Gaffney, R.F. & Mooney, N.J. 1992. The Wedge-tailed Eagle Recovery Plan: Management Phase. Department of Parks, Wildlife and Heritage, Tasmania.

Hollands, D. 1984. Eagles, Hawks and Falcons of Australia. Nelson, Melbourne.

Marchant, S. & Higgins, P.J. (eds) 1993. Handbook of Australian, New Zealand and Antarctic Birds, Vol. 2. Raptors to Pratincoles. Oxford University Press, Melbourne.

Mooney, N. 1988. Tasmania area co-ordinators report for 1987. Australasian Raptor Association News 9, 24.

Le Souef, D. 1918. Food of diurnal birds of prey. Emu 18, 88-95.

Olsen, P. 1995. Australian Birds of Prey. UNSW Press, Sydney.

Ridpath, M. & Brooker, M. 1986. Age, movements and the management of the Wedge-tailed Eagle, *Aquila audax*, in arid Western Australia. Australian Wildlife Research 13, 245-60.

Smith, P. 1984. The forest avifauna near Bega, N.S.W. I. Differences between forest types. Emu 84, 200-210.

Steyn, P. 1992. Birds of Prey of Southern Africa. David Phillips, Cape Town.

Tracey, G. 1982. The Vegetation of the Humid Tropical Region of North Queensland. CSIRO, Melbourne.

Bird Populations Density in Thinned, Unthinned and Old Lowland Regrowth Forest, East Gippsland, Victoria

A.S. Kutt

Department of Conservation and Natural Resources, Orbost Office, Gippsland Area, Orbost, Vic. 3888
Present address: Australian Centre for Tropical Freshwater Research, James Cook University, Townsville, Qld 4811

The response of forest avifauna to disturbance from timber harvesting has been well documented in southeastern Australia (Pattemore & Kikkawa 1975; Loyn et al. 1980; Loyn 1980; Kavanagh et al. 1985; Recher 1991; Loyn 1993). One major effect of harvesting is the simplification of the forest structure by decreasing the complexity of the vegetation profile (Recher 1991). This shift towards a more homogenous, even-aged stand alters the foraging, nesting and breeding resources available to forest birds and in most cases reduces species diversity and density (Recher 1991). Where alternative silvicultural techniques to clear-felling are used, the changes to the vegetation structure and composition can be more variable (Brown et al. 1991).

The effect on bird populations of thinning regrowth forest — the removal of a proportion of the basal area of regrowth trees in a selected stand with the aim of increasing resources available to the remaining trees and increasing their growth rate — has been examined in Australia and the United States. In East Gippsland, Brown et al. (1991) found a reduction in bird species richness and abundance in sites recently thinned, while in the United States, Wood & Niles (1978) recorded a decrease in the richness and abundance of native pine

forest bird species in response to thinning practices that eradicated the understorey and destroyed dead trees.

This survey examined the differences in the density of bird populations between old regrowth, unthinned regrowth and thinned regrowth forest; it was predicted that lower densities would be recorded in the the regrowth forest types. Other components of this study examined the responses of reptiles (Kutt 1993), arboreal mammals and nocturnal birds (Kutt 1994) and microchiropteran bats (Kutt 1995).

Five sites were surveyed in state forest 50 km east of Orbost, East Gippsland, Victoria. Within these sites, three types of forest stand were examined: 25-35 year-old regrowth coupes thinned between 1988–92 (hereafter thinned), 25-35 year-old regrowth coupes (hereafter unthinned) and old regrowth forest that was only selectively logged approximately 50 years ago (hereafter old). Bird censuses were conducted between 7 January 1993 and 14 March 1993, along 200 m fixed-line transects, placed through a representative area of the selected coupe. Transects were at least 100 m from the boundary of adjacent coupes to minimise edge effects. A total of 11 thinned, ten unthinned and five old forest transects were available for sampling. Each tran-

sect was surveyed three times and all species seen or heard were identified, counted and their perpendicular distance from the transect line estimated.

Density estimates of total bird populations in each forest type were calculated from these results using the computer program DISTANCE (Laake et al. 1993). This program estimates densities using a variety of models to predict $f(0)$, the probability density function at the location of the transect line. The perpendicular distances of birds observed were grouped into intervals (0-19 m, 20-39 m, 40-59 m and 60-80 m) to enhance the robustness of the model (Buckland et al. 1993).

