# CHAPTER 4

# HABITAT REQUIREMENTS

## 4.1. INTRODUCTION

Previous descriptions of Rufous Scrub-bird habitat are summarized in Table 4.1. While qualitative descriptions such as these provide a valuable starting point for the study of habitat, detailed quantitative information derived from intensive research is desirable for the purposes of status assessment and habitat management (Shugart and Patten 1972; Conner and Adkisson 1976; Rotenberry 1981; Shugart 1981; Smith *et al.* 1981; Ride and Wilson 1982; Davies *et al.* 1982). In the case of the Rufous Scrub-bird, detailed habitat information can contribute to the assessment of status in two ways:

1. Refinement of the planning, implementation, and interpretation of population surveys. While a survey technique has already been developed in Chapter 3, there remains the problem of deciding which areas should be sampled in order to assess the abundance of the Rufous Scrub-bird. One solution would be to randomly or systematically locate transects throughout the bird's entire geographical range. Because the species is apparently rare and patchily distributed within its range, this approach would probably require enormous sample sizes, and therefore enormous effort, in order to obtain acceptable precision. This effort could be reduced by restricting sampling to areas considered likely to support suitable habitat. The delineation of these areas must be based on an accurate knowledge of the bird's habitat requirements. If such knowledge is too general, little reduction in sampling effort will be achieved. If the knowledge is more specific, but inaccurate, estimates of abundance are likely to be negatively biased. D.G. Dawson (1981c) has emphasized the need for a two-stage process in assessing the abundance of a rare species. The first stage involves establishing the distribution and habitat requirements of the species, based on reconnaissance surveys. The second stage involves intensive sampling within potentially suitable areas.

2. Prediction of the influence of land-use practices on habitat suitability. The apparent decline in abundance of the Rufous Scrub-bird since European settlement has often been attributed to destruction of

TABLE 4.1

Post-1970 descriptions of Rufous Scrub-bird habitat.

| Source | Habitat Description |
| --- | --- |
| Macdonald (1973) | "mountain forests with dense tangled undergrowth" |
| Slater (1974) | "thickets in rainforest" |
| Smith (1976b) | "subtropical and temperate rainforest and wet temperate forest where a dense understorey has developed because of breaks in the canopy. Beech *Nothofagus* appears to be its primary habitat" |
| Morris (1977) | "Rufous Scrub-birds appear to favour the undergrowth of the negrohead beech temperate rain forests.........." |
| Robinson (1977) | "The Rufous Scrub-bird *Atrichornis rufescens* inhabits temperate and sub-tropical rainforest and wet sclerophyll forest but is restricted to very dense undergrowth where the canopy has been broken" |
| Roberts (1979) | "highland rainforest, particularly of Beech *Nothofagus*, above 600 metres" |
| Smith (1979) | "The primary habitat is wet forests where the birds occupy the ecotone on the edge of the forest, or in areas where the forest canopy is broken along streams or by the death of trees within the forest. Within these areas, suitable habitat is only found where there is sufficient water and light to allow the growth of a dense zone of rushes and shrubs" |
| Pizzey (1980) | "densest tangles of ferns, undergrowth or tussocks, surroundings of fallen logs; in temperate rainforests including stands of Antarctic Beech *Nothofagus*" |
| King (1981) | "*Nothofagus* forest, edges of subtropical rainforest and wet sclerophyll forest with a dense scrub layer" |
| Morris *et al.* (1981) | "rainforests and contiguous wet sclerophyll forests ....... extinct below 400 metres" |

habitat by man (e.g. Chisholm 1951; Smith 1977; Slater 1978; Hermes 1980; King 1981). The effects of current land-use practices (e.g. clear-felling, logging, prescribed burning) need to be considered in order to determine the species' present status. In previous studies effects such as these have been assessed in two quite different ways. The "direct approach" involves direct comparison of the abundance (or presence/absence) of a species in areas subjected to different types of disturbance, or in the same area before and after disturbance (e.g. Christensen and Kimber 1975; Pattemore and Kikkawa 1975; Hindmarsh and Majer 1977; Friend 1979; Loyn *et al.* 1980; Recher *et al.* 1980; Fox and McKay 1981). This approach can be very time-consuming if the effects of many different types of disturbance need to be determined, as is the case with the Rufous Scrub-bird. Within this thesis emphasis is therefore placed on the "indirect approach", which involves prediction of such effects based on detailed knowledge of a species' habitat requirements (e.g. Shugart and Patten 1972; Conner and Adkisson 1976; Rotenberry 1981; Noon 1981; Smith *et al.* 1981; Smith 1982). This approach can be viewed as a two-stage process involving (1) the identification of a species' basic habitat requirements from intensive research, and (2) the utilization of information from other studies to assess the effects that different types of disturbance are likely to have on these requirements.

Karr (1981b) has suggested that a habitat research programme should be organized around three major questions:

1. Why measure habitat?
2. What habitat variables should be measured?
3. How should those variables be sampled and analyzed?

The "why" question pertaining to the present study has already been answered above. The reasons for conducting this research place important constraints on the "what" and "how" questions.

What habitat variables should be measured? Previous research on birds has suggested that species often select habitats on the basis of factors not immediately associated with their survival. These proximate factors are probably used as easily perceived predictors of ultimate factors directly related to survival (Svardson 1949; Hilden 1965; James 1971; Bertin 1977; Partridge 1978; Rotenberry 1981). For example, vegetation structure may be used as a proximate factor indicating the availability of food. However, vegetation structure may also act as an ultimate factor by providing cover for protection from predators. In most cases careful experimentation is needed to distinguish between proximate and ultimate factors. For the purposes of this thesis, both will be viewed simply as "critical habitat factors"; those variables determining, either proximately or ultimately, the suitability of habitat. The main aim of the research described below has been to identify these critical habitat factors for the Rufous Scrub-bird.

The first criterion used in choosing habitat variables was therefore the likelihood that a variable may represent a critical habitat factor. This choice was based on previously published ideas concerning Rufous Scrub-bird habitat (see Table 4.1) and on my own preliminary observation in areas where scrub-birds were or were not found. A large number of habitat variables appeared to be associated with the presence of scrub-birds. Such variables do not necessarily represent critical habitat factors. There are many other possible reasons why a variable might be correlated with scrub-bird presence. Three examples are depicted in Fig.4.1:

1. A variable may be influenced by a critical habitat factor. If ground cover is a critical factor, then an example could be relative humidity at ground level.
2. A variable may influence a critical factor. An example could be forest canopy density influencing ground cover.
3. A variable may be influenced by the same variable that influences a critical factor. An example could be number of epiphytes on tree trunks being influenced by canopy density.

All of these variables will in turn influence, and be influenced by, still more variables that may therefore be correlated with scrub-bird presence. This complexity poses problems in the choice of habitat variables. The best solution is to measure a wide selection of potentially important variables, and then employ multivariate statistical methods to identify critical habitat factors, or at least those variables that are separated from the critical habitat factors by as few intervening variables as possible.

How should the habitat variables be sampled and analyzed? The aims of habitat research place important constraints on sampling and analysis (Karr 1981b). Most of the strategies adopted in previous habitat research are poorly suited to the aims of the present study. The majority of previous studies has focused attention at the community or guild level.

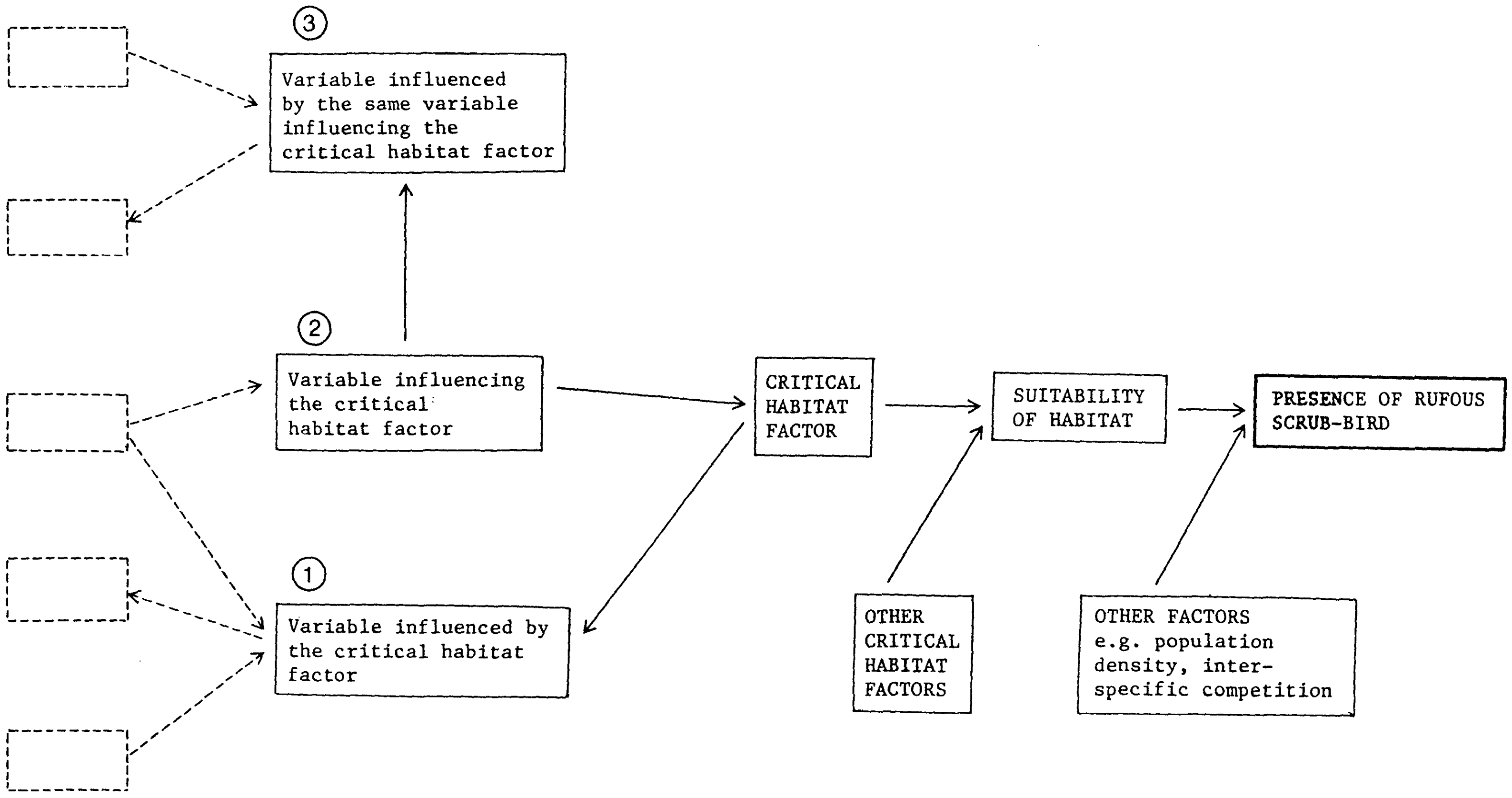



FIGURE 4.1. Hypothetical relationships between habitat variables and presence of the Rufous Scrub-bird.

The sampling and analysis strategies used in such studies have usually been aimed at identifying habitat differences between species or habitat gradients underlying faunal community structure (e.g. James 1971; Anderson and Shugart 1974; Whitmore 1975; K.G. Smith 1977; Dueser and Shugart 1978; Rotenberry and Weins 1980; Sabo 1980; Folse 1981; Fox and Fox 1981, Maurer *et al.* 1981; Raphael 1981; Kikkawa 1982). Emphasis is placed on habitat variables that best describe differences in the habitats of different species within a community or differences in faunal composition between different communities. These variables are not necessarily the variables that best define habitat suitability for any particular species occurring within those communities. For example, consider a hypothetical bird community consisting of only two species, A and B. The main habitat requirements of species A are a closed forest canopy, a deep leaf litter layer, and a dense shrub layer. The main habitat requirements of species B are a closed forest canopy, a deep leaf litter layer, and a sparse shrub layer. A community-oriented study would probably identify shrub-layer density as the only important habitat variable. However, for the purposes of conservation and management all of the species' requirements are important, not just those that differ between species.

Two different sampling strategies have previously been used to elucidate the habitat requirements of individual species. The first strategy involves measuring the density, or presence/absence, of a species on a number of randomly or systematically located plots, transects, or trap-sites. Habitat variables are also measured for each of these sampling units, thereby allowing correlations between density and habitat to be investigated (e.g. Shugart and Patten 1972; Barnett *et al.* 1978; Christensen 1980; Cavallaro *et al.* 1981; Grue *et al.* 1981; Noon 1981; Rice *et al.* 1981; Statham and Harden 1982). This approach is not well suited to the Rufous Scrub-bird. If small sampling units are used, the species is unlikely to be recorded in more than a very small percentage of units due to the rarity and wide dispersal of territories. If large sampling units are used, the habitat data are unlikely to adequately detect small scale variations in habitat, apparently of great importance in this species (Smith 1976b). The alternative strategy, adopted in this thesis, is to compare habitat within plots centred on known territories (or nest-sites) to habitat within plots located in unoccupied areas. This approach is gaining popularity in habitat studies of territorial species, especially birds (e.g. Martinka 1972; Conner and Adkisson 1976; Riechert 1976; Titus and Mosher 1981;

Whitmore 1981; Morris and Lemon 1983).

The habitat requirements of a species should be defined not only in terms of critical habitat factors, as discussed above, but also in terms of the required area of suitable habitat. The habitat research on the Rufous Scrub-bird therefore included a detailed study of the size and shape of home range.

## 4.2 FIELD METHODS

### 4.2.1 Habitat Plots

The transect data for Wiangarie and Barrington Tops (see Chapter 2) formed the basis for the study of scrub-bird habitat requirements in these two areas. Habitat measurements were made on two types of plots (see Fig.4.2.):

1. Scrub-bird plots. These were centred on the "activity centres" (Koeppl *et al.* 1975) of male territories. (The calculation of activity centres will be described in greater detail later in this chapter.) Selection of territories for habitat analysis was based on data from the first 14 transect walks at Wiangarie (2 September 1981 to 29 June 1982) and Barrington Tops (13 September 1981 to 13 July 1982). During these walks, 23 different territories were located at Wiangarie and 22 territories were located at Barrington Tops. In order to equalize the samples, one randomly chosen territory at Wiangarie was deleted, yielding a sample of 22 scrub-bird plots for each study area.

2. Non-scrub-bird plots. These were centred on points located at random throughout the 300 metre wide transect strips. Selection of random points involved the following steps: (1) The sections of transect at each study area were viewed as one long transect (total length of Wiangarie transect = 18,088 metres; total length of Barrington Tops transect = 18,182 metres). (2) A distance along the total transect was randomly selected (e.g. at Wiangarie, this was a random number between 0 and 18,182). (3) A side (left or right) of the transect was randomly chosen. (4) A random number between 0 and 150 was selected to give the perpendicular distance, in metres, of the point from the transect line. (5) If the point was less than 50 metres from the centre of the nearest scrub-bird plot, it was discarded and a new point was selected. A sample of 40 non-scrub-bird plots was selected for each study area. A total of 124 habitat plots was therefore considered in the analysis; 44 scrub-bird plots and 80 non-scrub-bird plots.

The sampling configuration used for each plot is depicted in Fig.4.3. This consisted of four primary sampling points; one located at the centre point of the plot and three located 20 metres from the centre point along

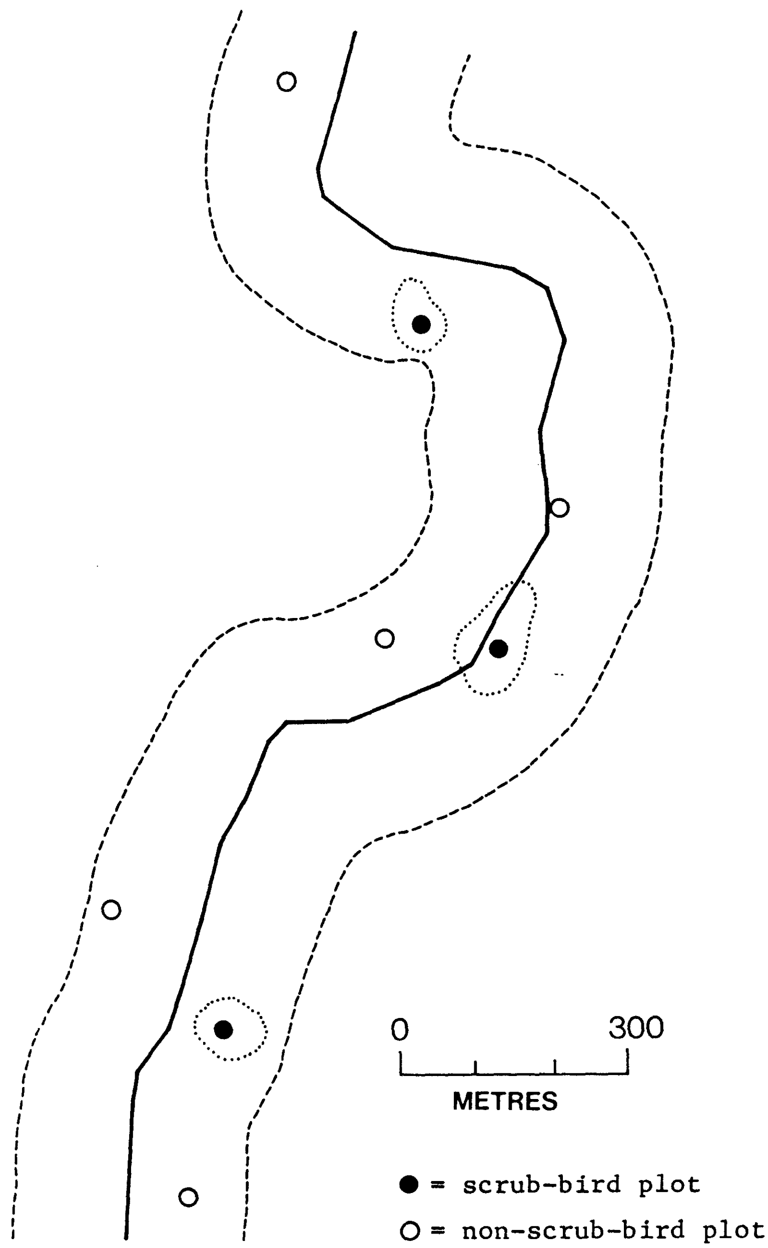



FIGURE 4.2. Distribution of habitat plots along a typical portion of the Wiangarie transect. The solid line is the transect line and the broken lines define an area 150 metres either side of the transect line. The boundaries of scrub-bird territories are indicated by dotted lines (see Fig.3.6). Each symbol indicates the centre of a habitat plot.

