# Chapter 3. SITE SELECTION AND STUDY SPECIES

## 3.1 THE STUDY AREA

### 3.1.1 Location and climate

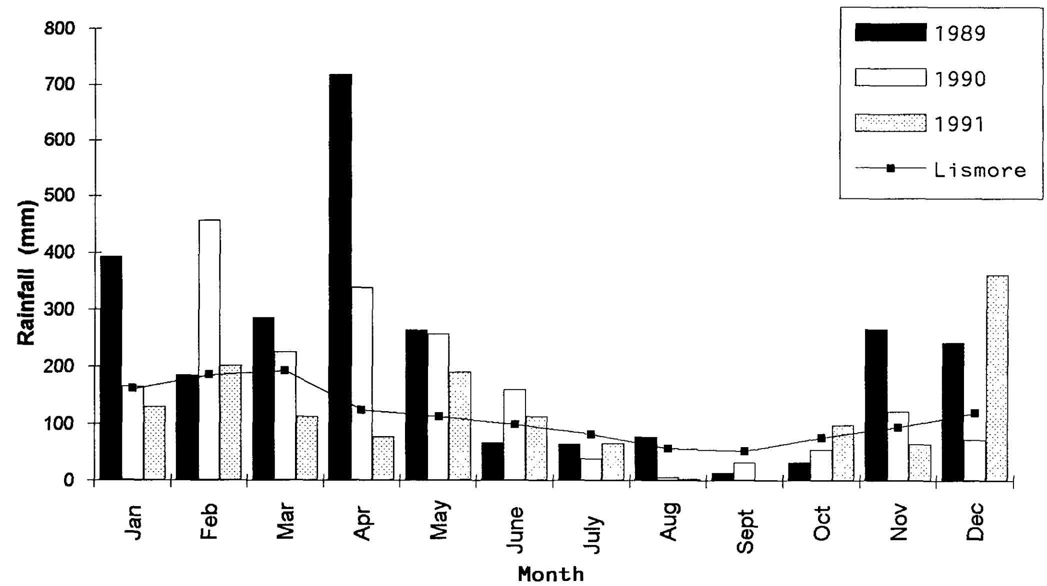
The study area is located in the north-east of New South Wales, in a region surrounding Lismore (28°49'S, 153°17'E). The main feature of the region is the low basaltic plateau (100-200m altitude) which is part of the residual slopes of the Mt Warning shield volcano to the north (Figure 1.1). There is a distinct escarpment to the east, falling 100-140m to the coastal plain, and to the south, above Tuckean swamp. The basaltic plateau has been dissected by the Richmond River and its tributary, Wilsons River. Tuckean Swamp collects waters from several streams in the southern part of the plateau, then discharges into the Richmond at Broadwater. Between Lismore and Alstonville, the Lismore Plateau (up to 150m in elevation) is a relatively flat basaltic plateau often with undulating land of 3-8°, which has escaped dissection by the rivers (Firth 1979).

The original basalt lava flow from Mt Warning extended to the area of sedimentary rocks at Meerschaum Vale and Broken Head (Figure 3.1), where metamorphosed mesoic sedimentary rocks are now found (Dept. of Mines NSW 1972, Floyd 1977). A later lava flow was more viscous, covered the basalt near the Qld/NSW border but did not extend as far south. This flow produced rhyolite, which now forms the northern boundary to the basalt plateau, in Nightcap National Park and Whian Whian State Forest. The basalt left exposed to the south of the rhyolite forms the Lismore (Dunoon/Alstonville) plateau and outlier plateau remnants (eg. Uralba, Coolgardie, Buckombil). The plateau slopes gently from its northern source to the south (Floyd 1977).

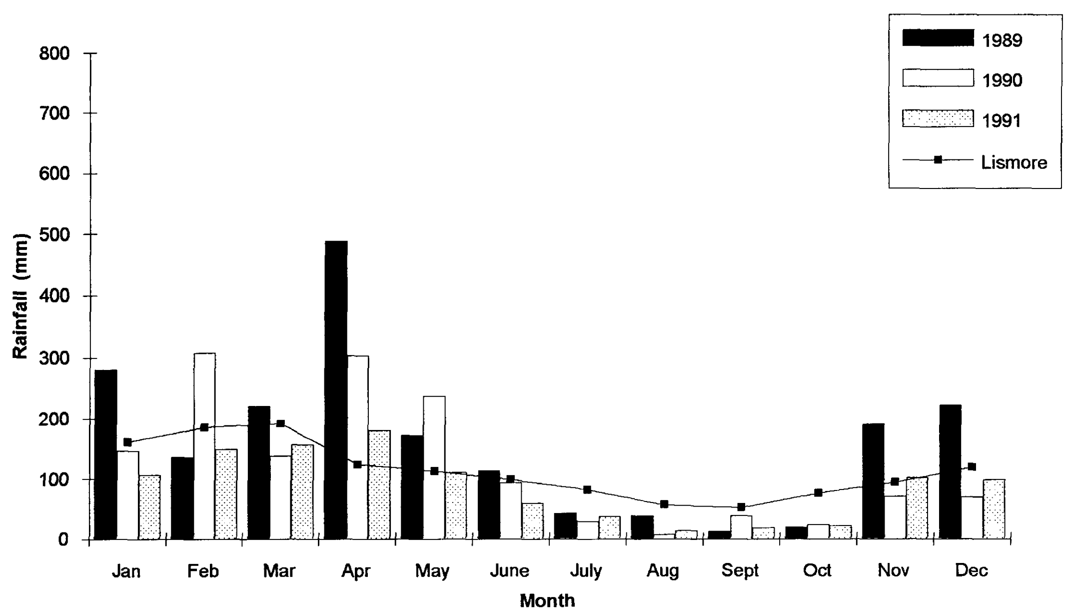
Table 3.1 and Figure 3.2 present climatic averages for Lismore. Mean annual rainfall is 1358mm, with 127 raindays per year (Bureau of Meteorology 1988). The wettest period is December to April, the driest is August to October. Rainfall is higher along the coast and on adjacent plateau areas such as Alstonville (1700mm) (Firth 1979), Rous and the Nightcap Range. Variability increases and expectancy generally decreases from the coast westward. Slopes on the southern side of the Wilson River valley, because of their north-western aspect, form a drier area that penetrates deeply into the wetter plateau areas (Holmes 1987). Rainfall during the study period was represented by a wet year with floods in 1989, an 'average year' in 1990 and 1991, and a dry year in 1992 and 1993, in comparison with the means for Lismore (Figure 3.3) and Alstonville.

**Figure 3.3** Rainfall at Boomerang Falls and Rous (Davis Scrub) between 1989 and 1991, compared with Lismore averages.

a) Boomerang Falls

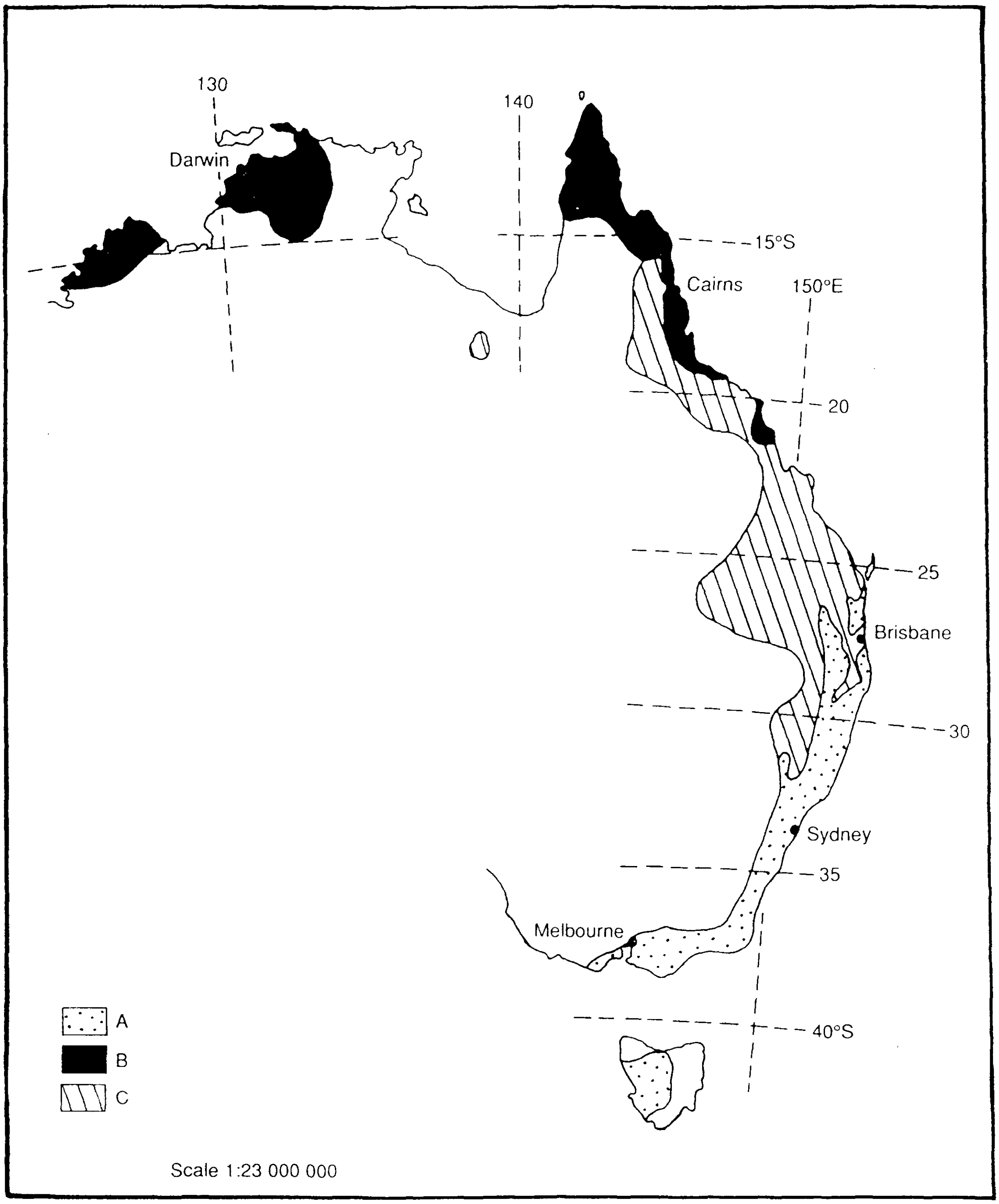



b) Rous




Annual rainfall (in mm) during the study for Boomerang Falls (B) and Rous (R):-
*1989*: 2609 (B) and 1944 (R); *1990*: 1930 (B) and 1469 (R), *1991*: 1422 (B) and 1423 (R), *1992*: 1115 (B) and 1056 (R), *1993* : 1114 (B) and 1166 (R). Mean annual rainfall for Lismore:1358mm (Bureau of Meteorology 1988) and Alstonville: 1700mm (Firth 1979).

**Figure 3.4** Rainforest ecofloristic regions (after Webb *et al.* 1984, map from Adam 1992) (see section 3.1.2 for description of regions A, B, C)




### 3.1.2 Vegetation and soils

The Big Scrub refers to the subtropical rainforest which occurred mainly on the low basaltic plateau near Lismore (Figure 3.1). (Some dry rainforest occurs on the margins of the Lismore plateau, and eucalypt forest on drier ridges.) The rainforest has been estimated to have exceeded 75000 ha (Floyd 1990b, Holmes 1987), forming one of the largest continuous expanses of rainforest in Australia. Clearing has reduced the area to approximately 556 ha (0.74%), much of this as remnants of forest less than 5 ha (Lott & Duggin 1993). Historically, widespread logging of red cedar *Toona australis* occurred in the Big Scrub after 1842. Subsequently, much of the region was cleared for agriculture, and shortly after the turn of the century, most of the forest was gone (Daley 1966, Jeans 1991). Most of the remnants have remained at their current size for the last 50 years (Holmes 1987). Past grazing and selective logging would have caused ground and canopy disturbance to some remnants. However except for a portion of Davis Scrub (section 3.2.4), the current canopy of the original remnants (interpretation of 1986 air photos) is continous with occasional emergents, and lacks significant areas of secondary regrowth, suggesting that most of the canopy trees remain from the primary rainforest.