Two line transect models, the uniform and half-normal distributions with combinations of hermite, polynomial and cosine adjustments, were used to examine the data. Both of these functions are considered to be suitable starting points for model fitting for estimating vertebrate densities from line-transect data (Vernes 1993). Model selection was made on the basis of Akaike's information criterion (AIC), the model with the lowest AIC being the more appropriate for analysing the data (Buckland et al. 1993). In addition, the higher the resultant probability value, the better the fit of the density function to the data (Laake et al. 1993; Buckland et al. 1993).

Density estimates using the DISTANCE program for each line transect were compared with the mean number of bird observations per transect line using Pearson correlations. This provided an indication of how well a simple estimate of relative density correlated with the estimates of absolute density. Statistical analysis of total densities and observations per transect were made using a non-parametric method: the Kruskal-Wallis one-way Analysis of Variance by ranks (Siegel & Castellan 1988).

A total of 55 species of birds was recorded from all surveys at all sites (Table 1). The half-normal key with cosine adjustment was the appropriate model to use in estimating bird population densities (Table 2). The density detection functions calculated for each forest type were close and the 95% confidence limits were narrow for each forest treatment type indicating comparisons between sites are valid. Density per hectare for all bird species increased from thinned (9.9 ± 1.1) to unthinned (11.7 ± 1.3) to old forest (12.7 ± 1.2) but was not significantly different. Estimates of density for individual species were attempted; however, the total number of observations for most species were too small to confidently predict values using the models in Distance (Buckland et al. 1993). The density of birds estimated

for each transect and the mean number of birds observed for each transect were correlated ($r = 0.544$, $d.f. = 1$, $P = 0.004$).

Previous surveys of forest bird communities in Australia have indicated that older aged forest support a greater diversity and density of forest birds due to their floristic and structural complexity (Loyn 1980; Loyn & MacFarlane 1984; Kavanagh et al. 1985; Recher et al. 1985; Loyn 1993). Conversely, studies examining silviculturally thinned forest have suggested that lower total bird density in these forests was due to the loss of this resource complexity (Wood & Niles 1978; Saxon et al. 1990; Brown et al. 1991).

Although the results of this survey were not statistically significant, they indicate a general series trend for increasing bird density from thinned to old forest. Concurrent surveys of vegetation patterns in the surveyed coupes identified a decrease in large overstorey trees, understorey species richness and groundcover complexity and an increase in small tree density from old to thinned forest (B. Thompson & A. Trumbull-Ward unpubl. data). Though these data were unavailable for statistical scrutiny against the estimated bird densities due to differences in survey protocol, intuitive extrapolation of their results suggest at the very least some correspondence between changes in the forest structure and bird density. Further detailed survey of both bird community patterns and environmental variables would be required to confirm this opinion.

In reference to the bird data set collected, the total number of observations was low and represented only a single season. This limitation may account for the lack of a significant result. Bird species vary in visibility over seasons and between sexes (Keast 1984) and may occur sporadically in time and space, with many years of sampling in some sites still not accurately counting total species present in an area (Recher et al. 1983). Longer-term, seasonal recording should be undertaken to more accurately reflect the dynamics of bird species composition and density in the forest types surveyed in this study.

Three criteria for measuring absolute density from line transect bird counts are generally recognised: all birds present on or within the transect area are recorded, no bird is counted more than once and no birds move in or out of the area during census due to attraction or repulsion (Recher et al. 1983; Pyke & Recher 1984; Bell & Ferrier 1985). If these assumptions are violated, then over- or under-estimation of density occurs. The correspondence in the density detection

Table 1 Mean number of observations per transect for all bird species recorded in the thinned, unthinned and old regrowth forest sites. Bold type indicates forest treatment with the highest number of observations.