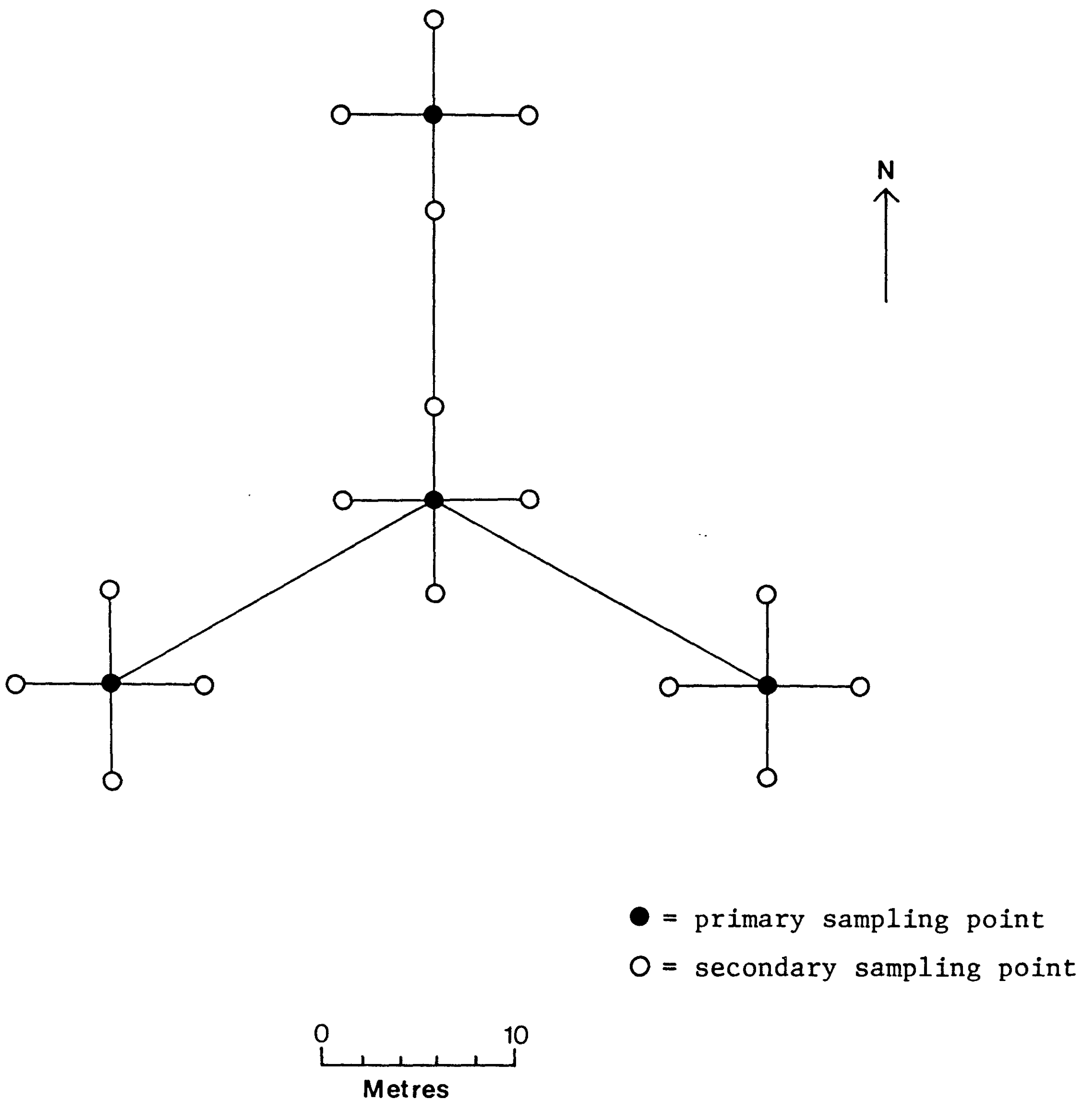



FIGURE 4.3. Sampling configuration for habitat plots.

compass bearings of 0° (north), 120°, and 240°. Each primary sampling point was surrounded by four secondary sampling points located 5 metres out along compass bearings of 0°, 90°, 180°, and 270°.

The habitat data were collected between early May and late August, 1982. Two visits were made to each plot. During the first visit all measurements except the temperature and humidity measurements (measurements 15-18 below) were made. The order in which plots were visited was largely determined by practicalities such as time, plot location, and weather. First visits were made at an average rate of approximately 3 plots per day. During the second visit only temperature and humidity measurements were made. This allowed all plots to be visited within a relatively short period, thereby minimizing the influence of variation in weather. For each study area (Wiangarie and Barrington Tops) all second visits were made over two consecutive days of still, fine weather during August 1982. No measurements were made less than 1 hour after sunrise or less than 1 hour before sunset. The order in which plots were visited was predetermined, scrub-bird plots being interspersed with non-scrub-bird plots. The general pattern was ......S N N S N N S......, where S = scrub-bird plot and N = non-scrub-bird plot.

The following measurements were made on all plots (the habitat variables derived from these measurements are described in the Results section) :

1. Distance (metres) to the nearest tree >20cm dbh (diameter at breast height) in quarters around each primary sampling point (16 measurements per plot). The quarters were defined by two axes, one running North-South and the other East-West. For details of the point-quarter sampling technique see Cottam and Curtis (1956), Mueller-Dombois (1974), and Noon (1981).
2. Diameter (cms) of the nearest tree >20cm dbh in quarters around each primary sampling point (16 measurements per plot).
3. Type of nearest tree >20cm dbh in quarters around each primary sampling point (16 types per plot). Trees were classified into the following types:
    (a) *Nothofagus moorei*
    (b) Rainforest species other than *N.moorei*
    (c) Rough-barked *Eucalyptus sp.*

(d) Smooth-barked *Eucalyptus sp.*

(e) Sclerophyll species other than *Eucalyptus sp.*

4. Special features of the nearest tree >20cm dbh in quarters around each primary sampling point (16 values per plot for each of 6 features). The prominence of each feature was rated on a three point scale: 0 = absent or nearly so, 1 = present but not highly conspicuous, 2 = highly conspicuous. The following features were recorded (terminology follows Webb *et al.* 1976):

   (a) Large epiphytes

   (b) Hemi-epiphytes

   (c) Woody vines

   (d) Hanging mosses/lichens

   (e) Mosses/lichens on lower tree trunks

   (f) Root buttresses

5. Distance (metres) to the nearest tree 5-20cm dbh in quarters around each primary sampling point (16 measurements per plot).

6. Type of nearest tree 5-20cm dbh in quarters around each primary sampling point (16 types per plot). Trees were classified into the following types:

   (a) *Nothofagus moorei*

   (b) Rainforest species other than *N.moorei*

   (c) *Eucalyptus sp.*

   (d) Sclerophyll species other than *Eucalyptus sp.*

   (e) Tree-fern

   (f) Palm

7. Distance (metres) to the nearest tree or shrub <5cm dbh in quarters around each primary sampling point (16 measurements per plot).

8. Type of nearest tree or shrub <5cm dbh in quarters around each primary sampling point (16 types per plot). Trees were classified into the following types:

   (a) *Nothofagus moorei*

   (b) Rainforest species other than *N.moorei*

   (c) *Eucalyptus sp.*

   (d) Sclerophyll species other than *Eucalyptus sp.*

   (e) Palm

9. Vertical incident light intensity (lux) at 2cm, 50cm, 100cm and 150cm above the ground at each secondary sampling point (64 measurements per plot). These measurements were used to calculate cover indices according to the method developed by Fox (1979):

$$\text{Cover Index} = \log_e(I_A/I_B)$$

where $I_A$ = light intensity immediately above the layer for which density is being estimated

$I_B$ = light intensity immediately below the layer

All measurements were made with a Gossen Panlux light meter. A 3cm length of 4cm diameter cardboard tube was fitted over the photo-electric cell in order to reduce the "dappling effect" (Fox 1979) caused by the pattern of sunlight and shadow.

10. Presence/absence of 12 cover types between 5cm and 50cm above the ground, within a 50cm radius of each secondary sampling point (16 values per plot for each cover type). The cover types were (categories and terminology derived from Webb *et al.* 1976 and Noon 1981):
    (a) Grass (narrow-leafed herb)
    (b) Sedge (strap-leafed herb)
    (c) Large-leafed herb (with long wide leaves)
    (d) Forb (broad-leafed herb)
    (e) Fern
    (f) Vine (foliage)
    (g) Shrub (or tree, foliage)
    (h) Palm (foliage)
    (i) Tree-fern (foliage)
    (j) Log
    (k) Fallen debris (branches, vines etc.)
    (l) Rock (with sufficient space beneath to act as cover for scrub-birds)
11. Presence/absence of 12 cover types between 50cm and 150cm above the ground, within a 50cm radius of each secondary sampling point (16 values per plot for each cover type). Cover types as above.
12. Genus of ground-cover plant nearest to each secondary sampling point, with foliage between 5cm and 50cm above the ground (16 records per plot).
13. Volume ($cm^3$) of leaf litter present within a 60cm by 60cm quadrat centred on each primary sampling point (4 measurements per plot). Following removal of large twigs from the quadrat, the litter was scraped from the soil surface by hand and placed in a measuring bucket (effort was made to avoid compression).
14. Depth (cms) of penetration into soil of a hand-held, blunt-ended, 2cm diameter wooden pole at each secondary sampling point (16 measurements

per plot). This was used as an index of soil-surface compactability (see Dueser and Shugart 1978).

15. Dry bulb temperature 2cm above the ground at each primary sampling point (4 measurements per plot). Measurements were made to the nearest 0.1°C with a Zeal whirling psychrometer.
16. Dry bulb temperature 200cm above the ground, as above.
17. Wet bulb temperature 2cm above the ground, as above.
18. Wet bulb temperature 200cm above the ground, as above.
19. Average slope of plot in 10° intervals (1 value per plot). Estimated from field observations and 1:25,000 Topographic Maps.
20. Average aspect of plot in 45° degree intervals; 0°-45°, 45°-90° etc. (1 value per plot). Estimated from field compass bearings and Topographic Maps.
21. Average altitude of plot to nearest 20 metres (1 value per plot). Estimated from Topographic Maps.
22. Ground distance from plot centre to nearest stream, either perennial or intermittent, marked on Topographic Maps (1 value per plot). Estimated to nearest 50 metres.
23. Ground distance from plot centre to nearest patch of rainforest (1 value per plot). Estimated to nearest 50 metres using field observations, forest type maps produced by the Forestry Commission of N.S.W., and Lands Department aerial photographs.
24. Ground distance from plot centre to nearest patch of *Nothofagus moorei* dominated cool temperate rainforest (1 value per plot). Estimated as above.
25. Ground distance from plot centre to nearest neighbouring scrub-bird territory (1 value per plot). Estimated to nearest 50 metres.

Information concerning logging and fire histories in the two study areas was provided by the Forestry Commission of N.S.W. and the National Parks and Wildlife Service of N.S.W.

### 4.2.2 Home Range Data

In order to collect more detailed data on the use of space by territorial males, 22 territories were selected for intensive study (11 territories at Wiangarie and 11 territories at Barrington Tops). Following preliminary observations (during 1980 and early 1981) a system of mapped reference points was established for each selected territory.

These points were marked with coloured tape combinations, and their locations were mapped by the compass-traverse method using a hand-held compass and tape measure (Mosby 1971). The location of reference points was based on two criteria: (1) that these points could be visited with minimal disturbance to the occupants of the territories, and (2) that these points allowed accurate bearings to be taken on birds heard within, and up to 50 metres beyond, the known boundary of their territory (based on preliminary observations). Additional reference points were mapped later in the study if the initial system was found not to cover a bird's territory adequately. A typical system of reference points is depicted in Fig.4.4. The location of a singing male was estimated by triangulation of compass bearings taken from two or more (usually three) reference points (see Bell 1964; Schleidt 1980). Effort was made to maximize accuracy by taking bearings at approximately right angles to each other and as close to the bird as possible (see MacDonald and Amlaner 1980).

In order to minimize problems of temporal contingency between successive observations (Ford and Myers 1981) two rules were enforced: (1) no more than two estimates of location were obtained for each territory on any one day, and (2) these two estimates were separated by at least four hours. Estimates of location were usually obtained opportunistically, governed by the varying demands and nature of other research activities. Subsidiary information including detections of females and roost sites was also collected opportunistically, and recorded on the territory maps. Date and time were recorded for all observations.

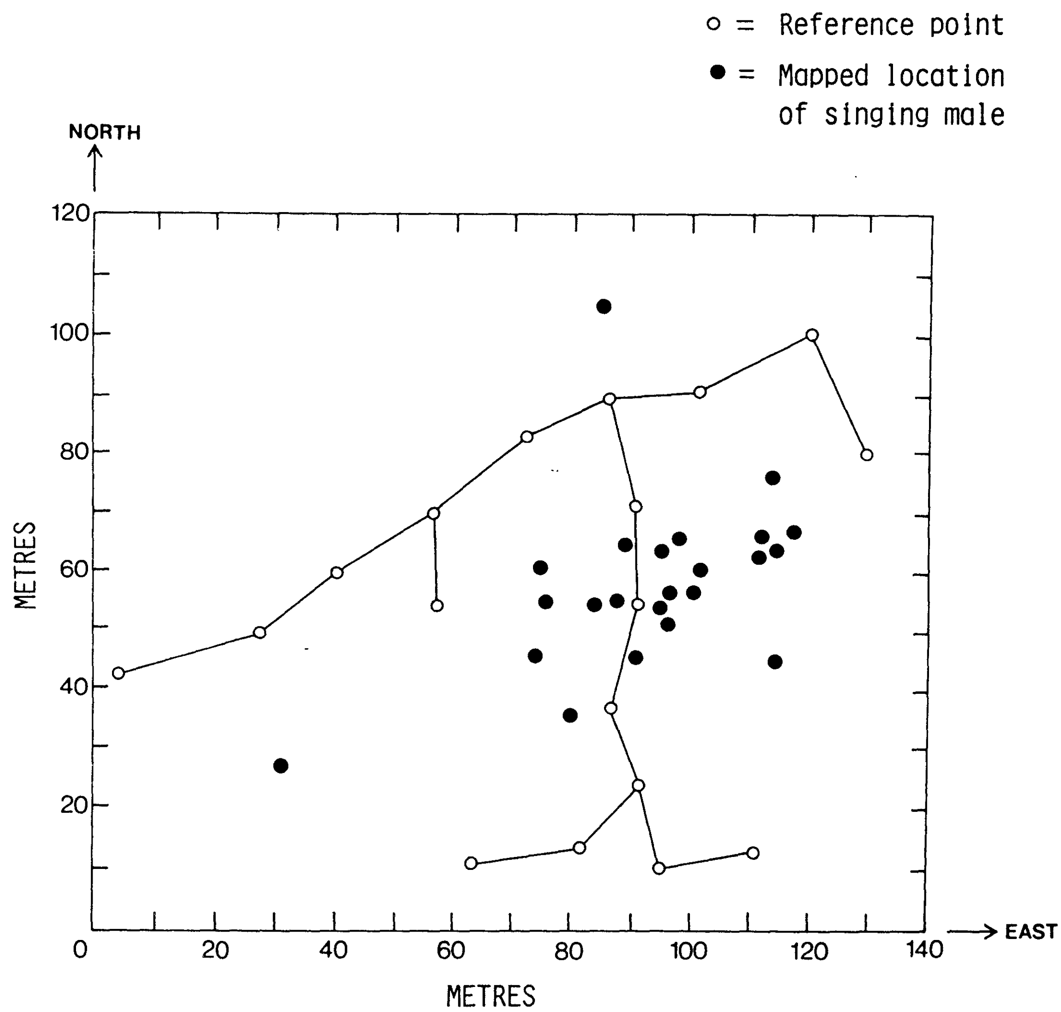



FIGURE 4.4. Typical home range map (Bird 11, Barrington Tops) showing reference points, mapped singing points, and the South-North, West-East axes used to determine the coordinates of mapped points for analysis.

## 4.3. ANALYSIS AND RESULTS

### 4.3.1 HABITAT REQUIREMENTS

#### 4.3.1.1 Plant Community Approach

The habitat requirements of the Rufous Scrub-bird have often been described in terms of particular plant communities, especially cool temperate rainforest dominated by *Nothofagus moorei* (see Table 4.1). If the species is in fact closely associated with a particular plant community, this type of habitat definition would be very useful. Areas of suitable habitat could be conveniently mapped using forest type maps and aerial photographs. The process of identifying critical habitat factors could be largely bypassed. The "plant community approach" is based on the assumption that a plant community will serve as an adequate indicator of the availability of critical habitat requirements, and therefore the presence of a species. The usefulness of this approach is largely determined by the degree of association between a species and one or more plant communities (Kikkawa 1968; Fox and Fox 1981).

In the present study potential associations between the Rufous Scrub-bird and vegetation types were investigated using cluster analysis of sample plots. Cluster analysis was used to classify plots into groups on the basis of four different sets of data:

1. Floristic characteristics of trees forming the forest canopy. The data were derived from Measurement 3 (see Field Methods) in which trees >20cm dbh were recorded as one of five different types. While these "types" have both a floristic and a physiognomic basis (see Webb *et al.* 1970), they will be treated as floristic categories to distinguish them from the purely physiognomic-structural characteristics described below.
2. Floristic characteristics of all trees. The data were derived from Measurement 3 (see Field Methods) in which trees >20cm dbh were recorded as one of five different types, Measurement 6 in which trees 5-20cm dbh were recorded as one of six types, and Measurement 8 in which trees <5cm dbh were recorded as one of five types (a total of 16 variables in the analysis).
3. Physiognomic-structural characteristics of trees forming the forest canopy. The data on six characteristics (average ratings for each

plot) were derived from Measurement 4 (see Field Methods).

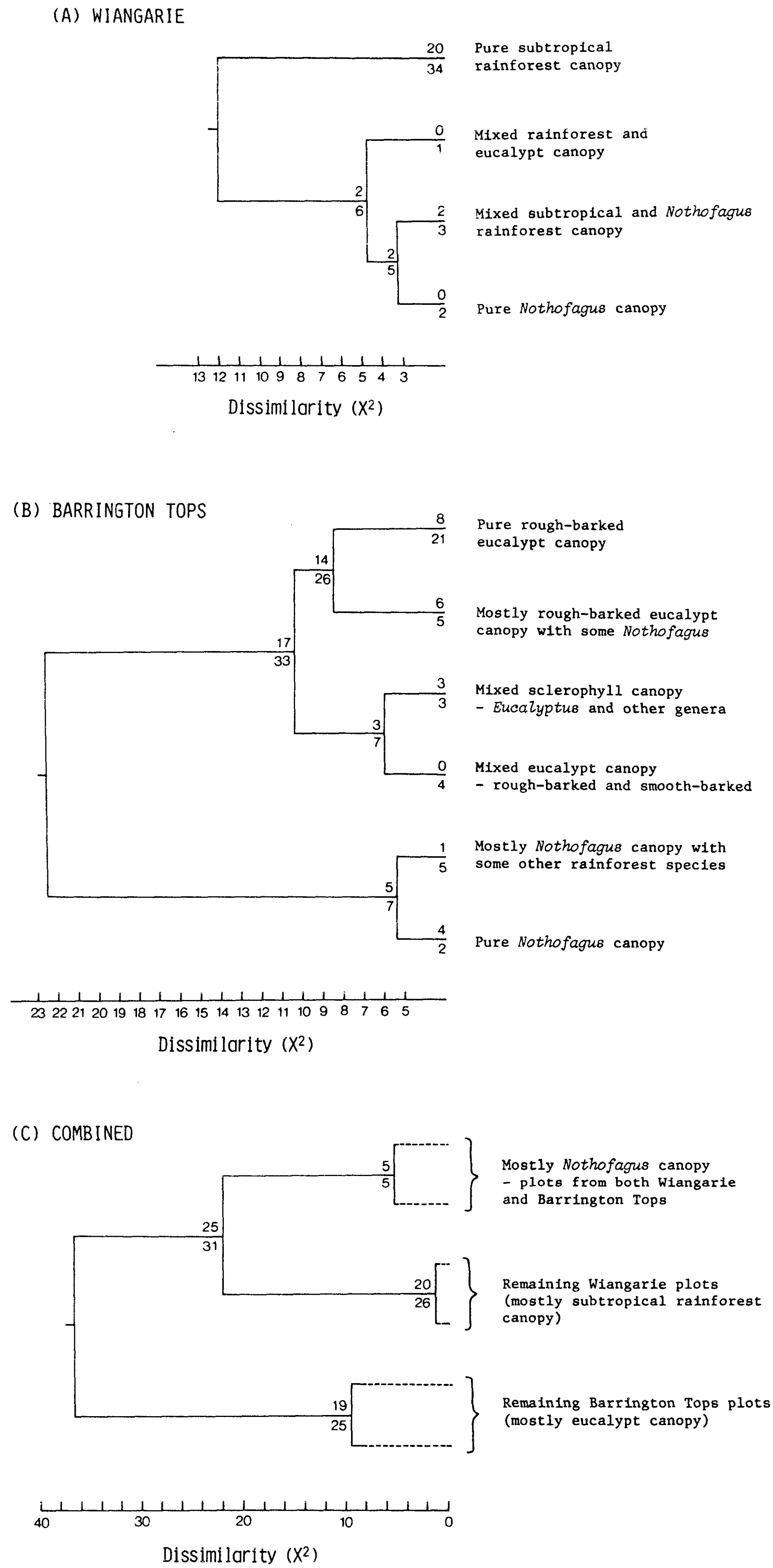
4. Floristic characteristics of ground cover vegetation. The data on genera of ground cover plants were derived from Measurement 12 (see Field Methods).

