AUSTRALIAN FIELD ORNITHOLOGY 2009, **26**, 53–75

Bird Responses to Targeted Revegetation: 40 Years of Habitat Enhancement at Clarkesdale Bird Sanctuary, Central-western Victoria

R.H. LOYN[1], J.T. FARAGHER[2], D.C. COUTTS[2] and G.C. PALMER[2,3]

[1]Arthur Rylah Institute for Environmental Research, P.O. Box 137, Heidelberg, Victoria 3084 (Email: richard.loyn@dse.vic.gov.au)
[2]Clarkesdale Advisory Committee (formerly Committee of Management)
[3]Centre for Environmental Management, University of Ballarat, P.O. Box 663, Ballarat, Victoria 3353

Summary

A program of planting Australian shrubs and trees has been conducted in degraded farmland at the Clarkesdale Bird Sanctuary (central-western Victoria) since the 1960s, to address the issue of declining native birds, as perceived by the late landowner Gordon Clarke. The shrubs and trees were selected to attract birds, and included many species that were not native to the region. This form of management is often practised by private landholders (at various scales), but its effects are rarely documented. Bird surveys were conducted for this study between 1999 and 2001 at 27 sites: 11 in native eucalypt forest on ridges and slopes, 13 in planted areas on ridges and slopes, and three in planted areas on river-flats and a small gully (with three supplementary sites in a pine plantation). Total bird abundance and species per count were highest in the planted sites on river-flats and gully, and higher in the planted sites on ridges and slopes than in native forest on similar topography. Honeyeaters (Meliphagidae), Superb Fairy-wrens *Malurus cyaneus*, open-country birds, seed-eating birds and five insectivorous guilds reached their maximum abundance in planted sites. Bark-foraging insectivores, canopy-foraging insectivores, frugivores and a generalist insectivore were marginally more common in native forest than in planted sites. Introduced birds were uncommon. Generalised linear modelling showed that total bird abundance was positively related to the cover of planted native vegetation, native low shrubs and young wattles *Acacia* spp. and to the presence of indigenous Cherry Ballart *Exocarpos cupressiformis*. Various guilds showed positive relationships with the cover of planted native vegetation, native low shrubs, young wattles, original old wattles, original old eucalypts and trees with small or large hollows. The planting program has provided new habitat for many native forest birds. A greater challenge is to address the needs of some uncommon species that have declined locally, such as the Brown Treecreeper *Climacteris picumnus* and Speckled Warbler *Chthonicola sagittata*.

Introduction

In recent years much effort has been devoted to revegetating parts of the rural landscape, to address a range of issues including erosion, salinity and biodiversity conservation (Salt *et al.* 2004; Youl *et al.* 2006; Munro *et al.* 2007). Relatively little effort has been devoted to assessing the effects of these initiatives on biodiversity, with some exceptions, such as recent work on fauna in commercial eucalypt plantations (Hobbs *et al.* 2003; Kavanagh *et al.* 2005; Loyn *et al.* 2007) and in agricultural landscapes (Kavanagh *et al.* 2007; Barrett *et al.* 2008; Selwood *et al.* 2009). Many revegetation initiatives are taken by individual landholders or local Landcare groups, and develop their own characteristics and idiosyncrasies, which may differ from those expected in commercial operations or larger government-sponsored programs. It is important to understand how biodiversity responds to individual revegetation efforts, because these all contribute to changes in the rural landscape and its associated biodiversity.

Many private landholders recognise a need to revegetate parts of their land with trees and shrubs for a wide range of purposes (Reid & Wilson 1985), often with a desire to provide habitat for native birds and other wildlife, especially in gardens or home-paddocks. They may select trees and shrubs partly for that purpose, including species not indigenous to the local area, but effects of such management have rarely been documented. One of the early landowners to adopt this philosophy was the late Gordon John Clarke of Linton, near Ballarat in central-western Victoria. He realised his vision by buying land and initiating a vigorous revegetation program in the 1960s, coming to fruition as the Clarkesdale Bird Sanctuary.

The main aim of this study was to compare assemblages across the main habitats currently represented at the Sanctuary, and in particular to compare revegetated sites with remnant native eucalypt forest. This could help to assess whether planting had helped restore a bird fauna that resembled that of native forest, and identify any differences. This was seen as a useful benchmark, while recognising that the planting program had broader aims. The benefits of the planting program could also be assessed, if it were assumed that the initial bird populations of degraded sites were extremely low. No attempt was made to conduct surveys on cleared pasture or paddocks infested with Gorse *Ulex europaeus*, as these habitats are no longer evident in the Sanctuary. However, data on such sites are available from companion studies in the region (our unpubl. data), and populations of forest and woodland birds in such habitats are indeed known to be generally low.

This paper presents an analysis of data collected by volunteers from 27 sites and three broad habitats on seven occasions between 1999 and 2001. The data are of general interest, because they shed light on the effects of a visionary but controversial approach to bird-habitat enhancement, which deliberately avoided the constraints of many modern programs that insist on using plant species native to the area in question (i.e. indigenous).

Study area

The Clarkesdale Bird Sanctuary covers 535 ha of land at Piggoreet south-east of Linton (Anon. 1999), at an altitude of 500 m at the south-western end of the Great Dividing Range. Most of the land is owned by Bird Observation and Conservation Australia (BOCA) and the Trust for Nature (Victoria), together with the adjacent Linton Flora and Fauna Reserve under Parks Victoria's jurisdiction. Its management is overseen by a strategy committee appointed by BOCA, including representatives from these and other organisations, with input from the Clarkesdale Advisory Committee.

The Sanctuary owes its existence to the visionary conservationist and grazier Gordon Clarke, who grew up at Piggoreet, near Linton, and farmed the land over many decades. From the 1950s he was among the first to recognise that populations of woodland birds were declining and new approaches to rural land management were needed to reverse these declines. He developed a program to buy degraded land locally, including land supporting extensive Gorse infestations, and restore some of its value as bird habitat by a vigorous program of planting Australian native trees and shrubs. He eschewed the purist philosophy of solely planting species indigenous to the local area, and aimed to improve on nature by selecting plants with special characteristics favoured by birds. Many of the shrubs selected were Western Australian species known for their capability to produce prolific nectar and attract honeyeaters.

The work continued to include other areas of cleared or partly cleared land, with varying levels of initial weed infestation. Gordon Clarke made special efforts to involve the community in his work, and the Bird Observers Club of Australia (BOCA, now Bird Observation and Conservation Australia) became an active participant at an early stage, in planting and recording bird species present. Formal reservation of the Sanctuary was achieved in 1975, and the Gordon Clarke Trust was established to provide funds for its management. A management plan was prepared (Anon. 1999). This defined the vision for the Sanctuary as being 'to optimise, manage and create habitat at Linton as a Sanctuary to increase the diversity and populations of native birds in perpetuity'. This reflected Gordon Clarke's focus on the needs of birds, rather than any attempt to restore vegetation to its pre-European form. One of the needs identified in the management plan was to conduct surveys of birds to determine how bird populations may have responded to the planting program, hence this study.

The Sanctuary consists of a mosaic of native eucalypt forest and planted areas, together with a Monterey Pine *Pinus radiata* plantation (25+ years old), small remaining cleared areas and several small and medium-sized wetlands. Most sites in native forest were within ~200 m of planted sites. Examination of maps of Ecological Vegetation Classes (EVC) (estimated for the pre-European state, Department of Sustainability & Environment) revealed that the river-flats would be classed as Creek-line Herb-rich Woodland EVC. Most planted sites (including the pine plantation) would have supported Valley Grassy Forest EVC, which grows on fertile soils and has been extensively cleared. The revegetated areas contained a few relict (i.e. original) trees that survived initial clearing, but were essentially dominated by planted trees and shrubs, including many flowering shrubs endemic to Western Australia (e.g. *Hakea* spp., *Grevillea* spp., *Melaleuca* spp., etc.). The native forest was classed as Heathy Dry Forest, with dominant trees including Messmate *Eucalyptus obliqua*, Narrow-leaved Peppermint *E. radiata*, Candlebark *E. rubida*, Red Stringybark *E. macrorhyncha*, Scent-bark *E. aromaphloia*, Swamp Gum *E. ovata* and Broad-leaved Peppermint *E. dive*s forming an open overstorey ~20 m tall. A relatively low, sparse shrub layer included Myrtle Wattle *Acacia myrtifolia*, Black Wattle *A. mearnsii*, Golden Bush-pea *Pultenaea gunnii*, Bitter-pea *Daviesia* sp., Drooping Cassinia *Cassinia arcuata*, Heath Tea-tree *Leptospermum myrsinoides*, Common Heath *Epacris impressa* and Small Grass-tree *Xanthorrhoea minor*. Austral Bracken *Pteridium esculentum* and Grey Tussock-grass *Poa sieberiana* were common components of the understorey. The native forest has been subject to selective logging and other disturbance over many years, as have most forests in this region. The native forest has not been burnt for a long period (>20 years).

Methods

Field methods

A total of 27 sites was used for this study (along with three in pine plantations that are not included in the analysis). They included 11 sites in native forest, 13 in areas of similar topography where native trees and shrubs had been planted as part of the program of habitat restoration, and three in planted areas on river-flats and a small gully (Table 1). One of the latter sites was next to one of the small dams. Observers surveyed each site on seven occasions: 19 October, 2 November 1999 (spring), 14 December 1999 (summer), 8 March, 22 March 2000 (autumn), 24 January 2001 (summer) and 7 March 2001 (autumn). An active timed area search method was used (after Loyn 1986, 1998) in which an area of 1 ha was searched for 10 minutes. The observer walked through each area, and recorded numbers of all species observed (seen or heard). Birds observed off-site were recorded separately, and not considered further in the current analysis.

Basic habitat data (Table 1) were collected from each site on the initial visit. Habitat variables were assessed visually and scored on a scale of 0 (absent) to 3 (dominant, or for native vegetation as in uncleared forest). The presence or absence of Cherry Ballart *Exocarpos cupressiformis* and trees bearing mistletoe *Amyema* spp. was noted.

Note that this study did not consider nocturnal birds, of which at least four species (Tawny Frogmouth *Podargus strigoides*, Australian Owlet-nightjar *Aegotheles cristatus*, Powerful Owl *Ninox strenua* and Southern Boobook *N. novaeseelandiae*) inhabit the Sanctuary.

Analysis

Mean abundances of each species were calculated across the seven visits for each site. Sites were grouped according to the three main habitats (native forest on ridges and slopes, planted sites on similar topography, and planted river-flats and gully). Mean abundances of

Table 1

Mean values for selected habitat features of the 27 study sites at Clarkesdale Bird Sanctuary, central-western Victoria, 1999–2001. Numerical scores are on a scale of 0 (none) to 3 (dominant, or for native vegetation as in uncleared forest).

Habitat feature	*Native eucalypt forest*	*Planted sites on similar topography*	*Planted river-flats and gully*
Native vegetation cover (unplanted)	2.45	1.08	1.67
Planted native vegetation cover	0.45	2.23	2.33
Exotic vegetation (weeds)	0.36	0.38	1.00
Trees with large hollows	1.09	0.31	1.00
Trees with small hollows	1.45	0.54	1.00
Original eucalypts (>50 years old)	1.91	1.08	1.67
Original wattles (>50 years old)	0.45	0.38	0.67
Young eucalypts (0–50 years old)	1.55	1.69	1.33
Young wattles (0–50 years old)	1.36	1.46	1.33

each species were then calculated and tabulated for each of these three habitats. Analysis of variance was used to compare mean abundances of common species between native forest and planted sites on similar topography. Logistic regression was used to compare occurrence of less common species between sites in each of those two habitats.

Species were classified into a number of guilds based on feeding ecology, preferred nest-site, migratory status, status (native or introduced) in Victoria or habitat (Appendix 1). The abundance of each guild was calculated for each visit to each site by summing the numbers of individuals of the respective species observed at the site on that visit. Numbers of individual birds in each guild per site per visit were taken as the dependent variable for subsequent analysis. The total numbers of individual birds per visit, and the numbers of species observed on each visit, were also considered as dependent variables.

Analyses of variance were then conducted to assess variation between seasons and habitats, and their interactions. Square-root transformations were found necessary in some cases to meet the assumptions of the analysis. Visit sessions and sites were taken as random variables, and seasons and habitats as fixed variables. The three habitats were as already described (native forest on ridges and slopes, planted sites on similar topography, and planted river-flats and gully). Generalised linear modelling was used to relate the same dependent variables (i.e. total bird abundance, abundance of bird guilds) to habitat variables (i.e. explanatory variables) collected in the field.

Results

Seventy-nine bird species were recorded on the 27 sites during the seven visits, including 13 waterbird species associated with the dam (Appendix 1). In terms of species per count, the sites in native forest appeared less diverse than the planted sites on similar topography, which in turn were less diverse than the planted river-

Table 2

Mean abundances (birds per 10 counts) of bird guilds in three main habitats (native eucalypt forest on ridges and slopes, planted sites on similar topography, and planted river-flats and gully) at Clarkesdale Bird Sanctuary, central-western Victoria, 1999–2001, including waterbirds. The planted sites were planted with native Australian trees and shrubs (many of them not indigenous to the local area) from the 1960s. Number of bird species recorded in each guild is shown in parentheses.

Guild type	*Guild*	*P value*	*Mean birds per 10 counts*		
	Broad habitat:	*Native forest vs planted sites on similar topography*	*Native forest*	*Planted sites on similar topography*	*Planted river-flats and gully*
Number of sites:			**11**	**13**	**3**
Bird species per count:			**4.3**	**6.0**	**8.1**
Feeding	Aerial insectivores (4)	–	2.1	2.4	21.0
	Bark-foraging insectivores (4)	0.123	4.4	3.1	2.9
	Canopy-foraging insectivores (10)	0.187	17.9	12.6	25.2
	Damp-ground or understorey insectivores (5)	0.152	4.2	9.8	13.8
	Generalist insectivores (1)	0.976	2.9	2.1	1.4
	Mid-storey insectivores (3)	0.031	4.3	7.4	6.7
	Open-ground-among-trees insectivores (7)	0.150	13.8	22.4	27.1
	Open-ground insectivores (5)	0.032	2.1	7.6	5.2
	Nectarivores (honeyeaters) (7)	<0.001	27.9	69.3	64.8
	Frugivores (2)	–	0.4	0	0
	Seed-eaters close to ground (8)	0.044	2.5	5.2	10.5
	Seed-eaters at all levels (2)	0.084	5.3	6.9	9.5
	Carnivores (9)	0.420	1.6	2.7	3.3
	Waterbirds (12)	–	0.1	0.2	11.4
Nesting	Brood-parasites (cuckoos) (4)	–	0.5	1.4	0.5
	Hole in ground (1)	–	2.3	0.5	0.5
	Ground (3)	–	0	0.2	11.0
	Ledge on tree or building (3)	–	3.0	2.3	3.8
	Large hollow in tree (7)	0.104	7.0	8.5	16.7
	Small hollow in tree (7)	0.136	7.7	4.9	25.2
	Branch of tree or shrub (45)	–	68.8	133.0	145.2
	Not nesting in Australia (1)	–	0	0.9	0
Migrant	Non-migrant (62)	–	74.7	135.2	166.7
	Summer migrant (17)	–	14.7	16.6	36.2
Status	Introduced to Australia (3)	–	0.4	1.8	3.8
	Native (76)	–	89.0	150.0	199.1
Habitat	Forest or woodland birds (49)	–	82.1	109.0	143.8
	Heathland birds (2)	–	1.7	31.5	31.0
	Open-country birds (15)	–	5.5	11.0	13.8
	Waterbirds (13)	–	0.1	0.2	14.3

flats and gully (Appendix 2). The mean abundance of each species in these three habitats is also shown in Appendix 2, and the mean abundance of each guild in each habitat is shown in Table 2. Total bird abundance (mean birds of all species per site per visit) was highest on planted river-flats and gully sites, and higher in the planted sites on ridges and slopes than in native forest on similar topography (Appendix 2, Table 2). The differences were highly significant ($P < 0.001$). The same trend was evident in species per count (Appendix 2). At conventional significance levels ($P < 0.05$), just two species (White-throated Treecreeper and Spotted Pardalote; see Appendix 1 for scientific names) were more common in native forest than planted sites on similar topography. Black-faced Cuckoo-shrikes were recorded only in native forest during the study, and White-winged Choughs were present more consistently in native forest than elsewhere. Five species (Superb Fairy-wren, New Holland Honeyeater, Red Wattlebird, Australian Magpie and Australian Raven) were significantly more common in planted sites on ridges and slopes than in native forest on similar topography. Two others (White-browed Scrubwren and Eastern Spinebill) showed the same trend but at a lower level of significance ($0.1 > P > 0.05$). Red-browed Finches were recorded only at planted sites.

Habitat modelling showed that total bird abundance was positively related to the cover of native low shrubs, planted native vegetation, young wattles and Cherry Ballart (Table 3).

Feeding guilds

Four feeding guilds appeared more common in native forest than in planted sites on similar topography, but the differences were not statistically significant at conventional levels ($P < 0.05$). Apparent preference for native forest was greatest among bark-foraging insectivores (Table 2). Honeyeaters, Superb Fairy-wrens and birds regarded as open-country species were substantially more abundant at planted sites (on ridges and slopes as well as on river-flats and gully) than elsewhere (Appendix 2). Five insectivorous and both seed-eating guilds were particularly common at planted sites (Table 2).

Aerial insectivores

The relative abundance of aerial insectivores was highest over planted river-flats (Table 2), particularly at the site near the dam, where Tree Martins were the

Table 3

Generalised linear models for abundance of bird guilds in relation to habitat variables at Clarkesdale Bird Sanctuary, central-western Victoria, 1999–2001.

Dependent variable (square root)	*Coefficient*	*Variable*	*Significance*	*% variance explained by model*
Total bird abundance		Regression model	<0.001	66.8
	1.871	[constant]		
	0.349	Native low shrubs	0.012	
	0.500	Planted native vegetation	<0.001	
	0.345	Young wattles	0.019	
	0.781	If *Exocarpos* is present	0.028	

Table 3 continued

Dependent variable (square root)	*Coefficient*	*Variable*	*Significance*	*% variance explained by model*
Bark-foraging insectivores		Regression model	<0.001	49.0
	0.374	[constant]		
	–0.095	Native tall shrubs	0.04	
	0.246	Original old eucalypts	<0.001	
Canopy-foraging insectivores		Regression model	0.029	13.0
	0.891	[constant]		
	0.166	Native vegetation	0.029	
Damp-ground or understorey insectivores		Regression model	0.024	18.4
	0.807	[constant]		
	–0.146	Native tall shrubs	0.07	
	0.160	Planted native vegetation	0.017	
Generalist insectivores		Regression model	<0.001	50.2
	0.264	[constant]		
	0.133	Native low shrubs	0.006	
	–0.168	Original old eucalypts	0.006	
	0.277	Trees with small hollows	<0.001	
Mid-storey insectivores		Regression model	0.007	20.4
	0.586	[constant]		
	0.166	Native low shrubs	0.007	
Open-ground-among-trees insectivores		Regression model	0.015	16.5
	0.940	[constant]		
	0.335	Native low shrubs	0.015	
Open-ground insectivores		Regression model	0.017	15.7
	0.233	[constant]		
	0.176	Planted native vegetation	0.017	
Nectarivores (honeyeaters)		Regression model	<0.001	54.9
	0.762	[constant]		
	0.455	Planted native vegetation	<0.001	
	0.447	Young wattles	0.008	
Seed-eaters close to ground		Regression model	0.003	30.9
	0.336	[constant]		
	0.142	Native low shrubs	0.045	
	0.288	Original old wattles	0.009	
Seed-eaters at all levels		Regression model	<0.001	40.5
	0.093	[constant]		
	0.342	Original old eucalypts	0.001	
	0.278	Planted native vegetation	<0.001	
	–0.600	If mistletoe is present	0.002	
Carnivores		Regression model	0.004	28.9
	–0.114	[constant]		
	0.188	Weeds	0.006	
	0.280	Young wattles	0.001	
Birds that nest in large tree-hollows		Regression model	0.002	33.3
	0.340	[constant]		
	0.249	Trees with large hollows	0.005	
	0.183	Planted native vegetation	0.007	
Birds that nest in small tree-hollows		Regression model	<0.001	31.9
	0.476	[constant]		
	0.318	Trees with small hollows	<0.001	

dominant species. They were particularly common there in spring, nesting in old eucalypts and feeding over open country and the dam. Tree Martins were observed in smaller numbers but more widely in other seasons, along with a few Dusky Woodswallows, Welcome Swallows and White-throated Needletails.

