CHAPTER 3

THE STUDY SPECIES

3.1 Introduction

The moist eucalypt forests of the NSW north coast support one of the most diverse assemblages of birds in Australia. A total of 229 species (122 diurnal passerines, 96 diurnal non-passerines, and 11 nocturnals) occur in this region (NSW NPWS 1994a). This represents 53% of the 430 species of forest-dwelling vertebrates recorded in north-east NSW (NSW NPWS 1994a). The region is a population stronghold for many passerines and some non-passerines and provides important over-wintering habitat for migratory species (NSW NPWS 1994a).

The diurnal passerines of these forests include nectarivores (e.g., honeyeaters), frugivores (e.g., orioles, figbirds), granivores (e.g., finches), foliage-, ground- and bark-foraging insectivores (e.g., robins, scrubwrens, flycatchers, thornbills, gerygones, treecreepers), ground-foraging insectivores that rake litter and soil (e.g., Eastern Whipbird, Logrunner and the lyrebirds), and predatory and scavenging species such as butcherbirds, currawongs and crows (NSW NPWS 1994a; Smith *et al.* 1995). The diurnal, non-passerine forest avifauna of the region include cockatoos, parrots, cuckoos, Australian Brush-turkey *Alectura lathami*, kingfishers, pigeons, doves and button-quail, and birds of wetlands, waterways and forest edges (e.g., ibis, egrets, rails, bitterns, herons, raptors) that may use forest trees for nesting and roosting (NSW NPWS 1994a). Old tree hollows are used for nesting by cockatoos, parrots and some kingfishers while raptors perch on dead branches and nest in large forks of old trees. Nocturnal forest birds of the region comprise six owl species, including the endangered (in NSW) Powerful Owl *Ninox strenua*, Sooty Owl *Tyto tenebricosa*, Masked Owl *T. novaehollandiae*, and Marbled Frogmouth *Podargus ocellatus* (Smith *et al.* 1995). The endangered (in NSW) Bush Stone-curlew *Burhinus magnirostris* also occurs in these forests (NSW NPWS 1994a). Large forest owls require large tracts of forest with hollow-bearing trees for nesting and a reliable and adequate supply of vertebrate prey (see Kavanagh & Bamkin 1995; Kavanagh 1997). They are particularly sensitive to habitat fragmentation associated with large-scale intensive logging and clearing (Lacey *et al.* 1990).

The North East Forests Biodiversity Study concluded that 16% of north-east NSW's diurnal passerine species are of priority conservation significance, ten of which are listed as endangered or vulnerable under the NSW Threatened Species Conservation Act 1995 (NSW

NPWS 1994a). Twenty-one percent of the region's diurnal non-passerine birds are of conservation significance, fifteen species of which are listed under this legislation (NSW NPWS 1994a). Five of the nocturnal bird species are listed as endangered while a sixth species is considered to be of conservation importance in the region (see Gilmore & Parnaby 1994).

The avian community of my study area is a subset of these groups. Insectivores that forage on ground, foliage and bark substrates comprise the bulk of this assemblage. Common species are Eastern Yellow Robin, White-browed Scrubwren, Large-billed Scrubwren, Variegated Fairy-wren, Brown Gerygone, Brown Thornbill, White-throated Treecreeper *Cormobates leucophaeus*, Grey Fantail *Rhipidura fuliginosa*, Grey Shrike-thrush, Golden Whistler and Striated Pardalote *Pardalotus striatus*. Larger ground-foraging insectivores include Noisy Pitta, Superb Lyrebird *Menura novaehollandiae*, Russet-tailed Thrush *Zoothera heinei*, and Australian Brush-turkey. Nectarivores (e.g., Scarlet Honeyeater *Myzomela sanguinolenta*, Eastern Spinebill, Noisy Friarbird *Philemon corniculatus*, Rainbow Lorikeet *Trichoglossus haematodus*), omnivores (e.g., Lewin's Honeyeater, Yellow-faced Honeyeater *Lichenostomus chrysops*, Regent Bowerbird), and granivores (e.g., Australian King Parrot *Alisterus scapularis*, Red-browed Finch) commonly occur throughout the study area. Frugivores such as White-headed Pigeon *Columba leucomela*, Topknot Pigeon *Leucosarcia melanoleuca*, Green Catbird and Brown Cuckoo-Dove *Macropygia amboinensis* are common during summer when rainforest trees are fruiting. Predatory and scavenging species such as Pied Currawong *Strepera graculina*, Grey Butcherbird *Cracticus torquatus*, Brown Goshawk *Accipiter fasciatus*, Grey Goshawk *A. novaehollandiae* and Laughing Kookaburra *Dacelo novaeguineae* frequently occur in the study area.

I chose to study six insectivorous species that forage on the forest floor and in the understorey (Table 3.1) for several reasons (see also Section 1.3). First, there has been little quantitative investigation of the ecology of these species, especially in north-east NSW (see NSW NPWS 1994a; Smith *et al.* 1995). Instead, attention has focused on describing patterns of bird species distribution, abundance and diversity across a number of foraging guilds and forested landscapes (see Pattemore & Kikkawa 1975; Milledge 1979; Howe *et al.* 1981; Osborne 1982, 1991; Howe 1986; York & Shields 1992). For instance, little is known of the

foraging and breeding biology of Pale-yellow Robins, Yellow-throated Scrubwrens and Spectacled Monarchs. Nothing is known of their home range behaviour. There has been only one quantitative study (Cameron 1975) of Rufous Fantails in Australia.

Second, terrestrial and understorey insectivores have been identified as being sensitive to habitat modification and fragmentation in forests around the world (Howe 1986; Wilcove *et al.* 1986; Recher & Serventy 1991; Willson *et al.* 1994; Sieving *et al.* 1996; Burke & Nol 1998; Recher & Davis 1998). This has been attributed to their dependence on specific amounts of core or 'interior' forest habitat, reliance on specific features of their living space, competition for scarce resources, and preference for densely vegetated nest sites and specific nesting and foraging substrates (Howe 1986; Yom-Tov 1987; Recher & Serventy 1991; Rowley & Russell 1991; Willson *et al.* 1994; Burke & Nol 1998). Recher (1999) has postulated that ground- and shrub-foraging insectivores are part of the 'next wave' of Australian passerines threatened with local extinction through the loss of suitable breeding habitat. These include ground-foraging birds that are widely distributed but scarce or are confined to narrow geographic ranges but locally abundant (see Ford 1990; Garnett 1992). Even the ubiquitous White-browed Scrubwren depends on suitable ground and low shrub substrates for food, shelter and nest sites (Cale 1994).

Third, little ecological information exists on the response of these bird species to timber harvesting in Australia. This is of particular relevance in my study area since Pale-yellow Robins and Spectacled Monarchs are species of conservation concern in NSW (Gilmore & Parnaby 1994; NSW NPWS 1994a). Spectacled Monarchs may be sensitive to habitat loss and alteration associated with logging and land clearing for agriculture (Gilmore & Parnaby 1994; NSW NPWS 1996a).

Fourth, the impact of gaps and clusters logging on the study species or other birds in Australia is not known. Only one previous study (Craig 1999) investigated the impact of gapping on forest birds. However, this involved larger (9 ha) gaps, lacked distinct gap, cluster, riparian and interstitial zones, and was conducted in a Western Australian jarrah forest.

The fifth reason for selecting these birds to study was that each species could be readily captured and their home ranges were small enough to be closely monitored in each plot. This allowed the collection of enough data to permit statistical analysis of avian population size, survivorship, home range and habitat use patterns in the research plots (see Chapters 4-7).

Sixth, the selection of congeneric or ecologically similar species provided interesting opportunities to compare patterns of response to logging among the three sets of insectivores that I studied (i.e. *E. australis* versus *T. capito*, *S. citreogularis* versus *S. frontalis*, *R. rufifrons* versus *M. trivirgatus*). This also allowed the logging responses of the first four (resident) species to be contrasted against those of the last two (migratory) species.

Finally, my study species are all members of the old Australian lineage that arose and radiated endemically (Sibley & Ahlquist 1985; Schodde 1991). This has heightened the significance of their conservation at a global scale (Schodde 1991).

In this chapter I introduce each species to provide the necessary background for subsequent chapters, which investigate how populations of these species respond to logging. I describe their identification, habitat, distribution and abundance, foraging ecology and home range, and breeding ecology. I also list other Australian birds that are ecologically similar to these species.

3.2   Eastern Yellow Robin

Identification and similar species

The Eastern Yellow Robin is a small, insectivorous passerine of eastern Australian forests and woodlands (Plates 3.1 and 3.2). It is recognisable by its bright yellow breast, tail-cocking while perched, and flirting of wings. Although identical in plumage colouration, adult males are larger in wingspan and head-to-bill length and weigh more than adult females (19-23 g cf. 16-19 g, Huggett unpubl. data - this study). Immature birds are identified by brown flecks on the primary wing coverts, nape or crown (Plate 3.2), which

Plate 3.1

Adult Eastern Yellow Robin *Eopsaltria australis* (race *chrysorrhoa*)   Photograph by Bob Weeks

Plate 3.2

Three month-old *E. australis* (race *chrysorrhoa*) showing brown-flecked crown and nape, brown-edged wing coverts and pointed tail feathers

Photograph by Bob Weeks

are moulted in their second year of life. Variation in vocalisations and breeding behaviour also distinguish between the sexes (see Marchant 1987, 1992; Doyle 1996).

Other robins that are ecologically similar to *E. australis* are the congeners, Western Yellow Robin *E. griseogularis* and White-breasted Robin *E. georgiana* of south-west and south coastal Western Australia and Mangrove Robin *E. pulverulenta* of coastal tropical northern Australia. The taxonomic relationships between other broadly similar species and their generic allocations are generally uncertain (Christidis & Boles 1994). These species include Dusky Robin *Melanodryas vittata* of Tasmanian forests and woodlands, Hooded Robin *M. cucullata* of drier woodlands and forests throughout mainland Australia, Grey-headed Robin *Heteromyias albispecularis* of north-east Queensland highland rainforests, and White-browed Robin *Poecilodryas superciliosa* of monsoonal northern Australia.

Habitat, distribution and abundance

In addition to forest and woodland, Eastern Yellow Robins occur in rainforest, mallee, *Acacia* scrub and coastal heath. Gardens and golf-courses are also frequented. Two races are recognised: the nominate in Victoria and southern NSW and *chrysorrhoa* in northern NSW and Queensland. Birds in my study feature bright yellow rumps and so belong to race *chrysorrhoa*. However, this variation in plumage colouration is likely to be clinal (Keast 1958; Ford 1979).

E. australis is an abundant, although sometimes sparsely distributed (see Oliver *et al.* 1999; Wilson 1999), resident throughout its range. Its density in dry eucalypt woodland varies from 0.22-0.68 individuals/ha in the highly fragmented northern NSW tableland communities (Ford & Bell 1981; Ford *et al.* 1985; Ford *et al.* 1986; Chan 1995; Oliver *et al.* 1999) to 0.97 individuals/ha on the NSW south coast (Marchant 1979, 1992). In moist eucalypt forest in NSW and Victoria, densities range from 0.56 to 3.0 individuals/ha (Disney & Stokes 1976; Loyn 1980; Loyn *et al.* 1980; Loyn 1993; Kutt 1996; Mac Nally 1997b; Huggett unpubl. data - this study). In the moist eucalypt forests of north-east Queensland, densities of the northern race are often higher (2-4 birds/ha, A. Chapman unpubl. data).

Foraging ecology and home range

The Eastern Yellow Robin forages on the ground. It searches for invertebrates by scanning leaf litter and exposed soil surfaces from vantage points while perched, often vertically, on the sides of saplings and shrubs. These are commonly situated 1-3 m above ground level from where the bird flies down to pounce on prey (the 'perch-and-pounce' strategy, Ford 1985a,b) such as cockroaches, millipedes, slugs, earthworms and ants (Barker & Vestjens 1989). Prey that cannot be quickly consumed at the site of capture are transported to nearby sites screened by lower canopy shrubs where presumably there is a reduced risk of predation (pers. obs.).

Understorey vegetation is also used as refuge from predators and for nesting and territory defence. The robin appears to prefer a lower-mid canopy height of 8 m or a lower shrubby canopy of up to 5 m with minimal ground cover (Marchant 1979, 1992). I observed this species foraging primarily in forest comprising a shrubby 5-10 m tall understorey with varying degrees of ground cover. I also observed robins frequently foraging along the exposed surfaces of snig tracks and the edges of newly established gaps.

The Eastern Yellow Robin occupies specific areas or home ranges within forests, woodlands and other vegetation communities. Marchant (1985, 1987, 1992) estimated home range size of this species at 0.8-2 ha in dry open forest and woodland near Moruya on the NSW south coast. Boundaries of territories are generally more loosely defined in the non-breeding season as birds forage more widely (Marchant 1987; pers. obs.).

