

**Ecology and Behaviour of *Pachycephala rufogularis*
and *P. inornata* (Aves: Pachycephalidae)
in Woodlands of South Australia**



Immature *Pachycephala rufogularis* at Gluepot. (Photo D. Moise)

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CHAPTER 5 HABITAT REQUIREMENTS OF *PACHYCEPHALA RUFOGULARIS* AND *P. INORNATA*

5.1. Introduction

5.1.1. *Habitat selection in birds*

Habitat selection in birds has been an important topic in behavioural ecology for a long time (Svårdson 1949, Cody 1985, Wiens 1989) and still is a research priority (Martin 2001, Doligez *et al.* 2002, Wilson and Paton 2004). Habitat selection refers to a series of behavioural responses that may result in a disproportionate use of the available habitats, in order to increase the survival and fitness of individuals (Jones 2001). Birds actively select their habitat according to ultimate factors such as food resources, protection from predators and parasites and availability of nest sites (Lack 1933, Svårdson 1949, Hilden 1965) and on the basis of proximate factors such as landscape features, vegetation structure, habitat configuration (size, shape and distribution of the vegetation in an area) and floristics (Wiens 1969, Gilmore 1985, Rotenberry 1985). Single factors or combinations of factors are important to different bird species (Anderson and Shugart 1974). Consequently, birds may be associated with particular vegetation types or may show a close affinity with a certain plant species (Bergin 1992, Storch 1993, Lane *et al.* 2001). Other factors such as inter- and/or intra-specific competition and/or attraction, predation and parasitism, disease, and dispersal barriers might influence habitat selection and consequently bird species distributions (Cody 1985, Wiens 1989).

In recent decades, studies of habitat selection have assumed a new significance, as a result of the importance of including habitat information into conservation planning (Caughley 1994). Management of wildlife populations generally involves habitat management, and the success of the conservation programs for threatened species depends on a sound understanding of their habitat requirements. When the habitat preferences of threatened species are determined, priorities can be set to protect their habitat (Sutherland 2000).

5.1.2. Habitat partitioning

Since the theoretical and empirical studies from the early 20th century, the coexistence of similar species in ecological communities has been one of the most studied and intriguing issues in ecology (Gordon 2000). According to the principle of competitive exclusion, which has become a fundamental tenet of ecology, “as a result of competition two species hardly ever occupy similar niches, but displace each other in such a manner that each takes possession of certain kinds of food and modes of life in which it has an advantage over its competitor” (Gause 1934). One of the key mechanisms that allow ecologically similar species to coexist is resource partitioning along the axes of habitat, food, or time (Schoener 1986). Among these axes, habitat was found to be the most important, and differential habitat selection one of the principal factors permitting similar species to coexist (Rosenzweig 1981). Studies of avian ecology that found similar, locally coexisting bird species using different habitats in the northern hemisphere (Cody 1978, Morse 1985, Wenny *et al.* 1993) are mirrored by studies in Australia (Ford and Paton 1976, Ford 1983, Cameron 1985). Where similar species show overlap in habitat preferences, the habitat partitioning occurs by means of mutually exclusive territories (Saether 1983) or by species occupying different niches within the same habitat (MacArthur 1958).

5.1.3. Habitat requirements of *Pachycephala rufogularis* and *P. inornata*

To date, there is only one study that has measured and compared the habitats of the ecologically similar Red-lored Whistler *Pachycephala rufogularis* and Gilbert’s Whistler *P. inornata*, in an endeavour to shed more light on the ecology of *P. rufogularis*, prompted by the concern of an eventual negative impact of broombush harvesting in Big Desert, Victoria (Woinarski 1987). The study included data on two other Pachycephalids: Golden Whistler *P. pectoralis* and Rufous Whistler *P. rufiventris*. In the field *P. rufogularis* and *P. inornata* occupied different habitats, and apparently did not occur in the same areas. The vegetation at the sites where the two species were recorded differed in both floristics and structure. The plant species with significant cover, more commonly encountered at *P. rufogularis* sites were: *Eucalyptus incrassata*, *Callitris verrucosa*, *Melaleuca uncinata*, *Leptospermum coriaceum*, *Baeckea behrii*, *Hakea muelleriana*, *Eucalyptus leptophylla*, *Calytrix tetragona*, *Triodia irritans*, *Baeckea crassifolia* and *Phebalium bullatum*. The plant species with significant cover, more commonly encountered at *P. inornata* sites were: *Melaleuca uncinata*, *Eucalyptus incrassata*, *Baeckea behrii*, *Eucalyptus baxteri*, *Allocasuarina muelleriana*, *Hakea muelleriana*, and *Callitris rhomboidea*. *P. rufogularis* occurred at sites with denser vegetation

at low height intervals and with less cover of taller vegetation, while *P. inornata* occurred at sites with relatively open low vegetation layers but dense tall vegetation. The vegetation profile for *P. rufogularis* sites was approached most closely by that for *P. pectoralis* sites, while the vegetation profile for *P. inornata* sites was similar to that for *P. rufiventris*. *P. rufogularis* sites also had the highest proportion of bare ground of all the whistler sites, of which *P. inornata* had the lowest proportion. The differences in vegetation structure were consistent with the different fire history of the sites. Vegetation in *P. rufogularis* sites was significantly younger than in *P. inornata* sites. Also, *P. rufogularis* was not recorded in vegetation that had not been burnt for more than 40 years (Woinarski 1987).

The literature suggests that *P. rufogularis* has rigid habitat requirements, the most important aspects being the age of vegetation (the species being recorded mostly in areas regenerating 5-40 years after fire) (Carpenter and Matthew 1986; Woinarski 1987, Higgins and Peter 2002), and the vegetation structure (open low mallee scrub, shrubland or heathland, with dense and patchy understorey) (Woinarski 1987, Higgins and Peter 2002). *Pachycephala rufogularis* is patchily distributed even in the areas with suitable habitat (Boles 1988). By contrast, *P. inornata* seems to be much more flexible in its habitat requirements, occupying a broader range of habitats (Boles 1988).

Close (1982), Carpenter and Matthew (1986) and Woinarski (1987) indicate that disjunct distributions seem typical for the two species. However, some records indicate co-occurrence of the two species in some areas (Parsons and McGilp 1934, Reilly 1974, Glover 1976). Given their ecological similarity, the question is how the two species can manage to co-exist. According to the limiting similarity theory (MacArthur and Levins 1967), the two species should differ in some aspects of their ecology (e.g. different use of resources, niche partitioning), in order to avoid competition (see also Chapters 3 and 7 of this study). At Chapman's Bore and other parts of the western Murray Mallee, *P. inornata* replaced *P. rufogularis* over a period of 20 years (Garnett and Crowley 2000). Whether this process is passive, with the vegetation becoming less suitable with age for *P. rufogularis* but more suitable for *P. inornata*, or involves interspecific competition is unknown (Woinarski 1987).

5.1.4. The usage of the term ‘habitat’

The term ‘habitat’ has been defined in a variety of ways, very often ambiguously (Murphy and Noon 1991). After reviewing 50 papers from 1980 to 1994 that discussed wildlife-habitat relationships, Hall *et al.* (1997) concluded that in the great majority (89%) of the papers, the term ‘habitat’ was used incorrectly (incompletely defined or confused with vegetation association). Among the habitat-related terms, the term most commonly used incorrectly was ‘habitat type’, in 94% of papers indicating actually vegetation association.

Hall *et al.* (1997) suggested standard definitions of habitat and habitat-related terms, to be used by all wildlife ecologists in order to improve communication between them, and between them and other scientists, managers, and the public. The definition of habitat presented by Hall *et al.* (1997), based on definitions given by Morrison *et al.* (1992) and Block and Brennan (1993), is “the resources and conditions present in an area that produce occupancy - including survival and reproduction - by a given organism.” Hall *et al.* (1997) argued that habitat is organism-specific, relating the presence of a species, population or individual to an area’s physical and biological characteristics. The authors insisted that, being the sum of the specific resources that are needed by organisms, habitat implies more than vegetation or vegetation structure. For this study, I used the term ‘habitat’ as defined by Hall *et al.* (1997). Since in assessing *P. rufogularis* and *P. inornata* habitats I assessed mainly the vegetation, I use the term ‘vegetation type’ instead of ‘habitat type’, as recommended by Hall *et al.* (1997).

5.2. Aims

This chapter aims to address the following questions:

- What types of vegetation are being used by the two Pachycephalid species?
- Do they differ in the vegetation they use?
- What are the key habitat requirements for the two Pachycephalid species?
- Which, if any, environmental variables (such as landscape attributes, vegetation age, structure and floristic composition) correlate with the presence of each of the two species?
- What is the extent of habitat specialization for the two species?
- As a declining species, is *Pachycephala rufogularis* more of a habitat specialist than the more common and widespread *P. inornata*?

5.3. Methods

The habitat was assessed within the core areas (25% UD) of seven *Pachycephala rufogularis* and eight *P. inornata* home ranges at Gluepot and three *P. rufogularis* home ranges at Ngarkat. For both species, these home ranges were mainly of individual pairs, but also of individual birds. Because of the perceived tag effect reflected in different habitat use, the home ranges of radio-tracked individuals were not considered for this analysis (see Chapter 4). The core areas were chosen for assessing the habitat, as they were the most used, and therefore were more likely to contain the preferred habitat for each species (cf. Samuel *et al.* 1985).

Physical environment and vegetation details were collected from 30m x 30m quadrats, as recommended by Heard and Channon (1997). The size of the quadrats was based on a nested species-area curve in Ngarkat mallee-heath and used in mallee surveys in Victoria (Gullan 1991), being therefore appropriate for the purpose of this study.

Three quadrats per core area were surveyed. The position of the quadrats within the core areas was not randomly chosen, but centred around an actual fix of an individual bird. Care was taken to choose well-spaced fixes, to avoid quadrat overlap. Considering these, the locations of vegetation quadrats were determined in ArcView. For consistency, all quadrats had the corners oriented towards the cardinal points (respectively N, E, S and W). While in the field, if a quadrat happened to land in an ecotone, its position was not shifted to encompass only one (homogenous) vegetation type, as recommended by Heard and Channon (1997). The ecotones were considered in vegetation assessments, as they also reflected the birds' preference, the purpose of this study being to determine the key habitat features for the birds, not describing vegetation types *per se*. At Ngarkat, three more quadrats were surveyed, centred on initial *P. rufogularis* sightings in winter and spring 2004. Vegetation assessments in plots centred on the point where the bird was first sighted were previously undertaken for *P. rufogularis* by Woinarski (1987) and Clarke (2004). The additional three quadrats surveyed at Ngarkat correspond to initial sightings of three separate individual birds with insufficient fixes to have their home range determined by kernel methods (see Chapter 4). In all, 45 quadrats were surveyed at Gluepot (21 for *P. rufogularis* and 24 for *P. inornata*) and 12 at Ngarkat.

Methods of vegetation assessment were based on Heard and Channon (1997) and Bayley and Brouwer (2004). The variables measured are given in Table 5.1. In determining the floristic composition, efforts were made to ensure that every plant species within the quadrat was recorded. However, it is possible that some might have been overlooked, especially the small ones, represented by just few individuals. Also, due to the fact that the vegetation surveys were undertaken in autumn and winter, it is possible that many annuals were missed. Only the vascular plants were considered. All plant species recorded within the quadrats were identified mostly to species level. For species that could not be identified in the field, samples were taken and labeled for later identification. Plant identification was undertaken using the Gluepot Reference Herbarium (for Gluepot plant species), and also using various field guides (Jessop and Toelken 1986, Prescott 1988, McCann 1989, Costermans 2003, Kutsche and Lay 2003).

Vegetation structure was assessed using the Line Transect Intercept technique (Bayley and Brouwer 2004). Two measuring tapes were placed diagonally across the quadrat along N-S and E-W directions, and the cover of every plant overlapping these (the shaded portion of the measuring tape) was recorded, together with the plant species and the height class (see Table 5.1.). Every 1 m along the measuring tapes, the vertical foliage density profile was measured to the first 2 m above the ground using a 2 m vertical pole (of 2 cm diameter). The pole was divided into 10 cm sections and the number of touches of vegetation for each 10 cm interval was recorded. In all, a total of 84 samples of vertical foliage density profile were collected for each quadrat.

Along the quadrat diagonals, the first (up to) ten trees (regardless of species, but see specifications below) that intersected the tape measure were measured for various parameters, described in Table 5.2. Similarly, the first (up to) ten shrubs (regardless of species) were measured (Table 5.2), and also, when present, the first (up to) ten spinifex (*Triodia*) (Table 5.1). The trees, shrubs and spinifexes were measured in order along the tape measure starting from the north corner, then, if necessary, continuing from the east corner. Caution was taken to not measure the same tree, shrub or spinifex twice (those situated in the centre of the quadrat). In the mallee habitats, only the mallee eucalypts were considered for measuring, in regard to their particular phenotype. As the mallee trees have multiple stems, often going in various directions and at various angles, measuring canopy height would have given a distorted image of the actual canopy volume. Because of that, the canopy height was not

measured for the mallees. It also must be stressed that in estimating the overall canopy cover I followed Forward and Robinson (1996) in considering the *crown* cover, defined as the area of ground covered by a vertical projection to the periphery of the crown, and not the *canopy* cover sensu Muir (1977), which takes into account only the area of individual foliage clumps within one tree's crown, and not including the open space (for example within a mallee's sometimes widely spaced foliage clumps).

The ground cover as percent bare ground, leaf litter and spinifex was estimated using the chart for visual assessment of ground cover (i.e. Figure 14 in Bayley and Brower 2004). The percentage of cryptogamic crust was not determined separately, but included in the *bare ground* category.

Table 5.1. Variables measured within the vegetation assessment quadrats

variable	description/categories
landform	dune / swale
broad vegetation description	Gluepot: mallee with <i>Triodia</i> (MT), mallee- <i>Triodia</i> with <i>Callitris</i> (MT(CAVE)), mallee over shrubs (MS), prickly <i>Acacia</i> thicket (ACCOth), <i>Casuarina</i> woodland (CAPAw) Ngarkat: mallee (M), heath (H), mallee-heath (MH)
age	estimated time since the last fire
species	plant species
dominance/codominance	flagged for up to 3 overstorey and up to 5 understorey species
cover/abundance	Braun-Blanquet scale, modified: + - cover < 5%, few individuals, 1 - cover < 5 %, any number of individuals, 2 - cover 5-20 %, any number of individuals, 3 - cover 20-50 %, any number of individuals, 4 - cover 50-75 %, any number of individuals, 5 - cover 75-100 %, any number of individuals
life form	Muir's code, modified: GL - grass <0.5 m, H - hummock grass, VL – sedge < 0.5 m, VT – sedge >0.5 m, J – forb, SD - shrub <0.5 m, SC - shrub 0.5-1 m, SB - shrub 1-1.5 m, SA - shrub 1.5-2 m, S - shrub >2 m, KS – low mallee (<3 m), KT - mallee (>3 m), L - tree 2-5 m, M - tree >5 m, V – vine
vegetation density	number of touches of vegetation for each 10cm interval along a vertical pole of 2 cm diameter
cover line intercept	the cover of every plant intersecting the quadrat diagonals (the shaded portion of the tape)
height class	height class of the plants measured along the quadrat diagonals: <0.5 m, 0.5-1 m, 1-1.5 m, 1.5-2 m, 2-3 m, 3-5 m and >5 m
maximum height	maximum height of the tallest vegetation layer, in metres
canopy cover	percentage overall canopy cover
ground cover	percentage bare ground (BG), leaf litter (LL) and spinifex (Sp)
10 trees	parameters measured for the first (up to) 10 trees along the quadrat diagonals (see Table 5.2)
10 shrubs	parameters measured for the first (up to) 10 shrubs along the quadrat diagonals (see Table 5.2)
10 spinifexes	parameters measured for the first (up to) 10 spinifexes along the quadrat diagonals: life form: clump (C/1), irregular clump (IC/2), ring (R/3), broken ring (BR/4), life stage: vigorous (V/1), senescent (S/2), dead (D/3), height, minimum and maximum external and internal (for rings) diameters; all measurements in centimeters

Table 5.2. Variables measured for trees and shrubs

variable	description/categories
species	tree or shrub species.
height	height (in metres for trees, in centimetres for shrubs). usually measured with the use of a clinometer in trees and with the graduated pole (used for measuring of the vertical density) in shrubs.
# live stems*	number of live stems emerging from the same root (lignotuber) of the measured mallee.
# dead stems*	number of dead stems of the measured mallee.
diam stem*	diameter (measured at hip height = at 1 m off the ground) of the thinnest living stem = minimum diameter (in centimetres). measured with calipers.
DIAM stem*	diameter (measured at hip height) of the thickest living stem = maximum diameter (in centimetres). measured with calipers.
epicormic growth*	percentage epicormic growth (shoots and/or branchlets) from the total foliage.
mistletoes	presence/absence.
canopy height*	height from where the canopy starts (in metres). measured only for <i>Casuarina</i> .
diam (canopy)	minimum diameter of the canopy projected onto the ground (in metres for trees, in centimetres for shrubs).
DIAM (canopy)	maximum diameter of the canopy projected onto the ground (in metres for trees, in centimetres for shrubs).
openness (canopy)	average percentage of light obstructed by the foliage, determined with the use of a transparency showing the various canopy types (app. 3H in Heard and Channon 1997)
# clumps*	number of large, distinctive clumps forming the canopy
clumps separation*	spacing between clumps, ranked as follows: 1 – isolated (only for trees with a single clump), 2 - well separated (100-50 cm), 3 - clearly separated (50-10 cm), 4 - slightly separated to touching (10-0 cm), 5 - (touching to) overlapping
dead branches*	number of dead branches on live stems
% dead**	percent of shrub that is dead

* - variable measured for trees only

** - variable measured for shrubs only

5.4. Data analysis

Floristic and structural dissimilarities between *P. rufogularis* and *P. inornata* preferred habitats were explored using multivariate analysis, performed with PC-ORD software, ver. 4.34 (McCune and Mefford 1999).

