CHAPTER 2

STUDY AREA AND GENERAL METHODS

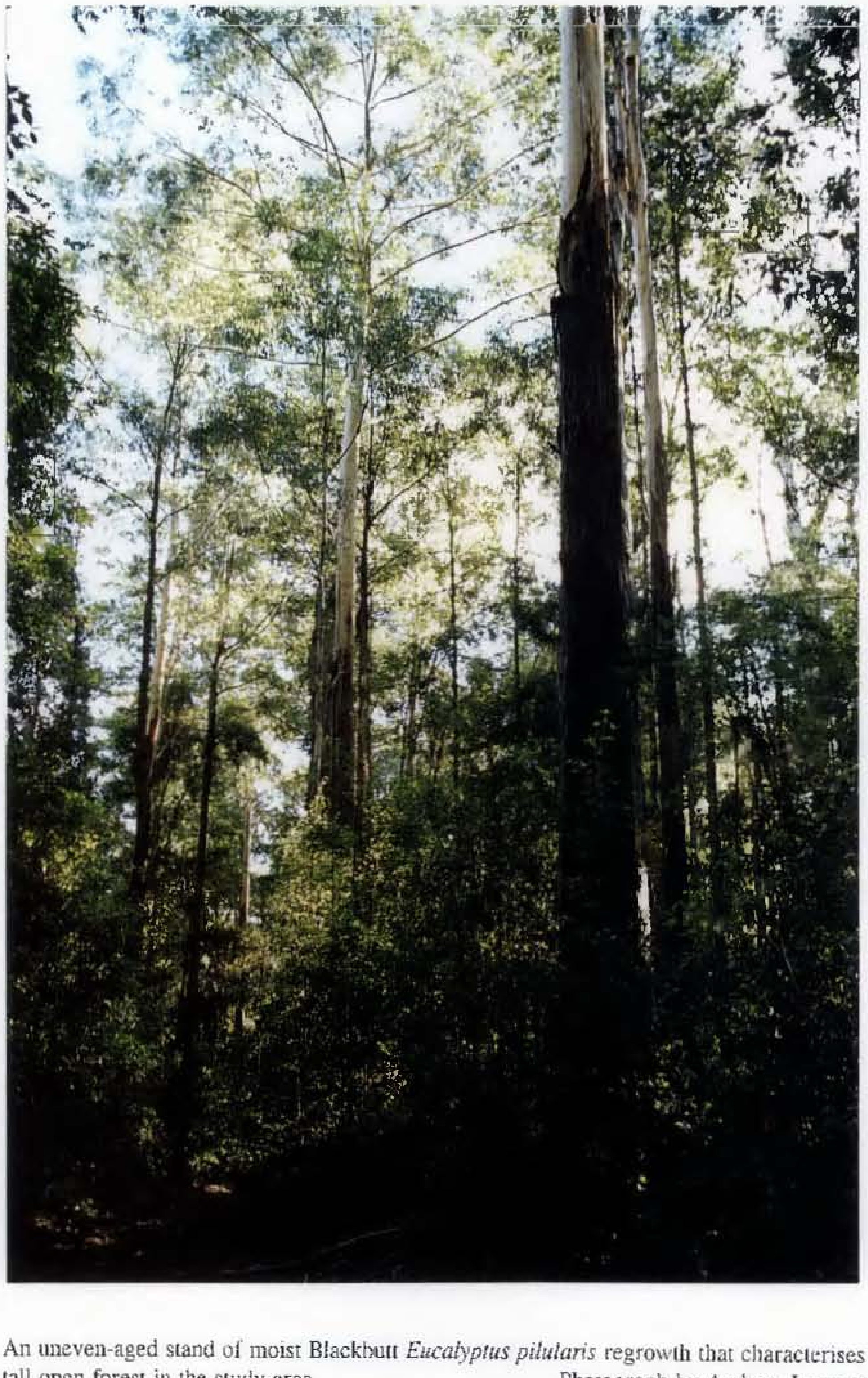
2.1 Introduction

The moist eucalypt forests of north-east NSW have been harvested for timber commercially since the 1890s (SFNSW 1995a). Over time, these forests have been converted to stands of uneven-aged regrowth (Plate 2.1), with occasional pockets of older growth.

Selective logging has been the predominant harvesting system used in the north-east NSW forests (Plate 2.2). This has contrasted with more intensive timber harvesting, such as clearfelling on the NSW south coast and tablelands (see Recher 1976, Kavanagh *et al.* 1985; Recher *et al.* 1985; Shields 1990), south-east and central Victoria (see Loyn *et al.* 1980; Loyn & Macfarlane 1984; Loyn 1985a,b,c; Loyn 1993), southern Tasmania (see Pattemore 1977, 1980; Dickinson *et al.* 1986; Taylor 1991; Taylor *et al.* 1997), and south-west Western Australia (Carron 1985; Burrows *et al.* 1993, 1994; Calver & Dell 1998a,b; Craig 1999). In this context, the north-east NSW forests are more continuous semi-natural systems that accommodate taxonomically rich and biogeographically significant biota of considerable conservation value (NSW NPWS 1994a,b, 1995, 1996a,b; Smith *et al.* 1995).