Breeding ecology

E. australis breeds either as simple pairs or cooperatively in which helpers assist the parents raise the young (Marchant 1985, 1987). Helpers are usually males produced by the adult pair during the previous season, since young females tend to disperse out of the natal territory at or soon after the end of the breeding season or remain inconspicuous (Marchant 1987).

The Eastern Yellow Robin breeds from July-December, depending on the severity of winters and summers (Marchant 1985). The breeding cycle is initiated in July-August with primary males giving explosive 'chyop-chyop' (Pizzey & Knight 1997) calls from perches 3-6 m up in the understorey to proclaim territories and advertise for mates. This distinctive calling is maintained throughout the breeding season. Once established, territories are actively defended, intruders being repelled by both sexes in melées of low swooping dives and harsh, scolding 'k-k-kair' (Pizzey & Knight 1997) or 'chet-chet-chet-cheeet' calls (pers. obs.). These pursuits often continue over linear distances of approximately 40-80 m through the forest (pers. obs.).

Courtship feeding is practised in this species in which males feed females to build-up their energy reserves for egg-laying. This is often embellished by reciprocated behavioural rituals (see Marchant 1985) that reinforce the pair bond and are a prelude to mating. Females become inactive during this stage, conserving energy during which time mating occurs (Doyle 1996).

Suitable nest sites are investigated by both sexes but construction is undertaken by the female over 8-15 days (Marchant 1985). More than one attempt is usually made. I observed that favoured positions for nests were in forks of lower canopy trees and shrubs at heights of 1.8-7 m. They are open, cup-shaped and built of bark lined with dry grass and decorated with bark, lichen and moss. The female incubates 1-3 eggs and is fed by the primary male and occasionally one or two helpers (Plate 3.3).

Nestlings are fed and faecal sacs are removed by males with increasing female involvement in feeding as fledging approaches at 10-14 days after the hatching of the last egg (Marchant 1985; Plate 3.4). Newly fledged robins have streaked, rich brown plumage. They take refuge in temporary dormitories near the ground comprising dense low shrubs, windblown debris, vine tangles and lantana clumps. Parents and helpers provision the young in these dormitories for between 2-3 weeks after fledging (pers. obs., Marchant 1985). I observed a female parent employing a 'broken-wing' routine to distract me from newly fledged young perched in a temporary dormitory. This behaviour has also been recorded for Hooded Robins *Melanodryas cucullata* (see Graham 1993; Fitri & Ford 1997).

Plate 3.3

Adult male *E. australis* (race *chrysorrhoa*) provisioning incubating female

Photograph by Brian O'Leary

Plate 3.4

Adult *E. australis* (race *chrysorrhoa*) feeding day-old nestlings   Photograph by Brian O'Leary

Following this period the fledglings, now capable of full flight, abandon the dormitories and move up into the lower and mid-canopy strata. They progressively moult into adult plumage from around this time (Marchant 1985). They remain attended by parents and possibly helpers for a further 4-5 weeks after which full independence is gained (pers. obs.). Helpers are thought to leave their natal territories usually after their first helping season (Marchant 1985, 1992). I did not observe birds re-nesting after successful attempts, although birds that failed in their first nesting attempt usually made further attempts within the season.

3.3   Pale-yellow Robin

Identification and similar species

Pale-yellow Robins are denizens of moist coastal forests in eastern and north-eastern Australia (Plate 3.5). They are smaller than *E. australis*, engage in less tail-cocking and wing-flirting but otherwise have similar behavioural traits as Eastern Yellow Robins. Adult males are distinguished from females by their larger wingspan, head-to-bill length and body weight (13.5-16 g cf. 11.4-14.5 g, Huggett unpubl. data - this study). Immature birds are usually discernible by small flecks of rich brown juvenile plumage on their nape, crown or primary wing coverts (Plate 3.6).

The slightly smaller White-faced Robin *T. leucops* is the only congener of *T. capito*. It inhabits tropical rainforests and vine-scrubs in the northern part of Cape York and in Papua and New Guinea. *T. capito* is considered to be of conservation concern by NSW NPWS, primarily because of the isolated nature of its distribution, poorly understood ecology, unknown threatening processes, and preference for rainforest and moist eucalypt forest habitats (Gilmore & Parnaby 1994). It is also a relict of an ancient lineage of rainforest-adapted birds now confined to the mesic forests of north-east NSW, south-east Queensland and the wet tropics of north Queensland (Schodde & Calaby 1972; NSW NPWS 1994a).

Habitat, distribution and abundance

Pale-yellow Robins occur in rainforest, tall open eucalypt forest and dense riparian vegetation. In the research plots, I mainly observed this species in moist eucalypt forest with dense lower canopies (2-8 m tall) dominated by Bangalow Palm *Archontophoenix*

Plate 3.5

Adult female Pale-yellow Robin *Tregellasia capito* (nominate race)

Photograph by Bob Weeks

Plate 3.6

Four month-old *T. capito* (nominate race) showing brown-flecked face, crown and throat

Photograph by Bob Weeks

cunninghamiana, Murrogun *Cryptocarya microneura*, Rose Maple *C. rigida*, dense mantles of Water Vine, thickets of Lawyer Vine *Calamus muelleri*, Scentless Rosewood *Synoum glandulosum* and other rainforest species. I found that regenerating old snig tracks and shrubby mid-lower slopes adjoining Bangalow Palm-dominated creeklines were also favoured.

Two races of *T. capito* are recognised. The nominate race occupies lowland rainforest and moist eucalypt forest on and east of the Dividing Range from the lower north coast of NSW to south-east Queensland. Early records from the Bellinger and the upper Clarence Rivers on the NSW north coast describe the species as "freely dispersed in scrubs...and dense and luxuriant vegetation of brush-covered creeks" (North 1901-1904). Race *nana* is isolated from the nominate, commonly occurring in mainly highland rainforests (to 1500 m asl) in the Atherton region of north-east Queensland (Blakers *et al.* 1984). Birds of this race have buff instead of white lores. North-east NSW and south-east Queensland are the strongholds of the species (North 1901-1904; Gilmore & Parnaby 1994).

Pale-yellow Robins are common residents throughout their range. In the study area, they coexist with *E. australis*. However, in the north Queensland wet tropics, the species occupy separate types of forest, possibly because of site-specific variation in vegetation structure and density (Chapman & Harrington 1997). In this region, areas of tall open forest invaded by rainforest comprise dense lower canopies that reduce the amount of incident light and create confined foraging space. This favours the smaller and possibly more manoeuvrable Pale-yellow Robin at the expense of its larger counterpart (see also Smyth 1996).

There are very few measures of the abundance of this species. Osborne (1991) recorded the nominate race at significantly higher abundance (0.47 birds/station covering a 120 m point count area) in subtropical rainforest at low altitudes (300-400 m asl) than at higher elevated sites (0.17 birds/station) in the Washpool area west of Grafton in northern NSW. Binns (unpubl. data) obtained densities of 0.64-0.8 individuals/ha before logging in upland rainforest near Urbenville in northern NSW. In my study, I recorded pre-logging densities of 0.78-1.44 individuals/ha.

Foraging ecology and home range

T. capito employs a similar perch-and-pounce foraging strategy to that used by *E. australis*. Swivelling around shrub and sapling stems when perched vertically is commonly used to scan larger areas of the forest floor and detect threats (pers. obs.; Frith 1984). Pale-yellow Robins also make successive raids or sorties from low vantage points such as small saplings and fallen logs, pouncing on prey on the ground and returning to the same or nearby perch to consume the food (Chisholm 1960; Crome 1978; Frith 1984). Prey items include beetles, cockroaches, ants, earthworms, millipedes and other invertebrates obtained from moist leaf litter (Blakers *et al.* 1984).

I observed Pale-yellow Robins foraging more frequently on vegetated ground surfaces than *E. australis*. However, insects are occasionally gleaned from the incubation mounds of Australian Brush-turkeys, often while the mounds are being worked (Jones 1987). I did not observe Pale-yellow Robins foraging along the exposed surfaces of logging trails or fire-trails in the research plots.

The home range of the Pale-yellow Robin has not been determined by previous studies.

Breeding ecology

The breeding season of *T. capito* extends from September-December (nominate race) (Pizzey & Knight 1997) and July-January (race *nana*) (Boles 1988). Pale-yellow Robins breed as simple pairs or cooperatively, although I only observed three instances of the latter strategy in my study. I found that helpers were yearling males that may or may not have been related to the breeding pair. Cooperative breeding has not been previously documented for this species. I also observed this species living in small groups both in the breeding and non-breeding seasons. More work is needed to determine the nature of the relationships between individual birds within these groups.

Male Pale-yellow Robins proclaim territories by issuing repetitious squeaks of mid-high pitch from perches located 2.5-9 m up in the lower-mid canopy (pers. obs.). Harsh, scolding 'scairr' (Pizzey & Knight 1997) calls are sometimes given to repel intruding males. These

are often followed by vigorous pursuits using fast horizontal flights at heights of 2-9 m, sustained for linear distances of approximately 25-50 m (pers. obs.). Helpers are generally tolerated in breeding territories. I observed adult male Pale-yellow Robins courtship-feeding females.

The selection and construction of nest sites is undertaken by the female (North 1901-1904; pers. obs.). I recorded females constructing nests over periods of 7-15 days. Nests are open, cup-shaped structures of grass, leaves, rootlets, thin bark strips and moss bound together with spider web. Lichen, moss and bark strips decorate the exterior. Favoured positions are forks in saplings and junctions of stems and Lawyer Vine leaves situated at 1.5-6 m above the ground. A dense canopy that often features Bangalow Palm fronds in the mid-layer and rainforest trees and emergent eucalypts in the upper stratum is required. I observed pairs making only one or two nesting attempts in the season.

I observed females incubating two eggs over periods of 14-18 days. During this time, I observed them being fed by the primary male and leaving the nest for short periods to forage, bathe and preen. Males fed nestlings and removed faecal sacs. Where present, auxiliary males also delivered food but less frequently than primary males. Females delivered food as nestlings become more developed and food was distributed evenly among fledglings (pers. obs.).

I recorded fledging in this species at 15-19 days after the second egg hatched. Newly fledged birds perch in dormitories, usually located under dense mantles of *Cissus* vine and thick rainforest shrubs at heights of 1.5-3 m. They remain huddled together for the first 3-4 days after fledging and are attended by both parents and, where present, the helper (pers. obs.). After this time, I found that fledglings separate, each following either parent and continuing to use temporary dormitories for a further 7-10 days. These dormitories were spaced further apart and increasingly higher up (4-9 m) in the low-mid canopy strata, reflecting the fledglings' improving manoeuvrability through the dense understorey.

I recorded parent Pale-yellow Robins continuing to chaperone and feed their young for a further 7-8 weeks. During this time the fledglings abandoned dormitories, developed and refined their own foraging skills, and moulted into their adult plumage. Helpers no longer

assisted in the care of the young birds. I determined that full independence was achieved at approximately 9-10 weeks after fledging. I did not observe birds re-nesting after successful attempts. I was not able to determine if birds that failed in their first nesting attempt made further attempts within the same season.

3.4 Yellow-throated Scrubwren

Identification and similar species

Yellow-throated Scrubwrens are terrestrial insectivores of eastern and north-eastern Australian forests and woodlands. Males are distinguished from females by a black mask extending from bill to lores and a bright yellow throat (Plate 3.7), with females possessing a brown facial mask (Plate 3.8). Immature birds lack the plum-red iris characteristic of adults (Geering 1992; pers. obs.). Adult males weigh between 15-19 g while adult females range from 14.1-17.2 g (Huggett unpubl. data - this study).

Ecologically similar congeners include White-browed Scrubwren *S. frontalis*, Tasmanian Scrubwren *S. humilis*, Tropical Scrubwren *S. beccarii*, and Atherton Scrubwren *S. keri*. The Fernwren *Oreoscopus gutturalis* of montane rainforests near Atherton in north-eastern Queensland has similar foraging and nesting habits but different behavioural traits (see Bravery 1970; Gill 1970).

Habitat, distribution and abundance

Yellow-throated Scrubwrens inhabit rainforest, moist eucalypt forest, woodlands and creeks with dense ground cover, fallen logs and woody debris. Moist eucalypt forest regenerating after logging is commonly utilised (pers. obs.). The availability of a permanent or ephemeral water supply seems to influence the location of home ranges and nest sites (Marshall 1930; pers. obs.).

Yellow-throated Scrubwrens occur in two geographically isolated populations: the Atherton region of north-east Queensland and coastal south-east Queensland to the Illawarra region in NSW. Atherton birds are found almost entirely above 500-600 m asl in upland tropical

Plate 3.7

Adult male Yellow-throated Scrubwren *Sericornis citreogularis*
Photograph by Bob Weeks

Plate 3.8

Adult female *S. citreogularis* that bred with the male shown in Plate 3.7 in 1998
Photograph by Bob Weeks

rainforest and moist eucalypt forest (Frith 1984; Boles & Longmore 1989). Birds of the southern population are "inhabitants of the rich brushes of the coastal districts and secluded valleys" (North 1901-1904), situated below 800 m asl.

