CHAPTER 5

HOME RANGE AND HABITAT USE IN EASTERN YELLOW ROBINS AND PALE-YELLOW ROBINS IN AN EXPERIMENTALLY LOGGED MOIST EUCALYPT FOREST

5.1 Introduction

A knowledge of how animals use space is central to understanding their response to change in the availability and composition of resources over time (e.g., Alvarez & Santos 1992; Goldingay & Kavanagh 1993; Naef-Daenzer 1994; de Roos & Sabelis 1995). Two important parameters of space use are home range and the use of habitat (see Lima *et al.* 1987; Robinson 1992; Anders *et al.* 1998; Martin 1998).

In wood production forests, information on how logging operations may affect home range and habitat use in birds and other fauna should be a core ingredent of sustainable resource management plans (see Recher 1991, 1996; Matthysen & Currie 1996). In Australia, the impact of small-scale (<5 ha), gap-based logging systems on avian home range and habitat use has not been investigated. Instead, work has focused on the impact of comparatively large-scale clearfelling and selective logging operations on bird species diversity, abundance and distribution (see Loyn 1980, 1985a,b,c, 1993; Pattemore 1980; Recher *et al.* 1980; Kavanagh *et al.* 1985; Smith 1985; Dickinson *et al.* 1986; Shields 1990; Taylor 1991; Taylor & Haseler 1995; Taylor *et al.* 1997).

In this chapter I describe the short-term impact of experimental logging on home range and habitat use in the Eastern Yellow Robin and Pale-yellow Robin. I specifically describe the impact of logging trials on the size, overlap, shape and location of home ranges of monitored individuals of both species. I investigate each species' use of treatment zones and microhabitat before and after logging. I also describe their use of woody debris piles and gap-crossing behaviour. I defer discussion of factors that may account for these responses until after data for the other study species have been presented (see Chapter 8).

I distinguish between home range and territory in this chapter in order to avoid confusion (e.g., see Whitcomb *et al.* 1981; Marchant 1985; Greenberg & Gradwohl 1986, 1997; Bridges 1992, 1994; Stokes 1995; Brooker 1998; Smith *et al.*1998; Craig 1999). Home range is the area through which an animal moves to obtain food, reproduce and care for its young (Burt 1943). In contrast, territory is an area that an animal actively defends against rivals, especially during the breeding season, and is often smaller than its home range (Noble 1939; Brown & Orians 1970). I focus on home range in this study and thus do not attempt to define the location, size or other aspects of territories.

I postulate four models to predict the response in the home range and habitat use dynamics of both robin species to the experimental logging trials. These are:

1. *Incorporation*: birds include newly created gaps in their home ranges; home range size is generally maintained or increased; overlap between the home ranges of neighbouring birds of the same species is maintained; home range shape and location is generally maintained; use of treatment zone (ie. gapped, thinned, and retained forest) is influenced by home range size but not by logging; microhabitat use is influenced by logging.
2. *Modification*: birds exclude newly created gaps from their home ranges; home range size is generally maintained or decreased; overlap between the home ranges of neighbouring birds of the same species increases; home range shape changes and home ranges are relocated to retained forest; use of treatment zone (ie. gapped, thinned, and retained forest) and microhabitat are influenced by logging.
3. *Partial adjustment*: birds include only parts of gaps in their home ranges; home range size and overlap between the home ranges of neighbouring birds of the same species are generally maintained; home range shape changes and home ranges extend into retained forest; use of treatment zone (ie. gapped, thinned, and retained forest) and microhabitat are influenced by logging.
4. *Emigration*: birds depart from gapped plots after logging and do not return during the monitoring periods.

5.2 Methods

5.2.1 Quantifying space use by forest birds

I based my investigation of the use of space by both robin species on the computer-aided estimation of home range and use of treatment zone and microhabitat. In the small number of previous home range studies of Australian birds, territories and home ranges have been manually mapped from field observations (Section 5.4.3).

I selected two measurable parameters of home range - size and overlap, and two quantifiable habitat-based variables - use of treatment zone and microhabitat class. I defined *overlap* as the amount of space shared by two or more neighbouring birds of the same species. I defined *treatment zone* as the area of forest within logged plots that was gapped, thinned or

retained during the logging trials (see Section 5.2.3). These attributes of home range and habitat use provided data for the testing of hypotheses relating to logging impact (see Section 5.3). I assessed changes in the location and shape of home ranges after logging and the degree of connectivity with riparian, hillslope and ridgeline forest. I also described the use of woody debris piles by birds in gaps and the willingness of birds to cross gaps created during the logging trials.

5.2.2 Estimating home range

The accurate estimation of animal home ranges requires the collection of location data from a number of individuals of the species being studied, preferably over several years (White & Garrott 1990; Kenward & Hodder 1996). This information allows analyses of resource use, behaviour, response to disturbance, and other attributes to be carried out. I approached the estimation of avian home ranges in the research plots by collecting information on bird movement and undertaking analyses to estimate home range size and overlap. I did not use radiotelemetry to monitor the movement of individual birds because of the degree of philopatry exhibited by both species and the logistics, cost and ethics associated with fitting microtransmitters to small forest birds.

Recording bird movement

I used the methods described in Section 4.2.2 to locate colour-banded birds of both species and record their movements before and after logging in each experimental plot and during the equivalent periods in each control plot. Specifically, I recorded the routes taken by individual birds, pairs or groups during their daily journeys through the forest. Locations of individual birds were recorded at approximately one (1) minute intervals for both species, along with time (24 hour format), treatment zone and microhabitat class. The location of only one bird was recorded if pairs were moving together or near each other. Birds were not usually followed beyond plot boundaries.

Birds were not monitored during periods of moderate-heavy rainfall, high temperature, or strong wind. I specifically avoided the 'herding' of monitored birds (see Tidemann 1990; Brooker 1998) when following individuals or pairs so as to ensure birds behaved as naturally as possible.

I mapped the journeys of 63 colour-banded and known, unbanded individuals of both species across all plots over a period of approximately 14 months (1 May 1997-23 December 1998). These journeys or 'traces' were marked on detailed 1:1250 scale maps of each plot that showed treatment zone (logged plots only), contours, drainage lines, net stations, logging tracks and the position of grid marker pegs.

I obtained a total of 319 traces (111 before logging and 208 after logging) from 32 individuals of *E. australis* across all plots throughout the study. This represented a total of 1970 locations or fixes (967 before logging and 1003 after logging) of this species across all plots. For *T. capito*, I obtained 190 traces (96 before logging and 94 after logging) from 31 individuals across all plots, comprising a total of 1867 fixes (959 before logging and 908 after logging). More intensive sampling of Year 2 plots produced a 21.6% increase in the number of fixes obtained compared with the Year 1 plots. The C1 Plot was less intensively sampled than the other plots (Chapter 4).

I used transparent acetate overlays on which I marked grids that encompassed the total area, in Australian Map Grid (AMG) coordinates, of each plot. AMG coordinates were obtained from plot surveying (Chapter 2). I then positioned the 1:1250 scale field maps showing the actual journeys of monitored birds in each session under the relevant plot grid and read off the AMG coordinates (eastings and northings) of each location in each trace using a clear perspex 90° square-ruler. In this way, I obtained the coordinates of each location in each bird's monitored journey and entered this data, together with date, time, period (before/after logging), treatment zone and microhabitat class into a database.

Home range analysis

Selection of movement data

I examined all traces obtained for monitored individuals of both species in all plots to determine their suitability for home range analysis. I used the number of locations, degree of independence between successive locations, spatial distribution of locations, extent of trace occurrence within plots, and proportional number of locations obtained before and after logging as criteria to decide suitability for home range analysis.

Sample size is a critical factor in avian home range analysis (Smith *et al.* 1994; Kenward & Hodder 1996; Seaman *et al.* 1999). Small numbers of locations usually underestimate the size and misrepresent the shape of home ranges of individuals (Smith *et al.* 1994; Kenward & Hodder 1996). Overly large location data sets are often time consuming to compile and exceed the quantity needed to depict home ranges accurately.

I determined the minimum number of locations that were needed to represent accurately the home ranges of each species of robin by calculating observation-area asymptotes (Odum & Kuenzler 1955). That is, for each species I selected 100 locations at random from 300 independent locations that were obtained from the traces of 6 adult birds (3 males and 3 females) on different days or on the same day but separated by at least 3 hours. I then calculated the size of the minimum convex polygon as each location was added and plotted area against number of locations (see Harris *et al.* 1990). In this way, I determined that a minimum of 50 locations per species was needed to estimate home range size for *E. australis* and *T. capito*. These were obtained from the same 4 individuals of each robin species before and after logging in each plot. Therefore, data were obtained from a total of 16 Eastern Yellow Robins and 16 Pale-yellow Robins across all plots.

Autocorrelation analysis

The size of an animal's home range can be underestimated if frequent successive locations of its movement are used in analytical procedures (Swihart & Slade 1985, 1997; Worton 1987; Hejl *et al.* 1990). The positive correlation between successive locations of an animal is termed *autocorrelation* (Swihart & Slade 1985). Some workers have cautioned against the elimination of autocorrelation in animal movement data sets because this reduces sample size and the biological significance of home range analyses (de Solla *et al.* 1999; Otis & White 1999). Goldingay & Kavanagh (1993) recommended that as many locations as possible should be used in home range analysis and that care should be exercised when reducing the number of locations to achieve statistically independent data points.

I did not reduce sample sizes below the minimum number of locations required to estimate the home range size of both species. I performed autocorrelation analysis on the trace data of each individual of each robin species in each plot before and after logging using the home range program, RANGES V (Kenward & Hodder 1996). This routine plots increasing

sampling intervals in minutes (x-axis) against Schoener's Index (y-axis) which indicates the degree of independence that exists between time and distance in successive locations of animals (Schoener 1981). As sampling intervals increase, distances between locations usually become less correlated with time and Schoener's Index rises.

I computed the time taken to reach peaks in Schoener's Index at the specified level of 1.96 (see Swihart & Slade 1985; Kenward & Hodder 1996). Kenward & Hodder (1996) recommend this approach for determining the optimal interval for sampling locations of monitored birds. This interval or mean time to independence (TTI) was 23.6 minutes for *E. australis* before logging and 24.4 minutes after logging. Mean TTI was 27.8 minutes for *T. capito* before logging and 23.7 minutes after logging.

I considered that these TTI totals gave overly conservative measures of independence of observations of both species since I regularly observed individuals moving throughout their home ranges in approximately half the time stipulated by the respective TTI estimates. Also, location data that were needed to prepare home range maps would have been omitted if these long intervals were adopted. Therefore, to minimise the effects of autocorrelation I used sampling intervals of 12 minutes for *E. australis* and 13 minutes for *T. capito*.

I examined the spatial distribution of all traces obtained for both species in each plot. I generally rejected traces that exhibited a pronounced degree of clumping around focal sites such as nests and waterholes. I selected traces that were distributed as widely as possible across each plot. Traces that only included corners of plots and appeared to extend outside of plots were usually excluded.

Methods of home range analysis

I used both non-parametric and parametric methods to estimate the home range size and overlap of both robin species before and after logging in each plot. The non-parametric method used was minimum area convex polygons (MCP) while the parametric method adopted was contouring based on harmonic means (HM) (Kenward & Hodder 1996). Both methods were run using RANGES V (Kenward & Hodder 1996).

The MCP method draws outlines or polygons around a set of fixes or locations of animals that are within a given distance of a range centre (Mohr 1947). The outermost polygon includes 100% of fixes while the 90% and 95% polygons have been commonly used to define home ranges of birds (see Davies & Lundberg 1984; Rolando 1996; Kavanagh 1997; Anders *et al.* 1998; Johnstone 1998; Jansen 1999). However, the area and shape of minimum convex polygons are highly sensitive to outlying fixes (outliers) and so can include areas that are rarely used by individuals. This produces estimates of home range size that are often larger than those obtained using the harmonic mean method (see Goldingay & Kavanagh 1993). At least 30 independent fixes are required by the MCP technique to achieve stable area estimates (Kenward & Hodder 1996). I used the MCP method because it allows comparison with other studies and produces maps that are easy to compare between treatments and periods.

The HM method is based on the estimation of the density of fix distribution. This is equivalent to the probability of encountering a bird in its home range. I used the harmonic mean model of Dixon & Chapman (1980), which identifies core areas within an individual's home range and can produce stable area estimates of an individual's range with only 15-20 fixes, although more fixes are preferable (Boulanger & White 1990; Kenward & Hodder 1996). A drawback is that this method assumes a continuous density distribution of fixes which can over-estimate home range size (Kenward & Hodder 1996; Seaman & Powell 1996).

In both MCP and HM techniques I fitted contours to fixes to include 95% of all fixes obtained for each bird. This best represented the home range size and usage pattern of both species in each plot. In the HM method, I stipulated a default 40x40 grid to ensure adequate contouring detail and used fixes that were uncentred between grid intersections in order to counter the effects of grid size (see Kenward & Hodder 1996). I chose a tracking resolution of 1 m since I followed birds from close (less than 7 m) distances over relatively small areas. I chose the HM method because it was comparable to approaches used in previous studies (e.g., Goldingay & Kavanagh 1993; Smith *et al.* 1994; Smith *et al.* 1998) and it identified the location of core centres of activity within home ranges.

Analysis of home range overlap

I analysed changes in the degree of overlap in the home ranges of individuals of both species in each plot before and after logging. This was undertaken to provide a measure of the impact of the logging trials on the robins' home ranges and on range fidelity. I used the same individuals of both species as selected in the range size analysis.