The Big Scrub is a subset of the rainforests occurring in southeastern Queensland/northeastern New South Wales. In turn, these are a subset of a region of similar rainforest types along eastern Australia, classified by Webb *et al.* (1984): Based on analysis of rainforest and monsoon communities from northern Australia to Tasmania, Webb *et al.* (1984) grouped Australian rainforests into 3 distinct 'ecofloristic regions':
A. south-eastern rainforests, which incorporates temperate (microtherm) and subtropical (mesotherm) humid evergreen rainforests;
B. northern, entirely tropical (megatherm) with humid evergreen to highly seasonal raingreen (monsoon) forests;
C. mid-eastern coastal and subcoastal, subtropical (mesotherm) extending into the subhumid tropics, with moderately seasonal humid/subhumid raingreen subtropical forests with tropical outliers (Figure 3.4).
Each region has its distinctive flora but all three regions (A, B, C) have some species in common. *Castanospermum australe* is one such species.

The 'ecofloristic' regions were further divided into 8 'ecofloristic provinces'. For each, a core area was identified. Climatic-edaphic factors were important in differentiating these rainforests (Webb *et al.* 1984). Within the south-eastern rainforests (region A.), a sub group (province A1) is centred on subtropical coastal southern Queensland and northeastern New South Wales, including the Big Scrub, on basalt soils at low altitudes (generally up to 200-300m) and is generally complex notophyll vine forest (Webb *et al.* 1984).

The classification of Webb *et al.* (1984) based on floristics, matches rainforest type A1 with the humid mesotherm regime of Nix (1982) and includes complex notophyll vine forest (subtropical rainforest), araucarian notophyll vine forest (dry rainforest, in part) and simple notophyll vine forest or simple notophyll vine-fern forest (Webb *et al.* 1984). The tree species which are most common and diagnostic for this core element are *Argyrodendron trifoliolatum, Brachychiton acerifolius, Cryptocarya obovata, Diploglottis cunninghamii, Dysoxylum fraseranum, Elaeocarpus grandis, Flindersia schottiana, Gmelina leichhardtii, Toona australis and Ficus watkinsiana.* (cf. Holmes 1987). These species occur in most remnants of the Big Scrub (37-94% of sites per species). The core element corresponds with the Booyong, Black Bean and Palm (*A. trifoliolatum, Castanospermum australe, Archontophoenix cunninghamii*) rainforest types of Baur (1965) (Webb *et al.* 1984). Baur (1957) noted that the rainforest of the Big Scrub is mainly complex notophyll vine forest (subtropical rainforest), but with some *Araucaria* dominated vine forest on the margins. In general they show little species dominance. Table 3.2 lists common Big Scrub species and their typical location.

Within province A1, some 42 of the 98 rainforest genera of primitive angiosperms and gymnosperms listed by Specht *et al.* (1974) for Australia (Webb & Tracey 1981b, Webb *et al.* 1984) are found. A subset of these are found in the Big Scrub (see Specht *et al.* 1974). The diversity is partly because the southeastern Queensland/northeastern New South Wales region includes representatives from both the Tropical (northern) and Temperate (southern) floras (Burbidge 1960). The region which spans from the Macpherson Ranges in the north to the Macleay River in the south has been termed the MacPherson/Macleay Overlap (Burbidge 1960, see Figure 1.1). The vegetation of the Overlap includes wet sclerophyll forest, eucalypt woodland, coastal heath, wetlands, and in the wetter habitats of the eastern slopes of the ranges, the rainforests of south-east Queensland/north-east NSW. Much of the rainforest within the Overlap is part of the Mount Warning shield which extends between Beenleigh on the northern edge of the shield and the Richmond River on the southern edge (Figure 3.1). The lowland or warm subtropical rainforests of this shield form the major core area for lowland subtropical rainforest on the Australian continent (Webb & Tracey 1981b). These have been largely cleared for agricultural purposes and settlement, including the Big Scrub as already described.

There are three soil types within the true Big Scrub. These are kraznozem, chocolate and alluvial soils. All three are formed from basalt parent material (Tertiary Lismore Basalt), with some sites having influences (Quaternary Alluvium) from the Nimbin Rhyolite to the north in the Nightcap Ranges. Kraznozems cover most of the Big Scrub. Weathered from basalts, they are generally on well drained sites, on hilly uplands and plateaux (Stace *et al.* 1972). The mixing of rhyolite alluvia with basalt soils occurs at the base of the waterfalls and on Rocky Creek in the Big Scrub Flora Reserve (F.R.). In these sites, the rainforest occurs below the rhyolite, on the basalt slopes and in the valley alluvium. Several remnants, such as at Big Scrub F.R., Minyon Falls and Boomerang Falls occur at the northern margin of the Big Scrub, at slightly higher elevation and rainfall, with influences from the rhyolite cap immediately above the basaltic valleys. Although they could be expected to be different from more southern Big Scrub rainforest remnants, all previous studies have accepted these northern sites as part of the Big Scrub. This is probably largely due to the work of Floyd (1990b), who while recognising the potential differences of Big Scrub F.R., described the forest along Rocky Creek in Big Scrub F.R. as once a fine example of *Castanospermum-Dysoxylum* suballiance (prior to logging of *Toona australis* and *Castanospermum australe*) which may once have been similar to other remnants of the Big Scrub (Davis and Johnston's Scrub; Floyd 1990b).

There are conflicting views as to the geographic limits of the Big Scrub (see Lott & Duggin 1993 for comparison of definitions from Floyd 1977, 1990b; Holmes 1987, Connelly & Specht 1988, Mezzatesta 1992). However, all sites used in this study were selected to occur within one vegetation alliance using a conservative definition of the Big Scrub, so this argument was not an issue. The selection criteria for the study sites are outlined in the following section.

**Table 3.2** Typical plant species of rainforest types relevant to study sites, within Big Scrub (dry rainforest and littoral rainforest species excepted) (Source: Holmes 1987).

| SCIENTIFIC NAME | COMMON NAME |
|---|---|
| Common, widespread spp | |
| *Argyrodendron trifoliolatum* | White Booyong |
| *Cryptocarya obovata* | Pepperberry |
| *Castanospermum australe* | Black Bean |
| *Ficus* spp | figs |
| *Diopyros pentamera* | Myrtle Ebony |
| *Planchonella australis* | Black Apple |
| *Endiandra pubens* | Hairy Walnut |
| *Diploglottis australis* | Native Tamarind |
| *Toona australis* | Red Cedar |
| *Archontophoenix cunninghamiana* | Bangalow Palm |
| Common smaller trees and shrubs | |
| *Arytera distylis* | Twin-leaved Coogera |
| *Notelaea johnsonii* | Veinless Mock Olive |
| *Wilkiea huegeliana* | Veiny Wilkiea |
| *Ervatamia angustisepala* | Banana Bush |
| *Triunia youngiana* | Honeysuckle Bush |
| *Cordyline rubra* | Red-fruited Palm -Lilly |
| *Linospadix monostachyus* | Walking-stick Palm |
| *Quassia* sp. nov. | Southern Quassia (less numerous but characteristic) |

| | |
|---|---|
| <u>Rainforest edge/disturbed areas</u> | |
| *Flindersia schottiana* | Cudgerie |
| *Alphitonia excelsa* | Red Ash |
| *Guioa semiglauca* | Guioa |
| *Jagera pseudorhus* | Foambark |
| *Mallotus philippensis* | Red Kamala |
| <u>Rhyolite</u> | |
| *Ceratopetalum apetalum* | Coachwood |
| *Caldcluvia paniculosa* | Soft Corkwood |
| *Quintinia verdonii* | Grey Possumwood |
| *Austromyrtus lasioclada* | Velvet Myrtle |
| *Anopterus macleayanus* | Macleay Laurel |
| <u>Rhyolite/Poorer sedimentary rock</u> | |
| *Schizomeria ovata* | Crabapple |
| *Callicoma serratifolia* | Callicoma |
| *Canarium australasica* | Mango Bark |
| *Cryptocarya rigida* | Rose Maple |
| *Endiandra discolor* | Rose Walnut |
| *Amorphospermum whitei* | Rusty Plum |
| *Abrophyllum arnans* | Native Hydrangea |
| *Helicia ferruginea* | Rusty Helicia |
| *Elaeocarpus reticulatus* | Blueberry Ash |
| *Trochocarpa laurina* | Tree-Heath |
| <u>Alluvium</u> | |
| *Castanospermum australe* | Black Bean |
| *Cryptocarya obovata* | Pepperberry |
| *Syzygium francissii* | Giant Water Gum |
| *Cinnamomum oliveri* | Oliver's Sassafras |
| *Toona australis* | Red Cedar |
| *Aphananthe philippinensis* | Rough-leaved Elm |
| *Ficus coronata* | Creek Sandpaper Fig |
| *Streblus brunonianus* | Whalebone Tree |
| *Ehretia acuminata* | Koda |
| *Cryptocarya bowiei* | Glossy Laurel |
| <u>Exotic species</u> | |
| *Cinnamomum camphora* | Camphor Laurel |
| *Solanum mauritianum* | Wild Tobacco |
| *Ligustrum* spp. | privets |
| *Lantana camara* | Lantana |

## 3.2 THE STUDY SITES

### 3.2.1 Selection criteria for the study sites

A comparison of seed ecology between remnants requires selecting several sites with a similar vegetation association, in this case preferably containing a similar abundance of *C. australe*. There are approximately 38 rainforest remnants of the Big Scrub, but most are less than 5 ha in size (Lott & Duggin 1993). For most, their vegetation type has not been defined, presumably due to their small size and disturbed condition. Of the more intact remnants within the Big Scrub, Floyd (1990b) recognised four major floristic suballiances, of which the *Argyrodendron* suballiances include *C. australe*. Sites described by Floyd (1977, 1981, 1990a,b) are listed in Table 3.3.

Suballiance 5 (*Castanospermum-Dysoxylum*) seemed most appropriate for a study of *C. australe*. It offered the best range of remnant sizes, these occurred on public lands with reasonable access, and it was a vegetation association where *C. australe* was relatively common. Suballiance 1 sites were less suitable: sites were more widely spaced geographically, the size range was less evenly distributed, and two small sites were prone to flooding and other disturbance and were roosting sites for flying fox colonies. Suballiance 3 was rejected as there were too few documented sites.

Five remnants of suballiance 5 (*Castanospermum-Dysoxylum*) were selected for study (Table 3.4): Big Scrub F.R., Boomerang Falls, Johnston's Scrub, Wollongbar and Davis Scrub. These remnants were selected because they spanned a range of sizes (148.2, 62.5, 21.5, 1.7 and 10.5 ha of primary rainforest, respectively). Sites were not replicated for size, due to the lack of suitable sites which were accessible within the time constraints. Other potential sites classified by Floyd (1990b) were excluded. That is, Wanganui and the base of Minyon Falls were relatively inaccessible, in addition to which, Minyon Falls only contains a minor pockets of suballiance 5; Eltham ("a small site on a stony basaltic ridge") appeared too disturbed and invaded by Lantana *Lantana camara*, Privet *Ligustrum* sp. and Camphor Laurel *Cinnamomum camphora*; at Kellin Falls, access was not available, and the canopy is dominated by *D. muelleri* and the introduced *C. camphora*, with *C. australe* less common (Floyd 1990b); and at Morton's Scrub, Emery's Scrub and Rocky Creek, the sites have been disturbed by grazing and canopy damage (e.g. logging), resulting in considerable invasion by *L. camara* and Lawyer Cane *Calamus muelleri* and at times, by vines, *Ligustrum* spp. and *C. camphora* (Floyd 1981; R. Lott pers. obs.). Figure 3.1 indicates the location of the study sites within the Big Scrub.