Each data set was used to generate classifications for three different sets of habitat plots: (a) Wiangaire plots only, (b) Barrington Tops plots only, and (c) Wiangarie and Barrington Tops plots combined (a total of 12 classifications). The separate Wiangarie and Barrington Tops classifications each involved 62 plots (22 scrub-bird plots and 40 non-scrub-bird plots). Due to computational restrictions the combined classifications were limited to 100 plots. Twelve randomly selected non-scrub-bird plots from each study area were deleted, leaving a total of 44 scrub-bird plots and 56 non-scrub-bird plots. The analyses were conducted using programs from the BMDP Statistical Software Package (Dixon 1981). The Chi-square ($\chi^2$) dissimilarity measure was used in the floristic classifications. The standardized Euclidean distance measure was used in the physiognomic-structural classifications. Plots were grouped using an agglomerative polythetic group-average strategy (Clifford and Stephenson 1975).

The classifications obtained from the 12 analyses are summarized in Figs.4.5 to 4.8. Descriptions of the vegetation types shown in Figs.4.5 to 4.8 are based on an examination of attribute means at each division of the classifications. The $\chi^2$ test was used to test for associations between the Rufous Scrub-bird and vegetation types. The ratio of scrub-bird plots to non-scrub-bird plots occurring within a particular vegetation type was compared to the ratio of plots occurring elsewhere.

Scrub-bird territories displayed little association with forest types classified according to either floristic or physiognomic-structural characteristics of trees (see Figs.4.5 to 4.7). The only significant exception was a negative association with the pure eucalypt forest type (i.e. eucalypt overstorey and understorey) at Barrington Tops (Fig.4.6). The general impression obtained from the classifications shown in Figs.4.5 to 4.7 is that scrub-birds at the two study areas occurred in a wide variety of forest types. This is especially highlighted in the combined classifications. The species is clearly not confined to *Nothofagus moorei* forest, as implied by some previous observers (see Table 4.1), but also occurs in other types of rainforest and eucalypt open forest.

FIGURE 4.5. Classifications obtained from cluster analysis of habitat plots using floristic characteristics of canopy trees. Numbers indicate the distribution of scrub-bird and non-scrub-bird plots occurring in a particular vegetation type. The lower number is the number of non-scrub-bird plots occurring in that type. Significant associations between the Rufous Scrub-bird and vegetation types, based on $\chi^2$ tests, are indicated in the following manner: (+) = positive association, $p<0.05$; (++) = positive association, $p<0.01$; (+++) = positive association, $p<0.001$; (-) = negative association, $p<0.05$; (--) = negative association, $p<0.01$; (---) = negative association, $p<0.001$.



(A) WIANGARIE
20
34
Pure subtropical rainforest canopy
0
1
Mixed rainforest and eucalypt canopy
2
6
2
3
Mixed subtropical and *Nothofagus* rainforest canopy
2
5
0
2
Pure *Nothofagus* canopy
13 12 11 10 9 8 7 6 5 4 3
Dissimilarity ($X^2$)
(B) BARRINGTON TOPS
8
21
Pure rough-barked eucalypt canopy
14
26
6
5
Mostly rough-barked eucalypt canopy with some *Nothofagus*
17
33
3
3
Mixed sclerophyll canopy - *Eucalyptus* and other genera
3
7
0
4
Mixed eucalypt canopy - rough-barked and smooth-barked
1
5
Mostly *Nothofagus* canopy with some other rainforest species
5
7
4
2
Pure *Nothofagus* canopy
23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5
Dissimilarity ($X^2$)
(C) COMBINED
5
5
Mostly *Nothofagus* canopy - plots from both Wiangarie and Barrington Tops
25
31
20
26
Remaining Wiangarie plots (mostly subtropical rainforest canopy)
19
25
Remaining Barrington Tops plots (mostly eucalypt canopy)
40 30 20 10 0
Dissimilarity ($X^2$)

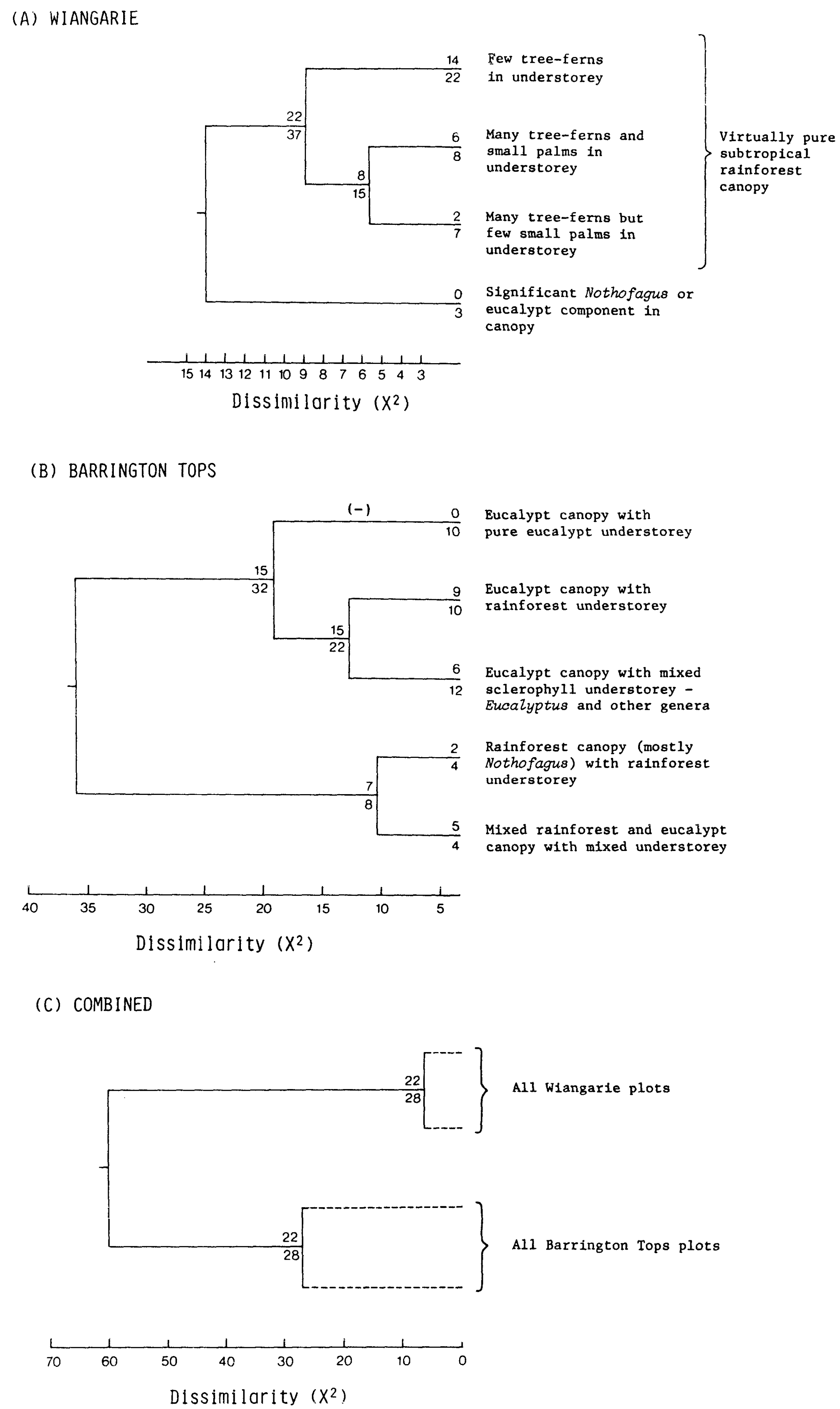



FIGURE 4.6. Classifications obtained from cluster analysis of habitat plots using floristic characteristics of all trees. For explanation see Fig.4.5 caption.

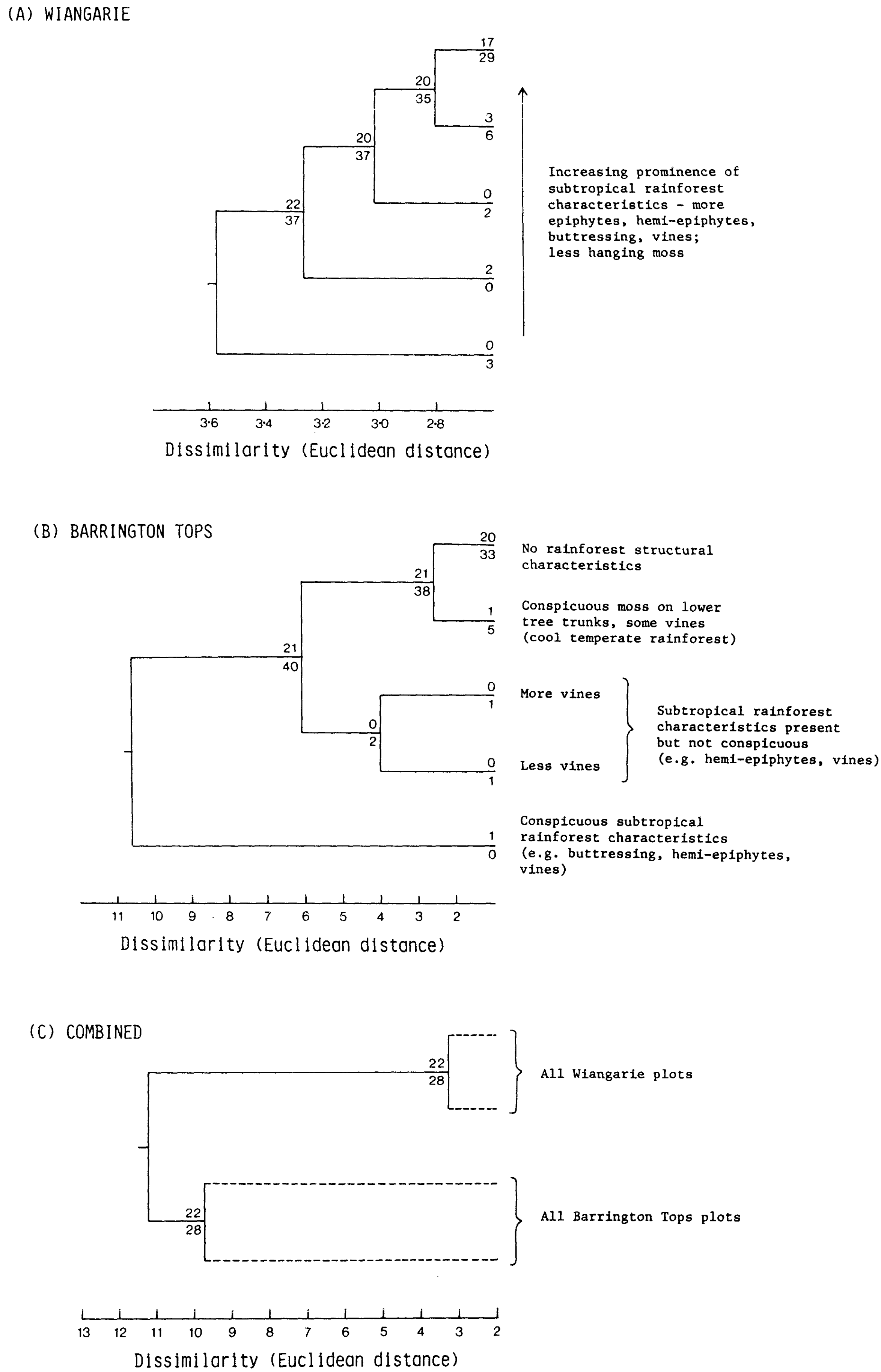



FIGURE 4.7. Classifications obtained from cluster analysis of habitat plots using physiognomic-structural characteristics of canopy trees. For explanation see Fig.4.5 caption.

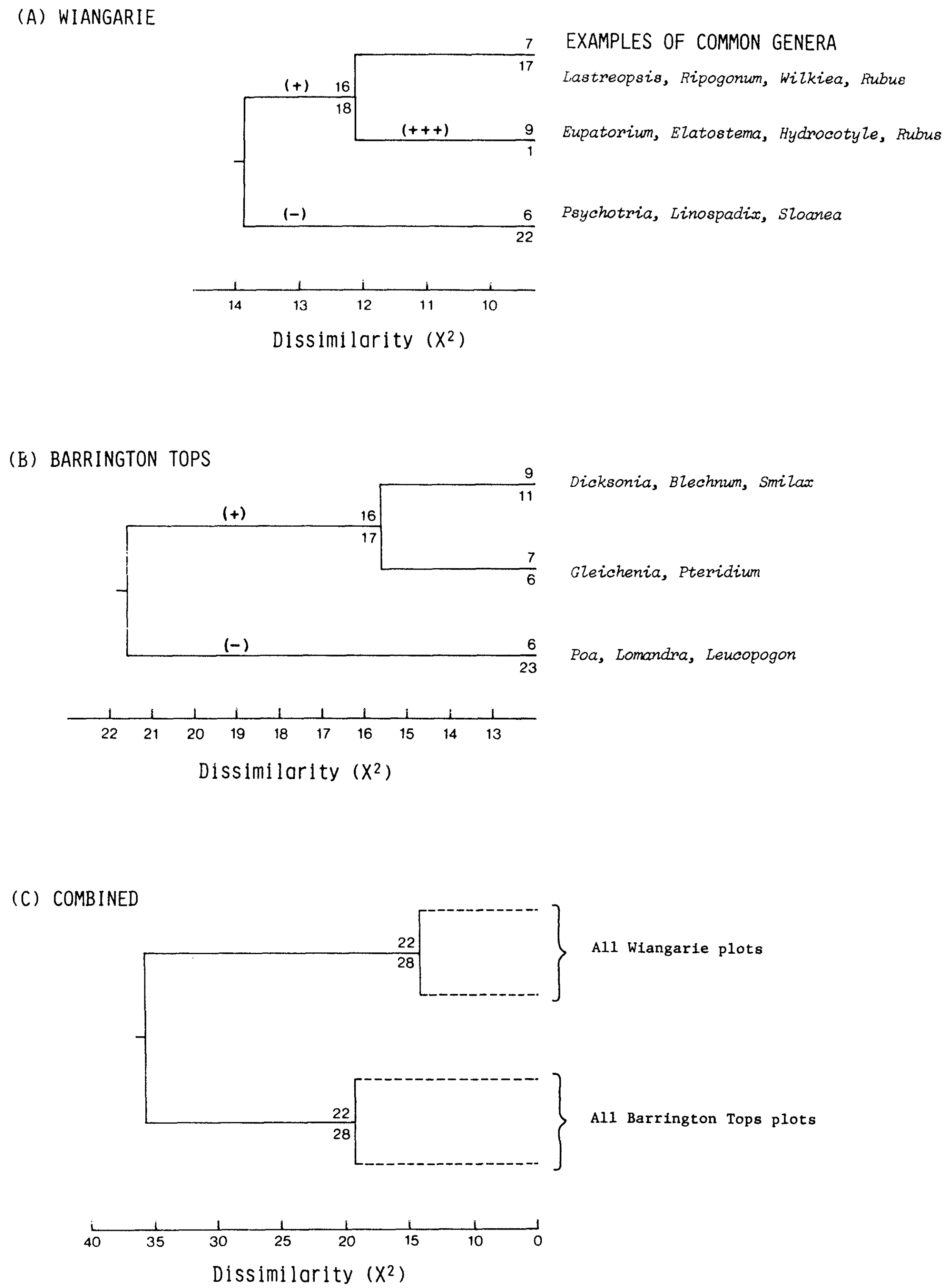



FIGURE 4.8. Classifications obtained from cluster analysis of habitat plots using floristic characteristics of ground cover. For explanation see Fig.4.5 caption.

The separate ground cover classifications for Wiangarie and Barrington Tops suggested that scrub-birds were associated with particular floristic associations of ground cover plants (see Fig.4.8). However, each of these relationships was confined to only one or the other of the study areas and could not be generalized to both areas. This is clearly demonstrated in the combined classification (Fig.4.8).

The general conclusion drawn from the above analyses is that the habitat requirements of the Rufous Scrub-bird cannot be adequately defined in plant community terms.

#### 4.3.1.2 Critical Habitat Factors

What are the critical habitat factors determining the suitability of habitat for the Rufous Scrub-bird? The 46 variables considered in the following analysis are described in Table 4.2. Many of these variables displayed significant differences between scrub-bird and non-scrub-bird plots. The results of univariate tests are summarized in Table 4.3.

A variable correlated with scrub-bird presence is not necessarily a critical habitat factor (see Fig.4.1). Many of the habitat variables listed in Table 4.3 were correlated with one another. The primary aim of the analysis was to separate those variables that were most likely to represent critical habitat factors from those variables that were correlated with scrub-bird presence simply because they were correlated with a critical factor. This was accomplished using discriminant function analysis, a statistical technique that has been widely applied to habitat research (e.g. James 1971; Shugart and Patten 1972; Conner and Adkisson 1976; Riechert 1976; Bertin 1977; Dueser and Shugart 1978; Cavallaro *et al.* 1981; MacKenzie and Sealy 1981; Raphael 1981; Rice *et al.* 1981; Smith *et al.* 1981; Titus and Mosher 1981; Fox 1982; Morris and Lemon 1983). Discriminant analysis mathematically combines variables into discriminant functions in a way that maximizes separation between two or more groups. In habitat research these "groups" usually consist of habitat plots grouped according to presence or absence of a particular species. In the present study discriminant analysis was used to compare scrub-bird plots and non-scrub-bird plots. The data from the two study areas (Wiangarie and Barrington Tops) were initially analyzed separately.

TABLE 4.2

Habitat variables used in the discriminant analysis. Unless otherwise stated a variable equals the mean value for the measurement indicated (all measurements are described in the Field Methods section).

| Habitat Variable | Description |
|---|---|
| 1. Density of trees > 20cm dbh | Derived from Measurement 1 using standard point-quarter sampling calculations (Cottam and Curtis 1956; Mueller-Dombois 1974). |
| 2. Diameter of trees > 20cm dbh | Measurement 2. |
| 3. Density of trees 5-20cm dbh | Derived from Measurement 5 (as for Variable 1). |
| 4. Density of trees < 5cm dbh | Derived from Measurement 7 (as for Variable 1). |
| 5. Moss on lower tree trunks | Measurement 4(e). |
| 6. Density of cover 2-50cm above ground | Cover index derived from Measurement 9 using the method described by Fox (1979). |
| 7. Density of cover 50-100cm above ground | Cover index derived from Measurement 9 (as for Variable 6). |
| 8. Density of cover 100-150cm above ground | Cover index derived from Measurement 9 (as for Variable 6). |
| 9. Grass 5-50cm above ground | Measurement 10(a). |
| 10. Grass 50-150cm above ground | Measurement 11(a). |
| 11. Sedge 5-50cm above ground | Measurement 10(b). |
| 12. Sedge 50-150cm above ground | Measurement 11(b). |
| 13. Large-leafed herb 5-50cm above ground | Measurement 10(c). |
| 14. Large-leafed herb 50-150cm above ground | Measurement 11(c). |
| 15. Forb 5-50cm above ground | Measurement 10(d). |
| 16. Forb 50-150cm above ground | Measurement 11(d). |
| 17. Fern 5-50cm above ground | Measurement 10(e). |
| 18. Fern 50-150cm above ground | Measurement 11(e). |
| 19. Vine 5-50cm above ground | Measurement 10(f). |
| 20. Vine 50-150cm above ground | Measurement 11(f). |
| 21. Shrub 5-50cm above ground | Measurement 10(g). |
| 22. Shrub 50-150cm above ground | Measurement 11(g). |

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TABLE 4.2 (cont.)

| Habitat Variable | Description |
|---|---|
| 23. Palm 5-50cm above ground | Measurement 10(h). |
| 24. Palm 50-150cm above ground | Measurement 11(h). |
| 25. Tree-fern 5-50cm above ground | Measurement 10(i). |
| 26. Tree-fern 50-150cm above ground | Measurement 11(i). |
| 27. Log 5-50cm above ground | Measurement 10(j). |
| 28. Log 50-150cm above ground | Measurement 11(j). |
| 29. Fallen debris 5-50cm above ground | Measurement 10(k). |
| 30. Fallen debris 50-150cm above ground | Measurement 11(k). |
| 31. Rock 5-50cm above ground | Measurement 10(l). |
| 32. Rock 50-150cm above ground | Measurement 11(l). |
| 33. Leaf litter volume | Measurement 13. |
| 34. Soil surface penetrability | Measurement 14. |
| 35. Temperature 2cm above ground | Measurement 15 adjusted for temporal variation in temperature*. |
| 36. Temperature 200cm above ground | Measurement 16 adjusted for temporal variation in temperature*. |
| 37. Wet bulb depression 2cm above ground | Measurement 17 subtracted from Measurement 15, and adjusted for temporal variation in temperature and humidity#. |
| 38. Wet bulb depression 200cm above ground | Measurement 18 subtracted from Measurement 16, and adjusted for temporal variation in temperature and humidity#. |
| 39. Slope | Measurement 19. |
| 40. North-south aspect | Derived from Measurement 20. Values are: 1 = 0°-45° or 315°-360°, 2 = 45°-90° or 270°-315°, 3 = 90°-135° or 225°-270°, 4 = 135°-180° or 180°-225°. |
| 41. East-west aspect | Derived from Measurement 20. Values are: 1 = 45°-90° or 90°-135°, 2 = 0°-45° or 135°-180°, 3 = 315°-360° or 180°-225°, 4 = 270°-315° or 225°-270°. |
| 42. Altitude | Measurement 21. |
| 43. Distance to nearest stream | Measurement 22. |

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TABLE 4.2 (cont.)

| Habitat Variable | Description |
|---|---|
| 44. Distance to nearest rainforest | Measurement 23. |
| 45. Distance to nearest *Nothofagus moorei* rainforest | Measurement 24. |
| 46. Distance to nearest neighbouring scrub-bird territory | Measurement 25. |

* Temperature was adjusted for temporal variation using the following equation:

Adjusted Temp = Recorded Temp - b (Adjacent Temp - Mean Temp)

where Adjacent Temp = the mean temperature recorded for the 4 non-scrub-bird plots and 2 scrub-bird plots measured closest in time to the plot of interest.