Species	Thinned ($n = 11$)	Treatment Unthinned ($n = 10$)	Old ($n = 5$)
Brown Goshawk *Accipiter fasciatus*	**0.1**	0	0
Common Bronzewing *Phaps chalcoptera*	0	0	**0.4**
Glossy Black-Cockatoo *Calyptorhynchus lathami*	0	0	**0.81**
Yellow-tailed Black-Cockatoo *Calyptorhynchus funereus*	0.54	0.21	**1.59**
Gang-gang Cockatoo *Callocephalon fimbriatum*	**0.27**	0.21	0
Rainbow Lorikeet *Trichoglossus haematodus*	0	0	**0.6**
Crimson Rosella *Platycercus elegans*	0.27	0.6	**1.2**
Fan-tailed Cuckoo *Cacomantis flabelliformis*	0.54	**0.6**	0
Horsfield's Bronze-Cuckoo *Chrysococcyx basalis*	0	**0.3**	0
Shining Bronze-Cuckoo *Chrysococcyx lucidus*	0.1	0	**0.21**
Laughing Kookaburra *Dacelo novaeguineae*	**1.26**	0.6	0.36
Sacred Kingfisher *Todiramphus sanctus*	0	0.4	**0.6**
Superb Lyrebird *Menura novaehollandiae*	0.27	**0.4**	**0.4**
White-throated Treecreeper *Cormobates leucophaeus*	3.18	2.79	**4.2**
Red-browed Treecreeper *Climacteris erythrops*	**0.18**	0.1	0
Superb Fairy-wren *Malurus cyaneus*	5.16	**7**	6.81
Southern Emu-wren *Stipiturus malachurus*	0	0	**0.4**
Spotted Pardalote *Pardalotus punctatus*	0.18	0.1	**0.6**
Striated Pardalote *Pardalotus striatus*	0.1	**0.3**	0.21
White-browed Scrubwren *Sericornis frontalis*	1.62	1.59	**5.19**
Brown Gerygone *Gerygone mouki*	**0.63**	0	0
Brown Thornbill *Acanthiza pusilla*	3.27	1.8	**3.6**
Striated Thornbill *Acanthiza lineata*	5.25	6.9	**9.4**
Red Wattlebird *Anthochaera carunculata*	0	0.4	**0.6**
Lewin's Honeyeater *Meliphaga lewinii*	0.63	0.4	**1.0**
Yellow-faced Honeyeater *Lichenostomus chrysops*	**1.44**	1.2	0.4
White-eared Honeyeater *Lichenostomus leucotis*	**0.36**	0.3	0.21
White-naped Honeyeater *Melithreptus lunatus*	**0.1**	**0.1**	0
Cresent Honeyeater *Phylidonyris pyrrhoptera*	0.1	**0.3**	0
New Holland Honeyeater *Phylidonyris novaehollandiae*	**0.1**	0	0
Eastern Spinebill *Acanthorhynchus tenuirostris*	0.27	0.54	**0.6**
Jacky Winter *Microeca fascinans*	0.1	0	**0.21**
Scarlet Robin *Petroica multicolor*	0.36	**0.6**	0.21
Rose Robin *Petroica rosea*	0	**0.1**	0
Eastern Yellow Robin *Eopsaltria australis*	**3.27**	2.91	3.0
Eastern Whipbird *Psophodes olivaceus*	1.08	0	**1.8**
Spotted Quail-thrush *Cinclosoma punctatum*	**0.36**	**0**	0
Varied Sitella *Daphoenositta chrysoptera*	0	**1.59**	0
Crested Shrike-tit *Falcunculus frontatus*	0	0	**0.21**
Golden Whistler *Pachycephala pectoralis*	0.27	**0.7**	0
Rufous Whistler *Pachycephala rufiventris*	0.18	**0.4**	**0.4**
Grey Shrike-thrush *Colluricincla harmonica*	0.63	0.81	**0.9**
Black-faced Monarch *Monarcha melanopsis*	0.36	0.3	**0.4**
Rufous Fantail *Rhipidura rufifrons*	0.18	0	**0.4**
Grey Fantail *Rhipidura fuliginosa*	1.65	2.5	**2.58**
Black-faced Cuckoo-shrike *Coracina novaehollandiae*	0.24	0.1	**0.81**
Cicadabird *Coracina tenuirostris*	0	**0.18**	0
Olive-backed Oriole *Oriolus sagittatus*	0.27	0.1	**0.6**
Australian Magpie *Gymnorhina tibicen*	0	0.1	**0.6**
Pied Currawong *Strepera graculina*	2.16	1.29	**3.2**
Grey Butcherbird *Cracticus torquatus*	0	**0.1**	0
Satin Bowerbird *Ptilonorhynchus violaceus*	**0.1**	**0**	0
Australian Raven *Corvus coronoides*	0	0.1	**0.21**
Red-browed Finch *Neochmia temporalis*	**0.45**	**0**	0.21
Silvereye *Zosterops lateralis*	0	0.3	**0.6**
Mean total individuals per 200 m transect	12.6	13.2	18.6
Mean total individuals per km	63	66	93