Bark-foraging insectivores

Bark-foraging insectivores showed little difference in abundance between the three habitats, although they tended to be most common in native forest (Table 2). No significant differences were found between habitat type ($P = 0.551$) or season ($P = 0.676$), and there was no interaction between habitat type and season ($P = 0.395$). The commonest species in the group, the White-throated Treecreeper, occurred in all habitat types (including pines), although it was most numerous in native forest ($P = 0.031$, Appendix 2). Crested Shrike-tits and Varied Sittellas were recorded in low numbers mainly in planted sites. Red-browed Treecreepers were recorded only at planted river-flats and in native forest; this species occurs here at the extreme western limit of its range.

Habitat modelling showed that the abundance of original old eucalypts made a positive contribution, and native tall shrubs made a negative contribution (Table 3). The latter effect may be because most shrubs had been planted on the most degraded sites with few remaining old trees; that is to say, relatively intact treed areas had not been targeted for extensive shrub plantings. In general, Heathy Dry Forest EVC does not support an extensive cover of shrubs, particularly of tall shrubs.

Canopy-foraging insectivores

No significant difference was found between the sites in native forest on ridges and slopes and planted sites on similar topography (Table 2). Two species in the group appeared to be more common in native forest than elsewhere (Spotted Pardalote and Black-faced Cuckoo-shrike), although the difference was significant only for the Spotted Pardalote (Appendix 2). The guild was more common in spring or summer than in autumn ($P = 0.019$), and no interaction was found between habitat type and season ($P = 0.315$). It was virtually absent from the pine plantation (our unpubl. data).

A habitat model showed that the cover of native vegetation made a weak positive contribution (Table 3).

Damp-ground or understorey insectivores

Species that feed from the understorey or from damp ground were common at planted sites and somewhat less common in native forest (Table 2). No significant differences were found between these habitats ($P = 0.165$) or seasons ($P = 0.438$), and there was no interaction between them ($P = 0.179$). The most common species in the guild, the White-browed Scrubwren, was particularly common in planted river-flats and gully (Appendix 2).

A habitat model indicated a weak positive contribution from the cover of planted native vegetation, with a paradoxical and nearly significant negative contribution from native tall shrubs (Table 3).

Generalist insectivores

This guild was represented by a single species, the Grey Shrike-thrush, which takes invertebrates and small vertebrates from the canopy, bark and open ground. Grey Shrike-thrushes were widespread in all habitats (Table 2), and no significant differences were found between habitats (P = 0.785). Fewer were observed in autumn than in spring or summer (P = 0.045), and there was no interaction between season and habitat (P = 0.825).

Habitat modelling showed that the cover of native low shrubs and the abundance of trees with small hollows made positive contributions, while (paradoxically) the abundance of original old eucalypts made a negative contribution (Table 3).

Insectivores that feed from tall shrubs (mid-storey insectivores)

Two of the species that feed from tall shrubs (Brown Thornbill and Golden Whistler) were about equally common on planted river-flats and other planted sites (Appendix 2). The third member of the guild, the Fan-tailed Cuckoo, was uncommon, and was found only on planted ridge and slope sites. No significant differences were found between habitats across the 27 sites (P = 0.105), although there was a trend for lower abundance in native forest (Table 2). When native forest was compared directly with planted sites on similar topography, the guild proved to be significantly more common in the latter (P = 0.031). There was no evidence for any seasonal difference (P = 0.764) or interaction between season and habitat (P = 0.711).

A habitat model showed that the cover of native low shrubs made a weak positive contribution, whereas tall shrubs did not (Table 3).

Insectivores that feed from open ground among trees (open-ground-among-trees insectivores)

This guild was common in planted sites, including river-flats and gully and other sites, and appeared to be less common in native forest (Table 2). The differences between habitats were not significant (P = 0.150). Three of the species in the guild (Scarlet Robin, Buff-rumped Thornbill and White-winged Chough) were common among pines and in native forest. Superb Fairy-wrens dominated the guild at planted sites. This insectivorous guild was less common in autumn than in spring or summer (P <0.001), and no interaction was found between season and habitat (P = 0.310).

Habitat modelling showed a weak positive response to the cover of native low shrubs (Table 3).

Insectivores that feed from open ground, often not among trees (open-ground insectivores)

This guild showed the same trend as for insectivores that feed from open ground among trees. Significant differences were found between habitats (P = 0.032), but not between seasons (P = 0.632), and there was no interaction between habitat and season (P = 0.596). The most common species in the group were Australian Magpie and Yellow-rumped Thornbill, and these were particularly common in planted sites away from river-flats (Appendix 2). Magpie-larks and Common Starlings were recorded in low numbers, and Masked Lapwings were observed near the dam. Some open-country species in this guild were notable by their absence, with Willie Wagtail *Rhipidura leucophrys* being a prominent example.

Habitat modelling showed a weak positive response to planted native vegetation (Table 3).

Nectarivores

Honeyeaters were the only nectarivorous species observed (Appendix 2). They were much more numerous at planted sites than in native forest (Table 2) and the differences were highly significant ($P < 0.001$). They were more common in spring than autumn ($P = 0.022$), and intermediate numbers were found in summer. An interaction was found between habitat and season ($P = 0.045$), with both classes of planted sites showing less of a reduction in numbers in summer than did native forest.

Seven species of honeyeater were recorded during the study, and three (Eastern Spinebill, New Holland Honeyeater and Red Wattlebird) appeared much more abundant at planted sites than in native forest. This difference was significant for the latter two species ($P = 0.006$ and 0.031, respectively) but not for Eastern Spinebills ($P = 0.068$) at conventional levels. White-eared Honeyeaters appeared more common in native forest (although the difference was not significant), and the remaining three species (White-naped Honeyeater, Brown-headed Honeyeater and Yellow-faced Honeyeater) were similarly common in native forest and planted sites on similar topography (Appendix 2).

Habitat models showed that nectarivore abundance was positively related to the cover of planted native vegetation and young wattles (Table 3).

Frugivores

Only two frugivorous species (Silvereye and Mistletoebird) were recorded, and they were found in low numbers and only in native forest (Table 2).

Seed-eaters that take food from the ground or low vegetation (seed-eaters close to ground)

This guild was more abundant in planted river-flats and gully than in other planted sites, and generally more common in the latter than in native forest sites (Table 2; $P = 0.044$). Eastern Rosellas and Long-billed Corellas showed a preference for planted river-flats, whereas up to seven Blue-winged Parrots were observed at several other planted sites and in native forest. The most common small seed-eater, the Red-browed Finch, was recorded at both groups of planted sites, and not found elsewhere during these surveys (Appendix 2). There was no seasonal effect for the guild ($P = 0.831$). Weak evidence was found for an interaction between season and habitat ($P = 0.071$), with numbers apparently increasing in native forest in autumn and decreasing elsewhere in autumn.

Habitat modelling identified positive responses to the cover of native low shrubs and old wattles (Table 3).

Seed-eaters that take seeds and other food at all levels (seed-eaters at all levels)

This guild was widely distributed in all habitats (Table 2). Effects of habitat were not significant at conventional levels ($P = 0.084$). No significant effects were found for season ($P = 0.305$), and there was no interaction between season and habitat ($P = 0.934$). The guild was dominated by Crimson Rosellas, with smaller numbers of Yellow-tailed Black-Cockatoos, and no other species.

Habitat modelling identified positive responses to the cover of original old eucalypts and planted native vegetation, and a negative response to mistletoe (Table 3).

Carnivores (birds that take vertebrates as an important part of their diet)

Carnivores were widely distributed in low numbers in all habitats (Table 2), but there were no significant differences between habitats ($P = 0.478$), and no interaction between season and habitat ($P = 0.934$). The guild was substantially more common in spring and summer than in autumn ($P < 0.001$) because its most common species, the Sacred Kingfisher, is a summer migrant to these forests.

Habitat modelling identified positive responses to the cover of weeds and young wattles (Table 3).

Other guilds

The following accounts deal with groups of birds that overlap with the feeding guilds already discussed. Separate analysis was warranted for the guilds of birds that nest in small or large tree-hollows. Birds that make nests on branches formed the vast majority of birds recorded, and generally followed the same pattern as described for total bird abundance. Brood-parasites and birds that nest in special situations were represented by too few species and individuals to warrant statistical analysis.

Birds that nest in large tree-hollows

This guild was most abundant in planted sites on the river-flats and gully ($P = 0.024$), and showed little difference between native forest and planted sites on similar topography (Table 2, $P = 0.104$). The abundance of trees with large hollows made a significant positive contribution when included as a covariate ($P < 0.005$). Parrots, cockatoos and the Laughing Kookaburra constituted the guild.

Habitat modelling showed positive responses to large hollow-bearing trees and the cover of planted native vegetation (Table 3).

Birds that nest in small tree-hollows

This guild was most abundant on planted river-flats and gully (Table 2; $P = 0.033$) and showed little difference in abundance between other habitats. The abundance of trees with small hollows made a significant positive contribution when included as a covariate ($P < 0.001$). The guild contained a wide range of species (Appendix 1), with White-throated Treecreeper, Striated Pardalote and Tree Martin being the most common. The species differed widely in their apparent responses to habitat (Appendix 2).

Habitat modelling showed a positive response to numbers of trees with small hollows (Table 3).

Waterbirds

Waterbirds were found almost exclusively near dams in the planted river-flats (Table 2). Two species (Australian Shelduck and White-faced Heron) were observed occasionally in native forest in spring, and may have been nesting there at the time. The distribution of these species was too restricted for statistical analysis to be useful.

Introduced birds

Three species were recorded during the study (Appendix 1). Common Blackbirds and European Goldfinches were observed regularly at planted sites, and Common Starlings were seen there infrequently in low numbers (Appendix 2). In addition, Goldfinches were observed regularly in pines, and Blackbirds were observed occasionally in native forest. Altogether, introduced birds formed 0.4% of the individual birds recorded in native forest, 1.1% of those on planted sites on similar topography and 1.9% of those on planted river-flats and gully; they also formed 7.5% of those in pines (our unpubl. data). Numbers were too low for useful analysis beyond that level.

Discussion

The study has given a snapshot of the bird assemblages of three main habitats at the Clarkesdale Bird Sanctuary. In general the results accord well with what might be expected from general experience and work elsewhere in Victoria (e.g. Loyn 1985; Emison *et al.* 1987), with minor anomalies as noted in Appendix 2, arising when species were observed on few occasions. Several uncommon forest or woodland birds could be expected to occur intermittently at the Sanctuary, mainly in native forest rather than planted sites. Species that might be expected to occur at times in this sort of forest include Painted Button-quail *Turnix varius*, Chestnut-rumped Heathwren *Hylacola pyrrhopygia*, Spotted Quail-thrush *Cinclosoma punctatum*, Leaden Flycatcher *Myiagra rubecula* and lorikeets. These species are known to occur in surrounding forest areas and occasionally at the Sanctuary, but each has specific habitat requirements. Historical records show that some woodland birds (notably Brown Treecreeper *Climacteris picumnus*, Speckled Warbler *Chthonicola sagittata*, Hooded Robin *Melanodryas cucullata* and Diamond Firetail *Stagonopleura guttata*) occurred formerly at the Clarkesdale Bird Sanctuary (up until early 1990s), but have not been recorded for many years and are now very rarely recorded in the wider landscape (our unpubl. data).

The models developed in this study identify several variables that contribute positively to the abundance of particular bird guilds. These include the cover of planted native vegetation, native low shrubs, young wattles, original old wattles, Cherry Ballart, original old eucalypts and trees with small or large hollows. Such features, including large old trees and shrub cover, have also been found to be important in other studies investigating the biodiversity benefits of revegetation (e.g. Kavanagh *et al.* 2007; Selwood *et al.* 2009). If landholders wish to enhance habitat for particular guilds of birds, they could do so by enhancing these habitat elements through planting or retention of existing vegetation. Retention is the most practical strategy for elements that take many decades to develop (such as hollow-bearing trees, discussed on p. 66) or which pose practical difficulties for planting (such as Cherry Ballart, a root hemi-parasite).

Studies of birds in revegetation have often found these sites to support fewer species or only a subset of the species found in nearby remnant vegetation (e.g. Martin *et al.* 2004; Jansen 2005; Kavanagh *et al.* 2007). This result has been attributed to lower structural complexity in plantings (Kavanagh *et al.* 2007), age of vegetation (Selwood *et al.* 2009) and low floristic richness (Kavanagh *et al.* 2007). Although many of these studies investigated revegetation established for biodiversity purposes, few of these revegetation projects could be considered to be designed specifically to enhance bird communities. The plantings undertaken at Clarkesdale were heavily weighted towards the establishment of bird-attractant plants, and the benefits of such plantings (using non-indigenous native plants) are poorly understood (Munro *et al.* 2007). This study has shown that by expressly targeting the habitat requirements of a range of birds, revegetation of this kind can restore and enhance many components of bird communities, with benefits for the landscape avifauna.

Confounding variables (site fertility, EVC)

A general problem with retrospective studies is that the current pattern of habitats may be confounded with other factors that have a direct or indirect influence on the subjects of interest. In this case, many of the planted sites were originally on cleared paddocks, and still retained many of the features of grazed pasture, including introduced grasses and weeds and associated birds typical of open country (e.g. Australian Magpies and various cockatoos). When land is cleared for farming, the most fertile land is usually selected first (McIntyre *et al.* 2002), and this will have various habitat features not represented in the remaining native forest. Examination of pre-European vegetation maps (not available at the start of the study) confirmed that most of the planted sites would have been originally classed as Valley Grassy Forest, an EVC that grows on fertile soils and has been extensively cleared. This EVC is no longer represented at Clarkesdale and its bird fauna is not well known. It is often included with Heathy Dry Forest in a 'dry forests' grouping of EVCs, but the remaining stands of Heathy Dry Forest are an imperfect benchmark, representing a less fertile state on the fertility gradient. Valley Grassy Forest is one of many EVCs that have been extensively cleared, which need further work to document their values as habitat for fauna.

The fertility of cleared sites may have been further enhanced by agricultural practices including fertiliser application. Some forest birds and mammals are known to respond positively to natural site-fertility (Braithwaite *et al.* 1984), and fertiliser application can reduce plant diversity in pastures (McIntyre *et al.* 2002; Dorrough *et al.* 2006). Creeklines and gullies provide high-quality habitats for birds in agricultural landscapes (Jansen & Robertson 2001) and in intact forest landscapes (Loyn 1985; Mac Nally *et al.* 2000; Palmer & Bennett 2006). In our study, natural fertility, history of fertiliser application and similar confounding variables may have combined to drive some of the observed differences between planted sites and native forest. Nevertheless, the main structural and floristic features of the planted sites are a product of deliberate management (shrub establishment). Hence, it seems likely that most of the observed differences were influenced predominantly by this aspect of management history.

Positive effects of restoration planting

No sites were located entirely on cleared land, as little of it remains in the Sanctuary. Cleared pasture usually attracts few forest or woodland birds, and open-country specialists such as cockatoos and Australian Magpies dominate the bird fauna, at low density (Loyn 1985; Hobbs *et al.* 2003; Kavanagh *et al.* 2007; Loyn *et al.* 2007). A greater range of species may occur near the edge of woody vegetation, including Yellow-rumped Thornbills (recorded here on planted sites) and Willie Wagtails. Willie Wagtails were recorded previously at the Sanctuary (Anon. 1999; our unpubl. data), and may have disappeared in response to the reduced area of cleared land, and lack of domestic stock that produce dung and hence insects attractive to this species (Loyn 2002). Recent surveys in gorse-infested paddocks nearby revealed higher densities of forest or woodland birds than in cleared paddocks, but much lower densities than at the planted sites or native forest in the Sanctuary (our unpubl. data).

If the planted sites initially consisted of cleared pasture, they would have supported few forest or woodland birds. Hence at least 90% of the current bird population on these sites has probably benefitted directly from the management efforts. Many of the shrubs planted were not indigenous to the local area, and include Australian native plants mainly from Western Australia (Anon. 1999). Nevertheless, the effect of this planting has been to restore habitat for many of the forest birds that would have been present before clearing. Some species may not be as common as in adjacent native forest (e.g. treecreepers) and some have undoubtedly benefitted more than others. It seems clear that honeyeaters have benefitted greatly from the planting, and two or three species (New Holland Honeyeater, Red Wattlebird, and probably Eastern Spinebill) are now much more common than in native forest. It is reasonable to conclude that the planting of native trees and shrubs has resulted in greatly increased populations of honeyeaters and other bird species, to levels at least comparable with native forest and far exceeding those that are generally found in open or gorse-infested paddocks.

When Gordon Clarke embarked on his planting program, his vision was to establish something even richer as bird habitat than native forest. He refused to plant stringybarks and scent-barks (Anon. 1999), focussing instead on shrubs and trees that would be highly attractive to a wide range of bird species. This study shows that the planting has succeeded in moving towards his stated vision for Clarkesdale Bird Sanctuary. At the same time, it allows us to recognise some additional measures that would help achieve further conservation benefits as discussed opposite.

Tree-hollows

Tree-hollows are among the most difficult habitat elements to restore to cleared land, because useful hollows are usually found in large old trees and they take many decades to develop (Mackowski 1984; Wormington & Lamb 1999; Gibbons *et al.* 2000; Whitford 2002; Vesk & Mac Nally 2006). Many of the hollow-nesting birds that made use of planted sites at the Clarkesdale Bird Sanctuary are wide-ranging species such as parrots and cockatoos, and would have been able to gain access to nest-sites at various distances in nearby native habitat. A shortage of hollows in the planted sites could have contributed to the low numbers of treecreepers and Striated Pardalotes. However, treecreepers generally prefer larger trees for feeding, and select rough-barked species such as those that remain dominant in native forest (Loyn 1985; Noske 1985). They have proved to be scarce in eucalypt plantations elsewhere (Hobbs *et al.* 2003; Kavanagh *et al.* 2005; Loyn *et al.* 2007). Experiments with artificial hollows (nest-boxes) could help clarify whether hollows are limiting the abundance of these birds on the planted sites, and some nest-boxes have now been installed. One generalist species, the Grey Shrike-thrush, showed a positive response to trees with small hollows, despite not being an obligate hollow-nester (Higgins & Peter 2002). However, crevices and complex structures of bark and branches are among the wide range of sites used by this species both for nesting and foraging (Recher 1991; Higgins & Peter 2002). Such structures are more likely to be found in old trees (many of which contain hollows) than in young planted trees.

Any negative effects of restoration planting?

A more difficult question is to consider whether the planting has had any negative effects. Honeyeaters are notoriously aggressive, and some species habitually exclude a range of other bird species (e.g. Ford 1989; Clarke 1995). The most pugnacious species are the miners *Manorina* spp. (Dow 1977; Loyn 1987; Higgins *et al.* 2001) and these were absent from the survey sites. Noisy Miners *M. melanocephala* prefer structurally simple treed habitats and are known to be disadvantaged by the presence of dense shrubs and small trees (Hastings & Beattie 2006). The nature of the plantings undertaken would not provide favourable habitat for the Noisy Miner, which does occur in the Piggoreet district. Other species that were recorded, notably Red Wattlebirds and smaller honeyeaters, can have similar effects to miners (Higgins *et al.* 2001; Loyn 2002). A monitoring program has been initiated to monitor bird abundance on this set of sites to document any further changes in abundance of honeyeaters, small insectivorous birds or other species. Three species of honeyeater were more numerous in the planted sites than in native forest. One of these (Red Wattlebird) has become one of the most common and conspicuous birds in suburban gardens, where it has been blamed for reducing numbers of small insectivorous birds. Another (New Holland Honeyeater) is primarily a bird of heathlands, heathy forest or locally in parks and gardens where it specialises at feeding on nectar of proteaceous plants (Emison *et al.* 1987; Higgins *et al.* 2001). Small numbers enter other forest types erratically to feed on prolific nectar sources, with mistletoe often being favoured (Loyn 1985). However, it is unlikely that native forest at the Sanctuary would have supported resident populations of this species at anywhere near the levels observed at the planted sites. If the management aim had been to re-establish natural vegetation with a natural bird fauna, it may have been necessary to reduce the plantings of proteaceous species or other plants attractive to this group of honeyeaters.

Woodland decliners: An opportunity to do more?

