

Habitat use and distribution of the Beautiful Firetail (*Stagonopleura bella*) in foothill forests of the Victorian Highlands, Australia

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Abstract. The Beautiful Firetail (*Stagonopleura bella*) is an uncommon, granivorous finch from coastal south-eastern Australia, with a distribution extending from mid-coastal New South Wales to south-eastern South Australia, including Tasmania. This paper presents a quantitative assessment of habitat use by the Beautiful Firetail based on data collected from 30 paired riparian and non-riparian sites in the foothill forests of the Victorian Highlands, Australia. The Beautiful Firetail occurred in two of the three forest blocks surveyed and was found almost exclusively at riparian sites. The Beautiful Firetail was most likely to occur at riparian sites on the coastal fall of the ranges at sites with high sedge cover and low cover of shrubs and bare ground. The species occurred at low densities (0.10–0.19 individuals ha⁻¹) throughout the year. Records from the Atlas of Victorian Wildlife were used to describe the distribution of Beautiful Firetails in Victoria. Notable observations inland of the Great Dividing Range were recorded during the present study. Further study is required to understand the ecological requirements of the Beautiful Firetail throughout its range.

Introduction

The Beautiful Firetail (*Stagonopleura bella*) is one of three firetail finches (genus *Stagonopleura*), all of which are endemic to Australia. It is granivorous and has a restricted distribution along the coast of south-eastern Australia, ranging from Newcastle on the central coast of New South Wales, to the Mt Lofty Ranges in South Australia (Blakers *et al.* 1984; Barrett *et al.* 2003). It is the only species of native finch to inhabit Tasmania, where it is considered common (Immelmann 1965; Blakers *et al.* 1984). There are several gaps in its range, isolating several distinct populations (Blakers *et al.* 1984; Schodde and Mason 1999). In Victoria, Emison *et al.* (1987) reported 159 records of the species, concentrated in coastal areas. It was not recorded inland of the Great Dividing Range (Emison *et al.* 1987) and although it has been reported from the Lake Eildon and Mt Beauty areas (Pizzey 1980), such records are unconfirmed (Blakers *et al.* 1984). Notable population declines of this species have occurred in the western extent of its range (SAOA 1977; Barrett *et al.* 2003). Recent atlas data have shown that the reporting rate of the Beautiful Firetail decreased by > 20% in parts of its range over the last two decades, particularly at the western and northern extremities (Blakers *et al.* 1984; Barrett *et al.* 2003).

Schodde and Mason (1999) recognise three ultrataxa for the species, each of which is largely isolated from the others.

There are significant biogeographical barriers that fragment the distribution of the species. The semi-arid environment surrounding the mouth of the Murray River, South Australia, isolates *S. bella samueli* at the western extent of the species' distribution around the Mt Lofty Ranges and Kangaroo Island. Similarly, the coastal intrusion of the grassland-dominated Victorian Volcanic Plain bioregion around Warrnambool and Portland isolates the ultrataxon *S. b. interposita* – occurring east of the Murray River mouth in (SA) to west of Portland (Vic.) – from the most widespread form, *S. b. bella*, which occurs east of Warrnambool and into southern New South Wales. This ultrataxon also occurs in Tasmania, where it is separated from the mainland by Bass Strait.

The Beautiful Firetail is primarily considered a species of coastal habitats, being closely associated with coastal heaths and tea-tree scrubs (Immelmann 1965; Emison *et al.* 1987; Read 1987; Wood 1998). It also frequents heathy woodlands and wet forest gullies away from the coast, including regrowth forest following timber harvesting (Loyn *et al.* 1980; Emison *et al.* 1987; Joint Scientific Committee 1990). There has been little research on the ecological requirements of the Beautiful Firetail and its habitat preferences are poorly understood.

In this paper, I first outline known distribution of the Beautiful Firetail in Victoria, based on records from the Atlas of Victorian Wildlife (Department of Sustainability and

Environment). Then, within this geographical context, I describe the distribution and habitat use of Beautiful Firetails at a series of riparian and non-riparian sites in a forest mosaic in southern Victoria. Descriptive observations of other aspects of the species' ecology are also presented.