In this chapter I establish the geographical and methodological context of my study. Specifically, I describe the location and biophysical environment of the study area, selection of study sites, design and layout of research plots, and position within the local, regional and NSW landscape. I list previous surveys and studies within the region and describe the experimental logging trials that I undertook in the study area. This includes a treatment of the silvicultural background of the gaps and clusters technique and pertinent aspects of harvest planning and implementation. I detail the methods that I used to sample bird populations and plant communities in the research plots. I describe the structure, floristic composition and distribution of vegetation in these plots and assess whether there were significant differences in vegetation structure between plots before the logging trials. Finally, I identify the microhabitats of importance to the study species in the research plots.

Plate 2.1



An uneven-aged stand of moist Blackbutt *Eucalyptus pilularis* regrowth that characterises tall open forest in the study area Photograph by Andrew Leggett

Plate 2.2

A selectively logged stand of moist Blackbutt, Flooded Gum (*E. grandis*) and Sydney Blue Gum (*E. saligna*) in the Year 2 experimental plot, showing a characteristically dense layer of shrub regrowth

2.2 Study area

2.2.1 The biophysical environment

The study area is situated within the eastern sector of Lower Bucca SF in Coffs Harbour Management Area on the NSW mid-north coast (Fig. 2.1). The climate is generally warm temperate with hot summers, mild winters and a distinct winter/spring dry season. Average annual rainfall for the Lower Bucca area is approximately 1500 mm. January to March is the wettest period while July to September is the driest period. Mean temperatures range between a minimum of 5°C in July to a maximum of 27°C in January.

The dominant geology of the study area is Coffs Harbour Block metasediments of Lower Permian age (Soil Conservation Service of NSW 1994). These are the Coramba Beds comprising greywacke, slate, siliceous argillite, lithic and feldspathic sandstone. Principal soil types derived from these beds are chocolate soils, krasnozems and yellow podsolics. Landforms comprise flat to undulating slopes running off long wide ridges that trend north/north-easterly with slopes of up to 20-25°. Ephemeral streams incise these slopes, sometimes to bedrock, and drain into Bucca Bucca Creek within Orara River catchment. Altitude ranges between 96 and 212 metres above sea level.

The dominant broad forest type in the study area is moist hardwood with a rainforest sub-canopy. Emergent eucalypts are common and include Flooded Gum (*Eucalyptus grandis*), Sydney Blue Gum (*E. saligna*), Tallowwood (*E. microcorys*), Blackbutt (*E. pilularis*). These grow in association with other species such as Turpentine (*Syncarpia glomulifera*) and Brush Box (*Lophostemon confertus*). The rainforest sub-canopy is characterised by groves of Bangalow Palm *Archontophoenix cunninghamiana*, dense mantles of Water Vine *Cissus antarctica*, Five-leafed Water Vine *C. hypoglauca* and Morinda *Morinda jasminoides*. Drier tall open forest occurs on the upper slopes and ridges with *E. pilularis*, Northern Grey Ironbark (*E. siderophloia*), White Mahogany (*E. acmenioides*) and Small-fruited Grey Gum (*E. propinqua*) dominating the upper canopy. In this forest mid and lower canopy strata are generally more sparse and *Acacia* species, herbs and grasses dominate.

There is evidence of past fire damage to trees from post-logging burns and wildfire throughout the study area. However, litter accumulation depths and local forest management knowledge indicate that the most recent management burn of this area occurred in the late 1970s, with the most recent wildfire in 1951-1952 (R. Wells pers. comm.).

The native vegetation of the study area has been considerably altered by cattle grazing and logging which began with the establishment of Glenreagh Station in the 1840s (SFNSW 1998b,c). Lower Bucca SF was subjected to repetitive episodes of selective logging from the 1890s resulting in most of the area being fully cut over by 1928-30 (SFNSW 1997, 1998b).

The study area was treated by thinning and timber stand improvement during 1934-1938 and then selectively logged on about a ten year cutting cycle, salvaging and thinning as regrowth stands reached merchantable sizes. In recent years, only limited areas have been logged in each cycle, using mostly selective logging with small canopy openings and some experimental gapping trials (see Section 2.3.3). The most recent logging occurred in 1991-1992, during which bullock teams were still extracting logs from the E1 and C1 plots (C. Winkler pers. comm.). Cattle have not grazed Lower Bucca State Forest since the mid-1970s (C. Winkler pers. comm.).