Mean Temp = the mean temperature for all plots.

b = the regression coefficient from the regression equation relating recorded temperature to adjacent temperature.

# Wet bulb depression was adjusted for temporal variation using the following equation:

Adjusted Depression = Recorded Depression - $b_1$ (Recorded Temp - Mean Temp) - $b_2$ (Adjacent Depression - Mean Depression)

where Recorded Temp = the temperature recorded for the plot of interest.

Mean Temp = the mean temperature for all plots

Adjacent Depression = the mean wet bulb depression recorded for the 4 non-scrub-bird plots and 2 scrub-bird plots measured closest in time to the plot of interest.

Mean Depression = the mean wet bulb depression for all plots.

$b_1$, $b_2$ = partial regression coefficients from the multiple regression equation relating recorded depression to recorded temperature and adjacent depression.

TABLE 4.3

Results of t-tests (separate variance estimate) and nonparametric Mann-Whitney U-tests, testing for univariate differences in habitat variables between scrub-bird and non-scrub-bird plots. Only those variables that yielded significant differences are included.

| Habitat Variable | Wiangarie | | Barrington Tops | |
|---|---|---|---|---|
| | t-test | U-test | t-test | U-test |
| 1. Density of trees > 20cm dbh | --- | --- | | |
| 3. Density of trees 5-20cm dbh | --- | --- | | |
| 4. Density of trees < 5cm dbh | --- | --- | + | + |
| 5. Moss on lower tree trunks | + | ++ | +++ | +++ |
| 6. Density of cover 2-50cm above ground | +++ | +++ | +++ | +++ |
| 7. Density of cover 50-100cm above ground | +++ | +++ | +++ | +++ |
| 8. Density of cover 100-150cm above ground | ++ | ++ | + | ++ |
| 9. Grass 5-50cm above ground | | | -- | -- |
| 12. Sedge 50-150cm above ground | | | +++ | +++ |
| 15. Forb 5-50cm above ground | ++ | +++ | | |
| 16. Forb 50-150cm above ground | +++ | +++ | | |
| 17. Fern 5-50cm above ground | ++ | + | + | + |
| 18. Fern 50-150cm above ground | +++ | +++ | + | ++ |
| 19. Vine 5-50cm above ground | +++ | +++ | | |
| 20. Vine 50-150cm above ground | +++ | +++ | + | + |
| 22. Shrub 50-150cm above ground | | | +++ | +++ |
| 27. Log 5-50cm above ground | +++ | +++ | | |
| 28. Log 50-150cm above ground | + | ++ | | |
| 29. Fallen debris 5-50cm above ground | ++ | ++ | | |

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TABLE 4.3 (cont.)

| Habitat Variable | Wiangarie | | Barrington Tops | |
|---|---|---|---|---|
| | t-test | U-test | t-test | U-test |
| 30. Fallen debris 50-150cm above ground | + | ++ | | |
| 33. Leaf litter volume | -- | - | | |
| 34. Soil surface penetrability | | | +++ | +++ |
| 35. Temperature 2cm above ground | -- | -- | | |
| 36. Temperature 200cm above ground | -- | - | | |
| 37. Wet bulb depression 2cm above ground | --- | --- | --- | --- |
| 38. Wet bulb depression 200cm above ground | -- | -- | -- | -- |
| 43. Distance to nearest stream | - | - | - | -- |
| 44. Distance to nearest rainforest | | | --- | --- |
| 46. Distance to nearest neighbouring scrub-bird territory | + | + | ++ | ++ |

+ Scrub-bird mean > Non-scrub-bird mean ($p<0.05$)

++ Scrub-bird mean > Non-scrub-bird mean ($p<0.01$)

+++ Scrub-bird mean > Non-scrub-bird mean ($p<0.001$)

\- Scrub-bird mean < Non-scrub-bird mean ($p<0.05$)

-- Scrub-bird mean < Non-scrub-bird mean ($p<0.01$)

--- Scrub-bird mean < Non-scrub-bird mean ($p<0.001$)

The discriminant analyses were performed using the SPSS package (Nie *et al.* 1975; Hull and Nie 1979). All 46 variables listed in Table 4.2 were included in the analyses. The reason for including both significant and nonsignificant univariate variables is that apparently unimportant variables on a univariate basis may nevertheless be very important when combined with other variables (Cochran 1964; Eisenbeis 1977; Cavallaro *et al.* 1981). A stepwise procedure was used to select those variables that best separated scrub-bird plots from non-scrub-bird plots. This procedure worked in two stages (see Klecka 1975; Hull and Nie 1979):

1. Forward selection. Variables were added to the discriminant function one at a time. The order in which variables were added was based on their contribution to the multivariate F-ratio testing the difference between scrub-bird and non-scrub-bird plots. No minimum criterion was set for this contribution. The only criterion governing the inclusion of variables was a "minimum tolerance" of 0.1. The tolerance of a variable is the proportion of its variance not accounted for by other variables already included in the analysis. The tolerance criterion was enforced to avoid problems of multicollinearity that occur if highly redundant variables are included in a discriminant analysis (Cavallaro *et al.* 1981).
2. Backward elimination of those variables included in the discriminant function after forward selection. Variables were removed one at a time. The variable selected for removal at each step was the one that made least contribution to the separation of scrub-bird and non-scrub-bird plots over and above that made by all other remaining variables. This process continued until the partial F ratios of all remaining variables were significant ($p<0.05$).

The variables remaining in the discriminant analysis after backward elimination were interpreted as being critical habitat factors. While such variables may not represent the exact factors used by scrub-birds in selecting habitats, they are nevertheless the best approximations available based on the variables measured.

The variables remaining in the discriminant functions for Wiangarie and Barrington Tops are presented in Table 4.4. Two critical habitat factors were identified at Wiangarie:

1. Density of cover 2-50cm above the ground.
2. Density of cover 50-100cm above the ground.

TABLE 4.4

Habitat variables remaining in the Wiangarie and Barrington Tops discriminant functions following backward elimination of non-significant variables.

(a) Wiangarie

| Variables | Standardized discriminant function coefficient | Wilks' lambda | Significance of partial-F |
|---|---|---|---|
| Density of cover 2-50cm above ground | 0.81 | 0.25 | *** |
| Density of cover 50-100cm above ground | 0.48 | 0.13 | *** |
| Constant | -5.44 | | |

(b) Barrington Tops

| Variables | Standardized discriminant function coefficient | Wilks' lambda | Significance of partial-F |
|---|---|---|---|
| Density of cover 50-100cm above ground | 0.98 | 0.44 | *** |
| Wet bulb depression 2cm above ground | -0.34 | 0.17 | ** |
| Leaf litter volume | 0.36 | 0.17 | ** |
| Distance to nearest neighbouring territory | 0.41 | 0.18 | ** |
| Constant | -3.52 | | |

** $p<0.01$

*** $p<0.001$

Four critical habitat factors were identified at Barrington Tops:

1. Density of cover 50-100cm above the ground.
2. Relative humidity 2cm above the ground.
3. Leaf litter volume.
4. Distance to nearest neighbouring scrub-bird territory.

The multivariate F ratio testing the difference between scrub-bird and non-scrub-bird plots based on these variables was highly significant for both study areas (Wiangarie: $F = 254.5$; $df = 2,59$; $p<0.001$. Barrington Tops: $F = 76.3$; $df = 4,57$; $p<0.001$). The distribution of plots along the Wiangarie and Barrington Tops discriminant functions is shown in Fig.4.9. Note that complete separation of scrub-bird and non-scrub-bird habitat was achieved for both areas. The distribution of plots in relation to the original variables is also depicted in Figs.4.10 and 4.11.

Different variables were identified as critical habitat factors at Wiangarie and Barrington Tops. This does not necessarily mean that scrub-birds in these two areas have different habitat requirements. The availability of each requirement in an area may have played a large part in determining whether or not that requirement was identified. For example, consider the data on density of cover 2-50cm above the ground presented in Fig.4.12. Dense cover 2-50cm above the ground was relatively common at Barrington Tops and therefore failed to be identified as a critical component of scrub-bird plots. It was only at Wiangarie, where ground cover was generally sparse, that this variable emerged as an important factor governing the suitability of habitat. Note that the lower limits of the two scrub-bird samples in Fig.4.12 are roughly equivalent. This suggests that scrub-birds in the two areas require a similar density of ground cover. The difference between the two areas lies in the availability of this requirement, and hence its importance as a factor limiting the local distribution of suitable habitat.

A similar pattern existed for relative humidity (see Fig.4.13). Suitable moist habitat was more widespread within the rainforest at Wiangarie than within the predominantly open forest at Barrington Tops. This requirement was therefore identified only at Barrington Tops.

The identification of leaf litter volume only at Barrington Tops is more difficult to interpret. In the univariate analysis leaf litter volume

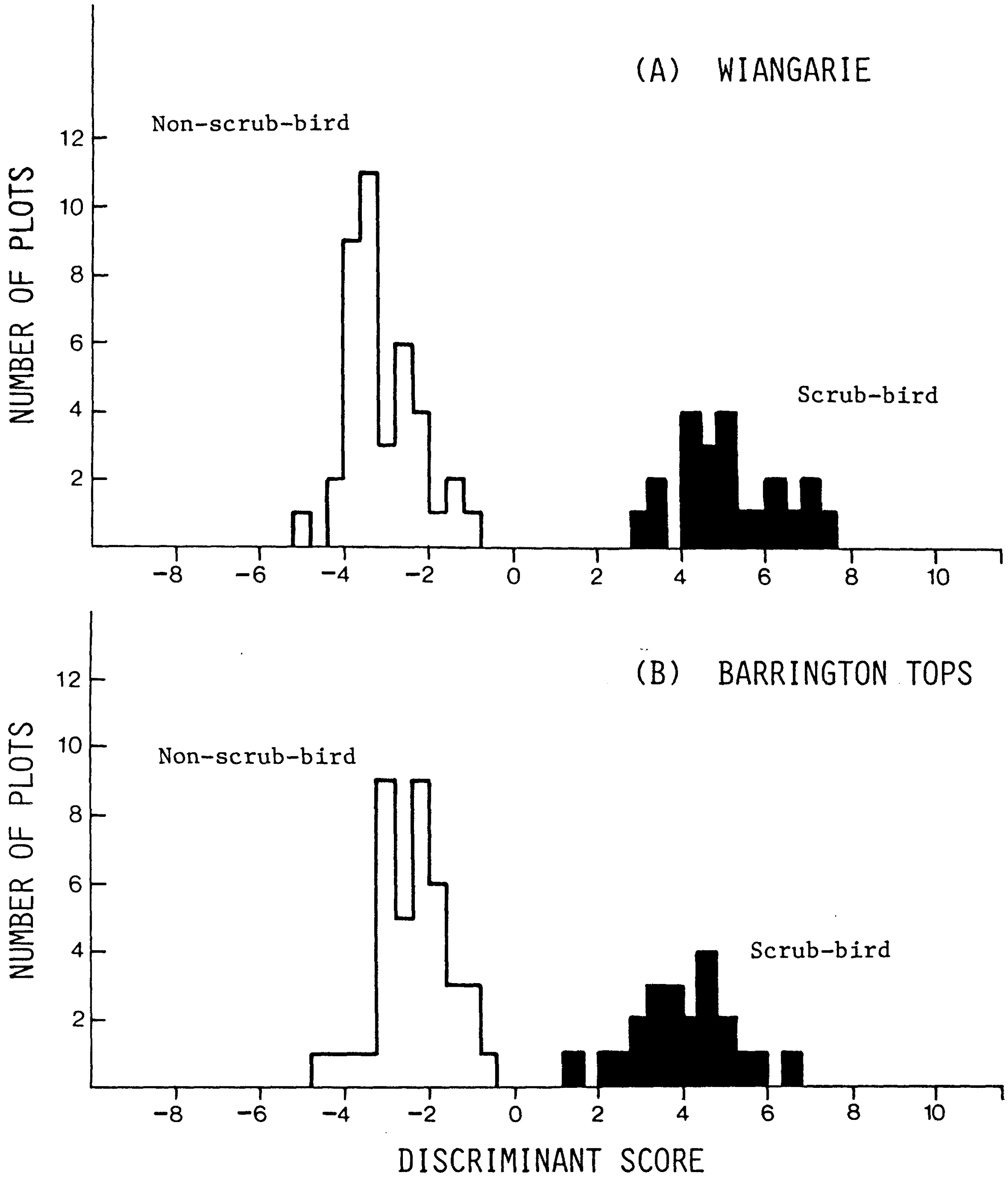



FIGURE 4.9. Distribution of scrub-bird plots and non-scrub-bird plots along the discriminant functions for Wiangarie and Barrington Tops.

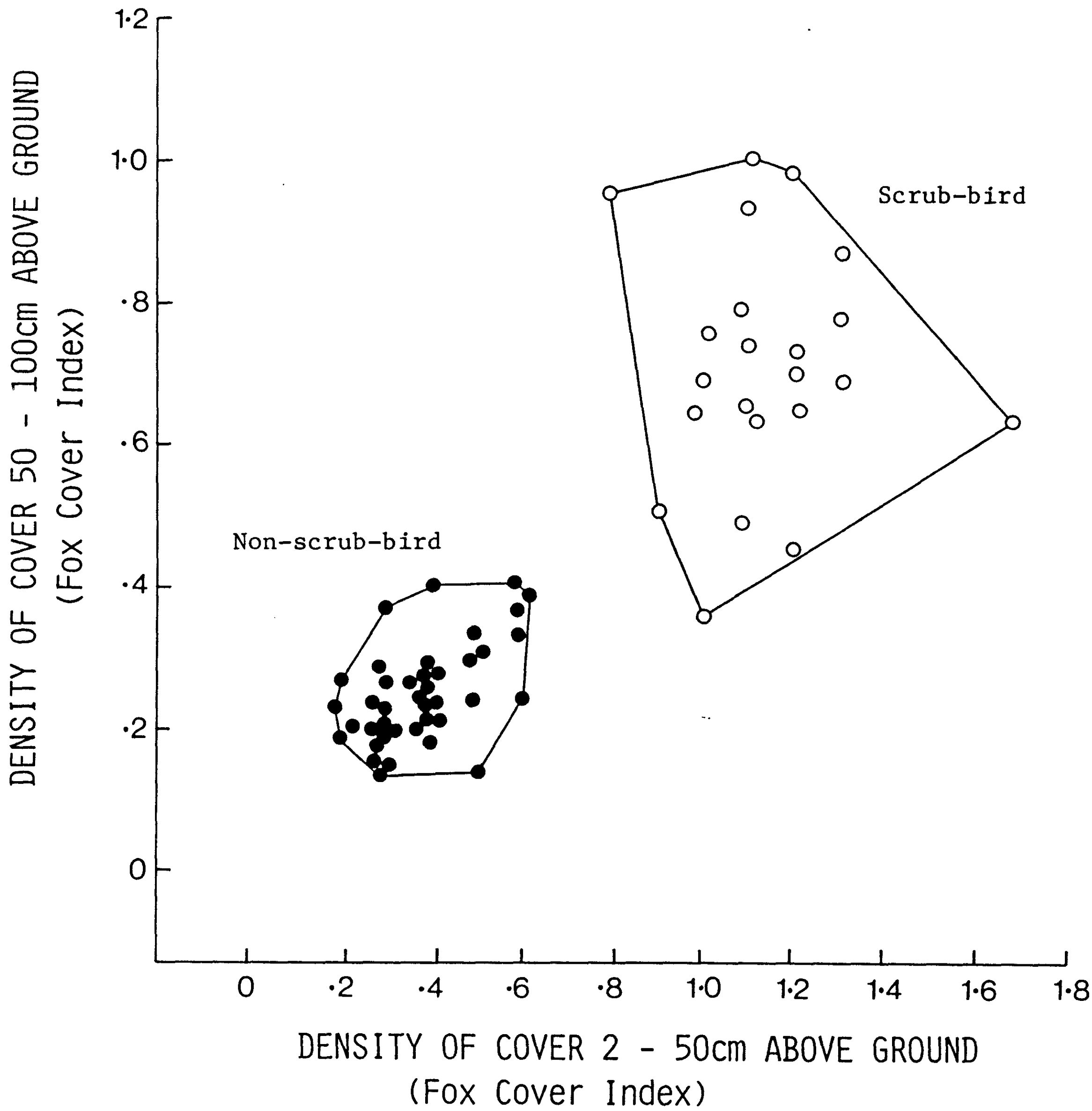



FIGURE 4.10. Bivariate distribution of Wiangarie habitat plots in relation to density of cover 2-50cm above the ground and density of cover 50-100cm above ground.

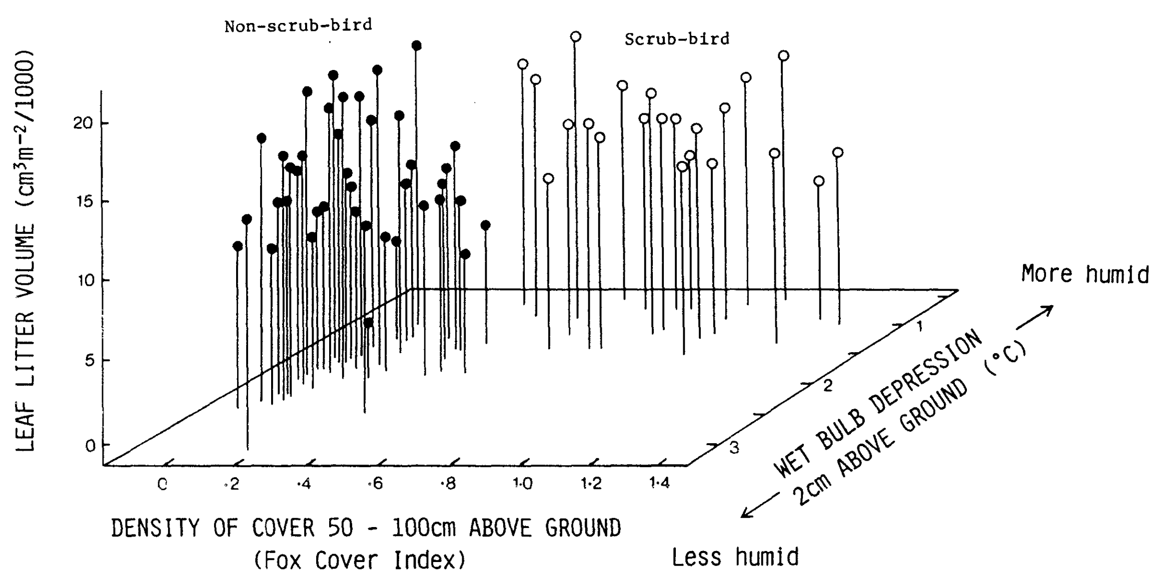



FIGURE 4.11. Trivariate distribution of Barrington Tops habitat plots in relation to density of cover 50-100cm above ground, wet bulb depression 2cm above ground, and leaf litter volume.