Firstly, the sites were classified using Cluster Analysis into discrete classes or groups (McGarigal *et al.* 2000), using Euclidean distance measure and Ward's method for group linkage (hierarchical grouping).

Dissimilarities between *P. rufogularis* and *P. inornata* sites were further investigated using Nonmetric Multidimensional Scaling (NMS) ordination. In contrast to classification, which attempts to organize entities into discrete classes or groups, ordination attempts to organize entities along a continuum (McGarigal *et al.* 2000). The ordination has the advantage of identifying the relationship between the variables and ordination scores, which can be explicitly represented as a joint plot: a diagram of vectors radiating from the data centroid, the angle and length of which tell the direction and strength (as expressed by the magnitude of r^2) of the relationship (McCune and Mefford 1999). For the NMS ordination, Sørensen (Bray-Curtis) distance measure was used, to retain sensitivity in more heterogeneous data sets and to give less weight to outliers (McCune and Mefford 1999). To attain the lowest possible stress, the “slow and thorough” option in autopilot mode was selected (starting number of axes: 6, instability criterion: 0.00001, iterations to evaluate stability: 50, maximum number of iterations: 400, number of runs with real data: 40, number of randomized runs: 40, step down in dimensionality with a default initial step length of 0.2).

Multi-Response Permutation Procedure (MRPP, similar in concept to Analysis of Similarity ANOSIM, McCune and Grace 2002) was used to test differences at both floristic and structural levels between vegetation types used by *P. rufogularis* and *P. inornata*. Euclidean distance and $n/sum(n)$ as weighting factor were used.

The Mantel test was used to detect any relationship between floristic and structural characteristics for both *P. rufogularis* and *P. inornata* sites. Sørensen (Bray-Curtis) distance and the randomization method for calculating the P-value (Monte Carlo test, with 1000 runs) were used.

Indicator Species Analysis (ISA) was used to detect and describe the value of different plant species in indicating the preferred habitat of *P. rufogularis* or *P. inornata* (groups defined by *species* variable, in this case, the two whistler species studied). For each of the two groups ISA produced indicator values for each plant species. The indicator values (IV) range from zero (no indication) to 100 (perfect indication). Perfect indication means that the presence of a plant species points to a particular group (whistler species) without error, at least with the data set in hand (McCune and Mefford 1999). The statistical significance of the maximum IV recorded for given plant species was tested using a Monte Carlo (randomization) technique. The null hypothesis was that IVmax is no larger than would be expected by chance (i.e. that the plant species has no indicator value). The probability of type I error is the proportion of times that the IVmax from the randomized data set equals or exceeds the IVmax from the actual data set (McCune and Mefford 1999). A total of 10,000 runs were chosen to achieve the desired precision of 0.001 alpha, as the P-value for a randomization test can be no smaller than 1/N, where N is the total number of runs (McCune and Mefford 1999).

To investigate the extent of correlation between the presence of a whistler species and a particular vegetation type, between the presence of a certain plant species and a particular vegetation type, and between the presences of plant species themselves, a cross-products matrix in Principal Component Analysis (PCA) was obtained. Initially, the data were standardised by "the norm" (relativisation parameter: 2), so that no site received any more weight in the analysis than any other (McCune and Mefford 1999). In interpreting the strength of the correlation the guide given in Fowler and Cohen (1996) was used.

The degree of specialization in habitat use for both whistler species was determined using the standardised form of the Shannon-Wiener index (evenness J'):

$$J' = H' / H \text{ max,}$$

where J' is the relative diversity (here, of vegetation), H' is the Shannon-Wiener diversity index (or degree of specialization, expressed by the formula

$$H' = - \sum p_i \ln p_i,$$

p being the proportion of observations (here, sites) in category i) and H max = the H' value obtained if the sites were distributed equally across all vegetation types. J' values range between 0 and 1, those close to 0 indicating specialisation and those close to 1 generalization. Evenness indices of $J' \leq 0.4$ were considered as indicating specialisation in relation to a

particular habitat, those of $J' \geq 0.6$ as indicating generalization (Brower *et al.* 1990).

Vegetation density data were pooled and vegetation profiles were constructed for *P. rufogularis* and *P. inornata* habitats, using the average of touches for each 10 cm increment. The participation of various groups of plants to density was also determined.

For the trees, shrubs and spinifexes measured, descriptive statistics were obtained. The various parameters were compared between *P. rufogularis* and *P. inornata* habitats and between *P. rufogularis* habitats from Gluepot and Ngarkat. The differences were tested using univariate techniques. The tests employed, mainly non-parametric (Chi-square, Mann-Whitney, Kruskal-Wallis) were performed with GraphPad Prism[®] ver. 3.03 statistical software (Motulsky 1999).

5.5. Results

5.5.1. Floristic composition

At Gluepot, the vegetation assessments identified 37 plant species in quadrats sampled within the *Pachycephala rufogularis* core areas and 43 in quadrats sampled within the *P. inornata* core areas (Appendix 3). At Ngarkat 62 plant species were identified in quadrats sampled within the *P. rufogularis* core areas. In addition, at Ngarkat there were a few species that could only be identified to genus (Appendix 4). In all, 40 genera from 19 plant families were recorded in vegetation sites at Gluepot and 48 genera from 23 families at Ngarkat.

5.5.2. Vegetation used by *Pachycephala rufogularis* and *P. inornata*

Floristic data collected within the *Pachycephala rufogularis* and *P. inornata* vegetation sites at Gluepot were structured in a matrix with 45 sites and 139 variables, and used in the multivariate analyses.

The Cluster Analysis produced a dendrogram (Figure 5.1) that grouped the *P. rufogularis* and *P. inornata* vegetation sites from Gluepot according to major vegetation types, described in Hyde (2001) and Forward and Robinson (1996).

All *P. rufogularis* sites clustered in five floristic groups (at 70% resolution) within the broad ‘mallee-*Triodia*’ vegetation type. Two of the five mentioned floristic groups represented ‘mallee-*Triodia* with *Callitris*’ vegetation sub-type. They also contained some *P. inornata* sites (Figure 5.1). *Pachycephala. inornata* sites clustered within the broad ‘mallee over shrubs’ vegetation type (three groups at 65% resolution), within ‘prickly *Acacia* shrubland’ (one group), within ‘*Casuarina* woodland’ (one group), and also within the ‘mallee-*Triodia* with *Callitris*’ (two groups at 70% resolution, together with certain *P. rufogularis* sites, Figure 5.1). A detailed description of the vegetation types used by the two whistler species is given in the discussion section.

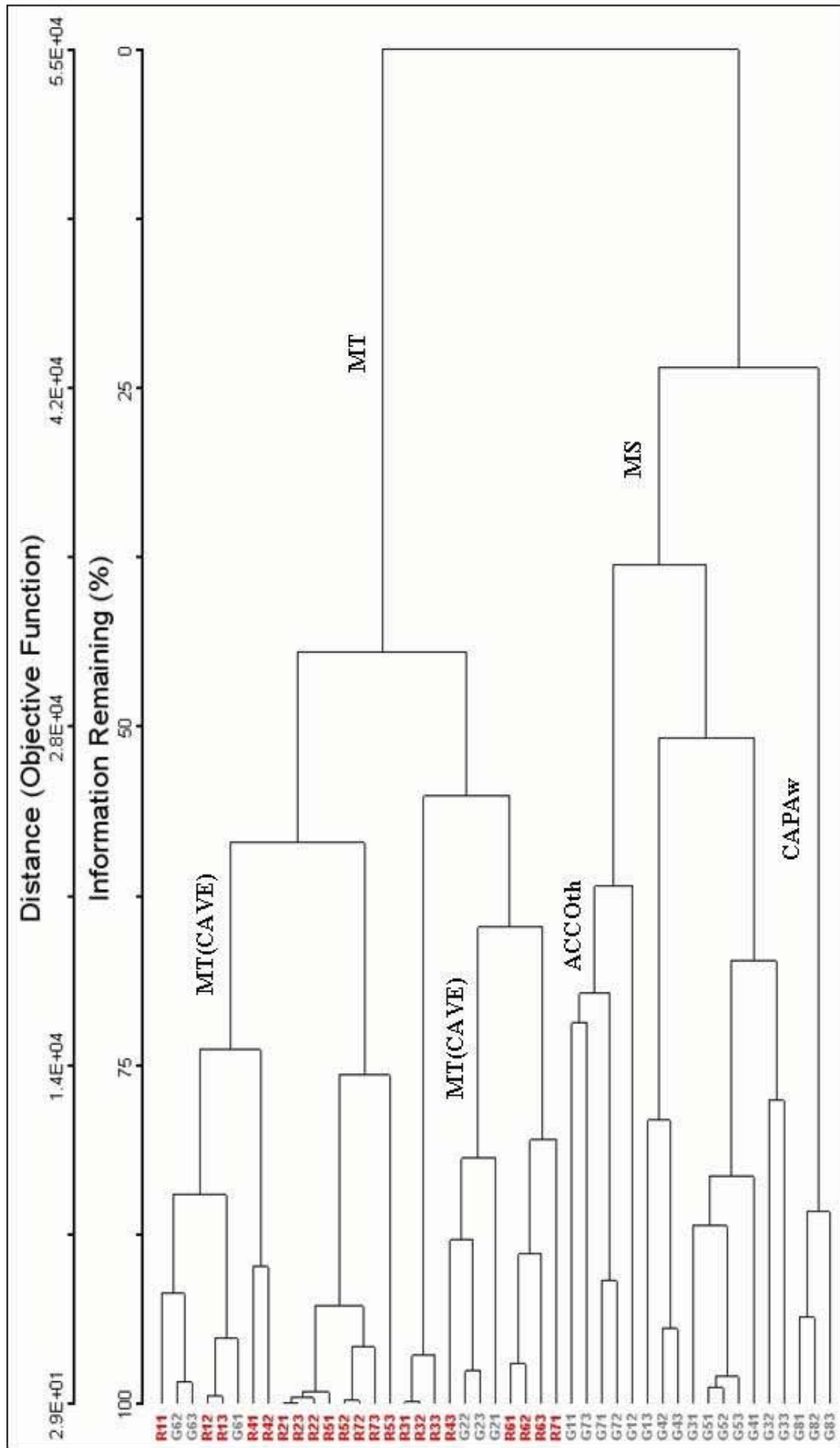


Figure 5.1. Dendrogram of the vegetation sites sampled within the core areas of *Pachycephala rufogularis* (red) and *P. inornata* (grey) home ranges. First figure represents the pair / individual number, followed by quadrat number. MT = mallee-Triodia, MT(CAVE) = mallee-Triodia with *Callitris*, MS = mallee over shrubs, ACCOth = prickly *Acacia* shrubland, CAPAW = *Casuarina* woodland

Of the 21 sampled vegetation quadrats within core areas of *P. rufogularis* home ranges at Gluepot, thirteen were in mallee-*Triodia* (Figure 5.2), six in mallee-*Triodia* with *Callitris*, and a further two landed in ecotones, one with predominant mallee-*Triodia*, the other with predominant mallee-shrubs floristic elements. All but one of the *P. rufogularis* vegetation sites were located on dunes. Of the 24 *P. inornata* sites, most (ten) were in mallee over shrubs, five in mallee-*Triodia* with *Callitris*, four in prickly *Acacia* shrubland (thicket), three in *Casuarina* woodland, one in mallee-*Triodia* and one in an ecotone between mallee over shrubs and prickly *Acacia* thicket. Eighteen *P. inornata* sites were located in swales, six on dunes.

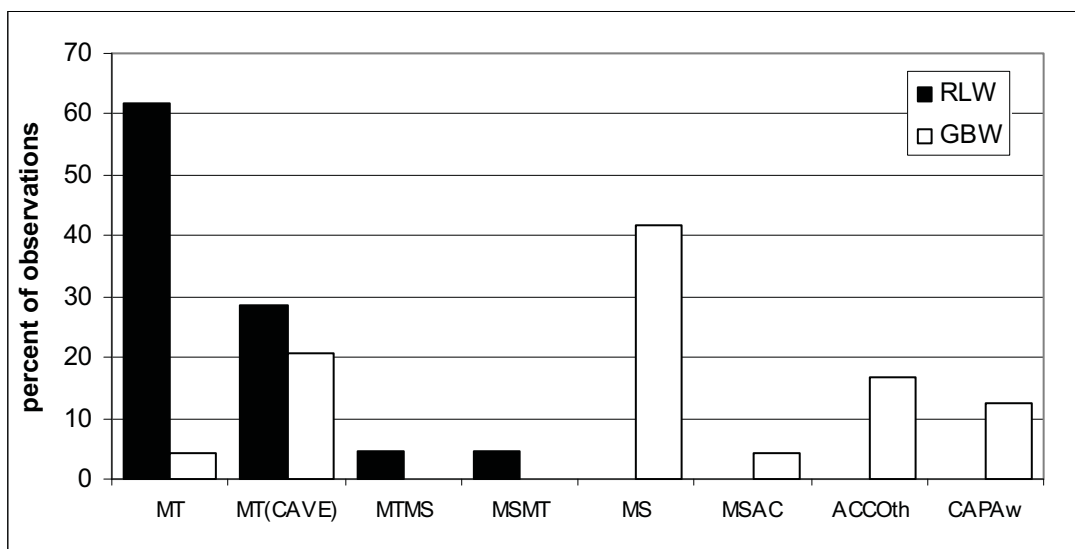


Fig. 5.2. Distribution by vegetation type of the quadrats sampled within the core areas of *Pachycephala rufogularis* (n = 21) and *P. inornata* (n = 24) home ranges at Gluepot
 MT – mallee-*Triodia*, MT(CAVE) - mallee-*Triodia* with *Callitris*, MS – mallee-shrubs,
 ACCOth - prickly *Acacia* thicket, CAPAw – *Casuarina* woodland,
 MSMT, MTMS, MSAC – ecotones; see text for details.
 RLW – *P. rufogularis*, GBW – *P. inornata*;

All twelve sampled vegetation quadrats within the core areas of *P. rufogularis* home ranges at Ngarkat were in areas 15 years post-fire, all except one being located on dunes. The majority (ten) were in mallee-heath, one in mallee, one in ecotone, and none in heath (Figure 5.3).

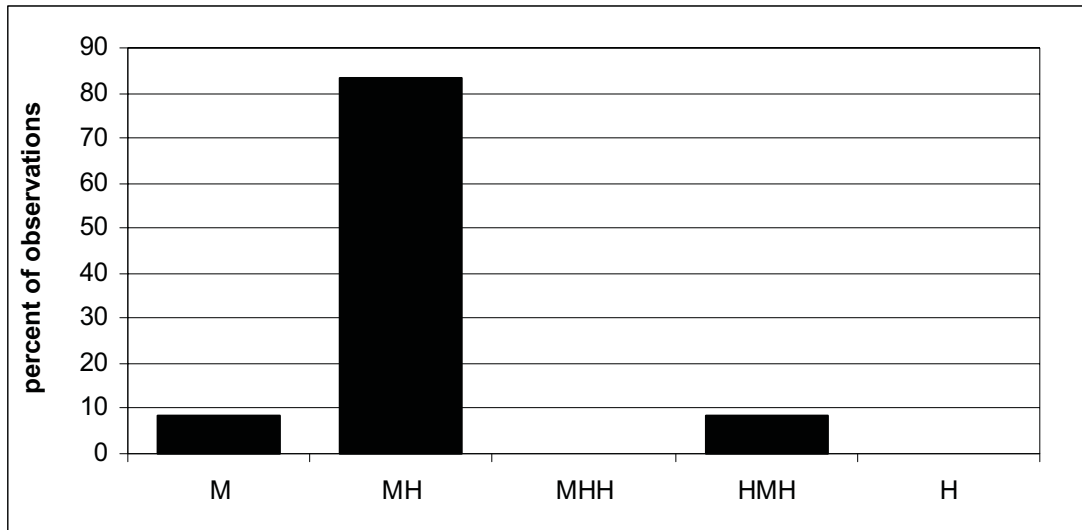


Fig. 5.3. Distribution by vegetation type of the quadrats sampled within the core areas of *Pachycephala rufogularis* (n=12) home ranges at Ngarkat.