S. citreogularis is a common resident throughout both divisions of its geographic range. It coexists with two congeners, the White-browed Scrubwren and the generally arboreal Large-billed Scrubwren *S. magnirostris*, in the northern (see Crome *et al.* 1994) and southern (see Kikkawa *et al.* 1965; Gibson 1977; Howe 1986; Smyth 1996) parts of this range.

The abundance of the Yellow-throated Scrubwren varies across its range. Norris (1964) recorded an average of 40 individuals at Tooloom Scrub in northern NSW each time a 3.2 km transect was censused. Binns (unpubl. data) recorded 1.1-1.3 birds/ha before logging in upland rainforest near Urbenville in northern NSW. I obtained pre-logging densities of 1.1-2.9 birds/ha in my research plots. Osborne (1991) found the species present at 15 of 30 stations sampled in upland subtropical rainforest at Washpool but absent from all but 3 of 30 stations in moist tall open forest. Howe (1986) found the species rare or absent in rainforest patches of 2.5 ha or less on Dorrigo Plateau in north-eastern NSW. Gosper (1992) recorded *S. citreogularis* on 77% of transect counts (mean of 2.5 individuals per count) in upland rainforest on the Richmond Range in north-eastern NSW.

Foraging ecology and home range

Yellow-throated Scrubwrens employ three foraging strategies. The main strategy involves a continuum of rapid hops across the moist forest floor to glean prey opportunistically from leaf litter or exposed soil surfaces such as snig tracks. The second method comprises slower, more methodical hopping forays over generally smaller areas in which soil, leaf litter and decaying wood surfaces are intensively searched for prey. Probing of leaf litter to reveal prey is mainly used in this system. The third strategy features a sequence of hop-short flight-hop forays along linear features of the forest floor such as prominent fallen logs.

The main prey items are beetles, cockroaches, winged termites, earthworms, woodlice, spiders and other insects. I observed birds eating fungi, mainly during winter when insects were less available. Small seeds have also been recorded in their diet (Marshall 1930).

Mated pairs usually forage together or in close proximity to each other throughout the year (pers. obs.). When separated, contact is maintained by high-pitched, nasally whistles given by both sexes. A sharp 'tick' (Pizzey & Knight 1997) is given upon alarm, occasionally followed by body-crouching in a motionless state (pers. obs.). In one instance when a Pied Currawong swooped low through the forest, I observed the maintenance of this position by a male bird for 4 minutes. Harsh 'rattle' vocalisations are also given by territory-holding males upon detection of intruders in apparent bids to repel them out of the immediate area.

Larger ground-foraging species such as Superb Lyrebird (see also Hyem 1937), Logrunner (see also Zusi 1978) and Australian Brush-turkey are often followed by this species (pers. obs.). On a number of occasions, I observed Yellow-throated Scrubwrens snatching insects disturbed by the vigorous raking actions of these species, often within 1 m of the foraging bird.

Previous studies have not determined the home range of this species.

Breeding ecology

The breeding season of this species usually extends from September-January in the south (pers. obs.) and July-March in the north (Pizzey & Knight 1997). *S. citreogularis* breeds as simple pairs in well defined territories. Breeding males use a strong melodious warble to proclaim territory boundaries and advertise their presence to prospective mates (pers. obs.). Females also occasionally warble although the call is fainter and truncated. Territories are defended against other individuals of this species, especially young roaming males. Repulsion of intruders by the male territory holder usually involves low swooping flights interspersed with 'branch-above' hopping, body posturing, feather-fluffing and harsh scolding vocalisations (pers. obs.). *S. frontalis* and other species are also occasionally repelled. I observed and heard males engaging in mimicry, often when resting on the ground under thick low cover such as clumps of *Lantana camara*.

Adult male *S. citreogularis* courtship-feed females during the weeks leading to mating. The rate of supply of prey items quickens in the 3-4 days before mating (pers. obs.). Potential

nest sites are surveyed by the female. I found that favoured sites were often over creekbeds or waterholes at heights of 2-8 m or in rainforest trees, Lawyer Vine or the underside of *Cissus* mantles 4-11 m above the ground. Nests are large, domed structures of rootlets, twigs, leaves, palm fibre, moss and lichen, usually with a protective hood of grass, rootlets and fine twigs. These are suspended from well-shaded Lawyer Vine, drooping branches of large-leaved rainforest trees such as Grey Bolleywood *Neolitsea dealbata* and Rose Walnut *Endiandra discolor* and occasionally, Bangalow Palm fronds. I observed construction occurring over 11-25 days and 2-4 attempts being made before a completed nest was used.

I observed females incubating 2-3 eggs over a period of 17-22 days. They were fed by the male and left the nest for short periods each day to forage, bathe and preen. Both sexes fed nestlings often with several winged termites supplied in each delivery.

Fledging takes place at 15-19 days after the last egg has hatched (pers. obs.). I observed fledglings taking refuge in dormitories situated 0.1-1.2 m above the ground, usually on fallen branchlets or logs under dense shrubs, lantana clumps, debris piles or ferns. Both parents delivered prey items in rapid succession to, and equally distributed among, the perched young. The fledglings huddled together for the first 6-9 days, moving between dormitories by hopping and flapping along the ground. Open areas are avoided and male parents often call to move fledglings onto safer dormitories if threatened (pers. obs.).

I witnessed the breakdown of dormitory use by *S. citreogularis* fledglings during the third week after fledging. With increasing strength and mobility, young birds eventually left dormitories to follow each parent separately on feeding journeys along the forest floor, noisily begging food. These chaperoned journeys were punctuated by 'rest stops' during which young would wait on or near the ground for parents to return with food at frequent intervals. Only areas of forest with closed or mostly closed lower-mid canopies were used for these journeys. I encountered male parents chaperoning young more often than I observed female parents undertaking this role.

After a further 3-4 weeks, young scrubwrens had gained sufficient foraging and threat awareness skills to become independent of their parents. Therefore, a total of 6.5-7 weeks was required for fledgling Yellow-throated Scrubwrens in the study area to gain full

independence. This approximates postfledging care periods observed in White-browed Scrubwrens (see Magrath *et al.* in press). It also supports the assertion that parental care is prolonged in Australian passerines compared with that experienced by their northern hemisphere counterparts (see Skutch 1976; O'Connor 1984; Rowley & Russell 1991).

I recorded the occasional rearing of second broods in which the adult female left the male during the last 2-3 weeks of chaperoning young while she began constructing a new nest. New nests at different sites were built for each separate nesting attempt by this species.

3.5   White-browed Scrubwren

Identification and similar species

White-browed Scrubwrens are small, mostly terrestrial insectivores of coastal eastern, southern and south-western Australia. Males have a black or blackish face mask and generally brighter plumage than females (Plates 3.9 and 3.10; Disney & Lane 1974). Ambrose (1985) found, however, that some West Australian males have brown faces. Immature birds are duller in plumage, lack a sub-terminal band on the tail feathers, have a less distinct white eyebrow and a fawn iris (North 1901-1904; pers. obs.). Adult males weigh between 10.9-13.6 g while adult females range from 9.7-12.8 g (Huggett unpubl. data - this study).

Ecologically similar congeners in Australia include Tasmanian Scrubwren, Atherton Scrubwren, Yellow-throated Scrubwren, and Tropical Scrubwren. The Fernwren of tropical rainforests in north-eastern Queensland has similar foraging habits but different behavioural traits (see Bravery 1970; Gill 1970).

Habitat, distribution and abundance

White-browed Scrubwrens inhabit dense low shrubs, woody debris piles, fallen logs and lantana clumps in eucalypt forest and woodland, rainforest, heath, mangroves, mallee and parks and gardens at all altitudes. They can persist in narrow strips of riparian vegetation and blackberry clumps surrounded by cattle pastures (Huggett 1991, 1994a,b; Wilson 1999).

Plate 3.9

A pair of White-browed Scrubwrens *Sericornis frontalis* (nominate race) bathing in creek (male on left)
Photograph by Brian O'Leary

Plate 3.10

Adult male *S. frontalis* (nominate race) with moth   Photograph by Brian O'Leary

Three races of *S. frontalis* are recognised (Ambrose 1985; Christidis & Boles 1994). The nominate race occurs in mainland south-eastern Australia west to the Adelaide region. Race *maculatus* has spotted throat and chest plumage and occupies saltbush, mallee and mulga habitats in coastal eastern, southern and south-western Western Australia. It appears to intergrade with the nominate race in the South Australian Ranges region (Blakers *et al.* 1984). Race *laevigaster* ranges from coastal north-east Queensland to the far north coast of NSW. Males of this race lack the distinct black facial mask that characterises males of the nominate race (Pizzey & Knight 1997). I observed only birds of the nominate race in my study.

White-browed Scrubwrens are one of the most common species of the Australian bush. They are breeding residents throughout their range and often coexist with other scrubwren species such as *S. citreogularis* and *S. magnirostris.*

A number of measures of abundance of this species have been obtained. Disney & Stokes (1976) recorded 5.0 birds/ha in moist eucalypt forest at Bathurst. Loyn (1980) and Loyn *et al.* (1980) recorded 0.3-4.4 birds/ha in dry and moist eucalypt forest at Boola Boola State Forest in south-east Victoria. Ambrose (1985) obtained population densities of 0.39-5.26 birds/ha in arid, semi-arid and moist coastal heath in Western Australia. Bell (1983) recorded a mean number of birds per flock of 3.63±1.4 in dry eucalypt woodland at Wollomombi on the NSW northern tablelands. Binns (unpubl. data) recorded 0.54-0.64 individuals/ha before logging in upland rainforest near Urbenville in northern NSW. Mac Nally (1997b) counted a maximum of 1.1 birds/ha in wet sclerophyll forest near Melbourne. Magrath *et al.* (in press) studied the breeding of 35-48 groups over 4 years (81.9-112.3 individuals or 2.05-2.81 birds/ha) in 40 ha of eucalypt woodland and planted native gardens at the Australian National Botanic Gardens, Canberra. In my study, I recorded pre-logging densities of 1.44-2.33 birds/ha.

Foraging ecology and home range

White-browed Scrubwrens forage for terrestrial and arboreal invertebrates using a combination of two different but complementary strategies (pers. obs.; see Keast 1978;

Thomas 1980; Calver & Wooller 1981; Ambrose 1985; Cale 1994). The first strategy involves searching for prey in leaf litter and woody debris on or just above the forest floor. In this system, pairs, individuals or small groups move by a series of hops and short, low flights. These are interspersed with periods of intensive examination of specific localities such as piles of woody debris for prey. These are obtained primarily by gleaning in which birds flick leaves aside and by probing. Common prey items are moths, millipedes, cockroaches, spiders, small beetles and earthworms. Fungi or possibly maggots within fungal caps are occasionally eaten, especially in winter (pers. obs.). In the second system, birds fly up into low shrubs and saplings, gleaning and probing for insects on leaf surfaces, under bark, and in the debris-laden apices of *Cordyline* sp. and Bangalow Palms (pers. obs.; Wooller & Calver 1981; Ambrose 1985; Recher & Davis 1998). These are usually brief forays that can also fulfil other goals such as reconnaissance and territory defence. Birds return to the ground-foraging mode after short periods in these arboreal locations.

Seasonal variation in insect availability and ambient temperatures may influence the proportionate use of either foraging strategy by *S. frontalis*. I observed individuals foraging in 1-2 m tall vegetation more commonly in summer than winter. This supports the argument that increased availability of foliage insects and rising ground temperatures in summer in temperate Australian woodlands and forests attracts winter ground-foragers into above-ground vegetation (Recher *et al.* 1983; Woinarski & Cullen 1984; Ford *et al.* 1990).

When separated, foraging scrubwrens maintain contact through short 'pips' (Ambrose 1985). Harsh scolding 'zizz-zizz-zizz' calls are given upon detection of intruders such as cuckoos, Lace Monitor *Varanus varius* and other scrubwrens entering breeding territories. I observed some individuals body-crouching when threatened by raptors and Pied Currawongs. Immature birds tend to forage together for some time after independence has been gained (pers. obs.).

In temperate environments, White-browed Scrubwrens may experience relatively minor seasonal variation in food supply (Magrath *et al.* in press). This is reflected in their use of home ranges of generally consistent size. In Western Australia, Ambrose (1985) and Ambrose & Davies (1989) recorded mean home ranges of groups after breeding in coastal heath at Hamelin and moist eucalypt forest at Rockingham of 3.16 and 3.52 ha, respectively.

Breeding ecology

White-browed Scrubwrens breed from July-February (Magrath 1997) as simple pairs or cooperatively in trios of a dominant pair and a subordinate or secondary male. Groups containing one or more additional subordinate males have occasionally been recorded (Bell 1983; Ambrose 1985; Ambrose & Davies 1989; Magrath & Whittingham 1997; Magrath *et al.* in press). Ambrose (1985) defined four social groups in this species: single pair, communal group featuring a breeding pair and helpers, group comprising a breeding pair and secondary birds that assist only in territory defence, and roaming, non-territorial groups of immature and non-breeding birds. Only the first two groups were detected in my study.