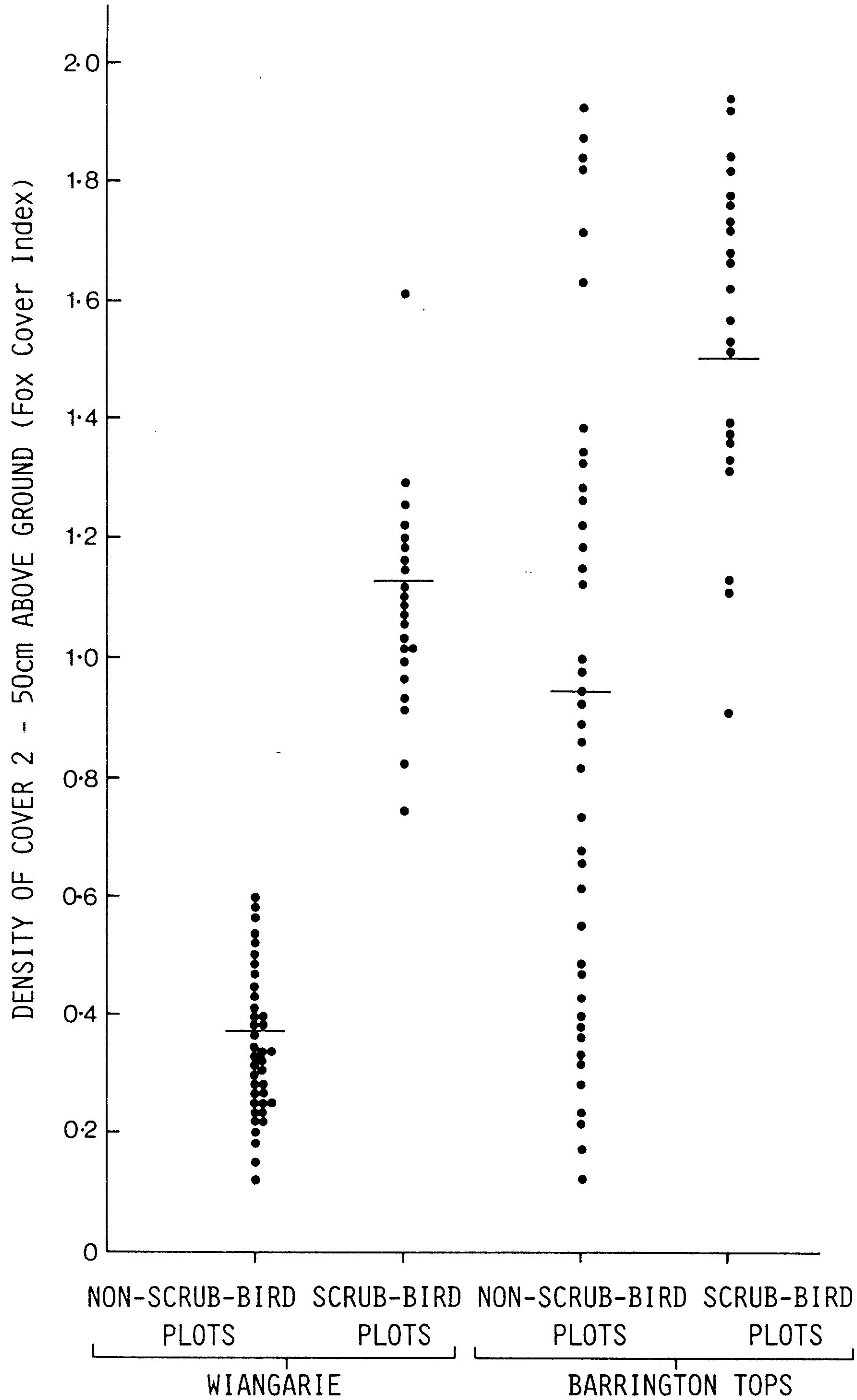



FIGURE 4.12. Density of cover 2-50cm above the ground for scrub-bird and non-scrub-bird plots at Wiangarie and Barrington Tops. Horizontal lines indicate sample means.

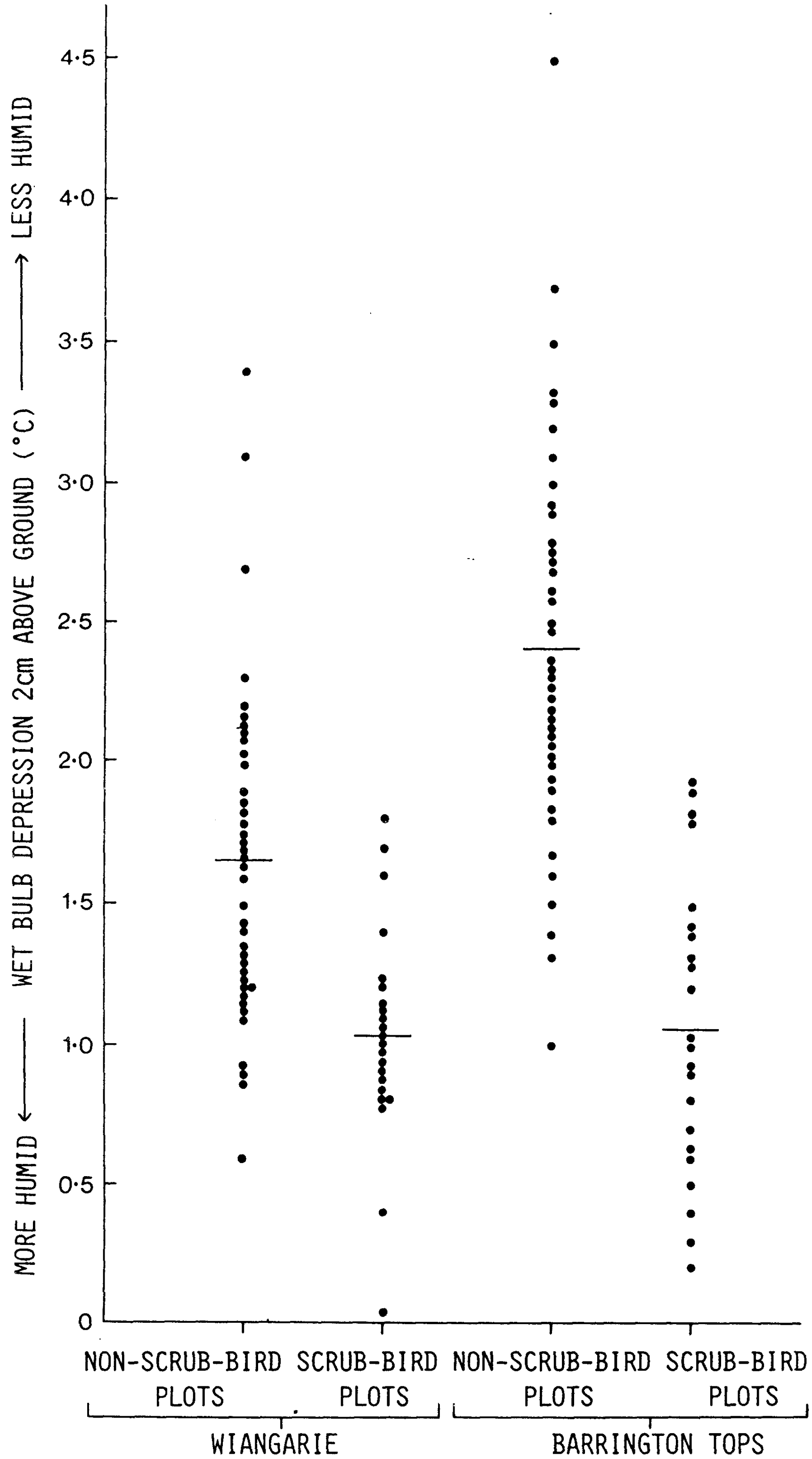
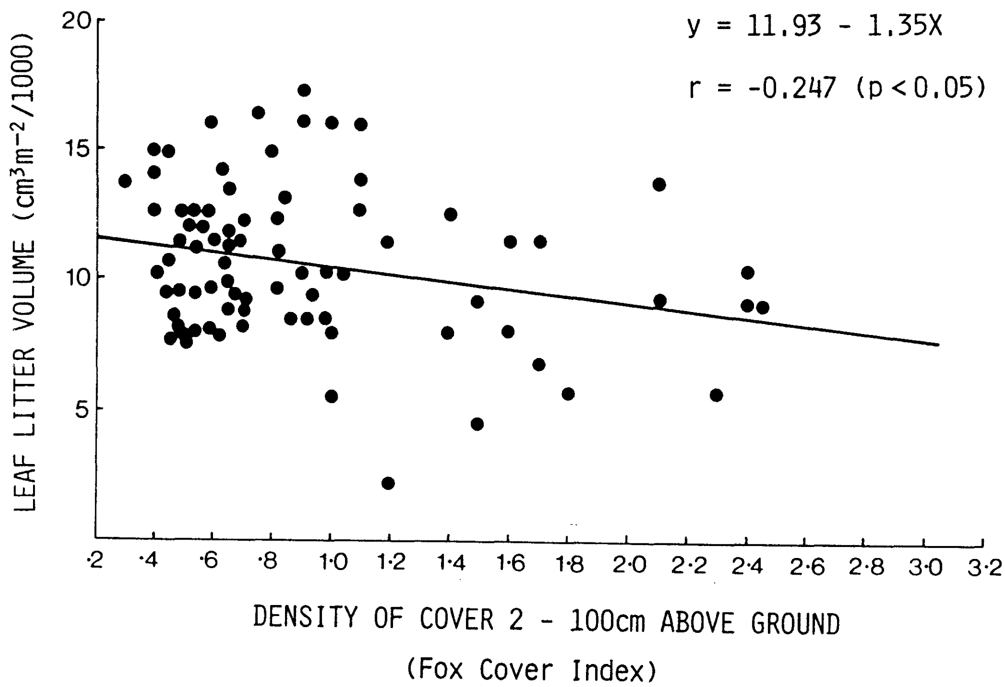



FIGURE 4.13. Wet bulb depression 2cm above ground for scrub-bird and non-scrub-bird plots at Wiangarie and Barrington Tops. Horizontal lines indicate sample means.

displayed a negative correlation with scrub-bird presence at Wiangarie and no correlation at Barrington Tops (see Table 4.3). In the discriminant analysis this variable displayed a positive correlation at Barrington Tops and no correlation at Wiangarie. A tentative interpretation of these results is presented in Fig.4.14. For the combined non-scrub-bird plots a negative correlation existed between density of cover 2-100cm above the ground (i.e. 2-50cm and 50-100cm indices combined) and leaf litter volume. This was probably due partly to the direct influence of ground cover on litter accumulation and partly to the influence of overstorey density on both variables (a negative influence on ground cover density and a positive influence on litter volume). In Fig.4.14b scrub-bird plots are shown in relation to the cover density - litter volume regression line calculated from non-scrub-bird plots. The density of cover 2-100cm above the ground was generally greater on scrub-bird plots at Barrington Tops than on scrub-bird plots at Wiangarie. This was because plots at Barrington Tops with sufficient cover 50-100cm above the ground were usually also extremely dense below 50cm. Note that leaf litter volume for the Barrington Tops scrub-bird plots tended to be higher than that expected based on the non-scrub-bird regression (Fig.4.14b). This suggests that at least some of the Barrington Tops habitat with sufficient cover 50-100cm above the ground may not have supported enough leaf litter. Because scrub-birds could only occur where there was both sufficient ground cover and sufficient leaf litter, the latter variable emerged as an important factor limiting the suitability of habitat at Barrington Tops.

The distance between a plot and the nearest neighbouring scrub-bird territory was also identified as a critical factor only at Barrington Tops. This can best be explained in terms of the distribution of habitat within the two study areas. At Barrington Tops suitable scrub-bird habitat generally occurred as long strips within open forest fringing the edge of rainforest. At Wiangarie suitable habitat occurred as small, isolated patches beneath gaps in the rainforest canopy. The discriminant functions for these two areas were recalculated, this time leaving out "distance to nearest territory". Each plot's discriminant score on these functions served as a measure of habitat suitability, ignoring the influence of neighbouring territory proximity. Non-scrub-bird plot scores are plotted against distance to the nearest territory in Fig.4.15. There was no correlation at Wiangarie, but a significant negative correlation at Barrington Tops. Suitable habitat in the latter area was more likely to

(A)




(B)

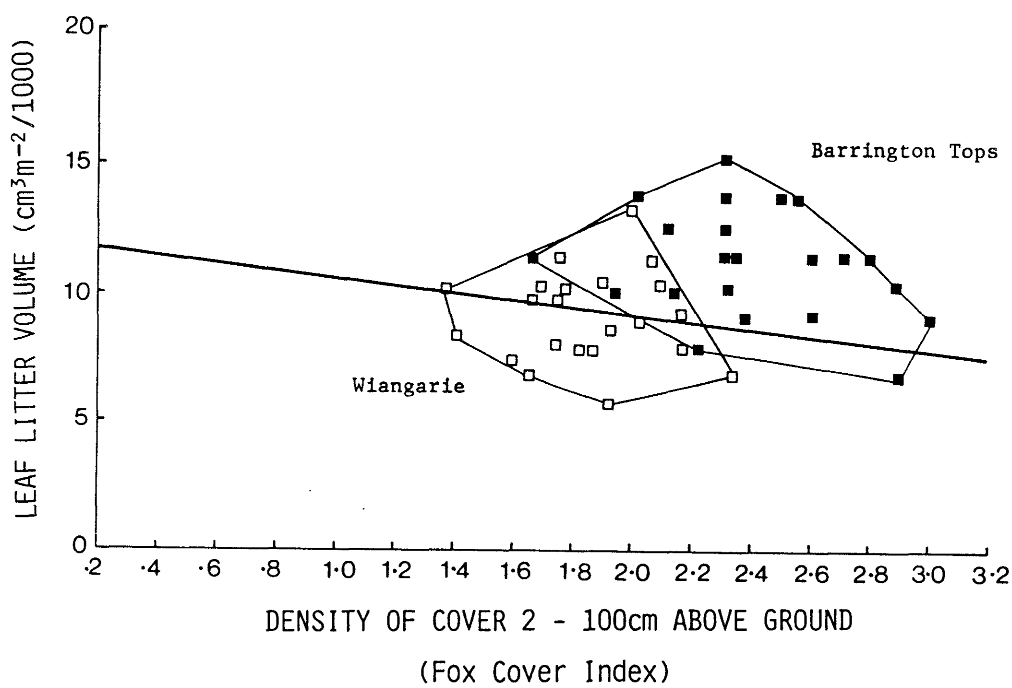
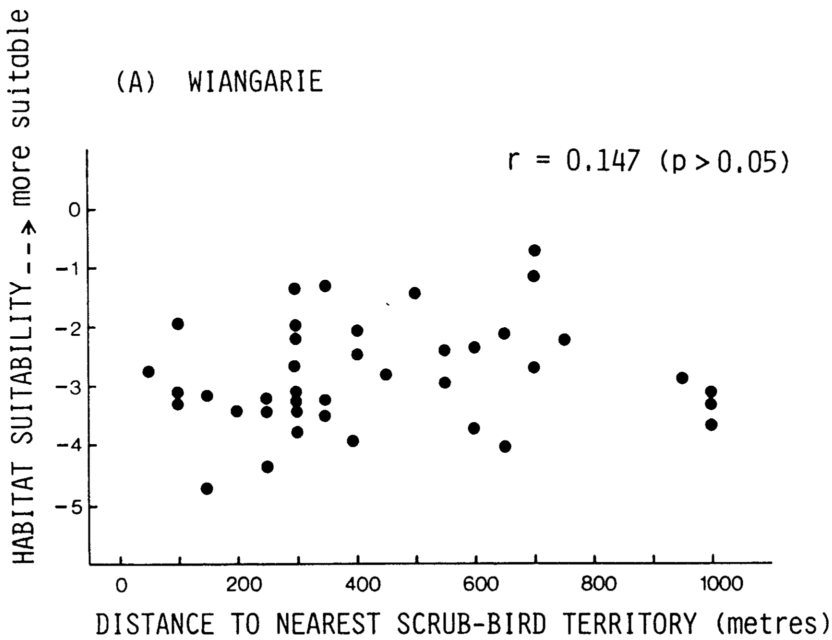



FIGURE 4.14. (A) Leaf litter volume plotted against density of cover 2-100cm above ground for all non-scrub-bird plots at Wiangarie and Barrington Tops.
(B) Leaf litter volume plotted against density of cover 2-100cm above ground for scrub-bird plots at Wiangarie (open symbols) and Barrington Tops (closed symbols). Also shown is the regression line from (A).



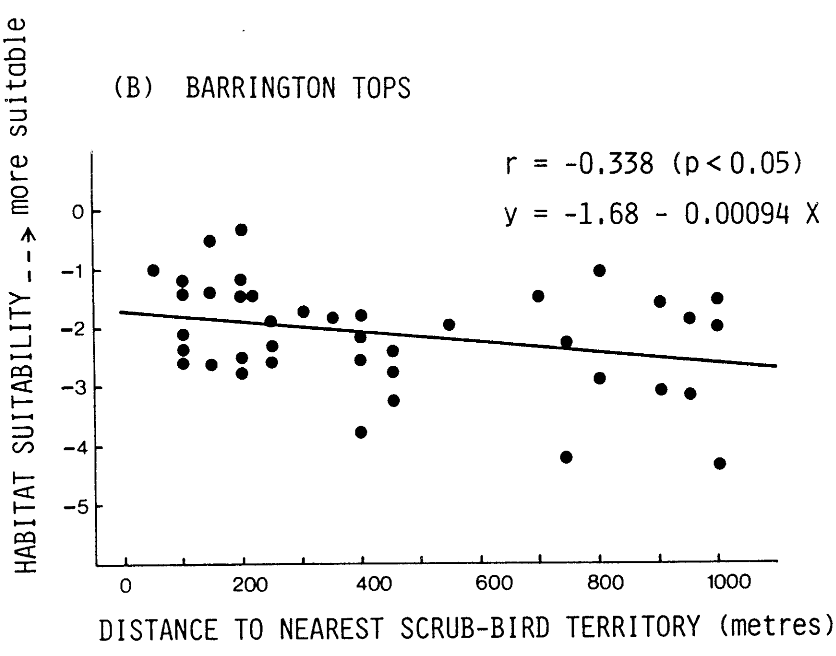




FIGURE 4.15. Habitat suitability plotted against distance to the nearest scrub-bird territory for non-scrub-bird plots at Wiangarie and Barrington Tops (see text for details).

be found close to an existing territory than it was farther away. Here, social spacing mechanisms seemed to play a critical role in preventing scrub-birds from taking up territories close to existing territories in what may otherwise have been ideal habitat. In other words territories were more widely spaced than would be expected if they were distributed randomly throughout available habitat. Such mechanisms seemed to be of less importance at Wiangarie where patches of habitat were already well spaced and each patch was usually too small to accommodate more than one territory.

Information on the spacing of territories was also collected at the subsidiary study areas described in Chapter 2. The ground distance between a singing male and its nearest detected neighbour was estimated wherever possible. A histogram of nearest neighbour distances for 130 territories is presented in Fig.4.16. Note that territory centres were rarely closer than 300 metres and never closer than 100 metres.