I constructed overlap matrices using the overlap analyses routine in RANGES V. This calculated the percentage overlap of range A on range B, and of B on A, for each pair of ranges. I used members of confirmed pairs of robins and members of neighbouring pairs of robins as the basis for data input. This meant that I also determined the percentage overlap of range C (a neighbour) on range A (one of the birds in a confirmed pair) and range A on range C, and so on. In this way, I obtained more overlap data than the total number of birds monitored in each plot. Matrices were created from HM edge files and were based on 95% uncentred hierarchic cluster isopleths. A minimum overlap value of 5% was used to reduce bias generated by very small overlap values and thus ensure accurate calculation of means (see Kenward & Hodder 1996).

Home range shape and location

I inspected each home range map to determine if there were appreciable changes in range shape and location after logging in each experimental plot. I based the assessment of shape of home ranges on the MCP-derived maps. Location of home ranges was assessed using both MCP- and HM-derived maps. Maps of both experimental and control plots were used.

Producing home range maps using RANGES V

I used location data from the trace mapping database to construct fix files and edge files for each species in each plot and period. Coordinates were entered in 3-digit format (eastings then northings) for each location, followed by 5 fix qualifying variables: period (prelog, postlog), date, time (24 hour format), treatment zone and microhabitat class (Section 5.2.3). Each bird was identified by the range variables of ID number, age, sex, month and year (4 digits) of trace commencement, e.g., AM1 5/1997 referred to adult male 1 that was first monitored in May 1997.

Habitat shape maps were prepared for each plot by entering coordinates for shapes (creeks, tracks and treatment zones) into map files using the acetate overlay system. Edge files and map files were then exported into DXF format (see Kenward & Hodder 1996). Home range boundaries and centres were assigned to individual ranges using a document viewer AutoManager® version 1.04 (Inso Corporation 1996). I achieved map output by using a CAD package MicroStation® 95 (MicroStation 1995) to create a DWG format file for importing to AUTOCAD® version Lt 97 (Autodesk Inc. 1997). This was needed because RANGES V did not permit direct importation of DXF files to AUTOCAD® version Lt 97. A total of 32 maps (1:1700 scale) were produced for both robin species in the research plots (Maps 1-32 Appendix 3).

Other individuals of both species of robin used parts of plots that appear as unoccupied space in the home range maps. However, insufficient location data prevented the mapping of space use by these individuals. Vehicular trails were omitted from plot maps because they obscured the clear delineation of home range boundaries derived by HM analysis.

5.2.3 Treatment zones, microhabitats and other variables

I identified and mapped to scale three treatment zones in each of the two experimental plots prior to the start of logging: gapped, thinned, and retained forest. Retained forest included riparian buffers, interstitial areas and clusters. Using the habitat analyses options in RANGES V, I calculated the percentage area of each bird's home range, as estimated by the 95% HM method, which occurred within each treatment zone.

I counted the number of locations that I recorded of each individual bird in 6-7 classes of microhabitat before and after logging in the experimental plots only. Using RANGES V, I determined the habitat content of home ranges in each relevant class of microhabitat for both robin species.

I compared aerial photographs and used detailed plot maps (Chapter 2) to assess visually the degree of connectivity with riparian, hillslope and ridgeline forest in each experimental plot. I described the use of woody debris piles left after logging and the use of edges of gaps by

E. australis. The willingness of birds to cross gaps and the observed distances involved were also reported.

5.2.4 Statistical analysis

Home range size and overlap

I used one-way Analysis of Variance (ANOVA) with planned or *a priori* comparisons of means (Sokal & Rohlf 1995; Zar 1999) to test the validity and significance of predictions of bird response to the logging trials. I specifically asked whether there were significant differences in mean home range size and mean percentage home range overlap between individuals of each species of robin after logging in the experimental plots relative to the control plots.

I examined home range size data for homogeneity of variances using Levene's Test (Ramsey & Schafer 1997) since homogeneity of variances could not be assumed. In an attempt to stabilise variances, I log-transformed size data where the results of Levene's Test were significant ($P<0.05$). Levene's Test was repeated on log-transformed home range sizes prior to performing ANOVA to confirm homogeneity of variances. Home range overlap data were in percentage form and so required arcsine transformation using Table B.24 in Zar (1999) before ANOVA was conducted.

Planned comparisons are extensions of the initial ANOVA procedure that test means or groups of means to determine which differ from one another (Sokal & Rohlf 1995). If I obtained a significant ($P<0.05$) ANOVA result or one that approached significance ($P=0$ 05-0.10), I ran three planned comparisons, using the home ranges of individual birds as the replicates, in the following sequence of plots: E1 and E2 v. C1 and C2, E1 v. C1, E2 v. C2. I derived F values for each planned comparison by dividing the group mean square into the error mean square of the initial ANOVA test for each species. Since experimental designs were orthogonal, I did not need to apply Bonferroni tests to adjust significance levels (Sokal & Rohlf 1995). I based anlayses of home range size and overlap on data derived using the 95% Harmonic Mean method.

Use of treatment zones

I constructed general linear models (GLM) to test the validity and significance of predictions of bird response to the logging trials. I defined three treatment zones (gapped, thinned, and retained forest) and asked two questions: first, whether logging influenced the use of each treatment zone by each species, and secondly, whether mean home range size affected each species' use of treatment zone.

The GLM model is a generalisation of the model used in ANOVA and is fitted using an ordinary least-squares regression (see Jongman *et al.* 1995). Relationships between response variables, factors and covariates are examined through the use of an interaction term. I assigned the proportion of fixes recorded in each treatment zone as the response variable, treatment (logged or unlogged) as the factor, and total area (ha) of each individual's home range (before and after logging) as the covariate. I used an unbalanced design and arcsine transformed all percentage data using Table B.24 in Zar (1999).

I fitted two GLM models to the data sets of each species in each treatment zone. Model 1 defined the interaction term by crossing treatment with the total area of home range. Model 2 separated treatment and the covariate to determine, using ANOVA, if either term significantly influenced each species' use of treatment zone. This was executed by taking out the interaction term of Model 1 (if Model 1 produced an insignificant result) and inspecting for a significant result for either term in the resultant ANOVA table. I confirmed the existence of an association between the response variable and the covariate by obtaining the Pearson product-moment correlation coefficient (Sokal & Rohlf 1995; Zar 1999).

Use of microhabitat

I used contingency table analysis to determine if the use of microhabitat by each species in each logged plot was independent of treatment. Since I considered both experimental plots as controls before they were logged, I did not analyse microhabitat use in the two control plots.

I performed two separate sets of analyses. In the first set I constructed 6x2 and 7x2 contingency tables in which the total number of locations recorded for each species in all classes of microhabitat (six rows for *E australis*, six-seven rows for *T. capito*) was analysed

against each treatment (two columns: before and after logging). I ran separate analyses for each logged plot and for both logged plots combined.

In the second set I compiled 2x2 contingency tables using combined data from E1 and E2 Plots. I performed tests on the total number of locations of birds recorded in each microhabitat class before and after logging versus the total number of locations of birds recorded in all other classes of microhabitat. I did not employ Fisher's Exact Test or pseudoprobability tests on these data because sample sizes were large ($n > 30$).

All statistical tests were performed using the software package Minitab® Releases 10Xtra and 11 (Minitab Inc. 1995, 1996).

5.3 Results

5.3.1 Home range size

I did not detect significant differences among plots in the mean home range sizes of Eastern Yellow Robins before logging. However, I found a significant difference in the mean home range sizes of *E. australis* among the four plots after logging (Table 5.1). Mean home range size increased in the experimental plots but remained relatively constant in the control plots after logging (Table 5.2). Eastern Yellow Robins held smaller home ranges in the control plots than in the logged plots after logging. I also detected a significant difference in *E. australis* mean home range sizes between both experimental plots and both control plots but not between E1 and C1 and E2 and C2 plots (Table 5.1). Other combinations of plots must have accounted for the initial significant result.

Prior to logging, I did not find significant differences among plots in the mean home range sizes of Pale-yellow Robins. After logging, there were significant differences among the four plots in the mean home range sizes of this species (Table 5.1). These featured decreased home range sizes in the experimental plots and maintenance of range sizes between periods in the control plots (Table 5.2). There were also significant differences in mean home range size between E2 and C2 Plots (Table 5.1). I detected a difference in mean home range size between E1 and C1 Plots that approached significance ($P=0.087$) (Table 5.1). This involved a 23.7% decrease in the size of *T. capito* home ranges after logging in

Plate 5.1 A lightly thinned zone in Year 2 experimental plot showing a new snig (log haulage) trail to the centre left of the photograph. A newly created gap occurs at the end of the trail. Note the presence of small piles of woody debris each side of the trail which provides foraging microhabitat for *E. australis* and other species.

E1 Plot, compared with a 0.4% decrease in this species' range size in C1 Plot during the same period (based on 95% HM method - Table 5.2).

5.3.2 Home range overlap

I did not detect a significant difference among the four plots in mean percentage overlap of Eastern Yellow Robin home ranges after logging (Table 5.3). Therefore I did not conduct planned comparisons of logged and unlogged plots. Mean percentage overlap after logging was highest in C2 Plot, lowest in E2 Plot, but similar in E1 and C1 Plots (Table 5.4).

I detected a difference among the four plots in mean percentage overlap of *T. capito* home ranges after logging that approached significance (P=0.065) (Table 5.3). This involved increased range overlap in E2 Plot and in the control plots (Table 5.4). There was a significant difference in mean percentage overlap of *T. capito* home ranges between E1 and C1 Plots (Table 5.3). I found a difference that approached significance (P=0.066) in mean percentage home range overlap for this species in both logged plots compared with both control plots (Table 5.3). This featured a 113.1% increase in mean percentage overlap in both experimental plots after logging, compared with a 40.5% increase in overlap in both control plots during the same period.

5.3.3 Home range shape and location

Eastern Yellow Robin

The home ranges of *E. australis* were mainly elliptical-rhomboidal in shape before and after logging (Appendix 3). Some individuals held broad rhomboidal ranges with long north-south axes that contracted to smaller, elliptical shapes with shorter north-south axes after logging. Home range shape was more variable in the logged plots than in the control plots.

The location of individual home ranges within each plot did not markedly change after logging (Maps 1-16, Appendix 3). Shifts in the centres of home ranges after logging were mostly between 24-77 m and possibly reflected the onset of breeding in the post-logging period. I detected only minor variation in the extent of range centre shifts in logged plots compared with control plots.

All monitored birds in both logged plots incorporated newly created gaps and thinned areas into their home ranges. Some individuals expanded their home ranges after logging to include these zones but maintained range centres in adjacent retained forest (e.g., AF2 in E1 Plot and AM2 in E2 Plot), or at the edge of new gaps (e.g., AF1 in E2 Plot). Others centred their ranges in new gaps and thinned zones, establishing new core centres of foraging activity in debris piles left after logging (e.g., AM2 in E1 Plot and AM1 in E2 Plot). Two individuals, AF1 in E1 Plot and AF1 in E2 Plot, built nests in *Allocasuarina torulosa* and *Eucalyptus resinifera* saplings situated along the edges of new gaps.

Pale-yellow Robin

Logging appeared to influence both the shape and location of *T. capito* home ranges (Maps 17-32, Appendix 3). In both experimental plots individual home ranges became narrower after logging. Pale-yellow Robins avoided newly created gaps and, to a lesser extent, thinned areas after logging in both of these plots. Some individuals shifted their range centres 60-170 m to densely vegetated creeklines (e.g., Maps 27-28, Appendix 3). The moist lower slopes of ridges were also used. Home range shape and location were less variable in the control plots than in the logged plots.

Most birds included portions of newly thinned forest (Plate 5.1) in their home ranges after logging in the experimental plots. Individuals occasionally foraged in these areas but retained their range centres in adjoining riparian habitat. Thinned forest may represent sub-optimal habitat for Pale-yellow Robins (Crome 1978; Frith 1984; Chapman & Harrington 1997).

5.3.4 Use of treatment zones in logged plots

I found that logging did not significantly influence the use of gaps, thinned areas or retained forest by Eastern Yellow Robins in the logged plots (Table 5.5). There was, however, a significant ($P=0.049$) correlation between the use of gaps and the size of individual *E. australis* home ranges after logging (Table 5.5). This involved a decrease in gap use with increasing home range size, ie. 32.4% use of gaps by birds with mean range size of 1.127 ha in E1 Plot compared with 29.6% use of gaps by birds holding 1.53 ha home ranges in E2

Plate 5.2 Part of a newly created pile of coarse woody debris in Gap 3 of Year 2 experimental plot. The extent of soil disturbance is visible in the foreground and a cluster occurs at the rear of the gap and continues around to the right of the gap.

Plot (Table 5.6). I also found a significant (P=0.040) correlation between home range size and the use of retained forest by individuals after logging, in which birds with smaller ranges used retained forest less than birds holding larger ranges (Tables 5.5 and 5.6). I did not detect a significant association between the home range size and use of thinned forest.

I found that logging significantly influenced the use of gaps by Pale-yellow Robins in both experimental plots (Table 5.5). Individuals completely avoided all gaps and their immediate edges after logging (Table 5.6; Maps 20 and 28, Appendix 3). They appeared to compensate for the loss of parts of their home ranges by extending into adjacent retained forest zones, especially riparian buffers and clusters. This was evidenced by significant increases in their use of retained forest after logging (33.7% in E1 Plot and 20.6% in E2 Plot - Table 5.6). Logging did not significantly affect the use of thinned forest by *T. capito* in either experimental plot (Table 5.5). I did not find significant associations between home range size and the use of gapped, thinned or retained forest by *T. capito* (Table 5.5).