All-purpose, year-round territories are established and maintained within the home ranges of pairs and groups of this species (see Brooker 1998). In my study, I observed primary males advertising and vigorously defending breeding territories against intruding *S. frontalis* males and other species such as Large-billed Scrubwrens, Brown Gerygones and Brown Thornbills.

Primary males and occasionally secondary males make short flights and hops up branches of low shrubs and saplings to proclaim territories, monitor the ground-based movements of other scrubwrens and predators, and repel intruders (Huggett 1992; pers. obs.). Strong and drawn-out 'tseer-tseer-tseer' or 'seat-you, seat-you, seat-you' (Ambrose 1985; Pizzey & Knight 1997) calls are broadcast from exposed perches in these shrubs. Roaming males that do not belong to the territory holder's group are chased away by territory holding male/s, often in melées of feather-fluffing, body-posturing, 'branch-above' hopping and scolding vocalisations.

Primary males engage in courtship-feeding of adult females (pers. obs.). I observed courting males frequently supplying prey items to females in the weeks prior to nesting. Nest sites are selected by females often in the presence of primary males. Nests are dome-shaped structures of dry grass, rootlets, twigs, bark strips and leaves with a rounded side-entrance (Plate 3.11). They are usually built over 9-14 days on or just above the ground and are well concealed in grass tussocks, exposed tree roots, ferny creek banks and flood debris (pers.

Plate 3.11

Adult male *S. frontalis* (nominate race) at entrance of concealed nest

Photograph by Graeme Chapman

obs.). Other locations include the forks of tea-tree 2-3 m above ground (North 1901-1904), in *Macrozamia* saplings (Ambrose 1985) and coats hanging in outhouses (Pizzey & Knight 1997).

Females lay 3 eggs per clutch at two-day intervals and incubate them over 17-22 days (Magrath *et al.* in press). They are fed by primary males and leave the nest for short periods to forage and bathe in nearby creeks and waterholes. Multiple-brooding often occurs in this species (see Ambrose 1985; Whittingham *et al.* 1997; Magrath *et al.* in press). Nestlings are provisioned by both parents and male helpers. Winged termites, beetle larvae, moths and weevils are favoured prey items during this phase (Ambrose 1985). Primary males remove faecal sacs and make low decoy flights to distract intruders from the vicinity of nests (pers. obs.).

Fledging occurs at between 12-18 days after the last egg has hatched (Magrath *et al.* in press). I observed fledglings taking refuge in grass tussocks, lantana thickets and other low vegetation. They remain huddled together in these temporary dormitories for the first 3-4 days, after which they begin pursuing adults for progressively greater distances through dense ground cover. Dormitories then become further spaced apart and are used for shorter periods. During this time, young birds are fed by both parents and a helper where one exists. I observed primary males detecting threats, repelling intruders, and calling fledglings to safe locations in dense ground cover. When chaperoning young, exposed areas such as snig tracks and newly created gaps were avoided by parents.

The use of dormitories generally ceases after about the second week since fledging (pers. obs.). Young birds usually follow either parent separately or one parent exclusively with only brief rests, begging food and being shown basic foraging techniques. This continues for a further 3-6 weeks until young birds are able to forage successfully for themselves. In my study, White-browed Scrubwrens had a post-fledging care period of 5-8 weeks (cf. 5.6-7.3 weeks recorded by Magrath *et al.* in press). Newly independent young females usually leave their natal territories, although their male siblings may remain to join breeding groups in subsequent seasons (Magrath *et al.* in press).

3.6   Rufous Fantail

Identification and similar species

Originally described as the Rufous-fronted Fantail (Latham 1801), this species is a small insectivore of coastal northern, eastern and south-eastern Australia. Sexes share identical plumage (Plate 3.12). Immature birds have duller plumage with rufous-edged wing feathers (Plate 3.13). Adult body weight varies between 8.5-12.0 g for both males and females (Huggett unpubl. data - this study).

The Rufous Fantail has four congeners in Australia. These are the smaller Grey Fantail *R. fuliginosa* and Mangrove Grey Fantail *R. phasiana*, and the larger Willie-Wagtail *R. leucophrys* and Northern Fantail *R. rufiventris*. Both the Northern Fantail and Mangrove Grey Fantail occur in tropical northern Australia. The Grey Fantail and Willie-Wagtail inhabit a wide range of habitats throughout Australia. Willie-Wagtails are common birds of open habitats such as roadsides, fields, parks and other urban sites.

Habitat, distribution and abundance

Rufous Fantails utilise ground, lower and mid-canopy strata in moist eucalypt forest, rainforest, mangroves, monsoon forest, low coastal woodland, parks and gardens. They are a summer breeding migrant to eastern and south-eastern Australia, arriving from New Guinea and north Queensland in September-October and departing to return there in March-April (Gilbert 1935; Bell 1970; Mac Nally 1997a; pers. obs.). Immature birds often leave north- east NSW forests one-three weeks after adults (pers. obs.). Birds migrating north have been recorded 19 km out to sea off Sydney (Anon. 2000).

Northern birds do not undertake the north-south migration of their southern counterparts, although an altitudinal movement from upland to lowland forests has been recorded in north-east Queensland in autumn (Boles 1988). Inland movements during the wet summer season near Darwin have been suggested (Storr 1977). *R. rufifrons* is a resident of Pacific islands such as the Marianas (Craig 1996) and Carolines (Pratt *et al.* 1987) and some Indonesian islands (Pizzey & Knight 1997).

Plate 3.12

Rufous Fantail *Rhipidura rufifrons* in full adult plumage.   Photograph by Bob Weeks

Plate 3.13

R. rufifrons in immature plumage. Note rufous shoulders, light eyebrows and faint black chest markings

Photograph by Bob Weeks

There are 30 nominal forms of the *R. rufifrons* complex (Christidis & Boles 1994). Despite attempts to identify separate races (see Blakers *et al.* 1984) and species (Storr 1984; Johnstone 1990), subspecific limits are unclear and extralimital populations have been poorly documented (Christidis & Boles 1994). Therefore, no races of this species are currently recognised.

Although generally common throughout their breeding range, Rufous Fantails exhibit considerable variation in abundance relative to forest type. In dry eucalypt woodland on the NSW south coast, 0.03-0.05 birds/ha have been recorded (Marchant 1979). In contrast, Loyn (1980) and Loyn *et. al.* (1980) counted 0.6-0.8 birds/ha in moist eucalypt forest in south-east Victoria. Robinson (1991) obtained a mean density of 0.69 ± 0.60 birds in February in montane wet sclerophyll forest in north-east Victoria. Gosper (1992) counted 2.6 (mean) birds per census in lowland tall open wet sclerophyll forest in the Richmond River district of northern NSW. In wet sclerophyll forest near Melbourne, Mac Nally (1997b) recorded a maximum of 0.28 birds/ha. Binns (unpubl. data) recorded 0.84-1.22 individuals/ha before logging in upland rainforest near Urbenville in northern NSW. In my study, I recorded 1.33-2.66 birds/ha prior to logging.

Foraging ecology and home range

Rufous Fantails forage for small insects in the foliage and bark of understorey vegetation to 10-14 m above ground and occasionally on or near the ground (Huggett 1991, 1994b). Main prey items include tipulid and tabanid flies, bugs (Hemiptera), beetles (Coleoptera), wasps (Hymenoptera), bees and ants, caterpillars, spiders (Araneida) and small moths and butterflies (Lepidoptera) (North 1901-1904; Cameron 1975, 1985; pers. obs.). In rainforest, the taxonomic composition of insect prey taken by *R. rufifrons* is narrow and invariable (see Cameron 1975).

Rufous Fantails locate prey using two basic methods: 'sit-and-wait' (Cameron 1975) and active hunting or progressive searching (Cameron 1975). In the former method, birds scan their surroundings from perches maintained for more than five seconds. The latter approach (also termed 'flitting', Crome 1978) involves birds rapidly searching for prey while on the

move through foliage or on the ground. Wings and tails are usually fanned, presumably to help flush insects from leaf, bark or log surfaces. Both methods are achieved by combinations of four types of movement: hops, switch-sidles (in which birds change the directions that they face during hops along branches), runs, and flights (see Cameron 1975).

R. rufifrons attacks and/or captures prey using three specific manoeuvres: hawking or flycatching, gleaning, and hovering (Cameron 1975; Crome 1978; pers. obs.). Hawking involves birds flying from a substrate to capture insects in the air. Cameron (1975, 1985) observed that flycatching comprised up to 70% of all foraging manoeuvres in this species. Fantails also glean insects from the surfaces of fallen logs, woody debris piles, leaf litter and occasionally exposed ground by snatching or pecking. Hovering entails birds flying to a substrate and gleaning or pecking the prey item while maintaining their position without perching.

Rufous Fantails generally forage alone. High-pitched squeaky 'chip-chip' calls are given, usually in quick succession, during foraging. Upon detection of predators, this call becomes higher-pitched, more repetitious and often accompanied by fast looping flights and quick retreats into dense vine mantles.

Previous studies have not determined the home range of this species.

Breeding ecology

Rufous Fantails breed from September-February as simple pairs (Pizzey & Knight 1997). In southern Queensland and north-eastern NSW, active nests have been recorded in early September (North 1901-1904).

Following their spring return to southern and eastern forests, *R. rufifrons* spend several days intensively foraging in low vegetation and on or near the ground (pers. obs.). Males reconnoitre tracts of forest for potential mates and suitable breeding territories. After approximately 10-21 days, males begin establishing territories (pers. obs.). Males defend territories against other male Rufous Fantails and Grey Fantails (pers. obs.). Strong, descending squeaky songs are given from prominent perches to proclaim territories and

advertise for mates. Intense vocal duels, featuring rapid and prolonged song given from a range of different perches, are occasionally undertaken by two males competing for one female (pers. obs.).

I observed varying degrees of courtship-feeding in *R. rufifrons* in the study area. Some males fed females regularly for 2-3 weeks prior to, and during, nest site selection and construction. Others only partially fed females during this period.

I observed both sexes in colour-banded pairs reconnoitring forest for suitable nest sites. Favoured sites were forks in low leafy shrubs and saplings, junctions in horizontal branches and vine tangles situated between 1.5-5 m above ground. Plants with large leaves such as *Guioa semiglauca*, *Endiandra discolor*, *Schizomeria ovata* and Bangalow Palm were selected for their screening quality by Rufous Fantails. I observed only females making the final selection of nest sites, occasionally after one or two unsuccessful nesting attempts.

Nest construction is undertaken by females only or both sexes in unison (pers. obs.). Nests are tightly woven cup-shaped structures with tapering bases attached to branches by dry grass and cobwebs. Thin bark strips, moss, rootlets, grass and spider web comprise the nest which is built over 8-15 days (Robin 1959; pers. obs.). Two-three eggs are laid and incubating commences up to 4-5 days after completion of the nest (Robin 1959). Eggs hatch after 15-17 days (pers. obs.; Robin 1959). Brooding females are fed by males and double broods are occasionally raised. Brush Cuckoos *Cacomantis variolosus* occasionally parasitise Rufous Fantail nests (North 1901-1904).

Both parents provision nestlings (Plate 3.14) and remove faecal sacs. Fledging occurs approximately 15-17 days after the last egg has hatched (Robin 1959; pers. obs.). Immediately after leaving the nest, I observed fledglings taking refuge in dense *Cissus* mantles 5-12 m above the ground. Huddled together in these temporary dormitories, they are fed by parents for 3-4 days, after which they begin moving out to separate dormitories at heights of 2-12 m (pers. obs.). Each parent attends only one fledgling which follows the foraging adult for increasingly longer distances through the understorey. Contact is maintained by constant 'chip-chip' calls of fledglings.

Plate 3.14

R. rufifrons feeding two nestlings at a nest in riparian rainforest   Photograph by Brian O'Leary

Dormitory use ceases after the second week since fledging and young birds begin learning foraging and survival techniques by continuing to follow parents for a further 2-3 weeks. Feeding is reduced and young fantails gradually develop their own prey detection, capture and threat avoidance skills during this period. I observed juveniles becoming fully independent of parents at 4-5.5 weeks after fledging. Unlike the newly independent young of resident species, immature Rufous Fantails may remain in or near their natal territories until their departure north in March-April (pers. obs.).

3.7   Spectacled Monarch

Identification and similar species

Originally described as the Black-fronted Flycatcher *Monarcha gouldi* (Temminck 1826 in Gould 1848), this species is a small insectivore of coastal eastern and north-eastern Australia. Adult males are slightly larger (head-to-bill length 33.7-35.0 mm; wingspan 243-250 mm) than adult females (head-to-bill length 33.2-33.9 mm; wingspan 230-244 mm) (Huggett unpubl. data - this study). Adult females also have a slightly duller black facial patch and orange chest than adult males (Boles 1988). Adult body weight is 11.8-14.0 g (Huggett unpubl. data - this study). Immature birds have a dull grey facial mask and grey throats.

