, most nests are built with natural materials. Larger birds tend to use bulky materials, such as twigs, bark strips, roots and small branches, 'woven' together to form a study platform held together by the bulk of material alone. Smaller birds use finer materials, such as bark fiber, dry grass, and fine roots, woven intricately together. In many nests, spider web is used for binding and fantails, robins, cuckoo-shrikes, sittellas, thornbills, warblers and honeyeaters, among others, use considerable amounts of spider web in building their nests. Spider web is also used as an adhesive to fix nests to the substrate, or, as with cuckoo-shrikes, to create a platform on which the nest is constructed. Lichens, bark, spider egg cases and other materials are then used to conceal the nest both by breaking its outline and by causing it to blend with the background substrate on which it is built. Feathers, wool, hair, fine bark and other insulating materials are used to line the nest.

Considerable time and effort goes into nest construction and birds, usually the female, travel long distances to find and collect the necessary materials. Of all the materials used by forest birds in nest construction, spider web may be a limiting resource. Cuckoo-shrikes even gather the silken filaments of ballooning spiders drifting through the air. Spider web appears to be most abundant on dead wood, among debris and in association with loose and decorticating bark and is commonly harvested from cavities and hollows in trees and logs. Lichen is also abundant on dead wood and mature trees. Although abundant in mature forest, spider web and lichen may be limited in plantations and less abundant in intensively used forests where forest structure is simplified and the number of large, old trees and the amount of dead wood is reduced.

Foraging Substrates

Foraging substrates which require special consideration for the management of forest birds include loose and decorticating bark, dead wood, epiphytes (e.g., lichen, mistletoe), litter and debris. Birds throughout Australia obtain the majority of their arthropod prey from foliage or from the ground, but between 10 and 25 % of prey taken by insectivorous birds in temperate eucalypt forests is obtained from the bark of tree trunks and branches (see also Keast 1985). Although sittellas, shrike-tits and treecreepers are the only birds to consistently take more than 90 % of their prey from bark (e.g., Recher *et al.* 1985; Recher and Holmes 1985; Ford *et al.* 1986; Recher and Davis 1998, 2002), other species, including honeyeaters (Meliphagidae) exploit bark seasonally and may rely on bark arthropods as a source of energy-rich carbohydrates when nectar and lerp are unavailable (see Wilson and Recher 2001). Depending on resource availability, between one and six species in a variety of eucalypt forests are bark specialists which take more than 40 % of their prey from bark.

Many bark foragers search for food under loose or flaking bark, and decorticating bark is an important foraging substrate for shrike-tits (in southeastern Australia), Red-browed Treecreepers and some honeyeaters (e.g., White-eared *Lichenostomus leucotis*, Yellow-plumed *L. ornatus* and Strong-billed *Melithreptus validirostris* Honeyeaters) (Keast 1976; Noske 1985; Recher *et al.* 1985; Ford *et al.* 1986; Wilson and Recher 2001). Loose and decorticating bark may be less abundant and sustain smaller prey populations on smaller and younger trees than larger and older trees. Large old trees have greater amounts of bark, loose bark and debris lodged in the tree, and have more dead wood than small trees.

Large trees may have larger and more diverse populations of arthropods, but data to confirm this are not available from Australia. Lundquist and Manuwal (1990) demonstrated that large trees in North American coniferous forests had greater numbers of arthropods and were selected over smaller trees as foraging substrates by bark-foraging birds. In Western Australia, Yellow-plumed Honeyeaters and Rufous Treecreepers *Climacteris rufa* foraged selectively in large eucalypts, probably because of the greater diversity of foraging substrates and more abundant food resources which are available (Luck *et al.* 2001; Wilson and Recher 2001). Norwood *et al.* (unpubl. data) found the proportion of bark-foraging by eucalypt forest birds in Western Australia increased along a wet-dry gradient as the abundance and biomass of bark arthropods increased. Tree species with the highest abundances and biomass of bark arthropods were selected over species with fewer bark arthropods irrespective of bark structure.