5.3.5 Use of microhabitat in logged plots

I detected a significant difference in the use of microhabitat (all classes compared) by Eastern Yellow Robins before and after logging in both logged plots (see *Total no. of locations of birds in all classes* column - Table 5.7). After logging, birds significantly increased their use of bare ground and woody debris piles and significantly reduced their use of the ground and lower canopy (Table 5.7).

The use of microhabitat (all classes compared) by Pale-yellow Robins differed significantly before and after logging in E1 Plot but not in E2 Plot (see *Total no. of locations of birds in all classes* column - Table 5.7). This may have reflected the retention of more forest in E2 Plot compared with E1 Plot. I detected a significant reduction in the use of the lower canopy by birds after logging in E1 Plot and a significant increase in use of the mid canopy after logging in E1 Plot (Table 5.7).

5.3.6 Other variables

Use of woody debris piles

Clearfelling of forest to establish gaps produced piles of coarse woody debris comprising the crowns or heads of harvested trees, stems of unmerchantable trees, bark strips and old stumps (Plate 5.2). Eastern Yellow Robins frequently entered newly established gaps to forage in these piles. Branches and stems of small trees that protruded out of piles were favoured perches from which birds detected and pounced on prey. The most intensive use of piles occurred during 2-3 weeks after logging when the potential for detecting invertebrate prey was probably high (pers. obs.). After this period, Eastern Yellow Robins made less frequent visits to debris piles.

The edges of gaps often contained smaller piles of woody debris. Eastern Yellow Robins routinely foraged along these edges and adjacent exposed ground. At least 60% of traces that I recorded of *E. australis* in both plots after logging involved birds moving around the edges of new gaps and into gap debris piles.

In contrast, I did not observe Pale-yellow Robins entering gaps, foraging in debris piles, or moving along gap edges in either experimental plot. Individuals generally maintained distances of 7-44 m from the edges of gaps. Centres of home ranges were located at least 22 m from gap edges (Appendix 3).

Gap-crossing

I frequently observed Eastern Yellow Robins crossing gaps over straight-line distances of 15-58 m in both experimental plots. Most birds crossed at the corners of gaps where straight-line distances to retained forest edges averaged 38.4 m in E1 Plot and 33.7 m in E2 Plot. Gap crossing was mainly undertaken as part of foraging journeys into and out of woody debris piles and involved a sequence of individual movements rather than single flights. I did not observe Pale-yellow Robins crossing gaps during my study. Individuals used retained forest to access different parts of their home ranges and avoided venturing near gap edges.

I observed other bird species crossing from the edges of forest to debris piles in gaps. These movements usually involved short straight-line distances of 6-32 m. They included White-browed Scrubwren (see Chapter 6), Grey Fantail, White-throated Treecreeper, Variegated Fairy-wren, Yellow-faced Honeyeater, Red-browed Finch, Grey Shrike-thrush, Pied Currawong, and Laughing Kookaburra.

Degree of connectivity

Logging did not markedly reduce the degree of connectivity with riparian, hillslope and ridgeline forest in both experimental plots or within the local forest landscape. In each experimental plot, gapping removed a total of 1.92 ha or 21.33% of forest while thinning affected a total of 2.06 ha (22.88%) of forest in E1 Plot and 0.83 ha (9.22%) of forest in E2 Plot. These zones of disturbance were interspersed with retained forest which comprised 5.02 ha in E1 Plot and 6.25 ha in E2 Plot. Slightly higher levels of disturbance occurred in E1 Plot than in E2 Plot (Chapter 2).

5.4 Discussion

5.4.1 Home range and habitat use responses to logging

Eastern Yellow Robins and Pale-yellow Robins responded to logging within their home ranges in sharply contrasting ways. Eastern Yellow Robins seemed quite resilient to logging, including newly created gaps and thinned areas in their home ranges. Some birds expanded their ranges to take in these piles. Birds maintained the location, overlap and basic shape of their ranges after logging. The foraging behaviour of *E. australis* also changed after logging, with increased foraging on the ground and bare ground and in woody debris piles left in and around gaps after logging. Eastern Yellow Robins also foraged less in the lower canopy after logging.

Pale-yellow Robins showed marked sensitivity to the logging trials. They avoided new gaps and shifted their home ranges to adjacent retained forest, mostly in densely vegetated riparian zones. Some individuals used forest that had been lightly thinned during the trials and that bordered riparian zones. Home ranges were significantly smaller after logging in E2 Plot. Avoidance of gapped areas meant that *T. capito* home ranges were often narrower and

overlapped considerably with those of neighbouring birds of this species. The ground-foraging behaviour of Pale-yellow Robins did not significantly change after logging. Birds did, however, use significantly less of the lower canopy in E1 Plot and significantly more of the mid-canopy in this plot after logging. These responses suggest that Pale-yellow Robins appear to be less resilient to small-scale gapping than Eastern Yellow Robins. They may, however, be capable of persisting in a gapped forest providing that only small gaps are created and adequate links are maintained with the unlogged matrix, especially riparian and moist lower slope forest.

5.4.2 Conformity of responses with models

The pattern of home range and habitat use response of Eastern Yellow Robins to the logging trials concurred with the *incorporation* model (Section 5.1). Birds included gaps in their home ranges, maintained or increased home range size, maintained home range overlap, basic shape and location, and foraged in microhabitat created or enhanced by the creation of gaps and thinned areas.

In contrast, the response of Pale-yellow Robins conformed with the *modification* model. Birds excluded gaps from their home ranges, experienced decreased home range size, increased home range overlap and altered home range shape, and re-located to adjacent retained forest. They used the lower canopy less and the mid-canopy more after logging in E1 Plot. These changes point to the importance of maintaining adequate connectivity within logged forest landscapes.

5.4.3 Other Australian home range studies

There has been a dearth of home range studies of small, ground-foraging insectivores in Australia. The few published studies deal mostly with species in non-forestry environments (Table 5.8). These include the works of Marchant (1985, 1987, 1992), Robinson (1990, 1992), Fitri & Ford (1997), and Zanette (1999).

Marchant's (1985, 1987, 1992) studied Eastern Yellow Robins over 7 years in dry eucalypt forest near Moruya on the NSW south coast. He estimated territories (home ranges) of 0.8-2.0 ha which are slightly larger than the home ranges that I recorded for this species. This

may have reflected the drier and perhaps lower habitat quality of the Moruya site where birds may have had to forage more widely than they did in my moist forest plots. Robinson (1990, 1992) obtained mean territory (home range) sizes of 1.8 ha for Flame Robins *Petroica phoenicea* and 3.2 ha (breeding)-6.6 ha (non-breeding) for Scarlet Robins *P. multicolor* in a 300 ha patch of dry eucalypt forest and grassland on the NSW southern tablelands. Fitri & Ford (1997) estimated a mean home range size of 18 ha (mean breeding territory of 6 ha) for Hooded Robins *Melanodryas cucullata* in fragmented open woodland near Armidale on the northern NSW tablelands. Also in this area, Zanette (1999) estimated Eastern Yellow Robin home ranges at 2.75±0.18 ha in 55 ha and >400 ha fragments surrounded by agriculture. These home range sizes are much larger than those that I estimated for *E. australis* and *T. capito*. This might reflect differences in the site-specific ecological requirements of these species and in the extent of fragmentation or variegation of their habitats and surrounding landscapes.

Only three home range studies have been undertaken in commercially logged forests. Smith (1989) mapped breeding territories of Eastern Yellow Robins and several other understorey species before and after fire in previously logged tall eucalypt forest near Bega, on the NSW south coast. Although he did not provide details of *E. australis* territory size, he found that the number (7) and distribution of territories remained the same after fire.

In logged subtropical vine forest in south-east Queensland, Smith *et al.* (1998) obtained a mean home range size of 4.0±1.8 ha (95% Harmonic Mean method) for Black-breasted Button-quail *Turnix melanogaster*. They found that home ranges of individuals overlapped considerably and were centred on preferred foraging and roosting sites. No use of adjacent young Hoop Pine plantation or agricultural land by individuals was detected.

Working in Western Australian jarrah forest, Craig (1999) found that Western Yellow Robins *Eopsaltria griseogularis* maintained similar sized territories (home ranges) before (1.53±0.57 ha) and after (1.24±0.38 ha) logging. The slight decrease in these sizes after logging contrasts with increases in mean home range size that I recorded for *E. australis* after logging in my experimental plots. This may have reflected the larger scale of gapping operation undertaken in Craig's study (mean gap size: 9.24±1.41 ha) compared with my trials (mean gap size: 0.64±0.10 ha). Both studies were conducted in previously logged, continuous forest. Mean home range overlap of *E. griseogularis* was similar after logging

(44%) to that determined for *E. australis* (38%) and *T. capito* (51%) in my study. Craig (1999) found that the location of individual home ranges did not differ significantly after logging or between treatment (logged, control, shelterwood or thinning), as I found for *E. australis* but not for *T. capito*.

Craig (1999) also found that birds foraged on a wider range of substrates, using fallen trees and debris more than standing live vegetation after logging. He suggested that this reflected the adaptability of Western Yellow Robins to logging and concluded that this species may not be significantly affected by gapping operations in forested landscapes. This concurs with my findings for Eastern Yellow Robins which heavily used woody debris piles at the expense of ground and lower canopy substrates after logging. However, since no post-logging burning was conducted in either Craig's (1999) study or mine, the full impact of gapping on either *E. griseogularis* or *E. australis* may not have been detected. That is, unburnt debris piles may have provided more favourable foraging conditions for these species than those created by the standard logging practice of burning all debris to promote rapid eucalypt regeneration.

5.4.4 Conclusions

The creation of small gaps in two tracts of continuous eucalypt forest on the NSW north coast over two years did not significantly affect the home range structure of Eastern Yellow Robins, although there were changes in their foraging behaviour. Individuals appeared to adapt well to gapping and thinning, expanding their ranges to include novel microhabitat such as woody debris piles left unburnt after logging. This supports previous findings of apparent resilience to larger-scale gapping in Western Yellow Robins in West Australian jarrah forest (Craig 1999).

In contrast, Pale-yellow Robins displayed marked sensitivity to logging, as evidenced by their avoidance of gaps, decreased home range size, increased range overlap and relocation of home ranges to adjacent retained forest. Thinned forest formed only the periphery of home ranges in this species. This evidence suggests that, at least in the short-term, *T. capito* may be negatively affected by this form of logging. Specific measures are needed to ensure the longer-term persistence of Pale-yellow Robin populations within gapped forest landscapes (Chapter 8).

Table 5.1 Summary of results of one-way ANOVA with orthogonal planned comparisons (PC) of mean home range size (95% Harmonic Mean) of individual Eastern Yellow Robins *E. australis* and Pale-yellow Robins *T. capito* after logging. Significant ($P<0.05$) results and the result that approached significance ($P=0.05$-0.10) are shown in bold.

Species	Levene's Test *P*	ANOVA (E1+C1+E2+C2)				PC 1 (E1+E2 v C1+C2)				PC 2 (E1 v C1)				PC 3 (E2 v C2)			
		N	*F*	*P*	df	N	*F*	*P*	df	N	*F*	*P*	df	N	*F*	*P*	df
E. australis	**0.000**	16	4.06	**0.033**	3,12	16	5.61	**0.038**	1,12	8	3.021	0.121	1,12	8	2.598	0.152	1,12
T. capito	0.612	15	5.36	**0.016**	3,11	15	0.017	0.910	1,11	8	3.631	**0.087**	1,11	7	6.426	**0.031**	1,11

Plots: E1 (Year 1 Experimental) C1 (Year 1 Control) E2 (Year 2 Experimental) C2 (Year 2 Control)
N = number of home ranges of individual birds (data derived using 95% Harmonic Mean method)
F = *F*-distribution (1-tailed)
PC calculate *F* using group MS/error MS. Each PC uses, as its denominator df, the error MS df derived in the initial ANOVA
P = 0.05
df = degrees of freedom

Table 5.2 Mean home range sizes (ha) of Eastern Yellow Robins *E. australis* and Pale-yellow Robins *T. capito* before and after logging in each plot. Results for both methods of home range calculation (HM and MCP) are given. The study means represent the means of both logged plots and both control plots. Standard error of the means is shown in brackets below each mean value.

Species	Method	Period	Mean home range size (ha) in each plot				Study Means	
			E1	*C1*	*E2*	*C2*	*E plots*	*C plots*
E. australis	95% HM	Before	0.901 (0.059)	0.835 (0.064)	1.119 (0.107)	1.106 (0.047)	1.010 (0.109)	0.970 (0.136)
		After	1.130 (0.153)	0.827 (0.021)	1.508 (0.232)	1.129 (0.080)	1.319 (0.189)	0.978 (0.151)
	95% MCP	Before	0.975 (0.115)	0.905 (0.084)	1.595 (0.251)	1.292 (0.036)	1.285 (0.310)	1.098 (0.193)
		After	1.265 (0.142)	0.990 (0.063)	1.967 (0.181)	1.267 (0.134)	1.616 (0.351)	1.128 (0.138)
T. capito	95% HM	Before	0.822 (0.048)	0.775 (0.032)	1.167 (0.023)	0.804 (0.100)	0.994 (0.172)	0.789 (0.014)
		After	0.627 (0.030)	0.771 (0.029)	0.955 (0.103)	0.747 (0.059)	0.791 (0.164)	0.759 (0.012)
	95% MCP	Before	0.952 (0.090)	0.910 (0.048)	1.517 (0.201)	0.972 (0.102)	1.234 (0.282)	0.941 (0.031)
		After	0.755 (0.039)	0.790 (0.033)	1.113 (0.128)	0.890 (0.107)	0.934 (0.179)	0.840 (0.050)

Table 5.3 Summary of results of one-way ANOVA with orthogonal planned comparisons (PC) of mean percentage home range overlap between individual Eastern Yellow Robins *E. australis* and Pale-yellow Robins *T. capito* after logging. Significant ($P<0.05$) results and those results that approached significance ($P=0.05$-0.10) are shown in bold.

