CHAPTER 1

GENERAL INTRODUCTION

Governor Arthur Phillip once observed "the wild appearance of the land entirely untouched by cultivation, the close and perplexed growing of trees....by degrees large spaces are opened, plans are formed, lines are marked, and a prospect at least of future regularity is clearly discerned" (cited in Frawley 1999). This early view marked the start of European impact on Australia's forest ecosystems. Prior to this, Aboriginal use of fire for hunting represented the initial wave of human impact on these natural systems (Flood 1986; Flannery 1994). With an increasing level of mechanisation in the 1940-1950s, logging emerged as a major agent of impact on the nation's forests and woodlands (Dargavel 1995).

Commercial wood production is an important revenue-generating industry in Australia. In 1989-1990 for example, forestry contributed more than $4.3 billion to the gross domestic product (National Forest Inventory 1998). In 1994-1995, 2.66 million m^3 of wood was produced from 13.35 million ha of multiple-use native forest (National Forest Inventory 1998). This represents 2.67% of the world's 500 million hectares of wood-producing forests that supply about 5 billion m^3 of wood annually (Food and Agriculture Organization 1997). Juxtaposed against this is Australia's status as one of the world's 12 biologically 'mega-diverse' countries (Common & Norton 1992), with 1227 species of vertebrates (561 birds) and 13622 species of higher plants (Commonwealth of Australia 1997). The forests of north-eastern NSW exemplify this standing by supporting 405 vertebrate species (181 birds) and 2211 higher plant species (NSW NPWS 1994a,b).

1.1 Human impact on forest ecosystems

Forests worldwide have been harvested for wood, cleared for agriculture and urban development, mined for minerals and, in some cases, reserved for conservation of biological diversity. In Australia, an estimated 37% of forest cover had been removed between 1788 and 1980 (National Forest Inventory 1998). Other estimates put this total at about 50% (Wells *et al.* 1984; Recher & Lim 1990; Resource Assessment Commission 1992). Of the remaining forest more than 80% has been modified by human activities (Resource Assessment Commission 1992). About half of the forests in conservation reserves have been logged prior to their gazettal (Norton 1996). In north-eastern NSW, 57.9% of native forest and woodland cover still remains (NSW Department of Urban Affairs and Planning 1999), although much of this has regrown after past logging and cattle grazing (Smith *et al.* 1995).

Habitat fragmentation or modification?

A key outcome of the expansion and intensification of human land use is the fragmentation or breaking up of continuous habitat (Saunders *et al.* 1991; Andrén 1994; Davidson 1998; Fahrig 1998). This involves the subdivision of animal and plant populations, production or increase in the amount of edge, and reduced dispersal or migration among populations (Wilcox 1980; Harris 1984; Fahrig & Merriam 1994). Fragmentation takes place in addition to the straightforward loss of habitat (Fahrig 1998). In a fragmented landscape, patches of habitat are isolated within a matrix of open space that acts as a barrier to animal movement - a notion that was once expounded within the practical limitations of the theory of island biogeography (see MacArthur & Wilson 1963, 1967; Diamond 1975).

In Australia, extensive clearing of land for agriculture has fragmented large tracts of eucalypt woodland and forest in the sheep-wheat belts of south-west Western Australia (Saunders 1989; Lambeck 1994; Brooker & Brooker 1997; Cale 1999) and western NSW (Reid 1999), and along parts of the east coast and uplands (Loyn 1987; Isaacs 1994; Gardner 1998). On the NSW northern tablelands, the pattern of habitat distribution is variegated rather than genuinely fragmented because patches of varying quality and connectivity occur in a matrix of grassland with scattered eucalypts (McIntyre & Barrett 1992). These intervening areas are modified forms of the original vegetation of this region and do not prevent the movement of most native species, especially birds (McIntyre & Barrett 1992; Ford & Barrett 1995). Indeed, 70% of bird species in this landscape are tolerant of moderate levels of habitat disturbance (McIntyre *et al.* 1992).

Commercial logging of Australian eucalypt forest usually modifies rather than fragments faunal habitats. In these forests, logging results in a short to medium term loss of habitat for some species and an increase in the amount of edge (Norton 1996; Recher 1996). However, this loss is matched by the provision or increase of alternative habitat for other species, such as woody debris piles and clumps of thick, shrub-dominated regrowth. Logging is generally confined to localised areas within continuous forest landscapes. The exception to this pattern is coupe-scale clearfelling and extensive clearfell gaps that may span several hectares (see Shields 1990; Norwood *et al.* 1995; Craig 1999; Wardell-Johnson & Williams 2000) creating potential barriers to the movement of some birds and other fauna and reducing the local availability of suitable nest sites and foraging substrates (Recher 1996; Lindenmayer 1997). In my study, I contend that the creation of small gaps modified rather than fragmented habitat, since each plot was embedded in a continuous forest matrix and retained a high degree of connectivity even after logging.