The general conclusion drawn from the above analyses is that the Rufous Scrub-bird appears to have the same habitat requirements at Wiangarie and Barrington Tops despite broad differences between the forest types occupied in these two areas. Casual observation confirmed that the requirements identified at Wiangarie and Barrington Tops were satisfied by all inspected territories in the subsidiary study areas. Suitable habitat was found to occur in a variety of situations within a diversity of forest types including subtropical, warm temperate and cool temperate rainforests, and adjoining eucalypt open forests. The required cover 2-100cm above the ground may consist of either living material such as ferns, shrubs, sedges, and vines, or non-living material such as logs and associated debris. Typical examples of Rufous Scrub-bird habitat are depicted in Plates 1 to 4.

#### 4.3.1.3 Habitat Classification

Discriminant functions such as those derived above can be used to classify unknown habitat as being either suitable or unsuitable for a particular species (e.g. Conner and Adkisson 1976; Smith *et al.* 1981). Classification rules were formulated for classifying habitat within the Wiangarie and Barrington Tops study areas. These were based on individual group covariance matrices and incorporated Bayesian adjustment for prior

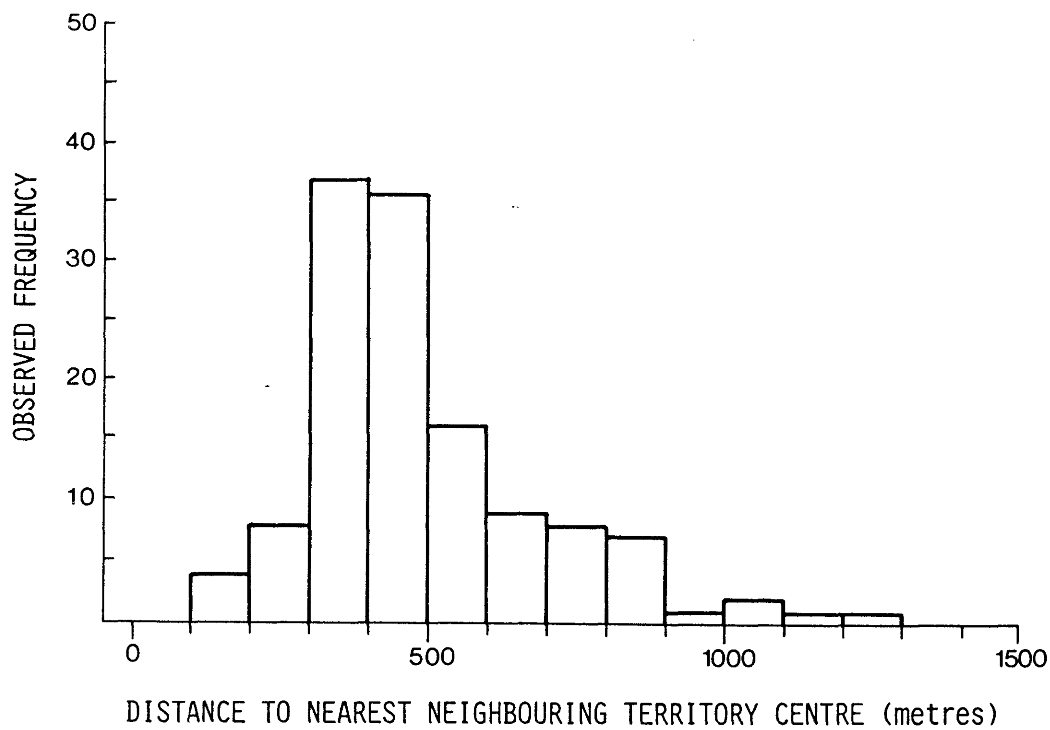



FIGURE 4.16. Frequency histogram of the distance between a singing male scrub-bird and the nearest neighbouring detected male. The sample of 130 birds is drawn from all study areas.

PLATE 1

Typical Rufous Scrub-bird habitat in subtropical rainforest, Wiangarie study area (Territory W.14).

PLATE 2

Typical Rufous Scrub-bird habitat in eucalypt open forest, Barrington Tops study area (Territory B.5). Darker vegetation in background is cool temperate rainforest.

PLATE 3

Examples of Rufous Scrub-bird habitat.

Top left : Territory 14, Wiangarie (creek-side habitat, unlogged rainforest).

Top right : Territory 3, Wiangarie (fern cover, logged rainforest).

Bottom left : Territory 1, Wiangarie (Forb cover, logged rainforest).

Bottom right : Territory 22, Wiangarie (cover provided by fallen tree and associated debris, unlogged rainforest).

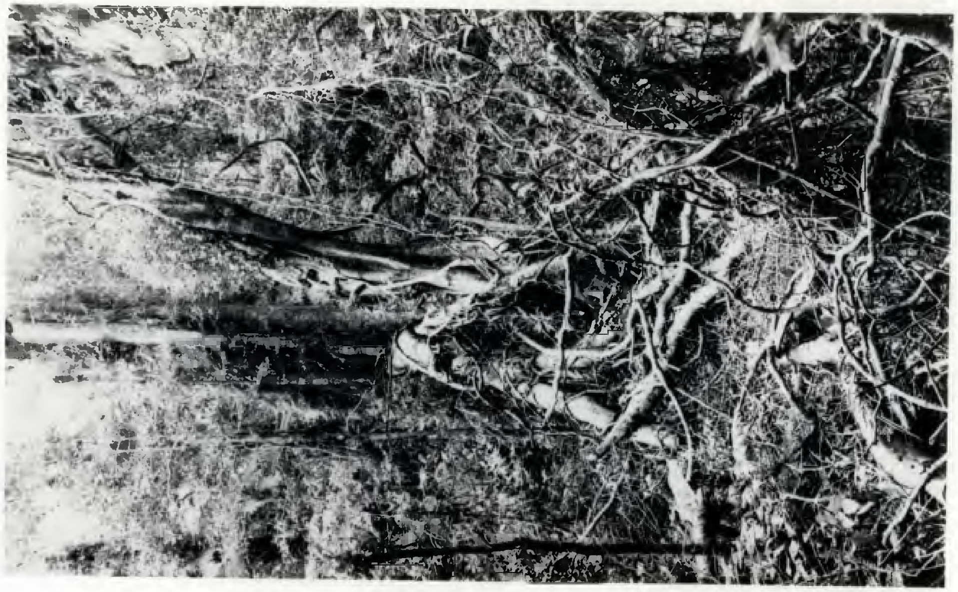
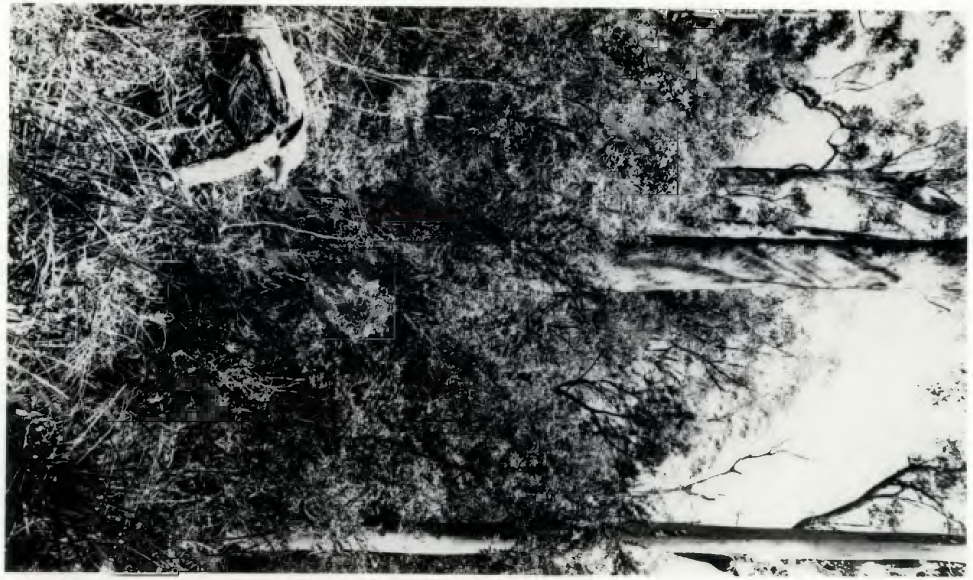



PLATE 4

Examples of Rufous Scrub-bird habitat.

| | | |
|---|---|---|
| Top Left | : | Territory 8, Wiangarie (vine cover, logged rainforest). |
| Top right | : | Territory 6, Barrington Tops (sedge cover, unlogged ecotone between rainforest and open forest). |
| Bottom Left | : | Territory 7, Barrington Tops (sedge and shrub cover, unlogged open forest). |
| Bottom right | : | Territory 10, Barrington Tops (sedge and shrub cover, unlogged open forest). |






probabilities of group membership (see Klecka 1975; Hull and Nie 1979; Smith *et al.* 1981; Williams 1981).

The classification rule for Wiangarie was: habitat is suitable for the Rufous Scrub-bird if

$$34.7\ (C1) + 24.0\ (C2) > 38.75$$

where C1 = cover index 2-50cm above the ground (as described earlier)
C2 = cover index 50-100cm above the ground

The classification rule for Barrington Tops was: habitat is suitable for the Rufous Scrub-bird if

$$26.9\ (C2) - 2.52\ (WBD) + 0.55\ \left( \frac{LV}{1000} \right) + 0.0067\ (DT) > 20.62$$

where C2 = cover index 50-100cm above the ground
WBD = adjusted wet bulb depression index of humidity 2cm above the ground in °C (as described in Table 4.2)
LV = leaf litter volume ($cm^3 m^{-2}$)
DT = ground distance (m) to centre of nearest neighbouring scrub-bird territory.

Unfortunately several of the variables in these equations are either difficult or time consuming to measure and are therefore unsuitable for rapid or large scale habitat assessment. Simplified versions of the classification rules were therefore developed to fulfil such needs. The cover index was transformed to percentage projected cover using the equation formulated by Fox (1979):

$$\text{Percentage projected cover} = 19 + 31\ (\text{Cover Index})$$

It should be noted that this relationship is based on measurements obtained in heath, and that its applicability in other habitats has not yet been confirmed. The amount of moss on lower tree trunks was used as an indicator of relative humidity. In the present study at Barrington Tops a plot's average moss rating was found to be negatively correlated with the wet bulb depression index ($r = -0.63$; $df = 60$; $p<0.001$). The regression equation relating these two variables is:

$$\text{Wet Bulb Depression Index} = 3.43 - 1.21\ (\text{Moss Index})$$

Distance to nearest scrub-bird territory was not included in the modified classification rules because of its irrelevance for the purposes of rapid or large scale habitat assessment.

The modified classification rule for Wiangarie was: habitat is suitable for the Rufous Scrub-bird if

$$1.12\ (P1) + 0.77\ (P2) > 74.73$$

where P1 = percentage projected cover 2-50cm above the ground
P2 = percentage projected cover 50-100cm above the ground

The modified classification rule for Barrington Tops was: habitat is suitable for the Rufous Scrub-bird if

$$0.79\ (P2) + 2.54\ (\text{Moss}) + 0.53\ \left(\frac{LV}{1000}\right) > 38.80$$

where Moss = average moss rating for lower tree trunks (0 = absent or nearly so, 1 = present but not highly conspicuous, 2 = highly conspicuous).
LV = leaf litter volume ($cm^3m^{-2}$)

A major disadvantage of the "classification rule" approach to habitat assessment is the underlying assumption that the effects of critical habitat factors will be additive. An unfavourable state of one variable can be balanced by an especially favourable state of another. For example, habitat at Wiangarie with extremely dense cover 50-100cm above the ground but with little cover 2-50cm above the ground could theoretically be classified as suitable for the Rufous Scrub-bird. The "classification rule" approach does not accommodate the possibility of a required threshold for each variable below which habitat is unsuitable regardless of the values of other variables. Another problem with the classification rules presented above is their limited applicability outside the study areas from which they were derived.

An alternative approach to the assessment of habitat suitability involves specifying required thresholds for each of the critical habitat factors. Habitat is classified as being suitable only if the thresholds for all factors are satisfied. This approach has the advantage of being generally applicable to habitat outside the two study areas. Rough guidelines for the identification of Rufous Scrub-bird habitat are presented in Table 4.5. The required threshold for each variable is the estimated value that would separate 95% of all scrub-bird plots from the

TABLE 4.5

Required thresholds for critical habitat factors (see text for details)

| Habitat Variable | Required Threshold |
|---|---|
| 1. Density of cover 2-50cm above ground measured using Fox Cover Index* (equivalent % projected cover in brackets). | > 0.83 (45%) |
| 2. Density of cover 50-100cm above ground. | > 0.48 (34%) |
| 3. Relative Humidity 2cm above ground measured using Moss Index#. | > 1.34 |
| 4. Leaf litter volume ($cm^3 m^{-2}/1000$). | > 6.59 |

* Fox Cover Index = $\log_e (I_A/I_B)$

where $I_A$ = light intensity immediately above the layer for which density is being estimated.

$I_B$ = light intensity immediately below the layer.

# Moss Index = average rating for moss/lichens on lower tree trunks; where 0 = absent or nearly so, 1 = present but not highly conspicuous, 2 = highly conspicuous.

non-scrub-bird mean (calculated from plots at both study areas), assuming a normal distribution. It was calculated as either:

$\bar{X} - 1.645\ S$ (if the scrub-bird mean was greater than the non-scrub-bird mean)

or $\bar{X} + 1.645\ S$ (if the scrub-bird mean was less than the non-scrub-bird mean)

where $\bar{X}$ = the mean of the scrub-bird plot sample (total of 44 plots from both study areas)

$S$ = the standard deviation of the scrub-bird plot sample.

#### 4.3.1.4 Effects of Logging on Habitat Suitability

The effects of some land use practices on scrub-bird habitat are obvious. For example, there is little doubt that the conversion of forest to farmland by clearfelling creates habitat totally unsuitable for the species. However, the influence of other activities such as selective logging may not be as obvious and can only be determined through careful research.

The data collected for the study of habitat requirements (described above) allowed some preliminary analysis to be made of the relationship between logging and habitat suitability. Both the Wiangarie and Barrington Tops study areas included a mixture of logged and unlogged forest (see Figs. 4.17 and 4.18). At Wiangarie a selective logging strategy of "50 percent canopy retention" was employed in the subtropical rainforest (C. Nicholson pers. comm.). Details concerning this logging technique have been given by Baur (1964), Burgess *et al.* (1975), Pattemore and Kikkawa (1975), and Horne and Gwalter (1982). At Barrington Tops logging has been mostly confined to the open forest in Barrington Tops State Forest. The average sawlog volume removed from logged areas was in the vicinity of $40 m^3 ha^{-1}$ (K. Carter pers. comm.).

Multiple regression analysis was used to investigate relationships between logging and habitat suitability on the 124 sample plots described earlier. Each plot's discriminant function score was used as a measure of habitat suitability for that plot (see Table 4.4 and Fig.4.9). This score served as the dependent variable in the multiple regressions. The independent variables were as follows:

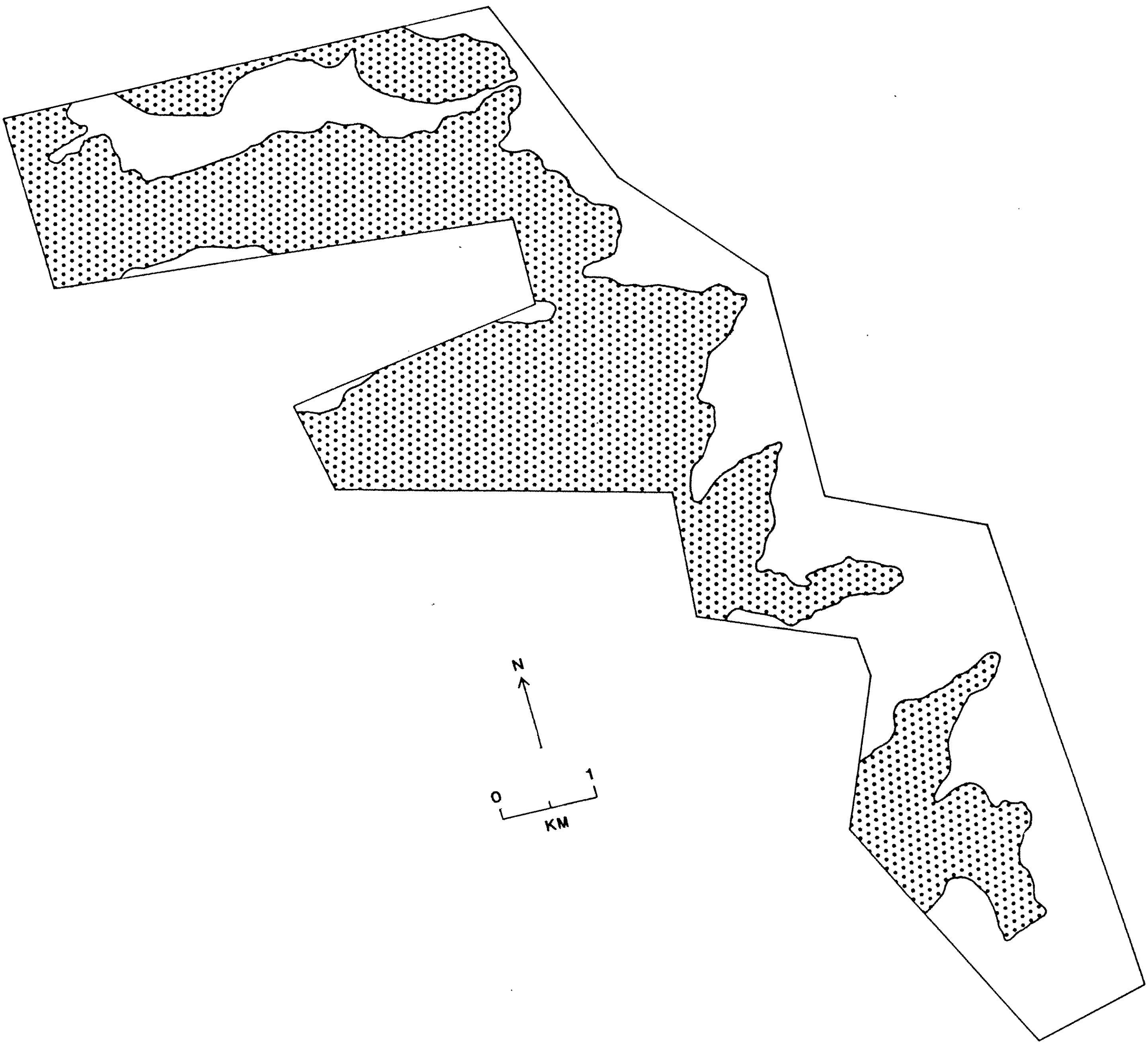



FIGURE 4.17. Logged areas within the Wiangarie study area.