Dead wood, with or without bark, is a major foraging substrate of sittellas. Noske (1985) reported Orange-winged Sittella *Daphoenositta chrysoptera* took 30 % of their prey from dead wood, and I have similar data for other sittellas. Oreinstein (1977) and Noske (1985) recorded White-throated Treecreepers taking 25 - 30% of their prey from dead wood. Logs and woody debris are important foraging substrates for Brown *C. picumnus* and Rufous Treecreepers, and serve as foraging perches for robins that pounce on ground-dwelling prey (Luck *et al.* 2001; Recher *et al.* 2002; Walters *et al.* 1999).

Litter, including coarse woody debris and logs, is an essential part of the structural and biological complexity of forests (Elton 1966; Thomas 1979; Maser *et al.* 1988; Hunter 1990; Maser and Sedell 1994; Andrew *et al.* 2000; Mac Nally *et al.* 2001; Lindenmayer *et al.* 2002). Woody debris and logs are important in forest nutrient cycles, including nutrient release and fixation and act as seed beds for forest plants (Franklin *et al.* 1981; Ashton 1986; Hunter 1990; McKenny and Kirkpatrick 1999; Lindenmayer *et al.* 2002). Litter, coarse woody debris and logs provide foraging sites and nesting material for birds, but are also habitat for invertebrates and small vertebrates fed upon by birds. It is likely that many invertebrates taken by canopy and bark-foraging birds spend part of their lives on the forest floor.

Besides bark and dead wood, there are many other substrates in forests which offer specialized foraging substrates for birds. For example, epiphytes, such as lichen and mistletoe, are common foraging substrates for a variety of forest birds. Sittellas frequently flake and probe among lichens on branches and tree trunks, while thornbills forage in mistletoe for insects. Mistletoe is also an important source of nectar for honeyeaters and of fruit for honeyeaters and Mistletoebird *Dicaeum hirundinaceum*.

Ground-foraging birds also require specific substrates or a mosaic of substrates on which to forage. Recher *et al.* (2002) found that species of ground-pouncing Australian robins (Petroicidae) differed in their choice of habitats and that these differences could be described in part by the structure of the available ground substrates. Despite habitat differences, the five species studied all selected foraging substrates that were a mosaic of bare ground, litter and ground vegetation. Disturbances, such as grazing, weed invasion or fire, which changed the mosaic, affected the species present within a habitat and their abundances. Recher *et al.* (2002) attributed the continental decline of these robins to landscape scale changes in the pattern of ground substrates.

Food

Despite what most people might think, not all forest birds are insectivorous. In addition to nectar-feeders and seed-eaters, many birds in eucalypt forests eat foliage in the form of soft, young leaves, as galls (with the insect larva inside), developing seed pods of *Acacia* and other legumes, and fruits, as well as feeding on a variety of energy rich carbohydrates. Manna, honeydew, sap and lerp are energy-rich carbohydrates used by eucalypt forest birds as sources of energy (Paton 1980). These are not simply substitutes for nectar, instead, they are the principal energy source for a wide range of species, including many often thought of as insectivorous (Recher and Davis unpubl. data).

Lerp, the sugary exudate of psyllid insects, is particularly significant as an energy source in eucalypt habitats. Pardalotes, Weebill, Striated Thornbill, and most foliage-gleaning honeyeaters are lerp-dependent species. In the absence of lerp, these birds are absent or present only in small numbers. At times of peak abundance, almost all birds feed on lerp and I have records of magpies and cockatoos feeding on lerp during a psyllid outbreak in the canopy of Salmon Gums *E. salmonophloia* > 20 m above ground. I also have records of Striated Pardalote *P. striatus*, a canopy foliage-gleaner, feeding in flocks on the ground on lerp that had been dislodged by heavy rain. Pardalotes and honeyeaters move long distances between psyllid outbreaks, but other lerp-dependent species are sedentary. All lerp-dependent species take nectar and other carbohydrates according to availability.

The abundance of psyllids differs between tree species and are most abundant on eucalypts with high foliar nutrient levels (Recher *et al.* 1991, 1996a). Lerp-dependent species forage preferentially on these trees (Woinarski 1985; Recher *et al.* 1991) and differences in bird species composition between eucalypt associations is partially attributable to differences in the abundance of eucalypts able to sustain high population densities of psyllids.