Methods

Study area

The study was conducted in three large, continuous forest blocks in the foothills of the Victorian Highlands, south-eastern Australia: Bunyip State Park (37°56'S, 145°35'E), Kinglake National Park (37°29'S, 145°22'E) and Marysville State Forest (37°34'S, 145°41'E). This region comprises an extensive forest mosaic and is characterised by mixed *Eucalyptus* species forests flanking the Great Dividing Range.

Study sites

Sites were selected as part of a broader study investigating the importance of riparian zones to bird assemblages in forest mosaics. Based on five stream systems in the forest mosaic, a series of 30 paired riparian and adjacent non-riparian sites (20 site-pairs in Bunyip State Park, five in Kinglake National Park, and five in Marysville State Forest) were investigated. Twenty site-pairs were located on the coastal fall of the Great Dividing Range (Bunyip State Park) and ten were located on the inland fall (Kinglake National Park and Marysville State Forest).

Riparian sites were confined to riparian forest ecological vegetation class and were positioned immediately adjacent to the streams, the inner boundary being ~5 m from the water channel. Non-riparian sites were on adjacent slopes, ~750 m from their riparian partners. Non-riparian sites occurred in several ecological vegetation classes, ranging from wet forest to lowland forest and heathy woodland.

Habitat assessments

Habitat measurements based on a life-form structural assessment were conducted at each site during spring 2002. Tree measurements were gathered within a randomly placed 0.25 ha (100 m × 25 m) quadrat at each site. All trees were counted and determined to be either canopy or mid-storey forms. The diameter-at-breast-height (dbh) of each tree was measured and counts recorded of trees < 10 cm dbh (Table 1). Visual estimates were made of the cover (%) of the canopy. For shrub assessments, a randomly placed 625 m² (25 m × 25 m) quadrat was used at each site.

Within this quadrat, shrubs were counted and assigned to one of two height-classes: tall shrubs (shrubs > 2 m) and low shrubs (shrubs < 2 m) (Table 1). The cover (%) of each height class was visually estimated. The cover (%) of a suite of vegetation life forms – low ferns, grasses and sedges – was also measured within this quadrat (Table 1). The cover abundance (%) of bare ground and fine litter was assessed in four 25 m² (5 m × 5 m) quadrats and average values generated for each site.

Bird surveys

Bird surveys were carried out at each site at a rate of five visits per season (i.e. one or two visits per month) between July 2001 and December 2002 (total = 29 visits). Surveys were conducted using a fixed-point count method (Pyke and Recher 1984). At each site, fixed-points were centrally located in two adjoining 50 m × 50 m plots, which yielded a combined sampling area of 0.5 ha. Consecutive 8-min counts were conducted at each point, in which all birds seen and heard were recorded, including those outside of plots. For visual observations of individual birds, the following positional and foraging data were collected: habitat structural feature, substrate, food item, behaviour, plant species and vertical position. Observations of breeding and other notable behaviour were also recorded. Bird surveys were conducted throughout the day (between sunrise and sunset) in suitably still and dry conditions. The sequence in which paired sites were visited was randomised for each stream system.

Analysis

The set of geographical, landscape and habitat variables was initially analysed using a univariate approach to assess their effect on the response variable, the presence of Beautiful Firetails. A correlation matrix between the predictor variables was used to assess collinearity levels. Owing to strong collinearity between several predictors, ecologically related variables – the low vegetation and ground cover variables – were transformed (using arcsine transformations to meet assumptions of normality), converted to a Bray–Curtis similarity matrix and analysed using MDS ordination (PRIMER; Clarke and Gorley 2001). This method was used to reduce ecologically related variables to a smaller set of predictor variables (MDS axes) representing low vegetation and ground cover.