There has been concern expressed that revegetation in many cases is not arresting the declines in species that are most vulnerable to and have been most affected by habitat loss (Selwood *et al.* 2009), although this may be a function of the young age of much of the revegetation previously investigated (e.g. Kavanagh *et al.* 2007; Loyn *et al.* 2007; Barrett *et al.* 2008). For example, in an agricultural landscape in southern New South Wales, young plantings (<3 years old) of native trees and shrubs were rarely occupied by ground-foraging insectivores, and such species were considered to be slipping through the revegetation safety net (Barrett *et al.* 2008). The observation that ground-foraging insectivorous species (e.g. Restless Flycatcher, Jacky Winter, Scarlet Robin and Buff-rumped Thornbill) were commonly recorded at planted sites at Clarkesdale Bird Sanctuary provides some grounds for optimism that as recent or future plantings mature they may come to provide habitat requirements of ground-foraging insectivores (see Antos & Bennett 2006, 2008).

Many bird species typical of woodland or open-forest environments have declined substantially in south-eastern Australia in recent decades (Robinson 1993; Ford *et al.* 2001). These include four woodland species that have disappeared from the Sanctuary in historical times (Brown Treecreeper, Speckled Warbler, Hooded Robin and Diamond Firetail). All four species inhabit dry forests with an open understorey, although Speckled Warblers and Hooded Robins also make use of shrub thickets. It is tempting to speculate that all may have been associated with Valley Grassy Forest, the lost EVC at this location. The management efforts at the Clarkesdale Bird Sanctuary have not been targeted explicitly at these species. Any attempt to restore habitat for these birds would need to consider their detailed requirements (see Antos & Bennett 2006, 2008), including hollows and fallen timber for Brown Treecreepers, grass seed for Diamond Firetails, and open spaces among trees and shrubs for Hooded Robins. Some woodland birds remain at the Sanctuary despite declines elsewhere, and make use of planted sites (e.g. Restless Flycatcher and Jacky Winter). Both require open areas with scattered trees, and may benefit from deliberate planning to provide appropriate mixtures and configurations of trees, shrubs, open spaces and other habitat elements. Coarse woody debris is likely to be an important requirement for Restless Flycatchers, as they often search for spiders and insects among fallen branches (Higgins *et al.* 2006). Sustainable supplies of coarse woody debris are likely to increase as plantings mature, and to depend greatly on management of fire and other human interventions (Mac Nally *et al.* 2001). Specific attention to the needs of these species may be helpful in avoiding further species loss, or restoring habitat for these declining species. For example, where dense grass cover may deter species such as the Brown Treecreeper and Hooded Robin, managed grazing may provide a potential mechanism to reduce grass cover and increase habitat suitability.

We conclude that planting programs such as this one can contribute positively at least for some species, but a range of approaches over many spatial scales will be needed to provide for the complex needs of the full suite of species. An important general message is to emphasise the importance (and difficulty) of recognising the nature of original vegetation on a site, and the habitat features in greatest need of restoration in the broader landscape.

Acknowledgements

Funds were generously provided by the Woady Yaloak Catchment Project, through Cam Nicholson and the Clarkesdale Committee of Management. The fieldwork was assisted by volunteers Wallie Coles, Bob Hughes, Helen O'Donnell, Alisoun McBean and Lachlan McBean. Students from the University of Ballarat have assisted in subsequent surveys. Colin Barraclough (BOCA) and Ed McNabb (Arthur Rylah Institute) provided initial advice and information. Lindy Lumsden (ARI), Hugh Ford, Greg Lollback and Julia Hurley made valuable comments on a draft.

References

Anon. (1999), *Clarkesdale Bird Sanctuary Draft Management Plan*, facilitated by M. Henderson, Trust for Nature, Melbourne.

Antos, M.J. & Bennett, A.F. (2006), 'Foraging ecology of ground-feeding woodland birds in temperate woodlands of southern Australia', *Emu* **106**, 29–40.

Antos, M.J. & Bennett, A.F. (2008), 'Where exactly do ground-foraging woodland birds forage? Foraging sites and microhabitat selection in temperate woodlands in southern Australia', *Emu* **108**, 201–211.

Barrett, G.W., Freudenberger, D., Drew, A., Stol, J., Nicholls, A.O. & Cawsey, E.M. (2008), 'Colonisation of native tree and shrub plantings by woodland birds in an agricultural landscape', *Wildlife Research* **35**, 19–32.

Braithwaite, L.W., Turner, J. & Kelly, J. (1984), 'Studies on the arboreal marsupial fauna of eucalypt forests being harvested for wood pulp at Eden, NSW. 3: Relationships between faunal densities, eucalypt occurrence and foliage nutrients, and soil parent materials', *Australian Wildlife Research* **11**, 41–48.

Clarke, M.F. (1995), 'Co-operative breeding in Australian birds: A review of hypotheses and evidence', *Corella* **19**, 73–90.

Dorrough, J., Moxham, C., Turner, V. & Sutter, G. (2006), 'Soil phosphorus and tree cover modify the effects of livestock grazing on plant species richness in Australian grassy woodland', *Biological Conservation* **130**, 394–405.

Dow, D.D. (1977), 'Indiscriminate interspecific aggression leading to almost sole occupancy of space by a single species of bird', *Emu* **77**, 115–121.

Emison, W.B., Beardsell, C.M., Norman, F.I., Loyn, R.H. & Bennett, S.C. (1987), *Atlas of Victorian Birds*, Dept Conservation, Forests & Lands and Royal Australasian Ornithologists Union, Melbourne.

Ford, H.A. (1989), *Ecology of Birds: An Australian Perspective*, Surrey Beatty, Sydney.

Ford, H.A., Barrett, G.W., Saunders, D.A. & Recher, H.F. (2001), 'Why have birds in the woodlands of southern Australia declined?', *Biological Conservation* **97**, 71–88.

Gibbons, P., Lindenmayer, D.B., Barry, S.C. & Tanton, M.T. (2000), 'The formation of hollows in eucalypts from temperate forests', *Pacific Conservation Biology* **6**, 218–228.

Hastings, R.A. & Beattie, A.J. (2006), 'Stop the bullying in the corridors: Can including shrubs make your revegetation more Noisy Miner free?', *Ecological Management & Restoration* **7**, 105–112.

Higgins, P.J. & Peter, J.M. (Eds) (2002), *Handbook of Australian, New Zealand and Antarctic Birds*, vol. 6, Oxford University Press, Melbourne.

Higgins, P.J., Peter, J.M. & Cowling, S.J. (Eds) (2006), *Handbook of Australian, New Zealand and Antarctic Birds*, vol. 7, Oxford University Press, Melbourne.

Higgins, P.J., Peter, J.M. & Steele, W.K. (Eds) (2001), *Handbook of Australian, New Zealand and Antarctic Birds*, vol. 5, Oxford University Press, Melbourne.

Hobbs, R., Catling, P.C., Wombey, J.C., Clayton, M., Atkins, L. & Reid, A. (2003), 'Faunal use of Blue Gum (*Eucalyptus globulus*) plantations in southwestern Australia', *Agroforestry Systems* **58**, 195–212.

Jansen, A. (2005), 'Avian use of restoration plantings along a creek linking rainforest patches on the Atherton Tablelands, North Queensland', *Restoration Ecology* **13**, 275–283.

Jansen, A. & Robertson, A.I. (2001), 'Riparian bird communities in relation to land management practices in floodplain woodlands of southeastern Australia', *Biological Conservation* **100**, 173–185.

Kavanagh, R., Law, B., Lemckert, F., Stanton, M., Chidel, M., Brassil, T., Towerton, A. & Herring, M. (2005), *Biodiversity in Eucalypt Plantings Established to Reduce Salinity*, Joint Venture Agroforestry Program, Canberra.

Kavanagh, R.P., Stanton, M.A. & Herring, M.W. (2007), 'Eucalypt plantings on farms benefit woodland birds in south-eastern Australia', *Austral Ecology* **32**, 635–650.

Loyn, R.H. (1985), 'Ecology, distribution and density of birds in Victorian forests', pp. 33–46 in Keast, A., Recher, H.F., Ford, H.A. & Saunders, D. (Eds), *Birds of Eucalypt Forests and Woodlands: Ecology, Conservation and Management*, Surrey Beatty, Sydney.

Loyn, R.H. (1986), 'The 20 minute search — A simple method for counting forest birds', *Corella* **10**, 58–60.

Loyn, R.H. (1987), 'Effects of patch area and habitat on bird abundances, species numbers and tree health in fragmented Victorian forests', pp. 65–75 in Saunders, D.A., Arnold, G.W., Burbidge, A.A. & Hopkins, A.J.M. (Eds), *Nature Conservation: The Role of Remnants of Native Vegetation*, Surrey Beatty, Sydney.

Loyn, R.H. (1998), 'Birds in patches of old-growth ash forest, in a matrix of younger forest', *Pacific Conservation Biology* **4**, 111–121.
Loyn, R.H. (2002), 'Patterns of ecological segregation among forest and woodland birds in south-eastern Australia', *Ornithological Science* **1**, 7–27.
Loyn, R.H., McNabb, E.G., Macak, P. & Noble, P. (2007), 'Eucalypt plantations as habitat for birds on previously cleared farmland in south-eastern Australia', *Biological Conservation* **137**, 533–548.
Mackowski, C.M. (1984), 'The ontogeny of hollows in Blackbutt (*Eucalyptus pilularis*) and its relevance to the management of forests for possums, gliders and timber', pp. 553–567 in Smith, A.P. & Hume, I.D. (Eds), *Possums and Gliders*, Surrey Beatty, Sydney.
Mac Nally, R., Parkinson, A., Horrocks, G., Conole, L. & Tzaros, C. (2001), 'Relationships between terrestrial vertebrate diversity, abundance and availability of coarse woody debris on south-eastern Australian floodplains', *Biological Conservation* **99**, 191–205.
Mac Nally, R., Soderquist, T. & Tzaros, C.L. (2000), 'The conservation value of mesic gullies in dry woodland landscapes: Avian communities in the box-ironbark system of southern Australia', *Biological Conservation* **93**, 293–302.
Martin, W.K., Eyears-Chaddock, M., Wilson, B.R. & Lemon, J. (2004), 'The value of habitat reconstruction to birds at Gunnedah, New South Wales', *Emu* **104**, 177–189.
McIntyre, S., McIvor, J.G. & Heard, K.M. (2002), *Managing and Conserving Grassy Woodlands*, CSIRO, Melbourne.
Munro, N.T., Lindenmayer, D.B. & Fischer, J. (2007), 'Faunal response to revegetation in agricultural areas of Australia: A review', *Ecological Management & Restoration* **8**, 199–207.
Noske, R. (1985), 'Habitat use by three bark-foragers of eucalypt forests', pp. 193–204 in Keast, A., Recher, H.F., Ford, H.A. & Saunders, D. (Eds), *Birds of Eucalypt Forests and Woodlands: Ecology, Conservation and Management*, Surrey Beatty, Sydney.
Palmer, G.C. & Bennett, A.F. (2006), 'Riparian zones provide for distinct bird assemblages in forest mosaics of south-east Australia', *Biological Conservation* **130**, 447–457.
Recher, H.F. (1991), 'The conservation and management of eucalypt forest birds: Resource requirements for nesting and foraging', pp. 25–34 in Lunney, D. (Ed.), *Conservation of Australia's Forest Fauna*, Royal Zoological Society of NSW, Sydney.
Reid, R. & Wilson, G. (1985), *Agroforestry in Australia and New Zealand*, Goddard & Dobson, Box Hill, Vic.
Robinson, D. (1993), '*Valé* Toolern Vale: The loss of our woodland birds', *Wingspan* **9**, 1–3, 20–21.
Salt, D., Lindenmayer, D.B. & Hobbs, R.J. (2004), *Trees and Biodiversity: A Guide for Farm Forestry*, Rural Industries Research & Development Corporation, Canberra.
Selwood, K., Mac Nally, R. & Thomson, J. (2009), 'Native bird breeding in a chronosequence of revegetated sites', *Oecologia* **159**, 435–466.
Vesk, P.A. & Mac Nally, R. (2006), 'The clock is ticking – Revegetation and habitat for birds and arboreal mammals in rural landscapes of southern Australia', *Agriculture Ecosystems & Environment* **112**, 356–366.
Whitford, K.R. (2002), 'Hollows in Jarrah (*Eucalyptus marginata*) and Marri (*Corymbia calophylla*) trees. I: Hollow sizes, tree attributes and ages', *Forest Ecology & Management* **160**, 201–214.
Wormington, K. & Lamb, D. (1999), 'Tree hollow development in wet and dry sclerophyll eucalypt forest in south-east Queensland, Australia', *Australian Forestry* **62**, 336–345.
Youl, R., Marriott, S. & Nabben, T. (2006), *Landcare in Australia*, 5th edn, SILC.

Received 18 December 2008

Appendix 1

Bird species recorded during bird surveys at 27 sites and seven dates at Clarkesdale Bird Sanctuary, central-western Victoria, 1999–2001, with the guilds for feeding, nesting, migration, status and habitat to which they have been assigned. See p. 73 for key to guild codes.

Species	*Scientific name*	*Feed*	*Nest*	*Migr.*	*Status*	*Hab.*
Common Bronzewing	*Phaps chalcoptera*	SG	N	N	N	F
Purple Swamphen	*Porphyrio porphyrio*	W	G	N	N	W
Eurasian Coot	*Fulica atra*	W	G	N	N	W
Australasian Grebe	*Tachybaptus novaehollandiae*	W	G	N	N	W
Little Black Cormorant	*Phalacrocorax sulcirostris*	W	N	N	N	W
Little Pied Cormorant	*Microcarbo melanoleucos*	W	N	N	N	W
Masked Lapwing	*Vanellus miles*	OG	G	N	N	W
Black-fronted Dotterel	*Elseyornis melanops*	W	G	N	N	W
White-faced Heron	*Egretta novaehollandiae*	W	N	N	N	W
Black Swan	*Cygnus atratus*	W	G	N	N	W
Australian Shelduck	*Tadorna tadornoides*	W	G	N	N	W
Pacific Black Duck	*Anas superciliosa*	W	G	N	N	W
Swamp Harrier	*Circus approximans*	V	G	N	N	O
Brown Goshawk	*Accipiter fasciatus*	V	N	N	N	F
Wedge-tailed Eagle	*Aquila audax*	V	N	N	N	F
Whistling Kite	*Haliastur sphenurus*	V	N	N	N	O
Brown Falcon	*Falco berigora*	V	N	N	N	O
Yellow-tailed Black-Cockatoo	*Calyptorhynchus funereus*	ST	LH	N	N	F
Sulphur-crested Cockatoo	*Cacatua galerita*	SG	LH	N	N	O
Long-billed Corella	*Cacatua tenuirostris*	SG	LH	N	N	O
Galah	*Eolophus roseicapillus*	SG	LH	N	N	O
Crimson Rosella	*Platycercus elegans*	ST	LH	N	N	F
Eastern Rosella	*Platycercus eximius*	SG	LH	N	N	O
Blue-winged Parrot	*Neophema chrysostoma*	SG	SH	S	N	F
Laughing Kookaburra	*Dacelo novaeguineae*	V	LH	N	N	F
Sacred Kingfisher	*Todiramphus sanctus*	V	SH	S	N	F
White-throated Needletail	*Hirundapus caudacutus*	A	X	S	N	F
Pallid Cuckoo	*Cacomantis pallidus*	OT	BP	S	N	O
Fan-tailed Cuckoo	*Cacomantis flabelliformis*	M	BP	S	N	F
Horsfield's Bronze-Cuckoo	*Chalcites basalis*	C	BP	S	N	H
Shining Bronze-Cuckoo	*Chalcites lucidus*	C	BP	S	N	F
Welcome Swallow	*Hirundo neoxena*	A	L	N	N	O
Tree Martin	*Petrochelidon nigricans*	A	SH	S	N	F
Grey Fantail	*Rhipidura albiscapa*	C	N	S	N	F
Satin Flycatcher	*Myiagra cyanoleuca*	C	N	S	N	F
Restless Flycatcher	*Myiagra inquieta*	OT	N	N	N	F
Jacky Winter	*Microeca fascinans*	OT	N	N	N	F
Scarlet Robin	*Petroica boodang*	OT	N	N	N	F
Eastern Yellow Robin	*Eopsaltria australis*	DG	N	N	N	F

Appendix 1 continued

Species	*Scientific name*	*Feed*	*Nest*	*Migr.*	*Status*	*Hab.*
Golden Whistler	*Pachycephala pectoralis*	M	N	N	N	F
Rufous Whistler	*Pachycephala rufiventris*	C	N	S	N	F
Grey Shrike-thrush	*Colluricincla harmonica*	G	N	N	N	F
Magpie-lark	*Grallina cyanoleuca*	OG	N	N	N	O
Crested Shrike-tit	*Falcunculus frontatus*	B	N	N	N	F
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	C	N	S	N	F
White-winged Triller	*Lalage sueurii*	C	N	S	N	F
Striated Thornbill	*Acanthiza lineata*	C	N	N	N	F
Brown Thornbill	*Acanthiza pusilla*	M	N	N	N	F
Buff-rumped Thornbill	*Acanthiza reguloides*	OT	L	N	N	F
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	OG	N	N	N	O
White-browed Scrubwren	*Sericornis frontalis*	DG	N	N	N	F
Little Grassbird	*Megalurus gramineus*	W	N	N	N	W
Australian Reed-Warbler	*Acrocephalus australis*	W	N	S	N	W
Superb Fairy-wren	*Malurus cyaneus*	OT	N	N	N	F
Dusky Woodswallow	*Artamus cyanopterus*	A	L	S	N	F
Varied Sittella	*Daphoenositta chrysoptera*	B	N	N	N	F
White-throated Treecreeper	*Cormobates leucophaea*	B	SH	N	N	F
Red-browed Treecreeper	*Climacteris erythrops*	B	SH	N	N	F
Mistletoebird	*Dicaeum hirundinaceum*	F	N	N	N	F
Spotted Pardalote	*Pardalotus punctatus*	C	B	N	N	F
Striated Pardalote	*Pardalotus striatus*	C	SH	N	N	F
Silvereye	*Zosterops lateralis*	F	N	S	N	F
White-naped Honeyeater	*Melithreptus lunatus*	N	N	N	N	F
Brown-headed Honeyeater	*Melithreptus brevirostris*	N	N	N	N	F
Eastern Spinebill	*Acanthorhynchus tenuirostris*	N	N	N	N	F
Yellow-faced Honeyeater	*Lichenostomus chrysops*	N	N	S	N	F
White-eared Honeyeater	*Lichenostomus leucotis*	N	N	N	N	F
New Holland Honeyeater	*Phylidonyris novaehollandiae*	N	N	N	N	H
Red Wattlebird	*Anthochaera carunculata*	N	N	N	N	F
Red-browed Finch	*Neochmia temporalis*	SG	N	N	N	F
White-winged Chough	*Corcorax melanorhamphos*	OT	N	N	N	F
Grey Currawong	*Strepera versicolor*	DG	N	N	N	F
Australian Magpie	*Cracticus tibicen*	OG	N	N	N	O
Bassian Thrush	*Zoothera lunulata*	DG	N	N	N	F
Common Blackbird	*Turdus merula*	DG	N	N	I	F
Australian Raven	*Corvus coronoides*	V	N	N	N	F
Little Raven	*Corvus mellori*	V	N	N	N	O
European Goldfinch	*Carduelis carduelis*	SG	N	N	I	O
Common Starling	*Sturnus vulgaris*	OG	SH	N	I	O

Key to guild codes

Feeding guilds

Insectivores taking insects mainly from open air (A), bark (B), tree-canopy (C), damp ground below shrubs or low understorey (DG), generally broad range of substrates (G), tall shrubs (i.e. mid-storey insectivores: M), open ground among trees (OT) or open ground often not among trees (OG).
Nectarivores taking nectar as a major part of their diet (N).
Frugivores taking fruit as a major part of their diet (F).
Seed-eaters taking small seeds close to the ground (SG) or feeding on seed and other food (e.g. gall insects) at all levels (ST).
Carnivores taking vertebrate prey as a major part of their diet (V).
Waterbirds (W).

Nesting guilds

Brood-parasites (BP); species nesting in burrows (B), on the ground (G), on ledges (L), in large or medium-sized hollows in trees (LH), in small hollows in trees (SH) or in 'normal' situations among branches of trees or shrubs (N). Migratory species that do not nest in Australia are marked X.

Migratory status

Summer visitors (S) are rare or absent from these forests for a predictable period each winter. Others are classed as non-migratory (N), although portions of the population may migrate or move nomadically. (Grey Fantail is an intermediate case, and was classed as a summer migrant for this analysis.)

Status

Species that were introduced to Australia (I) or native (N).

Habitat

Forest or woodland birds (F); heathland birds (H); open-country birds (O); or waterbirds (W).