Three congeneric species occur in Australia. These are the larger Black-faced Monarch *M. melanopsis* and Black-winged Monarch *M. frater*, and the smaller White-eared Monarch *M. leucotis*. *M. melanopsis* occurs sympatrically with *M. trivirgatus* but usually occupies the mid-upper canopy strata and extends south along the eastern Victorian coast and ranges (Blakers *et al.* 1984). *M. frater* occurs in tropical rainforest, woodland and mangroves on the north-east coast of Cape York and in New Guinea (Blakers *et al.* 1984). The endemic *M. leucotis* occurs sympatrically with both the Spectacled and Black-faced Monarchs but does not extend to the NSW south coast and Victoria (Blakers *et al.* 1984).

Both *M. leucotis* and *M. trivirgatus* are species of conservation concern in NSW. This is because of their low population densities, poorly understood ecology, the extent of loss and modification of their core moist forest habitat, and degree of ecological specialisation

(Gilmore & Parnaby 1994; NSW NPWS 1994a). *M. leucotis* is a nationally threatened species (see Gilmore & Parnaby 1994) and has been recorded as a vagrant at Woolgoolga Creek Flora Reserve, north of Coffs Harbour (Conole *et al.* 1995) and as a resident at Iluka Nature Reserve on the NSW far-north coast (Blakers *et al.* 1984).

Habitat, distribution and abundance

Spectacled Monarchs inhabit the lower-mid strata of rainforest, moist eucalypt forest and mangroves. In north-east NSW, they prefer dense groves of Bangalow Palm, *Guioa semiglauca*, *Quintinia verdonii*, *Caldcluvia paniculosa*, *Cryptocarya microneura*, *Ceratopetalum apetalum* and other rainforest species that are often cloaked in *Cissus* vine and situated along creeks, gullies and lower slopes (pers. obs.). Occasionally they forage and breed in small (0.5-1 ha) densely vegetated patches of regenerating moist eucalypt forest in rural residential areas that are contiguous with larger tracts of forest (pers. obs.).

Spectacled Monarchs are summer breeding migrants to south-east Queensland and north-east and east NSW, arriving in mid-September and returning north in April (Boles 1988). They are vagrants to the NSW central coast and Illawarra-Shoalhaven regions (Gilbert 1935; Gibson 1989; Russill & Russill 1996; Chafer 1997). In the northern part of their range (Rockhampton to Cape York) they are year-round residents but in winter move out of rainforest into more open habitats (Boles 1988). Some birds migrate across Torres Strait to New Guinea and to some Indonesian islands (Draffan *et al.* 1983; Beehler *et al.* 1986).

There are two recognised races of *M. trivirgatus*: *albiventris* on Cape York and *gouldi* south of 15°S (Storr 1973). Birds of the *albiventris* race have mainly white underparts while *gouldi* birds have mostly orange underparts. *Gouldi* birds are resident in the Atherton region but populations south of 25°S (near Hervey Bay, southern Queensland) migrate north in winter (Blakers *et al.* 1984). Both races co-exist on Cape York in winter (Blakers *et al.* 1984). *Gouldi* birds occurred in my research plots and surrounding moist forest.

Spectacled Monarchs are moderately common but sparsely distributed throughout their breeding range. North Queensland birds appear to be more common, at least during winter, than their southern counterparts (Crome 1978; Crome *et al.* 1996).

There are few measures of abundance of *M. trivirgatus*, reflecting the very few studies undertaken of this species. Shields *et al.* (1985) observed 0.6 birds/ha along a 1 km-long transect in upland rainforest in Upper Hastings River, west of Port Macquarie on the NSW mid-north coast. Gosper (1992) recorded 0.7 (mean) birds per census in lowland tall open wet sclerophyll forest in the Richmond River district of northern NSW. I recorded 0.33-0.55 individuals/ha before logging in my study.

Foraging ecology and home range

Spectacled Monarchs actively forage for small insects in the foliage of predominantly lower and mid-canopy vegetation. Foraging height ranges between 2-16 m, depending on the density, distribution and floristic composition of vine, shrub and tree layers (pers. obs.; Crome 1978). I observed birds flying to 20 m, presumably to survey the forest below. Hughes & Hughes (1980) observed this species foraging from just above ground level to 4.5 m in moist forest 'scrub' at Widgee in south-east Queensland. They also occasionally search for arthropods on the ground (Boles 1988; Russill & Russill 1996), on fallen logs, and in thick vine tangles just below the upper canopy (pers. obs.). Main prey items include moths, winged termites, flies, bugs, ants, cockroaches, small snails and spiders (MacGillivray 1917-1918; pers. obs.).

Spectacled Monarchs locate prey using a combination of the progressive searching and 'sit-and-wait' methods. Monarchs tumble or 'flit' (Crome 1978) over and through foliage and up and down the vertical vegetation profile (see Chapman & Harrington 1997). Tails and wings are occasionally fanned, presumably to help flush insect prey (pers. obs.). The 'sit-and-wait' strategy is used to scan branches, leaves and bark substrates thoroughly in dark microhabitats such as groves of Bangalow Palms and dense *Cissus*-clad foliage along creeks. Movements that feature hops, flights ('flutter-and-tumble') and vertical perches are used by *M. trivirgatus* in both methods of locating prey.

Prey is attacked and/or captured by *M. trivirgatus* using combinations of three main manoeuvres: gleaning, sallying and hawking (Crome 1978; pers. obs.). I also observed some individuals hovering next to Bangalow Palm apices and gleaning spiders. Gleaning is the

most frequently used manoeuvre (Crome 1978; pers. obs.). Sallying is occasionally used and involves birds detecting prey on leaves, branches or flowers from remote perches and flying directly to capture and consume prey at the site of detection (Crome 1978; pers. obs.). I observed birds hawking insects on a few occasions and generally near the edge of natural treefalls and overgrown old logging tracks.

Spectacled Monarchs usually forage in pairs or singly. I did not detect *M. trivirgatus* foraging in flocks of mixed species (see Blakers *et al.* 1984). However, near Mackay on the Queensland central coast, Spectacled Monarchs forage in winter flocks of several insectivorous species (H. A. Ford pers. comm.).

I observed adult pairs maintaining contact when foraging in dense riparian vegetation through plaintive, drawn-out 'phew-weee' ('breer,breer,breer', Pizzey & Knight 1997) calls repeated 2-6 times. Birds foraging alone also gave this call from prominent perches in the understorey, presumably to locate others of this species. Repetitious scratchy chatterings (Boles 1988; Pizzey & Knight 1997) are given while birds are foraging either together or singly. Harsh scolding 'zzit-zzit-zurrr' calls are repeated constantly by territory-holding males upon the detection of predators or intruding males of this species (pers. obs.). I observed a male Spectacled Monarch making low swooping flights over a Southern Angle-headed Dragon *Hypsilurus spinipes* and constantly giving this warning call from low perches near the reptile.

The home range of *M. trivirgatus* has not been previously determined.

Breeding ecology

Spectacled Monarchs breed from October-February as simple pairs (Boles 1988). North (1901-1904) recorded nesting from mid-late September in the upper Clarence River district of north-east NSW. In my study, I observed Spectacled Monarchs building nests from late October-late November.

Male *M. trivirgatus* spend the first two weeks after arriving from their spring migration surveying potential breeding territories and calling for prospective mates. I followed

individuals on repetitive forays up and down creeklines in the study area for estimated linear distances of 450±80 m. The main call used ('phew-weee') is constantly repeated by males and sometimes females during these mate-search journeys. Excited, wheezy chatterings and nasal squeaks are given when two birds make initial contact and is often accompanied by ritualised body posturing and feather-fluffing (pers. obs.).

Potential territories are selected by males and reviewed by females. I observed this to take approximately 2-4 weeks after the arrival of this species in my research plots. Territories are mostly riparian-based, with extensions up side-gullies and lower slopes where sufficiently dense understorey vegetation exists. Groves of Bangalow Palm and rainforest trees with dense, screening foliage such as *Guioa semiglauca*, *Archirhodomyrtus beckleri*, *Quintinia verdonii*, *Endiandra discolor* and *Callicoma serratifolia* were favoured by territory-holding birds in my study.

Males vigorously defend territories against rival males and other species such as Rufous Fantails, Black-faced Monarchs and Brown Gerygones (pers. obs.). On one occasion I observed a territory dispute involving four Spectacled Monarchs. The aggressor pursued one intruder in a series of short (about 8 m), low (1-2 m) meandering flights using fallen logs and head clumps as brief (1-3 second) rest perches. Both birds would land within approximately 15 cm of each other, fan their tails up to 180° in the horizontal, and dip their heads before resuming the pursuit. These pursuits were accompanied by raucous scolding 'zzit-zzit-zurrr' and harsh chattering vocalisations, given more frequently by the aggressor which eventually drove the intruder off. The aggressor then returned to repeat the process with the fourth bird (a likely male) in which all three birds engaged in a pursuit flight. Eventually the banded female foraged upstream with the aggressor. I did not observe males courtship-feeding females in my study.

Both sexes scan moist forest for suitable nest sites but only females select sites (pers. obs.). Preferred sites are in the junction of 2-3 forks angled upwards at 15-25° from the main stem of 1-6 m tall saplings (North 1901-1904; pers. obs.). An overhead foliage cover of 70-80% is preferred to screen nests adequately and proximity to water is important. In my study, Spectacled Monarchs selected *Guioa semiglauca*, *Syncarpia glomulifera* saplings, *Wilkea huegeliana*, *Trochocarpa laurina* and *Caldcluvia paniculosa* for nest sites.

Sites within 20 m of open snig tracks and newly created gaps were generally avoided or, if chosen, the nests were later abandoned before egg-laying occurred (pers. obs.). A nest containing two nestlings and built in a 0.5 ha patch of regenerating moist eucalypt forest in a rural residential area near Coffs Harbour was predated by the Black Rat *Rattus rattus* (pers. obs.).

Nests are constructed mainly by females, although I observed a male delivering moss strands to a nest. Nests are deep cup-shaped structures sometimes built to dip 10-25° downwards at one side (Plates 3.15 and 3.16). They consist of thin bark strips, old leaves, fine rootlets, green moss and bound together by spiders' web and lined with dry forest oak *Allocasuarina torulosa* needles. Nest exteriors are ornamented by spider egg sacs and thick strands of green moss procured from fallen logs and tree stems (pers. obs.). Nests are built over 3-6 weeks with females occasionally abandoning initial attempts. Two eggs are laid one day apart and hatch 15-18 days later (pers. obs.). Incubating females are fed by males and leave nests for short periods to forage, bathe and preen.

Both parents provision nestlings but only males remove faecal sacs. These are swallowed rather than carried to dump sites (pers. obs.). I observed fledging at 17-20 days after the hatching of the last egg. Infertile eggs are usually ejected from nests by either parent. Of the 5 *M. trivirgatus* nests that I observed in my study, I recorded only one nest that fledged two young: the remainder failed or produced only one fledgling.

Newly-fledged young use temporary dormitories situated in vine (especially *Cissus*)-clad foliage of shrubs and trees at heights of 4-10 m (pers. obs.). They are fed frequently by both parents and contact is maintained by fledglings giving plaintive 'cheeep-cheeep' calls. I did not follow the fate of young fledglings beyond the first few days after fledging in the study area.

There is no existing published information on post-fledging care in Spectacled Monarchs. However, I captured three immature birds unaccompanied by adults in mid-March 1997 and one young bird accompanied by an adult on 5 February 1998. Assuming that the adult in the latter case was the young bird's parent and fledging occurred in late December-early

Plate 3.15

Spectacled Monarch *Monarcha trivirgatus* (race *gouldi*) at nest adorned at the base with the egg sacs of spiders

Photograph by Bernice Stokes (courtesy Queensland Ornithological Society Inc.)

Plate 3.16

M. trivirgatus (race *albiventris*) feeding nestling: note the downward slope of the left side of the nest rim and lighter orange throat and chest and white underparts of this race compared with race *gouldi* (Plate 3.15).

Photograph by Brian O'Leary

January, this suggests a post-fledging care period of 5-6 weeks in this species. Further work is needed to confirm this and investigate other aspects of post-fledging care in Spectacled Monarchs.

My banding records suggest that newly independent Spectacled Monarchs roam widely prior to the autumn migration from forest in my research plots. I also found that most birds of this species still present in these plots during mid-March to early-April were independent young birds. This suggests that adult Spectacled Monarchs may begin their autumn migration 2-3 weeks earlier than their progeny.

CHAPTER 4

THE SIZE, SURVIVORSHIP AND MOVEMENT OF INSECTIVOROUS BIRD POPULATIONS IN AN EXPERIMENTALLY LOGGED MOIST EUCALYPT FOREST

4.1   Introduction

The harvesting of timber changes the structure and floristic composition of forests around the world (e.g., Robinson & Holmes 1984; Wardell-Johnson 1985; Norton & May 1993; Trzcinski *et al.* 1999). The quality of these communities as habitat for insectivorous birds of the forest floor and understorey is concomitantly, but usually not irrevocably, altered (see Freedman *et al.* 1981; Wiens 1994; Neave *et al.* 1996; Lindenmayer & Recher 1998; Craig 1999).