Lerp and other energy-rich carbohydrates are also important sources of energy for invertebrates and birds may seek out insects that have been feeding on nectar or other carbohydrates. Treecreepers, for example, may select ants that are engorged with, or carrying, nectar and other carbohydrates. In the original version of this chapter, I suggested that treecreepers appear to 'trapline'. That is they move sequentially between trees feeding preferentially on carbohydrate enriched ants or other insects, returning after an interval when the numbers of enriched insects have been renewed. This hypothesis has yet to be tested, but still merits consideration.

Discussion

The use of forests by people leads to internal fragmentation and changes affecting the entire range of nesting and foraging resources required by birds. The increased spatial heterogeneity arising from internal fragmentation creates units or patches of vegetation that may be too small to sustain territorial pairs or breeding groups of some species. Walters *et al.* (1999) suggested that Brown Treecreepers are not able to survive in small remnants due to the small total food resource. Intensive uses, such as hazard reduction burning, logging and roading, have the most immediate impacts, but grazing by domestic stock and recreational activities affect the structure and floristic composition of the vegetation (Tremont and McIntyre 1994; Green and Higginbottom 2000; Ludwig *et al.* 2000; Hamilton 2001); vegetation is degraded, soil is compacted and erosion accelerated.

Use by people facilitates colonization by open-country and edge species which in turn increases predation pressures and changes the competitive environment of forest birds. These changes are greatest with intensive use, but are not necessarily insignificant with even low level recreation. Despite this, little consideration is given to managing human impacts other than land clearing and production forestry on forest birds. Too often, as in the case of hazard reduction burning, adverse effects on wildlife are disregarded in the interests of protecting human property and life, or in achieving some economic or political gain.

Managing logging

Logging, regardless of its intensity, simplifies the forest environment by reducing the age and size class diversity of trees (Recher 1985). Initially, logging may increase the abundance of logs and large woody debris on the forest floor. However, with successive cuts the abundance of standing dead wood and the size of logs and amount of large woody debris is reduced (Hunter 1990). These processes are accelerated as logging becomes more intense and when fire is used to remove fallen wood after logging. Harris (1984), Hunter (1990), and Recher *et al.* (1980; 1987) suggested ways to modify harvesting (logging) plans so as to retain patches of mature and old growth forest large enough to accommodate the spatial and resource requirements of animals having large territories or home ranges. Their proposals were based on standard logging procedures and only required that areas of importance to wildlife be logged on a long rotation and that, before they were logged, adjacent logged patches have reached maturity. Abbott and Whitford (2002) made similar comments in discussing the management of forests in Western Australia, while Lindenmayer and Franklin (2002) present an updated range of forest wildlife management options for commercial forests.

The management of eucalypt ecosystems is more complex than setting aside reserves and patches of old growth (see Lindenmayer and Franklin 2002 for a recent review). A plant acquires new and changing values for wildlife throughout its life from seed to maturity, death and decay. No part of the cycle can be ignored or considered unimportant in the management of fauna.

For birds, this means the conservation and management of:

1. mature and overmature trees with dead wood to provide nesting and foraging sites;
2. logs and woody debris as foraging and nest sites, and as perches;
3. tree species with decorticating bark and those with high foliar nutrient levels and associated invertebrates;

4. a complex vegetative structure with ground, shrub, sub-canopy and canopy layers as foraging and nesting resources; and,
5. floristic diversity.

The retention of habitat trees for hole-nesters and providing patches and corridors of old growth may only partially meet these requirements.

Current logging prescriptions retain too few habitat trees and many of those retained fail to survive the effects of post-logging burns and increased exposure to wind (Gibbons 1999; Recher pers obs.). Moreover, while some prescriptions require retention of 'future habitat trees' (Recher 1996), they fail to make explicit provision for the retention of young trees, across a range of size classes, which would ultimately replace existing habitat trees as these die and fall (however, see Abbott and Whitford 2002). The trees which are to be retained for the future use of wildlife must be among the most vigorous and with the greatest prospect of surviving to form hollows. However, before this can be done, it is necessary to quantify the demographics of the relevant tree species, and to do this on each site being logged. I am not aware of any such data for any population of eucalypts in Australia. A succession of trees allowed to mature to senescence is also necessary to ensure a succession of logs of different age and size classes, as well as ensuring large amounts of standing dead wood for birds as nesting and foraging substrates.