M – mallee, MH – mallee-heath, H – heath, MHH, HMH – ecotones

Cluster Analysis of vegetation sites revealed that, at Gluepot, one vegetation sub-type was used by both whistler species: mallee-*Triodia* with *Callitris*. Multi-Response Permutation Procedure (MRPP) was employed to test whether any subtle floristic and/or structural differences could be detected between *P. rufogularis* and *P. inornata* sites within this vegetation sub-type. No significant difference was found for either floristic characteristics ($A = 0.007$, $P = 0.3249$) or structural characteristics ($A = 0.008$, $P = 0.4037$).

As MRPP has not detected any significant floristic or structural differences between *P. rufogularis* and *P. inornata* sites within mallee-*Triodia* with *Callitris* vegetation sub-type, these were further pooled when comparing the different vegetation types (see below), and for constructing the vegetation profile (Figure 5.5).

Except for the mallee-*Triodia* with *Callitris*, *P. rufogularis* and *P. inornata* occurred in different vegetation types. *Pachycephala rufogularis* occurred mostly in the mallee-*Triodia*, while *P. inornata* mostly in the mallee over shrubs, but also in prickly *Acacia* shrubland and *Casuarina* woodland. The floristic and structural differences among these vegetation types were tested using the non-parametric Kruskal-Wallis followed by Dunn's Multiple Comparison post-test to detect where specific differences lay. Significant differences were found when comparing the floristic diversity (species richness) (Kruskal-Wallis statistic = 23.49, $P = 0.0001$); and also when comparing the structure (vegetation density) (Kruskal-Wallis statistic = 72.38, $P < 0.0001$).

At the floristic level, Dunn's post-hoc test found significant differences only between mallee-*Triodia* and mallee over shrubs, between mallee over shrubs and *Casuarina* woodland, and between prickly *Acacia* shrubland and *Casuarina* woodland (Table 5.3.) At the structural level, Dunn's post-hoc test found considerably more significant differences between the vegetation types identified (see Table 5.3.) In other words, significant differences were detected at both floristic and structural levels between the vegetation types used by *P. rufogularis* and *P. inornata*, and also among the vegetation types used by *P. inornata* only.

Table 5.3. The differences in floristics diversity and vegetation structure among the vegetation types in which *Pachycephala rufogularis* and *P. inornata* occur, as revealed by Kruskal-Wallis test followed by Dunn's post-test.

MT =mallee-*Triodia*, MT(CAVE) = mallee-*Triodia* with *Callitris*, MS = mallee over shrubs,

ACCOth = prickly *Acacia* thicket, CAPAw = *Casuarina* woodland

ns = not significant, * = significant at 0.05 alpha, ** = significant at 0.01 alpha, *** = significant at 0.001 alpha

Dunn's Multiple Comparison Post-test	Floristics - diversity	Structural - density
	Significance	Significance
MT vs MT(CAVE)	ns	ns
MT vs MS	**	*
MT vs ACCOth	ns	*
MT vs CAPw	ns	***
MT(CAVE) vs MS	ns	**
MT(CAVE) vs ACCOth	ns	ns
MT(CAVE) vs CAPAw	ns	***
MS vs ACCOth	ns	**
MS vs CAPAw	**	*
ACCOth vs CAPAw	*	***

5.5.3. Vegetation structure

The vertical vegetation profiles to 2 m above the ground for the five vegetation types used by the studied whistler species are presented in Figures 5.4-5.8. The most open vegetation type was *Casuarina* woodland, with an overall average of 0.003 touches of vegetation in the first 2 m from the ground. The value for mallee over shrubs was 0.092. The remaining vegetation types were considerably denser (prickly *Acacia* thicket: 0.357, mallee-*Triodia* with *Callitris*: 0.477, mallee-*Triodia*: 0.604). The higher density of mallee-*Triodia* over mallee-*Triodia* with *Callitris*, although not very apparent from the figures, is due to the greater spinifex density, resulting in a greater number of touches within the first 40 cm of ground.

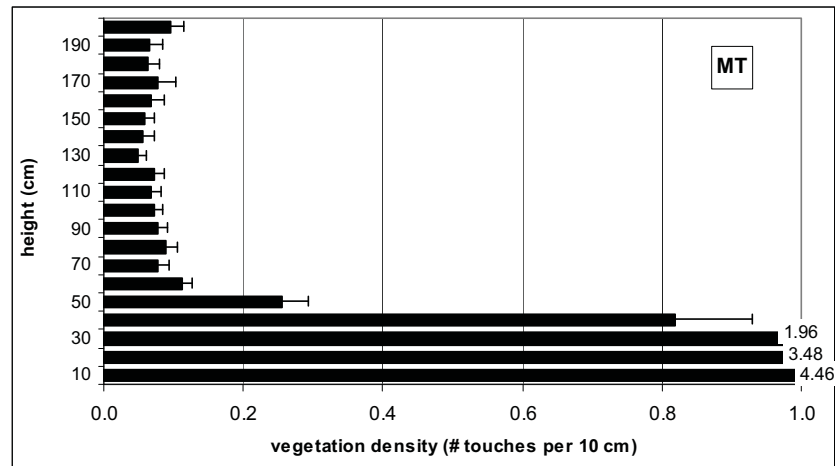


Fig. 5.4. Vegetation profile for the first 2 m (means + s.e. of vegetation touches) for mallee-*Triodia*, Gluepot Reserve

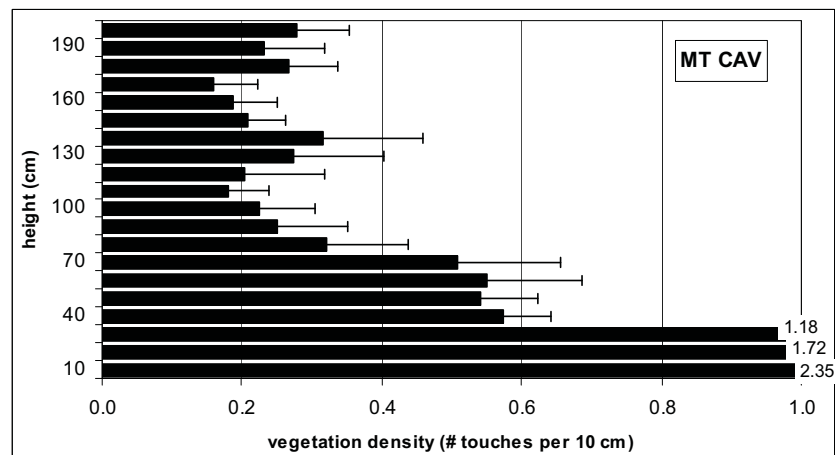


Fig. 5.5. Vegetation profile for the first 2 m (means + s.e. of vegetation touches) for mallee-*Triodia* with *Callitris*, Gluepot Reserve

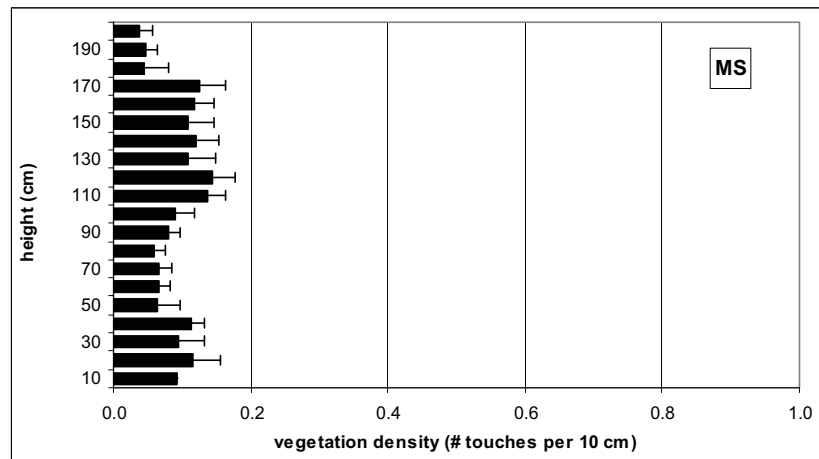


Fig. 5.6. Vegetation profile for the first 2 m (means + s.e. of vegetation touches) for mallee over shrubs, Gluepot Reserve

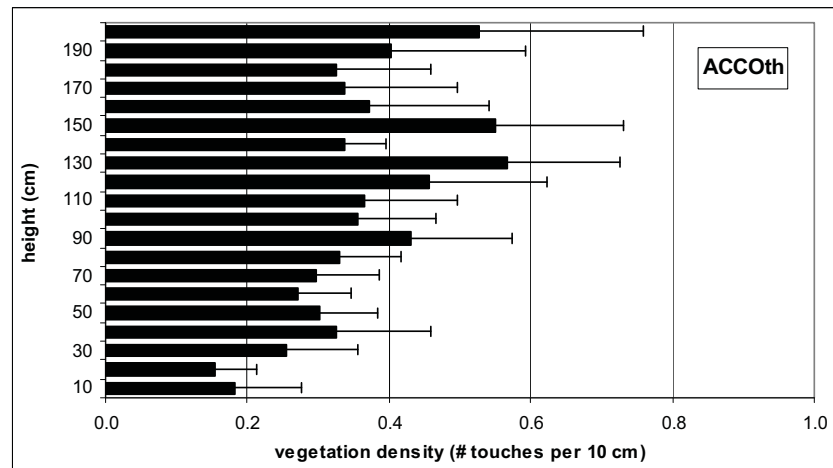


Fig. 5.7. Vegetation profile for the first 2 m (means + s.e. of vegetation touches) for prickly *Acacia* thicket, Gluepot Reserve

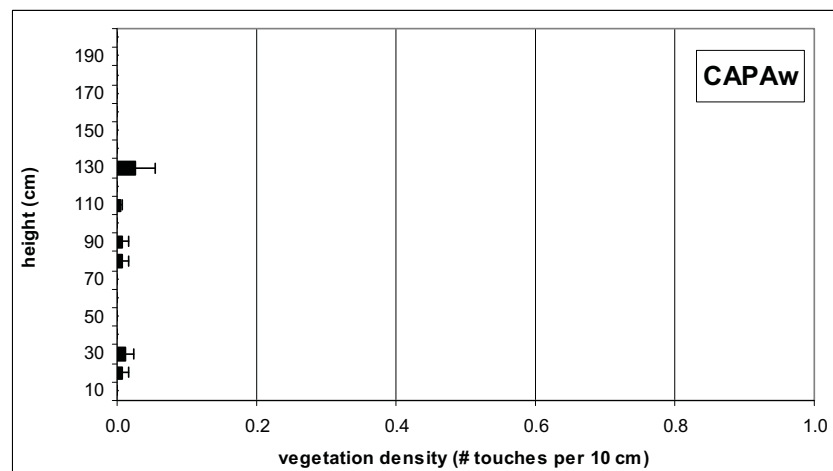


Fig. 5.8. Vegetation profile for the first 2 m (means + s.e. of vegetation touches) for *Casuarina* woodland, Gluepot Reserve

The contribution of different plant species to the vegetation profiles in the vegetation types used by the studied whistler species (excepting *Casuarina* woodland, which was very open in the first 2 m above the ground) are presented in Figures 5.9–5.12. These figures should be examined in conjunction with Figures 5.4–5.8., as the overall number of touches was not equal for each height interval; the reason for which I have chosen a 100% stacked bar chart was for a better visualisation of the contribution to vegetation density. In order to reduce the number of categories, some plant species were grouped together according to the taxonomy and/or the shared structural features (see the captions of Figures 5.9–5.12 for details).

In mallee-*Triodia*, the greatest contribution to the density was that of *Triodia scariosa*, which dominated the first 50 cm above the ground (Figure 5.9), and had 82% of the total vegetation touches. In mallee-*Triodia* with *Callitris* the greatest percentage of touches (42% of the total) belongs to *Triodia scariosa* as well, which dominates the first 40 cm above the ground. The second most important participation to density was that of *Callitris verrucosa* (31.7%), dominating the vegetation profile above 70 cm (Figure 5.10). In mallee over shrubs, Sennas (33%), prickly Acacias (25.3%) and *Acacia sclerophylla* (16.9%) were the major contributors to density (Figure 5.11). In prickly *Acacia* shrubland (Figure 5.12) the most of the vegetation density was due to *Acacia colletioides* / *nysophylla* (64.7%). Other important contributions to density were those of Sennas (19.5%) and *Eremophilas* (14.1%).

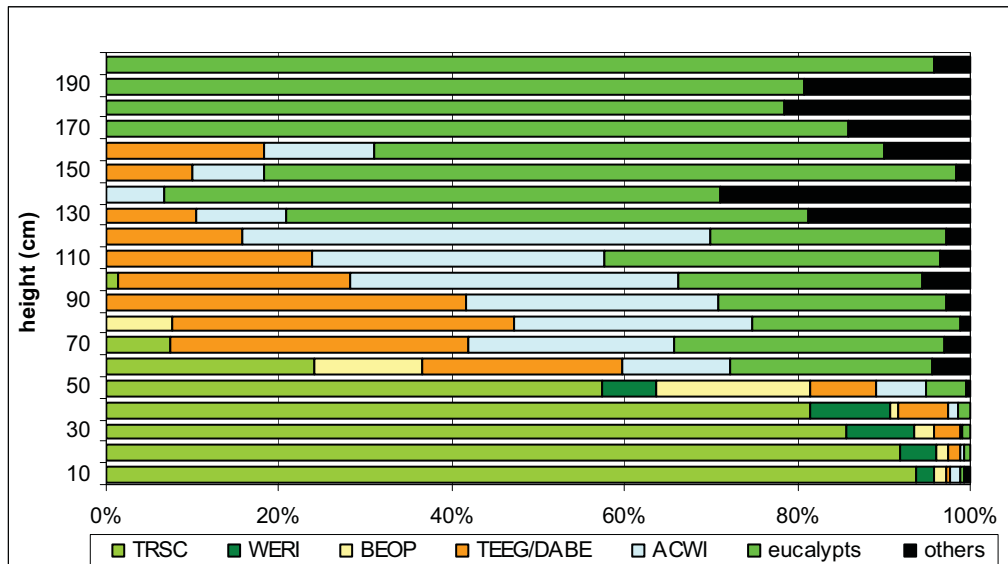


Fig. 5.9. The contribution to vegetation density in mallee-*Triodia*, Gluepot Reserve
 TRSC = *Triodia scariosa*, WERI = *Westringia rigida*, BEOP = *Beyeria opaca*,
 TEEG/DABE = *Templetonia egena* / *Daviesia benthamii*, ACWI = *Acacia wilhelmiana*
 eucalypts = *Eucalyptus socialis*, *E. dumosa*, *E. gracilis*, *E. leptophylla*;
 others = *Dodoneaea bursarifolia*, *Grevillea huegelii*, *Melaleuca lanceolata*, *Myoporum platycarpum*, etc.
 Data expressed in percent touches for each 10 cm interval; see text for details

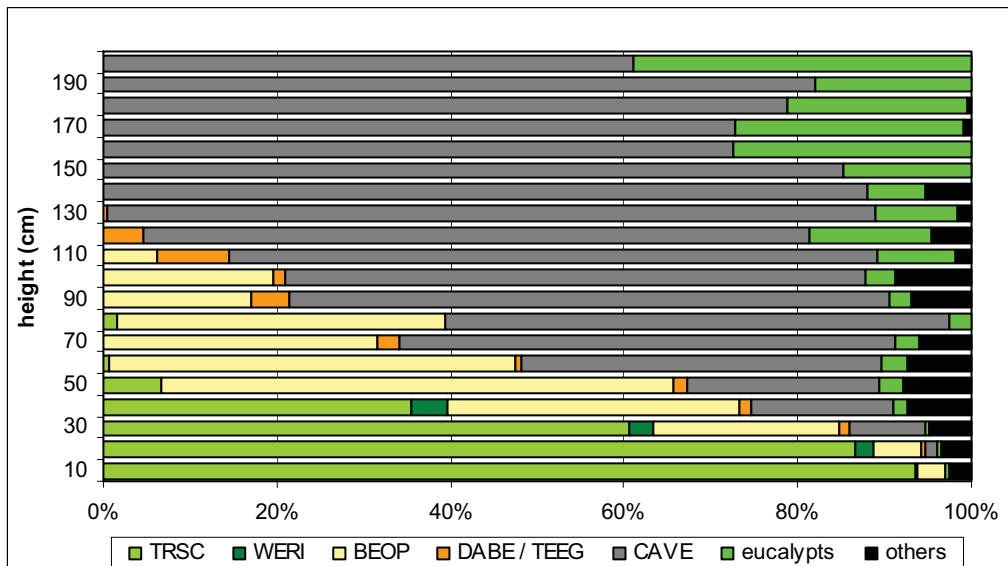


Fig. 5.10. The contribution to vegetation density in mallee-*Triodia* with *Callitris*, Gluepot Reserve
 TRSC = *Triodia scariosa*, WERI = *Westringia rigida*, BEOP = *Beyeria opaca*,
 TEEG/DABE = *Templetonia egena* / *Daviesia benthamii*, CAVE = *Callitris verrucosa*
 eucalypts = *Eucalyptus socialis*, *E. dumosa*, *E. gracilis*;
 others = *Baeckea crassifolia*, *Dodoneaea bursarifolia*, *Olearia muelleri*, *Santalum acuminatum*, etc.
 Data expressed in percent touches for each 10 cm interval; see text for details