Lower Bucca State Forest is flanked to its east, north and west by cleared land supporting beef cattle farms and hobby farms. It is connected to continuous forest cover to its south where it adjoins Orara East State Forest.

2.2.2 Study sites

I investigated thirty (30) potential study sites in Coffs Harbour and Urunga Management Areas (CHUMA) over the period, March-June 1996. Several criteria were used to determine the suitability of these sites for my study. These included land tenure, forest type, forest structure and floristic composition, forest management history, presence of study species, silvicultural suitability for gap and cluster treatment, other biophysical attributes (soil type, altitude, landform, slope, aspect, rainfall), and spatial qualities (position within the local and regional forest landscape, degree of representativeness of commercial moist eucalypt forest within the region, distance to forest edge, and connectivity to adjacent forest).

I considered only State forests and avoided forests grazed by livestock, forests subjected to recent or excessive wildfire or control burns, predominantly dry eucalypt forests, and forests described as comprising rainforest, old-growth, rare forest types, or otherwise subjected to investigation under conservation assessment protocols.

Two study sites were eventually selected using these criteria. The Year 1 site was 106 ha in area while the Year 2 site comprised 112 ha of forest.

2.2.3 Research plots

Basic design

Four research plots were established within the study area of which two plots were located in each of the two study sites (Fig. 2.2). The basic approach adopted was a modified BACI (Before/After and Control/Impact) design (Stewart-Oaten *et al.* 1986; Underwood 1991, 1992, 1994). That is, two plots were located in the Year 1 study site (part of Compartment 589): one was designated the experimental or logging trial plot (589E or E1 Plot), and the other ascribed the control plot (589C or C1 Plot) (Fig. 2.3). This was replicated in the Year 2 study site (parts of Compartments 595 and 596; 595-596E or E2 Plot and 595C or C2 Plot) (Fig. 2.4). I was unable to increase experimental replication because of the limit of two gapping trials over two years that was placed on my study (Section 2.3.6), the labour-intensive nature of my approach, and very limited field assistance.

Each plot was 300 x 300 m or 9 ha in area. Therefore, the four research plots occupied 36 ha of forest in the study area.

Spatial distribution

The specific location of each plot was determined by silvicultural suitability for gaps and clusters treatment, standard pre- and post-harvesting environmental protection requirements (SFNSW 1997, 1998b,c), specific ministerial approval conditions (Appendix 1), presence of study species, similar logging history, similar vegetation structure and composition, and minimum distance requirements between control and experimental plots in each study site.

Plate 2.3

Tall open forest with a dense, mesic understorey of rainforest shrubs, small trees, palms and vines typify the broad vegetation community of the research plots

Plate 2.5

The size, shape and location of all gaps established in the Year 1 trial (July 1997). Note the one year-old stage of regrowth within each gap. The experimental plot (9 ha) is the area enclosed by the white square.

Aerial photograph (1:5000) by Roger Dwyer & Associates (courtesy State Forests of NSW)

Plate 2.6

The size, shape and location of all gaps established in the Year 2 trial (July 1998). The experimental plot (9 ha) is the area enclosed by the white square. Note the woody debris piles visible within each gap. Gap 11 is not shown and is located approximately 100 m beyond the south-west corner of the photograph.

Aerial photograph (1:5000) by Roger Dwyer & Associates (courtesy State Forests of NSW)

Plate 2.7

Part of a designated gapping zone in the Year 1 experimental plot before the trial commenced, looking north along Turnaround Trail with part of a cluster in the background

Photograph by Andrew Leggett

Plate 2.8

Part of a designated gapping zone in the Year 2 experimental plot before the trial commenced, looking east along Short Run Trail with a cluster and riparian zone in the background

Plate 2.4

Dense patches of grasses, ferns, shrubs and palms rapidly cover old, arterial logging trails in the research plots, providing microhabitat for ground- and shrub-foraging birds

Field inspections were conducted by SFNSW forest management officers to advise on silviculturally suitable sites within the study area. Harvest planning was undertaken and pre-logging surveys were completed (see Section 2.3.4). Plots were located in tall open forest with mesic understorey (Plates 2.3 and 2.4).

Plots were separated by at least 250 metres of forest. Sites further apart had experienced more intense logging in the past and had structurally dissimilar understorey vegetation. This would not have allowed me to accurately compare the behaviour of the study species in each of the research plots. The spatial distribution of BACI-design plots in heterogeneous environments such as those of the study area is an important consideration in studies of space use by forest birds (Hockin *et al.* 1992; Hill *et al.* 1997; Mac Nally 1997c; Margules *et al.* 1998; Recher 1998).