More intensive forms of logging such as large-scale clearfelling, can generate short- to medium-term changes in the size, composition, movement and reproductive success of forest bird populations and communities (Recher *et al.* 1980; Tingay & Tingay 1984; Lynch 1987; Loyn 1993; King *et al.* 1996; Schmiegelow *et al.* 1997; Yahner 1997; Calver & Dell 1998a,b; Huhta *et al.* 1998). However, it is unclear whether, and in what ways, smaller-scale intensive logging systems such as the gaps and clusters approach implemented in this study (Chapter 2) may affect insectivorous bird populations and other fauna (see Attiwill *et al.* 1996; NSW Ministerial Advisory Committee 1996). This stems from a distinct lack of empirical evidence of the impacts of the gaps and clusters system on faunal assemblages, despite much recent conjecture and anecdotal claims (see Attiwill *et al.* 1996).

In this chapter I examine the short-term impact of the experimental logging trials on three key aspects of the ecology of each study species in the research plots. These are population size, survivorship, and movement between plots. In this context, I make three predictions concerning the expected responses of these birds to the logging events. These are:

1. after logging, there will be a reduction in the size of bird populations in the logged plots compared with the unlogged (control) plots;

2. after logging, the survivorship of individual birds will be lower in logged plots than in unlogged plots;

3. after logging, more birds should move from logged to unlogged plots than from unlogged to logged plots.

4.2 Methods

4.2.1 Colour-banding program

A systematic colour-banding program was undertaken in the study area over a period of 9 months before logging commenced (Year 1 plots: 26 November 1996 - 11 April 1997; Year 2 plots: 11 November 1996-25 April 1997 and 27 November 1997-12 March 1998). No banding occurred after the logging trials.

I colour-banded, weighed and measured as many individuals of the study species as possible during and after the two breeding seasons. Unique colour combinations of two plastic bands were applied to the left tarsus while a third plastic band (the plot identifier: blue=E1, pink=C1, red=E2, white=C2) was applied over a numbered aluminium band to the right tarsus of each bird. Metal bands were supplied under Licence R223 issued to me by the Australian Bird and Bat Banding Scheme (ABBBS) while colour bands were provided by the Australian Bird Study Association. The research project complied with the requirements of the SFNSW Animal Care & Ethics Committee.

I captured birds in 12 m x 2.7 m mist nets with 31 mm mesh, usually placed parallel to the slope and evenly distributed across all topographic units and treatment zones in each plot. I operated nets from approximately 0530-1230 hours in sets of 6-9 nets per session in Year 1 and 10-12 nets per session in Year 2. A total of 274 net stations were used across all 4 plots: 50 in E1 plot, 32 in C1 plot, and 96 in each of the E2 and C2 plots. I used a Petzl® headlamp to assist in the opening of nets at or before dawn.

I carried out a total of 110 netting sessions encompassing 802 field hours across all plots. The Year 2 plots were more intensively sampled than their Year 1 counterparts. I completed a total of 74 netting sessions (mean session duration of 6.84 ± 0.45 hours) in the Year 2 plots compared with 36 sessions (mean session duration of 6.76 ± 0.38 hours) in the Year 1 plots. I conducted approximately the same number of sessions in the experimental and control plots in both years. The greater sampling effort in the Year 2 plots was because more time was available after the completion of fieldwork in the Year 1 plots, more net stations were established, and I became more efficient at mist-netting and monitoring bird movement.

I systematically rotated the order of operation of net stations through different sectors of each plot during each netting round. I applied a minimum return interval of 3 (Year 1 plots)-4 (Year 2 plots) weeks between the subsequent use of any station. I alternated netting between different plots to increase this interval. These measures were employed to minimise the learning, and thus avoidance, of nets by resident birds (see Wilson *et al.* 1965; Karr 1981; Wooller 1986).

Nets were not operated during wet, windy or excessively hot or cold weather. The presence of predators such as Lace Monitor *Varanus varius*, Southern Angle-headed Dragon *Hypsilurus spinipes*, Pied Currawong, Laughing Kookaburra and Grey Butcherbird forced the closure of nets on occasion.

4.2.2 Detection and monitoring of birds

I searched for colour-banded birds before (autumn/winter) and after (spring/summer) logging in each experimental plot and during the equivalent periods in each control plot (to allow for seasonal variation in abundance, survival and movement) by traversing one of four sectors (150 x 150 m or 2.25 ha) per session. Searching was usually confined to the given sector and a different starting point and direction of travel (clockwise, anti-clockwise, diagonal) were used for each search performed within the same sector of each plot. This process was repeated in the second plot in each year, thus providing an interval of 8 days between subsequent searches in the same sector of a plot. These measures minimised the tendency of birds to become acclimatised to frequent human presence in their home ranges (see also Robinson 1992; Moysey 1997).

Upon detecting an individual or group of colour-banded birds, I recorded band colours, time, treatment zone, microhabitat and marked the location on a detailed plot map. I then followed the bird/s for as long as I could maintain visual contact, continuing to map the route taken and, at approximately one (1) minute intervals, recording the time, treatment zone and microhabitat class. I also noted any change in the composition of groups, although most groups were generally stable. Unbanded birds that were regularly observed with

banded birds or had distinctive plumage markings such as brown shoulder flecks were also monitored.

Mapping accuracy was 2 metres, given the detail with which each plot was marked (Chapter 2) and my familiarity with each plot. I maintained a distance of 3-7 metres, depending on the species, from each subject being followed to ensure birds behaved as naturally as possible (see also Hanski & Haila 1988; Gutzwiller *et al.* 1998). I used 10x42 Bausch & Lomb Discoverer™ field binoculars fitted to a ProHarness™ to identify and follow birds. I did not pursue birds beyond the boundaries of each plot, except to confirm identification and to determine distances travelled by Spectacled Monarchs. I occasionally went beyond the boundary of the sector in which I was monitoring birds to also confirm identification of individuals.

I spent approximately 14 months (2248 hours over the period 1 May 1997-23 December 1998) searching for, and recording the movements of, colour-banded bird populations in the study area. The Year 2 plots were again more intensively sampled (1440 hours: E2 plot=760 hours, C2 plot=680 hours) than the Year 1 plots (808 hours: E1=464, C1=344). A comparable level of monitoring was undertaken before and after logging in these plots.

4.2.3 Determining survivorship

I determined the survivorship of each study species by following the fate of colour-banded individual birds before and after logging in the experimental plots and during the equivalent periods in the control plots. In this way, the total number of monitored individuals of each species that were resighted after logging and the total number that were not resighted after logging in each plot were determined. I therefore used the number of resighted birds as a measure of the survivorship of each study species in each plot. Only colour-banded adults, unbanded adults paired to colour-banded birds, and individuals with distinctive plumage markings were included in each cohort. Therefore, colour-banded birds that returned to plots after logging but had not been monitored before logging were omitted. Birds that were not resighted after logging were assumed to have either died, left the plot, been predated, or went undetected. I considered that the intensity of my searching for individuals substantially minimised the possibility of birds being undetected.

Population sizes and hence survivorship, could not be determined for Rufous Fantails and Spectacled Monarchs before logging in Year 1. This was because these species were absent from the plots during the winter pre-logging sampling and time constraints arose during post-logging sampling in the spring/summer of Year 1 (see Chapter 2).

4.2.4 Statistical analysis

I used chi-square (χ^2) analysis in combination with a Monte Carlo procedure (a pseudo-probability test or PPT - Hernández & Weir 1989) and Fisher's Exact Test (Zar 1999), where appropriate, to test the validity and significance of the three predictions of bird response to the logging trials. Specifically, I asked whether the size of populations of the study species differed significantly between the logged and unlogged (control) plots. I then asked if the survivorship of monitored individual birds was significantly lower after logging in the experimental plots than in the control plots.

I constructed 4x2 (ie. 4 plots x 2 treatments) contingency tables for each of the four resident bird species (2 robins and 2 scrubwrens) in each of the population size and survivorship data sets. I used 4 plots (experimental and control in Years 1 and 2) and 2 treatments (logged and unlogged). The test variables were population size (numbers of individuals known-to-be-alive) and survivorship (numbers of monitored individuals that were resighted and numbers of monitored individuals that were not resighted after logging). I used 2x2 contingency tables for population size and survivorship data for Rufous Fantails and Spectacled Monarchs because data were only available for the Year 2 plots. For both robin and scrubwren species, I combined survivorship data for both logged plots and for both control plots to increase sample size for chi-square analysis. Otherwise, I avoided the pooling of population size and survivorship data sets in order to prevent loss of information (see Zaykin & Pudovkin 1993).

A requirement of χ^2 tests is that expected frequencies (e_i) should not be small - preferably not less than 4 (Roff & Bentzen 1989; Sokal & Rohlf 1995). I set this limit at 5, below which I used PPT for 4x2 tables and Fisher's Exact Test for 2x2 tables. Both tests examined data sets for the probability of homogeneity and confirmed whether the results obtained using the χ^2 procedure were significant. This helped to avoid Type I/II errors by confirming

whether the χ^2 tests correctly accepted or rejected the null hypotheses. Fisher's Exact Test is more powerful than the χ^2 test where small sample sizes are involved (Sokal & Rohlf 1995).

I used chi-square analysis and Fisher's Exact Test and compared tabulated data to examine the third prediction, ie. that more birds moved from logged plots into control plots than vice versa. I used plot (logged or unlogged) to represent treatment and the number of birds that departed from, and arrived in, the plots as the test variables. I combined the totals of both logged plots and both unlogged (control) plots and performed the χ^2 test on all species pooled. Very low sample sizes prevented chi-square analysis of movement data for each separate species.

All statistical tests were performed using the software package Minitab® Releases 10Xtra and 11 (Minitab Inc. 1995, 1996). Differences were considered significant at $P < 0.05$. The scientific graphing software SigmaPlot® Version 5.0 (SPSS Inc. 1999) was used to produce all figures.

4.3 Results

4.3.1 Number of individuals captured/recaptured

I captured and colour-banded a total of 462 birds of the study species in all plots during the study (Table 4.1). More birds were captured in the Year 2 plots than in the Year 1 plots, reflecting the increased Year 2 sampling effort. The number of individuals captured in each experimental plot relative to its control plot was comparable.

Rufous Fantails were the most abundant of the six study species captured, comprising 29% of this total. White-browed Scrubwrens and Yellow-throated Scrubwrens were next, constituting 22.9% and 19.5%, followed by Eastern Yellow Robins (14.3%) and Pale-yellow Robins (11%). Spectacled Monarchs were least abundant, comprising only 3.2% of all birds captured.

A total of 32.2% of banded individuals were recaptured across all plots during the study (Table 4.1). A higher proportion of banded birds was recaptured in the Year 2 plots (mean

of 37.4%) than in the Year 1 plots (mean of 25.6%), due to the lower sampling effort in C1 Plot. The proportion of banded birds recaptured in both Year 2 plots was comparable. Eastern Yellow Robins (47%), Yellow-throated Scrubwrens (42.2%) and White-browed Scrubwrens (34%) were recaptured more often than other species across all plots. I did not make any resightings of colour-banded birds during the banding program.

4.3.2 Size of monitored populations

I defined the size of monitored populations as the number of colour-banded individuals of the study species and their unbanded mates/helpers *known to be alive* in each plot in each of the two sampling periods (ie. before logging, after logging). Therefore, the size of monitored bird populations in each plot varied from the total number of birds that had been colour-banded (see Table 4.1). I monitored a total of 238 individuals of the study species across all plots.

The total size and density of populations of the study species in both experimental plots before logging (209 individuals at 11.61 birds/ha) was slightly, but not significantly ($P=0.155$, df$=1$,$\chi^2=2.020$), higher than that of both control plots (177 individuals at 9.83 birds/ha). After logging, I recorded a 34% decrease in the total size of these populations in the experimental plots (137 individuals at 7.61 birds/ha) and an 18% decrease in this total in the control plots (145 individuals at 8.06 birds/ha). These changes were not significant at the 95% confidence interval.

Figs. 4.1-4.6 show the number of individuals of each study species that were known to be alive in each plot before and after logging. There were no significant differences in the population sizes of any of these species before or after logging in any plot (Table 4.2). Application of PPT and Fisher's Exact Test confirmed that the null hypothesis of no difference in population sizes between treatments was correctly accepted for each species. Only the Yellow-throated Scrubwren returned a result that approached significance ($P=0.089$) (Table 4.2). This involved a 41% decrease in the size of *S. citreogularis* populations after logging in the logged plots, compared with an 8% decrease in these populations in the control plots during the same period.