Appendix 2

Mean abundances (birds per 10 counts) of bird species, and mean numbers of species per count, in three main habitats at the Clarkesdale Bird Sanctuary, central-western Victoria, 1999–2001. Waterbirds are excluded unless observed on sites away from small dams. Probability *P* values are shown where $P < 0.1$, bracketed if $0.1 > P > 0.05$. Species are marked – where data were too sparse or skewed for useful statistical comparisons between native forest on ridges and slopes and planted sites on similar topography, NS if differences were not significant ($P > 0.1$).

Species	*Broad habitat*	*P value*	*Mean birds per 10 counts*		
		Native forest vs planted sites on similar topography	*Native forest*	*Planted sites on similar topography*	*Planted river-flats and gully*
Number of sites:			**11**	**13**	**3**
Common Bronzewing		NS	0.3	1.1	1.0
Purple Swamphen		–	0	0	0.5
White-faced Heron		–	0.1	0	1.9
Australian Shelduck		–	0	0.2	0
Swamp Harrier		–	0	0	0.5

Appendix 2 continued

Species	*P value*	*Mean birds per 10 counts*		
Broad habitat	*Native forest vs planted sites on similar topography*	*Native forest*	*Planted sites on similar topography*	*Planted river-flats and gully*
Brown Goshawk	–	0.1	0.1	0
Wedge-tailed Eagle	–	0.1	0	0
Whistling Kite	–	0	0.1	0
Brown Falcon	–	0	0.1	0
Yellow-tailed Black-Cockatoo	NS	0.5	1.2	3.3
Sulphur-crested Cockatoo	NS	0.5	0.1	0.5
Long-billed Corella	NS	0.4	0	2.9
Galah	–	0	0.2	1.0
Crimson Rosella	NS	4.8	5.7	6.2
Eastern Rosella	NS	0.6	0.9	2.9
Blue-winged Parrot	NS	0.6	0.9	0
Laughing Kookaburra	–	0.1	0.3	0
Sacred Kingfisher	–	0.6	0.1	1.4
White-throated Needletail	–	0	0.9	0
Pallid Cuckoo	–	0.1	0.5	0
Fan-tailed Cuckoo	–	0	0.4	0
Horsfield's Bronze-Cuckoo	–	0	0.2	0
Shining Bronze-Cuckoo	–	0.4	0.2	0.5
Welcome Swallow	NS	1.3	0.2	1.9
Tree Martin	–	0	0.7	18.1
Grey Fantail	NS	5.5	5.1	9.0
Satin Flycatcher	–	0.4	0.2	1.0
Restless Flycatcher	NS	0.4	0.9	1.4
Jacky Winter	NS	1.0	1.3	0.5
Scarlet Robin	NS	1.0	0.3	0.5
Eastern Yellow Robin	NS	1.3	3.5	2.9
Golden Whistler	NS	0.8	1.5	1.9
Rufous Whistler	NS	2.3	2.4	4.3
Grey Shrike-thrush	NS	2.9	2.1	1.4
Magpie-lark[a]	–	0.3	0	0
Crested Shrike-tit	–	0.1	0.3	0
Black-faced Cuckoo-shrike	NS	0.8	0	0
White-winged Triller	–	0	0.1	0
Striated Thornbill	NS	4.2	2.9	7.6
Brown Thornbill	NS	3.5	5.4	4.8
Buff-rumped Thornbill	NS	0.9	1.4	1.0
Yellow-rumped Thornbill	NS	0.9	2.7	0
White-browed Scrubwren	(0.086)	1.6	4.1	8.6
Little Grassbird	–	0	0	0.5

Appendix 2 continued

Species	*Broad habitat*	*P value*	*Mean birds per 10 counts*		
		Native forest vs planted sites on similar topography	*Native forest*	*Planted sites on similar topography*	*Planted river-flats and gully*
Australian Reed-Warbler		–	0	0	0.5
Superb Fairy-wren		0.001	3.8	17.4	23.8
Dusky Woodswallow		NS	0.8	0.7	1.0
Varied Sittella		–	0	0.5	0
White-throated Treecreeper		0.031	4.2	2.2	2.4
Red-browed Treecreeper		–	0.1	0	0.5
Mistletoebird		–	0.3	0	0
Spotted Pardalote		0.037	2.3	0.5	0.5
Striated Pardalote		NS	2.1	1.0	2.4
Silvereye[b]		–	0.1	0	0
White-naped Honeyeater		NS	17.5	18.0	20.0
Brown-headed Honeyeater		NS	2.3	1.9	3.3
Eastern Spinebill		(0.068)	0.6	2.2	1.9
Yellow-faced Honeyeater		NS	3.0	4.2	0.5
White-eared Honeyeater		NS	1.7	1.2	0
New Holland Honeyeater		0.006	1.7	31.3	31.0
Red Wattlebird		0.031	1.0	10.5	8.1
Red-browed Finch		NS	0	1.8	1.0
White-winged Chough		–	6.5	0.5	0
Grey Currawong		NS	0.9	0.5	0.5
Australian Magpie		0.023	0.9	4.7	1.9
Bassian Thrush		–	0	0.2	0
Common Blackbird		NS	0.4	1.4	1.9
Australian Raven		0.038	0.1	1.0	1.0
Little Raven		NS	0.4	1.0	0.5
European Goldfinch		–	0	0.2	1.4
Common Starling		–	0	0.1	0.5
Total (including all waterbirds)			89.4	151.8	202.9
Total (excluding all waterbirds)			89.3	151.6	186.7
Introduced birds			0.4	1.7	3.8
Introduced as %			0.4	1.1	1.9
Bird species per count:			**4.3**	**6.0**	**8.1**

[a]Magpie-larks usually inhabit treed farmland and open woodland on river-flats, and avoid extensive areas of forest. The few records in this study happened to come from native forest.

[b]Flocks of Silvereyes often move into artificial habitats (including gardens and orchards) to feed on fruit, nectar or insects. They were remarkably rare during this study, and could be expected to occur erratically in planted sites when suitable foods are available. ■

AUSTRALIAN FIELD ORNITHOLOGY 2009, **26**, 76–99

Aspects of the Breeding Cycle of the Little Eagle *Hieraaetus morphnoides*

S.J.S. DEBUS[1] and A.J. LEY[2]

[1]Zoology, University of New England, Armidale, New South Wales 2351
(Email: sdebus@une.edu.au)
[2]19 Lynches Road, Armidale, New South Wales 2350

Summary

The breeding biology and behaviour of the Little Eagle *Hieraaetus morphnoides* were studied throughout 82 hours of observation from the incubation and nestling periods (three nests) to independence of juveniles (n = four families) at Armidale, on the Northern Tablelands of New South Wales, in spring–summer 2008–09. Incubation commenced in September (two clutches), and fledging occurred from mid to late December (four broods). At two nests, incubation (by both parents, but mostly by the female) lasted >35 days and 38–39 days, respectively. At three nests, females performed most of the parental care, but males shared the brooding or feeding of small chicks. The nestling period at three nests lasted 53–54 days, 58 ± 1 days and ~63 days, respectively. Breeding productivity was 0.86 young per occupied territory in 2008, and 0.67 young/pair/year in 15 pair-years 2006–08. The post-fledging dependence period lasted a minimum of 58–64 days (n = 3).

Introduction

Most aspects of the breeding cycle of the Little Eagle *Hieraaetus morphnoides* have been described in some detail, in terms of adult behaviour, nestling development, quantification of sex-roles, and the duration of the various phases (cf. Marchant & Higgins 1993; Debus *et al.* 2007a). However, there have been few determinations of the nestling and post-fledging periods, little quantification of parental sex-roles in either of these phases, and little information on juvenile development and independence in the post-fledging period. Previous observations on the post-fledging period have been fragmentary (cf. Debus 1984a,b, 1991, 2008; Bollen 1989, 1991).

This paper describes parts of the breeding cycle of four families of Little Eagles in the New England region of New South Wales in spring–summer 2008–09, in order to redress gaps in a previous study (Debus *et al.* 2007a), particularly for the nestling and post-fledging periods. There is still a need for natural-history information on the species, e.g. a full, quantified description of its entire life cycle, as a basis for understanding its ecology and decline in southern Australia (cf. Olsen & Fuentes 2005; Olsen & Osgood 2006; Olsen *et al.* 2008, 2009). We also examine evidence for a possible decline in the Little Eagle population in New England, because atlas sighting data may not match trends in nest-site occupancy and productivity (Olsen & Fuentes 2005).

Study area and methods

The study area, and observation and analytical methods, at Armidale (30°30′S, 151°40′E) on the Northern Tablelands of NSW, were as previously described (Debus *et al.* 2007a,b). Pairs 1–4 are coded as in the 2006 study of the same pairs of Little Eagles (Debus *et al.* 2007a), and inferences about sex-roles and events in the breeding cycle are also as for that study. An additional pair (Pair 5) was found with a nest in February 2008, and monitored from late in the incubation period in spring 2008. A juvenile of a further pair (Pair 6) was found by an informant at the fledging stage in 2008 and monitored thereafter. In Pair 6, the male was a light morph and the female a dark morph (i.e. the male and female could be readily distinguished in the field).

Pairs 1 and 2 were observed from the incubation period onwards, until death (Pair 1) or independence (Pair 2) of the juvenile. Pair 4 was monitored opportunistically during the first month of the post-fledging period. The Pair 5 female usually did not tolerate watching from the maximal unobstructed viewing distance (~60 m), so the nest was usually avoided until the late nestling period, then monitored from the fledgling's 'branching' stage until independence. Pair 6 was observed from week 7 of the post-fledging period until independence.

The incubation periods of Pairs 1 and 2 were observed by SD and AJL in rotation for a total of ~9 h over 13 days, mostly in the mornings and almost daily towards the end, to pinpoint hatching dates. Nest-watches were usually of 25–30 minutes (once 90 minutes). The nestling periods of Pairs 1 and 2 (SD) and Pair 5 (AJL) were observed for a total of ~18 h over 17 days, mostly in the mornings, and mostly in the early weeks, declining to checks only (on 15 days by SD, daily in the later stages), to pinpoint fledging dates. Nest-watches were usually of 30 or 60 minutes (occasionally 15–20 or 40–45 minutes).

The post-fledging period was observed by SD, again mostly in the mornings, mainly because juveniles were much easier to locate before or soon after weather permitted soaring, and before they were fed (i.e. still hungry and begging loudly, which also maximised the chance of observing prey deliveries). Attempts were made to monitor at least one fledgling per day, or each of the fledglings about every 3 days (with occasional lapses of a few days), switching from Pair 1 (after that fledgling was found dead) to Pair 6 after the juvenile and nest became known. The post-fledging periods of these four pairs were observed for a total of 55 h over 55 days, in watches usually of ~1 h (sometimes 30 or 90 minutes). During week 6 after fledging, the juvenile of Pair 6 was caught accidentally, in a landholder's fox trap (mesh cage), banded, and released at the nest-site (band supplied by the Australian Bird and Bat Banding Scheme). Because fledging dates were staggered, and the Pair 6 juvenile was the last to fledge, this fledgling was monitored almost daily in its last fortnight of dependence; local landholders also reported on its presence. Observations ceased in the juveniles' natal territories when the birds could not be located on 3–6 days over 2–3 weeks since the last sighting, during searches of 30–60 minutes each, and landholders had not seen the Pair 6 juvenile for a week. Opportunistic checks for the Pair 2 juvenile continued for a further month after it was last seen to be dependent.

The juveniles are identified hereafter by their natal territory (i.e. J1 = offspring of Pair 1, J2 of Pair 2, etc.), as there was only one fledgling per territory. Eaglets were sexed by size at fledging relative to their parents and, in the case of J6, by size in the hand, body weight (1005 g) and required band size (13) ~6 weeks after fledging. Some juveniles were individually recognisable: by a slight notch in the tail-tip (J5), or by the fact that J6 was the only dark-morph juvenile in the study area in 2008–09. J6 was assumed to have fledged around the midpoint between when it was seen still in the nest at the fledging stage (25 December) and the latest local fledging date known for this species (3 January: Debus 1984a), i.e. ~30 December. Observation sessions throughout the Eagles' breeding cycle were essentially opportunistic, rather than systematic.

Results

Eagle population

The four territories monitored around Armidale in 2006 (Debus *et al.* 2007a) were still occupied in 2008, with the exception that the light-morph male of Pair 3 was replaced sometime between July (when he was last seen) and early October 2008 by a dark-morph male. In 2007 and 2008 the female of Pair 3 was absent, and in 2008 a pair of Brown Goshawks *Accipiter fasciatus* used the Eagles' 2006 nest. In addition, territory 5 (not checked since the 1980s) was confirmed as still occupied, though with a new nest-site on the same hill, and the 'Pine Forest' male was confirmed as having a mate and nest (= Pair 6), now ~1.5 km east of the forest. His neighbour, the dark-morph male with whom he had territorial disputes in 2006 and which was assumed to be unpaired in 2006, also bred in 2008 (i.e. Pair 7), and there was another pair to the north of Pair 6 (i.e. Pair 8, whose nest was checked in 2006).

The Little Eagle territory neighbouring Pair 4 (in north Imbota Nature Reserve, = former Pair 9) was not re-occupied in 2008, even though Wedge-tailed Eagles *Aquila audax* (which may exclude Little Eagles) did not use their nest in north Imbota in 2007 or 2008 (cf. Debus *et al.* 2007b). The Little Eagle territory between north Imbota and Armidale city (= former Pair 10; only the male present in 2006) was vacant in 2008, since houses had been built on a subdivision (4 × 2-ha blocks), and the pine woodlot adjoining the former nest-site had been logged. The dark male of former territory 10 may have been the dark male that moved into vacant territory 3 (4 km away). Thus, within a semicircle of radius 10 km (i.e. 150 km^2) centred on Armidale there were 10 identified potential Little Eagle territories in the mid 2000s (Figure 1), of which two were vacant and one was occupied by a lone male in 2008 (i.e. seven pairs with nests). That is, not all territories may be occupied, or not all of the pairs may breed, in a given year.

The female of Pair 1 was the same female in 2008 as in 2006: in 2008 she still had the same bent secondary feather, which was by then very worn and over 2 years old, having not been shed in the 2007 or 2008 summer/autumn moults (thus also confirming incomplete annual wing-moult in this species). Her mate appeared to be the same well-marked male as in 2006, and Pair 2 also appeared to be the same adults as in 2006, on the basis of their behaviour and routines.

Eight Little Eagles passing through the local (Armidale) wildlife carers' network in the 1990s were mostly road-injured birds: four juvenile males, two juvenile females (one of which had struck a mesh fence) and two adult females. By contrast, only two passed through care in the 2000s (apart from the rescued chick discussed by Debus *et al.* 2007a): an adult female (road-injured), and the accidentally trapped juvenile female from Pair 6. This trend suggests a decline in the number of fledglings being produced, and possibly in the Eagle population.

Home-range

The adults of Pair 2 were seen foraging at least 1 km north and west of their nest, and >0.5 km south-east of the nest. The male of Pair 3 was seen foraging 1.8 km south-west of his nest, and at least 0.5 km north of the nest where he would have abutted or overlapped the home-range of Pair 2. The adults of Pair 5 were seen foraging 1.5 km south-east of the nest, and >0.5 km north and west of the nest. The adults of Pair 6 were seen foraging 1.3 km west and north-west of their nest, and (male) 2.3 km south-west of the nest. The dark male of Pair 7 was seen foraging and displaying over an area of ~2.5 × 1 km (~250 ha) that partly overlapped with the hunting range of the Pair 6 male. The male of Pair 8 was seen ~1.3 km south of his nest, interacting with the Pair 6 juvenile where the respective home-ranges abutted.

Neighbouring active nests were 2 km apart (Pairs 2 and 3), and 2.3 km apart (Pairs 6 and 8). The nests of Pairs 3 and 6 were 4 km apart, separated by the nest of Pair 7 (which was not found, but produced a juvenile in 2008). The nests of neighbouring Pairs 4 and 9 had been ~1.9 km apart, in opposite ends of the reserve. The neighbouring nests of former Pairs 9 and 10, and of Pairs 3 and 10, had been 4 km

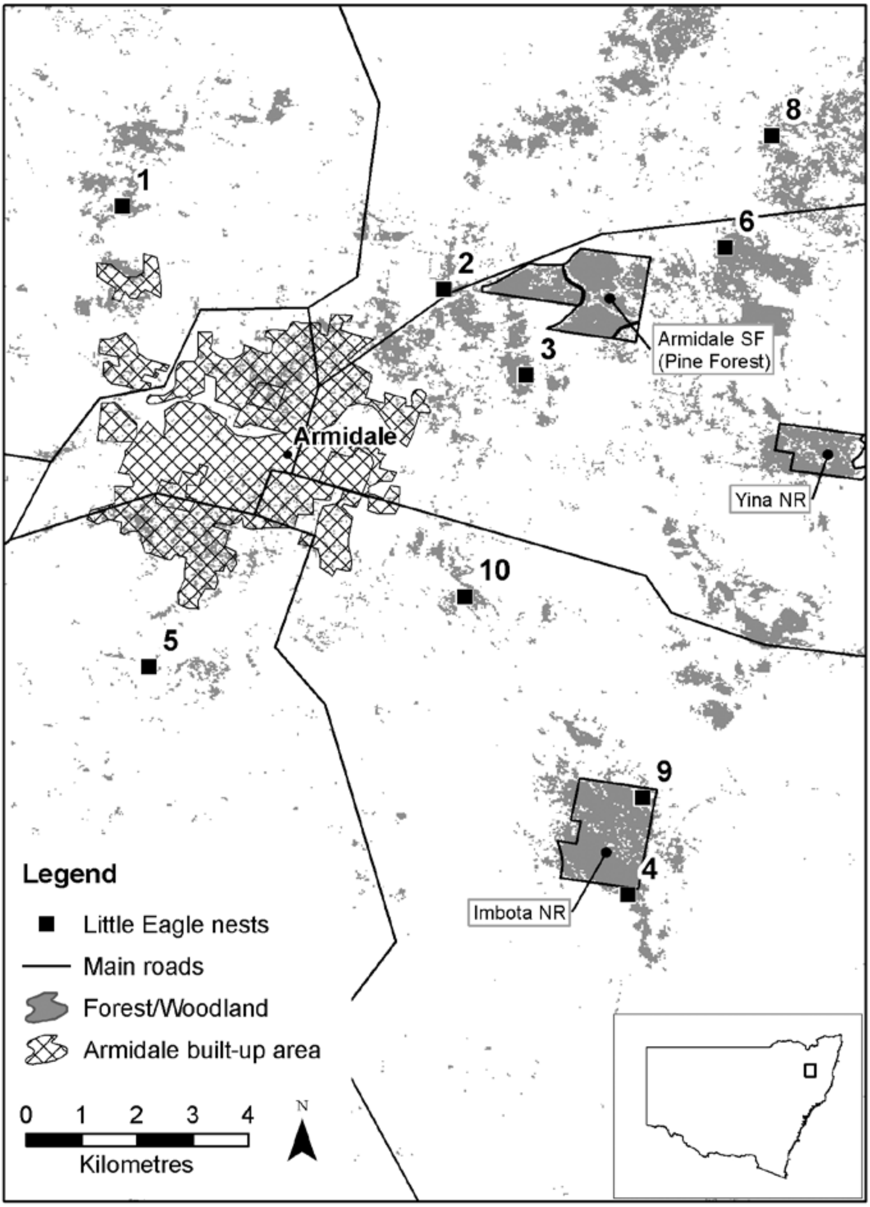


Figure 1. Map of study area (Armidale, NSW) showing tree cover, locations mentioned in text, and nest-sites of Little Eagle pairs (numbered as in text).

Map: Martin Dillon

Juvenile Little Eagle (light morph) in flight

Plate 13 Photo: David Whelan

Little Eagle (dark morph) in flight

Plate 14 Photo: David Whelan

Wild juvenile Little Eagle (light morph) feeding on road-killed Rabbit against fence

Plate 15 Photo: David Whelan

apart; and those of presumed neighbours, Pairs 5 and 10, had been 5 km apart. Thus, inter-nest distances ranged between ~2 and 5 km (Figure 1).

Nest-sites

Pairs 1 and 2 used the same nest-sites as in 2006 and 2007 (cf. Debus *et al.* 2007a; Debus 2008). Pair 4 used a different nest-site in 2007 and 2008, in contiguous eucalypt woodland on private land ~500 m south-east of the 2006 nest, but not accessible for study. Pairs 5 and 6 also nested in live eucalypts in eucalypt woodland (Table 1): Pair 5 used the same nest as in 2007, and Pair 6 had used the 2008 nest also from 2005 to 2007 (D. Breen pers. comm.).