Surveying and mapping

Each plot was initially surveyed using a Magellan Pro-Mark V® GPS receiver to locate each corner and the plot's position in relation to forest roads. A grid was established across each plot by using a compass to maintain parallel survey lines and accurate direction. A clinometer was used to determine topography from variations in slope and to maintain the uniformity of each plot. Each grid comprised thirty-six 50 x 50 m quadrats identified by white, numbered wooden stakes and pegs inserted at 50 m intervals along survey lines (Figs. 2.5-2.8). A metal star-picket painted in red and white bands was inserted in the corner of each plot and half way along each plot's boundaries.

At each 25 m point along the boundaries of each plot, red-white flagging tape was fixed to low branches or stems. Plot boundaries were also delineated by 'circles' of pink fluorescent marking spray on tree trunks, stumps or low branches. Orange flagging tape was fixed to the nearest sapling, shrub or vine at 25 m and 50 m points along each survey line within each plot. Thus, each plot was divided into 25 x 25 m blocks or sub-quadrats. Each quadrat was identified numerically and each sub-quadrat alphanumerically.

Detailed maps of each plot were prepared using data obtained from the surveying work. A spatially explicit mapping application, AUTOCAD® version Lt 97 (Autodesk Inc. 1997), was used to produce these maps.

2.2.4 Position within the landscape

The study area is situated within 7317 ha of relatively continuous native forest that comprise the State Forests of Lower Bucca (2827 ha) and Orara East (4490 ha). These forests form the southern part of a forested continuum that extends north to beyond Halfway Creek (Fig. 2.9). This includes the State Forests of Wedding Bells (5227 ha) and Conglomerate (6490 ha) and Sherwood Nature Reserve (4745 ha).

The continuum of forest occupies part of an undulating coastal range that separates an urbanised coastal plain from inland river valleys, ranges and plateaux. The valleys and parts of the inland ranges and plateaux have been extensively cleared for cattle grazing, horse studs and other agriculture and small villages (42438 ha). This general pattern of land use characterises north-east NSW.

National parks and nature reserves occupy mainly the moist eastern slopes of the ranges and plateaux, to the north-west, west and south-west of the study area (see Fig. 2.1). Within Coffs Harbour Management Area, native forest occupies 152784 ha or 78.26% of the land surface area (Fig. 2.9), while 21575 ha or 11.05% of the management area supports moist hardwood forest (Fig. 2.10). In north-east NSW, 5617613 ha or 57.9% of the land surface area supports native forest (Fig. 2.11), and 967097 ha or 9.97% of the region comprises moist hardwood forest (Fig. 2.12). In Coffs Harbour Management Area, the degree of fragmentation of forest cover is therefore considerably less than the extensively cleared major river valleys to the north, south and west of the area.

The study area occurs within a zone of overlap between two major zoogeographical divisions, the Torresian division of tropical northern and north-eastern Australia and the Bassian division of temperate south-eastern Australia (Schodde & Calaby 1972). This zone, termed the Macpherson-Macleay overlap (Burbidge 1960), extends from approximately Barrington Tops in NSW to Lamington National Park in south-east Queensland. The study area and other forests in this overlap zone feature rich, highly endemic faunal assemblages. Populations at or near their geographic limits are represented in these communities, ascribing outstanding biological significance to this region (Gilmore & Parnaby 1994; NSW NPWS 1994a,e, 1995, 1996a; SFNSW 1995a). Australia's second highest diversity of bird species occurs in the north-east NSW forests (Gilmore & Parnaby 1994).

2.2.5 Previous investigations

There have been no previous studies of the responses of birds to gaps and clusters silviculture in the forests of eastern Australia. However, a number of surveys, bird-banding projects, and other investigations have been completed in CHUMA and its environs (Table 2.1). Many of these exist as unpublished reports or lists of species sent to government agencies and bird-banding organisations. The surveys have been mainly associated with environmental impact studies and regional biodiversity investigations. These have been undertaken over periods of 2-36 months while the bird-banding projects have operated for 3-12 years. Only one prior investigation, a transect-based count of bird species present, has been conducted in Lower Bucca State Forest, approximately 1.5 km west of the study area (NSW NPWS 1995).

A wide range of other surveys and assessments have been conducted in or near the north-east forests of NSW. These have usually been undertaken as part of forestry, mining, transport, housing and commercial development proposals and regional conservation assessment programs. However, there is a lack of detailed investigation of the ecology of forest birds and other fauna and their response to wood production and other anthropogenic disturbances, especially over the longer term, in these forests (see Attiwill *et al.* 1996; NSW Ministerial Advisory Committee 1996; NSW NPWS 1996a).