Species	Levene's Test *P*	ANOVA (E1+C1+E2+C2)				PC 1 (E1+E2 v C1+C2)				PC 2 (E1 v C1)				PC 3 (E2 v C2)			
		N	*F*	*P*	df	N	*F*	*P*	df	N	*F*	*P*	df	N	*F*	*P*	df
E. australis	0.252	18	1.67	0.220	3,14	18	2.49	0.134	1,14	10	0.50	0.499	1,14	8	2.34	0.177	1,14
T. capito	**0.001**	12	3.61	**0.065**	3,8	12	4.76	**0.066**	1,8	8	7.415	**0.029**	1,8	na	na	na	na

Plots: E1 (Year 1 Experimental) C1 (Year 1 Control) E2 (Year 2 Experimental) C2 (Year 2 Control)
N = number of home ranges of individual birds (data derived using 95% Harmonic Mean method)
F = *F*-distribution (1-tailed): PC calculates *F* using group MS/error MS. Each PC uses, as its denominator df, the error MS df derived in the initial ANOVA
P = 0.05
df = degrees of freedom
na = not applicable due to very low sample sizes obtained

Table 5.4 Mean percentage home range overlap (95% Harmonic Mean) of Eastern Yellow Robins *E. australis* and Pale-yellow Robins *T. capito* before and after logging in each plot. Percentage data have been arcsine transformed. Ranges with overlap values of <5% were discarded. The study means represent the means of both logged plots and both control plots. Standard error of the means is shown in brackets below each mean value.

Species	Period	Mean % home range overlap in each plot				Study Means	
		E1	*C1*	*E2*	*C2*	*E plots*	*C plots*
E. australis	Before	14.28 (3.50)	49.10 (11.50)	54.60 (10.90)	68.35 (6.65)	34.44 (7.45)	58.72 (8.38)
	After	42.23 (4.24)	46.60 (4.15)	34.80 (12.80)	73.45 (0.75)	38.51 (6.55)	60.02 (6.67)
T. capito	Before	26.02 (1.47)	57.00 (12.00)	28.00 (12.40)	49.40 (21.20)	27.01 (5.79)	53.20 (10.21)
	After	38.40 (13.30)	73.72 (3.81)	76.75 (9.75)	75.75 (8.75)	57.57 (12.41)	74.73 (3.35)

Table 5.5 Results of general linear models of use of treatment zone by Eastern Yellow Robins *E. australis* and Pale-yellow Robins *T. capito* after logging in each experimental plot. Interaction terms in each model consist of a factor (treatment: logged or unlogged) and a covariate (size [ha] of the home range of an individual bird). In Model 2, the first row of *F* and *P* values given for each treatment zone shows the influence of treatment on use of treatment zone. The second row of *F* and *P* values represent the covariate value which, if significant, indicates that home range size influenced the use of the relevant treatment zone by *E. australis* or *T. capito*. Significant ($P<0.05$) results are shown in bold.

Species	Model 1 (Treatment x home range size)					Model 2 (Treatment, home range size)				
	Tzone	N	df	*F*	*P*	N	df	*F*	*P*	cc
E. australis	G	16	1,12	0.15	0.709	16	1,13	1.96	0.185	
								4.72	**0.049**	-0.405
	T	16	1,12	0.01	0.942	16	1,13	0.00	0.975	
								0.11	0.748	
	R	16	1,12	0.00	0.992	16	1,13	1.43	0.253	
								5.22	**0.040**	0.457
T. capito	G	15	1,11	0.43	0.525	15	1,12	11.18	**0.006**	0.704
								0.46	0.511	
	T	15	1,11	0.17	0.684	15	1,12	0.56	0.468	
								1.08	0.318	
	R	15	1,11	0.54	0.477	15	1,12	10.03	**0.008**	-0.618
								1.71	0.216	

Tzone = Treatment Zone: G gapped T thinned R retained forest
N = number of home ranges of individual birds (data derived using 95% Harmonic Mean method)
F = *F*-distribution (1-tailed)
df = degrees of freedom
cc = The Pearson product-moment correlation coefficient is given for significant results and is a measure of intensity of association between two variables (Sokal & Rohlf 1995; Zar 1999). Negative correlation coefficients indicate that an increase in value of one of the variables (in this case, treatment or home range size) is accompanied by a decrease in value of the other variable (Zar 1999). Positive correlation coefficients mean that for an increase in the value of one of the variables, the other variable also increases in value (Zar 1999).

Table 5.6 Mean percentage use of treatment zone by Eastern Yellow Robins *E. australis* and Pale-yellow Robins *T. capito*, showing home range sizes before and after logging in each experimental plot. Data derived by 95% Harmonic Mean method. Percentage data were arcsine transformed and thus mean percentage use totals for each plot and period do not sum to 100%. Standard error of the means is shown in brackets below each mean value.

Species	Plot	Period	Mean home range size (ha)	Mean percentage use of treatment zone		
				Gapped	*Thinned*	*Retained*
E. australis	E1	Before	0.900 (0.059)	32.8 (3.51)	33.5 (9.58)	43.5 (6.57)
		After	1.127 (0.152)	32.4 (6.83)	30.4 (5.57)	41.2 (4.35)
	E2	Before	1.125 (6.88)	25.7 (1.53)	20.6 (5.95)	55.1 (3.26)
		After	1.530 (0.201)	29.6 (5.50)	13.2 (4.10)	56.1 (4.86)
T. capito	E1	Before	0.820 (0.047)	40.2 (10.50)	20.3 (9.14)	48.3 (11.9)
		After	0.627 (0.031)	0 (0)	17.5 (4.20)	72.7 (4.20)
	E2	Before	1.16 (0.023)	25.8 (8.02)	19.2 (6.43)	60.7 (3.18)
		After	0.95 (0.106)	0 (0)	13.7 (1.01)	76.5 (0.697)

Table 5.7 Use of microhabitat by Eastern Yellow Robins *E. australis* and Pale-yellow Robins *T. capito* before and after logging in each experimental plot. Chi-square (χ^2) test results in the second column from the left are based on the total number of locations of birds recorded in *all* classes of microhabitat before and after logging in each plot. Separate χ^2 tests were conducted on the total number of locations of birds in *each* microhabitat class before and after logging versus the total number of locations of birds recorded in all other microhabitat classes. These results were obtained by combining data from E1 and E2 Plots and, where significant ($P<0.05$), are presented at the base of each microhabitat class column for each species. Significant results are shown in bold. Number of individual birds of each species used in χ^2 analysis in each plot=4. ns=not significant. na=not applicable. df=degrees of freedom.

Species/Plot/ Period	Total no. of locations of birds in all classes	Total no. of locations of individuals recorded in each microhabitat class and statistical significance						
		Ground	*Bare ground*	*Woody debris pile*	*Fallen logs*	*Dense shrub regrowth*	*Lower canopy*	*Mid canopy*
E. australis								
E1								
Before	255	42	7	13	20	2	171	na
After	240 **P=0.000** χ^2=106.8 df=5	15	15	101	13	1	95	na
E2								
Before	197	50	2	1	28	1	115	na
After	245 **P=0.000** χ^2=75.01 df=5	34 **P=0.000** χ^2=19.23 df=1	21 **P=0.000** χ^2=15.1 df=1	50 **P=0.000** χ^2=126.8 df=1	26 ns	15 ns	99 **P=0.000** χ^2=50.72 df=1	na
T. capito								
E1								
Before	233	22	6	4	24	3	147	27
After	211 **P=0.008** χ^2=17.38 df=6	25	5	11	25	1	99	45
E2								
Before	220	46	0	1	37	40	80	16
After	196 ns	36 ns	0 ns	3 ns	34 ns	35 ns	75 **P=0.031** χ^2=4.66 df=1	13 **P=0.030** χ^2=4.68 df=1

Table 5.8 Comparison of estimates of home range size of the Eastern Yellow Robin *Eopsaltria australis* and Pale-yellow Robin *Tregellasia capito* obtained in my study with previous studies of Petroicidae and some other Australian forest and woodland insectivores

Species	Investigator/s	Landscape/ vegetation type	Size of home range/territory (ha)	Methods used	Number of home ranges/territories or birds sampled
Eastern Yellow Robin	Huggett (this study)	Commercially logged continuous moist eucalypt forest near Coffs Harbour, NSW north coast	Before logging (all plots): 0.99 (mean, HM), 1.19 (mean, MCP) After logging (all plots): 1.15 (mean, HM), 1.37 (mean, MCP)	RANGES V software (95% MCP, 95% HM)	Total 16 birds & home ranges (8 in two logged plots & 8 in two control plots) - in gapped, thinned & retained forest
Pale-yellow Robin	Huggett (this study)	As above	Before logging (all plots): 0.89 (mean, HM), 1.09 (mean, MCP) After logging (all plots): 0.77 (mean, HM), 0.89 (mean, MCP)	RANGES V software (95% MCP, 95% HM)	Total 16 birds & home ranges (8 in two logged plots & 8 in two control plots) - in gapped, thinned & retained forest
Eastern Yellow Robin	Marchant (1985, 1987, 1992)	Continuous dry eucalypt forest, near Moruya, NSW south coast	0.8-2.0	Manual territory mapping (sightings/border disputes-based)	35 territories
Eastern Yellow Robin	Zanette (1999)	Eucalypt woodland remnants, Armidale district, NSW northern tablelands	2.75±0.18	Manual mapping	74 territories (home ranges) across two 55 ha and two >400 ha remnants
Western Yellow Robin	Craig (1999)	Commercially logged generally continuous jarrah forest, southern Western Australia	1.53±0.57 (before logging) 1.24±0.38 (after logging)	Manual territory mapping (marked trees used/drew polygons)	8 (gap) 12 (control) 11 (shelterwood) (total 31 territories)
Flame Robin	Robinson (1990, 1992)	Eucalypt forest & grassland, NSW southern tablelands	1.8 (mean)	Manual territory mapping (sightings-based)	30 pairs (60 birds)
Scarlet Robin	Robinson (1990, 1992)	As above	3.2 (mean, breeding) 6.6 (mean, non-breeding)	As above	22 pairs (44 birds)

Hooded Robin	Fitri & Ford (1997)	Open eucalypt woodland remnants, Armidale district, NSW northern tablelands	6 (mean, breeding territory), 18 (mean home range,breeding)	Manual home range/territory mapping (adjusted polygon technique)	56 birds (30 males, 26 females)
Rufous Whistler *Pachycephala rufiventris*	Bridges (1992, 1994)	Open eucalypt woodland remnants, Armidale district, NSW northern tablelands	1.7±0.9 (mean territory)	Manual territory mapping (adjusted polygons)	96 territories
Black-breasted Button-quail *Turnix melanogaster*	Smith *et al.* (1998)	Remnant subtropical vine forest between hoop pine/pasture, south-east Queensland	3.4 (mean home range, MCP) -4 (mean home range HM)	RANGES V software (95% MCP, 95% HM, 95% fixed Kernel)	4 radio-tracked birds (total of 370 fixes)
Chowchilla *Orthonyx spaldingii*	Jansen (1999)	Continuous tropical rainforest, Atherton Tableland, north Queensland	1.66 (mean, MCP) - 2.33 (mean, Kernel)	RANGES IV (MCP, 95% Kernel)	16 radio-tracked birds from 5 groups (total of 140 fixes)

CHAPTER 6

HOME RANGE AND HABITAT USE IN YELLOW-THROATED SCRUBWRENS AND WHITE-BROWED SCRUBWRENS IN AN EXPERIMENTALLY LOGGED MOIST EUCALYPT FOREST

6.1 Introduction

There is mounting global evidence that terrestrial and understorey insectivores are especially prone to the loss and fragmentation of forest habitat associated with logging, agriculture and urban development (e.g., Loyn 1980, 1993; Yahner 1993; Ciešlak 1994; Kattan *et al.* 1994; Robinson & Wilcove 1994; Stouffer & Bierregaard 1995; Recher 1999; Renjifo 1999). Habitat specialists appear to be more susceptible to land clearing activities than habitat generalists, particularly with respect to their reproductive success, capacity to use a range of microhabitats, response to edge and dispersal capability (see Böhning-Gaese *et al.* 1993; Wenny *et al.* 1993; Mac Nally & Bennett 1997; Baker *et al.* 1998; Burke & Nol 1998).

In continuous forests small ground- and shrub-foraging insectivores are likely to be at less risk of population decline and local extinction than their counterparts in fragmented forests (see Barrett *et al.* 1994; Arnold & Weeldenburg 1998; Gardner 1998). The question in continuous forests used for the commercial production of wood may be what elements of a species' ecology might be influenced and in what way by small-scale, site-intensive logging systems. For instance, does gaps and clusters logging significantly alter how birds space themselves through the forest matrix and how they utilise habitat within that matrix? This has important implications for the planning of commercial logging operations and conservation of forest biological diversity (see Norton 1996; Coates & Burton 1997; Lindenmayer *et al.* 1998).

In this chapter I compare the home range and habitat use responses to experimental logging of a habitat specialist, the Yellow-throated Scrubwren *Sericornis citreogularis* with those of a habitat generalist, the White-browed Scrubwren *S. frontalis*. I put forward four models to predict the nature of these responses in the research plots. These are:

1. *Incorporation*: birds include newly created gaps in their home ranges; home range size is generally maintained or increased; overlap between the home ranges of neighbouring birds of the same species is maintained; home range shape and location is generally maintained; use of treatment zone (ie. gapped, thinned, and retained forest) is influenced by home range size but not by logging; microhabitat use is influenced by logging.