Table 2 Detection function, density and summary statistics for all birds in species recorded in the thinned, unthinned and old regrowth forest sites.

Forest type	n	total L (km)	f(0)	AIC	χ² probability	Density /ha	s.e.
Thinned	138	2.2	0.04	259.5	0.81	9.9	1.1
Unthinned	132	2.0	0.04	207.9	0.72	11.7	1.3
Old	93	1.0	0.03	168.3	0.31	12.7	1.2

functions across the forest types in this study, and the fact that each detection function decreased monotonically away from the transect line suggest that the these assumptions have not been differentially violated across each forest type and that comparisons between forest types are valid. Furthermore, the DISTANCE sampling program expects objects to be missed, as the direct effects of structural differences on sightablity is covered by modelling the density function (Buckland et al. 1993). One potential problem, unaccounted for by this model, is if particular bird species behave differently (in terms of the assumptions) in each different forest type.

Intensive counts measuring relative density are thought to be sufficient to examine differences between forest types and patch size, as long as the relationship between relative and absolute remains fairly constant (Recher et al. 1983; Loyn 1986), although this relationship breaks down in cases where the detectability of birds differs between sites being compared (Recher et al. 1983). In reference to this study, the significant correlation between relative and absolute density for the each measured transect indicates that some relationship exists. Consequently, relative measures may have been used to describe the density patterns without resorting to detailed modelling of the probability density function. However, examination of the magnitude of change in the total relative (thinned 12.6 birds/transect; unthinned 13.2 birds/transect; old 18.6 birds/transect) and absolute density (thinned 9.9 birds/ha; unthinned 11.7 birds/ha; old 18.6 birds/transect) indicates that the relative measures exaggerate the level of observed change. Differences in sightability has most likely influenced the relative density estimates and modelling the detectability function has overcome this problem. An alternative is to undertake intensive, high repetition, cross-seasonal counts that provide relative measures corresponding more closely to actual values (Recher et al. 1983; Loyn 1986).

Though the results of this study were inconclusive,

they still suggest that in forests where regrowth forms a large component of native vegetation and where larger scale thinning operations may be undertaken, there will be an adverse influence on the bird densities in those forests. Longer term monitoring of these sites is necessary to examine whether the changes observed in this study are significant and how bird species and populations will further respond to changes in the forest if further intensive management is applied to the stands in an effort to enhance wood production potential.

Acknowledgements

References

Bell, H.L. & Ferrier, S. 1985. The reliability of estimates of density from transect counts. Corella 9, 3-13.

Brown, G.W., Cherry, K.A., Gilmore, A.M., Meggs, R.A., Milledge, D.R., Morris, B.J. & Nelson, J.L. 1991. Use of thinned and unthinned eucalypt forest by vertebrates. Management of Eucalyptus Regrowth in East Gippsland Technical Report No.18, CSIRO and Department of Conservation and Environment, Victoria.

Buckland, S.T., Anderson, D.R., Burnham, K.P. & Laake, J.L. 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall, London.

Kavanagh, R.P., Shields, J.M., Recher, H.F. & Rohan-Jones, W.G. 1985. Bird populations of a logged and unlogged

forest mosaic in the Eden woodchip area. Pp. 273-281 in Birds of Eucalypt Forests and Woodlands: Ecology, Conservation, Management. Eds. A. Keast, H.F. Recher, D. Saunders & H. Ford. Surrey Beatty and RAOU, Sydney.

Keast, A. 1984. Assessment of community composition and species richness in contrasting habitats. Pp. 19-24 in Methods of Censusing Birds in Australia. Ed S.J.J.F. Davies. Department of Conservation and Environment, Perth, WA, Bulletin 153.