2.3 Experimental logging trials

2.3.1 Introduction

Many studies of forestry impacts on avifauna around the world have focused on community or population responses to conventional selective harvesting and extensive clearfelling (Loyn *et al.* 1980; Recher *et al.* 1980; Shields *et al.* 1985; Johns 1991; Loyn 1993; Spies *et al.* 1994; King *et al.* 1996; Taylor *et al.* 1997; Aleixo 1999). Others have investigated the impacts of different partial logging systems on bird communities, where given portions of the forest canopy are removed by specific silvicultural operations such as advanced growth retention, overstorey removal and shelterwood logging or thinning (Abbott & Van Heurck 1985; Kavanagh *et al.* 1985; Shields 1990; Brown *et al.* 1991; Taylor & Haseler 1995; Dellasala *et al.* 1996; Annand & Thompson 1997; Rodewald & Smith 1998), and enrichment strips (Mason 1996).

An alternative silvicultural approach is the creation of gaps in the forest canopy. The gaps are matched by equivalent areas of retained forest or 'clusters'. Other components of this approach include thinning areas, interstitial areas, and internal reserves (see Section 2.3.4). In Australia, there is a paucity of experimental studies that examine the spatio-temporal impact of alternative silvicultural systems such as gaps and clusters on forest birds (Norwood *et al.* 1995; Lindenmayer 1997; Lindenmayer & Recher 1998; Recher 1998). This is illustrated by the absence of BACI-based applications of the gaps and clusters silvicultural approach to Australian eucalypt forest birds. Craig (1999) did, however, investigate the impact of larger (9 ha) gaps on West Australian jarrah forest birds using a BACI design, although this work was not technically based on the gaps and clusters approach (Section 2.3.3). This lack of gaps and clusters studies, coupled with recommendations for BACI-based research trials (see Attiwill *et al.* 1996; NSW Ministerial Advisory Committee 1996), provided the initial impetus for my study.

2.3.2 The gaps and clusters concept

In silvicultural terms, there are two principal avenues for the optimal production of wood from commercial eucalypt forests. These are the redistribution of growth by thinning, undertaken in the early-mid stages of the harvest rotation cycle, and restarting the growth cycle by regeneration through gap creation in the later stages of the cycle (SFNSW 1995a). Fig. 2.13 illustrates the effect of these two approaches on forest structure.

Forest managers have recognised that eucalypts regenerate and grow better when they receive more light, experience reduced competition and receive some site disturbance (Jolly

1920; Jacobs 1955; Floyd 1962; SFNSW 1995a,b). Jolly (1920) observed that this could be achieved by removing small groups of trees at or near their point of maximum economic value, thus creating larger gaps in the forest canopy. This practice was termed the Australian Group Selection system (AGS) by Jacobs (1955). He advocated the adoption of gaps of up to 40 metres diameter to raise growth rates and maintain form. This system is currently used in concert with selective logging in NSW north coast forests, with canopy openings of up to 70 metres diameter permissible where suitable stand conditions exist (NSW Department of Urban Affairs and Planning 1999).

The AGS system was modified in 1993 to include specific areas or clusters of less disturbed forest comprising habitat and recruitment trees (SFNSW 1995d,e). This aimed to offset the potential impact of canopy gaps on forest biodiversity. The maximum gap size was set at 60 metres diameter crown-to-crown in dry eucalypt forest and 80 metres diameter crown-to-crown in moist eucalypt forest (SFNSW 1995a,b). This new system was introduced by Horne who termed it the 'Gaps and Clusters Technique' (GCT) or 'Balanced Group Selection' (SFNSW 1993b, 1995a,b,d,e).

The GCT aims to 'arrange' or group forest structure to create spatial mosaics of small canopy gaps, thinned areas and retained forest across otherwise continuously forested landscapes. In doing so, the technique has been put forward as a silvicultural approach that attempts to balance the competing forest management objectives of wood production and conservation of biological diversity (see SFNSW 1995b,d,e; Attiwill *et al.* 1996). This 'dual imperative' (SFNSW 1995c,d; Attiwill *et al.* 1996) has been clearly expressed in the need to improve the silvicultural productivity of regrowth eucalypt forests in NSW and to respond to community demands for wood that is obtained in an ecologically sustainable manner (SFNSW 1993b, 1995a, 1998a, 1999; NSW NPWS 1996a).

The concept of arranging or patterning forest structure embodies five silvicultural zones along a disturbance/wood productivity continuum (Fig. 2.14). Zone IV is the preferred harvest regime that seeks to achieve the wood production/conservation balance in commercial NSW eucalypt forests (SFNSW 1995d). Current practice in the commercial north-east NSW native forests, however, is a harvest regime situated between Zones III and IV. That is, small gaps of up to 70 m diameter are part of integrated logging operations, mainly in moist eucalypt forest types, and encompass 15-22.5% of the net harvest area. Fig. 2.15 illustrates the outcomes for forest structure of Zones I-V.