In most instances, logging prescriptions do not specify the spacing or pattern of dispersion of trees retained for use by wildlife. The number of individuals or pairs that survive in a logged area is not necessarily in proportion to the number of nest sites or the amount of foraging substrate available after logging. Numbers are also determined by the size of territory or home range each individual requires. If retained trees and vegetation are clustered in one part of the logged area, all those resources may be within a single territory and unavailable to other individuals (Hunter 1990; Lindenmayer *et al.* 1990a,b; Gibbons 1999). An integrated programme of habitat tree management should have the following objectives:

1. a broad definition of a habitat tree to include trees which might lack hollows, but which provide essential foraging and nesting substrates, such as dead wood, arboreal debris, loose bark, epiphytes and spider web, and are of sufficient size to provide the full range of resources required by birds and other animals;
2. the retention of present and future habitat trees, based on the differing requirements of fauna, as determined by the demographic characteristics of the tree species available;
3. the number and dispersion of habitat trees, as defined above, should be based on specified management objectives as to the proportions of the animal populations originally present on the logging area that would be conserved (e.g., 10%, 40%, 90%) (see Thomas 1979 for examples); and,
4. the integration of habitat tree management with the management of coarse woody debris and logs as wildlife resources.

Logging, particularly selective thinning or culling, changes the tree species composition in the canopy and sub-canopy (Loyn 1980; Kellas 1988). The species that are reduced in abundance may have values for wildlife that are not compensated for by the retention of unlogged patches or corridors. For example, forestry practices in Western Australia select against Marri *Eucalyptus calophylla* in favour of the commercially more important Jarrah *E. marginata* and Karri *E. diversicolor*. All three species are important for birds, but differ in bark type, and bark and canopy arthropod faunas (Recher *et al.* 1991, 1996a,b; Majer *et al.* 2002), and size of seeds. Marri seeds are large and contained in a large capsule which both Baudin's Cockatoo *Calyptorhynchus baudinii* and Red-capped Parrot *Purpureicephalus spurius* exploit with a decurved, elongated upper mandible. Moreover, lerp-dependent foliage gleaners (e.g., pardalotes) select Marri over Jarrah because Marri supports larger populations of lerp-forming psyllid insects (Recher *et al.* 1991, 1996a).

The same differences between species of eucalypts occur in eastern Australia where each species provides a different array of resources through time. The pattern of resource availability also differs within and between regions. Management of wildlife in production forests needs to accommodate both the temporal and spatial dispersion of resources if conservation is to succeed. Unfortunately, there is little evidence of integration of wildlife management programs between different land tenures and the system of conservation reserves has not been designed with the view of providing spatially and temporally varying resources for migratory and nomadic organisms, such as birds.

Managing Fire

Where logging is associated with pre- and/or post-logging burns, and where hazard reduction burning is carried out, the rate and extent of change of the biophysical structure and composition of forest environments is increased. My greatest concerns are with increased fire frequency, independent of fire intensity, and where burning is done repetitively at the same time of year and with similar intensities. The tendency in Australia is to conduct hazard reduction burns in late winter and spring when conditions permit good reductions in fuel loads and fires are less likely to escape than in summer and autumn when it is hotter and drier. Unfortunately, late winter and spring burns coincide with the peak nesting season of birds in eastern and southern forests (Nix 1976; Marchant 1981, 1992; McLean *et al.* ms). The impact of this pattern of burning on forest birds is unknown, but could easily lead to the local extinction of species, if fire frequencies prevent populations from recovering between burns. Recovery in this instance means that vegetation and other resources are allowed to recover for a long enough period for one or more nesting seasons to coincide with climatic conditions favouring successful fledging of young - an event that does not necessarily occur every year or even every few years.