Logistic regression was used to estimate the probability of the occurrence of Beautiful Firetails at a site as a function of geographical and habitat variables. The dependent variable was the presence or

Table 1. Univariate analyses of the relationship between the presence of Beautiful Firetails and environmental variables at sites

Mean values of variables are presented for sites where the Beautiful Firetail was present or absent during the study. Significant variables are indicated in bold. Comparisons were made using either χ^2 tests or Student's *t*-tests, as shown in parentheses for each variable

Environmental variable	Present	Absent	Statistic	<i>P</i>
Geographical location (χ^2 , d.f. = 3)	–	–	12.25	< 0.001
Landscape position (χ^2 , d.f. = 3)	–	–	–19.82	< 0.001
No. small trees ha ^{–1} (<i>t</i> , d.f. = 58)	261.4	169.9	3.889	0.083
Coarse woody debris (<i>t</i> , d.f. = 58)	1.4	1.7	–0.701	0.486
% cover of:				
Canopy (<i>t</i> , d.f. = 58)	37	52	–3.505	0.001
Tall shrub (<i>t</i> , d.f. = 58)	17	24	–2.118	0.036
Low shrub (<i>t</i> , d.f. = 58)	6	19	–4.198	< 0.001
Fern (<i>t</i> , d.f. = 58)	29	25	0.704	0.484
Sedge (<i>t</i> , d.f. = 58)	42	14	5.803	< 0.001
Grass (<i>t</i> , d.f. = 58)	25	37	–1.312	0.171
Fine litter (<i>t</i> , d.f. = 58)	36	50	–2.472	0.016
Bare ground (<i>t</i> , d.f. = 58)	10	13	–0.767	0.446

absence of Beautiful Firetails at a site, pooled for the 29 visits. Predictor variables included geographical position (coastal or inland), canopy cover, number of small trees, tall shrub cover and two ordination dimensions, MDS1 and MDS2. A backward stepwise (likelihood ratio) method for elimination of variables was used for selection of the final model (SPSS 11.5; SPSS Inc., Chicago, IL, USA). Residuals and values with high leverage were checked to ensure the models assumptions were reasonable.

Seasonal variation in the distribution of the Beautiful Firetail in the forest landscape (i.e. number of sites recorded and relative abundance) was compared using single factor ANOVA.

The distribution of the Beautiful Firetail in Victoria was mapped based on records from the Atlas of Victorian Wildlife (AVW; maintained by the Victorian Department of Sustainability and Environment; accessed 25 February 2003). Existing AVW records (from the year 1800 to 2003) and those from this study were mapped using a geographic information system (ArcView 3.2; ESRI, Redlands, CA, USA).

Results

An affinity of Beautiful Firetails with coastal habitats is evident from the distribution of AVW records ($n = 683$) for the species in Victoria (Fig. 1). Records are concentrated in the East Gippsland Lowlands and the Gippsland Plains bioregions in the south-east, Wilsons Promontory, the Otways and the Glenelg River area in the south-west (Fig. 1). There are scattered records along the coastal fall of the ranges east of Melbourne and extending into Gippsland. There are only three records of the species inland of the Great Dividing Range: one extreme outlier in the Warby Ranges in north-eastern Victoria; a single record from the

Strathbogie Ranges in central Victoria; and a record from Murrindindi, ~70 km north-east of Melbourne (Fig. 1).

In the present study, the Beautiful Firetail was observed on 117 occasions. The species was detected at 70% ($n = 21$) of riparian sites (Fig. 2) and at four (13%) non-riparian sites, all in Bunyip State Park (Fig. 2). It was widely distributed in riparian habitats in Bunyip State Park, occurring at 19 of 20 sites (Fig. 2). The Beautiful Firetail was recorded infrequently at inland sites. It was recorded at two sites along the Acheron River in the Marysville State Forest, east of Narbethong, but was not recorded at comparable sites in Kinglake National Park (Fig. 2).

The results of univariate tests between the occurrence of Beautiful Firetails and the measured habitat variables are shown in Table 1. Sites at which Beautiful Firetails were present had significantly greater sedge cover and density of small trees, and reduced cover of shrubs and fine litter cover (Table 1).