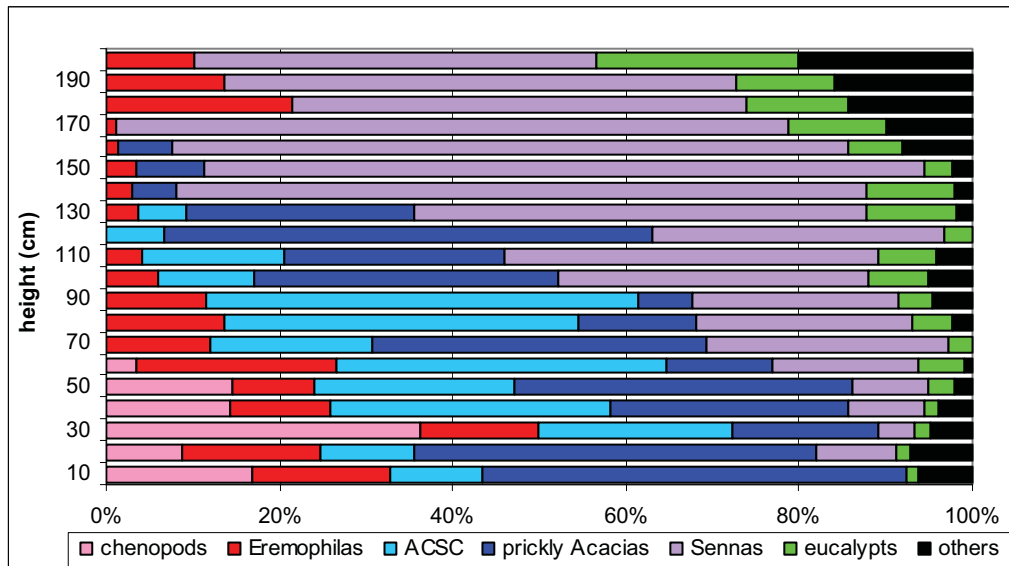


Fig. 5.11. The contribution to vegetation density in mallee over shrubs, Gluepot Reserve
 chenopods = *Atriplex stipitata*, *Maireana appressa*, *M. pentratropis*, *M. sedifolia*, *Rhagodia gaudichaudiana*;
 Eremophilas = *Eremophila glabra*, *E. scoparia*; prickly Acacias = *Acacia colletioides*, *A. nysophylla*;
 Sennas = *Senna* ft. *artemisioides*, *S. ft. coriacea*, *S. ft. nemophila*, *S. ft. petiolaris*;
 eucalypts = *Eucalyptus oleosa*, *E. gracilis*; others = *Zygophyllum apiculatum*, *Z. aurantiacum*, *Dodoneaea viscosa* ssp. *angustifolia*, *Grevillea huegelii*, *Cratystylis conocephala*, *Cassyltha melantha*, *Myoporum platycarpum*.
 Data expressed in percent touches for each 10 cm interval; see text for details

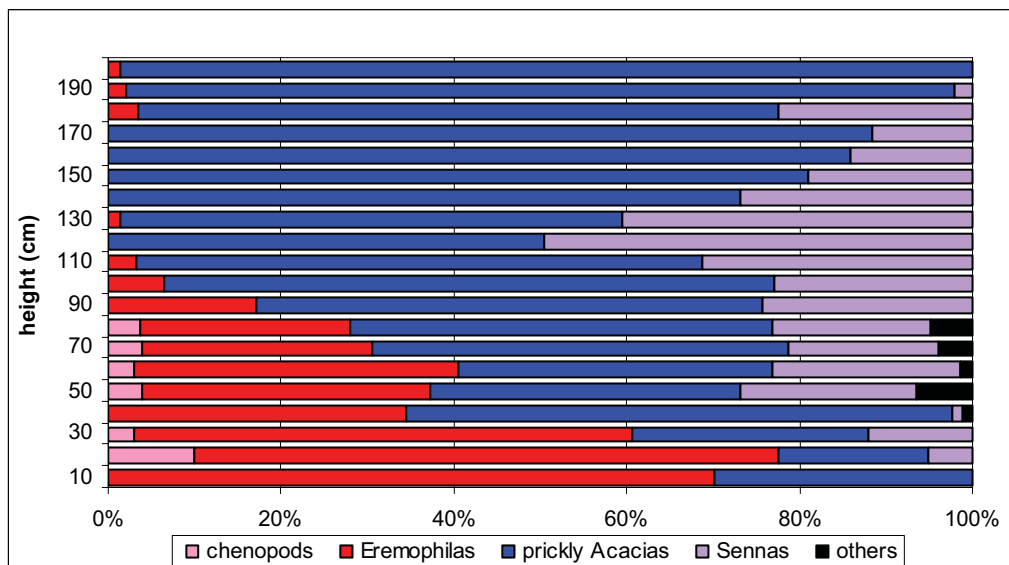


Fig. 5.12. The contribution to vegetation density in prickly *Acacia* shrubland, Gluepot Reserve
 (chenopods = *Enchylaena tomentosa*, *Maireana appressa*, *M. pentratropis*; Eremophilas = *Eremophila glabra*,
E. scoparia; prickly Acacias = *Acacia colletioides*, *A. nysophylla*;
 Sennas = *Senna* ft. *artemisioides*, *S. ft. coriacea*, *S. ft. nemophila*, *S. ft. petiolaris*;
 others = *Dodoneaea viscosa* ssp. *angustifolia*, *Grevillea huegelii*, etc.
 Data expressed in percent touches for each 10 cm interval; see text for details

The overall vegetation profile of the mallee-heath, predominantly used by *P. rufogularis* at Ngarkat, is presented in Figure 5.13 (because only one quadrat was in mallee vegetation, the vegetation profile for that is not presented here, as it may not be representative).

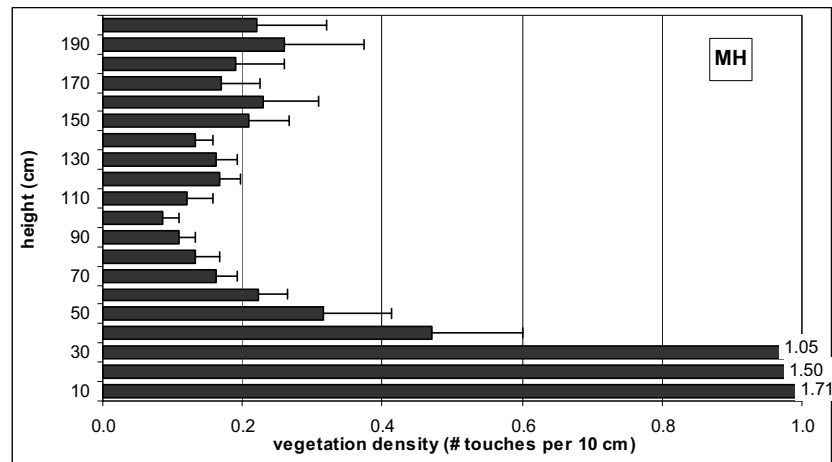


Fig. 5.13. Vegetation profile for the first 2 m (means + s.e. of vegetation touches) for mallee-heath, Ngarkat Conservation Park

The overall average density of vegetation in the first 2 m from the ground in mallee-heath was 0.381 touches, less than in *P. rufogularis* habitats from Gluepot. This is closely related to the cover of *Triodia*, the average of which was two times lower at Ngarkat than at Gluepot (see the descriptions of the *P. rufogularis* habitats from the two locations in the discussion section). The increasing number of touches above 1 m reflects the lower canopy of the mallee eucalypts in the mallee heath vegetation used by *P. rufogularis* at Ngarkat, due to the lower post-fire age. Along the quadrats' diagonals, from where the density data were collected, a total of 47 plant species were detected. Because of this relatively large number of species, that would have led to numerous categories even after grouping them according to the taxonomy/phenotypes, the chart of the contribution to density was not constructed, as for Gluepot.

5.5.4. The relationship between floristics and structure

The Mantel test, employed to detect any relationship between floristics and structure, revealed a strong relation between the two vegetation characteristics in both *Pachycephala rufogularis* ($r = 0.537$, $P = 0.001$) and *P. inornata* ($r = 0.533$, $P = 0.001$) sites from Gluepot. At Ngarkat however, floristics and structure were not associated ($r = 0.733$, $P = 0.059$).

5.5.5. NMS ordination

NMS ordination generated a two-dimensional model that represented 88.3% of the data variance (Axis 1: 19.5%, Axis 2: 68.9%). The stress was 12.2 and final instability 0.00001 (Figure 5.14). The grouping pattern of the vegetation sites was similar to the Cluster Analysis. The most influential variables in the NMS ordination of *Pachycephala rufogularis* and *P. inornata* vegetation sites, having $r^2 \geq 0.5$, were the cover of the following plant species: *Casuarina pauper* ($r^2 = 0.612$), correlating with the ordination axis 1, and *Acacia colletioides* ($r^2 = 0.592$), *Austrostipa nitida* ($r^2 = 0.547$), *Eucalyptus oleosa* ($r^2 = 0.537$), *Eucalyptus socialis* ($r^2 = 0.731$), *Maireana pentatropis* ($r^2 = 0.811$), *Senna* ft. *nemophila* ($r^2 = 0.568$), and *Triodia scariosa* ($r^2 = 0.646$), all correlated with the variation along axis 2.

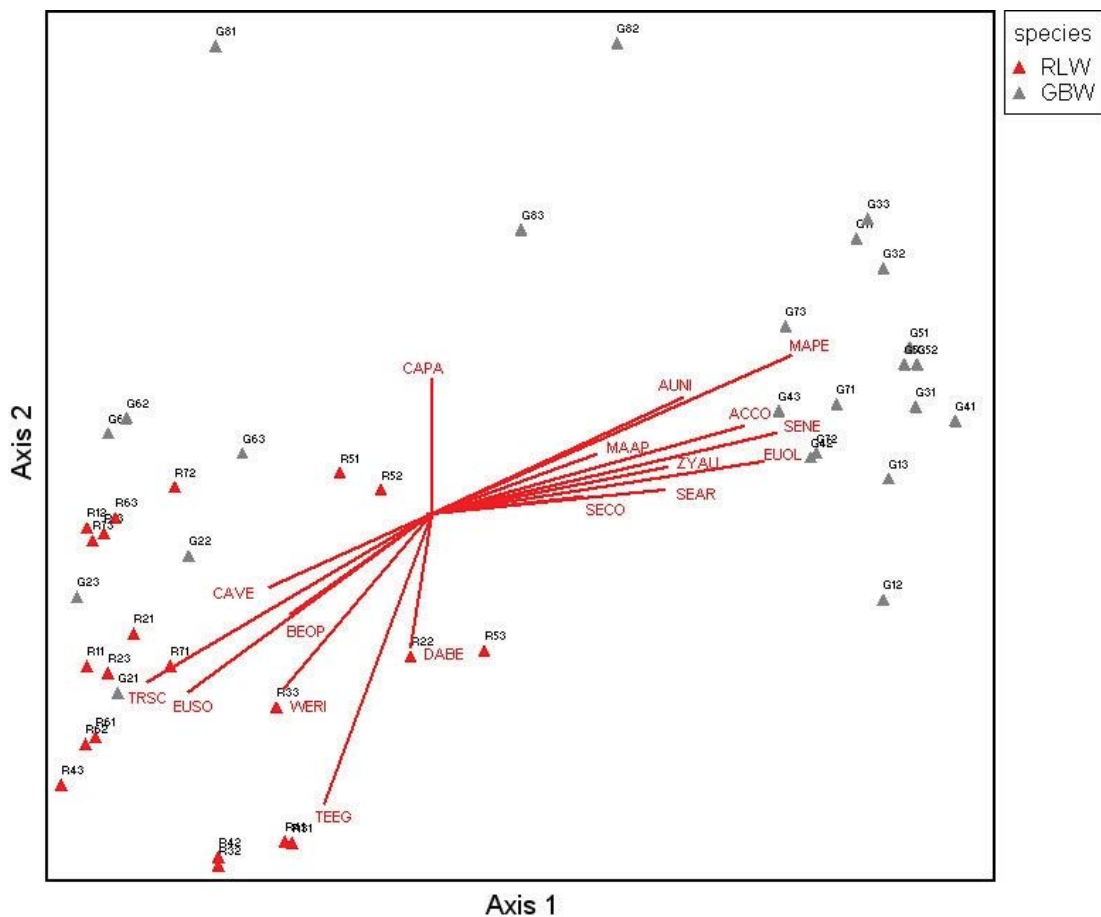


Fig. 5.14. NMS ordination of *P. rufogularis* (RLW) and *P. inornata* (GBW) vegetation sites from Gluepot, according to their floristic attributes (cover data).

The overlaid vectors have $r^2 \geq 0.3$. Stress = 12.2, final instability = 0.00001. Braun-Blanquet scores were used for cover/abundance.

ACCO: *Acacia colletioides*, AUNI: *Austrostipa nitida*, BEOP: *Beyeria opaca*, CAPA: *Casuarina pauper*, CAVE: *Callitris verrucosa*, DABE: *Daviesia benthamii*, EUOL: *Eucalyptus oleosa*, EUSO: *E. socialis*, MAAP: *Maireana appressa*, MAPE: *M. pentatropis*, SEAR: *Senna* ft. *artemisioides*, SECO: *S. ft. coriacea*, SENE: *S. ft. nemophila*, TEEG: *Templetonia egena*, TRSC: *Triodia scariosa*, WERI: *Westringia rigida*, ZYAU: *Zygophyllum aurantiacum*

5.5.6. Indicator Species and Correlation Analysis

The Indicator Species Analysis (ISA), used to detect and describe the value of different plant species as indicators of the preferred habitat of *Pachycephala rufogularis* or *P. inornata* was performed in two separate instances, using as grouping variable the whistler species first, then the vegetation type. The results are summarised in Table 5.4. The sites R22 and R53 were removed beforehand, as they represented ecotones.

Table 5.4. Plant species indicating *Pachycephala rufogularis* (RLW) or *P. inornata* (GBW) habitats at Gluepot, as revealed by Indicator Species Analysis (ISA).

ISA was performed twice, using as the grouping variable firstly the whistler species and secondly the vegetation type.

MT =mallee-*Triodia*, MS = mallee over shrubs, CAPAw = *Casuarina* woodland, MT(CAVE) = mallee-*Triodia* with *Callitris*, ACCOth = prickly *Acacia* shrubland.

Only plant species with significant indicator value (IV) presented.

a = absent, ns = not significant, * = significant at 0.05 alpha, ** = significant at 0.01 alpha, *** = significant at 0.001 alpha

species	RLW	GBW	MT	MS	CAPAw	MT(CAVE)	ACCOth
<i>Acacia colletioides</i>	a	***	a	ns	a	a	**
<i>Acacia nysophylla</i>	a	ns	a	ns	a	a	*
<i>Acacia sclerophylla</i>	ns	ns	ns	***	a	a	a
<i>Acacia wilhelmiana</i>	*	a	ns	a	a	ns	a
<i>Atriplex stipitata</i>	a	*	a	ns	a	a	*
<i>Austrostipa nitida</i>	ns	**	ns	*	ns	ns	ns
<i>Beyeria opaca</i>	*	ns	ns	a	a	*	a
<i>Casuarina pauper</i>	a	ns	a	a	***	a	a
<i>Callitris verrucosa</i>	ns	ns	ns	a	a	***	a
<i>Dodonea viscosa</i>	ns	ns	a	ns	a	a	*
<i>Enchylaena tomentosa</i>	a	**	a	ns	ns	a	ns
<i>Eremophila glabra</i>	ns	ns	a	ns	a	a	***
<i>Eucalyptus dumosa</i>	**	ns	***	a	a	ns	a
<i>Eucalyptus gracilis</i>	ns	ns	ns	**	a	ns	ns
<i>Eucalyptus leptophylla</i>	*	ns	ns	a	a	ns	a
<i>Eucalyptus oleosa</i>	ns	***	ns	***	a	a	ns
<i>Eucalyptus socialis</i>	***	ns	ns	ns	ns	***	ns
<i>Exocarpos aphyllus</i>	a	ns	a	a	**	a	a
<i>Grevillea huegelii</i>	*	ns	ns	ns	a	ns	ns
<i>Maireana appressa</i>	a	**	a	*	ns	a	ns
<i>Maireana pentratropis</i>	ns	***	ns	ns	ns	a	ns
<i>Maireana sedifolia</i>	a	ns	a	a	a	a	*
<i>Olearia muelleri</i>	ns	ns	ns	*	a	a	a
<i>Rhagodia ulicina</i>	a	ns	a	*	a	a	a
<i>Sclerolaena patentiuspis</i>	ns	ns	a	a	a	*	a
<i>Sclerolaena parviflora</i>	a	ns	a	a	a	a	*
<i>Senna ft. artemisioides</i>	ns	**	a	ns	a	a	*
<i>Senna ft. coriacea</i>	a	**	a	ns	a	a	**
<i>Senna ft. nemophila</i>	ns	***	a	*	ns	a	ns
<i>Senna ft. petiolaris</i>	a	*	a	ns	ns	a	**
<i>Templetonia egena</i>	***	ns	ns	ns	a	ns	a
<i>Triodia scariosa</i>	***	ns	***	a	a	ns	a
<i>Westringia rigida</i>	**	ns	*	a	a	ns	a
<i>Zygophyllum aurantiacum</i>	a	*	a	**	a	a	a
<i>Zygophyllum apiculatum</i>	a	**	a	***	a	a	ns

For *P. rufogularis* presence, highly significant ($P < 0.001$) indicator values (IV) were those for *Eucalyptus socialis* (IV = 68.6), species significant also in indicating mallee-*Triodia* with *Callitris* vegetation type (IV = 34.1), *Templetonia egena* (IV = 53.3), and *Triodia scariosa* (IV = 78.1), the later species being also significant in indicating mallee-*Triodia* vegetation type (IV = 55). For *P. inornata* presence, very highly significant indicator values had *Acacia colletioides* (IV = 54.2), significant also in indicating prickly *Acacia* shrubland (IV = 55.6), *Eucalyptus oleosa* (IV = 53.9), significant also in indicating mallee over shrubs vegetation type (IV = 53.4), *Maireana pentatropis* (IV = 54.5), and *Senna* ft. *nemophila* (IV = 58.1), the later species being also significant in indicating mallee over shrubs vegetation type (IV = 46.9).