Fire changes the structure and species composition of ground and shrub vegetation (Christensen and Abbott 1989; Gill 1975, 1999; Williams and Gill 1995) and reduces the amount of litter, coarse woody debris and logs (see York

1999). Effects are immediate, but changes in plant species composition occur progressively with successive burns at short intervals. These fire-induced changes affect the nesting and foraging resources available to birds with the greatest impacts on species which nest and/or forage on the ground and/or in shrubs (Woinarski and Recher 1997; Woinarski 1999a,b; Recher *et al.* 2002). The reduction in cover may also increase the incidence of predation and nest predation, nest parasitism, and increase competition from birds such as Noisy Miners *Manorina melanocephala* (Martin and Roper 1988; Grey *et al.* 1997, 1998; Fulton and Ford 2001). Increased fire frequency is a major factor in the decline of ground and shrub nesting and foraging birds throughout Australia (Garnett 1992). Birds other than ground-foragers are also affected by repeated fires. This occurs when the removal of litter and debris diminishes the number of arthropods emerging from the ground (York 1999) and entering the canopy where they are fed upon by aerial foragers, and foliage and bark gleaners. Inappropriate fire regimes, as well as grazing, affect the mosaic of bare ground, litter and ground vegetation and disadvantages ground-foraging birds, such as the ground-pouncing robins (Recher *et al.* 2002). Data on the effects of fire on ground and litter invertebrates are seen by some as contradictory (Christensen and Abbott 1989; York 1999) and studies of the exchange of invertebrates between the ground and canopy are lacking.

Despite the adverse effects of fire, burning can be used to manage eucalypt forests to create or maintain particular biophysical regimes for the benefit of species or entire communities (Gill *et al.* 1999). Fire is a means by which a mosaic of different age classes of vegetation, each with different structures and associated species can be created. However, the scale of the mosaic, both internally and in relation to the regional landscape, needs to be planned carefully. For most forests in Australia there are insufficient data on the requirements of fauna to reach final conclusions on the scale or timing of burns. Partly this is a lack of research, but contributing to the lack of information are the long time scales on which fire effects occur (Gill 1999).

Studies in the Nadgee Nature Reserve on the southeast coast of New South Wales show that the effects of a single wildfire on ground-dwelling mammals can be detected 30 years later (Recher *et al.* ms), while heath vegetation and associated bird communities continue to change 12 - 30 years post-fire (Recher unpubl. data). Among the changes in the heath avifauna are the decline of some species 4 - 30 years post-fire, while others only colonize after 7 - 12 years and possibly longer. Managing for one species (e.g, an early decliner, such as the Australian Pipit *Anthus novaeseelandiae*) will exclude another (e.g., a late colonizer, such as the Eastern Bristlebird *Dasyornis brachypterus*) and may be independent of the scale and pattern of fire mosaics.

Fire can be a useful tool in the management of complex ecosystems. However, it is necessary to have a clear vision of the desired result and the stages at which that will be achieved at different times in the future. It is also necessary to maintain an adaptive programme that can be adjusted annually in response to weather patterns and unplanned fires.

Restoring degraded landscapes

Since 1990, a new dimension has been added to wildlife management in Australia. The advent of the Landcare movement was a tacit admission of the need to manage agricultural lands differently and to restore degraded lands if the twin objectives of agricultural sustainability and biodiversity conservation were to be achieved at a continental scale. It is harsh to say that the Landcare movement has failed. Many land owners are committed to Landcare principles and the millions of trees planted over the past decade and a half are beginning to produce the benefits hoped and planned for. Land degradation has been slowed and Landcare plantings provide new and important habitat for a significant range of organisms that had been adversely affected by 200 years of agricultural development, land clearing and over grazing (see Majer and Recher 2001 and Majer *et al.* 2001 for comments on the restoration of insect biodiversity via Landcare plantings). Important as these benefits are, they are at the scale of individual properties and small catchments; the regional and continental decline of Australia's biodiversity continues to accelerate (Recher 1999) along with the on-going degradation of the continent's major waterways, coastal waters and land (for assessments of the state of the Australian environment see Commonwealth of Australia 1996, 2001).

Regardless of how much or how little has been achieved in meeting the goals of a Landcare philosophy, individuals and catchment groups throughout Australia will continue to plant trees, establish forests and restore biodiversity to the lands and waters they manage. Although dwarfed by the continued massive clearing of native vegetation in Queensland and New South Wales and by the replacement of native eucalypt forests by industrial forests and plantations in Tasmania, Victoria and New South Wales, their efforts are important and establish a precedent in ethical land management. In my opinion, the principles that need to be followed in restoring degraded landscapes and recovering lost biodiversity are now well-established and little different from those that need to be applied in managing a wood production forest, an agricultural landscape or a conservation reserve to mitigate the impacts of human use and provide the resources required by birds for nesting and foraging. These principles are comprehensively and adequately addressed in the literature and reader's requiring detail can consult Hobbs and Saunders (1993), Recher (1993) and Lindenmayer and Franklin (2002) among others for explanations and examples relevant to the social, economic and ecological environment of Australia.