Kutt, A.S. 1993. Initial observations on the effect of thinning eucalyptus regrowth on heliothermic skinks in lowland forest in East Gippsland, Victoria. Pp. 186-196 in Herpetology in Australia Eds D. Lunney & D. Ayers. Royal Zoological Society of New South Wales and Surrey Beatty, Sydney.

Kutt, A.S. 1994. Arboreal marsupials and nocturnal birds in thinned, unthinned and old lowland regrowth forest in East Gippsland, Victoria. Australian Forestry 57, 123-130.

Kutt, A.S. 1995. Stratification and activity of bat communities in thinned, unthinned and old lowland regrowth forest in East Gippsland, Victoria. Victorian Naturalist 112, 86-92.

Laake, J.L., Buckland, S.T., Anderson, D.R. & Burnham, K.P. 1993. DISTANCE User's Guide v2.0. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins.

Loyn, R.H. 1980. Bird populations in a mixed eucalypt forest used for the production of wood in Gippsland, Victoria. Emu 80, 145-156.

Loyn, R.H. 1986. The 20 minute search, a simple method for counting forest birds. Corella 10, 58-60.

Loyn, R.H. 1993. Effects of previous logging on bird populations in East Gippsland: VSP retrospective study. VSP Technical Report No.18, Wildlife Section, Department of Conservation & Natural Resources, Victoria.

Loyn, R.H., MacFarlane, M.A., Chesterfield, E.A. & Harris, J.A. 1980. Forest utilisation and the flora and fauna in Boola Boola State Forest in south-eastern Victoria. Bulletin No. 28, Forests Commission of Victoria.

Loyn, R.H. & MacFarlane, M.A. 1984. Changes in bird and mammal populations after harvesting eucalypts for sawlogs and pulpwood in East Gippsland. Unpublished Research Branch Report No. 269, Forests Commission of Victoria.

Pattemore, V. & Kikkawa, J. 1975. Comparison of bird populations in logged and unlogged rainforest at Wiangarie State Forest, New South Wales. Australian Forestry 37, 188-198.

Pyke, G.H. & Recher, H.F. 1984. Censusing Australian birds: a summary of procedures and a scheme for standardisation of data presentation and storage. Pp. 55-63 in Methods of Censusing Birds in Australia. Ed. S.J.J.F. Davies. Bulletin 153, Department of Conservation and Environment, Perth, WA.

Recher, H.F. 1991. The conservation and management of eucalypt forest birds: resource requirements for nesting and foraging. Pp. 25-34 in Conservation of Australia's Forest Fauna. Ed. D. Lunney. Surrey Beatty and Royal Zoological Society of New South Wales, Sydney.

Recher, H.F., Milledge, D.R., Smith, P. & Rohan-Jones, W.G. 1983. A transect method to count birds in eucalypt forest. Corella 73, 49-54.

Recher, H.F., Holmes, R.T., Schultz, M., Shields, J. & Kavanagh, R. 1985. Foraging patterns of breeding birds in eucalypt forest and woodland of south-eastern Australia. Australian Journal of Ecology 10, 399-419.

Saxon, M.J., Cherry, K.A., Collins, M.G. & Peake, P.P. 1990. Pre-thinning vertebrate fauna survey. Management of Eucalyptus Regrowth in East Gippsland Technical Report No.8, CSIRO and Department of Conservation & Environment, Victoria.

Siegel, S. & Castellan, N.J. 1988. Non-parametric Statistics for the Behavioral Sciences. McGraw-Hill, New York.

Vernes, K. 1993. Life on the edge: the ecology of the Red-legged Pademelon Thylogale stigmatica (Gould) (Marsupialia: Macropodidae) in fragmented upland rainforest in the North Queensland Wet Tropics. M.Sc. Thesis, James Cook University of North Queensland, Townsville.

Wood, G.W. & Niles, L.J. 1978. Effects of management practices on non-game bird habitat in longleaf-slash pine forests. Pp. 40-49 in Management of Southern Forests for Non-Game Birds. Ed. R.M. DeGraaf. Proceedings of Workshop, Atlanta, Georgia.