Before obtaining the cross-product matrix in PCA, sites R22 and R53 (the ecotones) were removed, as they were identified as outliers at a cut-off of 2 standard deviations. Outliers can strongly influence the correlation matrix (McCune and Grace 2002). The PCA cross-product matrix revealed that the presence of *P. rufogularis* was strongly correlated with mallee-*Triodia* ($r = 0.73$) and dunes ($r = 0.78$). The presence of *P. inornata* was strongly correlated with swales ($r = 0.78$), and only modestly correlated with mallee over shrubs ($r = 0.53$). Each species was negatively correlated with the vegetation type and the landform to which the other correlated positively, to the same extent (having similar values, in negative: e.g. presence of *P. inornata* was strongly negatively correlated with mallee-*Triodia*: $r = -0.73$). The correlation coefficients between the presence of the whistler species and presence / cover of certain plant species, indicating ecological significance (equal and over 0.5 and equal or less than -0.5) are given in Table 5.5. The presence of *P. rufogularis* was strongly correlated (r values equal or over 0.7) with both presence and cover of *Triodia scariosa* and cover of *Eucalyptus socialis*, while the presence of *P. inornata* was strongly correlated only with presence and cover of *Maireana pentatropis*. The correlation coefficients between the plant species' presence and the vegetation types are given in Table 5.6.

Table 5.5. The most significant (≥ 0.5 and ≤ -0.5) Pearson correlation coefficients between the presence of the whistler species and presence/cover of plant species in sampled sites at Gluepot.

plant species	<i>Pachycephala rufogularis</i>		<i>Pachycephala inornata</i>	
	presence	cover	presence	cover
<i>Acacia colletioides</i>	-0.60	-0.54	0.60	0.54
<i>Eucalyptus dumosa</i>	0.51	0.38	-0.51	-0.38
<i>Eucalyptus oleosa</i>	-0.57	-0.57	0.57	0.57
<i>Eucalyptus socialis</i>	0.60	0.72	-0.60	-0.72
<i>Maireana pentratropis</i>	-0.74	-0.71	0.74	0.71
<i>Senna ft. artemisioides</i>	-0.53	-0.52	0.53	0.52
<i>Senna ft. nemophila</i>	-0.67	-0.62	0.67	0.62
<i>Triodia scariosa</i>	0.72	0.71	-0.72	-0.71
<i>Westringia rigida</i>	0.47	0.54	-0.47	-0.54

Table 5.6. Pearson coefficients of correlation between the plant species' presence and the vegetation types at Gluepot. Significant values (≥ 0.5 and ≤ -0.5) are in bold type.

MT – mallee-*Triodia*, MT(CAVE) - mallee-*Triodia* with *Callitris*, MS – mallee-shrubs, ACCOth - prickly *Acacia* thicket, CAPAw – *Casuarina* woodland.

plant species	MT	MT(CAVE)	MS	ACCOth	CAPAw
<i>Acacia brachybotrya</i>	-0.15	0.37	-0.13	-0.07	-0.06
<i>Acacia colletioides</i>	-0.44	-0.39	0.63	0.51	-0.18
<i>Acacia nysophylla</i>	-0.22	-0.20	0.00	0.72	-0.09
<i>Acacia sclerophylla</i>	-0.09	-0.39	0.76	-0.21	-0.18
<i>Actinoble uliginosum</i>	-0.19	-0.17	0.49	-0.09	-0.08
<i>Acacia wilhelmiana</i>	0.23	0.11	-0.21	-0.12	-0.10
<i>Atriplex rhagodioides</i>	-0.15	-0.14	0.40	-0.07	-0.06
<i>Atriplex stipitata</i>	-0.28	-0.25	0.25	0.56	-0.12
<i>Austrostipa nitida</i>	-0.32	-0.45	0.61	0.35	-0.07
<i>Baeckea crassifolia</i>	0.23	0.11	-0.21	-0.12	-0.10
<i>Beyeria lechenaultii</i>	-0.11	0.26	-0.09	-0.05	-0.04
<i>Beyeria opaca</i>	0.21	0.42	-0.39	-0.22	-0.19
<i>Boronia caerulea</i>	-0.11	0.26	-0.09	-0.05	-0.04
<i>Brachycome ciliaris</i>	-0.15	0.37	-0.13	-0.07	-0.06
<i>Cassutha melantha</i>	-0.11	-0.10	0.28	-0.05	-0.04
<i>Casuarina pauper</i>	-0.19	-0.17	-0.16	-0.09	1.00
<i>Callitris verrucosa</i>	-0.16	0.84	-0.41	-0.24	-0.20
<i>Chenopodium desertorum</i>	-0.19	-0.17	0.28	0.22	-0.08
<i>Cratystylis conocephala</i>	-0.15	-0.14	0.40	-0.07	-0.06
<i>Cryptandra propinqua</i>	0.07	0.28	-0.21	-0.12	-0.10
<i>Daviesia benthamii</i>	0.07	0.28	-0.21	-0.12	-0.10
<i>Dissocarpus paradoxus</i>	-0.11	-0.10	0.28	-0.05	-0.04
<i>Dodonea bursarifolia</i>	0.11	0.31	-0.26	-0.15	-0.13
<i>Dodonea viscosa ssp. angustifolia</i>	-0.22	-0.20	0.00	0.72	-0.09
<i>Enchylaena tomentosa</i>	-0.31	-0.27	0.20	0.29	0.37
<i>Eremophila glabra</i>	-0.31	-0.27	0.20	0.72	-0.13
<i>Eremophila scoparia</i>	-0.11	-0.10	-0.09	0.48	-0.04
<i>Eucalyptus dumosa</i>	0.52	0.32	-0.53	-0.31	-0.26
<i>Eucalyptus gracilis</i>	-0.12	-0.26	0.59	-0.09	-0.22
<i>Eucalyptus incrassata</i>	-0.15	0.37	-0.13	-0.07	-0.06
<i>Eucalyptus leptophylla</i>	0.11	0.31	-0.26	-0.15	-0.13
<i>Eucalyptus oleosa</i>	-0.38	-0.44	0.79	0.28	-0.20
<i>Eucalyptus socialis</i>	0.44	0.39	-0.63	-0.15	-0.23

Table 5.6. (cont.) Pearson coefficients of correlation between the plant species' presence and the vegetation types at Gluepot. Significant values (≥ 0.5 and ≤ -0.5) are in bold type.

MT – mallee-*Triodia*, MT(CAVE) - mallee-*Triodia* with *Callitris*, MS – mallee-shrubs, ACCOth - prickly *Acacia* thicket, CAPAw – *Casuarina* woodland.

plant species	MT	MT(CAVE)	MS	ACCOth	CAPAw
<i>Exocarpos aphyllus</i>	-0.15	-0.14	-0.13	-0.07	0.81
<i>Grevillea huegelii</i>	0.35	-0.09	-0.16	0.04	-0.25
<i>Lomandra effusa</i>	-0.11	0.26	-0.09	-0.05	-0.04
<i>Lycium australe</i>	-0.11	-0.10	0.28	-0.05	-0.04
<i>Maireana appressa</i>	-0.36	-0.32	0.66	0.02	0.08
<i>Maireana pentratropis</i>	-0.55	-0.48	0.71	0.41	0.16
<i>Maireana sedifolia</i>	-0.15	-0.14	-0.13	0.69	-0.06
<i>Melaleuca lanceolata</i>	0.39	-0.06	-0.21	-0.12	-0.10
<i>Myoporum platycarpum</i>	-0.12	0.42	-0.22	-0.26	0.16
<i>Olearia muelleri</i>	-0.03	-0.27	0.50	-0.15	-0.13
<i>Olearia pimeleoides</i>	-0.11	-0.10	0.28	-0.05	-0.04
<i>Olearia teretifolia</i>	-0.15	0.12	0.14	-0.07	-0.06
<i>Prostanthera aspalathoides</i>	0.09	0.12	-0.13	-0.07	-0.06
<i>Pultenaea densifolia</i>	0.33	-0.14	-0.13	-0.07	-0.06
<i>Rhagodia gaudichaudiana</i>	-0.19	-0.17	0.28	0.22	-0.08
<i>Rhagodia spinescens</i>	-0.15	-0.14	0.14	0.31	-0.06
<i>Rhagodia ulicina</i>	-0.22	-0.20	0.58	-0.11	-0.09
<i>Santalum acuminatum</i>	-0.25	0.28	0.14	-0.12	-0.10
<i>Santalum murrayanum</i>	-0.11	0.26	-0.09	-0.05	-0.04
<i>Sclerolaena patentiuspis</i>	-0.15	-0.14	-0.13	0.69	-0.06
<i>Sclerolaena parviflora</i>	-0.25	0.62	-0.21	-0.12	-0.10
<i>Scaevola spinescens</i>	-0.11	-0.10	-0.09	0.48	-0.04
<i>Senna</i> ft. <i>artemisioides</i>	-0.39	-0.34	0.60	0.39	-0.16
<i>Senna</i> ft. <i>coriacea</i>	-0.28	-0.25	0.25	0.56	-0.12
<i>Senna</i> ft. <i>nemophila</i>	-0.49	-0.44	0.79	0.28	0.00
<i>Senna</i> ft. <i>petiolaris</i>	-0.31	-0.27	0.04	0.72	0.12
<i>Templetonia egena</i>	0.31	0.31	-0.34	-0.26	-0.22
<i>Triodia scariosa</i>	0.60	0.42	-0.64	-0.37	-0.32
<i>Westringia rigida</i>	0.50	0.14	-0.41	-0.24	-0.20
<i>Zygophyllum apiculatum</i>	-0.28	-0.25	0.73	-0.14	-0.12
<i>Zygophyllum aurantiacum</i>	-0.36	-0.32	0.93	-0.17	-0.15
<i>Zygophyllum glaucum</i>	-0.11	-0.10	0.28	-0.05	-0.04

Significant correlations were found among an entire array of species (see Table 5.7.), indicating plant associations within one vegetation type or another.

Table 5.7. Pearson coefficients indicating strong correlation ($r \geq 0.7$) among the plant species in sampled vegetation sites at Gluepot.

plant species of which presence is strongly correlated	Pearson r
<i>Acacia colletioides</i> - <i>Eucalyptus oleosa</i>	0.78
<i>Acacia colletioides</i> - <i>Maireana pentratropis</i>	0.80
<i>Acacia colletioides</i> - <i>Senna</i> ft. <i>artemisioides</i>	0.76
<i>Acacia colletioides</i> - <i>Senna</i> ft. <i>nemophila</i>	0.78
<i>Austrostipa nitida</i> - <i>Maireana pentratropis</i>	0.76
<i>Dodoneaea viscosa</i> ssp. <i>angustifolia</i> - <i>Eremophila glabra</i>	0.72
<i>Dodoneaea viscosa</i> ssp. <i>angustifolia</i> - <i>Senna</i> ft. <i>coriacea</i>	0.79
<i>Eucalyptus dumosa</i> - <i>Triodia scariosa</i>	0.82
<i>Eucalyptus oleosa</i> - <i>Maireana pentratropis</i>	0.79
<i>Eucalyptus oleosa</i> - <i>Senna</i> ft. <i>nemophila</i>	0.78
<i>Eucalyptus oleosa</i> - <i>Zygophyllum aurantiacum</i>	0.74
<i>Eucalyptus socialis</i> - <i>Triodia scariosa</i>	0.73
<i>Maireana appressa</i> - <i>Senna</i> ft. <i>nemophila</i>	0.74
<i>Maireana appressa</i> - <i>Zygophyllum apiculatum</i>	0.78
<i>Maireana appressa</i> - <i>Zygophyllum aurantiacum</i>	0.72
<i>Maireana pentratropis</i> - <i>Senna</i> ft. <i>artemisioides</i>	0.71
<i>Maireana pentratropis</i> - <i>Senna</i> ft. <i>nemophila</i>	0.90
<i>Senna</i> ft. <i>artemisioides</i> - <i>Senna</i> ft. <i>nemophila</i>	0.79
<i>Senna</i> ft. <i>nemophila</i> - <i>Zygophyllum aurantiacum</i>	0.74
<i>Templetonia egena</i> - <i>Westringia rigida</i>	0.79
<i>Zygophyllum apiculatum</i> - <i>Zygophyllum aurantiacum</i>	0.78

The correlation coefficients from the cross-product matrix, the ISA results, and also personal observations found that some plant species are usually present in one vegetation type and not in another (of the five identified here). Mallee-*Triodia*, mallee over shrubs and *Casuarina* woodland had distinct floristic spectra. Characteristic plants for mallee-*Triodia* vegetation type (mallee-*Triodia* with *Callitris* sub-type included) are: *Acacia brachybotrya*, *A. willhelmiana*, *Baekia crassifolia*, *Beyeria lechenaultii*, *B. opaca*, *Boronia caerulescens*, *Callitris verrucosa*, *Daviesia benthamii*, *Dodoneaea bursarifolia*, *Eucalyptus dumosa*, *E. incrassata*, *E. leptophylla*, *E. socialis*, *Melaleuca lanceolata*, *Templetonia egena*, *Triodia scariosa* and *Westringia rigida*. For mallee over shrubs vegetation type, the characteristic plants are: *Acacia colletioides*, *A. sclerophylla*, *Atriplex* sp., *Austrostipa nitida*, *Chenopodium desertorum*, *Cratystylis conocephala*, *Enchylaena tomentosa*, *Eremophila glabra*, *Eucalyptus*

gracilis, *Eucalyptus oleosa*, *Lycium australe*, *Maireana* sp., *Rhagodia* sp., *Senna* sp. and *Zygophyllum* sp. *Casuarina pauper* is to be found only in *Casuarina* woodland, and in no other vegetation type.

5.5.7. Ground Cover

The NMS ordination of the *Pachycephala rufogularis* and *P. inornata* vegetation sites from Gluepot by ground cover produced a two-dimensional model (Figure 5.15), with a stress of 7.2 and final instability of 0.01916. In all, 97.2% of the data variance was represented (Axis 1: 68.1%, Axis 2: 29.1%). The most influential variable in the NMS ordination, correlating with variation along axis 1, was the percentage of spinifex ($r^2 = 0.988$). The percentage of bare ground and leaf litter, both correlating with axis 2, had r^2 values of 0.799 and 0.685, respectively. The sites separated loosely in the ordination space according to whistler species; their clustering was influenced not by one single vector, but by a combination of two vectors. Accordingly, the *P. rufogularis* sites clustered towards higher values of spinifex cover, and also towards higher values of leaf litter cover. *Pachycephala inornata* sites clustered towards higher values of bare ground, and also towards higher values of leaf litter cover.