**Table 3.3** The four main suballiances within the Big Scrub, and examples of locations (Floyd 1977, 1981,1990b).

| | Area* (ha) | Adj. veg# | Soil parent material |
|---|---|---|---|
| ***Argyrodendron* alliance** (Subtropical rainforest) | | | |
| Suballiance No. 1 *Argyrodendron trifoliolatum* | | | |
| Big Scrub Flora Reserve (more elevated sections away from Rocky Creek) | 148.2 | + | Tlb,Tnr |
| Johnston's Scrub (higher elevations) | 21.5 | c | Tlb |
| Booyong | 11.9 | - | Qa |
| Victoria Park | 7.9 | - | Tlb |
| Hayters Hill (west) | 3 | - | Tlb |
| Currie Park | 2.9 | - | Qa |
| Suballiance No. 3 *Cryptocarya obovata-Dendrocnide excelsa-Ficus* spp-*Araucaria* suballiance | | | |
| Boatharbour N.R. | 13.1 | - | Qa |
| Suballiance No. 5 *Castanospermum-Dysoxylum muelleri* | | | |
| Big Scrub Flora Reserve (along Rocky Creek) | 148.2 | + | Tlb,Tnr |
| Minyon Falls | 68.4 | + | Tlb,Tnr |
| Boomerang Falls | 62.5 | + | Tlb,Tnr |
| Johnston's Scrub (mid-lower slopes) | 21.5 | c | Tlb |
| Davis Scrub N.R. | 10.5 | - | Tlb |
| Rocky Creek | 5.75 | c | Tlb,Qa |
| Morton's Scrub | 4.5 | - | Tlb, Qa |
| Emery's Scrub | 3.7 | - | Tlb |
| Kellin Falls | 2.75 | c | Tlb |
| Eltham (probably Glendower) | 1.9 | - | Tlb |
| Wollongbar | 1.7 | - | Tlb |
| Wanganui | scattered in valley | + | Tlb, Tnr,Qa |
| ***Drypetes-Araucaria* alliance** (Dry rainforest) | | | |
| Suballiance No. 21 *Araucaria* | | | |
| Wilson Park | 22 | + | Tlb |
| Rotary Park | 12.4 | - | Tlb |
| Hayters Hill (east) | 4.5 | - | Tlb |

* total area of primary rainforest only; the area attributed to each vegetation suballiance is not given.
# adjacent vegetation: (-) remnant isolated by cleared agricultural land, (c) connected to corridor of regrowth or native vegetation, (+) contiguous with native vegetation (eucalypt forest).
Soil parent material (Holmes 1987, Floyd 1990b): (Tlb) Tertiary Lismore basalt, (Tnr) Tertiary Nimbin rhyolite, (Qa) Quaternary alluvium.

**Table 3.4** Description of study sites.

| | Area* (ha) | Isolation distance (km)^ | Adjac. veg# | water | elevation (m)^ | Soil parent material^ |
|---|---|---|---|---|---|---|
| Big Scrub Flora Reserve | 148.2 | 0 | +,e,g | ++ | 160-310 | Tlb,Tnr |
| Boomerang Falls | 62.5 | 0 | +,e,g | ++ | 130-210 | Tlb,Tnr |
| Johnston's Scrub | 21.5 | 8 | c,r,g | + | 30-110 | Tlb |
| Wollongbar | 1.7 | 19.5 | -,g | - | 180 | Tlb |
| Davis Scrub N.R. | 10.5 | 25 | -,g | - | 160-170 | Tlb |

* area of primary rainforest determined from 1958 and 1967 air photos; minimal expansion of edge has occurred since then.

^ Holmes (1987); isolation distance is measured from nearest Nightcap Range remnant; see Table 3.3 for soil parent material groups.

# adjacent vegetation: (-) remnant isolated by cleared agricultural land, (c) connected to corridor of regrowth or native vegetation, (+) contiguous with native vegetation (eucalypt forest), (e) eucalypt forest, (r) small remnant rainforest patches and secondary regroth, (g) grazing land (grass).

Water: (++) stream dissects remnant, (+) mainly at perimeter of remnant, (-) none

Suballiance 5 occurs on moist alluvial flats and benches with fertile, deep basaltic red loams built up by weathering of lowland plateaux; colluvium on benches and terraces; or alluvial accumulation in river valleys (Floyd 1990b). All five remnants are located on kraznozem soils (Tertiary Lismore Basalt), however, Big Scrub F.R. and Boomerang Falls include alluvium from the Nimbin rhyolite which occurs on the Nightcap Range (Holmes 1987). In these sites, study trees were selected on the kraznozem slopes.

Figure 3.5 indicates the location of the study sites and study plots. At Big Scrub F.R., the study plots were placed in the upper elevations of the rainforest to improve access, and maximise distance away from the public. Some clarification of the choice of plot location is warranted, as the location of suballiances within Big Scrub F.R. is not clear from the literature: Floyd (1990b) described the slightly higher elevations of Big Scrub F.R. as now being *A. trifoliolatum* suballiance 1. However, he appears to have been referring to the lower region of the Flora Reserve (Figure 3.5a), where *C. australe* is absent or in low abundance, and *A. trifoliolatum* is abundant. Here, logging in the mid 1950s probably increased the relative abundance of *A. trifoliolatum*, while decreasing the abundance of *C. australe* and *Toona australis* (Floyd 1990b), species which were sought for their commercial value. The upper slopes of the Flora Reserve, adjacent to the eucalypt forest, have a high abundance of *C. australe*, and *A. trifoliolatum* is less abundant. This upper area may be continuous with the lower slopes of Rocky Creek, currently at the edge of Rocky Creek Dam. Indeed the areas visited by Floyd and described as suballiance 5 were a small remnant on Rocky Creek, 1 km below the Flora Reserve, and the foreshore of Rocky Creek Dam, formerly along Rocky Creek (A. Floyd pers. comm.). In the study plots at Big Scrub F.R. (section 3.2.2), *Dendrocnide excelsa, Sloanea australis, Syzygium crebrinerve, C. australe* and *A. trifoliolatum* were the most common trees. These species were described by Floyd (1990b) as the most common trees in the reserve (along with *Ficus watkinsiana*), and common in suballiance 5 along Rocky Creek. Given the common occurrence of *C. australe*, and the necessity to have a large site as a comparison with the smaller sites of suballiance No. 5 vegetation, the upper slope of Big Scrub F.R. was accepted as a suitable control site. This is also supported by Floyd's statement that it was probable that prior to logging, much of Big Scrub Flora Reserve was probably suballiance 5 (*Castanospermum-Dysoxylum*). The lower abundance of *D. muelleri* in the study plots is consistent with the suballiance 5 locations at Boomerang Falls and Minyon Falls.

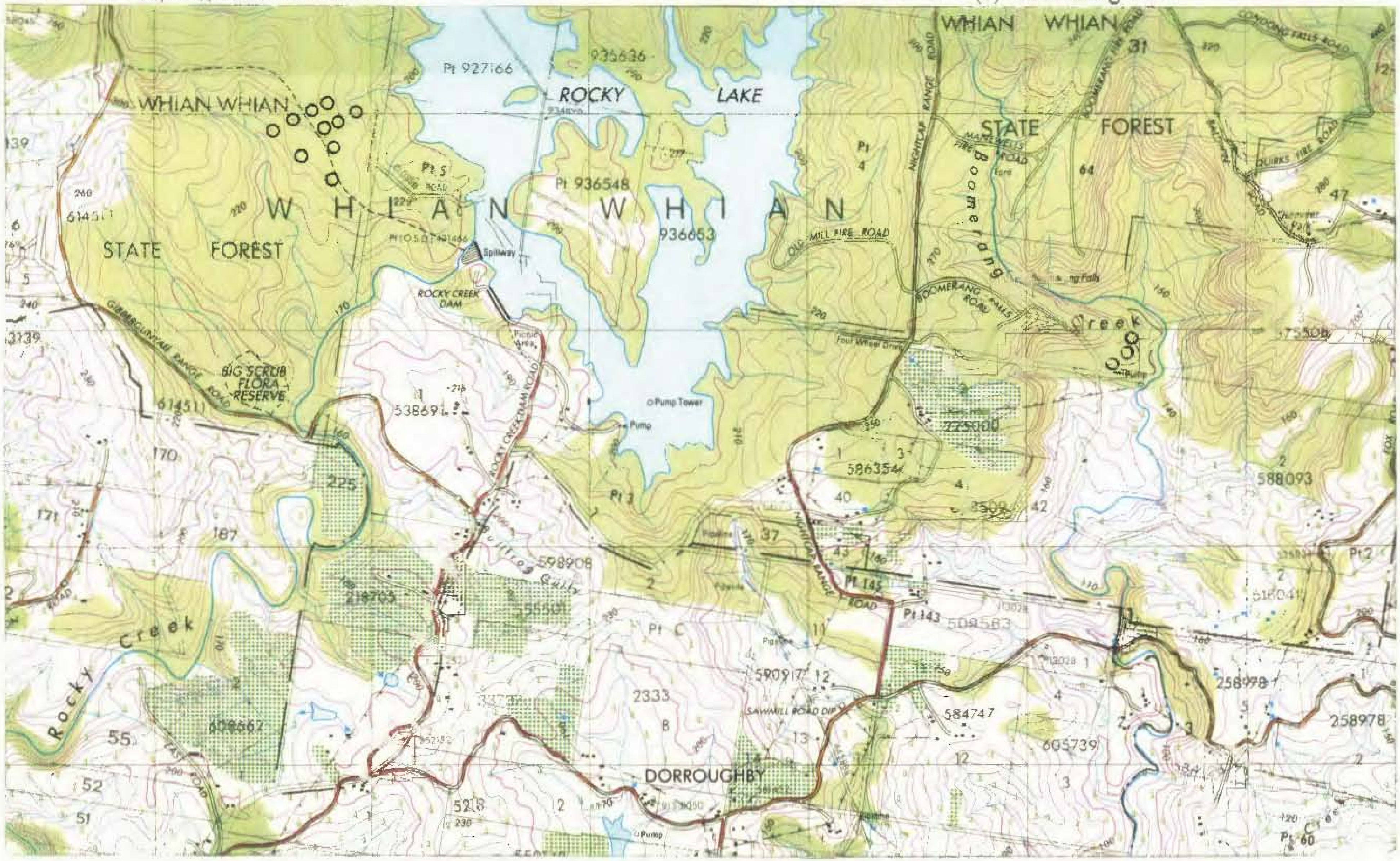
At Boomerang Falls, plots were located on the slightly elevated flat area between the junction of the two creeks, in the southern portion of the reserve (Figure 3.5b). At Johnston's Scrub, study trees were selected in the mid-lower slope of the remnant, well below the crest of the hill (Figure 3.5c).