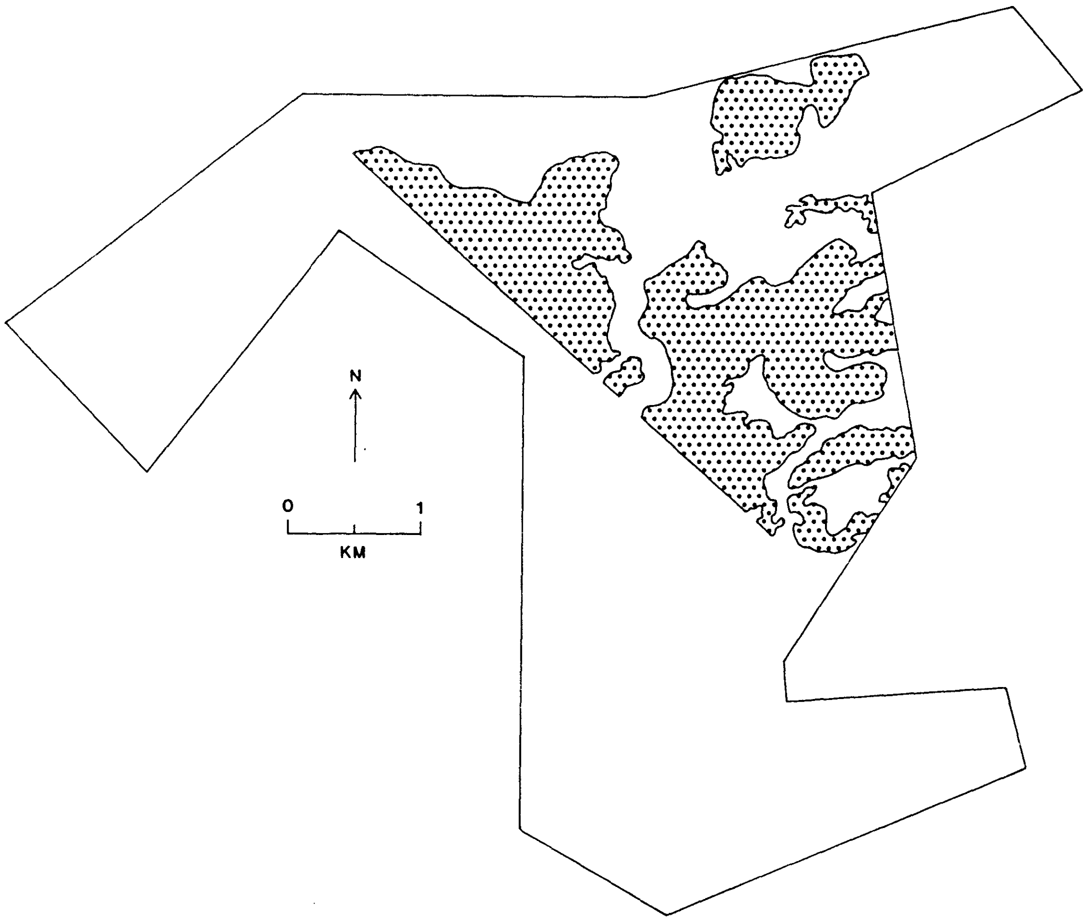



FIGURE 4.18. Logged areas within the Barrington Tops study area.

1. Basal area of trees greater than 20cm dbh (in $m^2ha^{-1}$). Basal area is the sum of the sectional areas at breast height of all trees measured (Burgess *et al.* 1975). This variable was calculated from Measurements 1 and 2 (see Field Methods) using the method described by Mueller-Dombois (1974). The basal area of trees greater than 20cm dbh was used as a measure of logging intensity, based on the assumption that logging was the major cause of variation in basal area within the two study areas.
2. Time since logging (in $years^{-1}$ prior to 1982). The year when the area encompassing a plot was last logged was estimated from compartment histories provided by the Forestry Commission of N.S.W. An inverse transformation was applied to the number of years since logging. In this way areas that had apparently never been logged, or had been logged prior to the commencement of compartment histories (1964 at Wiangarie and approx. 1960 at Barrington Tops) could be assigned a value of 0 (the inverse of an infinite number of years).
3. Canopy composition. Calculated as the proportion of measured trees >20cm dbh that were classified as either type (a) "*Nothofagus moorei*" or type (b) "Rainforest species other than *N.moorei*" (see Measurement 3 in Field Methods).
4. Altitude (Variable 42 in Table 4.2).
5. Slope (Variable 39 in Table 4.2).
6. North-South aspect (Variable 40 in Table 4.2).
7. East-West aspect (Variable 41 in Table 4.2).
8. Distance to nearest stream (Variable 43 in Table 4.2).
9. Distance to nearest rainforest (Variable 44 in Table 4.2).
10. Distance to nearest neighbouring scrub-bird territory (Variable 46 in Table 4.2).

The analysis was conducted using the "New Regression" program of the SPSS package (Hull and Nie 1981). Various preliminary analyses were made to check for non-linearity of relationships and for interactions between variables. The former were rectified by appropriate transformations while the latter were rectified by the inclusion of interaction terms in the final analysis. A backward elimination procedure was used to remove variables that did not make a significant contribution ($p<0.05$) over and above that of the other variables in the equation (see Hull and Nie 1981). The results of the regression analyses are summarized in Table 4.6.

TABLE 4.6

Multiple regression equations relating habitat suitability to logging and other variables (see text for details)

| | Wiangarie | Barrington Tops |
|---|---|---|
| Basal area of trees >20cm dbh ($m^2ha^{-1}$) | -0.14*** | 0.039** |
| Time since logging ($years^{-2}$) | 126.0*** | |
| Basal area x canopy composition (i.e. proportion that is rainforest) | | -0.087*** |
| Distance to nearest rainforest [$log_{10}$(metres/10)] | | -4.28*** |
| Distance to nearest scrub-bird territory (metres/10) | | 0.047*** |
| Constant | 3.47 | -0.23 |
| $R^2$ | 0.43 | 0.58 |

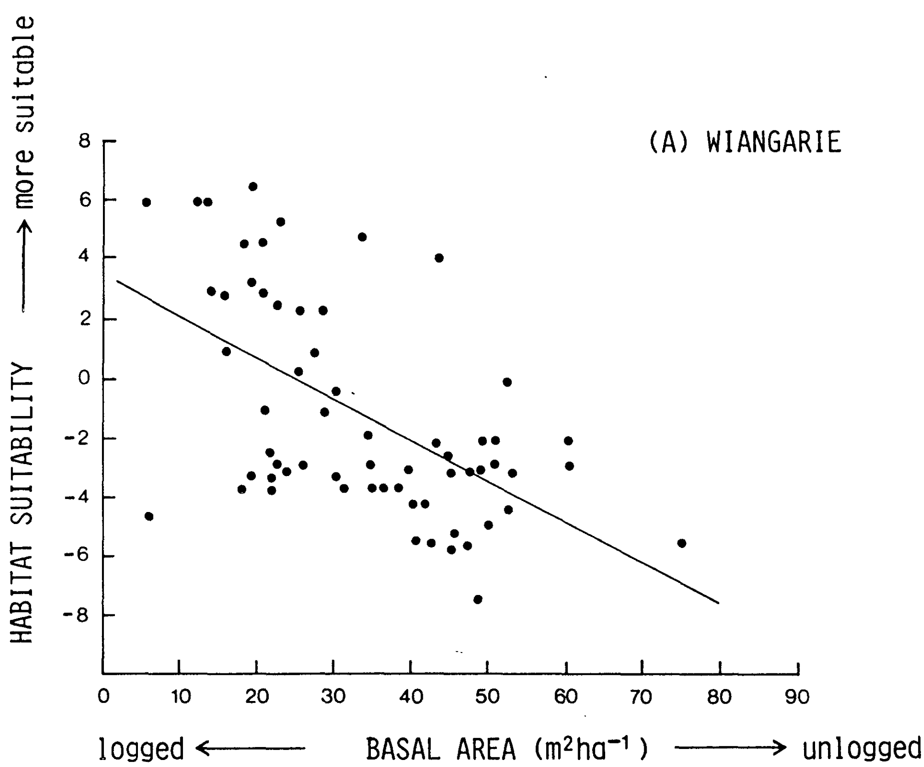
** $p < 0.01$

*** $p < 0.001$

At Wiangarie the only variables remaining in the regression after backward elimination were basal area of trees >20cm dbh and time since logging (transformed to years$^{-2}$). Basal area was negatively correlated with habitat suitability suggesting that logging probably promoted the development of suitable scrub-bird habitat (see Fig.4.19). However, it should be emphasized that the rainforest at Wiangarie was selectively logged (50% canopy reduction) and that the observed relationship between logging and habitat suitability cannot necessarily be extrapolated to heavier types of logging. Selective logging created gaps in the canopy, allowing more light to reach the ground and thereby promoting the development of dense ground cover, which was otherwise scarce within the rainforest. The effects of selective logging resembled those of natural tree falls, with which scrub-birds were also associated. The effects of heavier rainforest logging on habitat suitability are not known. While heavier logging at Wiangarie also creates dense ground cover (Pattemore and Kikkawa 1975), it may have detrimental effects on the availability of leaf litter and the microclimate at ground level, both of importance to the Rufous Scrub-bird.

Habitat suitability at Wiangarie declined with time since logging (Table 4.6). This was probably due to regenerating trees gradually reducing the amount of light reaching the ground and thereby the ground cover. The most recently logged plots studied had been logged 5 years previously and therefore little is known about habitat suitability less than five years after logging. Pattemore and Kikkawa (1975) have shown that 1 year after logging at Wiangarie the density of ground cover is low, resembling that of unlogged forest. Therefore it seems that habitat suitability is probably low immediately after logging, increases at some stage within 5 years following logging, and then gradually declines. The Wiangarie regression equation summarized in Table 4.6 could be used to predict long-term changes in the suitability of rainforest following removal of a known basal area. In order to make such predictions the recovery of basal area over time would have to be taken into account. This could perhaps be achieved using Horne and Gwalter's (1982) model describing the recovery of basal area after logging at Wiangarie.

At Barrington Tops, the regression equation remaining after backward elimination of non-significant variables was more complex than at Wiangarie (see Table 4.6). There was a significant interaction between the effects of basal area and canopy composition. In other words, the



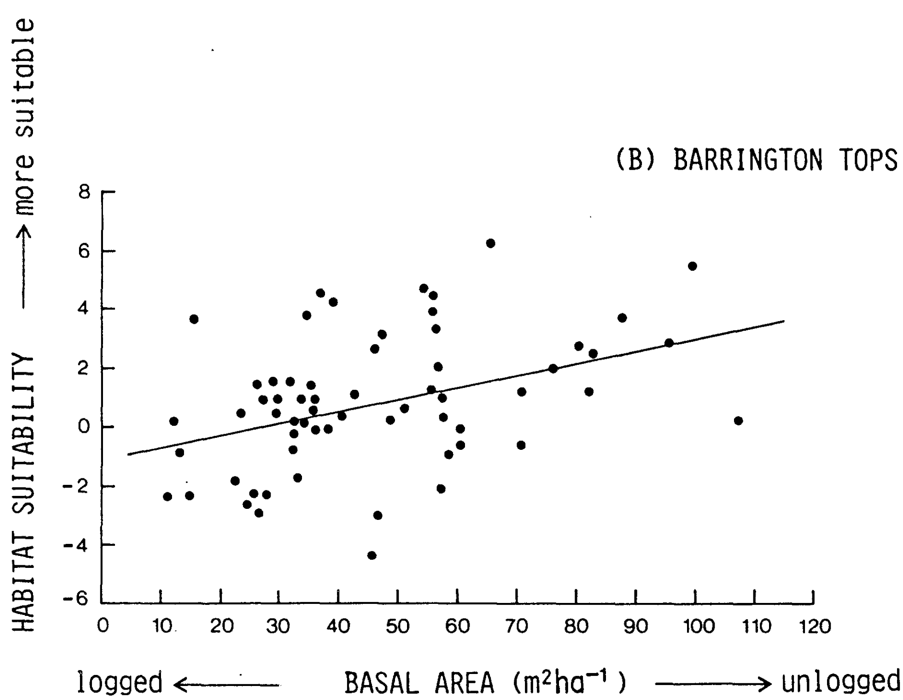




FIGURE 4.19. Habitat suitability (discriminant score) of habitat plots at Wiangarie and Barrington Tops plotted against basal area of trees >20cm dbh. Basal area provides an indication of logging intensity. Habitat suitability has been adjusted for other variables listed in Table 4.6 (all independent variables other than basal area are held constant at their mean values).

relationship between habitat suitability and basal area varied with forest type. The results of Table 4.6 suggest that in forest with a predominantly rainforest canopy basal area was negatively correlated with habitat suitability, as was the case at Wiangarie. However, in forest with a predominantly eucalypt canopy, which was much more common at Barrington Tops, basal area was positively correlated with habitat suitability (see Fig.4.19). This suggests that logging within eucalypt open forest had a detrimental effect on habitat suitability. This effect probably resulted not from changes in ground cover density, but rather from a reduction in leaf litter volume and humidity at ground level due to loss of overstorey vegetation. Logging at Barrington Tops was relatively selective. The effects of heavier logging on habitat suitability within eucalypt open forest are not known. While heavier logging would probably promote regeneration of dense ground and shrub vegetation (Recher *et al.* 1980), this influence may again be counteracted by a reduction in litter volume and humidity. Time since logging was not retained as a significant variable in the Barrington Tops regression. This does not necessarily mean that habitat suitability remained constant following logging. Diameter growth rates are much faster in eucalypt forest than in rainforest (Burgess *et al.* 1975), and therefore changes in habitat suitability following logging of eucalypt forest are probably predicted adequately by changes in basal area. The suitability of habitat probably increases as basal area recovers following logging.

Distance to nearest rainforest was retained as a significant variable in the Barrington Tops regression (Table 4.6). In Fig.4.20 it can be seen that habitat suitability in open forest drops off sharply between 0 and 200 metres from the edge of rainforest. It therefore appears that although rainforest proximity is not a critical habitat factor determining habitat suitability (see earlier analyses), the variable is nevertheless a good predictor of habitat suitability within open forest. This raises some interesting questions regarding the potential role of rainforest as a buffer and/or refuge from fire for scrub-birds in open forest and the effects of fire on open forest habitat suitability in general. These questions are discussed in detail in Chapter 6 in the light of the exploratory survey results.

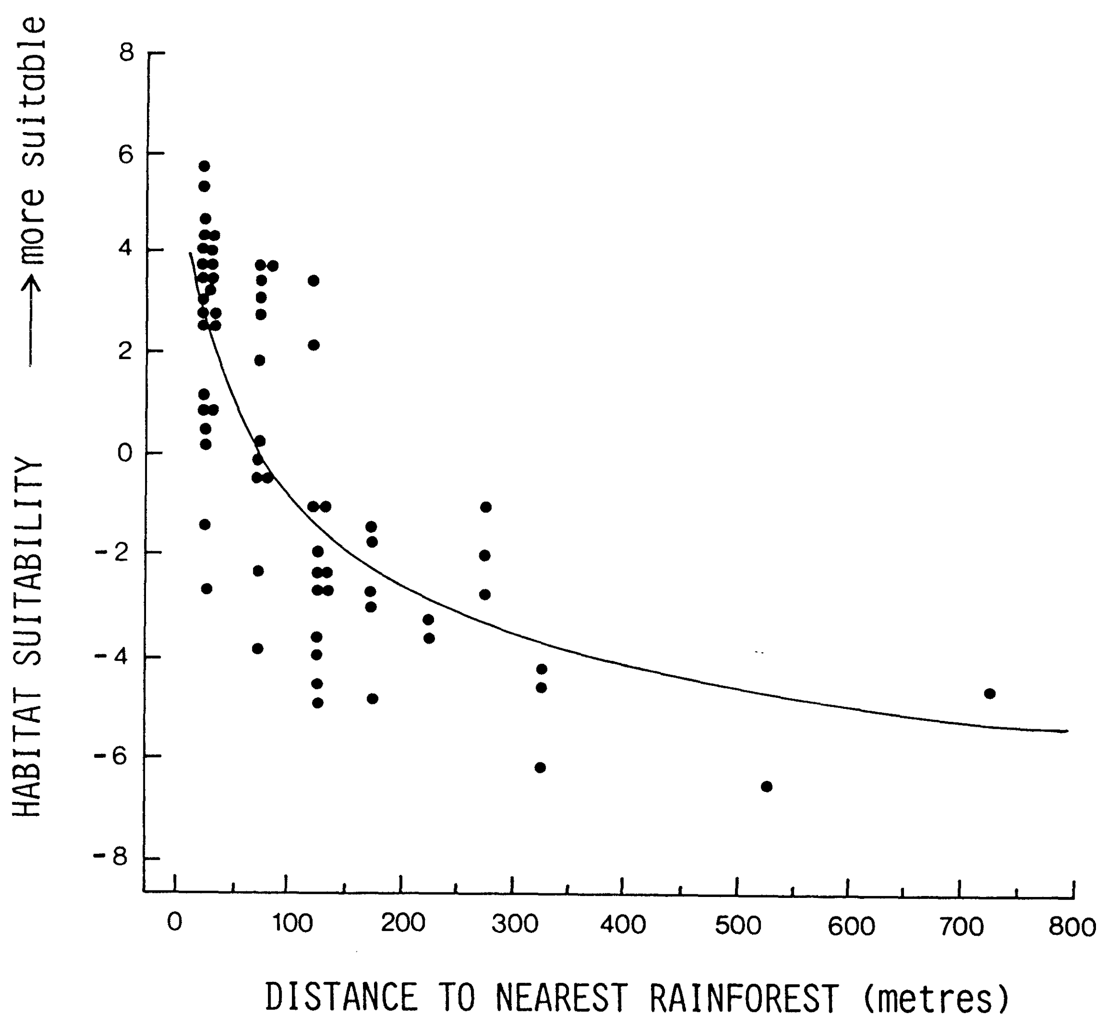



FIGURE 4.20. Habitat suitability (discriminant score) of habitat plots at Barrington Tops plotted against distance to nearest rainforest. Habitat suitability has been adjusted for other variables listed in Table 4.6 (all independent variables other than distance to rainforest are held constant at their mean values).

## 4.3.2 HOME RANGE

In order to define adequately the habitat requirements of a species we must not only determine the type of habitat required but also the area of such habitat required by an individual. The latter can be roughly assessed by measuring the home ranges of selected individuals. The most generally accepted definition of home range appears to be that proposed by Burt (1943) - "that area traversed by the individual in its normal activities of food gathering, mating, and caring for young", The home range data analyzed below consist of mapped locations of vocalizing male scrub-birds. The areas defined by these points should perhaps be viewed more correctly as territories rather than home ranges; i.e. as "defended areas" (Noble 1939) or "exclusive areas" (Schoener 1968). Because birds could only be located when singing, it was not known to what extent individuals moved beyond the boundaries of their singing territories during periods of silence. Estimates of home range size based on locations of singing birds must therefore be regarded as conservative. For the sake of simplicity in presenting the following results, "territory" and "home range" will be considered analogous.

Cooper (1978) had shown how important it is to assess the stability of home range over time, before attempting to describe home range size. The scrub-bird data were collected over a period of 13 months (mid-August 1981 to mid-September 1982). The stability of home ranges during this time was tested in the following way. A sub-sample of 100 points (i.e. mapped locations) was randomly selected from the total sample of 417 points pooled from all 22 birds. For each selected point, a second point was randomly chosen from the same bird. The distance and number of days separating each pair of points were recorded. If shifts in individual home ranges were common during the period of data collection we would expect a positive correlation between the number of days separating points and the distance between those points. The actual relationship between these two variables is shown in Fig.4.21. There was no significant correlation ($r = 0.11$; $df = 98$; $p>0.05$) which suggests that individual home ranges were generally stable throughout the sampling period.

### 4.3.2.1 Relative Indices of Home Range Size

An index of home range size was sought to help answer questions such as "Does home range size differ between Wiangarie and Barrington

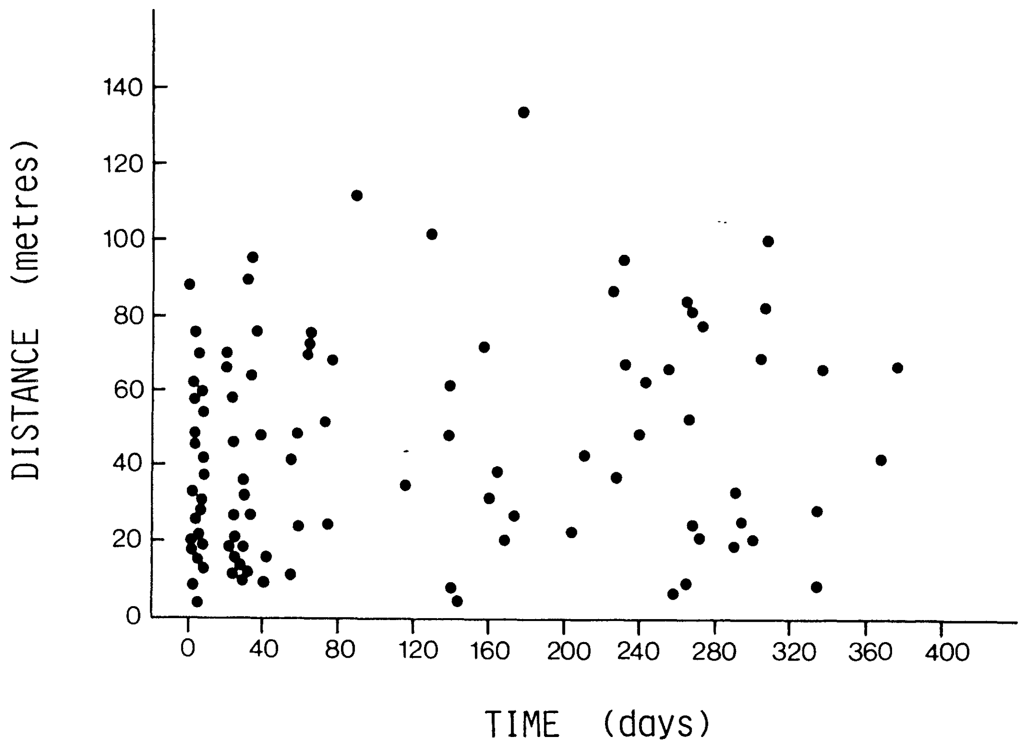



FIGURE 4.21. The relationship between the distance separating two points within a home range and the number of days separating those two records ($r = 0.11$, $df = 98$, $p > 0.05$). See text for details.