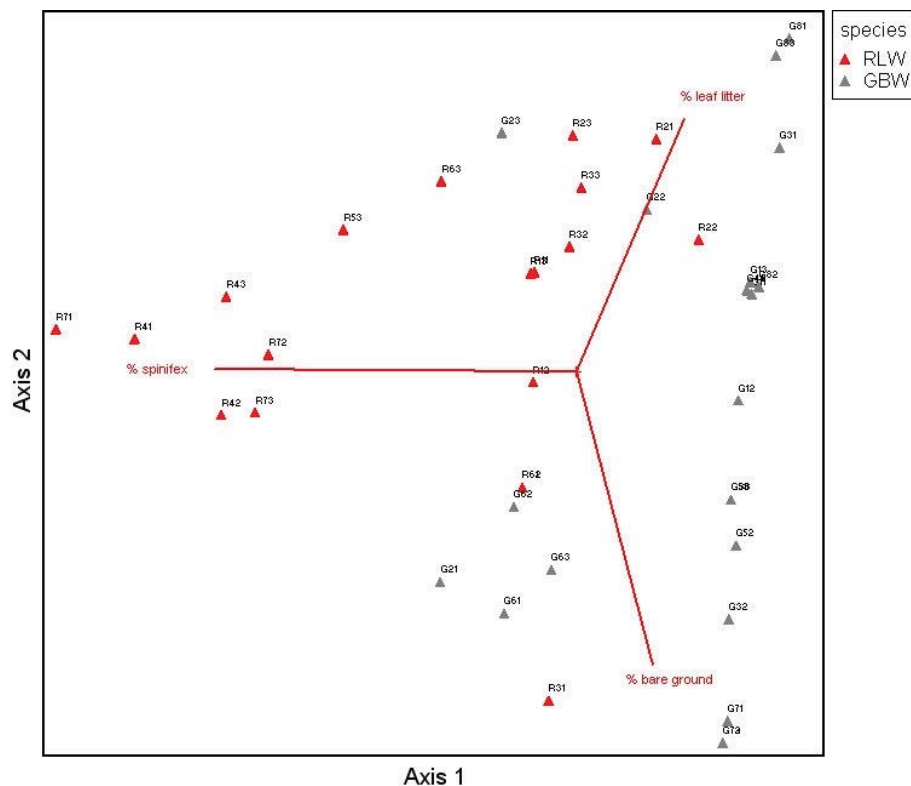


Fig. 5.15. NMS ordination of *Pachycephala rufogularis* (RLW) and *P. inornata* (GBW) vegetation sites from Gluepot, according to their ground cover.

The overlaid vectors have $r^2 \geq 0.6$. Stress = 7.2, final instability = 0.01916.

The summary of the percentage ground cover of *P. rufogularis* and *P. inornata* sites at Gluepot and *P. rufogularis* sites at Ngarkat is given in Table 5.8.

Table 5.8. The percentage ground cover (mean \pm standard error) of *Pachycephala rufogularis* (n = 21) and *P. inornata* (n = 24) sites at Gluepot and *P. rufogularis* (n = 12) sites at Ngarkat. BG = bare ground, LL = leaf litter, Sp = spinifex
RLW = *P. rufogularis*, GBW = *P. inornata*

ground cover	RLW Gluepot	GBW Gluepot	RLW Ngarkat
%BG	37.4 \pm 3.71	59.6 \pm 3.93	36.1 \pm 4.80
%LL	26.6 \pm 3.87	35.6 \pm 4.11	46.5 \pm 5.91
%Sp	36.0 \pm 5.60	4.8 \pm 1.81	17.4 \pm 10.20

Significant differences between *P. rufogularis* and *P. inornata* sites from Gluepot were in percentage bare ground (Mann Whitney U = 98.0, P = 0.0005) and spinifex cover (Mann Whitney U = 43.5, P < 0.0001). Significant differences between *P. rufogularis* sites from Gluepot and Ngarkat were in percentage leaf litter (Mann Whitney U = 59.0, P = 0.0128) and spinifex cover (Mann Whitney U = 13.0, P < 0.0001).

5.5.8. Trees, shrubs, spinifexes

For mallee-*Triodia*, a vegetation type predominantly used by *Pachycephala rufogularis*, 114 trees had their parameters measured. For mallee-*Triodia* with *Callitris*, a vegetation type predominantly used by *P. rufogularis* but also by *P. inornata*, 91 trees were measured. For mallee over shrubs and *Casuarina* woodland, vegetation types predominantly used by *P. inornata*, the numbers of measured trees were 93 and 30 respectively. As stated in the *Methods*, only the mallee eucalypts were measured in the mallee habitats, the tree measurements being in fact designed for their particular, multi-stemmed habit. The summary of these measurements is given in Table 5.9. As the statistical tests (Chi-square, Mann-Whitney) found no difference between the mallees from *P. rufogularis* and *P. inornata* sites within mallee-*Triodia* with *Callitris* vegetation sub-type, their parameters were pooled. The presence of mistletoes as a parameter was excluded from Table 5.9, as no mistletoes were present in the measured trees, or in sampled sites. However, mistletoes (the wire-leaved mistletoe *Amyema preissii* and the harlequin mistletoe *Lysiana exocarpi*) were occasionally detected in both *P. rufogularis* and *P. inornata* habitats (pers. obs.).

Table 5.9. The tree parameters (mean \pm standard error) from *Pachycephala rufogularis* and *P. inornata* habitats at GluepotMT – mallee-*Triodia* (n = 114), MT(CAVE) - mallee-*Triodia* with *Callitris* (n = 91),MS – mallee-shrubs (n = 93), CAPAw – *Casuarina* woodland (n = 30).

n/a - not applicable

variable	MT	MT(CAVE)	MS	CAPAw
height (m)	3.7 \pm 0.08	3.5 \pm 0.05	5.6 \pm 0.09	8.1 \pm 0.33
# live stems	3.7 \pm 0.25	3.9 \pm 0.27	4.8 \pm 0.23	n/a
# dead stems	1.5 \pm 0.18	1.4 \pm 0.19	1.7 \pm 0.12	n/a
diam stem (cm)	4.2 \pm 0.25	4.0 \pm 0.34	4.8 \pm 0.19	n/a
DIAM stem (cm)	6.3 \pm 0.32	5.8 \pm 0.21	8.1 \pm 0.28	n/a
epicormic growth	1.6 \pm 0.06	1.3 \pm 0.11	0.9 \pm 0.04	n/a
diam canopy (m)	3.3 \pm 0.12	3.2 \pm 0.07	4.7 \pm 0.20	3.1 \pm 0.24
DIAM canopy (m)	4.1 \pm 0.15	4.3 \pm 0.09	6.1 \pm 0.21	3.6 \pm 0.30
openness canopy	44.5 \pm 0.54	45.0 \pm 0.66	49.3 \pm 0.76	45.7 \pm 0.71
# clumps	4.9 \pm 0.24	4.7 \pm 0.34	6.1 \pm 0.29	n/a
clumps separation	3.1 \pm 0.10	2.9 \pm 0.12	3.8 \pm 0.09	n/a
dead branches	1.3 \pm 0.08	1.4 \pm 0.10	1.2 \pm 0.07	0.1 \pm 0.01

Table 5.9. shows that there was no or very little difference between the mallees from mallee-*Triodia* and those from mallee-*Triodia* with *Callitris*. In comparison, the mallees from mallee over shrubs were taller, had thicker stems and wider and denser canopies. The main difference in the considered parameters between the black oaks *Casuarina pauper* (the trees measured for *Casuarina* woodland) and mallees resided in the height, the black oaks being considerably taller. The differences in tree parameters between the vegetation types used by *P. rufogularis* and *P. inornata* were confirmed by the non-parametric Kruskal-Wallis test followed by Dunn's Multiple Comparison post-test (Table 5.10.)

Table 5.10. The differences in tree parameters among the vegetation types in which *Pachycephala rufogularis* and *P. inornata* occur, as revealed by Kruskal-Wallis test followed by Dunn's post-test
 MT =mallee-*Triodia*, MT(CAVE) = mallee-*Triodia* with *Callitris*, MS = mallee over shrubs,
 CAPAw = *Casuarina* woodland
 n/a - not applicable, ns = not significant, * = significant at 0.05 alpha, ** = significant at 0.01 alpha,
 *** = significant at 0.001 alpha

variable	MT vs MT(CAVE)	MT vs MS	MT vs CAPAw	MT(CAVE) vs MS	MT(CAVE) vs CAPAw	MS vs CAPAw
height (m)	ns	**	***	**	***	**
# live stems	ns	ns	n/a	ns	n/a	n/a
# dead stems	ns	ns	n/a	ns	n/a	n/a
diam stem (cm)	ns	***	n/a	***	n/a	n/a
DIAM stem (cm)	ns	***	n/a	***	n/a	n/a
epicormic growth	ns	**	n/a	*	n/a	n/a
diam canopy (m)	ns	***	ns	***	ns	**
DIAM canopy (m)	ns	***	*	***	*	***
openness canopy	ns	**	ns	**	ns	**
# clumps	ns	**	n/a	**	n/a	n/a
clumps separation	ns	ns	n/a	ns	n/a	n/a
dead branches	ns	ns	**	ns	**	*

A total of 121 shrubs were measured for mallee-*Triodia* vegetation type, 94 for mallee-*Triodia* with *Callitris*, 85 for mallee over shrubs and 50 for prickly *Acacia* shrubland. The summary of the measured shrub parameters is given in Table 5.11.

Table 5.11. The shrub parameters (mean \pm standard error) from *Pachycephala rufogularis* and *P. inornata* habitats at Gluepot
 MT =mallee-*Triodia*, MT(CAVE) = mallee-*Triodia* with *Callitris*, MS = mallee over shrubs,
 ACCOth = prickly *Acacia* thicket

variable	MT	MT(CAVE)	MS	ACCOth
height (cm)	99.0 \pm 3.52	86.3 \pm 5.62	122.1 \pm 4.86	139.8 \pm 6.60
diam (cm)	91.7 \pm 4.46	71.2 \pm 3.67	102.2 \pm 6.39	127.6 \pm 8.62
DIAM (cm)	125.2 \pm 5.81	103.6 \pm 6.95	126.6 \pm 7.75	146.8 \pm 5.74
openness	44.2 \pm 1.48	43.8 \pm 3.78	37.0 \pm 0.96	48.6 \pm 1.27
% dead	41.6 \pm 3.07	22.3 \pm 2.96	31.9 \pm 2.98	30.8 \pm 4.52

As for the trees, no significant differences were found between the shrubs from *P. rufogularis* and *P. inornata* sites within mallee-*Triodia* with *Callitris* vegetation sub-type, so their parameters were pooled. Data for the shrub parameters were compared between the vegetation types used by *P. rufogularis* and *P. inornata* using Kruskal-Wallis test followed by Dunn's Multiple Comparison post-test (Table 5.12.).

Table 5.12. The differences in shrub parameters among the vegetation types in which *Pachycephala rufogularis* and *P. inornata* occur, as revealed by Kruskal-Wallis test followed by Dunn's post-test
 MT =mallee-*Triodia*, MT(CAVE) = mallee-*Triodia* with *Callitris*, MS = mallee over shrubs,
 ACCOth = prickly *Acacia* thicket
 ns = not significant, * = significant at 0.05 alpha, ** = significant at 0.01 alpha,
 *** = significant at 0.001 alpha

variable	MT vs MT(CAVE)	MT vs MS	MT vs ACCOth	MT(CAVE) vs MS	MT(CAVE) vs ACCOth	MS vs ACCOth
height	*	**	***	***	***	*
diam	ns	***	***	***	***	ns
DIAM	ns	***	***	***	***	ns
openness	ns	***	**	***	**	**
% dead	ns	**	*	**	ns	ns

The only significant difference between the shrubs from mallee-*Triodia* and from mallee-*Triodia* with *Callitris* was in height, the former being slightly taller. The ones from the mallee over shrubs vegetation type were comparatively larger, although more open. The shrubs from prickly *Acacia* thickets (mainly *Acacia colletioides* and *A. nysophylla*) were the largest and densest of all.

Overall, 209 spinifexes (*Triodia scariosa*) were measured, 122 from mallee-*Triodia* and 87 from mallee-*Triodia* with *Callitris*. The summary of the spinifex measurements is given in Table 5.13. No differences were found between the spinifexes from *P. rufogularis* and *P. inornata* sites within mallee-*Triodia* with *Callitris* vegetation sub-type, so the data were pooled. The only significant differences detected between the spinifexes from mallee-*Triodia* and from mallee-*Triodia* with *Callitris* were in height ($\chi^2 = 21.68$, d.f. = 86, $P = 0.0333$), life form ($\chi^2 = 18.21$, d.f. = 86, $P = 0.0482$) and life stage ($\chi^2 = 23.88$, d.f. = 86, $P = 0.0389$), the former being slightly taller and generally healthier (more vigorous). (As the sample sizes were unequal, only 87 spinifexes were compared (as this was the smallest sample size, of mallee-*Triodia* with *Callitris*). From the larger sample of mallee-*Triodia* the appropriate number of spinifexes was randomly excluded, as suggested by Zar (1996). In excluding spinifexes from the analysis, the random number generation function in Excel was used.)

Table 5.13. Summary (mean \pm standard error) of the spinifex parameters measured
MT =mallee-*Triodia*, MT(CAVE) = mallee-*Triodia* with *Callitris*

variable	MT	MT(CAVE)
height (cm)	40.4 \pm 0.83	31.3 \pm 2.02
diam ext (cm)	98.5 \pm 3.53	87.9 \pm 6.25
diam int (cm)	66.0 \pm 3.08	69.1 \pm 2.01
DIAM EXT (cm)	102.1 \pm 3.42	103.2 \pm 4.58
DIAM INT (cm)	68.1 \pm 3.08	70.2 \pm 2.37
life form	3.1 \pm 0.08	3.4 \pm 0.99
life stage	1.3 \pm 0.03	1.7 \pm 2.47

At Ngarkat, 73 trees (mallee eucalypts) from the mallee-heath were measured; the summary is given in Table 5.14. As only one *P. rufogularis* vegetation site was in mallee at Ngarkat, the trees from this vegetation type were not included in the analysis, as they were not a sufficient sample. Nevertheless, they were taller (average height = 2.6 m, s.e. = 0.20) and denser (average canopy openness = 54%, s.e. = 6.21) than the mallees from mallee-heath.

Table 5.14. The differences in tree parameters (mean \pm standard error) between *Pachycephala rufogularis* (RLW) habitats from Ngarkat (mallee-heath) and Gluepot (mallee-*Triodia*, including mallee-*Triodia* with *Callitris*), as revealed by chi-square and/or Mann-Whitney tests

ns = not significant, * = significant at 0.05 alpha, ** = significant at 0.01 alpha,

*** = significant at 0.001 alpha

variable	RLW Ngarkat	RLW Gluepot	P	test
height (m)	2.0 \pm 0.06	3.6 \pm 0.07	***	chi-sq
# live stems	4.5 \pm 0.33	3.7 \pm 0.26	ns	Mann-W
# dead stems	1.4 \pm 0.17	1.4 \pm 0.19	ns	Mann-W
diam stem (cm)	1.7 \pm 0.08	4.1 \pm 0.30	***	Mann-W
DIAM stem (cm)	2.6 \pm 0.10	6.1 \pm 0.27	***	Mann-W
epicormic growth	0.0 \pm 0.02	1.5 \pm 0.09	***	Mann-W
diam canopy (m)	1.5 \pm 0.10	3.3 \pm 0.10	***	chi-sq
DIAM canopy (m)	1.9 \pm 0.11	4.2 \pm 0.12	***	chi-sq
openness canopy	45.2 \pm 1.02	44.7 \pm 0.60	*	chi-sq
# clumps	4.9 \pm 0.47	4.9 \pm 0.29	ns	Mann-W
clumps separation	4.0 \pm 0.17	3.0 \pm 0.11	***	Mann-W
dead branches	0.9 \pm 0.08	1.4 \pm 0.09	ns	Mann-W

The measured mallees from mallee-heath at Ngarkat were considerably smaller and significantly different in almost all parameters to their counterparts from *P. rufogularis* habitats at Gluepot (see Table 5.14.). These differences related mostly to the age of vegetation (15 years post-fire at Ngarkat, over 50 years at Gluepot) and less to the phenotypic differences between the mallee eucalypt species from the two locations.

The summary of the measurements of the 94 shrubs from the mallee-heath at Ngarkat is given in Table 5.15. As only one *P. rufogularis* vegetation site was in mallee at Ngarkat, the shrubs from this vegetation type were not included in analysis, as they were not a sufficient sample. Only four shrubs from the mallee vegetation were measured. They were all moonahs (*Melaleuca lanceolata*) and were considerably larger than the shrubs from mallee-heath vegetation (average height = 2.1 m, s.e. = 0.246, average of minimum diameter = 2.4 m, s.e. = 0.387, average of maximum diameter = 2.6 m, s.e. = 0.020, average openness = 65%, s.e. = 4.082).

Table 5.15. The differences in shrub parameters (mean \pm standard error) between *Pachycephala rufogularis* (RLW) habitats from Ngarkat (mallee-heath) and Gluepot (mallee-*Triodia*, including mallee-*Triodia* with *Callitris*), as revealed by chi-square and/or Mann-Whitney tests
ns = not significant, * = significant at 0.05 alpha, ** = significant at 0.01 alpha,
*** = significant at 0.001 alpha

variable	RLW Ngarkat	RLW Gluepot	P	test
height (cm)	46.3 \pm 5.93	92.6 \pm 4.57	***	chi-sq
diam (cm)	42.2 \pm 7.08	81.4 \pm 4.06	***	chi-sq
DIAM (cm)	51.7 \pm 7.45	114.4 \pm 6.38	***	chi-sq
openness	39.5 \pm 1.73	44.0 \pm 2.63	***	chi-sq
% dead	9.3 \pm 2.35	31.9 \pm 3.01	***	Mann-W

The measured shrubs from mallee-heath at Ngarkat were considerably smaller and significantly different in all parameters from the shrubs from *P. rufogularis* habitats at Gluepot (see Table 5.15.). While to some extent these differences relate to the vegetation age, they also reflect the different floristic spectrum of the understorey from the two locations.