2.3.3 Applications of the gaps and clusters technique

In Australia, silvicultural systems that use gap creation and thinning techniques were first introduced in 1985 in the dry jarrah forests of south-west Western Australia (Stoneman *et al.* 1989; Norwood *et al.* 1995). In these forests, gaps of up to 10 ha in size (analogous to Zone V in Fig. 2.14) with intervening strips of undisturbed forest approximately 100 metres wide have been established (see also the work of Wardell-Johnson & Williams 2000 in karri forest in this region). Defined cluster, thinning and interstitial zones were not included in these operations. A second study in these forests, the Kingston Block experiment, also investigated potential impacts of gaps of up to 10 ha in size and separated by unlogged forest, on a range of vertebrates (Burrows *et al.* 1993, 1994; Morris & Williams 1998). As part of this work, Craig (1999) investigated the impact of 9 ha gaps and other silvicultural treatments on bird community structure and abundance, and on the foraging ecology of four forest bird species (Chapter 5).

On the NSW north coast, AGS-based coupes were established on a trial basis in the moist coastal eucalypt forests of CHUMA over the period 1992-1994 (SFNSW 1995e,f). These comprised gaps of 1-5 ha and were interspaced with strips of retained forest, thus resembling an extensive gap system similar to Zone 5 in Fig. 2.14. They occurred in Wedding Bells, Tuckers Nob, Pine Creek, Orara East and Lower Bucca State Forests. The Lower Bucca State Forest gaps were established in the Clarkes and Fosters Roads area approximately 1.2 km north of my study area.

A series of experimental gaps were also established in commercial blackbutt forest at Kendall, near Wauchope to examine the effects of a range of canopy gap diameters on regeneration (SFNSW 1993b). Both the CHUMA and Kendall gaps were technically not applications of Horne's gaps and clusters system but rather larger-scale experimental gapping attempts to restart the timber productive cycle by stimulating forest regeneration (SFNSW 1995d).

In 1995 a model demonstration of Horne's full gaps and clusters system was planned in 10 ha of moist eucalypt forest in Compartment 573, Orara East State Forest. A corresponding trial was proposed for dry eucalypt forest in Compartment 249, Boundary Creek State Forest in Grafton Management Area. These were proposed to address concerns over the potential ecological impacts of the gaps and clusters approach and allow for further refinement of the model gaps and clusters operation (SFNSW 1995f). However, the NSW government imposed a State-wide moratorium on all proposed and existing gaps and clusters logging on 20 September 1995, pending scientific assessment of the potential ecological impacts and sustainability of the system (NSW Ministerial Advisory Committee 1996). My study was exempted from this edict (Section 2.3.4).

Gaps created by the clearfell removal of trees and shrubs are also part of current silvicultural strategies in central USA hardwood forests (Annand & Thompson 1997), temperate rainforests of south-east Alaska (Dellasala *et al.* 1996), coniferous forests of USA's Pacific Northwest (Mannan & Meslow 1984; Medin & Booth 1989; McGarigal & McComb 1995; Chambers *et al.* 1999), and the coastal montane forests of British Columbia (Arnott & Beese 1997; Beese & Bryant 1999). These operations commonly involve the creation of large gaps (similar to Zone V in Fig. 2.14), as part of integrated stand management techniques that can include extensive clearfelling for plantation development and selective harvesting.

2.3.4 Operational planning

Planning of the gaps and clusters trials in the study area spanned the period, November 1996-June 1998. The Year 1 logging trial (E1 Plot) was planned for May-June 1997, while the Year 2 trial (E2 Plot) was scheduled for June 1998.

I integrated the organisation of both trials into the standard SFNSW harvest planning process. This included consultations to ensure the research plots and proposed gaps and clusters trials were included in the relevant harvest plans and all regulatory requirements were met, especially pre-logging surveys and conservation protocols for threatened plant and animal species (see SFNSW 1997, 1998b). The remainder of each compartment that comprised the study area was identified for standard selective logging and small (up to 50 m diameter) gaps. A setback zone of at least 100 metres around each control plot was established to ensure logging contractors did not enter these plots.

Key aspects of the planning of the experimental logging trials were the field delineation of treatment zones, regulatory compliance and community consultation, and forest landscape context. I marked three (3) proposed gaps and clusters in each of the two experimental plots and eight (8) gaps and clusters in forest surrounding each of these plots (Figs. 2.16 and 2.17). Therefore, I set aside a total of 22 gaps or 6.48% (14.08 ha) of the study area for gap creation over the two year trial period (Fig. 2.18). I also marked thinning areas, interstitial zones and riparian buffers in each experimental plot and additional thinning areas around each of these plots. Both trials produced only local discontinuities in forest cover, maintained riparian and ridgeline connections, and thus provided an accurate representation of the first gaps and clusters cycle of Horne's original model (Fig. 2.19). Appendix 1 provides further details of the operational planning and silvicultural aspects of my experimental logging trials.