Some large declines in the size of populations after logging (e.g., Yellow-throated Scrubwren in E2 Plot [Fig. 4.3], White-browed Scrubwren in C1 and E2 Plots [Fig. 4.4], and Rufous Fantail in E2 and C2 Plots [Fig. 4.5]) reflected the dispersal of juveniles out of plots at the conclusion of the breeding season. This generally preceded the logging periód. The size of adult populations of the study species was generally comparable between treatments in each plot.

4.3.3 Survivorship

A mean total of 66% of birds known to be alive before logging were detected again after logging across all plots (Table 4.3) while 34% were not detected. In both logged plots, 60.9% of individuals of all study species combined were re-sighted after logging and in both unlogged (control) plots 70.7% of individuals were re-sighted. This difference was not significant (Table 4.3).

I found that survivorship after logging was highest in Eastern Yellow Robins and Pale-yellow Robins across all plots, ranging from means of 83.6% (Pale-yellow Robin) to 79.9% (Eastern Yellow Robin) (Table 4.3). Survivorship of Yellow-throated Scrubwrens and White-browed Scrubwrens was higher in unlogged plots than in logged plots (Table 4.3). The survivorship of Rufous Fantails, returning after their 5-6 month winter absence in Year 2, was similar in the logged plot (37.5%) compared with the unlogged plot (33.3%) (Table 4.3). Only 20% of monitored Spectacled Monarchs reappeared in the logged plot in the spring of Year 2, compared with 66.6% in the unlogged plot (Table 4.3), although only small sample sizes were obtained.

I did not detect significant differences in the survivorship of any of the populations of study species between logged plots and unlogged plots (Table 4.4). Therefore, I accepted the null hypothesis that the number of individuals of each species that survived was independent of treatment. Application of PPT and Fisher's Exact Test confirmed that this acceptance was correctly made. However, I nearly rejected the null hypothesis for Yellow-throated Scrubwrens in both logged plots compared with both unlogged plots ($P=0.070$) (Table 4.4). This involved a 37% decrease in the number of monitored individuals of this species that

were resighted in the experimental plots after logging, compared with a 25.9% reduction in the number of *S. citreogularis* resighted in the control plots during this period.

4.3.4 Movement of birds between plots

I detected 13 colour-banded birds that moved between plots during my study. Of these, 11 individuals moved between plots after logging (Table 4.5) and the remaining two birds moved between plots before logging. There was no significant difference ($P=0.492$) between the total number of birds that moved out of logged plots after logging and the total number of birds that moved out of control plots after logging. Some of the birds that moved out of logged plots were juveniles dispersing from their natal areas.

Two adult White-browed Scrubwrens moved the greatest distances (650-880 m) between plots. Dispersing juvenile robins of both species traversed distances of 515-605 m; dispersing young Yellow-throated Scrubwrens covered 560-720 m; adult Rufous Fantails moved over 350-505 m and two adult Spectacled Monarchs were found at least 500 m from their point of initial capture.

4.4 Discussion

4.4.1 Population size and survivorship

The results of this study suggest that small-scale gapping in a continuous moist eucalypt forest does not significantly affect the size or survivorship of local populations of birds of the study species. A number of plausible reasons can be advanced to account for this outcome. These include resilience or ecological tolerance, nature of the surrounding landscape, spatial and temporal scale of logging, and power of statistical tests given the small sample sizes obtained for most of the study species.

Insectivorous birds of the ground and understorey vary considerably in their resilience to habitat loss or modification. For instance, birds of fragmented British woodlands are markedly intolerant of habitat disturbance (see Ford 1987; Hinsley *et al.* 1995, 1996; Newton 1995). In contrast, tropical rainforest birds are very resilient to habitat loss and

alteration (see Johns 1986, 1991; Canaday 1997; Marsden 1998; Aleixo 1999). Although the mechanisms are not well understood, resident habitat generalists in temperate Australian eucalypt forests and woodlands may be more tolerant of habitat loss or modification than habitat specialists and migratory species (e.g., see Shields 1990; Trémont 1994; Catterall *et al.* 1997).

In my study, the ability of each study species to survive logging in numbers similar to their pre-logging levels and to survive equally well in logged and unlogged plots may indicate that they were relatively resilient to small-scale gapping. The resident habitat generalists, the Eastern Yellow Robin and White-browed Scrubwren, maintained their adult populations at similar sizes after logging. Resident habitat specialists, the Pale-yellow Robin and Yellow-throated Scrubwren, were also present in similar adult numbers after logging. Retention of riparian and moist lower slope vegetation allowed both migrants, the Rufous Fantail and Spectacled Monarch, to also maintain the size of their adult populations after logging.

The nature of the surrounding landscape can influence the abundance, distribution, composition and persistence of forest-dependent bird communities and other fauna in disturbed vegetation (see Wiens 1989a,b; VanderWerf 1993; McGarigal & McComb 1995; Hobbs & Wilson 1998; Lindenmayer & Franklin 1998). Tracts of formerly extensive forest surrounded by agriculture (e.g., Saunders 1989; Newmark 1991; Ford *et al.* 1995; Smyth 1996), industry (e.g., Harris 1984; Niemi *et al.* 1998) and housing development (e.g., Mason 1985; DeGraaf & Wentworth 1986; Recher & Serventy 1991; Sewell & Catterall 1998) are often only able to support depauperate subsets of their original avifaunas. Even in less fragmented tracts of forest, local variation in logging, burning and grazing histories can influence the structure and diversity of bird communities (see Recher 1991; Smith *et al.* 1995; Craig 1999).

In my study, all plots are embedded in a continuously forested landscape of 7317 ha. After logging, both experimental plots remained linked with adjacent retained forest through riparian and lower slope vegetation and non-merchantable stands. Therefore, the degree of landscape connectivity (*sensu* Merriam 1984, 1991) is high and although habitat has been lost, fragmentation has not occurred. This may have contributed to the lack of detection of a significant impact of logging on the size and survival of sampled bird populations. That is,

the impact of the logging trials could have been absorbed by the remaining forest cover without adversely affecting the size or survival of these populations. Conversely, this degree of connectivity and lack of fragmentation may have allowed birds to leave logged plots. However, if the landscape was highly fragmented and isolated, birds may have had to remain in the logged plots.

Scale is a critical factor in determining how populations of birds and other fauna respond to logging and other activities (e.g., see Keitt *et al.* 1997; Mac Nally 1997c; Tang & Gustafson 1997; Mac Nally & Quinn 1998). Variation in the spatial and temporal scale of logging operations can initiate changes of contrasting magnitude in the structure and survival of forest bird communities. Large-scale (100+ ha) clearfelling can remove entire home ranges of birds and alter the composition of bird communities to favour the short-term prevalence of species preferring open habitats at the expense of forest-dependent birds (see Recher 1976; Taylor 1991; Annand & Thompson 1997). Smaller-scale clearfelling (5-25 ha) can lower the diversity and abundance of bird communities, at least in the first few years after logging (see Kavanagh *et al.* 1985; Smith 1985; Rodewald & Smith 1998). However, over time, regenerating clearfell sites can provide foraging and breeding habitat for a range of understorey- and shrub-nesting birds (see Shields 1990; Loyn 1993; Rudnicky & Hunter 1993).

Partial logging systems involve the removal of 20-70% of forest canopy, generally by a mix of selective logging and small-scale gapping, and the retention of interconnected riparian and hillslope forest (SFNSW 1995a; Taylor & Haseler 1995). This approach has a potentially lower impact on birds than clearfelling and numbers of species present can be comparable with mature forest (see Shields 1990; Taylor & Haseler 1995). In removing less than 30% of forest cover in each trial plot, my study is situated at the lower end of this spectrum of logging impact.

Recher (1998) and Lindenmayer & Recher (1998) outlined the problems of designing a logging study to operate at appropriate spatial and temporal scales, using the Kingston study in West Australian jarrah forest (see Burrows *et al.* 1994; Morris & Williams 1998; Craig 1999) as an example. In this study, sampling grids were small (2.6 ha) and thus probably did not include the entire home ranges of individual birds or mammals. Also, control blocks

were not well separated from logged blocks. Recher (1998) suggested that multiple replicates of the Kingston study may be required to adequately evaluate logging impacts on birds and mammals. Longer-term monitoring of fauna populations before logging is also needed to understand how numbers of individuals fluctuate between years. This could allow any changes detected in population numbers after logging to be related to treatment effects (see Recher 1998).

I designed my study to ensure that research plots were large enough to contain the whole home ranges of individuals of each study species. I selected control plots that were sufficiently spatially separated from logged plots. However, multiple replication of my trial plots over a number of years and longer-term pre- and post-logging monitoring of bird populations were not possible because of time, budgetary and approval constraints. Therefore, insufficient spatial and temporal replication of the logging trials may have masked the detection of a significant effect of logging on the population size and survival of my study species.

Sample size exerts considerable influence over the power of statistical tests to detect the impact of logging on birds and other fauna (Calver et $al.$ 1999a,b; Goodall 1999). One way of achieving high power in a test is to obtain large samples of individuals or populations being studied (Calver et $al.$ 1999a). The small size of my population size and survivorship data sets will have reduced the power of my statistical tests to detect logging impacts on the study species. I nearly rejected the null hypotheses for population size ($P=0.089$) and survivorship ($P=0.070$) in Yellow-throated Scrubwrens. This may have been partly attributable to the lower power of chi-square analysis when small sample sizes are used (see Zar 1999). I countered this possibility by applying the PPT and Fisher's Exact Test. These tests confirmed that the null hypotheses of no differences in population size and survivorship between treatments were correctly accepted for each study species. However, the PPT outcome on survivorship of Yellow-throated Scrubwrens approached significance ($P=0.066$).

The results for the Yellow-throated Scrubwren indicate that, after logging, there was a 91% ($P=0.089$) probability of decline in population size and 93% ($P=0.070$) probability of lower survival. Some authors (e.g. Calver 2000) have argued that, when considering the

impact of an action, one can apply the Precautionary Principle and adjust the level of statistical significance from 5% ($P=0.05$) to 10% ($P=0.10$). If this is done then one may conclude that the Yellow-throated Scrubwren is affected by logging, despite failing to reject the null hypotheses at the conventional 5% level. Kavanagh (2000) considered P-values of less than 0.10 significant in his study of the effects of variable-intensity logging on the distribution of the Greater Glider *Petauroides volans* in the NSW southern tablelands.

4.4.2 Movement between plots

My study suggests that the localised movement of birds of the study species within a continuous forest tract is not significantly affected by small-scale gapping. Most (69.2%) birds moved between plots before logging occurred. These movements appeared to be part of the annual post-breeding dispersal of young out of natal areas and re-locations by adults tracking local variation in resources (see Robinson 1992; Rotenberry & Wiens 1998). Birds that left plots after logging were all adults and departed from control plots only, usually prior to onset of the breeding season.

Monitoring of movements between plots also point to a higher degree of site fidelity in both robin species than in both scrubwren species, although the data set is small. No movements by adult robins were detected between plots while two adult White-browed Scrubwrens and one adult Yellow-throated Scrubwren moved over distances of 0.5-0.9 km between years. Rufous Fantails exhibited some degree of site infidelity upon their spring return to the study area, with two individuals settling in plots that they did not occupy in the previous season. However, the degree of philopatry was higher (to within 30-75 m of original capture sites) in Rufous Fantails than in Spectacled Monarchs (to within 50-120 m of first detection or capture site), although sample sizes were small.

Other plausible reasons for the observed lack of significant impact of logging on bird movement between plots may include the resilience of the study species, the continuous nature of the surrounding forest landscape, and the small scale and limited replication of the logging trials (Section 4.4.1). The location of logged plots within a 7317 ha tract of continuous forest and the retention of about 70% of the vegetation in these plots presumably meant that sufficient suitable habitat was available for birds displaced by logging. A

significant effect on the localised movement of birds might therefore have been obtained if there was greater replication of the logging trials and less forest was retained in gapped plots.

4.4.3 Conclusions

Application of two small-scale but site-intensive logging events over two years in the study area did not significantly reduce the size or survivorship of marked populations of six species of forest birds. I contend that most of these birds were able to persist until the next breeding season in the logged plots in numbers similar to the control plots primarily because adjoining forest was retained and the local forest landscape was not fragmented. I concede that more replication, perhaps involving a range of gaps of different sizes harvested over a period of at least 5 years, coupled with more colour-banded birds in each plot, may reveal a significant impact of logging on the size and survivorship of these populations.

Logging did not significantly influence the movement of birds between plots. The number of birds that moved from logged to unlogged plots was not greater than the number that moved from unlogged to logged plots after gapping. Presumably individual birds remained in logged plots because there was still suitable habitat, given that approximately 70% of forest cover was retained after logging. They were also strongly philopatric and probably conservative in their use of forest space (see Chapters 5-7). The non-fragmented nature of the surrounding forest landscape might have helped absorb birds displaced by logging and reduced the need for birds to move between plots to access forest habitats. Further replication of the trials over a longer term is needed to fully assess the impact of gaps and clusters silviculture on the localised movement of the study species (Chapter 8).