A total of 96 spinifexes were measured at Ngarkat; the summary is given in Table 5.16. Their parameters differed significantly to those of spinifexes from *P. rufogularis* habitats at Gluepot (see Table 5.16.). The spinifexes from *P. rufogularis* sites at Ngarkat were generally taller, more compact (mostly in intact clumps) and generally healthier (more vigorous) than those from *P. rufogularis* sites at Gluepot.

Table 5.16. The differences in spinifex parameters (mean \pm standard error) between *Pachycephala rufogularis* (RLW) habitats from Ngarkat (mallee-heath) and Gluepot (mallee-*Triodia*, including mallee-*Triodia* with *Callitris*), as revealed by chi-square and/or Mann-Whitney tests
ns = not significant, * = significant at 0.05 alpha, ** = significant at 0.01 alpha, *** = significant at 0.001 alpha

variable	RLW Ngarkat	RLW Gluepot	P	test
height (cm)	49.1 \pm 1.65	35.8 \pm 1.43	***	chi-sq
diam ext (cm)	54.5 \pm 3.28	93.2 \pm 4.89	***	chi-sq
diam int (cm)	56.3 \pm 5.53	67.6 \pm 2.55	***	chi-sq
DIAM EXT (cm)	62.0 \pm 3.47	102.6 \pm 4.00	***	chi-sq
DIAM INT (cm)	56.3 \pm 5.53	69.1 \pm 2.72	***	chi-sq
life form	1.8 \pm 0.16	3.3 \pm 0.53	***	Mann-W
life stage	1.1 \pm 0.04	1.5 \pm 1.25	**	Mann-W

5.5.9. Habitat specialisation

The values of J' (evenness) which reflects the degree of specialisation in habitat were 0.486 for *Pachycephala rufogularis* and 0.725 for *P. inornata* at Gluepot. These values suggest that *P. inornata* is more of a generalist with respect to habitat than *P. rufogularis*. Although *P. rufogularis* showed greater specialisation in habitat at Gluepot, its evenness value was not below the threshold of 0.4 that indicate habitat specialists. *Pachycephala rufogularis* from Ngarkat were more specialised in habitat than *P. rufogularis* from Gluepot, with J' = 0.352.

5.6. Discussion

5.6.1. Vegetation types used by *Pachycephala rufogularis* and *P. inornata*

With one exception, *Pachycephala rufogularis* and *P. inornata* differed in the vegetation types they used. The vegetation preferentially used by *P. rufogularis* can be defined in very broad terms as “low open mallee woodland with *Triodia* on dunes” (Carpenter 1998, Hyde 2001), and is one of the two main vegetation types occurring at Gluepot, occupying, according to the floristic vegetation map, ca 42.4% of the reserve. The canopy layer was dominated by Beaked Red Mallee (*Eucalyptus socialis*) and/or Dumosa Mallee (*E. dumosa*), had an overall cover ranging between 15-40% (mean = 25.3, s.e. = 2.73, n = 19) and was usually less than 5 m high (the average of the maximum canopy height in the sampled quadrats was 4.8 m, s.e. = 0.152, n = 19, while the average height of the measured trees was 3.6 m, s.e. = 0.07, n = 205). The ground layer was dominated by hummocks of spinifex (*Triodia scariosa*), covering from 15% to 90% (mean = 41.5, s.e. = 6.12, n = 19) of the ground in the sampled sites. The shrub layer ranged from absent to sparse to moderately dense (up to 40% cover). Where the shrub layer was absent, the spinifex had the highest density (Figure 5.16). The understorey was formed commonly by a mix of species (Figure 5.17) such as Hard-leaf Wattle (*Acacia sclerophylla*), Low Hop-bush (*Dodonaea bursarifolia*), Desert Broom (*Templetonia egena*) and Stiff Westringia (*Westringia rigida*). In some areas, the understorey was dominated by a single shrub species, as Dark Turpentine Bush (*Beyeria opaca*, Figure 5.18), Moonah (*Melaleuca lanceolata*, Figure 5.19), or Dwarf Nealie (*Acacia wilhelmiana*, Figure 5.20).

A sub-type of the mallee-*Triodia* vegetation is that in which the Mallee Cypress Pine (*Callitris verrucosa*) was present (Figure 5.21). Hyde (2001) described it as a separate vegetation association, I, however, consider it as a variant of mallee-*Triodia*, as Carpenter (1998) did. This vegetation sub-type was described as occurring only on taller, steep dunes (Carpenter 1998, Kutsche 1999), but it occurs on some low dunes also (pers. obs.). The highest *Callitris* cover in sampled quadrats was 25%. In some areas, such as the one at the eastern end of the Central Gluepot block, around 6261500 Northing (at the end of the Maleefowl Walk), *Callitris* is even denser and is the dominant canopy species; hence the name “*Callitris* woodland” under which that particular area is known (GMC 2004), although this was not separately described and mapped by Hyde (2001), probably because it does not



Fig. 5.16. *Pachycephala rufogularis* habitat at Gluepot: mallee-*Triodia* with no shrubby understorey. Observe the density of spinifex hummocks. The arrow points to a nest site. (Photo D. Moise)



Fig. 5.17. *Pachycephala rufogularis* habitat at Gluepot: mallee-*Triodia* with shrubby understorey, here co-dominated by *Acacia sclerophylla* and *Templetonia egena*. (Photo D. Moise)



Fig. 5.18. *Pachycephala rufogularis* habitat at Gluepot: mallee-*Triodia* with *Beyeria opaca* understorey.
(Photo R. Wilson)



Fig. 5.19. *Pachycephala rufogularis* habitat at Gluepot: mallee-*Triodia* with *Melaleuca lanceolata* understorey.
The white pole is two metres and was used in recording the vegetation density, see text. (Photo D. Moise)



Fig. 5.20. *Pachycephala rufogularis* habitat at Gluepot: mallee-*Triodia* with *Acacia wilhelmiana* understorey. Most of the *A. wilhelmiana* shrubs were dead, as this one in the foreground. (Photo D. Moise)

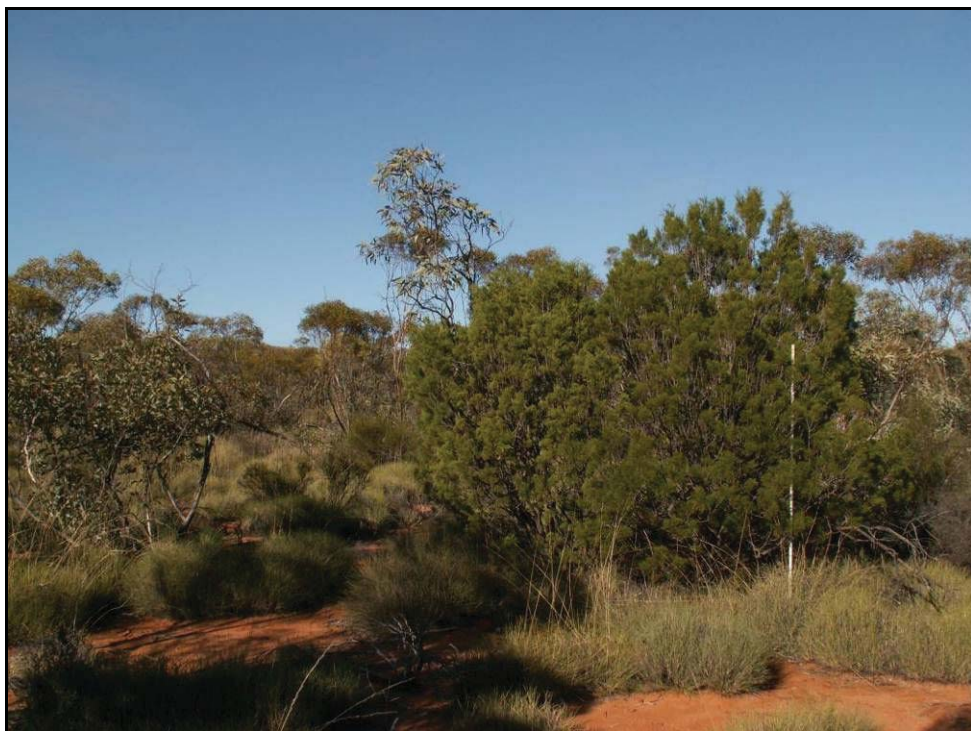


Fig. 5.21. *Pachycephala rufogularis* habitat at Gluepot: mallee-*Triodia* with *Callitris verrucosa*. This vegetation type is also favoured by *P. inornata*. (Photo D. Moise)

cover a wide area. The understorey in the mallee-*Triodia* with *Callitris* vegetation sub-type did not differ considerably from the understorey commonly found in mallee-*Triodia* vegetation. Although some plant species were recorded only in quadrats of this vegetation sub-type (*Acacia brachybotrya*, *Beyeria lechenaultii*, *Boronia coerulescens*, *Brachycome ciliaris*, *Eucalyptus incrassata*, *Lomandra effusa*, *Santalum murrayanum*, *Sclerolaena parviflora*), only the last one had a significant indicator value ($P = 0.0256$, ISA performed with vegetation type as grouping variable). The mallee-*Triodia* with *Callitris* is of particular significance for this study, as it was used not only by *P. rufogularis*, but also by *P. inornata*, being the only vegetation type in which the two species actually co-occurred at the extent of core areas, as was the case for *P. rufogularis* pair R1 and the *P. inornata* pair G31 at the end of the Maleefowl Walk.

The vegetation preferentially used by *P. inornata* can be defined in very broad terms as “tall open mallee woodland with shrubs in swales and flats” (Forward and Robinson 1996, Kutsche 1999, Hyde 2001), and is the most widespread vegetation type at Gluepot, occupying ca 27.5% of the reserve. The canopy layer was dominated by Acorn Mallee (*Eucalyptus oleosa*) and/or White Mallee (*E. gracilis*), had an overall cover ranging between 10-30% (mean = 20.4, s.e. = 2.32, n = 10) and was usually taller than in the mallee-*Triodia* vegetation type (the average of the maximum canopy height in the sampled quadrats was 6.2 m, s.e. = 0.08, n = 10, while the average height of the measured trees was 5.6 m, s.e. = 0.09, n = 93). The ground was usually bare, except for isolated tussocks of grass (*Austrostipa* spp.) and leaf litter under the mallees and shrubs. The shrub layer ranged from very sparse to moderately dense (5-45% cover) and it fits into the “sclerophyll-semi-succulent” understorey description of Specht (1972). The understorey was formed in some areas, as mentioned, by scattered low chenopods such as Mallee Salt-bush (*Atriplex stipitata*), Erect Mallee Blue-bush (*Maireana pentatropis*), Cottony Salt-bush (*Rhagodia gaudichaudiana*), Mallee Copperburr (*Sclerolaena patentiscuspis*), and Shrubby Twinleaf (*Zygophyllum*) species (Figure 5.22). Most commonly the understorey was formed by a mix of species (Figure 5.23), consisting of Wait-a-while (*Acacia colletioides*), Narrow-leaf Hop-bush (*Dodonaea viscosa angustissima*), Emu-bush (*Eremophila* sp.), Desert and Silver Cassia (*Senna* sp.). Most of these shrub species are woody increaser species (Kutsche 1999, Kutsche and Lay 2003), reflecting the degradation of habitat as a result of the grazing pressure in the past (Gluepot Reserve being a Pastoral Lease for the 120 years before the property was acquired by Birds Australia). The understorey was dominated in some areas by a single shrub species, such as Daisy Blue-bush (*Cratystylis*

conocephala, Figure 5.24) or Hard-leaf Wattle (*Acacia sclerophylla*, Figure 5.25). The mallee with *Acacia sclerophylla* understorey (Figure 5.25) was found in areas towards the eastern end of the study area, being crossed by the transect between 439000-439500 Easting. Contrary to the general occurrence of the mallee over shrubs vegetation, the mallee with *Acacia sclerophylla* understorey occurred on low dunes, this being probably the reason for which it was included within the “mallee with *Triodia* understorey on dunes” in the Gluepot floristic vegetation map (Hyde 2001), although no *Triodia* is present. Although it is primarily *P. inornata* habitat, *P. rufogularis* also used it, probably on a seasonal basis (Chapter 7).

Pachycephala inornata also used, at Gluepot, the prickly *Acacia* shrubland (Figure 5.26). This vegetation type occurred in swales and flats and was found in notable areas east of Babbler campsite, east and south of Froggy’s Dam (Kutsche 1999) and, in Birdseye Block, patchily in natural clearings within the mallee over shrubs vegetation. It was dominated by two *Acacia* species with rigid, needle-like leaves: Wait-a-while (*Acacia colletioides*) and Spinebush (*A. nysophylla*). Other shrub species were sometimes co-dominant, such as Desert and Silver Cassia (*Senna* sp.), Narrow-leaf Hop-bush (*Dodonaea viscosa angustissima*) and Emu-bush (*Eremophila* sp.). No overstorey was present, and the shrub layer had up to 55% cover. Most of the shrubs in this vegetation type were woody increaser species, considered to have had invaded areas in which they now dominate to the detriment of the original vegetation, usually recognised as being Pearl Blue-bush (*Maireana sedifolia*), Daisy Blue-bush (*Cratystylis conocephala*) and Salt-bush species (*Atriplex*, *Rhagodia* etc), grazed in the past (Kutsche 1999). However, this vegetation type represents valuable habitat for birds (Kutsche 1999). *Acacia colletioides* and *A. nysophylla*, with their dense and prickly structure, provided very good concealment and protection for nesting and roosting birds, including whistlers (pers. obs.). Prickly *Acacia* shrubland was not described by Hyde (2001), although Forward and Robinson (1996) consider it as a distinct vegetation type. In the Cluster Analysis, the four sites of prickly *Acacia* shrubland clustered within the mallee over shrubs vegetation type, probably because of the same floristic composition regarding the shrub species.

Another vegetation type used by *P. inornata* at Gluepot was the *Casuarina* woodland (Figure 5.27). This vegetation type was found in discrete patches confined to depressions that have intermittent standing water and heavy soils (Hyde 2001). Black Oak (*Casuarina pauper*)



Fig. 5.22. *Pachycephala inornata* habitat at Gluepot: mallee over very sparse chenopod understorey. (Photo D. Moise)



Fig. 5.23. *Pachycephala inornata* habitat at Gluepot: mallee over mixed shrubs, here *Senna* sp. and *Dodoneaea viscosa angustissima*. (Photo D. Moise)



Fig. 5.24. *Pachycephala inornata* habitat at Gluepot: mallee with *Cratystylis conocephala* understorey
(Photo C. Coleborn)



Fig. 5.25. *Pachycephala inornata* habitat at Gluepot: mallee with *Acacia sclerophylla* understorey.
(Photo D. Moise)

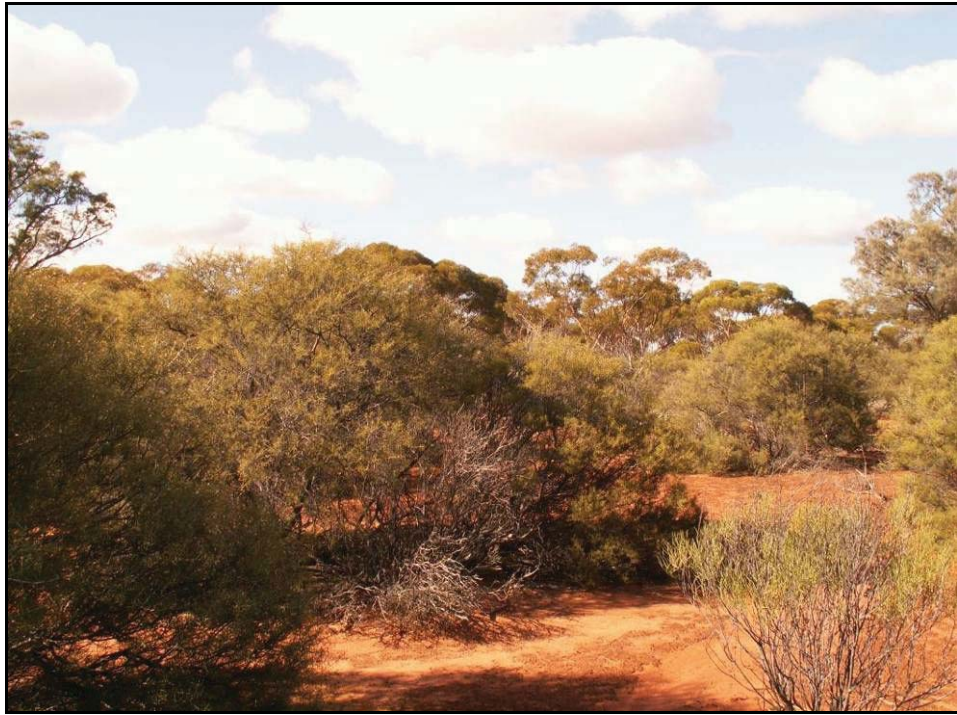


Fig. 5.26. *Pachycephala inornata* habitat at Gluepot: *Acacia colletioides* shrubland.
(Photo D. Moise)



Fig. 5.27. *Pachycephala inornata* habitat at Gluepot: *Casuarina pauper* woodland.
(Photo D. Moise)

dominated the canopy, which had a cover between 40-60% and a maximum height of 13 m in the sampled quadrats. The average height of the measured trees was 8.1 m (s.e. = 0.33, n = 30). *Casuarina* leaf litter covered up to 70% of the ground, which was otherwise bare. The understorey was usually absent, or very sparse, formed by scattered Ruby Saltbushes (*Enchylaena tomentosa*), Sugarwoods (*Myoporum platycarpum*) and the odd Leafless Cherry (*Exocarpos aphyllus*). Because of the location in natural soaks, where the dams were placed, this vegetation type has been heavily disturbed by grazing in the past (Hyde 2001).