2. *Modification*: birds exclude newly created gaps from their home ranges; home range size is generally maintained or decreased; overlap between the home ranges of neighbouring birds of the same species increases; home range shape changes and home ranges are relocated to retained forest; use of treatment zone (ie. gapped, thinned, and retained forest) and microhabitat are influenced by logging.
3. *Partial adjustment*: birds include only parts of newly created gaps in their home ranges; home range size and overlap between the home ranges of neighbouring birds of the same species are generally maintained; home range shape changes and home ranges extend into retained forest; use of treatment zone (ie. gapped, thinned, and retained forest) and microhabitat are influenced by logging.
4. *Emigration*: birds depart from gapped plots after logging and do not return during the monitoring periods.

6.2 Methods

I investigated the size, overlap, shape and location of home ranges, use of treatment zone and microhabitat, and willingness to cross gaps in both species of scrubwren before and after logging in each plot. I generally followed the approach described in Chapter 5 but adopted some measures that were specific to each scrubwren species, particularly in the collection and analysis of data. These are described in the following sections.

6.2.1 Estimating home range

Recording bird movement

Most journeys of both species of scrubwren involved a pair of birds moving along the forest floor or in low (<2 m) vegetation and usually close to each other. White-browed Scrubwrens occasionally moved in groups of three, often comprising two males and a female. They tended to forage in low vegetation more frequently than Yellow-throated Scrubwrens, although most (>70%) records were of birds foraging in leaf litter on the ground, debris piles and along fallen logs. I recorded birds moving together or close to each other as one trace because of the lack of independence between each individual bird's movement (see Chapter 5).

I mapped the journeys of 89 colour-banded and known, unbanded individuals of both species across all plots over the 14 month monitoring period (see Chapter 5). I obtained a total of 348 traces (154 before logging and 194 after logging) from 42 individuals of *S. citreogularis* across all plots throughout the study. This represented a total of 2357 locations or fixes (1126 before logging and 1231 after logging) of this species across all plots. For *S. frontalis*, I obtained 397 traces (177 before logging and 220 after logging) from 47 individuals across all plots, comprising a total of 2800 locations (1326 before logging and 1474 after logging).

Home range analysis

Selection of movement data

I selected 18 individuals of *S. citreogularis* and 21 individuals of *S. frontalis* for detailed home range analysis. The number of individuals used for range analysis in each plot was 4-6. Trace data obtained for *S. frontalis* in the E2 Plot included one group of three adult individuals (AMMF1: two adult males and one adult female). The movements of this group were frequently mapped as one unit.

I selected only traces that comprised a minimum of 50 locations from the pool of traces obtained for each species. These were used to estimate home range size in each scrubwren species. Most traces comprised between 50-100 locations each (a mean of 68.6 ± 6.7 locations for *S. citreogularis* and a mean of 77.4 ± 5.9 locations for *S. frontalis*). These locations were not significantly autocorrelated (see below) and were obtained from the same set of individuals of each species before and after logging in each plot.

Autocorrelation analysis

I computed the mean time to independence (TTI) between consecutive locations of individuals of both scrubwren species using autocorrelation analysis in RANGES V (see Chapter 5). The mean TTI for *S. citreogularis* was 25.1 minutes before logging and 24.4 minutes after logging. For *S. frontalis*, TTI before logging was 26.9 minutes before logging and 27.5 minutes after logging.

I found that these TTI totals placed overly conservative constraints on the use of location data to accurately estimate the home range sizes of these species. Based on field observations of distances travelled and time taken by individuals to move through their home ranges, I chose sampling intervals of 12.5 minutes for *S. citreogularis* and 13.5 minutes for *S. frontalis*.

Producing home range maps using RANGES V

I produced a total of 32 home range maps (Maps 33-64, Appendix 3), using both methods of home range analysis. Although other individuals of both scrubwren species used other areas of each plot, I recorded insufficient locations of these birds to map their home ranges.

6.2.2 Treatment zones, microhabitats and other variables

I used the same treatment zones (ie. gapped, thinned, and retained forest) and classes of microhabitat that I presented in Chapter 5. An exception was that I did not use the mid canopy class of microhabitat, replacing it with bark piles/fallen dead debris (ie. branches and branchlets with and without foliage that had fallen on the ground) in the analysis of habitat use in White-browed Scrubwrens. I also investigated the use of woody debris piles by both scrubwren species and their willingness to cross gaps.

6.2.3 Statistical analysis

Home range size and overlap

I used one-way ANOVA to assess whether there were significant differences in mean home range size and mean percentage home range overlap in each species of scrubwren after logging in the experimental plots relative to the control plots (see Chapter 5). Planned comparisons of means were only used where the initial ANOVA result was significant ($P<0.05$) or approached significance ($P=0.05$-0.10).

Use of treatment zones and microhabitat

I used general linear models to test whether there were associations between logging and the use of treatment zones by individuals of each species and between home range size and treatment zone use (see Chapter 5). I used contingency table analysis to determine if the use of microhabitat by each species in each logged plot was independent of treatment. I performed tests at two levels: all classes of microhabitat and each separate class before and after logging (see Chapter 5). The second level of tests involved combining data from E1 and E2 Plots and performing the tests on the total number of locations of birds recorded in each microhabitat class before and after logging versus the total number of locations of birds recorded in all other classes of microhabitat. All tests were undertaken using the same software described in Chapter 5.

6.3 Results

6.3.1 Home range size

I did not detect significant differences among plots in the mean home range sizes of Yellow-throated Scrubwrens before or after logging (Tables 6.1 and 6.2). Therefore, I did not conduct planned comparisons of experimental and control plots.

The mean home range sizes of White-browed Scrubwrens did not significantly differ between plots before or after logging, although the ANOVA result approached significance ($P=0.081$) (Table 6.1). This reflected a 2.3% decrease in the mean size of *S. frontalis* home ranges after logging in the experimental plots, compared with a 3.5% decrease in mean home range size in the control plots during the same period (based on 95% HM method - Table 6.2). This result prompted planned comparisons which did not reveal significant differences in mean home range sizes between combinations of logged plots and control plots (Table 6.1). White-browed Scrubwrens held larger home ranges in the second year plots than in the first year plots, although increased monitoring in Year 2 may have accounted for this difference.

6.3.2 Home range overlap

I did not detect a significant difference among plots in mean percentage overlap of Yellow-throated Scrubwren or White-browed Scrubwren home ranges after logging (Table 6.3). Therefore, I did not conduct planned comparisons of logged and control plots. Mean percentage overlap of *S. citreogularis* home ranges was highest after logging in E1 Plot but similar between periods in the other plots (Table 6.4). Mean percentage overlap of *S. frontalis* home ranges was lower after logging in both experimental plots but higher in the corresponding period in C1 Plot and similar between periods in C2 Plot (Table 6.4).

6.3.3 Home range shape and location

Yellow-throated Scrubwren

Logging appeared to influence the shape of *S. citreogularis* home ranges. Birds in both experimental plots held prism-shaped home ranges with long north-south axes before logging that contracted to smaller, squarer shapes with shorter north-south axes after logging (see Maps 33-34 and 41-42, Appendix 3). Home range shape was less variable in the control plots than in the experimental plots after logging (Appendix 3).

There were distinct shifts in the location of individual home ranges after logging in each experimental plot (Maps 33-36 and 41-44, Appendix 3). These involved the movement of range centres away from gaps and into adjacent retained forest, creating a pattern of closely packed home ranges in these plots. Range centres were separated by an average of 90.4 m before logging and 74.8 m after logging. I found that the location of home ranges in control plots changed less after logging than they did in experimental plots. Some home ranges extended into newly thinned forest in each experimental plot. However, thinned forest formed only the periphery of the home ranges of this species.

White-browed Scrubwren

Logging did not appear to affect the shape or location of White-browed Scrubwren home ranges. Rounded, block-shaped ranges with broad east-west axes were maintained between periods in experimental and control plots (Maps 49-50, 53-54, 57-58 and 61-62, Appendix

3). For example, the AMMF1 group held a disproportionately large, round home range that occupied approximately 30-35% of E2 Plot before and after logging (Maps 57 and 58, Appendix 3).

In both logged plots birds maintained the position and spacing of their home ranges after logging. Spacing between range centres in these plots averaged 90.9 m before logging and 99.6 m after logging. An exception was the AMMF1 group in E2 Plot that shifted their range centre 60 m to the south from gapped forest to a grassy creek bed (Maps 57-58, Appendix 3) where I suspected nesting to have occurred. The location of home ranges in control plots did not change appreciably between periods (Appendix 3).

6.3.4 Use of treatment zones in logged plots

I found that treatment (logged/unlogged) significantly influenced the use of gaps by Yellow-throated Scrubwrens in both experimental plots (Table 6.5). Mean percentage use of gaps was more than halved following logging in these plots (Table 6.6). Individuals used only the outer parts and edges of gaps in both logged plots. There was no significant association between treatment and the use of thinned or retained forest by *S. citreogularis* in the experimental plots. There was no significant effect of home range size on use of treatment zone. No interaction between treatment and home range size was detected (Table 6.5).

Treatment did not significantly influence the use of gaps, thinned or retained forest by White-browed Scrubwrens in either experimental plot (Table 6.5). Mean percentage use of gapped zones and retained forest by *S. frontalis* were similar in both plots before and after logging (Table 6.6). There was a 100% increase in *S. frontalis* use of thinned forest after logging in E1 Plot but a 33% decrease in thinned forest use in E2 Plot following logging (Table 6.6). The size of individuals' home ranges did not significantly affect their use of treatment zones nor did the interaction between treatment and home range size (Table 6.5). Birds included newly established gaps and thinned zones in their home ranges.

6.3.5 Use of microhabitat in logged plots

I detected a significant difference in the use of microhabitat (all classes compared) by Yellow-throated Scrubwrens before and after logging in both experimental plots (see *Total*

no. of locations of birds in all classes column - Table 6.7). Yellow-throated Scrubwrens significantly increased their use of woody debris piles after logging in the experimental plots but significantly decreased their use of fallen logs (Plates 6.1-6.3) after logging in E2 Plot (Table 6.7).

There were significant differences in the use of microhabitat (all classes compared) by White-browed Scrubwrens before and after logging in both experimental plots (see *Total no. of locations of birds in all classes* column - Table 6.7). White-browed Scrubwrens significantly increased their use of woody debris piles and significantly decreased their use of fallen logs and bark piles/fallen dead debris following logging in these plots (Table 6.7). This species' use of the lower canopy also significantly decreased after logging in E1 Plot but significantly increased during this period in E2 Plot (Table 6.7).

6.3.6 Other variables

Use of woody debris piles

Yellow-throated Scrubwrens used only the outer parts of woody debris piles that were within 14 m of adjacent retained forest. Individuals that entered the gap periphery were mostly males foraging alone. These debris pile visits were brief (no more than 4-5 minutes) and more frequent 2-3 weeks after logging when the potential for detecting invertebrate prey was probably high (pers. obs.).

White-browed Scrubwrens regularly travelled between retained forest and gaps to forage in woody debris piles within the gaps. Nineteen per cent of all traces after logging involved individuals, pairs or trios foraging in these piles. Birds crossed from retained forest into debris piles where the distance between the pile and forest edge did not exceed 37 m. Most crossings however, involved shorter distances (4-18 m). These forays were usually initiated by adult males that called females or other males in the group into piles. Birds spent 15.7±5.8 minutes in debris piles, foraging close together through the multiple horizontal layers of branches and logs. They rarely used 'observation posts' (see Ambrose 1985) but maintained frequent vocal contact while in the piles.

Plate 6.1 Large decaying logs left after previous logging provide important foraging microhabitat for *S. citreogularis, S. frontalis* and other birds, and food and shelter for herpetofauna and invertebrates. Note the amount of fallen branchlets, bark and other debris present on the forest floor.

Plate 6.2 Piles of fallen logs and heads of trees felled during previous logging operations commonly occur throughout the research plots. They form clumps of woody debris that provide important foraging microhabitat for *S. citreogularis*, *S. frontalis* and other birds and reptiles. The pink markings on trees in the background denote a proposed gap boundary while the yellow paint indicates the start of a cluster immediately beyond the gap.

Plate 6.3 Dense thickets of *Lantana camara* grow rapidly over fallen logs and tree heads left after previous logging operations in the research plots. They provide foraging habitat and protection from air-borne predators for Yellow-throated Scrubwrens, White-browed Scrubwrens, Logrunners and other ground-foraging birds and reptiles.

Gap-crossing

Yellow-throated Scrubwrens appeared unwilling to cross newly established gaps and instead travelled around gaps under forest cover. Birds that did enter gaps flew low (0.4-0.8 m above ground level) and fast in a 'zig-zag' style to perches situated 0.2-0.7 m above the ground and under the dense cover of debris piles. The mean straight-line length of these crossings was 14 m (7.2±6.9 m).

In contrast, White-browed Scrubwrens crossed gaps of 4-37 m to forage in woody debris piles. I did not observe birds travelling right across gaps, although some individuals flew across gap corners. Flight trajectories across bare ground between retained forest and debris piles were low (0.2-1.0 m above ground level) and fast in either straight lines or swerving to perches situated low down (0.1-0.8 m) in piles.

6.4 Discussion

6.4.1 Home range and habitat use responses to logging

The contrasting responses to logging that I recorded in the scrubwrens provide further evidence of the differential fragility (*sensu* Hobbs 1996) of bird species to habitat loss and modification (see Chapter 5). Yellow-throated Scrubwrens appeared to be more sensitive to logging than White-browed Scrubwrens. This was evident in their changes in home range shape and location following logging to avoid newly created gaps. White-browed Scrubwrens maintained the structure of their home ranges after logging by accommodating gaps and thinned areas into their ranges. Onset of the breeding season after logging may have influenced changes in home range shape during this period.