1.2 The effects of logging on birds

Previous studies in Australia and overseas have shown that timber harvesting can reduce the biological diversity of forest ecosystems (e. g., Wilcove *et al.* 1986; Bierregaard & Lovejoy 1989; Norton & May 1994; Szaro 1996; Wardell-Johnson & Horwitz 1996; Beese & Bryant 1999). Logging can affect the biological and ecological processes that influence, at the individual, species, population and community levels, patterns of avian distribution, abundance, diversity, use of space, reproduction and predation (Recher & Lim 1990; Recher 1996). Logging may also influence landscape diversity and connectivity (Norton & May 1994).

Biological and ecological processes can be significantly impaired by changes wrought by timber harvesting, but are markedly scale-dependent (Norton & May 1994; Mac Nally 1997c; Tang & Gustafson 1997). Extensive clearcutting at a regional scale may produce climate change by modifying the carbon and water cycles while small-scale logging can initiate changes in soil microclimates along forest edges and within forest interiors (Pickett & White 1985; Chen *et al.* 1992). Both logging systems may therefore influence the quality of foraging and nesting habitat for ground-dwelling birds and other fauna and their consequent patterns of space use. Logging can also inhibit the reproductive and dispersal capabilities of birds by removing connective forest links, improving predator access along expanded road networks, and aiding the spread of disease, parasitic species and birds that exploit open space (see Recher 1991; Norton & May 1994). Management associated with logging may also cause changes in fire regimes and in the floristic composition and structure of vegetation, which may influence patterns of food availability and habitat use (Loyn 1993; Attiwill 1994a,b).

Studies in temperate Australian eucalypt forests have demonstrated that logging can reduce the diversity and abundance of forest bird populations (e.g., Loyn 1980, 1993; Pattemore

1980; Smith 1985; Taylor & Haseler 1995; Craig 1999). For instance, in Western Australian jarrah forest, Craig (1999) found that insectivores such as Golden Whistlers *Pachycephala pectoralis* and omnivores such as White-naped Honeyeaters *Melithreptus lunatus* significantly decreased in number after the creation of medium-sized (about 9 ha) gaps. Logging may also threaten the persistence of remnant populations that are representative of the pre-European geographical range of forest species (Kirkpatrick *et al.* 1991; Norton & Lindenmayer 1991).

Adequate diversity and connectivity in logged forest landscapes is needed to permit dispersal of individuals and gene flow between bird populations (Norton 1996; Woinarski *et al.* 1996). Birds that require continuous cover to move between forest patches may rely on the retention of interconnected tracts of unlogged forests within a harvested matrix. Large-scale logging operations such as alternate coupe (clearfell) harvesting can increase the prospect of the extinction of local populations of vulnerable bird species (Recher & Lim 1990). In a meta-population context (see Opdam 1990; Hanski & Gilpin 1991), logging on this scale might threaten the persistence of populations and lead to regional extinctions (Norton 1996).

The potential impact of gaps and clusters logging on bird populations may be greater than selective logging but less than the coupe-scale clearfelling that has occurred in south-eastern NSW, Victoria, Tasmania and Western Australia (see Shields 1990; Taylor 1991; Norwood *et al.* 1995; Smith *et al.* 1995; Attiwill *et al.* 1996). Gaps and clusters logging involves the creation of clearfelled gaps in the forest canopy and the retention of equivalent areas of forest (clusters) to help compensate for the loss of habitat caused by gapping. Selective logging involves the removal of individual trees of economic value and trees that may inhibit the growth of commercial species.

An important distinction between the potential impact of gaps and clusters logging and clearfelling concerns scale. Clearfelling potentially affects entire home ranges of many small insectivorous birds, whereas gaps, as implemented in my study, are smaller and thus may affect only parts of avian home ranges. Both logging systems affect a number of specific habitat components of birds, including tree hollows and hollow fallen logs, shrubs and ground cover, uneven age and old growth forest structure, and important food plants (Attiwill *et al.* 1996).

Hollow-bearing trees and large hollow logs are usually removed during clearfelling of forest to create gaps. In north-east NSW forests, 17 bird species and many arboreal mammals and bats depend on tree hollows for nesting and refuge (Attiwill *et al.* 1996). Fallen hollow and decaying logs retain moisture for long periods, support invertebrate populations, and provide foraging microhabitat for birds such as Yellow-throated Scrubwrens *Sericornis citreogularis*, White-browed Scrubwrens *S. frontalis*, and Logrunners *Orthonyx temminckii*, Pale-yellow Robins *Tregellasia capito* and Eastern Yellow Robins *Eopsaltria australis*. Bird abundance and species diversity is significantly higher in forests with well-developed shrub layers and deep leaf litter (Smith *et al.* 1992). Large forest owls and gliders have been shown to be more abundant in old growth forest (Milledge *et al.* 1991; Kavanagh *et al.* 1995), while uneven-aged stands provide a broader range of nesting, foraging and roosting opportunities for birds than even-aged forests (see Gilmore 1985; Recher 1991). Logging may also remove important food plants such as fruiting understorey shrubs and flowering vines and shrubs.

Our current knowledge of logging impacts on birds is unfortunately poor. Substantial gaps exist in our understanding of how individuals, species and local populations respond to different harvesting regimes, especially over the longer-term. We do not know what specific biological and ecological processes underpin these responses, and the efficacy of specific protective measures, such as riparian buffers, clusters of retained forest and connection corridors. We also need to know the implications of these responses for sustainable forest management (see Lindenmayer 1997). The acquisition of this knowledge should be a high priority for research programs in Australia's native forests.