Pachycephala inornata also used, at Gluepot, the mallee-*Triodia* with *Callitris*, primarily a *P. rufogularis* habitat. This particular use of mallee-*Triodia* with *Callitris* seems unusual, as *P. inornata* does not commonly use mallee-*Triodia* vegetation. Perhaps this use may be explained by the presence, and particularly the structure of the Mallee Cypress Pine *Callitris verrucosa*. In the mallee-*Triodia* with *Callitris* vegetation sub-type, *Callitris* contributed substantially to the vegetation density, particularly above 50 cm of the ground (Figure 5.10). The vertical density profile of mallee-*Triodia* with *Callitris* (Figure 5.5) approached the one of prickly *Acacia* shrubland (Figure 5.7), another vegetation type used by *P. inornata*. Furthermore, Kruskal-Wallis with Dunn's Multiple Comparison post-test did not find significant differences in vertical density between *Triodia* with *Callitris* and prickly *Acacia* shrubland (Table 5.3.). Similar to the prickly *Acacia*, the dense structure of *Callitris* provided good concealment and protection for roosting and nesting birds. At Gluepot, the *P. inornata* pair G17 selected in 2004 a *Callitris* tree as a nest site. Also at Ngarkat, the only recent record of *P. inornata*, from the mid-1990s, came from an area with mallee and *Callitris* (D. Paton, pers. comm.). The preference of *P. inornata* for *Callitris* has been recorded elsewhere (Carpenter and Matthew 1986, Higgins and Peter 2002).

In the Gluepot dendrogram, *P. inornata* sites of mallee-*Triodia* with *Callitris* were actually split into two groups (Figure 5.1), according to the floristic differences in the shrub layer.

The vegetation preferentially used by *P. rufogularis* at Ngarkat, mallee-heath (Figures 5.28 and 5.29), corresponds to the mallee with “sclerophyll” understorey description of Specht (1972). The canopy layer in the sampled quadrats was formed by Ridge-fruited Mallee (*Eucalyptus incrassata*), Narrow-leaved Red Mallee (*Eucalyptus leptophylla*) or Beaked Red Mallee (*Eucalyptus socialis*) and dominated by either species, or in combination. The overall canopy cover ranged between 10-30% (mean = 21.6, s.e. = 8.41, n = 10) and was usually less than 3 m high, given the post-fire age of vegetation (the average height of the measured trees was 2 m, s.e. = 0.07, n = 73). *Triodia* was present in all mallee-heath sites, covering between 10% and 30% of the ground (mean = 19.4, s.e. = 13.32, n = 10). The moderately dense shrub layer (up to 40% cover), was formed by a variety of species commonly found in the adjacent heathland: Broom Baeckea (*Baeckea behrii*), Coast Tea-tree (*Leptospermum coriaceum*), Slaty She-oak (*Allocasuarina muelleriana*), Desert Banksia (*Banksia ornata*), Broombush (*Melaleuca uncinata*), Desert Hakea (*Hakea muelleriana*), Common Fringe-myrtle (*Calytrix tetragona*), Guinea-flower (*Hibbertia* sp.) etc (see Appendix 2). The first three mentioned species usually dominated the shrub layer.

The only mallee site at Ngarkat occurred in a swale with clayey soil and around 15% surface strew cover of small laterite (ironstone) pebbles. The canopy layer, of 65% cover, was co-dominated by South Australian Blue Gum (*Eucalyptus leucoxylon*) and Beaked Red Mallee (*Eucalyptus socialis*). The average height of the ten trees measured was 2.6 m (s.e. = 0.20). The ground layer was formed by tussocks of Variable Sword-sedge (*Lepidosperma laterale*), providing 10% cover. The understorey was represented by scattered Moonahs (*Melaleuca lanceolata*).



Fig. 5.28. Mallee-heath, the vegetation preferentially used by *Pachycephala rufogularis* at Ngarkat (Photo D. Moise)



Fig. 5.29. The mosaic pattern of mallee-heath and heath found in the areas where *Pachycephala rufogularis* occurs at Ngarkat. (Photo D. Moise)

5.6.2. Habitat requirements of *Pachycephala rufogularis* and *P. inornata*

Triodia scariosa was present in all *Pachycephala rufogularis* sites from Gluepot, as well as Ngarkat. At Gluepot, this species had the highest value in indicating *P. rufogularis* presence. Also, *Triodia scariosa* (presence and cover) correlated stronger than any other plant species with the presence of *P. rufogularis*. These findings support the presumption that the presence of *Triodia* may be a critical habitat requirement for *P. rufogularis*, as suggested by others (Parsons and McGilp 1935, Pedler 1982, Higgins and Peter 2002). The requirement for *Triodia* is not clear, as *P. rufogularis* does not use this plant for shelter, as other bird species (Striated Grasswren *Amytornis striatus*, Mallee Emu-wren *Stipiturus mallee*) do. Furthermore this plant is not used when foraging (Chapter 7). However, *P. rufogularis* preferentially uses *Triodia* clumps as nest sites (Higgins and Peter 2002, Pizzey and Knight 2003, L. Pedler, pers. comm., also pers. obs.), and this may (albeit partially) explain it.

Another important feature for *P. rufogularis* in selecting the habitat seems to be the density of vegetation. At both Gluepot and Ngarkat *P. rufogularis* occurred at sites with dense vegetation at low height (in the first 50 cm above the ground). At Gluepot, the high vegetation density above the ground at *P. rufogularis* sites strongly related to the *Triodia* cover; at Ngarkat, where the cover of *Triodia* was two times lower than at Gluepot, the low, heathy understorey contributed considerably to this particular density.

The finding that *P. rufogularis* occurred at sites with denser vegetation at low height at both Gluepot and Ngarkat is consistent with that of Woinarski (1987), in Big Desert. In the same study, Woinarski (1987) found that *P. inornata* occurred characteristically in areas with relatively open low vegetation layer (to 1.5 m above the ground) but dense tall vegetation. This is confirmed by my study, but only partially. While at Gluepot *P. inornata* mostly occurred in mallee over shrubs, which has indeed a relatively open low vegetation layer, it also occurred in vegetation which is relatively denser in the first 1.5 m from the ground (prickly *Acacia* shrubland, mallee-*Triodia* with *Callitris*).

An interesting observation was that *P. rufogularis* at Ngarkat does not seem to use the heath vegetation. The great majority of the sites where the vegetation was assessed, within the core areas of the birds' home ranges, were in mallee-heath vegetation, and none was in heath. *Pachycephala rufogularis* did not use the heath vegetation either for foraging (Chapter 7) or

breeding (Higgins and Peter 2002, pers. obs.), but to move between patches of mallee-heath. These observations indicate and reinforce the notion that *P. rufogularis* is a mallee bird in essence. Also, these observations suggest that presence of (mallee) trees might be a habitat requirement, and a limiting factor for *P. rufogularis*. The presence of trees seems to be a limiting factor for *P. inornata* as well, at Gluepot this species used the prickly *Acacia* thickets only in conjunction with, and where it occurred within the mallee over shrubs, in clearings. The importance of trees as a habitat requirement for *P. rufogularis* and *P. inornata* is highlighted by their foraging behaviour, both species feeding predominantly in the canopy (Chapter 7).

The presence, cover and density of shrubs seem to be also habitat requirements, more important for *P. rufogularis* than for *P. inornata*. For *P. rufogularis* the presence of a shrub layer might be a limiting factor, since this species seemed to avoid the *Casuarina* woodland, where the understorey was usually absent.

It was suggested that a limiting factor for *P. rufogularis* is the age of the vegetation, the species being recorded mostly in areas with vegetation in early successional stages following fire (Carpenter and Matthew 1986; Woinarski 1987, Higgins and Peter 2002). In Big Desert, *P. rufogularis* was not recorded in vegetation that had not been burnt for more than 40 years (Woinarski 1987). The author argued that long intervals between fires may result in the exclusion of this species, due to decreasing of vegetation suitability or changes in floristic composition with age, e.g. decline in vigour of *Triodia* (Woinarski 1987). However, *P. rufogularis* used and successfully bred in vegetation more than 50 years post-fire at Gluepot. Although old, this vegetation was still suitable for *P. rufogularis*, having high density at low height above the ground (relating mostly to the cover of *Triodia*), as required. I might argue here that the structure is more important than the age in determining the suitability of vegetation for *P. rufogularis*. In the same way, the vegetation regenerating after fire may not be suitable for *P. rufogularis* recolonisation for many years, until it recovers the required structure. For example, if a *P. rufogularis* individual is recorded in vegetation 5 years post fire then this does not mean that the bird is a permanent resident, or can successfully survive and reproduce there. Yet the literature tends to overlook this (Matthew *et al.* 1996, Higgins and Peter 2002). At Ngarkat, where every part of the park has been burned at least once since 1945 and many areas have experienced multiple fires, *P. rufogularis* has

shown preference for vegetation 10 to 24 years post fire (Clarke 2005). During this project, *P. rufogularis* was recorded breeding at Ngarkat in vegetation 14-15 years post fire.

In comparison, *P. inornata* was mostly recorded in older, long-unburnt vegetation (Carpenter and Matthew 1986, Woinarski 1987, Clarke 2005). Woinarski (1987) recorded *P. inornata* mainly in vegetation older than 40 years. At Gluepot, where the vegetation was more than 50 years old, *P. inornata* was listed as *locally common* (GMC 2005). The preference for long-unburnt vegetation may explain why this species has probably gone extinct in Ngarkat.

5.6.3. The impact of grazing

At Gluepot, *Pachycephala inornata* occurred in areas that were moderately to highly disturbed by past grazing (as mentioned, Gluepot Reserve was a Pastoral Lease for 120 years). The grazing impact in some areas was very obvious, such in *Casuarina* woodland, where the understorey was virtually absent (Kutsche 1999). In other areas, the grazing impact could be inferred from the floristic composition and the proportion and cover of woody increaser and unpalatable shrubs such as *Acacia colletioides* / *A. nysophylla*, *Dodonaea viscosa angustissima*, *Senna* spp. (Kutsche 1999). In this respect, the prickly *Acacia* thickets could be regarded as modified habitat.

In comparison, at Gluepot *P. rufogularis* occurred in areas less disturbed or undisturbed by grazing. The low grazing impact at *P. rufogularis* sites related to the cover of *Triodia*, not grazed by sheep or goats (Kutsche and Lay 2003). These observations lead to the assumption that, while *P. inornata* might profit from the habitat modification and simplification caused by grazing, *P. rufogularis* could be negatively impacted by it. Overgrazing and soil disturbance caused by the hooves of sheep and goats can result in the drastic reduction of vegetation density at low height, to the complete destruction of the understorey, rendering the habitat unsuitable for *P. rufogularis*.

5.6.4. Habitat specialization

This study revealed that *Pachycephala rufogularis* have indeed strict habitat requirements, as suggested in the literature. The rigid habitat requirements, together with the sedentary nature, render this species vulnerable to disturbance from grazing and fire. The documented specialization in habitat of *P. rufogularis* (this study) may have important conservation implications, being a possible cause of the decline of this species. *Pachycephala inornata*, on the other hand, is more flexible in its habitat requirements and uses a broader range of vegetation types, therefore being more of a generalist in respect to habitat. The perceived flexibility in habitat requirements may be one of the reasons why *P. inornata* is more successful than its sibling species, *P. rufogularis*.

5.6.5. Competition or coexistence?

The results of this chapter revealed that in the field *Pachycephala rufogularis* and *P. inornata* were segregated by habitat. Therefore the resource partitioning between the two similar species in the areas where they were found coexisting happened by and large at the macrohabitat level, and the “ghost of the competition past” concept can be invoked here (Krebs and Davies 1993). At Gluepot *P. rufogularis* mostly used the low mallee with *Triodia* vegetation on low sand dunes, while *P. inornata* mostly used the tall mallee with shrubs vegetation on interdunes. However, there was a vegetation type both species used: mallee-*Triodia* with *Callitris*. In some areas of such vegetation at Gluepot, *P. rufogularis* and *P. inornata* had overlapping home ranges, and were observed coexisting for extended periods of time (Chapter 4). The key for the coexistence at this level was a behavioural one, *P. inornata* acting as a subordinate species. In these areas individuals of this species generally kept a low profile, being rather inconspicuous, less vocal and submissive towards *P. rufogularis*. The general impression was that in the areas of mallee-*Triodia* with *Callitris* where both species coexisted, *P. inornata* were “tolerated” by the otherwise dominant *P. rufogularis*.

Perhaps *P. rufogularis* and *P. inornata* are not direct competitors, and I support this affirmation with the situation from Ngarkat. *Pachycephala inornata* does not occur at Ngarkat (most probably anymore). Despite this, instead of using a broader range of vegetation types as expected from potential ‘competitive release’, *P. rufogularis* use virtually only one vegetation type at Ngarkat.

5.7. Future work

5.7.1. Used versus unused habitat

If funding could be secured for further research, a further step in assessing habitat selection and preference for *Pachycephala rufogularis* and *P. inornata* might be comparing the suitable habitat for both species with the habitats in unoccupied areas and testing for differences. The unused habitat was not assessed this time because the vegetation assessments at the level of detail achieved for this study are extremely tedious and time consuming. Besides, only two years were allocated for field work, time in which other aspects of these birds' ecology had to be investigated.

5.7.2. Vegetation density

The detailed vegetation profiles in the habitats used by the studied bird species were constructed only for the first two metres above the ground, an interval in which it could have physically been measured at a fine resolution. Future research should on vegetation densities in areas used by the birds should overcome this impediment and determine vertical vegetation profiles above 2m of height.

5.7.3. Habitat suitability models

My findings on the habitat requirements of *P. inornata* at Gluepot are at odds with those of Clarke (2005). In his modelling approach of the habitat suitability for threatened mallee birds, *P. inornata* from Bookmark Biosphere Reserve (of which Gluepot Reserve is part) were positively correlated with Mallee/*Triodia* vegetation and negatively associated with Mallee/Black oak (*Casuarina*) and Mallee plain (described here as 'mallee over shrubs'), contrary to the findings of my study (see also Chapter 6). Clarke's models are limited by the coarse scale of vegetation mapping used for inferring habitat suitability. The vegetation layer used by Clarke was derived from the vegetation map produced for the South Olary Plains Biological Survey, consisting of a combination of primary, secondary and tertiary vegetation units (Forward and Robinson 1996). At Gluepot, the typical habitat of *P. inornata*, mallee over shrubs, commonly occurs as a mosaic with mallee-*Triodia*, a pattern not detectable on the map used by Clarke.

My finding that in the more heath-dominated environments (as in Ngarkat) *P. rufogularis* uses preferentially the patches of mallee-heath is again at odds with the findings of Clarke (2005). In his habitat suitability model for *P. rufogularis*, this species at Ngarkat displayed a positive association with *Tall open heath* (one of the five vegetation classes derived from the Veg_MurrayMallee_MU_50 GIS layer). With my current understanding of the ecology of this bird derived from my field experience at Ngarkat, I assume that *P. rufogularis* displayed a positive association with the patches of mallee-heath within the Tall open heath (see Figure 5.29), probably not shown in the GIS layer used by Clarke.

For *P. rufogularis* and *P. inornata*, the habitat suitability model of Clarke (2005) is misleading, and should be used cautiously in management decisions for conservation of these threatened species. The failure of Clarke's modeling approach resides in using coarse scale vegetation maps, which are known to be poor predictors for habitat suitability models (Guisan and Zimmermann 2000, Seoane *et al.* 2004). Future vegetation mapping will need to be much more detailed and to have a finer spatial resolution before a habitat suitability model for *P. rufogularis* and *P. inornata* can be developed. This study has focused on identifying the vegetation types used by the two species, their key habitat requirements, and the key environmental variables correlated with their presence. These ecological data should be included when constructing future habitat suitability models for the two species.