The management and planning of Landcare plantings for birds requires only minor embellishments to encourage a return of the birds which previously enhanced the rural landscape. Recher (1993) presented a number of ecologically-based guidelines to follow in restoring or rehabilitating natural ecosystems. These are the same principles to follow when managing wildlife in remnant natural vegetation or in a wood production forest. They are also relevant to the management of conservation reserves where the restoration or manipulation of habitats may be necessary to encourage particular species. Among the principles were: establish corridors to enable organisms to disperse and provide habitat; exclude exotic species and reduce disturbance; retain or add dead wood as stags, logs, debris and litter; create a structurally complex, species-rich vegetation; and, minimize edges by having wide corridors and utilizing remnant native vegetation to increase the size of areas under natural vegetation.

Apart, perhaps, from the recommendations on dead wood, there was nothing unique in these guidelines; most are commonsense principles and have been recommended by others. Hobbs and Hopkins (1991), for example, called for the creation of a 'web' of corridors linking the different parts of the landscape. Landcare advisors now routinely talk about the need for dead wood for both biodiversity and ecosystem function and there is national concern over the impact of harvesting fuelwood from remnants and roadsides.

Once the needs of birds for food, cover and water are understood, it is not difficult to provide or conserve the resources birds require for feeding and nesting. In the absence of mature trees with hollows, hole-nesting birds may need to have artificial nest sites provided and some canopy nesters which require tall trees and dead branches may only return with time and tree growth. They will return provided regional populations remain as a source of colonists. This is more likely to occur if remnant vegetation is protected from disturbance.

Future directions

The impact of human activities on forest ecosystems is not restricted to birds. Because I understand them best, I used birds to illustrate the complexity of relationships between the fauna of eucalypt forests and the resources they require for feeding and breeding. Other vertebrates also use decorticating bark as a foraging resource or feed on invertebrates in litter. A complex, species rich vegetation with multiple layers provides a greater range of food resources and cover for mammals, reptiles and frogs, as well as birds. Invertebrates also benefit from increased structural and floristic complexity. Unique invertebrate communities, as well as individual species, probably occur in association with each species of plant and in association with standing and fallen dead wood and litter (Aust. Entomological Soc. 1990; Recher *et al.* 1996a; York 1999). Logs, litter and coarse woody debris not only benefit the terrestrial fauna, but, as sources of energy and substrates for aquatic life, are integral to aquatic ecosystems rising from and flowing through forests (Franklin *et al.* 1981; Maser *et al.* 1988; Maser and Seddell 1994). Management practices designed to retain or enhance the nesting and foraging resources of birds will therefore benefit the full range of fauna.

There are many impediments to resolving the conflicts between people concerned about the long-term survival of Australia's biota and those whose vision for the future is restricted to one of endless and mindless economic growth and resource development. The first step in balancing the needs of fauna with the exploitation (a history of pillage really) of forest ecosystems by people is to understand the complexity of the systems being managed and the diverse requirements of the biota. I think we already understand what motivates people to behave irrationally towards the environment on which their long-term survival depends - evolution has always selected for individuals who act in their own self-interest regardless of any long-term consequences to the survival of the species. Long-term conservation of biodiversity requires a level of altruism and respect for other species that is absent from mainstream human behaviour and society. And in that, I include the majority of the environmental movement (Recher 2002a,b).

Taking the first step requires improved communication between conservation biologists and land managers. An ethic among land owners and managers also needs to evolve which accepts the inevitable economic trade offs between maximum exploitation for the instantaneous gratification of people and reserving resources for the needs of other species; a decade and more of Landcare has made a valuable start in this direction, but needs wider support from the Australian public (Recher 1997). These are significant challenges which will be met only when the entire community works together and agrees to a common set of goals and methods of setting priorities (Saunders and Burbidge 1988; see papers in Saunders *et al.* 1995; Hale and Lamb 1997).