2.3.5 Implementation

The full gaps and clusters model involves a sequence of canopy gaps established in three cutting cycles over a 45-year rotation in moist hardwood forest (SFNSW 1995d,f). In the north-east NSW forests, however, current stand conditions would require 6-10 cutting cycles to fully implement the gaps and clusters model (Horne pers. comm.). The short-term nature of my study meant that only a single cutting cycle could be implemented in each experimental plot.

As much as possible, the gaps and clusters trials reflected standard harvesting practice so as to minimise inherent biases such as tree marking and thinning intensities in field operations (see Burrows *et al.* 1994). However, woody debris piles were left in gaps after logging. Normally these piles are burnt and the ash spread to promote regeneration. The first year was too dry to allow burning of woody debris and although the soil was sufficiently moist in Year 2, all piles remained unburnt to ensure conformity with the Year 1 approach. The piles offer microhabitat for several bird species, hence the post-logging environment may have been more suitable than before logging in these plots (Chapters 5-7).

The Year 1 trial commenced on 18 July 1997 and was completed on 15 August 1997. This included all gaps and thinning within and around the E1 Plot. Within this plot, all gaps and thinning were completed on 26 July 1997. The Year 2 trial began on 3 July 1998 and finished on 17 July 1998, with the completion of all gaps and thinning in the forest surrounding the Year 2 Plot. Within the Year 2 plot, all gaps and thinning were completed on 13 July 1998.

I calculated the total volume of wood product extracted from gaps and thinning zones both inside and outside each trial plot, and for the overall study (see Table 1, Appendix 1). In this way, a measure of the intensity of the experimental trials could be obtained. More than twice the total volume of wood was extracted in Year 1 compared with Year 2. This reflected the higher site quality of the predominantly older (40-60 year-old) regrowth blackbutt stands in E1 Plot. However, the volume of timber harvested from the gaps and thinning zones situated within each plot were comparable - only the volume of timber extracted from the gaps and thinning zones located outside the plots differed.

The first gap (G1 in Fig. 2.5) in E1 Plot was approximately 100 metres (1 ha) in diameter (measured diagonally, crown-to-crown), due to an error that occurred in the extent of clearing of the western boundary. All other gaps were 80 m in diameter to conform with the NSW NPWS licence specifications.

Aerial photographs were taken before (6 April 1997 at 1:25000 scale) and after (2 September 1998 at 1:5000 scale) the creation of gaps in the study area. The change in scale was used to display in detail the size, shape and location of gaps (Plates 2.5 and 2.6). Photographs were taken on the ground before, during and after the logging trials (Plates 2.7-2.12).

2.3.6 Delays

The logging trials were delayed because I had to negotiate with NSW NPWS, NSW Environment Protection Authority (EPA), and community groups. This reduced the amount of field sampling and monitoring of bird populations that could be undertaken, especially before the Year 1 logging trial. Gaining an exemption from the gaps and clusters moratorium took 9 months in the first year.

In addition to this delay, there were holdups in obtaining harvest plan approvals for both trials. Licences in Year 1 were not obtained from NSW NPWS and EPA until 4 July and 18 July 1997, respectively, so that logging had to be postponed for 10 weeks. A shorter, although significant, delay beset the Year 2 trial. Originally scheduled for 1 June 1998, it started 4 weeks late. Both delays required the rescheduling of logging contractors and adjustment of the pre-logging bird movement monitoring program in the experimental plots.

2.4 Sampling of bird populations

I identified moist forest insectivores as a priority group to study because of significant gaps in the knowledge of their use of space and response to logging in coastal lowland forests in Australia and overseas (see Recher *et al.* 1985; Shields *et al.* 1985; Johns 1986, 1989; Smith *et al.* 1995; Morse & Robinson 1999; Robinson & Robinson 1999). I carried out preliminary surveys of the study area to identify suitable species within this group and select study sites. I used four other criteria to determine suitability of birds and sites for my study: frequency of capture and species mix, vegetation structure and composition, topographic position and forest management history.

I set up seven 12 m x 2.7 m x 31 mm mist-nets at various moist forest sites throughout the study area (September-October 1996) and then in the four selected plots (October-November 1996). As a result, 12 species were initially short-listed for study on the basis of frequency of capture. They included Eastern Yellow Robin, Pale-yellow Robin, Yellow-throated Scrubwren, White-browed Scrubwren, Large-billed Scrubwren *Sericornis magnirostris*, Rufous Fantail, Spectacled Monarch, Black-faced Monarch *Monarcha melanopsis*, Golden Whistler, Lewin's Honeyeater *Meliphaga lewinii*, Green Catbird *Ailuroedus crassirostris*, and Logrunner. Six of these species were finally selected for study because they were abundant, easy to detect, foraged mainly on the ground and/or in the understorey, and some were possibly sensitive to gaps and clusters logging. They are Eastern Yellow Robin, Pale-yellow Robin, Yellow-throated Scrubwren, White-browed Scrubwren, Rufous Fantail and Spectacled Monarch (Chapter 3).