The correlation matrix between the independent habitat variables showed many significant correlations, particularly among ecologically related variables, such as measures of low vegetation and ground cover (e.g. low shrub, fern, sedge, grass, fine litter and bare ground) (Table 2). There was a strong positive correlation between sedge cover and density of small trees and riparian habitats, while increased canopy cover, shrub cover and litter cover were associated with non-riparian habitats (Table 2).

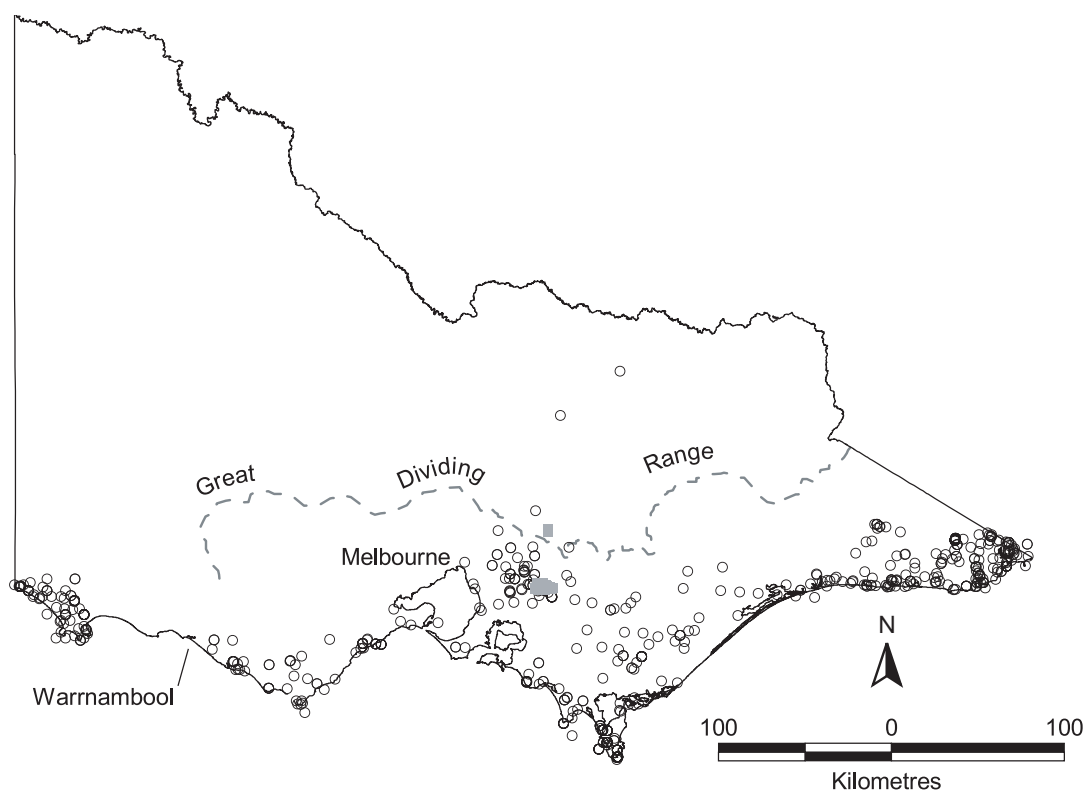


Fig. 1. The distribution of the Beautiful Firetail in Victoria, 1800–2003. Records from the AVW (○) and the present study (grey areas) are shown.