Combining data in this study (Table 1) with data for 2006 (Debus *et al.* 2007a) gives the following nest-site measurements: tree height 19–25 m (mean 22 m),

Table 1: Nest-site characteristics of Little Eagle nests at Armidale, NSW, 2008, additional to those studied by Debus *et al.* 2007a: characteristics of nest-tree and position of nest (nest numbers follow the sequence of Debus *et al.* 2007a). For tree species, 1 = Manna Gum *Eucalyptus viminalis*; 2 = Apple Box *E. bridgesiana*; dbh = diameter at breast height; nest height = height of nest above ground.

Pair/nest	*Tree species*	*Tree height (m)*	*Tree dbh (cm)*	*Nest height (m)*	*Position*
5	1	19	36	14	NW slope, flank of minor gully
6	2	25	102	17	SW slope, flank of minor gully

nest-tree diameter at breast height 36–102 cm (mean 69 cm), and height of nest above ground 14–20 m (mean 15 m; n = 6).

Breeding chronology

Pairs 1 and 2 were found incubating on 29 September and 14 September, respectively. Hatching occurred around 2 November and 24 October, respectively, and the single juveniles fledged on 30 December and 16 December, respectively. Pair 5 apparently hatched a chick on 21 October, and it fledged on 23 December. The Pair 6 juvenile was in the nest, at the fledging stage, on 25 December (D. Breen pers. comm.), and thus fledged around the same time as Pair 1 (assumed here to be the same date).

Reaction to disturbance

The Pair 2 female usually tolerated observation at the viewing distance accepted in 2006 (140 m, cf. Debus *et al.* 2007a), but in 2008 she occasionally left the nest (flushed?) during the incubation and nestling periods as the observer's vehicle approached the viewing point. On one occasion (week 6 of the nestling period) she appeared reluctant to approach the nest with prey while observers were at the viewing point (so the observers left).

The Pair 5 female usually flushed off the egg(s) or chick when the observer approached within unobstructed viewing distance (~60 m), and gave a squealing alarm call. Even though the male was less wary and sometimes took her place on the nest, observations were usually aborted if she flushed. The secluded nest was ~150 m, ~200 m and ~250 m, respectively, from three occupied rural-residential houses in different directions, but out of direct line of sight.

The nest of Pair 6 was ~140 m from the nearest occupied house/shed complex, which was in direct line of sight of the nest, but over a property boundary, so that the nest was secluded from close human activity.

Incubation

At nests 1 and 2, both parents shared daytime incubation. At nest 1, the eggs were covered for 91% of observation time (5 h), the nest was unattended for 8% (for 2–13 min.), and the female was on the nest-branch, beside the nest, for 1%. Where the sexes could be distinguished, the female sat for 77% of observed incubation time (1.9 h), and the male for 23%. The male incubated for one stint of 12 minutes and one for >14 minutes. At nest 2, the eggs were covered for 97% of observation time (4 h), the nest was unattended for 3% (for 1–5 min.), and the female was standing on the nest for <1%. Where the sexes could be distinguished, the female sat for 75% of observed incubation time (1.9 h), and the male for 25%. The male incubated for one stint of 28 minutes, and it was probably the female that incubated for one stint of >90 minutes.

During one stint and changeover at nest 1, the male went to the unattended nest and incubated until the female arrived on the nest-branch, piping softly ('clucking'), and he left before she settled to incubate. During another changeover, the incubating male called (two-note) while peering up, then left apparently to challenge an intruding conspecific; the female, which had been piping and three-note calling in the trees, then arrived on the nest-branch, piping, before settling to incubate. As each adult had a full crop, it appeared that the male had delivered food and relieved the female while she ate. Similarly, on one occasion at nest 2 the male went to the unattended nest and incubated until the female arrived in the nest-tree, piping; as she moved to the nest, he left, then she settled.

At nest 1, incubation from before 29 September to hatching on 2 November ± 1 day gave an incubation period of >35 days. At nest 2, incubation from 14 September to hatching on 23 or 24 October gave a minimum incubation period of 38 or 39 days.

Nestling period: parental behaviour

Although data were sketchy, particularly after week 1, at nests 1 and 2 it appeared that daytime parental care and attendance declined, from mostly brooding in week 1 to the female mostly standing on the nest in weeks 2–5 (though sometimes brooding up to week 5 in cool or stormy conditions), to the nest being mostly unattended from week 6 onwards (though the female sometimes stood on the nest or soared over) (Table 2). Parental absences (excluding those possibly observer-induced) ranged from 1–23 minutes in week 1 (n = 2), to 13–34 minutes in week 2 (n = 2), 26 minutes in week 3 (n = 1), >45 minutes in week 4 (n = 1), and >30 minutes in week 6 (n = 1). Parental feeding of chicks, bill to bill, continued until at least week 5 and possibly into week 6 (Table 3). A female sometimes shaded her chick (weeks 1, 2 and 4), usually by standing with her back to the sun so that her shadow fell on the chick, but once (week 1) also by partly spreading her wings. These trends in parental attendance apparently parallelled the growing and feathering chicks' ability to thermoregulate (cf. Table 4).

At nest 2, the male brooded for one stint of 5 minutes in week 1, after delivering prey in the female's absence; when she arrived to feed the chick, the adults touched bills before he left. At nest 5 in week 1, when the female flushed off the nest, the male arrived and fed on prey that was already on the nest, and appeared to feed the chick, before brooding for 20 minutes until the female returned, whereupon he left and she settled.

In week 1, the male of Pair 1 food-called (soft two-note call) in the nest area, then took the prey to the nest, billed the female's nape, then left as she remained brooding; later she removed old prey remains (a stripped hindleg of a Rabbit *Oryctolagus cuniculus*) and dumped them among the trees in the nest-stand, then returned with greenery (at 1010 h). In week 2, the male arrived food-calling (piping) in the trees, dropped prey on the nest (where the female was standing), and left. At nest 2 in week 2, in the female's absence, the male delivered prey to the nest and tore at it for 3 minutes until the female arrived, calling, to feed the chick, and he left. At nest 2 there was fresh greenery on the nest in week 2 (day 12, by 0815 h) and week 4 (day 22).

At nest 1, the only two observed prey deliveries (in weeks 1 and 2) were by the male. At nest 2, the male made two observed prey deliveries (in weeks 1 and 5), and the female made one (in week 6, day 38).

Few data were obtained, but there was some indication that the duration of parental feeding sessions, and the size of the nestlings' meals, increased as the nestling grew (Table 3).

At nest 1 in week 2, towards sunset, the male roosted in a live eucalypt in the nest-stand (within ~50 m of the nest). At nest 2 in week 4, towards sunset, the male roosted on the branch of a live eucalypt next to the nest-tree, while the female remained on the nest.

Table 2

Parental activity at Little Eagle nests, Armidale, NSW, in the nestling period, October–December 2008 (nests 1 and 2 of Debus *et al.* 2007: see text). F = female, M = male parent.

Week	*Comments*
1	Nest 1: F brooded for 79% of observation time (total 3.5 h, spread through the day) and stood on the nest for 10%; M stood on the nest for <1%; nest unattended for 11% (in mid/late morning).
	Nest 2: M brooded (mid morning) for 13% of observation time (40 min.); F stood on the nest (late morning) for 75%; nest unattended for 13%.
2	Nest 1: on day 8, during a late-afternoon check, F was brooding; on days 13–14 (late afternoon and mid morning) F stood on the nest for 83% of observation time (75 min.), nest unattended for 17%.
	Nest 2: F brooded (day 12, late afternoon) for 1% of observation time (2.5 h), and perched in the nest-tree for 16%; nest unattended for 23%. For the remainder (days 12–13, mid morning), F may have been flushed (and stayed off) for 20%, and may have been perched in the nest-tree, but not visible from the viewing point, for 40%.
3	Nest 1 (mid morning, day 20): F stood on the nest for 13% of observation time (30 min.); nest unattended for 87%.
	Nest 2 (late afternoon, day 17): during a check of 15 minutes, F soared over the nest area.
4	Nest 1 (late afternoon, day 28): during a check of 15 minutes, F brooded the large, feathering chick during a storm.
	Nest 2 (days 22–23): F stood on the nest (late afternoon) for 67% of observation time (135 min.), in one case for >60 minutes with her shadow falling on the chick; nest unattended for 33% (mid morning).
5	Nest 1: no data.
	Nest 2 (day 29): F brooded the large, feathering downy chick (in mid morning) for 60% of observation time (70 min.), and stood on the nest (in late morning) for 28%; M stood on the nest for 4%; nest unattended for 8%.
6	Nest 1: during a 30-minute watch (day 36, late morning) the nest was unattended; during a check on day 39 (late afternoon) F was standing on the nest, apparently having fed the chick, but left (possibly flushed?)[a].
	Nest 2 (mid morning, day 38): during a 40-minute watch the nest was unattended, but for the final 28 minutes F soared over the nest area with prey in her foot (possibly reluctant to land on the nest while observers present).
7	Nest 2 (mid morning, days 45 and 49): nest unattended for total observation time (35 min.), but for 15 minutes (day 49) F soared over the nest area.
8	Nest 2 (mid morning, day 53): check only, nest unattended.

[a]During checks only in weeks 7–9 (on 5, 3 and 2 days, respectively), across all 2-hr periods of the day, nest 1 was always unattended.

Nestling period: development of young

Eaglets were downy for their first 4 weeks, with remiges emerging in week 3 and rectrices in week 4; from week 4, feathers gradually appeared dorsally, then ventrally, then finally on the head (week 6), until by 7 weeks old they were mostly feathered with some down still on the forehead and throat. Down persisted on the underwings until fledging in week 8 or 9, when the primaries and tail were still incompletely grown (Table 4).

Table 3

Parental feeding of Little Eagle nestlings, Armidale, NSW, October–December 2008 (nests 1 and 2 of Debus *et al.* 2007 and nest 5: see text): chicks' meal sizes and morsel consumption rates. All feeding by female parent.

Week/day	*Nest no.*	*Length of parental feeding bout*	*No. morsels taken by chick*
1/1	2	>5 min.	No data
2/14	1	5 min./pause/4 min. (total 9 min.)	31 pieces in 5 min. (= 6.2 pieces/min.); pause of 13 min.; then 16 pieces in 4 min. (= 4.0 pieces/min.)
3/16	5	>7 min.	No data
5/29	2	14 min.	~80 pieces in 14 min. (= 5.7 pieces/min.)

Eaglets could stand, totter around the nest, flap their wings and defaecate over the nest-rim late in week 2, by which stage they were alert and pecked at objects in the nest. In week 3, one pecked at (and took small pieces from) a food item in the nest. From week 4 they increased in competence, until in week 7 they flapped in the breeze or jumped and flapped between the nest and nest-branch. In week 8, they ventured to branches (i.e. 'branched') in the nest-tree 2–3 days before fledging (Table 4).

At nest 1, hatching on 2 November ± 1 day to fledging on 30 December gave a nestling period of 58 ± 1 days for this female eaglet. At nest 2, hatching on 23 or 24 October to fledging on 16 December gave a nestling period of 53 or 54 days for this male eaglet, but fledging may have been slightly premature during a minor mishap at the 'branching' stage. This juvenile was not seen 'branching', and the structure of the nest mistletoe and surrounding branches could have made the eaglet lose its footing and become airborne accidentally. In support of this interpretation, this fledgling took a few days longer than the others to reach the free-flying and soaring stage (see below and Appendix 1). At nest 5, apparent hatching by 21 October to fledging on 23 December gave a minimum nestling period of 63 days for this male eaglet, which was an adventurous 'brancher' over the preceding 2 days (i.e. from 61 days old: Table 4).

Fledging

On its last 3 days at the nest, Juvenile 1 (= J1) was either perched on the nest-branch or (once) lying in the nest. On the morning of its fledging day it was perched in the next tree, ~30 m away, in the absence of its parents. Over its last week before fledging, J2 was either standing or (once) lying on the nest. On the morning of its fledging day it was piping softly in the dense woodland canopy <50 m away, as the female (with full crop) arrived in the nest-tree with prey, perhaps expecting the juvenile to be in the nest. (At this point, searching for the eaglet was aborted, to avoid disturbance, so it was not determined where the food transfer took place). On its last 2 days before fledging, J5 'branched' to 1.5 m, in different directions. On the morning of its fledging day it was in the next tree, ~15 m away, in the absence of its parents. There was no indication that adults used enticement behaviour to encourage their young to fledge; rather, they continued to bring food to the nest over the following days (see below and Appendix 1).

Table 4

Growth and development of nestling Little Eagles, Armidale, NSW, October–December 2008 (nests 1, 2 and 5 and correspondingly J1, J2 and J5: see text). F = female parent, M = male parent, J = juvenile.

Week	*Day*	*Comments*
1	4	J1: small and downy (rusty-tinged first down), dark eye-rings, cream cere; moving on nest.
	5	Nest 2: two chicks visible.
2	12	J2 (single surviving chick): downy, white with dark eye-rings; cere and gape creamy yellow. Stood up, tottered and flapped wings; defaecated over nest-rim. Alert, peering, pecked in nest, preened.
3	15	J1: in white second down.
	20	J1: downy with remex and scapular pins. Active, flapped wings, pecked at prey delivered by M (in F's absence), picked bits of meat from prey with bill.
4	22	J2: downy; wing pins emerged, tips burst (showing as a dark line along wing edge).
	23	J2: remiges and scapular pins burst, upperwing-covert and tail pins emerged, cere creamy yellow. Flapped wings, walked and stumbled around nest (slow, clumsy steps), pecked at nest contents.
	28	J1: large and downy, upperwings and scapulars feathering, crown and tail pins burst, cere and gape pale creamy yellow.
5	29	J2: upperwings and scapulars feathering, tail pins burst.
6	36	J1: feathered dorsally; head-feathers emerged, with tufts of down sticking to ends; down on forehead and around throat; cere pale blue-grey, gape creamy yellow.
	38	J2: feathering; head-feathers emerged, downy forehead.
	39–40	J1: well feathered, including head; down on throat.
7	44	J1: feathered, including ventrally, but down on throat; wings short.
	46	J2: feathered dorsally and ventrally, down on chin, tail ~½ full length.
	47	J1: fully feathered except for down on throat.
	48	J1: fully feathered except for down on chin and underwings; wings and tail short. Flapped in breeze; jumped and flapped between nest and branch.
	49	J1: folded wing-tips barely beyond tertials, tail ~¾ full length.
		J2: fully feathered, down on throat, tail well grown, primaries short.
8	50–51	J1: little down on chin.
	53	J2: fully feathered.
	54	J2: fledged.
	56	J1: 'branching' behaviour.
9	59	J1: fledged; wings and tail slightly short.
		J5: fully feathered, appeared ready to fledge.
	62	J5: 'branching' behaviour to ~1.5 m up tree from nest. Appeared close to adult proportions, feet creamy yellow.
	63	J5: 'branching' behaviour to ~1.5 m along nest-branch. Tail almost full length; folded wing-tips short and rounded, but extended ~¾ down tail.
10	64	J5: fledged; wings and tail slightly short.

Post-fledging period

In their first week after fledging, juveniles mostly perched in live trees <50 m from the nest, begging. J1 was fed at the nest, and roosted at the nest on some nights (Table 5), whereas J2 was never detected back at the nest after it fledged, despite checks in late afternoon and early morning. However, the female initially brought prey to the nest-tree on J2's fledging day (see above). J1 died, of unknown causes, <3 weeks after fledging.

In their second week after fledging, juveniles also perched in the nest area (<50 m from the nest), begging, usually in a live tree though sometimes in a dead tree (Appendix 1). They started to become mobile, in low flights around the treetops, from the end of week 2 or early in week 3, by which time they were approaching adult proportions; the bases of J1's outer primaries were still ensheathed at >7 days after fledging (Appendix 1). One parental food transfer to J5 in week 3 (day 16) was inferred to have been in a tree near the nest-tree. In week 3, juveniles became increasingly mobile, though still in low flapping flight, and ranged to 100 m from the nest (Appendix 1).

In week 4, juveniles started soaring, ranging to >300 m from the nest, and harassing their parents in flight for food. From week 5, they had adult-like aerial abilities, ranging up to ~500 m from the nest; they started practising hunting manoeuvres, making at first tentative and unsuccessful passes or attacks at prey, but making determined attempts from week 7, and investigating carrion from week 6 (Appendix 1). From week 6, juveniles ranged up to ~1 km from the nest and sometimes, by their harassing behaviour, interfered with their parents' foraging. Juveniles begged strongly, and were fed by their parents, until week 9 or 10 (Appendix 1). Thereafter, they appeared to start hunting for themselves, and were seen only intermittently (alone, and not begging) in their natal territories until the last sighting in week 9 (J5, male) or week 11 (J6, female). J2 (male) could not be found in weeks 10 and 11, but was seen twice in or on the edge of the natal home-range in week 13 (Appendix 1).

In weeks 5–9, parental food deliveries were made to the nest-woodland, with food transfers at a perch, even if juveniles tried to intercept food-bearing parents en route to the nest area. From week 7, juveniles sometimes waited on lookout perches towards their parents' hunting grounds, and in week 9 sometimes flew to collect food from a parent away from the nest woodland (Appendix 1). Males made the sole observed prey deliveries to J1 and J4 (in weeks 1 and ~5, respectively); both the male and female made prey deliveries to J2 (one and three observed, respectively: male in week 6, female in weeks 5, 7 and 9). Prey items delivered to juveniles were often the still-furred, gutted hindquarters of partly eaten Rabbit kittens, but in one case the kitten had been completely plucked (female of Pair 2, in week 5).

From about week 4 onwards, when juveniles were likely to harass their parents, the adults appeared to avoid them and the nest area, except when delivering prey. Conversely, when J5 was apparently absent from his natal territory on several days in week 8 (before returning in week 9), his male parent readily hunted again in the vicinity of the nest, unmolested by the juvenile. In week 9, J6 begged to the neighbouring adult male, which responded aggressively (Appendix 1).

J2 (male) was last seen to be dependent, and fed, at 58 days after fledging, and occasionally lingered on the edge of, or returned to, the natal territory until 90 days after fledging. J5 (male) was last seen in the natal territory, apparently independent, at 60 days after fledging. J6 (female) was last seen to be dependent, and fed, at 64 days after fledging, and last seen in the natal territory (though apparently independent) at 71 days after fledging. The post-fledging dependence period thus lasted at least 58–64 days, with independent juveniles sometimes lingering around or revisiting the natal home-range for up to a further month.

Supplementary data from diverse sources support these observed patterns. The juvenile male of Pair 7 was soaring and begging to his aerially hunting male parent, and practising foraging behaviour (aborted 'parachute' drop at Eastern Rosellas *Platycercus eximius* and Australian Magpies *Cracticus tibicen*, which flushed) in early March 2009, 2.5–3 months after the fledging dates of the other local juveniles. In a previous year (1995), a juvenile female of Pair 2 was slightly injured (rehabilitated and released) while feeding on a road-killed Rabbit in mid January, i.e. within a month of fledging. A juvenile near Canberra, Australian Capital Territory, on 1 January 2009 was nest-bound, doing little practice flapping, but fledged by 3 January; a month later it was patrolling the nest area at much lower height than is usual for adults, and descended on and caught a lizard 20–30 cm long (R. Curnow pers. comm.; confirmed as juvenile Eagle from a photograph). In mid February 2009, i.e. when fledged for probably 1.5–2 months, a juvenile in southern Victoria was still begging incessantly when its parents were nearby, and it fed on a road-killed Rabbit (D. Whelan pers. comm.).

Juvenile morphology

Fledglings and advanced nestlings tended to have creamy-yellow cere, gape and feet, or sometimes a pale blue-grey cere (Table 4). The juvenile female from Pair 2 in 1995, a light morph, was in typical plumage, including rufous spots on the lesser upperwing-coverts and dark (fawn), non-contrasting secondary coverts (cf. Debus 1989; Marchant & Higgins 1993); within a month of fledging she had dark-brown eyes, yellow gape, and creamy-yellow cere and feet. J6, a dark morph, resembled light-morph juveniles (except for the underwing pattern and lack of rufous spots on the upperwings), but had heavier black breast-streaking and retained strong ventral rufous colouring until independence; at ~6 weeks after fledging she had dark-brown eyes, a creamy-yellow gape, and pale creamy-grey cere and feet.