1.3 The gaps and clusters experiment

My study uses an experimental Before/After and Control/Impact (BACI) approach to investigate the short-term impact of gaps and clusters silviculture on some insectivorous birds of a moist eucalypt forest. It specifically aims to determine if this form of logging produces significant changes in the size, survival, home range and habitat use patterns of individuals and populations of these birds. A secondary aim is to assess the implications of these responses for forest management and propose ameliorative measures. In this way, my study hoped to test whether small-scale gapping could balance the competing forest management objectives of wood production and biodiversity conservation, also termed the 'dual imperative' (SFNSW 1995e).

My study was undertaken in a 7317 ha tract of continuous State forest near Coffs Harbour on the NSW mid-north coast. This area has been selectively logged since the 1890s, resulting in most of the forest being cut over by 1930. Fire and cattle grazing have been absent from the area for at least the past 20 years. The landscape immediately surrounding this tract has been cleared for cattle grazing, hobby farms and small villages. However, the extent of continuous forest cover within the district and region is high, largely because of the size of the state forest and national park estates. There have been no recorded extinctions of bird species in this region. Birds in the forests of north-eastern NSW are reasonably well conserved, largely because of the extent of publicly owned forests and the general absence of clearfell logging operations. The exceptions are birds of remnant lowland forests and tableland woodlands and forests where the impact of farming and urban development has been most evident (Barrett *et al.* 1994; Ford *et al.* 1995; Smith *et al.* 1995).

I followed the fate of colour-banded individuals of six insectivorous bird species over two years and two logging trials in this forest landscape. These included four sedentary species, Eastern Yellow Robin, Pale-yellow Robin, Yellow-throated Scrubwren and White-browed Scrubwren, and two summer breeding migrants, Rufous Fantail *Rhipidura rufifrons* and Spectacled Monarch *Monarcha trivirgatus*. I also made observations of their foraging and breeding behaviour.

I selected these species for several reasons. First, each species belongs to the postulated 'next wave' of passerines threatened with local extinction through the loss of suitable breeding habitat (see Recher 1999). 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). Second, our knowledge of the ecology of four of these species is very poor. 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. Third, we do not know the impact of gaps and clusters logging on these or other bird species in Australia. 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. Fourth, Pale-yellow Robins and Spectacled Monarchs are species of conservation concern in NSW. Spectacled Monarchs may be sensitive to habitat loss and alteration associated with logging. Fifth, each species could be readily captured and their home ranges were small enough to be closely monitored in each plot.

In Chapter 2, I describe the biophysical and landscape characteristics of the study area. I detail the experimental design and silvicultural aspects of the gaps and clusters trials. I review the experimental research on the responses of forest birds to logging in Australia and show that it is deficient. Most previous investigations have been retrospective in approach and have compared logged with unlogged forest, have focused on communities rather individual species, and have not compared before and after logging responses. There is much support in the literature for the value of autecological studies in impact assessment research (e.g., Ford 1989; Taper *et al.* 1995; Simberloff 1998; Craig 1999; Recher 1999). I also describe methods used to sample bird populations and assess plant communities.

In Chapter 3, I provide a detailed account of the ecology of each of the study species. I specifically describe the identification, habitat, distribution, abundance, foraging ecology and home range, and breeding ecology of each species. This provides new data on some of these species and establishes the necessary background for the discussion of their responses to logging in subsequent chapters.

In Chapter 4, I ask whether or not logging significantly affected population size, survivorship, and movement of individuals of each species between plots. I make three predictions of expected responses to logging and test their validity using data obtained from the monitoring of individuals of each species before and after logging. I propose a number of reasons to account for the observed responses using evidence from other studies, principally in Australia but also in some northern temperate forests.

Chapters 5, 6 and 7 form the core of the thesis. They examine the impact of the logging trials on home range structure and patterns of habitat use in each species. At the start of each chapter, I present four models to predict the home range and habitat use responses of each species. These are later evaluated to determine which model best described the observed responses of each species. Throughout these chapters, I focus on home range rather than breeding territory as the main descriptor of space use. Only Chapter 5 contains a detailed description of home range methodology since the procedures used were largely generic to all six species. I used the software package RANGES V to estimate home range and habitat use in each species. Home range maps of each monitored bird are contained in Appendix 3.

In Chapter 8, I present a hypothesis to explain the observed home range and habitat use responses of each species to the logging experiment. Much of the evidence supporting this explanation is derived from my results, although I also draw on the few available studies of these and similar species in Australia and ecologically similar species in North America. I then discuss some supplementary hypotheses that might help account for these patterns of response. I discuss potential constraints to the interpretation of these responses. I review the implications of my results for forest managers and provide a set of recommendations for sustainable forest management. I also give directions for future research. I conclude the thesis by re-visiting the 'dual imperative' question that I posed at the outset of my study, namely, does gaps and clusters silviculture achieve a balance between the competing forest management objectives of conservation of biodiversity and wood production.