There were also contrasts between the scrubwren species in their use of treatment zone and microhabitat after logging. Yellow-throated Scrubwrens foraged in woody debris piles and around fallen logs along gap edges and close to forest cover but did not travel more than 14 m across open ground to reach these piles. Some individuals entered newly thinned areas to access these microhabitats. White-browed Scrubwrens did not modify their use of gapped, thinned or retained forest after logging. They increased their foraging in woody debris piles in and around newly established gaps and were travelled up to 37 m over open ground to

reach these piles. Their use of fallen logs and the lower canopy (E1 Plot) decreased after logging, possibly because woody debris piles retained in and around gaps provided attractive alternative foraging habitat.

6.4.2 Conformity of responses with models

I found that the *partial adjustment* model (Section 6.1) best described the pattern of home range and habitat use response of Yellow-throated Scrubwrens to the logging trials. Individuals included only the outer edges of gaps in their home ranges, maintained home range size and overlap but relocated to retained forest, with associated changes in home range shape. They increased their use of woody debris piles (edges only) and fallen logs after logging.

In contrast, I found that the response of White-browed Scrubwrens complied, in most part, with the predictions of the *incorporation* model. Individuals included new gaps in their home ranges and generally maintained home range size, overlap, shape and location after logging. Some departure from this model occurred, however, since use of treatment zone was not significantly influenced by home range size. This possibly reflected the versatile foraging behaviour of this species which allowed birds to utilise gapped, thinned or retained forest at similar levels regardless of the sizes of their home ranges. Birds increased their use of woody debris piles, especially in and around newly established gaps, and lower canopy (E2 Plot) but decreased their use of fallen logs and the lower canopy (E1 Plot) after logging.

6.4.3 Other Australian home range studies

There have been few studies of small ground-foraging insectivores in Australia (Table 6.8). Only one of these studies (Smith 1989) was conducted in a previously logged forest. There have been no previous home range studies of Yellow-throated Scrubwrens in any type of environment.

Smith (1989) estimated mean territory size of *S. frontalis* (nominate race) in 13 ha of tall eucalypt forest near Bega on the NSW south coast at 2.03±0.32 ha before a fire affected the site. Individuals foraged across drier slopes and ridges but bred mostly in intervening moist gullies dominated by Gully Peppermint *Eucalyptus smithii*. Territory size was clearly larger

than the mean home range size that I obtained for this species in my study. This probably reflected local variation in vegetation communities and distribution of microhabitat, and the method used to calculate territory size (manual territory mapping).

Brooker (1998) obtained a mean home range size of 1.8±0.59 ha for White-browed Scrubwrens (race *maculatus*) in 55 ha of arid shrubland in Western Australia. She found that these home ranges were stable between years and cooperative breeding did not occur. 'Floating' males or males that were not attached to breeding pairs held home ranges that varied from 2 to 4 ha. The home range size of her breeding pairs of this species is slightly larger than the *S. frontalis* home range sizes that I obtained in my study (Table 6.8). This can probably be attributed to the harsher environment of Brooker's study area where ground cover was considerably sparser and food was perhaps scarcer than in my moist forest plots (see Brooker 1998). Therefore, larger home ranges may have been required by these birds compared with the home ranges held by White-browed Scrubwrens in my study.

6.4.4 Conclusions

Two episodes of logging in continuous moist eucalypt forest on the NSW north coast significantly affected the home range structure of Yellow-throated Scrubwrens. Individuals moved to adjacent retained forest and included only the outer parts and edges of new gaps in their home ranges. Some birds foraged in woody debris piles and around fallen logs along gap peripheries and in newly thinned areas.

These responses demonstrated that Yellow-throated Scrubwrens appeared capable of making a partial but limited adjustment to the effects of gaps and clusters silviculture in a previously logged forest. Individuals successfully re-established their home ranges in retained forest at similar sizes to those held before logging. However, the general avoidance of gap interiors and an apparent unwillingness to cross gaps suggests that, at the individual level and at least in the short-term, *S. citreogularis* may be negatively affected by this form of logging.

White-browed Scrubwrens maintained the size, shape, overlap and location of their home ranges by incorporating newly created gaps and thinned zones into their home ranges after logging. They demonstrated a clear willingness to enter gaps to forage in woody debris piles left after logging. In some cases, individuals expanded their home ranges to include this

novel form of microhabitat. This evidence therefore suggests that the logging trials had minimal adverse impact on home range and habitat use in *S. frontalis* in the short-term. The prognosis for the longer-term persistence of this species in gapped forest landscapes may be reasonably good, providing that adequate areas of adjacent forest are retained during harvesting operations (Chapter 8).

Table 6.1 Summary of results of one-way ANOVA with orthogonal planned comparisons (PC) of mean home range size (95% Harmonic Mean) of individual Yellow-throated Scrubwrens *Sericornis citreogularis* and White-browed Scrubwrens *S. frontalis* after logging. The result that approached significance (P=0.05-0.10) is shown in bold.

Species	Levene's Test P	ANOVA (E1+C1+E2+C2)				PC 1 (E1+E2 v C1+C2)				PC 2 (E1 v C1)				PC 3 (E2 v C2)			
		N	F	P	df	N	F	P	df	N	F	P	df	N	F	P	df
Sericornis citreogularis	0.803	18	0.35	0.787	3,14												
S. frontalis	0.387	19	2.73	**0.081**	3,15	19	0.096	0.785	1,15	11	0.027	0.848	1,15	8	0.227	0.649	1,15

Plots: E1 (Year 1 Experimental) C1 (Year 1 Control) E2 (Year 2 Experimental) C2 (Year 2 Control)
N = number of home ranges of individual birds (data derived using 95% Harmonic Mean method)
PC calculate F using group MS/error MS. Each PC uses, as its denominator df, the error MS df derived in the initial ANOVA
F = F-distribution (1-tailed)
P = 0.05
df = degrees of freedom

Table 6.2 Mean home range sizes (ha) of Yellow-throated Scrubwrens *S. citreogularis* and White-browed Scrubwrens *S. frontalis* before and after logging in each plot. Results for both methods of home range calculation (HM and MCP) are given. The study means represent the means of both logged plots and both control plots. Standard error of the means is shown in brackets below each mean value.

Species	Method	Period	Plot				Study Means	
			E1	*C1*	*E2*	*C2*	*E plots*	*C plots*
S. citreogularis	95% HM	Before	0.905 (0.054)	0.905 (0.060)	1.186 (0.094)	0.989 (0.071)	1.045 (0.140)	0.947 (0.042)
		After	0.955 (0.176)	0.906 (0.062)	1.033 (0.144)	1.071 (0.083)	0.994 (0.039)	0.988 (0.082)
	95% MCP	Before	1.170 (0.287)	1.132 (0.074)	1.402 (0.101)	1.106 (0.044)	1.286 (0.116)	1.119 (0.013)
		After	1.175 (0.210)	1.107 (0.115)	1.088 (0.103)	1.292 (0.114)	1.131 (0.043)	1.199 (0.092)
S. frontalis	95% HM	Before	0.958 (0.092)	1.076 (0.053)	1.605 (0.492)	1.613 (0.134)	1.281 (0.323)	1.344 (0.268)
		After	1.043 (0.218)	1.006 (0.045)	1.461 (0.219)	1.588 (0.107)	1.252 (0.209)	1.297 (0.291)
	95% MCP	Before	1.230 (0.132)	1.236 (0.047)	1.690 (0.337)	1.772 (0.093)	1.460 (0.230)	1.504 (0.268)
		After	1.422 (0.242)	1.096 (0.060)	1.522 (0.231)	1.820 (0.152)	1.472 (0.050)	1.458 (0.362)

Table 6.3 Summary of results of one-way ANOVA of mean percentage home range overlap between individual Yellow-throated Scrubwrens *S. citreogularis* and White-browed Scrubwrens *S. frontalis* after logging. Planned comparisons were not conducted because the ANOVA results were not significant.

Species	Levene's Test *P*	ANOVA (E1+C1+E2+C2)			
		N	*F*	*P*	df
S. citreogularis	0.746	28	1.01	0.404	3,24
S. frontalis	0.129	37	1.39	0.263	3,33

Plots: E1 (Year 1 Experimental) C1 (Year 1 Control) E2 (Year 2 Experimental) C2 (Year 2 Control)
N = number of home ranges of individual birds (data derived using 95% Harmonic Mean method)
F = *F*-distribution (1-tailed)
P = 0.05
df = degrees of freedom

Table 6.4 Mean percentage home range overlap (95% Harmonic Mean) of Yellow-throated Scrubwrens *S. citreogularis* and White-browed Scrubwrens *S. frontalis* before and after logging in each plot. Percentage data have been arcsine transformed. Ranges with overlap values of <5% were discarded. The study means represent the means of both logged plots and both control plots. Standard error of the means is shown in brackets below each mean value.

Species	Period	Mean % home range overlap in each plot				Study Means	
		E1	*C1*	*E2*	*C2*	*E plots*	*C plots*
S. citreogularis	Before	41.5 (2.24)	32.3 (14.5)	32.7 (10.2)	37 (13.1)	37.1 (6.27)	34.65 (12.1)
	After	62.7 (9.07)	31.8 (11.8)	35.1 (9.94)	43.8 (7.51)	48.9 (9.42)	37.8 (8.45)
S. frontalis	Before	50.06 (4.40)	13.47 (2.17)	21.4 (5.42)	31.9 (15.5)	35.73 (9.77)	22.68 (8.67)
	After	25.27 (5.19)	28.65 (1.58)	10.51 (1.43)	32.9 (15.4)	17.89 (3.25)	30.77 (8.33)

Table 6.5 Results of general linear models of use of treatment zone by Yellow-throated Scrubwrens *S. citreogularis* and White-browed Scrubwrens *S. frontalis* after logging in each experimental plot. Interaction terms in each model consist of a factor (treatment: logged or unlogged) and a covariate (size [ha] of the home range of an individual bird). In Model 2, the first row of *F* and *P* values given for each treatment zone shows the influence of treatment on use of treatment zone. The second row of *F* and *P* values represent the covariate value which, if significant, indicates that home range size influenced the use of the relevant treatment zone by *S. citreogularis* or *S. frontalis*. The significant ($P<0.05$) result is indicated in bold.

Species	Model 1 (Treatment x home range size)					Model 2 (Treatment, home range size)				
	Tzone	N	df	*F*	*P*	N	df	*F*	*P*	cc
Sericornis citreogularis	G	18	1,14	0.01	0.928	18	1,15	12.57	**0.003**	0.676
								1.40	0.255	
	T	18	1,14	0.02	0.880	18	1,15	1.24	0.283	
								2.64	0.125	
	R	18	1,14	0.07	0.799	18	1,15	2.60	0.128	
								0.45	0.514	
S. frontalis	G	20	1,16	0.64	0.436	20	1,17	0.24	0.634	
								0.00	0.954	
	T	20	1,16	0.00	0.978	20	1,17	1.24	0.280	
								0.49	0.495	
	R	20	1,16	0.01	0.941	20	1,17	1.54	0.231	
								0.28	0.605	

Tzone = Treatment Zone: G gapped T thinned R retained forest
N = number of home ranges of individual birds (data derived using 95% Harmonic Mean method)
F = *F*-distribution (1-tailed)
df = degrees of freedom
cc = The Pearson product-moment correlation coefficient is given for significant ($P<0.05$) results and is a measure of intensity of association between two variables (Sokal & Rohlf 1995; Zar 1999). Negative correlation coefficients indicate that an increase in value of one of the variables (in this case, treatment or home range size) is accompanied by a decrease in value of the other variable (Zar 1999). Positive correlation coefficients mean that for an increase in the value of one of the variables, the other variable also increases in value (Zar 1999).

Table 6.6 Mean percentage use of treatment zone by Yellow-throated Scrubwrens *S. citreogularis* and White-browed Scrubwrens *S. frontalis*, showing home range sizes before and after logging in each experimental plot. Data derived by 95% Harmonic Mean method. Percentage data were arcsine transformed and thus mean percentage use totals for each plot and period do not sum to 100%. Standard error of the means is shown in brackets below each mean value.

Species	Plot	Period	Mean home range size (ha)	Mean percentage use of treatment zone		
				Gapped	*Thinned*	*Retained*
S. citreogularis	E1	Before	0.905 (0.053)	22.1 (7.73)	13.7 (2.08)	61.1 (5.94)
		After	0.958 (0.175)	10.2 (3.65)	31.9 (4.11)	56.8 (3.47)
	E2	Before	1.186 (0.093)	28.8 (2.57)	4.2 (3.35)	60.1 (2.35)
		After	1.032 (0.143)	9.6 (3.58)	3.3 (2.73)	77.7 (2.57)
S. frontalis	E1	Before	0.96 (0.091)	16.8 (5.99)	14.0 (4.71)	64.1 (5.49)
		After	1.045 (0.218)	23.0 (4.17)	28.0 (4.86)	51.3 (4.41)
	E2	Before	1.605 (0.493)	25.9 (2.89)	12.8 (5.96)	60.2 (3.06)
		After	1.46 (0.219)	22.4 (3.84)	8.6 (6.38)	63.9 (3.77)

Table 6.7 Use of microhabitat by Yellow-throated Scrubwrens *S. citreogularis* and White-browed Scrubwrens *S. frontalis* before and after logging in each experimental plot. Chi-square (χ^2) test results in the second column from the left are based on the total number of locations of birds recorded in *all* classes of microhabitat before and after logging in each plot. Separate χ^2 tests were conducted on the total number of locations of birds in *each* microhabitat class before and after logging versus the total number of locations of birds recorded in all other microhabitat classes. These results were obtained by combining data from E1 and E2 Plots and, where significant ($P<0.05$), are presented at the base of each microhabitat class column for each species. Significant results are shown in bold. Number of individual birds of each species used in χ^2 analysis in each plot=4. ns=not significant. na=not applicable. df=degrees of freedom.