In the remainder of the thesis, the following abbreviations will be used to designate the study sites:

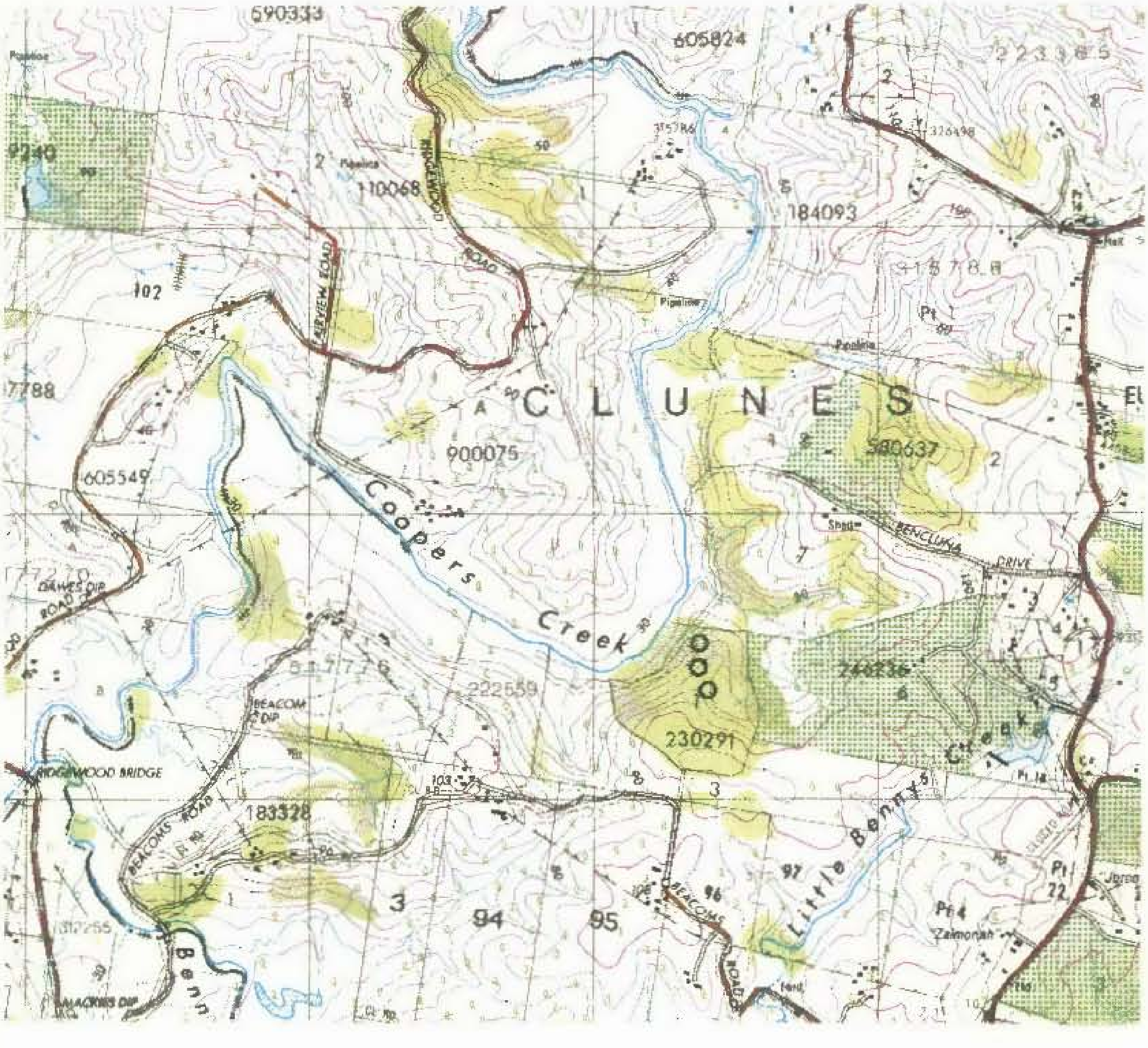
- Big Scrub Flora Reserve (Big Scrub, or BS)
- Boomerang Falls Flora Reserve (Boomerang, or Boom)
- Johnston's Scrub (Johnston's, or Johnst)
- Wollongbar (Wollongbar, or Woll)
- Davis Scrub Nature Reserve (Davis Scrub, Davis)

Figure 3.5 Locations of study sites and study trees within Big Scrub (circles indicate location of study trees).

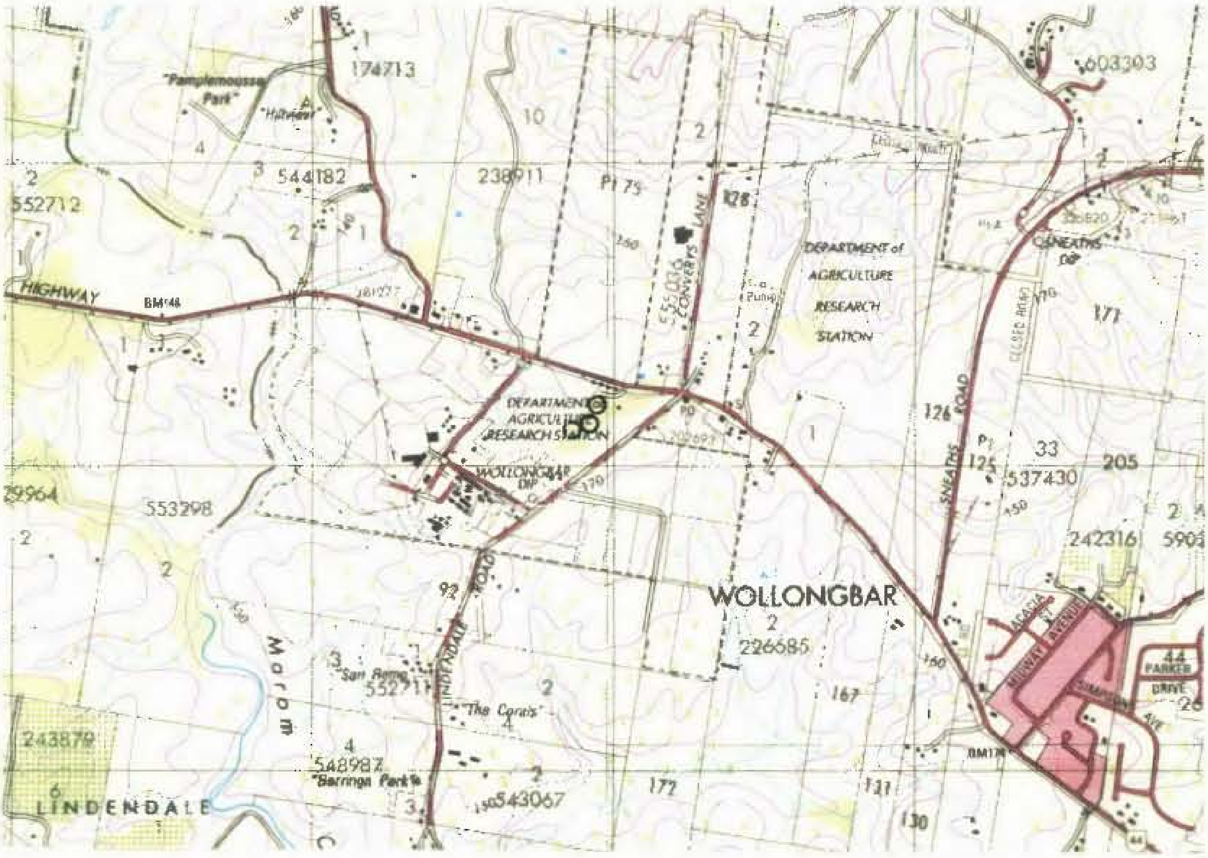
(a) Big Scrub Flora Reserve (b) Boomerang Falls



(c) Johnston's Scrub



(d) Wollongbar




(e) Davis Scrub

### 3.2.2 Vegetation at study sites (Species richness and composition)

In suballiance 5, the species most common differs between remnants (Table 3.5), and the suballiance appears less distinct in the northern sites. This is based on Floyd's (1990b) description of the study sites :- At Wanganui, the majority of rainforest is *Castanospermum-Dysoxylum*, with a minor occurrence of the *Elaeocarpus* suballiance No 4. Here, most common species (suballiance 5) are *D. muelleri, Toona australis, Syzygium crebrinerve* and *Sloanea australis. Castanospermum australe* is less common (Floyd 1990b). At Minyon Falls and Boomerang Falls, the narrow valleys of basalt below the rhyolite contain small localised areas where *C. australe* may predominate but *D. muelleri* is absent. At Boomerang Falls the major species are *C. australe, Geiossis benthamii, S. australis* and *S. woollsii*. Below Minyon Falls, the alluvium is mainly rhyolite which supports suballiance No. 33 *Ceratopetalum apetalum-S. woollsii*, but minor pockets of suballiance 5 occur on the better basaltic soil and are dominated by *C. australe* and *S. australis* (Floyd 1990b).

To describe the study sites, all trees over 5 dm d.b.h. were mapped and identified to species within each of three 20 x 20 m plots at each site. Each plot was centred on one of the *C. australe* study trees. A full list of the tree species recorded from plots at the five sites is given in Appendix 6. Table 3.6 gives tree species richness and diversity for individual plots and sites. Shannon-Wiener diversity indices are corrected for all known species of tree at each of the study sites, based on plant species lists from Holmes (1987).

Based on the plots, all sites contained *Argyrodendron trifoliolatum, Castanospermum australe, Arytera distilis* and *Anthocarapa nitidula*. *Dysoxylum muelleri* was present in plots at four sites, and although not detected, is present at Big Scrub (see Holmes 1987). *Castanospermum australe* and *D. muelleri* are the main species, in addition to *A. trifoliolatum*, that typify suballiance 5 (Floyd 1990b). Species which were recorded at four of the five sites were: *Neolitsea australis, Planchonella australis, Endiandra pubens, Diospyros pentamera, Sloanea australis, Endiandra muelleri* and *Cinnamomum oliveri*.

All four smaller sites had some species in common with Big Scrub F.R., the number of species decreasing with increased distance from Big Scrub F.R.: Boomerang Falls (22 species), Johnston's Scrub (18 species), Wollongbar (14 species) and Davis Scrub (12 species). For each site, there were some species which were not recorded at any other study site: Big Scrub F.R. (5), Boomerang Falls (5), Johnston's Scrub (8), Wollongbar (11) and Davis (4). Analysis of the literature revealed that most of these differences can be explained by species distributions and sampling: Most of the species are known from at least two of the study sites (Holmes 1987) but were not recorded within the plots, reflecting the low probability of encountering all species within the sampled area. Some species appear to occur in the more northern and coastal metamorphic sites of the Big Scrub region (see Holmes 1987) and thus are not expected in the southern study sites: *Caldcluvia paniculosa* (Boomerang Falls) has not been recorded outside Big Scrub and Boomerang Falls, *Archidendron grandiflorum* (Boomerang Falls) is known only from 8 of the 32 remnants surveyed, *Castanospora alphandii* (Johnston's Scrub) is known from 11 of the more northern sites and *Daphnandra tenuipes* (Johnston's Scrub) was only previously known from 3 sites (Holmes 1987). Another species *Euroschinus falcata*, which mainly occurs in alluvial and dry rainforest sites (see Holmes 1987), was recorded for the first time at Davis Scrub during this study. Two introduced species recorded only at Wollongbar during this study are not known at the other study sites.

Wollongbar and Big Scrub had a higher species richness than the other three sites (Table 3.6). Davis Scrub had a lower species diversity (H and E) than the other four sites, which were similar (Table 3.6). This is due to its lower number of species.