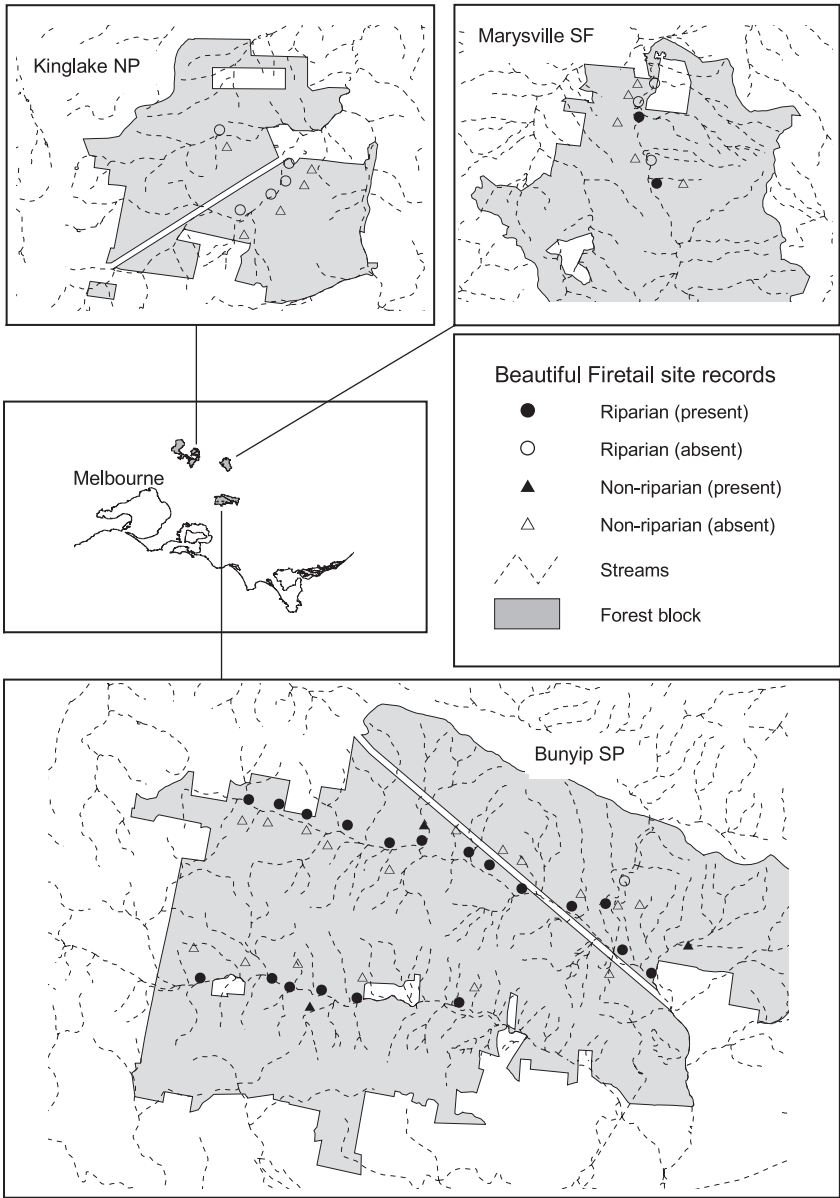


Fig. 2. Distribution of the Beautiful Firetail from survey sites in the Victorian Highlands, showing its preference for riparian sites.

Table 2. Spearman rank correlation matrix between independent habitat variables
Significant correlations are indicated in bold

	Small tree	CWD ^A	Canopy	Tall shrub	Low shrub	Fern	Sedge	Grass	Fine litter
Small tree	—								
CWD ^A	−0.279	—							
Canopy	0.434	−0.285	—						
Tall shrub	0.017	−0.224	−0.083	—					
Low shrub	0.714	−0.123	0.304	0.027	—				
Fern	−0.444	0.431	−0.098	−0.305	−0.464	—			
Sedge	−0.531	0.003	−0.460	0.059	−0.404	−0.126	—		
Grass	0.500	−0.392	0.293	0.108	0.444	−0.641	−0.042	—	
Fine litter	0.048	0.249	0.092	0.006	−0.094	0.443	−0.422	−0.533	—
Bare ground	−0.288	0.227	−0.193	0.143	−0.233	0.338	−0.194	−0.582	0.409

^ACWD, coarse woody debris.

Owing to the high collinearity between some habitat variables, an MDS ordination (PRIMER; Clarke and Gorley 2001) based on a set of ecologically related variables representing ground and low vegetation structure was used to reduce these variables to two ordination dimensions (MDS1 and MDS2) (Fig. 3). MDS1 represents a gradient from sites with high cover of grass and low shrubs (e.g. heathy woodland sites) to sites with high cover of ferns and large areas of bare ground and fine litter. MDS2 represents a gradient from sites with dense low shrubs and an open ground layer (e.g. heathy dry forest, herb-rich foothill forest) to sites with high cover of sedges (e.g. riparian forest).