Table 4.1   The total number of individuals of each study species captured, colour-banded and recaptured before logging in each logged plot and control plot and in all plots combined

Plot[1]	EYR[2]			PYR			YTS			WBS			RF			SM			Total		
	C[3]	R	RR	C	R	RR	C	R	RR	C	R	RR	C	R	RR	C	R	RR	C	R	RR
Ei	14	9	64.3	5	2	40	12	5	41.7	20	7	35	24	6	25	nd	nd	nd	75	29	39.2
C1	10	3	30	9	0	0	13	3	23.1	24	5	20.8	21	4	19	3	0	0	80	15	18.7
E2	17	9	52.9	16	5	31.2	35	17	48.6	34	13	38.2	53	12	22.6	8	2	25	163	58	35.6
C2	25	10	40	21	4	19	30	13	43.3	28	11	39.3	36	6	16.7	4	3	75	144	47	32.6
All plots	66	31	47	51	11	21.6	90	38	42.2	106	36	34	134	28	20.9	15	5	33	462	149	32.2

[1] E1 Year 1 experimental plot C1 Year 1 control plot E2 Year 2 experimental plot C2 Year 2 control plot
[2] EYR Eastern Yellow Robin PYR Pale-yellow Robin YTS Yellow-throated Scrubwren WBS White-browed Scrubwren
RF Rufous Fantail SM Spectacled Monarch
[3] C total number of individuals captured and colour-banded R total number of individuals recaptured RR recapture rate (%)
nd no data available

Table 4.2 Statistical test results of variation in population size between logged and control plots after logging. The result that approached significance (P=0.05-0.10) is shown in bold.

Study species	Chi-square (χ^2)			Pseudo-probability Test (P) [1]	Fisher's Exact Test (f) [2]
	χ^2	df	P		
Eastern Yellow Robin	1.219	3	0.748	0.791	
Pale-yellow Robin	1.464	3	0.690	0.744	
Yellow-throated Scrubwren	6.505	3	**0.089**	0.103	
White-browed Scrubwren	5.633	3	0.131	0.140	
Rufous Fantail	0.092	1	0.762		1.000
Spectacled Monarch	0.178	1	0.673		0.500

[1] a Monte Carlo procedure (Hernández & Weir 1989), 1000 runs made;
P=estimated probability of homogeneity at 95% confidence interval
[2] f=Fisher's exact probability of homogeneity (closest tail) at P=0.05
df=degrees of freedom

Table 4.3 Survivorship of study species after logging in logged and control plots

Study species	Logged plots		Control plots		Mean percentage of individuals resighted (all plots)[3]
	Number of monitored individuals resighted[2]	Number of monitored individuals not resighted	Number of monitored individuals resighted[2]	Number of monitored individuals not resighted	
Eastern Yellow Robin	13 (76.5)	4	15 (83.3)	3	79.9
Pale-yellow Robin	9 (90)	1	17 (77.3)	5	83.6
Yellow-throated Scrubwren	17 (62.9)	10	20 (74.1)	7	68.5
White-browed Scrubwren	21 (65.6)	11	27 (77.1)	8	71.3
Rufous Fantail[1]	9 (37.5)	15	6 (33.3)	12	35.4
Spectacled Monarch[1]	1 (20)	4	2 (66.6)	1	43 3
All study species	70 (60.9)	45	87 (70.7)	36	66

[1] data available only for Year 2 plots
[2] mean percentage of monitored individuals that were resighted is shown in brackets
[3] based on mean number of monitored individuals of each study species resighted after logging across all plots

Table 4.4 Statistical test results of variation in the survivorship of study species between logged and control plots after logging. Results that approach significance ($P=0.05$-0.10) are shown in bold.

Study species	Chi-square (χ^2)			Pseudo-probability Test (P) [1]	Fisher's Exact Test (f) [2]
	χ^2	df	P		
Eastern Yellow Robin	2.881	3	0.410	0.470	
Pale-yellow Robin	1.649	3	0.653	0.756	
Yellow-throated Scrubwren	7.052	3	**0.070**	**0.066**	
White-browed Scrubwren	3.139	3	0.371	0.365	
Rufous Fantail	0.078	1	0.780		0.520
Spectacled Monarch	1.742	1	0.187		0.286

df=degrees of freedom
[1] P=estimated probability of homogeneity at 95% confidence interval
[2] f=Fisher's exact probability of homogeneity (closest tail) at $P=0.05$

Table 4.5 The total number (11) of colour-banded individuals of each study species that moved between plots after logging. Plots from which birds left or arrived are shown in brackets. Individuals that left plots after logging were not the same individuals that arrived in plots after logging (ie. birds that left a plot did not return to it).

Study species	Number of individuals that left after logging	Number of individuals that arrived after logging
Eastern Yellow Robin	0	0
Pale-yellow Robin	0	0
Yellow-throated Scrubwren	2 (C2)	1 (E2)
White-browed Scrubwren	2 (C1)	1 (C2), 1 (E1)
Rufous Fantail	1 (C1), 1 (E1)	1 (C2), 1 (C1)
Spectacled Monarch	0	0
All study species	6	5

Figure 4.1 Eastern Yellow Robins known to be alive in each plot before
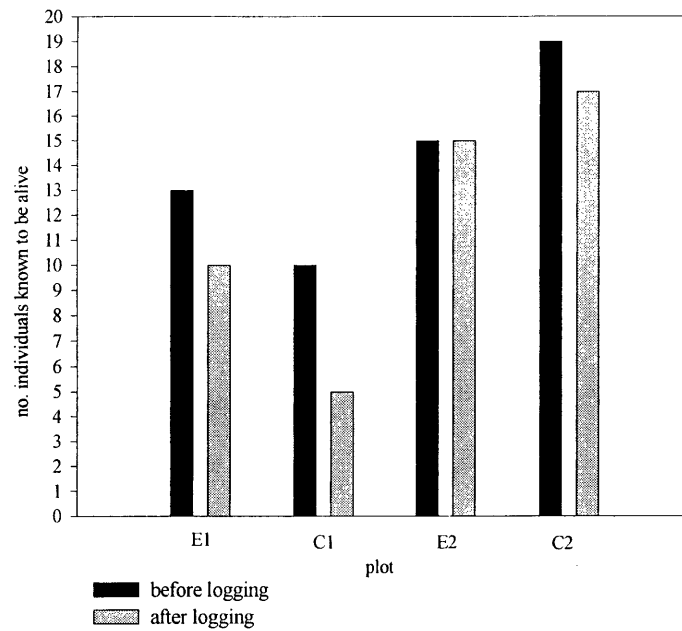and after logging

Figure 4.2 Pale-yellow Robins known to be alive in each plot before
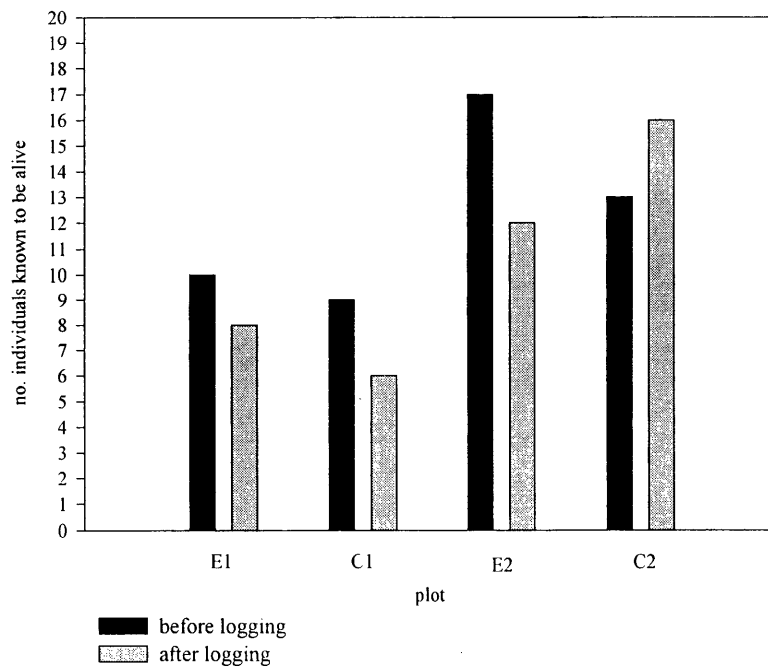and after logging

Figure 4.3 Yellow-throated Scrubwrens known to be alive in each plot before
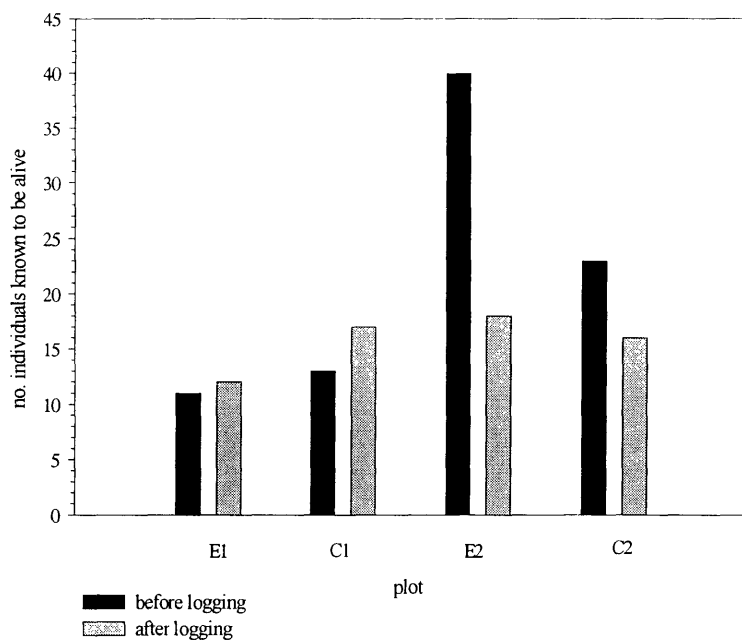   and after logging

Figure 4.4 White-browed Scrubwrens known to be alive in each plot before
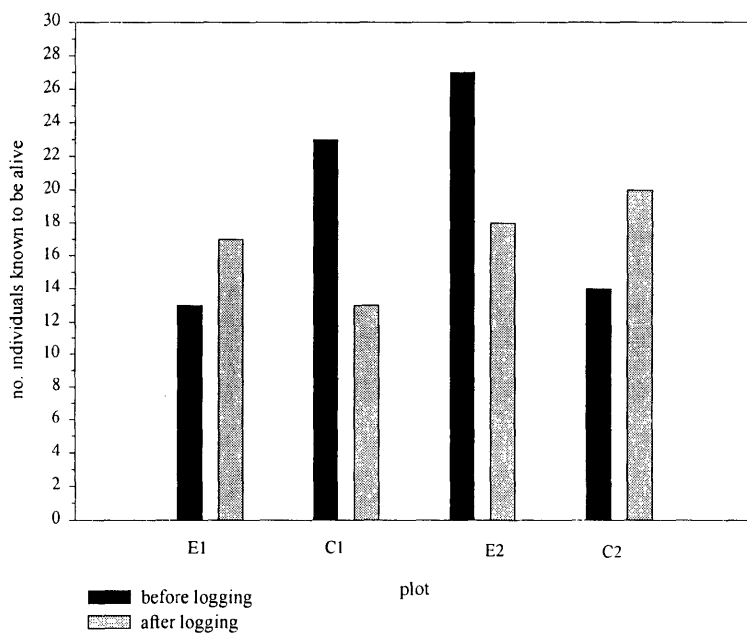   and after logging

Figure 4.5 Rufous Fantails known to be alive in each Year 2 plot
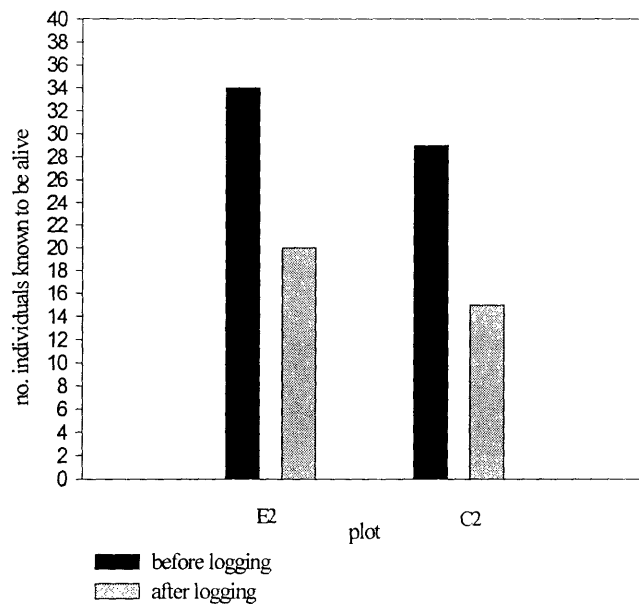before and after logging

Figure 4.6 Spectacled Monarchs known to be alive in each Year 2 plot
before and after logging