**Table 3.5** Common species within sites of suballiance 5 in the Big Scrub (Source: Floyd 1990b)

| Site | Common species |
|---|---|
| Davis Scrub | *Castanospermum australe, D. muelleri, Syzygium crebrinerve, Ficus macrophylla* |
| Wollongbar | *C. australe, D. muelleri, Flindersia xanthoxyla, F. schottiana, A. trifoliolatum, Toona australis* |
| Johnston's Scrub | *C. australe, Ficus watkinsiana, Dendrocnide excelsa, Anthocarapa nitidula, A. trifoliolatum* |
| Eltham | *C. australe, D. muelleri, D. fraserianum, A. trifoliolatum* |
| Kellin Falls | *D. muelleri, Cinnamomum camphora* (*C. australe, Sloanea australis, Syzygium moorei* and *A. trifoliolatum* are less common) |
| Big Scrub F. R. | *C. australe, S. crebrinerve, S. australis, A. trifoliolatum, F. watkinsiana, D. excelsa* |
| Boomerang Falls | *C. australe, Geiossois benthami, S. australis, S. woollsii* |
| Below Minyon Falls | *C. australe, S. australis* |
| Wanganui | *D. muelleri, Toona australis, S. crebrinerve, S. australis* (*C. australe* is less common.) |

**Table 3.6** Species diversity of 20 x 20m vegetation plots at the study sites (H= Shannon-Wiener diversity index, Krebs 1978).

| Site | Plot No. | No. species | No. individuals | H | H max* | Equitability (H / Hmax) |
|---|---|---|---|---|---|---|
| Big Scrub | 1 | 16 | 38 | 3.49 | 7.5 | 0.47 |
| | 2 | 16 | 51 | 3.29 | 7.5 | 0.44 |
| | 6 | 24 | 61 | 3.42 | 7.5 | 0.46 |
| *combined site* | - | *38* | *150* | *4.0* | *7.5* | *0.53* |
| Boomerang | 1 | 21 | 56 | 4.07 | 7.03 | 0.58 |
| | 2 | 16 | 37 | 3.49 | 7.03 | 0.49 |
| | 3 | 15 | 50 | 3.34 | 7.03 | 0.47 |
| *combined site* | - | *33* | *143* | *4.18* | *7.03* | *0.59* |
| Johnston's | 1 | 21 | 52 | 3.67 | 7.04 | 0.52 |
| | 2 | 17 | 38 | 3.33 | 7.04 | 0.47 |
| | 3 | 14 | 44 | 2.79 | 7.04 | 0.4 |
| *combined site* | - | *32* | *134* | *3.72* | *7.04* | *0.53* |
| Wollongbar | 1 | 20 | 41 | 3.92 | 6.78 | 0.58 |
| | 2 | 16 | 75 | 3.39 | 6.78 | 0.5 |
| | 3 | 24 | 77 | 3.96 | 6.78 | 0.58 |
| *combined site* | - | *35* | *193* | *4.13* | *6.78* | *0.61* |
| Davis | 1 | 11 | 49 | 2.2 | 7.14 | 0.31 |
| | 2 | 14 | 60 | 2.46 | 7.14 | 0.34 |
| | 3 | 12 | 40 | 2.62 | 7.14 | 0.37 |
| *combined site* | - | *26* | *149* | *2.8* | *7.14* | *0.39* |

* H max is H corrected for total known tree and shrub species per site (see Table 3.8)

### 3.2.3 Fauna

Compared with other Australian rainforests, the south-east Queensland and north-east New South Wales rainforests form a distinct region, with a distinct fauna. In terms of rainforest species diversity, this regions holds a position intermediate between northern Queensland and the temperate rainforests of Victoria and Tasmania (Frith 1976). Eight species of native mammal (Table 3.7) and about half of the true rainforest birds (from throughout

Australia) are commonly found in rainforest of the region (Frith 1976). All of these mammal and bird species appear to have occurred within the original Big Scrub.

Four of the mammal species are restricted to rainforest (obligate). These are the Fawn-footed Melomys *Melomys cervinipes*, Mountain Brushtail Possum *Trichosurus caninus* (Smith *et al.* 1989) and two Pademelon species *Thylogale stigmatica, T. thetis* (Frith 1976). All eight mammal species have been recorded in Big Scrub F.R. Two additional species, *Potorous tridactylus* and *Dasyurus maculatus* may depend on rainforest ('rainforest obligate'), but they are rarely found in northeastern New South Wales (Smith *et al.* 1989). In the remnants, mammal species' occurrence depends on size and location of the remnant (Appendix 2; Lott & Duggin 1993).

Survey information for individual Big Scrub remnants is limited. The only specific study of the Big Scrub is Holmes (1987), who surveyed the avifauna (and flora species) of 32 remnants. As part of the study of *C. australe*, I conducted small mammal trapping at the five study sites. Methods are given in Chapter 5. Several other studies have included a systematic survey of 1-6 remnants of the Big Scrub, to determine species occurrence. These are Date *et al.* (1991, pigeons); Smith *et al.* (1989, fauna of the Mount Warning Caldera); Eby (1990, bats); Eby, Lunney and Milledge (pers comm., data on flying fox camps); N. Campbell (pers comm, small mammals); and the North East Forest Fauna Survey (NSW NPWS 1994, henceforth abbreviated NEFFS). No systematic sampling of invertebrates appears to have been done in the Big Scrub. Table 3.8 gives plant and vertebrate species richness for the five study sites investigated in this thesis.

There is little known about the specific ecology of the rainforest fauna, from which to interpret individual species response to habitat alteration and forest fragmentation. Species occurrence data is available for 13 Big Scrub sites for frogs, reptiles, mammals and bats (Appendix 2); and 35 sites for birds. Methodology differed between researchers and years, and for several sites, trapping did not include the range of small elliott, cage trap and spotlighting (nor a mix of baits), which is ideal for detecting a range of species. From the available sources, Lott and Duggin (1993) tabulated species lists for 13 sites. These indicate that there is reduced richness of birds and mammals in small remnants of the Big Scrub, compared with Big Scrub F.R. (Figure 3.6) and other large tracts of subtropical rainforest within the region. Surveys of reptiles are inadequate to determine whether there has been an effect of forest fragmentation on species composition of sites.

**Table 3.7** Mammal species found in rainforest of the Border Ranges and Big Scrub.

| Family | Species | Rainforest obligate | Facultative | Non-rainforest but sometimes present |
|---|---|---|---|---|
| Ornithorhynchida | *Ornithorhynchus anatinus* | | + | |
| Tachyglossidae | *Tachyglossus aculeatus* | | | + |
| Dasyuridae | *Dasyurus maculatus* | + | | |
| | * *Antechinus stuartii* | | + | |
| Peramelidae | * *Perameles nasuta* | | + | |
| | *Isoodon macrourus* | | | + |
| Phalangeridae | * *Trichosurus caninus* | + | | |
| Petauridae | * *Pseudocheirus peregrinu* | | + | |
| Macropodidae | * *Thylogale thetis* | + | | |
| | * *T. stigmatica* | + | | |
| | *Macropus dorsalis* | | + | |
| | *M. parma* | | + | |
| Potoroidae | *Potorous tridactylus* | + | | |
| Muridae | *Hydromys chrysogaster* | | + | |
| | * *Melomys cervinipes* | + | | |
| | * *Rattus fuscipes* | | + | |
| | # *Rattus rattus* | | | + |
| | # *Mus domesticus* | | | + |

Designation of rainforest dependence based upon Smith *et al.* (1989) and Frith (1976).
*commonly found in rainforest of northeastern New South Wales
# introduced species

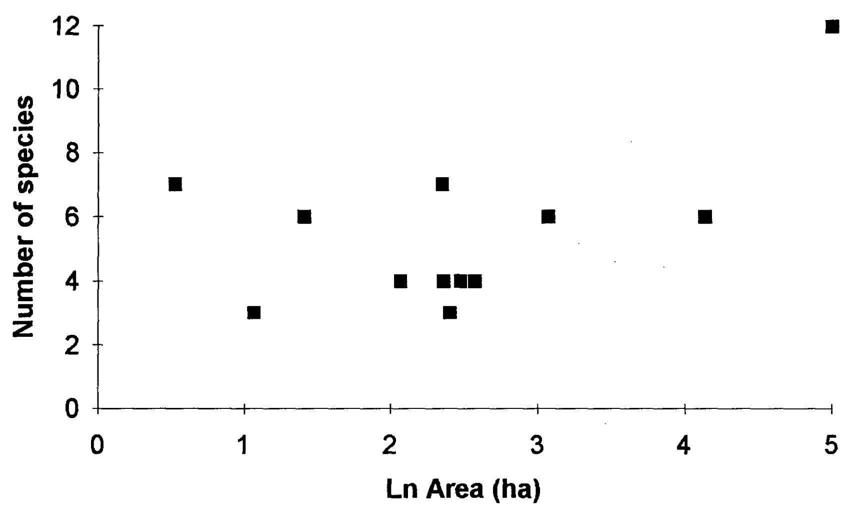
**Table 3.8** Species richness of plants and animals at the study sites.

| Site | No. tree spp. in plots | Tree* & shrubs | Birds* | Rainforest dependent birds | Mammals excl. bats# (native) | Reptiles# & amphibians | Rare plant spp.# | Area 1° Rf.# |
|---|---|---|---|---|---|---|---|---|
| Big Scrub | 38 | 181 | 45 | 24 | 12(11) | 13 | 11 | 148.2 |
| Boomerang | 33 | 131 | 38 | 23 | 6(5) | - | 9 | 62.5 |
| Johnston's | 32 | 132 | 24 | 16 | 5(3) | - | 8 | 21.5 |
| Wollongbar | 36 | 110 | 8 | 4 | 5(3) | - | 5 | 1.7 |
| Davis | 26 | 141 | 24 | 14 | 7(2) | 3 | 9 | 10.5 |

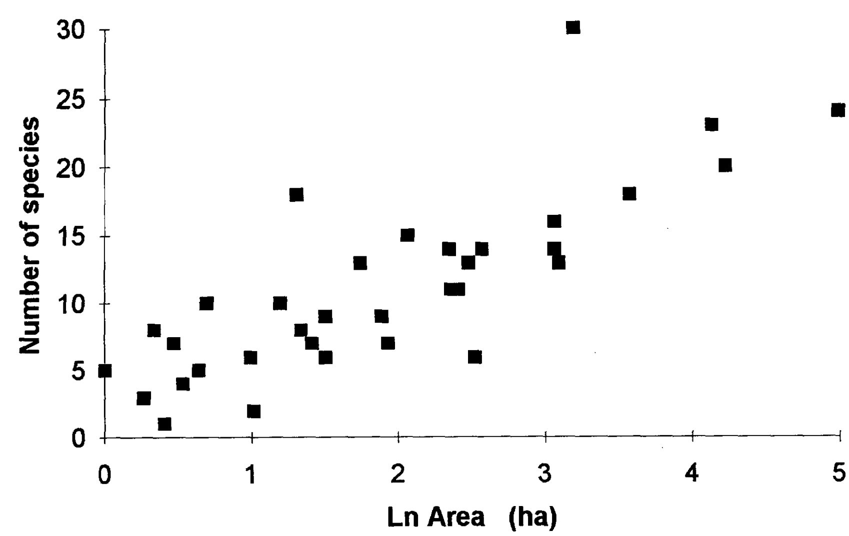
# Lott & Duggin (1993)
* Holmes (1987)
- not surveyed

**Figure 3.6** Species-area curves for fauna of Big Scrub remnants

a) Mammals excluding bats (13 sites)




b) Rainforest-dependent bird species (35 sites)




Regression $y=4.196x+3.183$, $p<0.001$, $R^2=0.67$

(Source: Holmes 1987, Lott & Duggin 1993 and references within)

### 3.2.4 Land use at study sites

Big Scrub Flora Reserve, and the majority of the rainforest at Boomerang Falls are administered by Forestry Commission of NSW. The complete area of rainforest at Boomerang Falls has mixed tenure, spanning State Forest and private land. Davis Scrub Nature Reserve and Johnston's Scrub Nature Reserve (previously Byron Shire Council Trustee, gazetted NPWS estate 26 March 1993) are administered by National Parks and Wildlife Service (NPWS). Wollongbar is also on public land (Department of Agriculture).

Big Scrub F.R. and Boomerang Falls are contiguous with eucalypt forest (Table 3.4). Therefore, although they are remnants of rainforest, they are not isolated patches. Johnston's Scrub is an isolated remnant but is adjacent to regrowth corridors and small remants of forest along the creek and hillside. Part of this corridor contains small areas of original rainforest, present prior to at least 1967 (1967 air photos). All remnants have a sharply truncated boundary on at least one side (sometimes with a fence within 3m of the base of the trees), and a distinct land use change outside (Table 3.4). Wollongbar is surrounded by grazing land and is bordered on two sides by a road. It is also divided by a road, reducing its effective size as fauna and flora habitat. Davis Scrub is isolated, and surrounded by grazing lands and a cemetary. Recently (ca 1989+), plantations of *Macadamia* sp. and avocado have been planted adjacent to Davis Scrub, Big Scrub F.R. and Boomerang Falls.