A systematic and comprehensive mist-netting and colour-banding program was undertaken in each of the four plots in specific periods from November 1996-March 1998 (Section 4.2.1). I captured, banded, measured and weighed individuals of the study species before releasing them. I also applied metal bands only to small numbers of other birds captured (ie. the 'by-catch'), mostly in Year 1. These included Noisy Pitta *Pitta versicolor*, Regent Bowerbird *Sericulus chrysocephalus*, Bassian Thrush *Zoothera lunulata*, Logrunner, Eastern Whipbird *Psophodes olivaceus*, White-browed Treecreeper *Cormobates leucophaeus*, Red-browed Treecreeper *Climacteris erythrops*, Variegated Fairy-wren *Malurus lamberti*, Large-billed Scrubwren, Brown Gerygone *Gerygone mouki*, Brown Thornbill *Acanthiza pusilla*, Lewin's Honeyeater, Eastern Spinebill *Acanthorhynchus tenuirostris*, Golden Whistler, Grey Shrike-thrush *Colluricincla harmonica*, Green Catbird, Red-browed Finch *Neochmia temporalis* and Australian Owlet-nightjar *Aegotheles cristatus*.

Colour-banded birds of the study species were searched for, detected and followed in each plot from May 1997-December 1998. These movements were recorded on detailed plot maps (1:1250 scale) to determine population size, survivorship and movement (Chapter 4) and home range and microhabitat use (Chapters 5-7). I also made a number of observations of the foraging and breeding ecology of each study species (Chapter 3).

I required a number of permits and licences to undertake my research on protected avifauna in a State forest. These included a bird-banding licence and colour marking authority from Environment Australia's Australian Bird and Bat Banding Scheme, a scientific investigation licence from NSW NPWS, and research permits from SFNSW.

2.5 Vegetation assessment

I assessed the vegetation of the research plots before the experimental logging trials began. This involved sampling and describing the structure, floristic composition, distribution, slope, aspect, topographic unit and disturbance history of dominant plant communities in each plot. Previous work has demonstrated the influence of vegetation structure on the use of space by birds (see Robinson & Holmes 1982, 1984; Howe 1984, 1986; Niemi & Hanowski 1984; Brooker *et al.* 1990; Kutt 1996; Arnold & Weeldenburg 1998).

I sampled 13 vegetation structure variables in each plot before the logging trials began (Table 2.2). I visually estimated and checked, using an Abney level (see Gilmore 1985), the maximum height of each vegetation layer or stratum, from ground cover to the upper canopy. I used a crownometer to determine percentage projective foliage cover (see Norwood *et al.* 1995). Both variables were sampled in a 2 m wide and 12 m long strip along each net station in the Year 1 plots (82 stations) and selected net stations in the Year 2 plots (40 stations). Botanists identified the dominant plant species present in each stratum at these stations. Some specimens were sent to the Royal Botanic Gardens (Sydney) for identification. I then counted the number of juvenile (10-40 cm dboh), pole (41-80 cm dboh) and mature (81-160 cm dboh) stems along these stations. This allowed me to obtain representative profiles of the structure and floristic composition of vegetation in each of the research plots (Appendix 2).

I determined slope using a clinometer and aspect using a compass, both held in a downslope direction from the centre-point of each net station. Topographic units were categorised as upper, mid, lower and drainage line. I obtained past disturbance history from SFNSW compartment history files. At the broader scale, I obtained maps produced by the North-East NSW Comprehensive Regional Assessment project (NSW Department of Urban Affairs and Planning 1999) to provide a regional vegetation distribution perspective (see Figs. 2.9-2.12).

I calculated means and standard deviations for each vegetation structure variable that was sampled in each plot (Table 2.2). I used multivariate statistics to compare the vegetation structure between plots before logging. I performed multivariate analysis of variance (MANOVA, Zar 1999) on the 13 vegetation structure variables using data from 20 net stations in each plot (Table 2.3). Data were transformed to ensure multivariate normality and to stabilise variances. Percentage data (ground stratum cover, lower stratum cover, mid stratum cover and upper stratum cover) were arcsine transformed. Count data (number of juvenile stems, pole stems and mature stems) were square root transformed.

The MANOVA showed that there was a significant difference in vegetation structure as sampled between the plots (Wilks' $\lambda=0.19543$, $F_{39,190}=3.59$, $P=0.000$). Univariate analyses showed that eight of the thirteen variables sampled differed significantly ($P<0.05$) between