Species/Plot/Period	Total no. of locations of birds in all classes	Total no. of locations of individuals recorded in each microhabitat class and statistical significance						
S. citreogularis		*Ground*	*Bare ground*	*Woody debris pile*	*Fallen logs*	*Dense shrub regrowth*	*Lower canopy*	*Bark pile/ fallen dead debris*
E1								
Before	189	103	11	7	42	13	13	na
After	287 **$P=0.000$** $\chi^2=56.947$ df=5	94	13	79	44	39	18	na
E2								
Before	320	57	32	11	85	87	48	na
After	316 **$P=0.014$** $\chi^2=14.185$ df=5	81 ns	23 ns	25 **$P=0.000$** $\chi^2=53.121$ df=1	69 **$P=0.012$** $\chi^2=6.292$ df=1	80 ns	38 ns	na
S. frontalis								
E1								
Before	339	98	14	19	69	58	49	32
After	342 **$P=0.000$** $\chi^2=57.956$ df=6	100	19	82	40	54	24	23
E2								
Before	299	61	28	5	93	43	34	35
After	338 **$P=0.000$** $\chi^2=57.349$ df=6	66 ns	20 ns	67 **$P=0.000$** $\chi^2=95.093$ df=1	79 **$P=0.004$** $\chi^2=8.442$ df=1	44 ns	40 **$P=0.038$** $\chi^2=4.299$ df=1	22 **$P=0.012$** $\chi^2=6.386$ df=1

Table 6.8 Comparison of estimates of home range size of the Yellow-throated Scrubwren *Sericornis citreogularis* and White-browed Scrubwren *S. frontalis* obtained in my study with previous studies of Pardalotidae and Maluridae

Species	Investigator/s	Landscape/ vegetation type	Size of home range/territory (ha)	Methods used	Number of home ranges/territories or birds sampled
Yellow-throated Scrubwren	Huggett (this study)	Commercially logged, continuous moist eucalypt forest near Coffs Harbour, NSW north coast	Before logging (all plots): 1.00 (mean, HM), 1.20 (mean, MCP) After logging (all plots): 0.99 (mean, HM), 1.16 (mean, MCP)	RANGES V software (95% MCP, 95% HM)	Total 18 birds & 18 home ranges (9 in two logged plots & 9 in two control plots) - in gapped, thinned & retained forest
White-browed Scrubwren	Huggett (this study)	As above	Before logging (all plots): 1.31 (mean, HM), 1.47 (mean, MCP) After logging (all plots): 1.27 (mean, HM), 1.46 (mean, MCP)	RANGES V software (95% MCP, 95% HM)	Total 21 birds & 19 home ranges (10 in two logged plots & 9 in two control plots) - in gapped, thinned & retained forest
White-browed Scrubwren	Ambrose (1985), Ambrose & Davies (1989)	Arid coastal heath/mallee, southern and western West Australia	1.36±0.08 - 2.63±0.30	Manual territory mapping	11 territories wholly within plot
White-browed Scrubwren	Smith (1989)	Previously logged tall eucalypt forest near Bega, NSW south coast	2.03±0.32 (before fire or drought)	Manual territory mapping	7 territories
White-browed Scrubwren	Brooker (1998)	Arid *Acacia* shrubland, Peron Peninsula, Western Australia	1.8±0.59 (breeding pairs)	Manual territory mapping based border disputes and vocal defence	9-12 well defined territories
Superb Fairy-wren	Rowley (1965)	Planted and natural eucalypt forest/woodland, Australian National Botanic Gardens, Canberra	0.6	Manual territory mapping	
Superb Fairy-wren	Nias (1984)	Remnant patch of eucalypt woodland near Armidale, NSW northern tablelands	1.5 (mean)	Manual territory mapping	

Superb Fairy-wren	Tidemann (1990)	Semi-arid chenopod shrubland at Booligal, south-western NSW	Mean (late spring): 2.2	Manual territory mapping based on capture and display points in a 900x400m grid	4-13 territories
Splendid Fairy-wren	Brooker & Rowley (1995)	Eucalypt woodland/heath, southern West Australia	4.4	Manual territory mapping	
Splendid Fairy-wren and Variegated Fairy-wren	Tibbetts & Pruett-Jones (1999)	Semi-arid chenopod shrubland and mallee, 100 km north-east Adelaide, South Australia	3.1 (mean, both species)	Manual territory mapping	9-12 groups
Blue-breasted Fairy-wren	Rowley & Russell (1997)	Dry open woodland, southern West Australia	1-2 (estimated)		
Red-winged Fairy-wren	Rowley & Russell (1997)	Tall open forest, southern West Australia	1.2		

CHAPTER 7

HOME RANGE AND HABITAT USE IN TWO MIGRATORY PASSERINES IN AN EXPERIMENTALLY LOGGED MOIST EUCALYPT FOREST

7.1 Introduction

In Australian temperate forests and woodlands, a complex pattern of avian migration has emerged in response to seasonal fluctuations in climate, prey availability and historical isolation (Ford 1989; Robinson 1990). This has involved a small but important group of species of which rhipidurine (e.g., Rufous Fantail) and monarchine (e.g., Spectacled Monarch) flycatchers are members (Ford 1989; Christidis & Boles 1994).

Previous studies have suggested that migratory Australian landbirds may face a different set of pressures to survive and reproduce than those experienced by resident species (Cameron 1975, 1985; Robinson 1990, 1992; Bridges 1992, 1994; Trémont 1994). Many migrants must re-establish breeding territories, choose mates and complete nesting within shorter periods of time than resident birds (Cameron 1975; Robinson 1990), although some species such as Rufous Whistlers *Pachycephala rufiventris* may return to the same territory and use the same mate each year (Bell & Ford 1987; Bridges 1994). This compression of the breeding cycle can intensify competition for resources and influence the location, size and shape of territories (Cameron 1975, 1985; Robinson 1990; Bridges 1992). Some migrants such as Rufous Fantails may be less productive than residents (e.g., Grey Fantails, Willie Wagtails *Rhipidura leucophrys*), having small, less variable clutch sizes (Cameron 1985).

In eucalypt forests these postulated constraints may make migratory insectivores particularly sensitive to logging operations. Home range structure and habitat use might vary considerably between and within species under these conditions. For instance, in logged moist eucalypt forest Spectacled Monarchs forage in dense lower and mid canopy vegetation and hold narrow home ranges that are confined to unlogged moist gullies and lower slopes (Section 7.3.2). In comparison, Black-faced Monarchs *Monarcha melanopsis* range across thinned ridges and slopes and unlogged riparian zones, as long as adequate canopy cover exists (pers. obs.).

A number of important questions arise from these considerations. Are migratory birds able to utilise newly gapped forest? What are the effects of logging on the size, overlap, shape and location of the home ranges of these birds? How important is retained forest to migrants? Do they utilise new microhabitat created by logging operations and, if so, to what extent?

These questions underpin the approach that I adopt in this chapter. I assess how the home range and habitat use of two summer breeding migrants, the Rufous Fantail *Rhipidura rufifrons* and Spectacled Monarch *Monarcha trivirgatus*, change in response to logging. I base this assessment on three predictive models. These are:

1. *Incorporation*: birds include newly created gaps in their home ranges; home range size is generally maintained or increased; overlap between the home ranges of neighbouring birds of the same species is maintained; home range shape and location is generally maintained; use of treatment zone (ie. gapped, thinned, and retained forest) is influenced by home range size but not by logging; microhabitat use is influenced by logging.
2. *Modification*: birds exclude newly created gaps from their home ranges; home range size is generally maintained or decreased; overlap between the home ranges of neighbouring birds of the same species increases; home range shape changes and home ranges are relocated to retained forest; use of treatment zone (ie. gapped, thinned, and retained forest) and microhabitat are influenced by logging.
3. *Partial adjustment*: birds include only parts of newly created gaps in their home ranges; home range size and overlap between the home ranges of neighbouring birds of the same species are generally maintained; home range shape changes and home ranges extend into retained forest; use of treatment zone (ie. gapped, thinned, and retained forest) and microhabitat are influenced by logging.

7.2 Methods

I used the methods described in Chapter 5 to investigate home range structure and habitat use in Rufous Fantails and Spectacled Monarchs. I did not obtain enough location data to allow estimation of either species' home ranges before or after logging in the Year 1 plots. No location data were obtained for either species before logging in Year 2 plots because monitoring was conducted in autumn-winter when Rufous Fantails and Spectacled Monarchs were absent from the plots. Therefore, I only used data collected in Year 2 plots after logging, ie. upon the birds' spring return to these plots. I also used some methods that were specific to these species. These are described in the following sections.

7.2.1 Estimating home range

Recording bird movement

Most Rufous Fantail traces were of single individuals erratically flitting and tumbling through lower and mid-canopy strata at heights of 0.7-8 m (Chapter 3 this study; Cameron 1975; Driscoll 1985). I followed Spectacled Monarchs moving singly and in pairs at heights of 2-12 m along densely vegetated creeklines and lower slopes. They used a range of fluttering, tumbling and darting motions to traverse their home ranges (Chapman & Harrington 1997). Birds moving together or close to each other were recorded as the one trace because of the lack of independence between each individual bird's movement (see Chapter 5).

I mapped the journeys of 35 colour-banded and known, unbanded individuals of both species across both Year 2 plots over a period of approximately 3 months (14 September 1998 - 23 December 1998). Since this coincided with the period after logging, I adopted a logged (ie. E2 Plot) versus unlogged (ie. C2 Plot) approach rather than a before/after basis to compare home range and habitat use in both species. I obtained a total of 131 traces (547 locations) from 24 individuals of *R. rufifrons* in both Year 2 plots. For *M. trivirgatus*, I compiled 53 traces (379 locations) from 11 individuals in both plots.

Home range analysis

Selection of movement data

I selected 8 Rufous Fantails (4 in each plot) and 6 Spectacled Monarchs (3 in each plot) for detailed home range analysis. I selected only traces with a minimum of 30 locations for each species. This limit was established to take into account the small number (see above) of traces that were obtained for these migrants.

I computed the mean time to independence (TTI) between consecutive locations of individuals of both species using autocorrelation analysis in RANGES V (see Chapter 5). The mean TTI for *R. rufifrons* was 21.2 minutes and 26.1 minutes for *M. trivirgatus*. Field observations of distances travelled and time taken by individuals to move through their home

ranges indicated that these TTI totals were overly conservative estimates and, if adopted, would inhibit the accurate estimation of home range size in these species. Therefore, I selected sampling intervals of 11 minutes for *R. rufifrons* and 13 minutes for *M. trivirgatus*.

Home range shape and location

I compared the shape and location of individual home ranges of both species in the logged plot with those in the control plot in the period after logging. This provided an indirect measure of the impact of logging on the shape and location of both species' home ranges.

Producing home range maps using RANGES V

I produced a total of 8 home range maps using RANGES V (Maps 65-72, Appendix 3). These showed the ranges of the selected individuals of both species after logging for both methods of home range analysis. Too few locations of other individuals of both species were obtained to permit the mapping of their home ranges.

7.2.2 Treatment zones, microhabitats and other variables

I quantified treatment zone use by both species after logging in E2 Plot only, using the approach adopted in Chapter 5. I counted the number of locations recorded for each individual bird in 7 classes of microhabitat after logging in E2 Plot and during the same period in the C2 Plot. I determined the habitat content of home ranges in each of these classes for each species using RANGES V. The use of woody debris piles and gap-crossing behaviour was described for both species.

7.2.3 Statistical analysis

I used two-sample *t* tests (Zar 1999) to determine if there were significant differences in mean home range size and mean percentage home range overlap in each species in the logged plot relative to the control plot. Critical values of the *t* distribution were obtained from Table B.3 in Zar (1999).

I examined home range size and overlap data for homogeneity of variance using the Variance Ratio Test (Hartley's F_{max} Test) (Zar 1999). This test determines whether the calculated ratio of sample variances (ie. F) deviates sufficiently far from 1.0 to permit rejection of the null hypothesis (ie. that variances of both populations are equal) at $P<0.05$ (Zar 1999). I specified pooled variances and divided the larger variances into the smaller variances. I did not transform data since calculated F values were not significant ($P>0.05$) (Section 7.3).

I used contingency table analysis to determine if the use of microhabitat by each species in E2 Plot (relative to C2 Plot) was influenced by logging. Tests were conducted for each separate class of microhabitat in both plots. I did not statistically analyse treatment zone use because of the lack of pre-logging data for both species.

7.3 Results

7.3.1 Home range size and overlap

I did not detect significant differences between the E2 and C2 Plots in the mean home range sizes of Rufous Fantails or Spectacled Monarchs after logging (Table 7.1), although both species had slightly smaller home ranges in the E2 Plot than in the C2 Plot. I did not reveal significant differences between the E2 and C2 Plots in mean percentage home range overlap of Rufous Fantails after logging (Table 7.2). The difference between E2 and C2 Plots in the mean percentage home range overlap of Spectacled Monarchs after logging approached significance ($P=0.081$) (Table 7.2). This involved a difference of 28 percentage points in the degree of overlap of home ranges in E2 Plot (69.9%) compared with C2 Plot (41.9%).