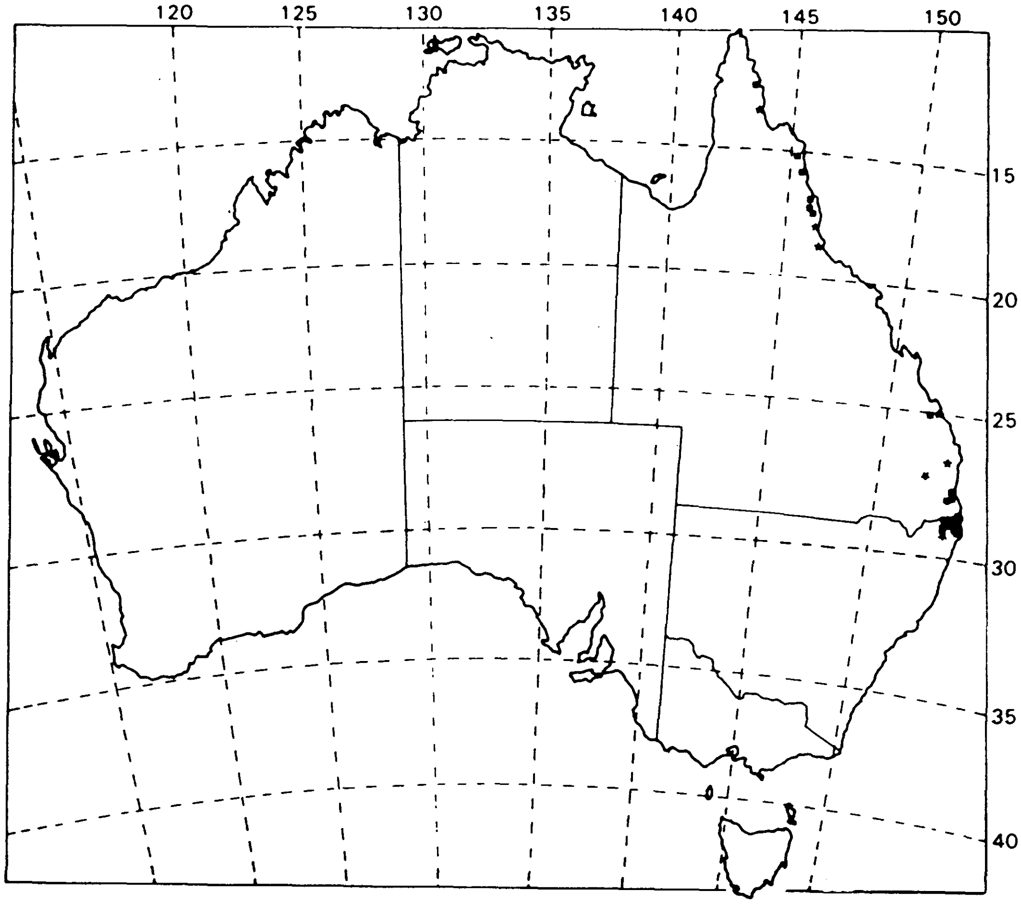
Cattle grazing along the boundaries of Johnston's was removed in 1990 (approx.). In Wollongbar, the southern part of the remnant is open to cattle grazing and the northern part has only relatively recently been fenced off (Holmes 1987). Cattle were not seen in the northern sections where this study was conducted. Davis Scrub contains an abandoned dam and a farm vehicle track (bulldozed in 1976 and previously, Floyd 1977) through its southern half, the clearings for which are still evident. Although now fenced, cattle and sheep gain sporadic access to Davis Scrub and manure has been found inside the edge of the remnant. Cattle may have had access to the edge of Boomerang Falls prior to 1989.

For each of Johnston's Scrub (western side only) (Floyd 1977, 1981), Big Scrub F.R.and Boomerang Falls, at least part has been selectively logged for trees such as *Castanospermum australe* (pers. obs., Mr Johnston Jr. pers. comm.). All remnants have a relatively low level of infestation by woody weeds and exotic vines, reflecting the lack of structural damage to the remnant. Big Scrub F.R., Boomerang Falls and Johnston's Scrub have a border of *Lantana camara* along the artificial edges of the remnants. At Johnston's, regrowth has occurred around the edge since 1967. Wollongbar has minimal weed infestation along its edge, but within the remnant has been invaded by asparagus

*P. plumosus*, large-leaved privet *L. lucidum* and other exotic species. Some regrowth has occurred between patches since 1967, including bamboo. Davis Scrub has recently been cleared of lantana along the eastern boundary (in 1991) and work by NPWS has cleared some of the weeds from the old dam site within the southern part of the remnant. There has been no change to the size of the remnant since 1967.

Big Scrub F.R. and Davis Scrub receive low levels of recreational use. Big Scrub F.R., Davis Scrub F. R. and Johnston's Scrub have been used for research and student projects because of their access, size or known fauna presence (eg. flying-foxes *Pteropus* spp.).

**Figure 3.7** Distribution of *C. australe* within Australia (source: Boland *et al.* 1984).




## 3.3 *CASTANOSPERMUM AUSTRALE* (FABACEAE): A REVIEW OF ASPECTS OF ITS BIOLOGY AND ECOLOGY

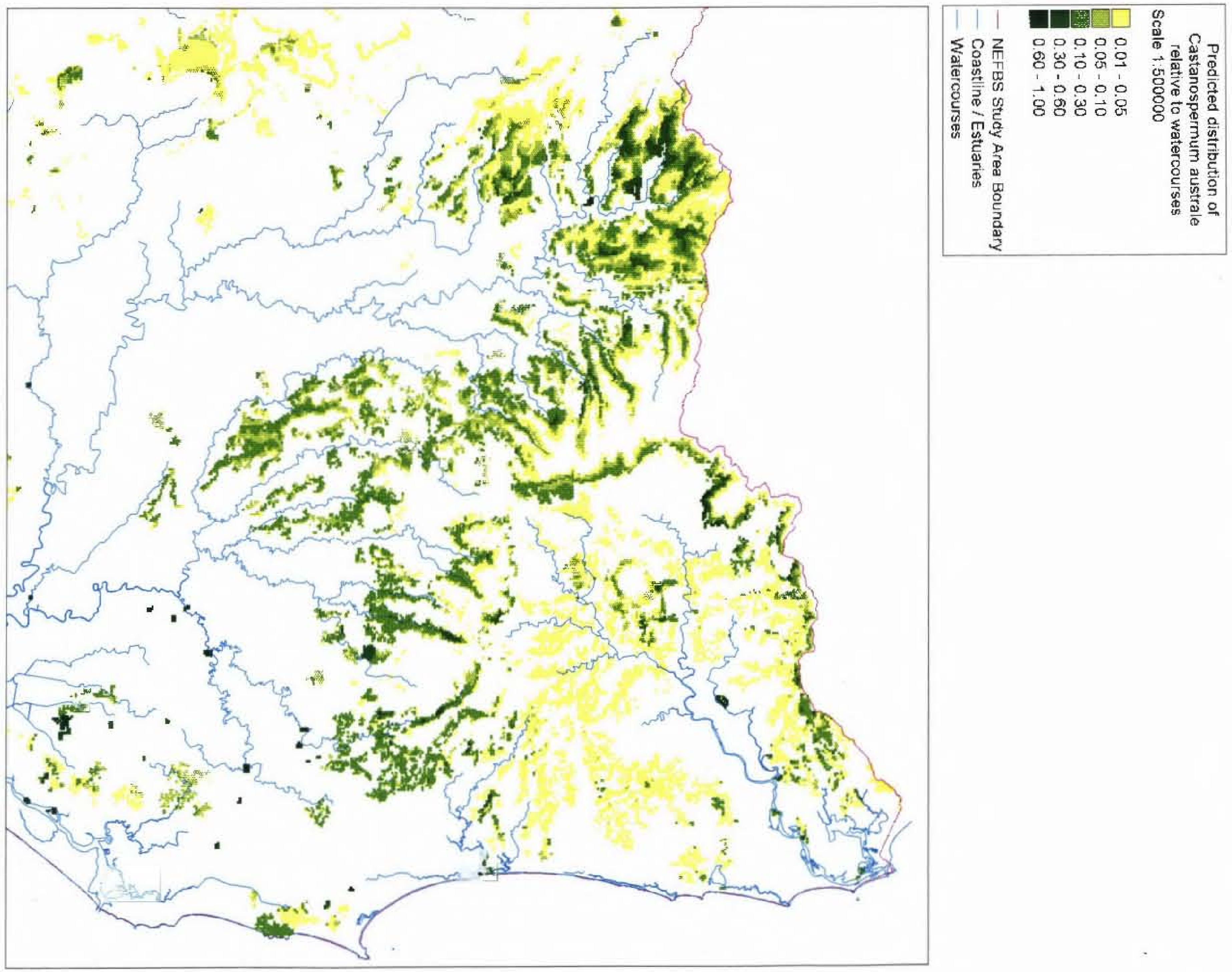
### 3.3.1 Species description and distribution

Black Bean *Castanospermum australe* Cunn. & C. Fraser ex Hook. is a large tree up to 35m height (in N.S.W., Floyd 1989) and 140cm girth. It occurs in subtropical and tropical rainforest, and its distribution ranges from the Orara and Bellinger Rivers, northeastern New South Wales, to Iron Range, Cape York Peninsula in northern Queensland, as well as New Caledonia and New Hebrides (Floyd 1989). Within Australia, its distribution ranges from latitude 12.5 - 29°S, and altitude 50-750m (Figure 3.7). Mean rainfall across the distribution varies from less than 1000 mm to 3800 mm (Boland *et al.* 1984). In New South Wales, *C. australe* occurs along the banks of streams in riverine rainforest, and in rainforest on level terraces on mountain sides (Floyd 1989, see Figure 3.8).

**Figure 3.8** Predicted distribution of *Castanospermum australe* in northeastern New South Wales, based on known occurrences

Darkest shading indicates known occurrences. Progressively lighter shading indicates lower probability of occurrence. Major watercourses are shown in blue.

Source: NSW NPWS (1994)



There are only two species of Fabaceae tree in rainforests of NSW: *Castanospermum* which is a monospecific genus, and *Erythrina vespertilio* (Floyd 1989). *C. australe* is relatively abundant in some rainforest associations or suballiances. In New South Wales, Floyd (1990b) identified two alliances in which the species is common. These are: (1) *Castanospermum-Dysoxylum muelleri* suballiance within the *Argyrodendron trifoliolatum* subtropical rainforest alliance, and (2) *Castanospermum-Waterhousia floribunda* dry rainforest alliance, within which are three suballiances, *Castanospermum-Grevillea robusta, Streblus-Austromyrtys, and Waterhousia floribunda-Tristaniopsis laurina*. The *Castanospermum-Dysoxylum* suballiance occurs on the Alstonville plateau, Border Ranges terraces and on alluvial floodplains, including the Tweed River and Big Scrub Flora Reserve along Rocky Creek. The *Castanospermum-Grevillea robusta* alliance occurs along river systems in northeastern New South Wales, including the Richmond and Clarence Rivers, but is not present in the Big Scrub region, where this study was conducted. For both groups, a reliable soil moisture appears to be important, and in the case of the dry rainforest suballiances, this limits them to narrow strips along river banks where subsoil moisture supplements the lower rainfall (Floyd 1990b).

Rainforest in northeastern New South Wales and southeast Queensland has been extensively cleared for agriculture and settlement. As a result, the distribution of *Grevillea-Castanospermum* suballiance has been greatly reduced (Griffith 1992), and in the Lismore region, the once extensive rainforests of the Big Scrub have been reduced to less than 1% of the original area (Lott & Duggin 1993), mostly as small remnants of forest. In addition, *C. australe* has a dark timber used for veneers, turnery and furniture (Floyd 1989), and has been selectively logged for use as a cabinet timber. Farmers and early settlers also used the timber for fence posts, with mixed longevity (Johnson pers. comm.). More recently, the retained trees may have been felled from pasture, to prevent cattle eating the seeds. The response of *C. australe* to forest fragmentation has not been investigated.