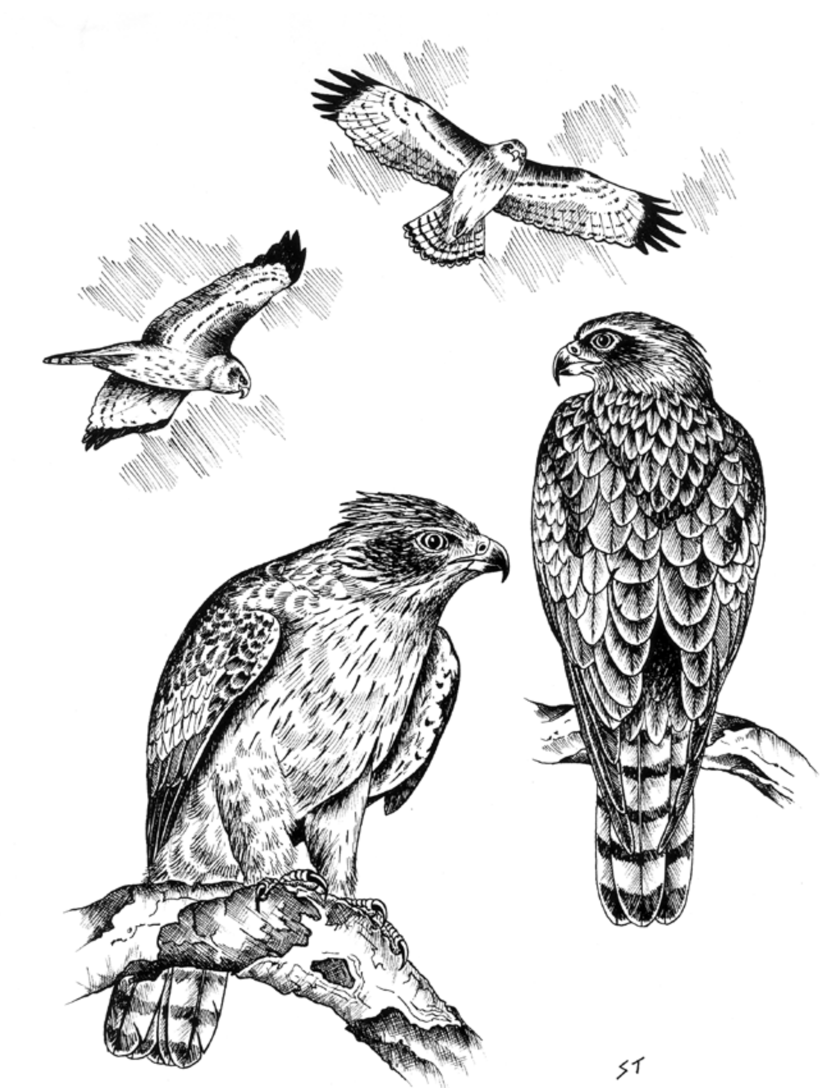
Within 1–2 months after fledging, one juvenile male weighed 655 g, and four juvenile females 865–1090 g (mean 970 g) (source: local rehabilitated birds weighed and banded by SD).

Breeding productivity

Pair 2 had two chicks visible on day 5 of the nestling period, but thereafter only one chick was seen. All three nests monitored throughout the cycle (Pairs 1, 2 and 5) fledged a single juvenile, and Pairs 4, 6 and 7 also had a single juvenile during the post-fledging period (i.e. one young per successful brood). Pair 3 (lone male) made no nesting attempt. Productivity was thus six young from seven occupied territories (0.86 young/pair) in 2008. Taking into account productivity in 2006 (one young from four attempts: Debus *et al.* 2007a) and 2007 (three young from four attempts: Debus 2008), productivity in the Armidale area was 0.67 young/pair/year over 15 pair-years 2006–08.

Feeding rates

Only one prey delivery to the incubating female was seen in 9 h (pooled for



Little Eagle

Plate 16 Sketch: Steve Tredinnick

Pairs 1 and 2) in the incubation period (0.1 item/h). Pooling the few data for Pairs 1 and 2, five prey deliveries were observed in the nestling period in 18 h, or 0.3 item/h. Pooling data for Pairs 1, 2, 5 and 6 in the post-fledging period, and including one inferred delivery to J5, eight deliveries were detected in 55 h or 0.1 item/h while juveniles were still dependent.

Diet and hunting

Prey items seen delivered to nests or juveniles included small Rabbit ×2, starlingsized native passerine, plucked bird and unidentified item (Pair 1); Rabbit kitten ×2, probable Rabbit ×3 and unidentified item (Pair 2); and probable Rabbit (Pair 6). Australian Wood Duck *Chenonetta jubata* pluckings were found under nest 2, and three Common Bluetongue *Tiliqua scincoides* skulls, and a pellet containing Bluetongue scales and Rabbit fur, were found under nest 5. (The female of Pair 5 was also seen carrying a Rabbit kitten in February 2008.) Breeding diet thus consisted mostly of Rabbits, with some birds and a few lizards.

In addition to the observations of adults hunting and juveniles practising what appeared to be typical hunting manoeuvres for this species (Appendix 1), the adult male of Pair 5 was seen hunting on two mornings in the post-fledging period: (1) from high quartering flight he made (i) a sudden vertical stoop, with closed wings, into the woodland canopy, flushing Eastern Rosellas (which escaped), then (ii) after kiting he made a long vertical stoop but aborted at treetop height; (2) after high quartering and kiting he made a steeply angled dive towards the ground (outcome unseen). Collectively, all the observations herein and those of Debus *et al.* (2007a) suggest that most foraging is done in flight (soaring and high-quartering), and attacks are variously stoops at avian prey, or dive attacks or drop attacks (sometimes in stages) at prey on the ground, and often preceded by, or interspersed with, kiting before launching the final strike.

Discussion

Breeding biology and behaviour

The Eagle foraging ranges in this study were limited to distances at which known individuals were seen travelling and returning, from observation points within view of their nest-sites. They are, therefore, underestimates of total home-range, which would need to be determined by individual marking and/or radio-tracking (e.g. Olsen & Osgood 2006). The similar Booted Eagle *Hieraaetus pennatus*, which occurs at over twice the density (inter-nest distances of only ~1 km) in probably more productive habitat, forages up to >10 km from the nest in home-ranges of up to >200 km^2 (Martínez *et al.* 2007). There is increasing evidence of long-term fidelity of individual Little Eagles to nest-sites and breeding territories (Debus 1984b, 1991; Debus *et al.* 2007a; this study), although confirmation is required from banding and individual marking.

Although some nesting Little Eagles are tolerant of the proximity of houses, there is much individual variation. Some are shy, using nests concealed from human view by the woodland canopy, and flushing off eggs or chicks (thus placing them at risk) if approached by humans (this study; Debus *et al.* 2007a). Some females that were disturbed by humans, and flushed off (successful) nests several times in 2006, used a different nest in 2007–08 (Debus 2008; this study). Urban development also affects the Little Eagle's foraging habitat as well as nest-sites (e.g. Olsen & Fuentes 2005; Olsen & Osgood 2006).

Data in this study confirm that Little Eagles nest in all common local *Eucalyptus* species, and apparently prefer large trees on slopes with a southerly component (cf. Debus 1984a; Debus *et al.* 2007a). Nest-site measurements at Armidale fall within known nest-site parameters (cf. Marchant & Higgins 1993).

Egg-laying dates were consistent with previous data for south-eastern Australia (cf. Marchant & Higgins 1993; Olsen 1995; Debus *et al.* 2007a). An incubation period of 38–39 days also supports previous values of ~36, 36–40 and 37–39 days (Debus

1984a; Bollen 1991; Debus *et al.* 2007a). Similarly, nestling periods of 53–63 days support and enlarge on previous values of 55 days, ~59 days, 54–60 days, and ~60–67 days (Baker-Gabb 1984; Debus 1984a; Bollen 1991; Marchant & Higgins 1993), and a case of premature (human-induced) fledging of two siblings at 52–56 days (Cupper & Cupper 1981).

Data on sex-roles in the incubation and nestling periods support previous findings (Debus *et al.* 2007a) on male sharing of incubation and brooding, and provide further evidence that males sometimes feed chicks (cf. Debus 1984b; Bollen 1989). From limited data (this study; Debus 1984b; Debus *et al.* 2007a), it appears that nestling meal sizes and duration increase with age, but confirmation is required. Limited data on the decline in parental care and nest attendance through the nestling period, as eaglets grow, support previous fragmentary data and assumptions (Debus 1984a,b; Bollen 1989; Debus *et al.* 2007a), but the definitive study of parental time-budgets remains to be conducted.

Fledgling productivity was variable in 2006–08: greater in 2007 and 2008 than in the poor year of 2006 (cf. Debus *et al.* 2007a). Overall, in the 2000s, it has averaged lower than in the 1980s to early 1990s (0.67 vs 1.0 young/pair/year, cf. Debus 1991).

Parental feeding rates in 2008 were similar to those of 2006 for the incubation period (0.1 item/h in both years) and nestling period (0.3 item/h cf. 0.2–0.3 item/h), and to those from 1980 for the post-fledging period (0.1 item/h in both years:Debus 1991; Debus *et al.* 2007a). It appears from limited observations that the food-delivery rate to juveniles may be lower than in the nestling period. However, confirmation is required, and it remains to be determined whether the feeding rate declines through the post-fledging period. Feeding rates in the incubation and nestling periods were similar to those recorded for Armidale in the 1980s (0.1 item/h and 0.2 item/h, respectively: Debus 1991), but lower than for the nestling period where the diet included a higher proportion of small birds (0.4–0.6 item/h: Bollen 1989, 1991).

Juvenile development and independence

Observations on nestling growth, development and morphology confirm and enlarge on previous reports (cf. Debus 1984a,b, 1991; Marchant & Higgins 1993). This study also confirms that juveniles fledge as either morph (dark or light), and that within each morph juveniles are 'redder' than adults (*contra* Hollands 2003). Data from the present study suggest that the rescued eaglet in 2006 (Debus *et al.* 2007a) may indeed have had somewhat retarded growth, as suspected, before it died of an undiagnosed illness or developmental impairment.

Synthesising the limited data from this study and others (Debus 1984a,b; Bollen 1989,1991; Debus *et al.* 2007a; Debus 2008), it appears that, in their first week or so after fledging, juvenile Little Eagles at least sometimes return to, roost on and are fed at the nest. For their first fortnight they mostly perch in the tree-canopy in the nest area, and the parents deliver food to them on perches in the nest-patch. Thereafter, when their flight-feathers are fully grown and they appear adult in proportions, juveniles make low tree-to-tree flights and start soaring low over the tree-canopy, until by their first month they can soar well in an adult-like manner and range several hundred metres from the nest. From this stage they start following their parents, practising hunting behaviour, and (mainly females) start investigating carrion such as road-kill, although parents still transfer food on a perch in the nest-patch. In their second month, they range >1 km from the nest, sometimes wait on lookout perches for food-bearing parents between the nest and hunting grounds, and sometimes collect food from a parent away from the nest area. They may start catching, or trying to catch, prey, and the smaller and more agile males may hawk flying insects. Finally, by the end of their second month when parental feeding ceases, they range >1.5 km and start venturing away from their natal territory for perhaps several days at a time, though they may return intermittently over at least a further month. Around the time juvenile Little Eagles approached independence in New England, prey animals such as juvenile or immature Common Bluetongues and dragon lizards (*Amphibolurus* and *Pogona*) were fairly common, and sluggish on cool mornings or evenings; adult lizards also basked conspicuously on roads (SD pers. obs.).

These results contrast with the view that juvenile Little Eagles may become independent 'quite quickly' (Hollands 2003). Rather, they are dependent on parental feeding for ~2 months after fledging, which finding supports previous inferences of dependence for at least 2 months (Marchant & Higgins 1993; Debus *et al.* 2007a).

So far as can be determined, the Little Eagle's post-fledging period, independence and dispersal phase may be similar to those of the Booted Eagle and Bonelli's Eagle *Aquila fasciata* (cf. Balbontín & Ferrer 2005, 2009; Cadahía *et al.* 2007, 2008), but this assumption requires confirmation by radiotelemetry. One Booted Eagle juvenile was dependent for at least 64 days after fledging (Ferguson-Lees & Christie 2001).

Aspects of the Little Eagle's post-fledging period appear to contrast with that of the Wedge-tailed Eagle (cf. Debus *et al.* 2007b). Unlike the larger species, Little Eagle families did not associate as close trios of parents and offspring; there was no evidence of adult Little Eagles hunting together or co-operatively, nor of juveniles accompanying hunting adults. Rather, juvenile Little Eagles harassed their parents for food and interfered with their foraging, and adults appeared to be solitary, avoiding dependent juveniles except when delivering prey to them. These differences may be related to differing predatory habits: in comparison with Wedge-tailed Eagles, Little Eagles appear to specialise more on active prey of a size they can carry, seldom eat carrion, and members of a pair appear not to share kills away from the nest.

There was no evidence that parent Little Eagles drove off their offspring at the end of the dependence phase, or acted aggressively towards them, although the male parent of J2 performed a territorial display when the now-independent J2 reappeared, after absences, in the natal territory at ~3 months since fledging. Claims of eagles driving away offspring may be based on misinterpretation of juveniles harassing parents for food, or being warned off when they stray into a neighbouring territory, as observed in this study.

Diet and hunting

The incidental dietary items observed in this study are a subset of those previously recorded in the district (cf. Debus 1984a, 1991, 2006a,b, 2008; Debus *et al.* 2007a), and indeed in south-eastern Australia generally (cf. Marchant & Higgins 1993). Further studies of breeding diet in little-studied regions (e.g. Western Australia and the tropics) would be valuable, as would studies of non-breeding diet (cf. Moleón *et al.* 2007, 2009).

The hunting episodes observed in this study are consistent with previous information (cf. Marchant & Higgins 1993; Aumann 2001; Debus 2006b; Olsen *et al.* 2006; Debus *et al.* 2007a). Little Eagles appear to do much foraging in flight, as suggested by Hollands (2003), and (especially breeding males) perform some Booted Eagle-type attack behaviour (cf. Ferguson-Lees & Christie 2001), e.g. swift stoops or dives.

Eagle population

The Little Eagle population around Armidale in the mid 2000s was about the same as in the 1980s and 1990s, i.e. ~10 known pairs within a radius of 10 km of Armidale (Debus 1984a, 1991), although by the late 2000s this had declined to eight known territories, seven of which were occupied by a pair with an active nest. Inter-nest distances and density were similar in the 2000s to the 1980s, i.e. 2–5 km between neighbouring nests and one breeding pair to 1500–1600 ha (cf. Debus 1984a). However, the number of Little Eagles passing through the wildlife carer network has declined substantially. Together with declining fledgling productivity, these trends suggest a declining population, although less so than for more southern parts of NSW to date (cf. Olsen & Fuentes 2005; Olsen & Osgood 2006; Debus *et al.* 2007a; Olsen *et al.* 2008, 2009). Furthermore, cases of apparent illness in a chick and an adult female (Debus *et al.* 2007a), and the premature death of fledgling J1 (anomalous at that age), suggest that there are potential problems for the local Little Eagle population (perhaps pesticides or other chemicals in the food chain, as suspected elsewhere: Olsen & Osgood 2006).

Atlas data showed a decline in the Little Eagle's reporting rate over 20 years: 14% nationally, with >20% decline across the Murray–Darling Basin and eastern sheep–wheat belt, and 39% in NSW, although there was no significant decline detected in the New England Tableland bioregion (Barrett *et al.* 2003, 2007). Surveys of nests found an 80–90% decline in the number of breeding pairs around Canberra, ACT, over the last 15 years, a trend not reflected in local atlas data (Olsen & Fuentes 2005; Olsen *et al.* 2009). Subsequent analysis of NSW atlas data found a 50% decline in the Eagle's reporting rate in south-eastern NSW over the past 30 years (B. Curtis in Canberra Ornithologists Group 2008). Where atlas sighting data and surveys of breeding pairs conflict, monitoring of nests more reliably indicates raptor population trends (Sergio *et al.* 2008; Olsen *et al.* 2009). In the case of the Little Eagle, objective survey data provided a case for listing as Vulnerable in the Australian Capital Territory (Olsen *et al.* 2008).

Conclusions

The Little Eagle's breeding biology and behaviour are similar to those of other small aquiline eagles, particularly the Booted Eagle and other *Hieraaetus* species (i.e. Booted, Wahlberg's *H. wahlbergi* and Ayres' Eagles *H. ayresii*, cf. Brown 1976; Cramp & Simmons 1980; Brown *et al.* 1982; del Hoyo *et al.* 1994; Ferguson-Lees & Christie 2001). The Little Eagle's general biology, as a composite picture from several partial studies, is now fairly well known. However, the present study was incomplete, particularly for the Little Eagle's nestling period. It remains to conduct a complete, quantified observational study throughout the breeding cycle, from nest-building to independence of juveniles, on plumage-dimorphic (i.e. readily sexed) pairs of Little Eagles, and to obtain more complete data on parental feeding rates in the post-fledging period, as for the Wedge-tailed Eagle (cf. Debus *et al.* 2007b).

Limited evidence suggests that Little Eagle numbers and breeding success may be starting to decline in New England, and that this decline may be related to habitat loss, and in particular urban and rural-residential expansion around inland cities, and competition from Wedge-tailed Eagles for increasingly scarce breeding habitat and nest-sites (Debus 1991; Debus *et al.* 2007a; this study). The apparent decline in the Little Eagle's population extends the decline elsewhere in south-eastern Australia, which is attributed to the same factors (e.g. Olsen & Fuentes 2005; Olsen & Osgood 2006; Olsen *et al.* 2008, 2009). It may continue and worsen, given the scale of ongoing clearing of native vegetation in NSW and thus consequences for the Eagle's native prey base, breeding habitat and nest-site availability (cf. Johnson *et al.* 2007; Olsen 2008). Hence, long-term monitoring of territory occupancy, breeding density and productivity, and adult turnover are required.

Recent studies on Booted and Bonelli's Eagles provide potential models for the studies required on the Little Eagle, to shed light on its decline and guide its conservation (cf. Mateo *et al.* 2003; Pagán *et al.* 2004; Bosch *et al.* 2005; López-López *et al.* 2006, 2007; Martínez *et al.* 2006, 2007, 2008; Martínez-López *et al.* 2007, 2008; Casado *et al.* 2008; and related studies cited by Debus *et al.* 2007a). An increasing issue of concern overseas is whether human-induced mortality of breeding adult eagles (e.g. through pesticides, electrocutions, or collisions with windfarms and other infrastructure) may act against the genetic fitness of the species, and so accelerate population declines (Balbontín *et al.* 2005).

Acknowledgements

We thank Brian & Sue Wilson, Rosemary Leitch and Geoff & June Currey for permission to study the eagles on their land; Des Breen for rescuing the young eagle from the fox trap, and for his continued interest; Phil & Julia Rose (Wildcare) for their role in getting the eagle cared for, banded and released; and Barry & Lucy McCann for reporting on the released eagle. Sofia Debus shared some of the observations, took reference photographs of the released eagle, and facilitated the drafting of this paper. The eagle was banded under Australian Bird and Bat Banding Scheme authority A1003, and NSW National Parks and Wildlife Service scientific licence S10824. We thank Roger Curnow and David Whelan for their information and photographs, and Tom Aumann, Jerry Olsen & Sue Trost, and Penny Olsen for comments on a draft. Martin Dillon (NSW Department of Environment & Climate Change) kindly prepared the map.

References

Aumann, T. (2001), 'Habitat use, temporal activity patterns and foraging behaviour of raptors in the south-west of the Northern Territory, Australia', *Wildlife Research* **28**, 365–378.

Baker-Gabb, D.J. (1984), 'The breeding ecology of twelve species of diurnal raptor in north-western Victoria', *Australian Wildlife Research* **11**, 145–160.

Balbontín, J. & Ferrer, M. (2005), 'Factors affecting the length of the post-fledging period in the Bonelli's Eagle *Hieraaetus fasciatus*', *Ardea* **93**, 189–198.

Balbontín, J. & Ferrer, M. (2009), 'Movements of juvenile Bonelli's Eagle *Hieraaetus fasciatus* during dispersal', *Bird Study* **56**, 89–95.

Balbontín, J., Penteriani, V. & Ferrer, M. (2005), 'Humans act against the natural process of breeder selection: A modern sickness for animal populations?', *Biodiversity & Conservation* **14**, 179–186.

Barrett, G., Silcocks, A., Barry, S., Cunningham, R. & Poulter, R. (2003), *The New Atlas of Australian Birds*, RAOU, Melbourne.

Barrett, G.W., Silcocks, A.F., Cunningham, R., Oliver, D.L., Weston, M.A. & Baker, J. (2007), 'Comparison of atlas data to determine the conservation status of bird species in New South Wales, with an emphasis on woodland-dependent species', *Australian Zoologist* **34**, 37–77.