Logistic regression modelling included three predictor variables in the final model: geographical location, canopy cover and MDS2 (Table 3). Landscape position (riparian or non-riparian habitat) was excluded from the multivariate analysis because it was considered to act as a surrogate variable for a range of specific habitat variables associated with riparian zones. Within the foothill forests of the Victorian Highlands, the Beautiful Firetail was most likely to occur at sites on the coastal fall of the ranges (Table 3). The significance of MDS2 in the logistic model indicates that the Beautiful Firetail is more likely to occur at sites with high sedge cover and low cover of shrubs and bare ground. The inclusion of canopy cover in the final model indicates that more open areas (i.e. less tree cover) were preferred (Table 3). The logistic model correctly predicted 76% (19 out

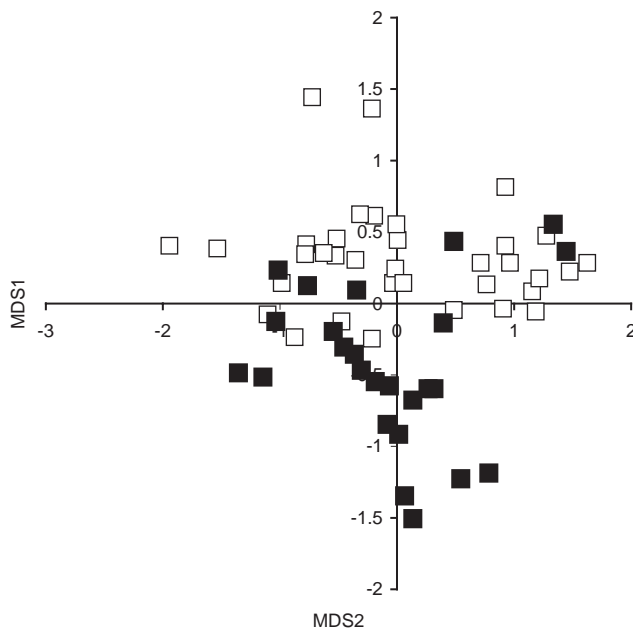


Fig. 3. Ordination of variables representing low vegetation structure and ground cover at sites in the Victorian Highlands where the Beautiful Firetail was present (■) or absent (□). Spearman rank correlations identified habitat variables significantly associated with each axis: MDS1 (+): grass ($r = 0.891$), low shrubs (0.509); MDS1 (-): low ferns (-0.812), fine litter (0.658), bare ground (0.664); MDS2 (+): low shrubs (0.608), fine litter (0.380); MDS2 (-): sedge (-0.909).

of 25 sites) of sites at which the Beautiful Firetail was recorded. For sites where it was not recorded, the model correctly predicted 91% (32 out of 35 sites).

The Beautiful Firetail was rarely recorded away from riparian habitats (Fig. 2). The species was recorded once in mature wet forest with a dense Austral Bracken (*Pteridium esculentum*) understorey where an individual was observed to perch briefly in a small Blanket-leaf (*Bedfordia arborescens*). On another occasion, a single bird was observed feeding on the seed heads of wire-grass (*Tetrarrhena* species) in lowland forest of Silvertop Ash (*Eucalyptus sieberi*) and Messmate (*E. obliqua*). Individuals were also observed at two sites in heathy woodland of Narrow-leaved Peppermint (*E. radiata*) and Mealy Stringybark (*E. considensiana*), with a dense understorey of *Hakea*, *Banksia* and wire-grass. It should be noted that each of these records was within 800 m of known Beautiful Firetail populations in riparian habitat.

The species occurred at rather low density at sites in the forest landscape; the annual range was 0.10–0.19 birds ha^{-1} (Table 4). There was no difference in density of the Beautiful Firetail between seasons ($F = 0.441$, d.f. = 3, $P = 0.725$). There was also no evidence to suggest that the species was more widespread (i.e. occurred at more sites) in one season than another ($F = 0.556$, d.f. = 3, $P = 0.649$) (Table 4).