### 3.3.2 Reproductive biology

The flowers of *C. australe* are yellow to orange-red, 4-5 cm long, and occur in racemes 8-15cm long, arising from the scars of fallen leaves (Floyd 1989). The inflorescence is usually cauline (arising from the stem), or at least produced on twigs below the leaves (Boland *et al.* 1984). In New South Wales, flowering occurs October-November. The flowers are visited by grey-headed flying foxes (P. Eby pers. comm.), spectacled flying fox (Richards 1990), possums (Floyd 1989; *Trichosurus vulpecula johnstoni*, Procter-Gray 1984), rainbow lorikeets, Lewins honeyeaters and little wattlebird (J. Lott, R. Lott pers. obs. 8/11/91). These animals are potential pollinators.

Immature fruits are evident on the trees by early December (NSW). Ripe fruit falls between March and September. (It appears that fruit fall occurs earlier in north Queensland, i.e. February-April was listed as the fruiting season by Boland *et al.* (1984).) Pods dehisce from the terminal point, either releasing seeds from the tree, or from the pod as it hits or lies on the ground. The pods have a slight tendency to twist but this is usually only evident in dry weather. The pod is about 10-25cm long and 4-5cm broad (Boland *et al.* 1984). It is shiny when new, straight, and has a hard brown woody exocarp. Inside this is a spongy white mesocarp and a thin papery endocarp, within which rest one to several seeds. The seeds are round or compressed, each with a shiny thin brown testa (Figure 3.9).

**Figure 3.9** Pod and seeds of *C. australe*

Photography: G.S. and J.J. Lott

There is little information on field germination rate and viability of seeds within the forest. Floyd (1989) noted that 'untreated seed should be sown when fresh as it may not store at room temperature after 4 months'. However in the field, *C. australe* seeds may survive longer than this. Hopkins and Graham (1987) buried seeds in bags at 0.5m depth, and some seeds germinated in the bags and persisted up to 2 years. Once transplanted, these seedlings survived (Hopkins & Graham 1987). This indicates that relative to other rainforest seeds, *C. australe* seed lasts a long time, and has the seed reserves to last as a seedling bank in shaded conditions.

Osunkoya *et al.* (1993) found that relative to other species tested, *C. australe* had a low responsiveness to light and a low relative growth rate. They concluded that the large seed size, and distribution of seedlings both in gaps and forest interior (ability to use more shaded environments), indicate that *C. australe* is a primary forest species (Osunkoya *et al.* 1992, 1993). Herwitz (1993) also classed *C. australe* as a shade tolerant primary forest species which may colonize narrow gaps. Species in this category are characterized by relatively slow growth rates in both shaded and full sunlight conditions. Herwitz (1993) found that the growth rate of *C. australe* was intermediate between two fast-growing pioneer species (*Toona australis, Aleurites moluccana*) and two slow growing species (*Argyrodendron peralatum, Dysoxylum pettigrewianum*). In 13 month old seedlings grown in controlled environment conditions, *C. australe* partitioned 26% of aboveground biomass as foliar tissue, whereas faster growing species had lower percentages, with more stem tissue (Herwitz 1993). The two fastest growing *C. australe* saplings achieved an aboveground biomass of ca 0.63kg after 13 months.

As well as forest understorey and treefall gaps, seedlings are found in disturbed habitats (Osunkoya *et al.* 1992). *C. australe* is able to modify its leaf tissue osmotic properties, to withstand the higher radiation and water stress levels encountered in open areas compared with shaded forest situations. This mechanism may contribute to its ability to colonize open pastures from which the rainforest has been cleared (Myers *et al.* 1987). Such a mechanism also allows species to respond to the sudden change in environment when a gap is created within the forest and to deal with direct sunlight as a canopy tree (Myers *et al.* 1987). Osunkoya *et al.* (1992, 1993) found that transplanted seedlings have a similar or higher survival in forest gaps than in the forest interior, both for caged (protected) and uncaged seedlings. Seedling biomass, leaf area and relative growth rate were greater in gaps than in the interior. Initially, seedling height was greater in gaps (Osunkoya *et al.* 1993), but subsequently this appears to have been confounded with poorer height growth in caged conditions.

### 3.3.3 Seed chemical defense and effect on fauna

Early studies found that *C. australe* seeds (Brunnich 1901) and leaves (Greshoff 1909) contain saponin (a glucoside compound). *C. australe* seeds also contain 0.3% castanospermine and are toxic to some eutherian mammals (Elbein and Molyneux 1987). Natural or synthesized castanospermine (e.g. St-Denis & Chan 1992, Mulzer *et al.* 1992) is being used in a range of research projects investigating the operation of glucose (e.g. Robinson *et al.* 1990, Howes *et al.* 1990, Winchester *et al.* 1990, Paul *et al.* 1992). Research is also investigating the potential of castanospermine as a therapy against certain tumors and cancer cells (Trugnan *et al.* 1986, Ostrander *et al.* 1988, Takahashi & Parsons 1992) and as an inhibitor of HIV formation and replication (Walker *et al.* 1987, Burgess *et al.* 1992, Taylor *et al.* 1992, Schols *et al.* 1992).

Castanospermine is an indolizidine alkaloid (Hohenschutz *et al.* 1981), which is a stereochemical mimic of glucose; that is, it interferes with carbohydrate metabolism and alters the distribution of glycogen in animals (Saul *et al.* 1985). It is known to inhibit the endoplasmic reticulum enzyme glucosidase I (Saul *et al.* 1985), and other glycosidases are also affected, for example castanospermine inhibited all intestinal mucosal disaccharidase activity tested in mice (Scofield *et al.* 1986). Consumption of the seeds by cattle causes inhibition of the lysosomal acid alpha-glucosidase. An absence of this enzyme is used to diagnose Pompe's disease, but may be misdiagnosed if cattle have been eating *C. australe* seeds (Reichman *et al.* 1987). Studies have found that small doses of *C. australe* seed (0.15g per day for 4 days) were sufficient to cause a reduction in enzyme activity in calves, which took about 4 weeks to return to normal, but continous exposure to small doses (1.2g per day for 13 months), although reducing enzyme activity, did not affect growth rate (Reichmann *et al.* 1989). Larger doses (eg. 16g seed/kg body weight) cause severe gastroenteritis in cattle (McKenzie *et al.* 1988).

Cribb and Cribb (1974) also experienced gastric problems when they ate *C. australe* seed which they had attempted to prepare. However, the aboriginals successfully ate the seed after treatment. The method of preparation differed among groups, but all appear to be based on grinding, steaming and/or leaching in water to remove toxins (Cribb & Cribb 1974, Hiddins 1980, A.K. Irvine pers. comm.). The resulting starch meal is fairly tasteless, as are most starch staples, but not unpleasant (A.K. Irvine pers. comm.). The leached 'porridge' is baked into a cake (Hiddins 1980). The composition of the cooked cake was found to be low in protein and fat compared with the grains often used for flours (Paul & Southgate 1978 in James 1985). However this lower nutrient value is probably more than compensated for by the seed's large volume.

Toxins such as alkaloids, cyanogenic glycosides, terpenoids and non-protein amino acids are found in numerous legumes (Harborne *et al.* 1971); for example Bayagenin (a triterpenoid) occurs in *C. australe* wood (Eade *et al.* 1963). Toxins are also found in the seeds of many legumes (Bell *et al.* 1977). Some legume seeds with plant secondary compounds conspicuously escape attack, while others have insect predators which appear to be specialized to detoxifying the compounds (Langenheim 1984). In some cases, seeds are attacked by insects, but rejected by vertebrates (e.g. Janzen 1980, Janzen *et al.* 1990). Although mammals often avoid toxic foods, there are also many examples of mammals which eat plants known to contain toxic secondary compounds (Freeland & Janzen 1974).

Several studies have shown that castanospermine is toxic or a feeding deterrent to insects (see references in Campbell *et al.* 1987). For example, castanospermine is a potential inhibitor of cellobiase and lactase activity in insects, and a feeding deterrent towards pea aphids (Campbell *et al.* 1987). However, there was no distinct relationship between adaptation to host plants containing castanospermine or other toxic alkaloids, and enyzme inhibition in the insects tested.

Native mammals eat *C. australe* seeds, despite their alkaloid content. Brunnich (1901) noted that "opossums are fond of the beans", apparently referring to observations in southeastern Queensland or Lismore, NSW. Floyd (1990a) noted a 'cache' of *C. australe* seeds at Numinbah Nature Reserve, northeastern New South Wales. As not all seeds in the cache were consumed, seeds may also be dispersed by these mammals. Seed removal has also been documented at some locations in north Queensland (Willson 1988, Osunkoya *et al.* 1992). The predators of *C. australe* seeds and seedlings have not been identified in either region.

The suite of rainforest-dwelling fauna differs between northern Queensland and northeastern New South Wales, with only *R. fuscipes* in common. Therefore levels of seed predation and seedling herbivory may differ between regions, and well as between continuous and fragmented forests. Sections 3.3.4 and 3.3.5 review the literature on seed predation and frugivory by mammals which occur in rainforests of northeastern New South Wales, and discuss which species are most likely to eat *C. australe* seeds. This aspect is investigated further in Chapter 5 where mammalian predators of the seed are identified. Chapter 5 also includes the results of some preliminary collections of insect fauna from *C. australe* seeds and pods.

### 3.3.4 Mammal fauna of the Big Scrub which eat seeds

A review of the literature and inspection of skull specimens (Department of Ecosystem Management, University of New England), revealed that several of the mammal species in the region (Table 3.7) are unlikely to eat *C. australe* seeds, although they occasionally or episodically eat soft fleshy fruit or small seeds. These are the dasyurids and canids, which have prominent canines spaced broadly apart, and the omnivores and insectivores, which have small incisors unsuited for gnawing very large round seeds. *Pseudocheirus peregrinus* also appears unsuited to the eating of large or hard fruits, due to its small skull, and small peg-like upper incisors. In addition, its arboreal habits suggest that it would not descend to the ground to eat fallen seeds. Flying-foxes eat large quantities of native and introduced fruits (Hall 1983, Richards 1983, McWilliam 1986, Parry-Jones 1987, Parry-Jones & Augee 1991a, Eby 1991a; Law & Lean 1992), but almost without exception these are soft fleshy fruits. While flying-foxes may be important pollinators of *C. australe* flowers, and could conceivably eat small immature fruits (see Lowry 1989, Funakoshi *et al.* 1993), they do not have the dentition, dexterity or feeding habits to eat large, hard seeds. The following section discusses fauna which potentially eat *C. australe* seeds.

In northeastern New South Wales rainforests, species which eat seed and fruit are the three species of macropodoid (*T. stigmatica, T. thetis, P. tridactylus*), three rodent species (*M. cervinipes, Rattus fuscipes* and the introduced *R. rattus*) and *T. caninus*.

### 3.3.5 Potential mammalian predators of *C. australe* seed

Little is known of the diet of Australian rainforest mammals, the extent of their granivory, or whether they will eat large seeds such as *C. australe*. This section reviews the type and quantity of seeds (or fruits which contain seeds) eaten by potential seed predators, whether their dentition indicates that they would be capable of eating large firm seeds, and the available information on native mammals known to eat plants with a high content of secondary compounds.

*Macropodoidea*

Most Macropodids for which the diet is known consume some seeds and/or fruit (Jarman 1994). Diaspores known to be eaten by Macropodids are generally from grasses, forbs, or small fleshy fruit:

*Thylogale stigmatica* appears to eat fruit and seed regularly, while *T. thetis* eats a smaller volume of seed and fruit, in a more episodic manner (see Redenbach 1982). *T. stigmatica* eats mainly fallen leaves, and some grass, fresh leaves and fruits (Harrison 1962; Cooke 1979 in Johnson 1983a; Archer *et al.* 1985), although occasionally up to 50% of faeces and stomach contents were fruit (Redenbach 1982). Fleshy fruits eaten include larger fruits such as *Ficus macrophylla* and the Burdekin Plum (Johnson 1983a). In north Queensland, Harrison (1962) found that *T. stigmatica* had eaten a species of hard green fruit (size unknown). *T. thetis* also eats some seed and fruit (Johnson 1977, Redenbach 1982), but all seeds known to be eaten are small (<10mm). The seeds eaten are grasses, and presumably fruits of those species which occur at the rainforest/eucalypt ecotone, where *T. thetis* most frequently occurs (see Johnson 1980, 1983b).