There are also many gaps in our knowledge of the basic ecology of Australia's forest fauna. I identified some of these in my original chapter, but since then there has been a strangulation of research support from government for ecological studies. While some progress has been made, it is less than I expected and there are no indications that the funding and support for conservation biology research will improve. However futile it may be, I feel responsible to identify some of the most important gaps in knowledge which need to be bridged for the development of comprehensive and adequate plans of management for eucalypt forest ecosystems and their birds.

In the original chapter, I focused on forest ecosystems and the impact of forestry practices and identified several key areas as requiring research. I wrote, "There are few data on the importance of either standing or fallen dead wood to Australian forest ecosystems or to the aquatic ecosystems rising in these forests. The details of the nest and foraging site requirements of forest birds are only sketchily known. There is little information on the relationship between litter, standing dead trees and logs, the invertebrate communities of bark, foliage or air and birds. The effects of fire are poorly understood and have not been quantified for most animals. .., we lack information for most Australian forests on the long-term effects of regular hazard reduction burning on plant and animal communities and nutrient cycling (Christensen *et al.* 1985; Saunders 1985)".

Since 1990, there have been useful studies of the role of 'dead wood' in eucalypt systems (see Lindenmayer *et al.* 2002 for a review). A start has been made in documenting ground, litter and bark arthropod faunas (e.g., Ferrier *et al.* 1999; York 1999; Heterick *et al.* 2001; Majer *et al.* 2002, 2003a,b) and those in the canopies of eucalypts (Recher *et al.* 1996a,b). It is now evident that eucalypt ecosystems have much richer biotas than previously acknowledged (Majer *et* *al.* 1992, 1994; Recher *et al.* 1996a). It is also evident that the fauna of litter, bark and canopy foliage are unique and differ significantly between tree species and over short distances in response to the changing biophysical environment. There are more data on the nesting requirement of birds, but few species have been studied in depth and the reasons for the continental decline in the Australian avifauna (Recher 1999) are not well-understood (Ford *et al.* 2001). Recher and colleagues (e.g., Recher *et al.* 1985; Recher and Davis 1998, 2002) have documented the foraging behaviour and resource requirements of birds across a broad range of eucalypt forests, which with the work of Ford *et al.* (1986) and others has greatly expanded our knowledge of avian resource requirements. However, these studies suffer from a lack of seasonal replication and there are few data on the effects of year to year differences in rainfall. In the glare of global climate change, the latter is a disturbing deficiency in our knowledge. Nonetheless, management will need to take into account the temporal changes in avian ecology, as well as provide for the migratory, nomadic and local movements of birds. None of this is currently allowed for in either the management of individual reserves or in the design of local, regional and continental reserve systems. Despite important advances (see Gill 1999; York 1999), our knowledge of fire effects and of hazard reduction burning, in particular, on Australian ecosystems is limited and inconclusive. A particular omission is the paucity of long-term studies; that is, studies longer than 50 years which may be the minimum required time span to detect the effects of different fire regimes on the biota and ecosystem function. Yet, long-term studies are not being initiated and those established in the 1960s and 70s are being closed down by competing interests (Recher 2002a,b).

The conservation of birds in eucalypt forests is primarily founded on the creation of conservation reserves within which wildlife management is generally restricted to pest and weed control, the exclusion of grazing by domestic animals, and prevention of wildfires. The last may entail prescription or hazard reduction burns which are sometimes used to create habitat for particular species. A small number of threatened birds, outside and within reserves, are managed more actively, including captive breeding and translocation programmes, as well as habitat manipulation and restoration. Various wildlife management protocols are applied in production forests and plantations, but with a continuing emphasis on the retention of trees with hollows in logging areas for hollow dependent fauna. The effects of logging and plantation establishment are also mitigated by alternating logged and unlogged areas, longer cutting cycles, and the retention of strips and patches of mature forest to provide habitat and movement corridors for wildlife. While these are useful, ensuring that the resources required by birds are available as needed means not only a more complex set of management tools, but it requires a reserve system which can accommodate seasonal movements of birds while having sufficient diversity to allow for yearly differences in patterns of resource abundance. This will only be possible when nature conservation and wildlife management is co-ordinated across all land tenures at landscape and continental scales (Recher 1985). The fact that many land owners now toil long hours to re-establish trees on their properties while others only a short distance away clear mature native vegetation shows how far we will need to go to guarantee a future for our children which includes the song and flight of birds.

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