Beautiful Firetails were observed attending nests on three occasions. All of these observations were in Bunyip State Park and all in riparian habitat. All nests were in *Leptospermum* shrubs, two in Woolly Tea-tree (*L. lanigerum*) and one in Prickly Tea-tree (*L. continentale*). Each nest was between 1 and 2 m above the ground and close to the stream channel (mean distance = 9.7 m, range = 0–17 m).

The species is known to construct distinctive roosting nests (Immelmann 1965) and these were observed at 64% of known Beautiful Firetail sites. All roosting nests were in riparian habitat. These structures were confined to *Leptospermum* species, except one in Prickly Currant Bush (*Comprosmia quadrifida*). One series of observations witnessed the destruction of an old roosting nest by a single Beautiful Firetail, with the retrieved material being incorporated into a new roosting nest being constructed nearby.

During this study the species was observed to be solitary, with most observations consisting of single birds (80%), and the others of pairs (20%). Owing to the variety of methods

Table 3. Logistic regression model of the probability of occurrence of the Beautiful Firetail at sites in the Victorian Highlands

The estimate of the coefficient, the standard error and the statistical significance are shown

Variable	Estimate	s.e.	P
Constant	3.420	1.908	0.073
Geographical position	-2.085	1.018	0.041
Canopy cover	-0.079	0.043	0.066
MDS2	-3.496	1.233	0.005

Table 4. Seasonal attributes of the distribution of the Beautiful Firetail in the forest landscape

Data were gathered from 30 paired riparian and non-riparian sites during 29 visits between July 2001 and December 2002

Season	Habitat	Summer	Autumn	Winter	Spring
Sites present	Riparian	13	13	10	14
	Non-riparian	1	–	1	2
Density (birds ha ⁻¹)	Riparian	0.16 (0–0.33)	0.16 (0–0.33)	0.11 (0–0.53)	0.19 (0–0.53)
	Non-riparian	0.01 (0–0.01)	–	0.01 (0–0.01)	0.01 (0–0.01)

from which AVW records are generated (i.e. different techniques and sizes of survey areas), it was not possible to recover conclusive data to support this finding. However, where Beautiful Firetails were recorded during bird censuses ($n = 66$), 66% were of single birds and 27% of pairs of birds. A total of seven birds was the most for a single bird census.

Beautiful Firetails restricted their activities to within 5 m of the ground. The species was typically observed in vegetation < 2 m tall (87%), although perched at greater heights when calling or disturbed. Beautiful Firetails were frequently observed searching for food, but too few direct observations of birds feeding were gathered to permit analysis. Individuals moved extensively among grasses and sedges and were rarely recorded on the ground – during the study only two observations were made of birds on the ground. Food items most frequently eaten were the seeds of sedges (*Gahnia* species). Firetails were also observed eating the seeds of wire-grass and *Rumex* species, the fruits of Prickly Currant Bush, flowering buds of Hazel Pomaderris (*Pomaderris aspera*) and one was observed gleaning invertebrates from the inner foliage of Woolly Tea-tree.

Discussion

The Beautiful Firetail was closely associated with riparian habitats in the coastal fall of the foothill forests of the Victorian Highlands and was rare in the inland forests of the ranges. Records of Beautiful Firetails in non-riparian habitats were also rare. While the value of such habitats should not be discounted, there was no evidence in this study to suggest that such habitats were used extensively at any time of the year.

The distinct structure of riparian vegetation provided important habitat for the Beautiful Firetail in the forest mosaic. Its preference for sites with increased cover of sedges is consistent with the known diet and foraging behaviour of Beautiful Firetails recorded by Read (1994) and Barker and Vestjens (1990): seeds from Cyperaceae, but also Asteraceae, Graminae, Rutaceae, and species of *Poa*, *Stipa*, *Rumex* and *Casuarina*, and invertebrates including coleopteran larvae. An assessment of the diet of this species in heathy vegetation in South Australia (Read 1994), found that Firetails fed predominantly on the seeds of native grasses and sedges, as well as the seeds of shrubs and small trees similar to the present study. Accordingly, the decreased abundance of the species in habitats dominated by low ferns and low shrubs may reflect the absence of suitable food sources. The availability of free

water in riparian habitats would also benefit a granivorous bird such as the Beautiful Firetail.