7.3.2 Home range shape and location

Rufous Fantail

The basic shape of Rufous Fantail home ranges varied from triangular and elliptical prisms to broad squares (Maps 65 and 67, Appendix 3). There was a trend toward narrower and longer home ranges in E2 Plot compared with broader, shorter ranges in C2 Plot.

Logging may have influenced the location of *R. rufifrons* home ranges in E2 Plot. Individuals appeared to avoid newly created gaps in preference for adjacent retained forest (Map 66, Appendix 3). Birds included only the outer portions of gaps in their ranges. After logging, the centres of home ranges were located at least 12 m from the nearest gap and were separated by an average distance of 134.5 m. These birds were detected within 50-75 m (E1 Plot) and 30-55 m (C2 Plot) of the sites where they were first captured in the season before logging. Each of the monitored birds was captured in the breeding season before logging in forest that was later gapped. The centres of home ranges in C2 Plot were spaced at an average distance of 113.2 m apart.

Spectacled Monarch

Logging appeared to have strongly influenced the shape and location of *M. trivirgatus* home ranges in E2 Plot. Long, narrow elliptical shapes characterised home ranges in E2 Plot while home ranges in C2 Plot comprised long but broader elliptical shapes (Maps 69 and 71, Appendix 3). There was a clear avoidance of newly created gaps and most thinned areas by Spectacled Monarchs in E2 Plot (Map 70, Appendix 3). The home ranges of these birds were generally compressed into an 80 m wide strip of riparian vegetation. After logging in E2 Plot, the centres of home ranges were located at least 50 m from the nearest gap and separated by an average distance of 58.3 m. Birds returned to within 77-120 m of their sites of capture in the previous season.

In C2 Plot a breeding pair (AM1/AF2) and an adult female (AF1) held home ranges that were well segregated along almost 300 m of two densely vegetated creeks (Map 72, Appendix 3). These ranges were not confined to the riparian zone but extended 30-70 m up the adjacent lower and mid-slopes. Other Spectacled Monarchs were occasionally observed traversing the drier ridge separating these creeks. Home ranges were centred in the Bangalow Palm-dominated creeks at an average of 94.6 m apart. Birds returned to within 50-83 m of their sites of capture in the previous season.

7.3.3 Use of treatment zones and microhabitat

Rufous Fantails used retained forest substantially more than thinned or gapped zones after logging in E2 Plot (Table 7.3). This may have reflected a movement away from gaps to

retained forest by individuals upon their spring return to the plot, although pre-logging data is needed to confirm or reject this possibility. The retention of 69.4 % of forest cover in this plot (of which 39.7% comprised riparian forest) might also have contributed to this pattern of use by Rufous Fantails. There was a small degree of use of gaps and thinned forest because some individuals foraged in woody debris piles left after logging in these zones (Section 7.3.4).

Spectacled Monarchs almost exclusively used retained forest after logging in E2 Plot (Table 7.3). One individual (AU1) occasionally foraged along the edges of a lightly thinned zone (Map 70, Appendix 3). The predominant use of retained forest may have reflected this species' avoidance of newly created gaps in E2 Plot as well as its preference for dense riparian habitat.

I found that Rufous Fantails used significantly more of the lower canopy and significantly less of woody debris piles and dense shrub regrowth after logging in the E2 Plot than during the same period in the C2 Plot (Table 7.4). Spectacled Monarchs used significantly less of the lower canopy after logging in E2 Plot compared with C2 Plot. This species' use of fallen logs after logging in E2 Plot compared with C2 Plot approached significance (P=0.061) (Table 7.4). Although sample sizes were small, this involved a 41.7% reduction in fallen log use in E2 Plot relative to C2 Plot.

7.3.4 Other variables

Use of woody debris piles

The use of woody debris piles by Rufous Fantails was sporadic and mainly confined to the outer parts of piles situated within 22 m of adjacent retained forest. Visits to piles were brief (2-5 minutes) and were characterised by birds rapidly foraging over bark, logs and branches from the ground to 2 m. Individuals often entered and exited debris piles close to retained forest.

In contrast, Spectacled Monarchs did not utilise newly created debris piles in or around gaps or older piles left after previous logging in retained forest in E2 Plot. Individuals maintained distances of 6-35 m away from the edges of new gaps.

Gap-crossing

Rufous Fantails appeared unwilling to cross newly created gaps in E2 Plot. Instead, individuals preferred to move around gaps under continuous forest cover. However, birds occasionally took short cuts over straight-line distances of 10-24 m across the exposed corners of gaps or crossed into debris piles within gaps. These flights were fast, at heights of 1-3 m, and made directly to exposed perches in debris piles and adjacent retained forest.

Spectacled Monarchs did not cross or venture near gaps. Individuals generally moved under the closed canopies of their core riparian zones. This produced a distinctively linear pattern of use of their home ranges in E2 Plot and to a lesser extent in C2 Plot.

7.4 Discussion

Statistical analyses suggested that there were no significant differences between the E2 and C2 Plots in mean home range size and overlap of Rufous Fantails or Spectacled Monarchs after logging. However, sample sizes of both species were small and data were not obtained before logging. These constraints also affected analyses of use of treatment zone and microhabitat by both species, although some significant results were obtained for the latter variable. Therefore, the following section is a tentative assessment of the sensitivity of Rufous Fantails and Spectacled Monarchs to gaps and clusters logging. It is based on apparent trends in the patterns of home range and habitat use that may be present in these species in the Year 2 plots.

7.4.1 Home range and habitat use with respect to models

My study provides preliminary data on the sensitivity of two migratory flycatchers to small gaps created in moist regrowth eucalypt forest. Rufous Fantails appeared to be less sensitive to gapping than Spectacled Monarchs. Individuals included the outer parts of new gaps in their home ranges which were of similar size but different shape than those in the control plot. Some individuals foraged in woody debris piles around the edges of gaps, providing that piles were within 22 m of retained forest, and took short cuts of up to 24 m across gap corners. Retained forest was used more than gapped or thinned forest after logging. Birds used significantly more of the lower canopy and less of woody debris piles and dense shrub

regrowth after logging in the logged plot than in the control plot. This pattern of home range and habitat use conformed most closely with the *partial adjustment* model (Section 7.1).

In contrast, Spectacled Monarchs avoided new gaps and most thinned areas, occupying instead home ranges along densely vegetated creeks and lower slopes. These ranges were narrow, slightly smaller in E2 Plot than in C2 Plot, and showed a high degree of overlap. Birds used significantly less of the lower canopy after logging in E2 Plot than in C2 Plot. No individuals were observed crossing gaps, taking short cuts across gap corners, or foraging along or within 6-35 m of gap edges. This pattern of home range and habitat use seemed to conform most closely with the *modification* model.

7.4.2 Other Australian studies of home range and habitat use

There have been no previous home range studies of Rufous Fantails or Spectacled Monarchs in Australian eucalypt forests. Cameron's (1975, 1985) study in previously logged moist eucalypt forest at Five Day Creek, about 60 km north-west of Kempsey on the NSW mid-north coast is the only investigation of home range use by sedentary and migratory flycatchers. She estimated territory sizes for the sedentary species - Willie Wagtails (average 3.3 ha) and Grey Fantails (mean 0.9 ha). She did not obtain sufficient data to estimate the size of Rufous Fantail territories. In my study, Rufous Fantails held mean home ranges that were intermediate in size between these two species, ie. 1.25 ha in E2 Plot and 1.45 ha in C2 Plot.

Other studies have investigated the distribution, abundance and habitat preferences of Rufous Fantails, Grey Fantails, Satin Flycatchers *Myiagra cyanoleuca* and other flycatchers in logged (e.g., Pattemore & Kikkawa 1975; Loyn *et al.* 1980; Milledge & Recher 1985; Loyn 1993, 1998; Norwood *et al.* 1995; Taylor & Haseler 1995; Kutt 1996; Mac Nally 1997b; Taylor *et al.* 1997). and unlogged (e.g., Milledge 1979; Pyke 1985; Tidemann *et al.* 1988; Leishman 2000) Australian eucalypt forests. At Boola Boola State Forest in south-east Victoria, Loyn *et al.* (1980) estimated the size of Rufous Fantail populations in 15 year-old regrowth eucalypt forest in gullies at 0.40 territories/ha and in mature gully eucalypt forest at 0.29 territories/ha. In the Victorian central highlands, Loyn (1998) found that the abundance of Rufous Fantails was highest (0.61 birds per 10 minute count) in 0-5 ha patches of old Mountain Ash *E. regnans* forest surrounded by younger forest. In dry eucalypt forest

in central and eastern Tasmania, Taylor & Haseler (1995) and Taylor *et al.* (1997) found that Satin Flycatchers were virtually absent from 6-12 year-old regrowth eucalypt forest but present in mature (80+ year-old) eucalypt forest. Loyn (1980) found that Satin Flycatchers were still scarce in 70 year-old regrowth eucalypt forest in Gippsland, Victoria. In east Gippsland, Kutt (1996) detected a general trend of increasing density of bird populations from thinned (25-35 year-old regrowth) to old (selectively logged 50 years prior to study) eucalypt forest. He found that Rufous Fantails and Black-faced Monarchs were more abundant in old forest. In wet sclerophyll forest near Melbourne, Victoria, Mac Nally (1997b) obtained median densities of 6.1, 23.6, and 5.3 birds/50 ha for Rufous Fantails, Grey Fantails and Leaden Flycatchers *Myiagra rubecula*, respectively.

Table 7.1 Mean home range sizes (ha) of Rufous Fantails *R. rufifrons* and Spectacled Monarchs *M. trivirgatus* after logging in Year 2 logged plot (E2) and control plot (C2), showing two-sample *t*-test results (1-tailed). Results for both methods of home range calculation (HM and MCP) are given. *t*-tests were based on data derived by 95% Harmonic Mean method. Standard error of the means is shown in brackets below each mean value. df=degrees of freedom, N=number of individuals sampled. $P=0.05$.

Species	Variance Ratio Test *F*	Method	Mean home range size in each plot		*t*-test results
			E2	*C2*	
R. rufifrons	1.96 ($P=0.29$)	95% HM	1.255 (0.058)	1.449 (0.231)	$t=-0.81$ $P=0.22$ df=6 N=8
		95% MCP	1.297 (0.103)	1.390 (0.290)	
M. trivirgatus	1.84 ($P=0.35$)	95% HM	1.341 (0.140)	1.737 (0.218)	$t=-1.52$ $P=0.10$ df=4 N=6
		95% MCP	1.093 (0.124)	2.380 (0.551)	

Table 7.2 Mean percentage home range overlap (95% Harmonic Mean) of Rufous Fantails *R. rufifrons* and Spectacled Monarchs *M. trivirgatus* after logging in Year 2 logged plot (E2) and control plot (C2), showing two-sample *t*-test results (1-tailed). df=degrees of freedom, N=number of home ranges sampled. Standard error of the means is shown in brackets below each mean value. The result that approached significance (P=0.05-0.10) is shown in bold.

Species	Variance Ratio Test *F*	Mean percentage home range overlap		*t*-test results
		E2	*C2*	
R. rufifrons	3.847 (P=0.090)	10.35 (1.15)	26.16 (7.37)	t=-1.31 P=0.11 df=8 N=10
M. trivirgatus	5.514 (P=0.094)	69.90 (6.94)	41.90 (20.20)	t=1.54 **P=0.081** df=8 N=10

Table 7.3 Mean percentage use of treatment zone by Rufous Fantails *R. rufifrons* and Spectacled Monarchs *M. trivirgatus* after logging in Year 2 logged plot. Data were derived using the 95% Harmonic Mean method. Standard error of the means is shown in brackets below each mean percentage use value.

Species	No. individuals sampled	Mean home range size (ha)	Mean percentage use of treatment zone		
			Gapped	*Thinned*	*Retained*
R. rufifrons	24	1.257 (0.057)	15.82 (3.33)	7.32 (7.10)	76.86 (6.10)
M. trivirgatus	11	1.340 (0.144)	0	5.61 (5.62)	94.39 (5.55)

Table 7.4 Use of microhabitat by Rufous Fantails *R. rufifrons* and Spectacled Monarchs *M. trivirgatus* after logging in Year 2 logged plot (E2) and control plot (C2). Chi-square (χ^2) tests were conducted on the total number of locations of birds in each microhabitat class after logging versus the total number of locations of birds recorded in all other microhabitat classes. These results were obtained by combining data from E1 and E2 Plots and, where significant ($P<0.05$), are presented at the base of each microhabitat class column for each species. Tests were not conducted on the total number of locations of birds in all classes of microhabitat since pre-logging data was not available. Significant results and the result that approached significance ($P=0.05$-0.10) are shown in bold. Number of individual birds of *R. rufifrons* used in χ^2 analysis in each plot=4 and for *M. trivirgatus*=3. ns=not significant. na=not applicable. df=degrees of freedom.

Species/Plot/Period	Total no. of locations of birds in all classes	Total no. of locations of individuals recorded in each microhabitat class and statistical significance						
		Ground	*Bare ground*	*Woody debris pile*	*Fallen logs*	*Dense shrub regrowth*	*Lower canopy*	*Mid canopy*
R. rufifrons								
E2								
After	262	5	5	27	32	48	95	50
C2								
After	285	5 na	3 na	46 **$P=0.045$** $\chi^2=4.019$ df=1	39 ns	72 **$P=0.050$** $\chi^2=4.019$ df=1	77 **$P=0.020$** $\chi^2=5.409$ df=1	43 ns
M. trivirgatus								
E2								
After	161	0	1	2	7	67	42	42
C2								
After	218	0 na	1 na	1 na	12 **$P=0.061$** $\chi^2=3.50$ df=1	64 ns	88 **$P=0.004$** $\chi^2=8.38$ df=1	52 ns