Bollen, C. (1989), 'Notes on Little Eagles breeding on the Southern Tablelands of New South Wales', *Australian Bird Watcher* **13**, 65–66.
Bollen, C (1991), 'Further notes on the Little Eagle breeding on the Southern Tablelands of New South Wales', *Australian Bird Watcher* **14**, 110–111.
Bosch, J., Borrás, A. & Freixas, J. (2005), 'Nesting habitat selection of Booted Eagle *Hieraaetus pennatus* in central Catalonia', *Ardeola* **52**, 225–233.
Brown, L.H. (1976), *Eagles of the World*, David & Charles, London.
Brown, L.H., Urban, E.K. & Newman, K. (Eds) (1982), *The Birds of Africa*, vol. 1, Academic Press, London.
Cadahía, L., Urios, V., López-López, P. & Negro, J.J. (2008), 'Estimating the onset of dispersal in endangered Bonelli's Eagles *Hieraaetus fasciatus* tracked by satellite telemetry: A comparison between methods', *Ibis* **150**, 416–420.
Cadahía, L., Urios, V. & Negro, J.J. (2007), 'Bonelli's Eagle *Hieraaetus fasciatus* juvenile dispersal: Hourly and daily movements tracked by GPS', *Bird Study* **54**, 271–274.
Canberra Ornithologists Group (2008), 'Nomination of a Vulnerable species to the ACT Flora and Fauna Committee—Little Eagle', *Canberra Bird Notes* **33**, 84–95.
Casado, E., Suárez-Seone, S., Lamelin, J. & Ferrer, M. (2008), 'The regulation of brood reduction in Booted Eagles *Hieraaetus pennatus* through habitat heterogeneity', *Ibis* **150**, 788–798.
Cramp, S. & Simmons, K.E.L. (Eds) (1980), *The Birds of the Western Palaearctic*, vol. 2, Oxford University Press, Oxford, UK.
Cupper, J. & Cupper, L. (1981), *Hawks in Focus*, Jaclin, Mildura, Vic.
Debus, S.J.S. (1984a), 'Biology of the Little Eagle on the Northern Tablelands of New South Wales', *Emu* **84**, 87–92.
Debus, S.J.S. (1984b), 'Further notes on nesting Little Eagles', *Australian Bird Watcher* **10**, 196–201.
Debus, S.J.S. (1989), 'Plumages and moult of the Little Eagle *Hieraaetus morphnoides*', *Australian Bird Watcher* **13**, 103–113.
Debus, S.J.S. (1991), 'Further notes on territory, breeding and plumage of the Little Eagle', *Australian Birds* **25**, 1–10.
Debus, S. (2006a), 'Wedge-tailed Eagle robs Little Eagle', *Boobook* **24**, 43.
Debus, S. (2006b), 'Avian food items of Little Eagle', *Boobook* **24**, 44.
Debus, S. (2008), 'Little Eagles in New England, NSW', *Boobook* **26**, 7.
Debus, S.J.S., Hatfield, T.S., Ley, A.J. & Rose, A.B. (2007a), 'Breeding biology and diet of the Little Eagle *Hieraaetus morphnoides* in the New England region of New South Wales', *Australian Field Ornithology* **24,** 137–157.
Debus, S.J.S., Hatfield, T.S., Ley, A.J. & Rose, A.B. (2007b), 'Breeding biology and diet of the Wedge-tailed Eagle *Aquila audax* in the New England region of New South Wales', *Australian Field Ornithology* **24**, 93–120.
del Hoyo, J., Elliott, A. & Sargatal, J. (Eds) (1994), *Handbook of the Birds of the World*, vol. 2, Lynx, Barcelona.
Ferguson-Lees, J. & Christie, D.A. (2001), *Raptors of the World*, Helm, London.
Hollands, D. (2003), *Eagles, Hawks and Falcons of Australia*, 2nd edn, Bloomings Books, Melbourne.
Johnson, C., Cogger, H., Dickman, C. & Ford, H. (2007), Impacts of Land Clearing: The Impacts of Approved Clearing of Native Vegetation on Australian Wildlife in New South Wales, WWF-Australia report, WWF-Australia, Sydney.
López-López, P., García-Ripollés, C., Aquilar, J.M., García-López, F. & Verdejo, J. (2006), 'Modelling breeding habitat preferences of Bonelli's Eagle (*Hieraaetus fasciatus*) in relation to topography, disturbance, climate and land use at different spatial scales', *Journal of Ornithology* **147**, 97–106.
López-López, P., García-Ripollés, C. & Urios, V. (2007), 'Population size, breeding performance and territory quality of Bonelli's Eagle *Hieraaetus fasciatus* in central Spain', *Bird Study* **54**, 335–342.
Marchant, S. & Higgins, P.J. (Eds) (1993), *Handbook of Australian, New Zealand and Antarctic Birds*, vol. 2, Oxford University Press, Melbourne.
Martínez, J.A., Calvo, J.F., Martínez, J.E., Zuberogoitia, I., Zabala, J. & Redpath, S.M. (2008), 'Breeding performance, age effects and territory occupancy in a Bonelli's Eagle *Hieraaetus fasciatus* population', *Ibis* **150**, 223–233.
Martínez, J.E, Pagán, I., Palazon, J.A. & Calvo, J.F. (2007), 'Habitat use of Booted Eagle (*Hieraaetus pennatus*) in a special protection area: Implications for conservation', *Biodiversity & Conservation* **16**, 3481–3488.

Martínez, J.E, Pagán, I. & Calvo, J.F. (2006), 'Interannual variations of reproductive parameters in a Booted Eagle (*Hieraaetus pennatus*) population: The influence of density and laying date', *Journal of Ornithology* **147**, 612–617.
Martínez-López, E., Marcia-Mojica, P., Calvo, J.F., Wright, J., Shore, R.F., Romero, D. & García-Fernández, A.J. (2007), 'Organochlorine residues in Booted Eagle (*Hieraaetus pennatus*) and Goshawk (*Accipiter gentilis*) eggs from southeastern Spain', *Environmental Toxicology & Chemistry* **26**, 2373–2378.
Martínez-López, E., Romero, D., Marcia-Mojica, P., Martínez, J.E., Calvo, J.F. & García-Fernández, A.J. (2008), 'Changes in blood pesticide levels in Booted Eagles (*Hieraaetus pennatus*) associated with agricultural land practices', *Ecotoxicology & Environmental Safety* **72**, 45–50.
Mateo, R., Taggart, M. & Meharg, H.A. (2003), 'Lead and arsenic in bones of birds of prey from Spain', *Environmental Pollution* **126**, 107–114.
Moleón, M., Bautista, J., Sánchez-Zapata, J.A & Gil-Sánchez, J.M. (2009), 'Diet of non-breeding Bonelli's Eagles *Hieraaetus fasciatus* at settlement areas of southern Spain', *Bird Study* **56,** 142–146.
Moleón, M., Gil-Sánchez, J.M., Real, J., Sánchez-Zapata, J.A., Bautista, J. & Sánchez-Clemot, J.F. (2007), 'Non-breeding feeding ecology of territorial Bonelli's Eagles *Hieraaetus fasciatus* in the Iberian Peninsula', *Ardeola* **54**, 135–143.
Olsen, J. & Fuentes, E. (2005), 'Collapse in numbers of breeding Little Eagles in the Australian Capital Territory', *Canberra Bird Notes* **30**, 141–145.
Olsen, J. & Osgood, M. (2006), 'Numbers of breeding Little Eagles in the Australian Capital Territory in 2006', *Canberra Bird Notes* **31**, 178–182.
Olsen, J., Fuentes, E., Rose, A.B. & Trost, S. (2006), 'Food and hunting of eight breeding raptors near Canberra, 1990–1994', *Australian Field Ornithology* **23**, 77–95.
Olsen, J., Osgood, M., Maconachie, M. & Dabb, G. (2008), 'Numbers of breeding Little Eagles *Hieraaetus morphnoides* in the Australian Capital Territory in 2007', *Canberra Bird Notes* **33**, 77–80.
Olsen, J., Osgood, M., Maconachie, M., Dabb, G. & Butterfield, M. (2009), 'Numbers of breeding Little Eagles *Hieraaetus morphnoides* in the Australian Capital Territory in 2008', *Canberra Bird Notes* **34**, 81–85.
Olsen, P. (1995), *Australian Birds of Prey*, New South Wales University Press, Sydney.
Olsen, P. (Ed.) (2008), 'The state of Australia's birds 2008', supplement to *Wingspan* **18**(4).
Pagán, I., Martínez, J.E., Carrete, M. & Calvo, J.F. (2004), 'Nest occupancy patterns of Booted Eagles *Hieraaetus pennatus* in southeastern Spain', pp. 645–652 in Chancellor, R.D. & Meyburg, B.-U. (Eds), *Raptors Worldwide*, World Working Group on Birds of Prey & Owls, Berlin, and BirdLife Hungary, Budapest.
Sergio, F., Newton, I. & Marchesi, L. (2008), 'Top predators and biodiversity: Much debate, few data', *Journal of Applied Ecology* **45**, 992–999.

Received 4 April 2009

Appendix 1

Behaviour of juvenile Little Eagles in the post-fledging period, Armidale, NSW, December 2008–March 2009 (single juveniles J1, J2, J4, J5 and J6 from respective nests 1,2, 4, 5 and 6: see text). F = female parent, M = male parent. J2 and J5 were male, J1 and J6 female (J6 assumed to have fledged on same date as J1: see text).

Week	*Day*	*Comments*
1	1	J1: perched in next (live) tree ~30 m from nest-tree.
		J2: perched in woodland canopy <50 m from nest-tree; F food delivery to nest-tree in late morning (further details not obtained).
		J5: perched in next (live) tree ~15 m from nest-tree.
	4	J1: perched on nest-branch in late afternoon (roosted there?).

Appendix 1 continued

Week	Day	Comments
1	5	J1: perched in mid canopy ~20 m from nest, well below nest height; M prey delivery to nest (late morning), F arrived at nest-branch then nest, M left; J1 returned to nest in stages by short scrambling flights, meanwhile F started to bill prey; J1 reached nest, claimed prey and mantled, F left, J1 fed from prey (clumsy at first, overbalancing when tearing prey on nest, then feeding successfully). In late afternoon, J1 perched in trees near nest (i.e. not at nest).
	6	J1: lay on nest in late afternoon for >1 h (roosted there?).
2	8	J1: perched in top of nest-tree, balancing on outer-canopy foliage, in late afternoon. Last sighting of J1 alive.
	9	J1: not detected in nest area in late afternoon (though M on roost-tree). Weathered remains subsequently found (10 days later, after lapse in observations) included outer primaries with bases still in sheath; approximate date of death (midpoint between J1 alive and remains found) = day 14 ± 5 days.
	13	J5: appeared approximately adult in proportions.
	14	J5: flew in flapping circuit low over tree-canopy around nest, then perched on dead tree, flapped wings.
3	19	J2: mobile in nest area, low flapping flight tree to tree within 100 m of nest; had difficulty balancing on high thin branch in wind; tumbled off, but landed competently on lower solid branch. Appeared adult in proportions.
4	25	J5: soared low over and around treetops around nest (within ~50 m); appeared practised, adult in proportions; wind-soared well, landed between flights, descending with retracted wings to perch.
	27	J5: soared in circles, landed competently on branch in live treetop, spiralled to >5 × treetop height, like adult; stooped to lose height, landed in tree ~100 m from nest.
	28	J5: soared up in circles, thermalling expertly in still air. Followed soaring parent (F?) to ~300 m from nest; then soared (begging) with M >300 m from nest, made passes at M with feet down, but M jinked away (not carrying prey).
?	?	J4: ~1 month after fledging, soared high, begging, ~300 m from nest as M approached in long shallow glide with prey in foot; M stooped to nest-woodland, J4 followed in stoop; food transfer at perch in nest-woodland.
5	29	J5: soared high, practised 'parachute' drop (aborted before reaching ground); soared very high, tracked Brown Falcon *Falco berigora* that was soaring lower, made mild stoops towards it (Falcon retreated); soared to ~400 m from nest, practised long fast glides, kiting, 'parachute' drops, stoop. Essentially adult-like aerial ability, but no attacks on prey seen.
	32	J5: soared, made pass at Galahs *Eolophus roseicapillus* on dead treetop (veered off when they flushed); practised swooping around and between tree-crowns.
	33	J2: F? prey delivery to nest-woodland (not to nest) in mid morning; J2 ate food on live tree-limb <50 m from nest. J2 subsequently flew to ~300 m from nest, returned wind-soaring and circling unsteadily, clumsy landing on dead treetop in wind. Then soared, circling to 2–3 × treetop height, landed on outer canopy, balancing; soared again, landed, then soared. Final landing competent, by descending among treetops with wings retracted, into wind (after earlier, heavier landings), i.e. noticeably improved with practice.

Appendix 1 continued

Week	*Day*	*Comments*
5	33	J5: soared, made full ‘parachute’ drop almost to ground (aborted); ranged ~500 m from nest.
	34	J2: soared low over hilltop trees of nest-woodland.
	35	J2: soared low over hill trees to ~150 m from nest, then circled to 2–3 × treetop height, stooped to former height, then circled again 200–300 m from nest for >4 min., to >4 × treetop height.
		J5: soared, paused over and almost stooped at Torresian Crow *Corvus orru* on or near ground; soared very high in adult-like manner, made sudden brief stoop; tracked Brown Goshawk; made long fast glide to soar with and stoop at distant soaring parent (which avoided contact); soared also with high-soaring, intruding (i.e. not parent) dark Little Eagle; swooped at one of pair of high-soaring Goshawks (~1000 m altitude).
6	37	J2: soared, ranging ~400 m from nest.
		J5: perched in nest area, peering intently at activity of small birds; soared high; Wedge-tailed Eagle glided high over, F attacked it with squealing alarm call; J5 followed high-soaring F.
	38	J6: entered fox-trap (mesh cage) for bait; banded and released at nest-site on day 40. Primaries and rectrices fully grown and hard-penned.
	39	J2: perched beside prominent stick nest (used by Australian Ravens *Corvus coronoides* in 2006) ~200 m from own nest. Then soared and begged over where F had stooped (unsuccessfully) into trees, then soared up to beg to high-soaring M, which left, but J2 soared very high and tracked M to ~800 m from nest. J2 returned in long fast glide, stooped at soaring F with feet down (F squealed, parried and left); J2 stooped to lower level, soared again, tracked F to ~1 km from nest before returning. In late morning, M prey delivery (with two- and three-note calls) to nest-woodland; J2 collected prey and fed competently on stout lower limb of live woodland tree <100 m from nest.
	42	J2: soared, swooped at hunting adult (M?), interfering with his descent at sighted prey. M was in a drop attack from ~5 × treetop height (or ~100 m?), J2 swooped faster to intercept, causing M to dodge; J2 tracked M during resumption of kiting and dropping until M dived and did not reappear. J2 resumed soaring and begging, practised ‘parachute’ drop; showed adult-like aerial ability.
7	43	J5: soared high, made long angled dive (unsuccessful) at Australian Magpies, which scattered with alarm calls.
	44	J2: soared high, made failed attack at prey (‘parachute’ drop with wings retracted, feet down, then final short dive at Australian Magpie on ground; Magpie flushed, J2 soared again). F food delivery (in late morning) to nest woodland >200 m from nest; soaring J2 made long shallow stoop into trees to collect prey.
		J6: soared up to beg from high-soaring F; then soared with and begged to M over his hunting grounds 1.3 km from nest. M landed and perch-hunted from live tree over Rabbit-infested area; J6 waited on dead tree, begging, ~150 m from M.
	46	J2: soared; practised kiting, long glide, height loss by short stoop, then long shallow stoop. Soared very high, made stoops at high-soaring F (which evaded). Rufous on belly now fading.
	49	J2: soared, kiting, hawked aerial insect.

Appendix 1 continued

Week	*Day*	*Comments*
8	52	J6: perched in prominent tree, begging, between nest area and parents' hunting grounds; soared well, ranging ~800 m from nest; landed competently within live tree-canopy.
	56	J2: soared, begged to and stooped at M ~800 m from nest.
9	59	J2: soared ~1 km from nest, practised hunting manoeuvres (kiting, 'parachute' drop); not begging from aerially hunting M. F appeared in flight ~1 km from nest with prey (mid morning); J2 followed F, begging and harassing her, back to nest-woodland, prey transfer in trees ~300 m from nest.
	61	J5: soared alone, apparently hunting, ranging up to 1.5 km W and N of nest; hawked aerial insect three times in 15 min.; no begging or interacting with parents seen, appeared independent; rufous on belly faded (whitening). Last sighting of J5.
		J6: soared in hunting mode (kiting, stoop which became 'parachute' drop then final drop attack to ground with wings retracted, alulae projecting, legs down; unsuccessful). Soared again, begging to distant soaring F.
	63	J6: soared, wide-ranging (to 1.3 km from nest); circled with neighbouring M (not M parent, on respective moult patterns) in neighbour's home-range ~1 km from J6's nest. Neighbour M soared in display posture, made 'warning' dive or pass at J6; J6 continued to circle and beg, neighbour M stooped and struck at J6, which tumbled briefly, shook herself in flight, then glided swiftly back to perch in own nest-woodland, begging.
10	65	J6: perched prominently between nest and parents' hunting grounds, begging, in early morning. Parent gave food-call (piping) from ridge 1.3 km away, J6 flew directly, begging, towards parent; food transfer, J6 carried prey to separate perch.
	66	J6: seen and heard (begging) around nest-woodland (B. & L. McCann pers. comm.).
	69	J6: soared high over nest area, not begging; made sudden long (several seconds) vertical stoop with closed wings, then pulled out to soar above treetops in hunting mode, descended among treetops (did not re-emerge).
11	72	J6: soared high in hunting mode (not begging); kiting, stooping, kiting again, then 'parachute' drop into woodland (did not re-emerge). Last sighting of J6.
13	86	J2: alone on edge of natal home-range (rural residential/suburban interface) ~1 km from nest.
	91	J2: glided back over nest hill, from excursion away from natal territory; M, soaring higher, displayed and called territorially. Last sighting of J2.

Footnote: The rescued eaglet previously discussed (Debus *et al.* 2007a) is now registered in the Australian Museum as specimen AM O.72565, confirmed as female. ■

AUSTRALIAN FIELD ORNITHOLOGY 2009, **26**, 100–102

Australian Ringneck *Barnardius zonarius* Variations and Possible Hybrid with Pale-headed Rosella *Platycercus adscitus* in South-western Queensland

JENNIFER SPRY

362 Rathdowne Street, Carlton North, Victoria 3054
(Email: malurus.jenny@gmail.com)

Summary. At Bowra Station, near Cunnamulla in south-western Queensland, between 5 and 7 November 2008, three distinct variations of Australian Ringnecks were observed at the bore overflow. The predominant subspecies was the Mallee Ringneck *Barnardius zonarius barnardi*, with 5–7 birds regularly coming to drink. In addition to these birds there were two different birds: one had markings consistent with Cloncurry Ringneck *B.z. macgillivrayi*, and one had a pale head and appeared to be a hybrid between a Mallee Ringneck and a Pale-headed Rosella *Platycercus adscitus*.

Hybridisation and colour variations are known for *Barnardius* parrots, and were commented on by Gray (1958), Harman (1981), Juniper & Parr (1998), Higgins (1999) and Forshaw (2002). Hybridisation is recorded between the nominate Australian Ringneck *B. zonarius zonarius* (hereafter Australian Ringneck) and the Mallee subspecies *B.z. barnardi* (hereafter Mallee Ringneck) in the wild, the resulting hybrid formerly considered a separate subspecies *B.z. whitei* (Schodde & Mason 1997). Hybridisation is also recorded between the Mallee Ringneck and the Cloncurry subspecies *B.z. macgillivray* (hereafter Cloncurry Ringneck), and between the Mallee Ringneck and the Adelaide subspecies of the Crimson Rosella *Platycercus elegans adelaidae*, in captivity and in the wild (Higgins 1999; Forshaw 2002).

As *Barnardius* parrots are known to hybridise with the Pale-headed Rosella *Platycercus adscitus* in captivity (Forshaw 2002), hybridisation between the Mallee Ringneck and the Pale-headed Rosella in the wild is feasible. Furthermore, a case of hybridisation in the wild between a Mallee Ringneck and an example of the Yellow subspecies of the Crimson Rosella *P.e. flaveolus* has been reported recently (Knight 2009); the three offspring were variably intermediate in plumage between a Mallee Ringneck and a juvenile or immature Yellow or Crimson *P.e. elegans* Rosella. Christidis & Boles (2008) noted that the two genera are so closely related that they have sometimes been proposed for combining (as genus *Platycercus*).