In contrast to the current study, the species has also been reported to forage extensively on the ground (Cooper 1975; Pizzey 1980; Emison *et al.* 1987). The Beautiful Firetail is cryptic in habit and such behaviour would be difficult to observe in the structurally complex ground layer habitats investigated in this study. The disassociation of Firetails from habitats comprising large areas of bare ground and fine litter (Table 1) suggests that open ground is avoided. It is likely that any ground foraging in forested habitats mostly occurs among or beneath understorey vegetation. This is likely to reflect the distribution of food, because fallen seeds would be concentrated below source plants, with less seed available in areas away from plants.

Beautiful Firetails do not form large feeding flocks as has been reported for other Australian finches (e.g. Garnett *et al.* 2005; Immelmann 1965). Low densities were maintained throughout the year and no more than two individuals were observed together on any occasion. The consistency of records from sites during the study suggests that the species is sedentary in habit. Beautiful Firetails are known to occupy large territories and form small, locally nomadic feeding flocks outside of the breeding season (Immelmann 1965; Emison *et al.* 1987).

All records of birds observed away from riparian habitats were during late spring and summer. These birds may represent individuals displaced from preferred habitats (e.g. breeding territories) or young birds dispersing from their natal territory.

The Great Dividing Range poses a barrier to the distribution of the Beautiful Firetail in south-eastern Australia. Of 683 records generated from the Atlas of Victorian Wildlife, just three were north of the Great Dividing Range. The species was not recorded north of the Great Dividing Range in either 'The Atlas of Victorian Birds' (Emison *et al.* 1987), or the first 'Atlas of Australian Birds' (Blakers *et al.* 1984). The Beautiful Firetail was not recorded inland of the Great Dividing Range in the recent atlas (Barrett *et al.* 2003).

The vegetation composition and structure of riparian habitats at sites on both the inland and coastal fall of the ranges was similar (Palmer and Bennett 2005). Little is known of the dispersal capabilities of the Beautiful Firetail. However, the maximum distance between banding site and recovery site for banded individuals ($n = 101$) is just 2 km, over a period of

four years (Baker *et al.* 1999). The disjunct distributions of ultrataxa along the coast of south-eastern Australia (Schodde and Mason 1999) further suggest that movements of this species over considerable distances are restricted.

The distribution of the Beautiful Firetail is highly fragmented, particularly at its western extent and the species is known to have become locally extinct in some areas (e.g. Thomas and Wheeler 1980; Read 1987). The fragmented distribution, coupled with observed population declines in several regions (SAOA 1977; Barrett *et al.* 2003), raises concerns for the ongoing conservation of local populations of the Beautiful Firetail. Potential threats include continued modification and fragmentation of habitats (Emison *et al.* 1987; Read 1987) especially modification of ground-layer habitats by processes such as grazing and inappropriate fire regimes. The establishment of weedy grasses may significantly alter ground layer structure and composition. Riparian habitats are particularly susceptible to invasion of weeds through water-borne transport and redistribution of seed; they are subject to frequent disturbance from changes in water flow and to increased nutrient levels (Gregory *et al.* 1991; Malanson 1993). The smaller proportions of seeds from introduced plants in the diet of the Beautiful Firetail compared with the Red-browed Finch (*Neochmia temporalis*) and Diamond Firetail (*Stagonopleura guttata*) in a South Australian study (Read 1994) suggests that encroachment of a weed-dominated ground layer is likely to be a threat to the Beautiful Firetail.

This study of the Beautiful Firetail in a forested environment of south-eastern Australia has shown it has a narrow habitat preference in foothill eucalypt forests, being closely associated with riparian habitats. Further study of habitat use by the Beautiful Firetail throughout its range is needed because habitat attributes identified in this study are likely to differ greatly from those important to the species in coastal heath environments.

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