In Tasmania and Victoria, studies of *P. tridactylus* found that its diet consisted of 1.2-16% seed and fruit (Guiler 1971, Bennett & Baxter 1989). The greater availability of fleshy-fruited species in rainforest (Willson *et al.* 1989) suggests that in northern NSW, *P. tridactylus* may eat more fruit than noted in the southern studies. This would be consistent with the diet of the related Musky Rat-kangaroo *Hypsiprymnodon moschatus* (Potoroidae), which inhabits tropical rainforest and eats insects, fruit and seeds with 'reasonably breakable testas' (Harrison 1962, Johnson & Strahan 1982, A. Dennis pers. comm.). However, all fruit species identified in the southern diets of *P. tridactylus* were small and fleshy (Guiler 1971, Bennett & Baxter 1989).

Therefore, *Potorous tridactylus, T. thetis* and *T. stigmatica* are potential seed-eaters and dispersers, but are not known to eat large seeds such as *C. australe*. Whether these mammals are capable of eating large hard seeds is not clear. *Thylogale* spp. have procumbent lower incisors, which are pointed and inserted at an acute angle to each other (Figure 5.7). The angle of the lower incisors is suggestive of spearing, clipping and plucking foods, rather than gnawing. This indicates that they may have some difficulty in gnawing *C. australe* seeds, although the upper incisors are broad and sharp, suited for cutting and gripping. In *P. tridactylus*, the first pair of upper incisors are large and prominent, and meet the diprotodont lower incisors in a manner similar to rodents, presumably allowing a gnawing action. However the teeth do not have the enamel hardening present in Rodentia incisors, and given the small size of the skull (smaller than a large *C. australe* seed), the muscle development may not be strong enough, nor the teeth sharp enough for eating a seed such as *C. australe*.

Of the Macropodoidae, *P. tridactylus* appears least likely to be a significant predator of *C. australe* seeds, due to its smaller size and less robust skull. In addition, the probable rarity of *P. tridactylus* in the Border Ranges and Big Scrub (Smith *et al.* 1989, Lott & Duggin 1993) indicates that it is not the major predator responsible for the widespread *C. australe* seed predation evident in the rainforests of the Border Ranges.

*Trichosurus caninus*

The only quantitative study of the diet of *T. caninus* was conducted in southern Australia. It indicated that fruit is eaten with a low frequency (mean 7%) (Seebeck *et al.* 1984). Other foods eaten extensively are leaves of mesophyllic shrubs, buds, fungi, lichens and occasionally bark (Owen and Thomson 1965, How 1983). However, in autumn and summer in southern Australia, large amounts of *Acacia* seed are eaten at times (Owen & Thomson 1965, D. Lindenmayer pers comm.). Like *T. vulpecula* (see Fitzgerald 1984a, Freeland & Winter 1975; cf. Evans 1986, 1992, Kerle 1985, Procter-Gray 1984), *T. caninus* probably eats more fruit and seed in the northern part of its range. *Trichosurus caninus* occurs within tall open and closed forests, from southern Victoria to southeastern Queensland (How 1983). In the northern part of its range, it appears to be restricted to closed forests, particularly rainforest, while the Common Brushtail Possum *T. vulpecula* occurs in the sclerophyll forests. Although *Trichosurus vulpecula* eats seed and fruit (Freeland & Winter 1975, Fitzgerald 1984a,b, Procter-Gray 1984, Kerle 1985, Evans 1986, 1992), it probably does not enter rainforest frequently, nor eat *C. australe* seeds: while it is possible that *T. vulpecula* may enter rainforest from adjacent eucalypt forest (A. P. Smith, P. Jarman pers. comm.), all animals caught at Big Scrub F.R. and Wilsons Creek (near Mullumbimby, Figure 1.1) in 1994 were *T. caninus* (D. Lindenmayer pers. comm.).

The dentition of *T. caninus* indicates that it is capable of eating *C. australe* seeds. The lower incisors are less fully procumbent than those of *Thylogale* spp, and are thus suitable for gnawing seeds (Figure 5.7). The upper incisors are thicker than those of *Thylogale* spp., and set further forward in the mouth. The cusps are hypsidont and suited for crushing. The hands are large enough to grasp *C. australe* seeds, with strong claws. In addition, *T. caninus* spends considerable time feeding on the ground and on fallen logs (How 1983) and could thus access the heavy seeds of *C. australe* from the ground, rather than attempting to open the large pods from within the canopy. The diets of related species indicate that *T. caninus* may find nut-like fruits attractive (including those such as *C. australe*). In agricultural areas, *Trichosurus* spp. will eat walnuts (*T. vulpecula*, Gilmore 1967) and pecan nuts (*T. caninus*, van Dyck 1979). In captivity, *Wyulda squamicaudata* was observed to prise seeds from cones of *Casuarina humilis* and to cache nuts (Fry 1971) and its dentition indicates that nuts may be important in the natural diet (McKay & Winter 1989).

Some Australian Phalangerids seem able to detoxify tannins and alkaloids. In southern and eastern Australia, *T. vulpecula* consumes a tannin-rich eucalypt leaf diet (Freeland & Winter 1975; Mead *et al.* 1979 in Hume 1982) and in northern Australia, the preferred leaf species eaten by *T. vulpecula arnhemensis* is *Erythorphleum chlorostachys* (Kerle 1985), which contains an extremely toxic alkaloid (Chippendale & Murray 1963). There is some evidence that the incidence of alkaloid-bearing plants is much greater in tropical than in temperate floras (Hartley *et al.* 1973, Levin 1976, Levin & York 1978). Thus, arboreal mammals in tropical forests should encounter a wider range of chemical defenses, especially toxins than in temperate forests (Cork & Foley 1991). This suggests that the rainforest-dwelling *T. caninus* would encounter and potentially detoxify secondary compounds in its diet. In southeastern Queensland, *T. caninus* has been observed to eat *Solanum mauritianum* bark and leaves, which are high in steroidal alkaloids (glycosides solamargine and solasonine; van Dyck 1979).

*Muridae*

Australian rodents are usually omnivorous, and eat a wide variety of foods depending on availability (Watts & Aslin 1981). Both *R. rattus* and *R. fuscipes* have a wide distribution across several habitat types (Watts & Aslin 1981, Strahan 1983), and fruit and seed consumption appears to vary with location and season. The diet of *R. fuscipes* may vary from almost totally herbivorous to insectivorous with seeds prominent in the diet (Watts 1977), solely endosperm (Stewart 1979), or an omnivorous mix of insects, seeds, plant material (Cheal 1978) and/or fungi (Warneke 1971, Watts & Braithwaite 1978, Cheal 1987, Carron *et al.* 1990). Seed and fruit intake often varies across the seasons (e.g. Freeland 1972, Cheal 1987). In subtropical rainforest, *R. fuscipes* eats fruits of *Crysophyllum pruniferum, Ficus watkinsiana* and *Archontophoenix cunninghamiana* (Freeland 1972). A higher proportion of fruit is eaten in summer (Freeland 1972), but the proportion of fruit in the diet has not been quantified. It is possible that *R. fuscipes* may eat seeds and fruit more regularly in rainforest where availability is higher (see Willson *et al.* 1989, 1990), although samples of *R. fuscipes coracius* stomachs in North Queensland only found 5-19% seed (Wellesley-Whitehouse 1981).

The diet of *R. rattus* varies from being largely fungivorous (Watts & Braithwaite 1978), to relying on plant material including seeds (Norman 1970, Copson 1986). Other foods eaten in smaller quantities include ripe fruit, insects, snails, eggs and nestling birds (Watts & Aslin 1981). There is no information on diet in rainforest habitats.

*Melomys cervinipes* eat leaves, fruit and a few seeds and insects (Harrison 1962, Freeland 1972, Watts & Aslin 1981, Lott & McIntyre 1991) and appear to be regular consumers of plant diaspores. Freeland (1972) found that *M. cervinipes* ate a little fruit in both winter and summer samples.

There are several examples from rainforest and tropical habitats of rodents which eat hard seeds. *Melomys* spp. and *Uromys caudimaculatus* eat the woody drupes of *Normanbya normanbyi* (Lott & McIntyre 1991, Lott *et al.* 1995), and despite a woody stone approximately 7mm thick, seeds of *Cerbera floribunda* and *Elaeocarpus bancrofti* are eaten by *U. caudimaculatus* (Lott unpublished data). Begg and Dunlop (1985) found that the diet of both *Zyzomys* species was almost wholly fruit and seed, including several hard shelled nuts. Thus *M. cervinipes* and *R. fuscipes* potentially eat quantities of seed in rainforest, including relatively hard seeds.

The introduced species *R. rattus* is also capable of eating through large hard seeds, including walnut shells and, reputedly, macadamia nuts, but it is unlikely to be the predator of *C. australe* seeds in large tracts of forest where native species are still present: Although *R. rattus* has successfully established away from human habitation, it is generally found in disturbed and degraded habitats, such as forest edges adjacent to agricultural land (Watts & Aslin 1981) and small remnants (Lott & Duggin 1993). There is no evidence that *R. rattus* has had any effect on the distribution and abundance of native true rats (habitat alteration being the major cause of decline of native species) (Watts & Aslin 1981). Similarly, although *Mus musculus* generally includes a relatively large proportion of seeds in its diet (Watts 1970, cf. Watts & Braithwaite 1978, Cockburn 1980, Copson 1986, Bomford 1987, Norton 1987, Tann *et al.* 1991), it was regarded as too restricted to within disturbed forest (Watts and Aslin 1981) and too small in size, to eat *C. australe* seed or to be an important predator in large areas of remnant forest.

There are several examples of Australian rodents eating seeds of cycad species, which are toxic to at least some mammals (Whiting 1963). In north Queensland, Willson (1988) found caches of *Lepidozamia* seeds, some of which were chewed open, and also found piles of *Cycas media* fruits, the seeds of which were often eaten. Although the predator was not identified, the seeds were probably eaten chiefly by rodents (Willson 1988). In New South Wales, *R. fuscipes* is known to eat *Macrozamia communis* seeds despite the presence of macrozamin (Ballardie & Whelan 1986). Thus *R. fuscipes* appears able to detoxify some secondary compounds in seeds. There is no information on dietary intake of toxic chemicals by *Melomys* spp.

### 3.3.6 Summary

In conclusion, *C. australe* produces large seeds held within large dehiscent pods. These are released from the tree over a 6-7 month period of the year (March-September). The large seeds are potentially an important food source, to fauna able to detoxify the alkaloid within the seed. Seeds are eaten by native mammals, and may be dispersed by them. This study identifies the mammalian predators of *C. australe* seed (Chapter 5). The potential predators of *C. australe* in northeastern NSW are: *T. caninus, T. stigmatica, T. thetis, M. cervinipes, R. fuscipes,* and *R. rattus.* The species most likely to be adapted for detoxifying food with a high chemical content are the Mountain Brushtail Possum *T. caninus* and the Bush Rat *R. fuscipes,* but the tolerance of the other species to plant secondary compounds has not been investigated.

There is a lack of information on levels of seed predation and seed survival. At one site in north Queensland, survival of transplanted seedlings was significantly reduced by an unknown herbivore or seed predator (Osunkoya *et al.* 1992), but otherwise there is little information on factors which influence *C. australe* seedling survival. Field germination rate and seedling survival are not known. Seedlings are known to grow relatively slowly and are tolerant of shade and sunlight gaps, indicating that the species is a shade tolerant primary species. Further aspects of seed predation, dispersal and seedling survival within rainforest fragments will be presented in subsequent chapters.