This note records single individuals of the Mallee Ringneck (i) associating, as a pair, with an individual of the Cloncurry Ringneck (well outside the latter's normal range), and (ii) associating with a probable hybrid between a Mallee Ringneck and a Pale-headed Rosella, at Bowra station, north-west of Cunnamulla (28°04′S, 145°41′E) in south-eastern Queensland. The suspected hybrid is described. A preliminary note on these observations has appeared elsewhere (Spry 2009).

Observations

The grouping of the birds at Bowra was the same each time that they came to drink at a bore overflow. The Cloncurry Ringneck was always paired with one Mallee Ringneck. At no time was the Cloncurry Ringneck seen in a larger group of Mallee Ringnecks. The apparent hybrid Mallee Ringneck × Pale-headed

Rosella was always in the company of two Mallee Ringnecks, as part of a group of three.

A further group of five Mallee Ringnecks also regularly visited the overflow, but at no time was the apparent Ringneck × Rosella hybrid or the apparent Cloncurry Ringneck seen to arrive with them to drink. On one occasion the Cloncurry Ringneck/Mallee Ringneck pair flew into a dead tree that had three other Mallee Ringnecks in it, but remained when the three Mallee Ringnecks left.

During 3 days of observing at the overflow, groups of Ringnecks were seen regularly as they came to drink. First arrival was in the mornings ~1 h after sunrise, at least one subsequent visit was made each day toward the middle of the day, and a final visit was made late in the day ~2 h before sunset. There were no Pale-headed Rosellas seen on the property, but they are common in the town of Cunnamulla 10 km away.

The possible hybrid

Because of the recorded colour variations known to occur in *Barnardius* parrots, the pale-headed bird may have been a colour variation and not a hybrid. The bird observed had the full body colour markings consistent with a Mallee Ringneck, but the head and neck were consistent with a Pale-headed Rosella. The overall colour of the head and shoulders was the same yellow as in the Pale-headed Rosella, with some slight dark mottling visible on the neck above the shoulder. There was no red frontal band.

This bird may have been a lutino colour variation, but if so then all the colour variation was to only the head and neck. There was no sense of colour variation from normal Mallee Ringneck plumage on any other part of the body. The fact that the bird was flying as a group of three could suggest a family unit with a partially lutino offspring, but the colour distribution was not what would be expected. The owner of the property, I. McLaren, advised (pers. comm.) that similar birds have been seen in Cunnamulla, and that a local person interested in birds had located a nest of a Mallee Ringneck × Pale-headed Rosella pair. From observing the bird over 3 days as it came to drink, firm conclusions were not possible but, based on McLaren's comments and the appearance of the bird, the possibility of its being a Mallee Ringneck × Pale-headed Rosella hybrid should be considered. Hybridisation may have been encouraged by a lack of conspecific mates at the edge of the Pale-headed Rosella's range.

Cloncurry Ringneck at Bowra

The described range of the Cloncurry Ringneck is to the north-west of Cunnamulla, south-east to approximately a line between Boulia and Cloncurry, but it ranges as far south-east as Barcaldine, Longreach and Winton (Lendon 1979). The range of the Mallee Ringneck extends north-west to the Diamantina River, Barcaldine, near Winton, and west to the Mayne and Cooper drainages (Forshaw 2002). Hybridisation and intergradation occur where these two ranges meet between Boulia and Winton (Blakers *et al*. 1984; Schodde & Mason 1997; Forshaw 2002; Joseph & Wilke 2006).

The apparent Cloncurry Ringneck at Bowra had all the field-marks of that subspecies, and showed no markings to suggest that it was a Mallee Ringneck hybrid. From the chest to vent was pale yellow, and there was no dark colouration to the back of the head. There was no red frontal band above the beak (frons), nor orange on the chest. Overall, the bird appeared paler than the Mallee Ringneck that accompanied it.

Although the distance between Cunnamulla and the normal eastern limit of the Cloncurry Ringneck is large, >500 km, the appearance of this subspecies at Cunnamulla is not impossible. It has been seen previously at Bowra (I. McLaren pers. comm.), though apparently undocumented.

The known hybridisation and colour variations of *Barnardius* parrots mean that this bird was possibly a hybrid or a colour variation. However, it was phenotypically a Cloncurry Ringneck. Genetic and morphological variation across the Ringneck subspecies are not perfectly correlated (Joseph & Wilke 2006), and it is possible that a 'Cloncurry' type could arise in a northern Mallee Ringneck population fairly close to the zone of contact between the two subspecies. Each time I saw this pair of birds, it was the Mallee Ringneck that was flying in front or landing first, giving the impression that the Cloncurry Ringneck was following the Mallee Ringneck and possibly attempting to pair.

I thank Ian & Julie McLaren for their hospitality and for making their property, Bowra, available for birdwatchers. I also thank Ian McLaren for his input and comments. John Barkla gave the initial impetus to submit the article and provided some excellent suggestions; his assistance is most appreciated. Feedback and comments from Stephen Debus have added greatly to the article and I thank him. Referees John Courtney and Ian McAllan commented helpfully on a draft. As always though, any omissions or errors are mine.

References

Blakers, M., Davies, S.J.J.F. & Reilly, P.N. (1984), *The Atlas of Australian Birds*, Melbourne University Press, Melbourne.

Christidis, L. & Boles, W.E. (2008), *Systematics and Taxonomy of Australian Birds*, CSIRO Publishing, Melbourne.

Forshaw, J. (2002), *Australian Parrots*, 3rd (rev.) edn, Alexander Editions, Robina, Qld.

Gray, A.P. (1958), *Bird Hybrids: A Checklist with Bibliography*, Commonwealth Agricultural Bureaux, The Banks, Mountfield, Buckinghamshire, UK.

Harman, I. (1981), *Australian Parrots in Field and Aviary*, Inkata Press, Melbourne.

Higgins, P. J. (Ed.) (1999), *Handbook of Australian, New Zealand and Antarctic Birds*, vol. 4, Oxford University Press, Melbourne.

Joseph, L. & Wilke, T. (2006), 'Molecular resolution of population history, systematics and historical biogeography of the Australian ringneck parrots *Barnardius*: Are we there yet?' *Emu* **106**, 49–62.

Juniper, T. & Parr, M. (1998), *A Guide to Parrots of the World*, Pica Press, Farnham Royal, East Sussex, UK.

Knight, B. (2009), 'Another Menindee mix-up', *NSW Bird Atlassers Newsletter* **101**, 6–7.

Lendon, A.H. (1979), *Australian Parrots in Field and Aviary*, rev. edn, Angus & Robertson, Sydney.

Schodde, R. & Mason, I.J. (1997), *Zoological Catalogue of Australia, 37.2, Aves*, CSIRO, Melbourne.

Spry, J. (2009), 'Australian Ringneck variations at Bowra Station, NW of Cunnamulla, Queensland', *Bird Observer* **859**, 15.

Received 13 February 2009 ■

AUSTRALIAN FIELD ORNITHOLOGY 2009, **26**, 103–104

A White-throated Treecreeper feeding upon the nectar of Umbrella Tree flowers by tongue lapping, near Malanda, north Qld

Plate 17 Photo: Clifford B. Frith

Photographic Evidence of Nectar-feeding by the White-throated Treecreeper *Cormobates leucophaea*

CLIFFORD B. FRITH

P.O. Box 581, Malanda, Queensland 4885 (Email: frithandfrith@bigpond.com)

Summary. An individual of the north-eastern Australian subspecies of the White-throated Treecreeper *Cormobates leucophaea minor* was closely observed and photographed while clearly feeding upon nectar from the flowers of an Umbrella Tree *Schefflera actinophylla*. Although the few other records of nectar-feeding by treecreepers (Family Climacteridae) are reviewed, this note presents the first substantiated evidence of nectar-feeding by Australasian treecreepers.

The most recent review of the biology of the Family Climacteridae as a whole described treecreepers as taking nectar from flowers at times (Noske 2007). However, few published records of nectar-feeding by any of the six Australian treecreeper species exist. Of the five species of the genus *Climacteris*, only one (the Brown Treecreeper *C. picumnus*) is known to occasionally drink nectar from ironbarks such as Mugga *Eucalyptus sideroxylon* (V. & E. Doerr, cited in Higgins *et al.* 2001) and from paperbarks (Orenstein 1977). The Black-tailed Treecreeper *C. melanura* has been observed feeding on the *Banksia*-like inflorescences of the

Bridal Tree *Xanthostemon paradoxus*, another myrtaceous species (R. Noske pers. comm.).

The White-throated Treecreeper *Cormobates leucophaea* was recently described as 'Almost wholly insectivorous, mainly bark-dwelling ants; occasionally take some plant material' (Higgins *et al.* 2001: p. 199). The details of the few previous records of feeding upon nectar by this treecreeper are unpublished. Orenstein (1977) recorded the White-throated Treecreeper eating *Banksia* nectar. In addition, V. & E. Doerr (cited in Higgins *et al.* 2001) observed the species probing flowers of Mugga, apparently for nectar. There appears to be no other record of nectar-feeding by this species, or by any Australasian treecreeper in rainforest.

On 27 December 2007 I was in a photographic blind atop a 4-m-tall tower, photographing various honeyeaters (Family Meliphagidae) near Malanda, southern Atherton Tablelands, northern Queensland. These birds were visiting an Umbrella Tree *Schefflera actinophylla*, projecting from the rainforest edge with its crown 4 m from the forest and above my garden lawn, to take nectar from its flowers. At 1425 h I was surprised to see a White-throated Treecreeper of the north-eastern Australian subspecies *C.l. minor* fly directly from the forest-edge foliage into the crown of the Umbrella Tree. There the treecreeper worked its way along the entire length of several flowering stems of the plant's crown to direct its bill-tip into the centre of many flowers (Plate 12, front cover). Through my close-focussing, high-quality 10 × 32 binoculars and 500-mm camera lens I could see no insects on the flowers utilised by the bird. Watching it through my camera lens, I could clearly see the bird extending its tongue-tip into nectar to lap it up. The accompanying digital photograph (Plate 17) clearly documents this nectar-feeding.

The tongue-tip of Australasian treecreepers has often been described as 'brush-tipped' and bifid (or forked), but it is in fact fimbricated (or fringed) and quadrifid (four-forked), albeit with poorly defined lateral notches (Noske 2007). Although this feature might be interpreted as a pre-adaptation (or phylogenetic previous adaptation) for nectar-feeding, many oscine species that also have such tongue-tips rarely or never eat nectar (Noske 2007).

I am most grateful to Dr Richard Noske for kindly reading a draft of this note and providing constructive criticisms and suggestions.

References

Higgins, P.J., Peter, J.M. & Steele,W.K. (Eds) (2001), *Handbook of Australian, New Zealand and Antarctic Birds*, vol. 5, Oxford University Press, Melbourne.

Noske, R.A. (2007), 'Family Climacteridae (Australasian Treecreepers)', pp. 642–660 in del Hoyo, J., Elliot, A. & Christie, D.A. (Eds), *Handbook of the Birds of the World*, vol. 12, Lynx Edicions, Barcelona.

Orenstein, R.I. (1977), Morphological Adaptation for Bark Foraging in Australian Treecreepers (Aves: Climacteridae), PhD thesis, University of Michigan, Ann Arbor, Michigan, USA.

Received 5 May 2009 ■

AUSTRALIAN FIELD ORNITHOLOGY 2009, **26**, 105–106

Inland Records of the Bell Miner in Northern New South Wales

R.A. WATTS[1] and A. ASHWORTH[2]

[1]181 Porcupine Lane, Kootingal, New South Wales 2352
(Email: barrababirds@optusnet.com.au)
[2]1245 Nundle Road, Dungowan, New South Wales 2340

Summary. A small group of about four Bell Miners *Manorina melanocephala* occurred at Dungowan, ~20 km south-east of Tamworth on the North-west Slopes of New South Wales, throughout at least February–May 2009. This occurrence followed an earlier, temporary one at Ogunbil, on the North-west Slopes ~20 km south-east of Dungowan, in the 1980s.

The distribution of the Bell Miner *Manorina melanophrys* in New South Wales is normally coastal and near-coastal, extending to the moist eastern escarpment of the Great Dividing Range, with no confirmed recent records west of the Great Divide (Higgins *et al.* 2001). The species is normally sedentary in colonies, although pioneers can establish new colonies 5–10 km from existing ones, and vagrants can occur (though not survive or persist) up to 100–300 km from the normal range (Higgins *et al.* 2001). This note records a small colony of Bell Miners persisting for at least 4 months, on the inland slopes of the Dividing Range in northern NSW ~30 km from the nearest likely source colonies.

At least four Bell Miners were observed by AA at Dungowan village (31°13′S, 151°07′E; <500 m above sea level) ~20 km south-east of Tamworth, on the North-west Slopes of NSW, on 10 February 2009. The record was confirmed on 24 February by a group of the Tamworth Birdwatchers, who saw a similar number of Bell Miners in the same small area. The birds were still present on 24 March, and in early May at least two were heard (AA pers. obs.). Elizabeth Reed (pers. comm.) observed Bell Miners near Ogunbil (~20 km south-east of Dungowan), also on the North-west Slopes on the Tamworth–Port Stephens road, but at higher elevation (~700 m asl) towards the crest of the Great Divide, during the late 1980s when the Miners stayed for about a week.

The Bell Miners at Ogunbil and Dungowan were potentially 20–30 km or more from the nearest likely location of colonies, in moist gullies of east-trending drainage lines over the crest of the Great Divide. However, Bell Miners often form temporary colonies, on the edge of their range, that last a few months then disappear, and the birds at Dungowan were only 30 km from where the species is common in the upper Barnard Valley (I. McAllan pers. comm.). There are many examples of similar temporary colonies extending into the Hunter Valley from the northern Blue Mountains (I. McAllan pers. comm.), but the Dungowan occurrence was a rare westerly incursion over the Great Divide onto the inland slopes.

These outlying, pioneer occurrences of Bell Miners may be part of the recent population expansion of this species, which has potentially adverse consequences for some other bird species, general avian diversity, and tree health in affected areas (Higgins *et al.* 2001; Dare *et al.* 2007). It would be useful to monitor the Miners at Dungowan for long-term persistence, and any establishment and growth of a breeding colony.

Stephen Debus edited our notes into the required format, and we thank Ian McAllan for helpful comments on a draft.

References

Dare, A.J., McDonald, P.G. & Clarke, M.F. (2007), 'The ecological context and consequences of colonisation of a site by Bell Miners (*Manorina melanophrys*)', *Wildlife Research* **34**, 616–623.

Higgins, P., Peter, J.M. &Steele, W.K. (Eds) (2001), *Handbook of Australian, New Zealand and Antarctic Birds*, vol. 5, Oxford University Press, Melbourne.

Received 30 March 2009, revised 11 May 2009

Postscript: The Bell Miners (6–10) were still present at Dungowan in mid July and late August 2009 (Joan Dunne and Geoff Mitchell pers. comm.), i.e. at least 6 months after being discovered there. ■

AUSTRALIAN FIELD ORNITHOLOGY 2009, **26**, 107–108

Review—

***Boom & Bust: Bird Stories for a Dry Country* edited by Libby Robin, Robert Heinsohn and Leo Joseph**, CSIRO Publishing, Melbourne, 2009. Hardcover, 14 × 20 cm, 300 pp., black-and-white illustrations. RRP $40.

This book is a collection of essays on various birds, and sometimes people too, and their relationships with and adaptation to their environment in the Australian arid, semi-arid and monsoon zones. The authors are mostly ornithologists or ecologists, but include a historian, an anthropologist and an archaeologist for perspectives on birds in our colonial history, Indigenous culture, and prehistory.

The introductory chapter, by Libby Robin and Mike Smith, presents the rationale for the book, which is to use the natural history of a range of bird species to highlight environmental variability in Australia, and thus, by understanding the natural rhythms of this continent, to foster better management of anthropogenic change. By using the concept of boom and bust, they contrast our continent, where variability is normal and rainfall does not follow regular patterns, with the expectations by European settlers of regular cyclic seasons. The authors challenge the Northern Hemisphere perspective of 'normal' annual seasons, and highlight some of the disastrous consequences this mentality has had for the Australian environment, such as the loss of one-third of our endemic mammal species since 1788 (a shameful world record).

Chapter 2, by Libby Robin and Leo Joseph, is an evocative, brief history of Australian arid-zone ornithology. It touches on the discovery of the boom-and-bust breeding cycle of the Banded Stilt, Harry Frith's work on the Malleefowl, and the growth of scientific interest in deserts that culminated in the work described in some of the later chapters in the book.

Chapter 3 is an account, by the late Graham Pizzey, of the ecology, irruptions and sudden departures of the Black-tailed Native-hen ('Barcoo Bantam'), driven by flooding rains in the interior drainage basins. Chapter 4, by Steve Morton, is a personal account of the ecology of the Zebra Finch and its remarkable adaptations to life, on a diet of grass seed, in a harsh land. Chapter 5, by David Roshier, details the movements of radio-tracked Grey Teal in the arid zone, and their uncanny ability to find water in the desert, sometimes only hours after a storm produces temporary pools. Chapter 6, by Julian Reid, explores the inland invasions of Australian Pelicans, to breed, on floodwaters and abundant fish in the Lake Eyre Basin, and the possible mechanisms by which they find such opportunities.

Chapter 7, by Penny Olsen, is a history of the discovery of the Night Parrot, the collection of subsequent specimens, and the little information obtained on its biology, with details on the human characters involved. It concludes that the parrot has gone 'bust' because of post-colonial grazing impacts in the rangelands, though it still clings to existence, and that we don't know whether it ever underwent cycles of abundance. Sadly, compared with Penny's book on the Paradise Parrot, this chapter of 22 pages is probably all that can be said in similar vein on the Night Parrot.

Chapter 8, by Mike Smith, is an account of the likely character, relationships and ecology of *Genyornis*: a large, prehistoric flightless bird that was thought to be a ratite (like the Emu) but is now thought to have been a gigantic goose-like anseriform. Chapter 9, by Deborah Bird Rose, explores Indigenous culture in the monsoon zone, and how it is organised by totemic figures such as ‘rainbirds’ (including the Channel-billed Cuckoo); it also details the loss of Indigenous resources to European impacts.

Chapter 10, by Leo Joseph, examines adaptation to the boom-and-bust nature of arid Australia over evolutionary time, by using the woodswallows as an example of the genetic consequences of booms (rapid diversification) and busts (genetic bottlenecks). Chapter 11, by Robert Heinsohn, describes how White-winged Choughs, via their social structure and behaviour, cope with a variable climate in the eucalypt woodlands. He presents the Chough’s societal collapse during hard times as a possible metaphor for human society during El Niño-induced droughts, if we keep pushing our land’s carrying capacity beyond its limits. The final chapter, by Libby Robin, is a history of our post-colonial relationship with the Emu, as a figure on our national coat of arms, as a perceived pest to be fenced out (with often fatal results) and even gunned down by the army, as various symbols of nationalism, and latterly as a research subject that has enhanced our understanding of the arid zone.

Each chapter has a long series of endnotes listing the sources used or quoted in the chapter, and the book concludes with a selected bibliography and a comprehensive index. Several chapters provide maps of locations mentioned, and each chapter is headed with a relevant greyscale bird image from John Gould’s works, or (Chapter 8) a traditional impression of *Genyornis* with, in the text, a current impression. The book is well written, I noticed very few typos, and I’m sure it would be enjoyed by ornithologists and amateurs birders alike.

This book is an essential and timely work that helps the reader understand the Australian environment and how our indigenous birds and people have adapted to cope with its vagaries. There are also many lessons on the consequences of trying to transplant Eurocentric ideas, and especially agricultural practices and expectations, to a very different land. We need to accept the reality that in much of Australia ‘drought’ is the norm, punctuated by occasional boom years, that our climate is highly variable and aseasonal, and that with climate change things may get worse. This book is a great catalyst for that mental transition, and is therefore highly recommended. And the Night Parrot is out there somewhere, waiting for someone with Frederick Andrews’ acumen (see Chapter 7) to take up where he left off (ironically, drowned in an inland waterhole) on documenting its biology.

Finally, it is appropriate to acknowledge that the lifetime work of Richard Zann, world authority on the Zebra Finch, underpinned much of Chapter 4, and that Richard, along with his wife and daughter, perished in the Victorian bushfires of February 2009: a tragic postscript to the book, and another example from this land of extremes with which we must better come to terms.

Stephen Debus
University of New England