Tops?" and "Is home range size correlated with habitat quality?". Answers to these questions are needed to determine whether or not home range estimates obtained in this study are likely to be applicable in other areas and/or habitats. Numerous home range indices have been developed over the last few decades (e.g. Hayne 1949; Stickel 1954; Odum and Kuenzler 1955; White 1964; Mohr and Stumpf 1966; Jennrich and Turner 1969; Koeppl *et al.* 1975; Van Winkle 1975; Dunn and Gipson 1977; Ford and Krumme 1979; Dixon and Chapman 1980; MacDonald *et al.* 1980; Ford and Myers 1981; Schoener 1981; Anderson 1982). These range from relatively simple estimates that are highly sensitive to sample size and departures from underlying assumptions, through to sophisticated nonparametric techniques requiring complex computation.

For the purposes of the present study three different types of index were employed:

1. Minimum convex polygon (Southwood 1966). This is defined as the area within the smallest convex polygon containing all the observed points. This measure is highly sensitive to sample size (Jennrich and Turner 1969; Ford and Myers 1981). For this reason an adjusted version of MCP was also calculated in the manner proposed by Schoener (1981):

$$\text{Adjusted MCP} = \frac{\text{MCP}}{C_n}$$

where $C_n$ = a sample size correction factor derived from Table 2 of Schoener (1981)

2. Bivariate normal 95% probability ellipse (Jennrich and Turner 1969; see also Koeppl *et al.* 1975). This is based on the assumption that the distribution of points within a home range follows a bivariate normal distribution, and is defined as the area within the 95% confidence ellipse of that distribution. This area was calculated using the formula:

$$\text{Area of 95\% probability ellipse} = 6\pi|S|^{\frac{1}{2}}$$

where $|S|$ = the determinant of the X,Y covariance matrix, in which X and Y represent the coordinates (in metres) of each point on two perpendicular axes, one running west to east and the other south to north (see Fig.4.4).

3. Harmonic isopleth index (Dixon and Chapman 1980). This is defined as the area within a selected isopleth about the harmonic mean centre of activity. The value of an isopleth can be roughly interpreted as the

average distance of all points from that line, calculated as:

$$\frac{1}{\frac{1}{P}\Sigma(\frac{1}{r_x})}$$

where $r_x$ = the distance to point x

P = the number of points.

Two isopleth values were used in the present study, 30 metres and 40 metres. Isopleths were plotted by interpolating from values calculated at 20 metre grid points (for details see Dixon and Chapman 1980). The harmonic isopleth index is theoretically free of sample size sensitivity and assumptions concerning the distribution of points.

The estimates obtained using the above techniques are summarized in Table 4.7. The minimum polygon index displayed greatest variation between birds, with a coefficient of variation (CV) of 42.2%. This was reduced to 29.2% after adjusting for sample size. The harmonic isopleth indices displayed least variation; CV's of 18.8% of the 30m isopleth and 8.6% for the 40m isopleth.

Correlations between the indices are summarized in Table 4.8. The minimum polygon, adjusted minimum polygon, and probability ellipse indices are all positively correlated. These three are negatively correlated with the 30m isopleth index and show no significant correlation with the 40m isopleth index. The two isopleth indices are not significantly correlated. These results may at first seem surprising, but not if we consider exactly what each index is measuring. The minimum polygon and probability ellipse methods measure similar home range properties and generally reflect the overall size of a home range (Madden and Marcus 1978; Smith 1983). Harmonic isopleths define areas containing an equal density of points, theoretically adjusting for sample size (Dixon and Chapman 1980). The density of points in small territories is likely to be higher than that in large territories, hence the negative correlation between the 30m isopleth index and the minimum polygon and probability ellipse indices.

4.3.2.2 Home Range Size In Relation to Other Factors

Multiple regression analysis was used to investigate relationships between home range size and the following variables:

TABLE 4.7

Relative indices of home range size for 22 territorial males (all indices expressed in hectares).

| | Bird | Sample Size | Minimum Convex Polygon | Adjusted Minimum Polygon | 95% Probability Ellipse | 30m Harmonic Isopleth | 40m Harmonic Isopleth |
|---|---|---|---|---|---|---|---|
| Wiangarie | W.17 | 17 | 0.29 | 0.68 | 0.73 | 0.34 | 0.62 |
| | W.14 | 31 | 0.68 | 1.18 | 1.47 | 0.22 | 0.52 |
| | W.8 | 15 | 0.30 | 0.76 | 0.82 | 0.28 | 0.65 |
| | W.3 | 12 | 0.32 | 0.97 | 0.90 | 0.28 | 0.55 |
| | W.28 | 8 | 0.13 | 0.55 | 0.50 | 0.32 | 0.54 |
| | W.7 | 30 | 0.45 | 0.78 | 0.70 | 0.32 | 0.62 |
| | W.6 | 18 | 0.22 | 0.51 | 0.48 | 0.36 | 0.57 |
| | W.22 | 25 | 0.41 | 0.78 | 1.07 | 0.34 | 0.66 |
| | W.21 | 15 | 0.27 | 0.69 | 0.74 | 0.29 | 0.57 |
| | W.23 | 13 | 0.28 | 0.80 | 0.92 | 0.15 | 0.54 |
| | W.5 | 15 | 0.45 | 1.15 | 1.21 | 0.29 | 0.52 |
| Barrington Tops | B.12 | 25 | 0.39 | 0.74 | 0.75 | 0.30 | 0.58 |
| | B.10 | 33 | 0.44 | 0.74 | 0.54 | 0.30 | 0.58 |
| | B.11 | 23 | 0.33 | 0.66 | 0.49 | 0.29 | 0.54 |
| | B.3 | 23 | 0.36 | 0.72 | 0.64 | 0.29 | 0.60 |
| | B.1 | 20 | 0.68 | 1.46 | 1.20 | 0.29 | 0.53 |
| | B.2 | 8 | 0.19 | 0.79 | 0.95 | 0.28 | 0.61 |
| | B.5 | 17 | 0.48 | 1.15 | 1.13 | 0.29 | 0.65 |
| | B.6 | 9 | 0.27 | 1.02 | 1.08 | 0.26 | 0.47 |
| | B.7 | 12 | 0.24 | 0.71 | 0.70 | 0.30 | 0.52 |
| | B.8 | 22 | 0.63 | 1.30 | 1.32 | 0.20 | 0.62 |
| | B.13 | 28 | 0.72 | 1.30 | 1.33 | 0.16 | 0.60 |
| Mean | | | 0.385 | 0.884 | 0.896 | 0.280 | 0.575 |
| C.V. (%) | | | 42.2 | 29.2 | 32.1 | 18.7 | 8.6 |

TABLE 4.8

Correlations between relative indices of home range size (n=22).

| | Adjusted Polygon | Probability Ellipse | 30m Isopleth | 40m Isopleth |
|---|---|---|---|---|
| Minimum Polygon | .835 *** | .725 *** | -.458 * | .104 |
| Adjusted Polygon | | .891 *** | -.574 ** | -.108 |
| Probability Ellipse | | | -.590 ** | -.028 |
| 30m Isopleth | | | | .173 |

* $p<0.05$

** $p<0.01$

*** $p<0.001$

1. Site; i.e. Wiangarie or Barrington Tops.
2. Habitat Quality; i.e. habitat score derived from discriminant analysis earlier in this chapter.
3. Song Output; i.e. adjusted probability of detection derived from logistic regression analysis in Chapter 3.
4. Proximity of neighbouring singing males; rated on a three point scale: 1 = no neighbours within human earshot, 2 = one or more neighbours within earshot but not audibly conspicuous, 3 = one or more audibly conspicuous neighbours.

These factors were used as independent variables in five separate regressions, one for each of the home range indices described above. In order to test and, if necessary, adjust for the influence of sample size and departure from bivariate normality, two additional independent variables were included in the analyses:

1. Sample size; i.e. number of points recorded for each bird.
2. Normality index; i.e. the probability ellipse estimate expressed as a ratio of the adjusted minimum polygon estimate. For a bivariate normal distribution this ratio should equal 1.0, whereas distributions deviating from normality will have values either greater than or less than 1.0. A value greater than 1.0 indicates probable inflation of the probability ellipse index due to non-normality, whereas a value less than 1.0 indicates probable deflation (Schoener 1981).

The regressions were carried out using the SPSS "New Regression " program (Nie *et al.* 1975). A backward elimination procedure was used to select variables that made a significant ($p<0.05$) contribution to the regression over and above that made by the other variables. The results of the regression analyses are summarized in Table 4.9.

Overall territory size as measured by the minimum polygon, adjusted minimum polygon, and probability ellipse indices did not appear to be related to either site, habitat quality, song output, or proximity of neighbouring males. The minimum polygon index was significantly correlated with sample size (see Fig.4.22a) while the probability ellipse index was significantly correlated with the normality index (see Fig.4.22b).

Two independent variables were retained in the 30m isopleth regression. These were site and proximity of neighbouring males. The 30m isopleth areas of home ranges at Wiangarie tended to be larger than

TABLE 4.9

Regression equations relating home range indices to other factors, following backward elimination of non-significant variables.

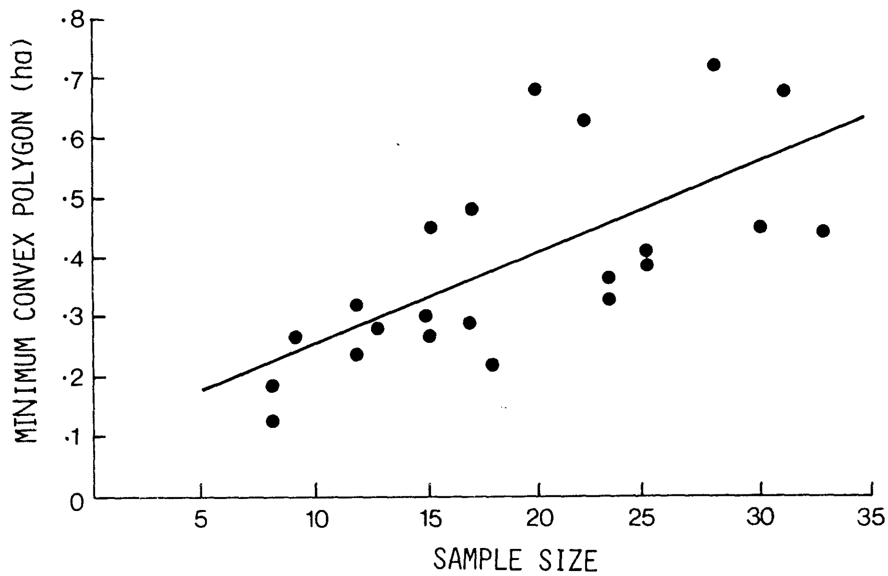
| | Independent Variables | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sample Size | Normality Index | Site | Habitat Quality | Song Output | Proximity of Neighbours | Constant | Equation $R^2$ | Equation F |
| Minimum Polygon | +0.015** | | | | | | 0.114 | 0.41 | 12.4** |
| Adjusted Polygon | | | | | | | | - | - |
| Probability Ellipse | | +1.030* | | | | | -0.133 | 0.25 | 6.0* |
| 30m Isopleth | | | -0.045* | | | +0.030* | 0.249 | 0.42 | 6.2** |
| 40m Isopleth | | | | | +0.146* | | 0.473 | 0.24 | 5.8* |

* $p<0.05$

** $p<0.01$

*** $p<0.001$

(A)




(B)

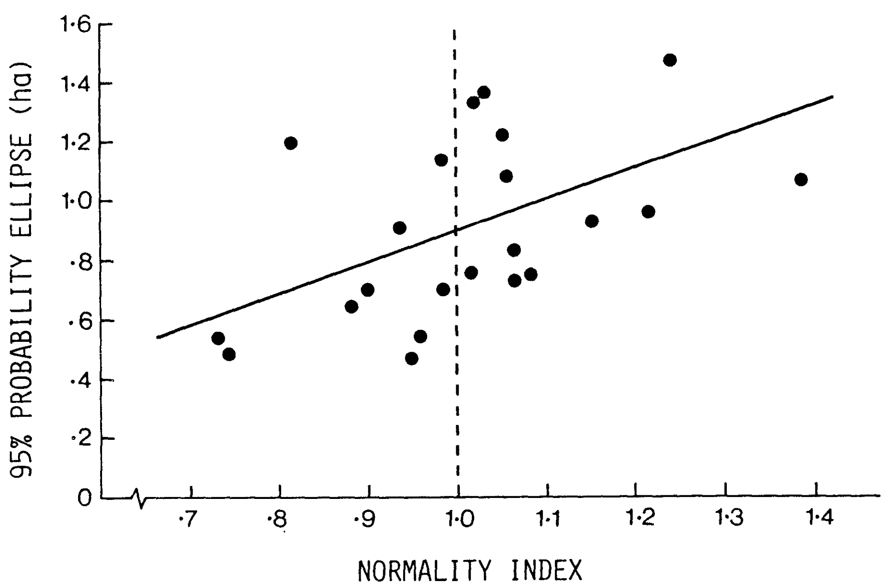



FIGURE 4.22. (A) The relationship between the minimum convex polygon home range index and sample size.

(B) The relationship between the 95% probability ellipse home range index and the normality index (see text). See Table 4.9 for regression statistics.

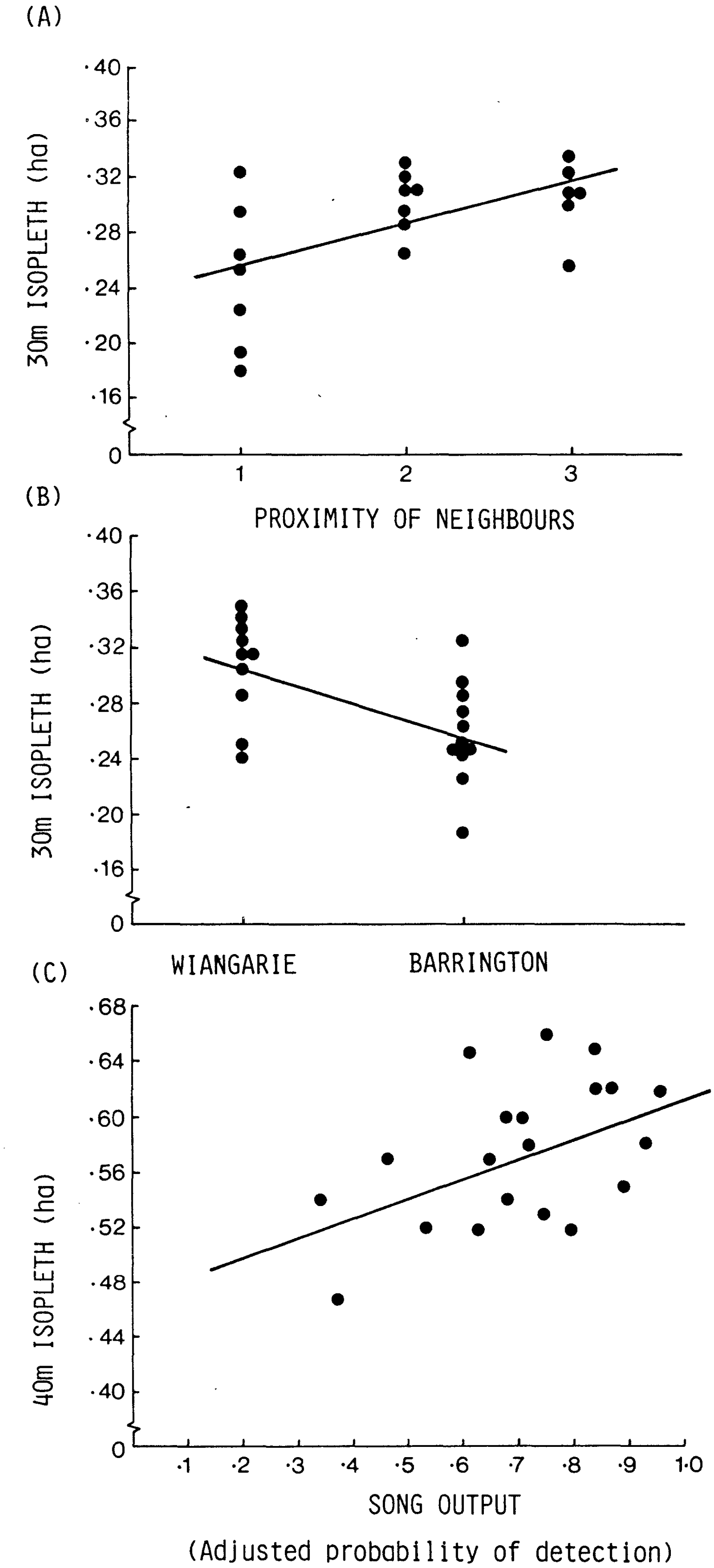



FIGURE 4.23. (A) The relationship between the 30m isopleth home range index and the proximity of neighbouring males, adjusting for the influence of site.

(B) The relationship between the 30m isopleth home range index and site, adjusting for the influence of neighbouring male proximity.

(C) The relationship between the 40m isopleth home range index and song output. See Table 4.9 for regression statistics.

those of home ranges at Barrington Tops (see Fig.4.23b). This is probably because territories at Wiangarie were generally associated with small patches of suitable habitat (e.g. beneath gaps in the rainforest canopy) whereas territories at Barrington Tops were generally situated within relatively large areas of suitable habitat (e.g. along rainforest-open forest ecotones). Birds at Wiangarie therefore tended to spend more time in the cores of their home ranges than birds at Barrington Tops. The proximity of neighbouring males was positively correlated with the 30m isopleth index (see Fig.4.23a). This could be because territorial males were repelled by the vocal activity of neighbours and thus forced to spend more time within the cores of their home ranges. The reverse could also be true, but seems less likely - i.e. that neighbours were able to be closer because a bird spent more time within its home range core, than near the home range boundary. The 40m isopleth index was positively correlated with song output (see Fig.4.23c) possibly reflecting a relationship between an individual's song output and the distribution of time spent at different distances from the territory centre. Further research is needed to clarify this relationship.

#### 4.3.2.3 Home Range Shape

Harmonic isopleths provide a convenient means of describing the shape and internal structure of a home range (Dixon and Chapman 1980). The 20m, 30m and 40m isopleths for each of the 22 home ranges studied are shown in Fig.4.24. The distribution of singing points within a home range generally followed a unimodal distribution. Departures from this pattern seemed to be associated with a patchy distribution of suitable habitat. Consider, for example, the trimodal distribution of Bird 22 at Wiangarie. This bird utilized three distinct patches of dense ground cover all separated from one another by areas of open ground cover. One patch was associated with a tree-fall, the second with a logged area, and the third with the edge of a road clearing.

The overall shape of a home range also appeared to be influenced by the distribution of suitable habitat. Consider, for example, the elongate home ranges of Bird 23 at Wiangarie and Bird 13 at Barrington Tops. Both these birds were associated with long, narrow strips of dense ground cover along the edges of road clearings.

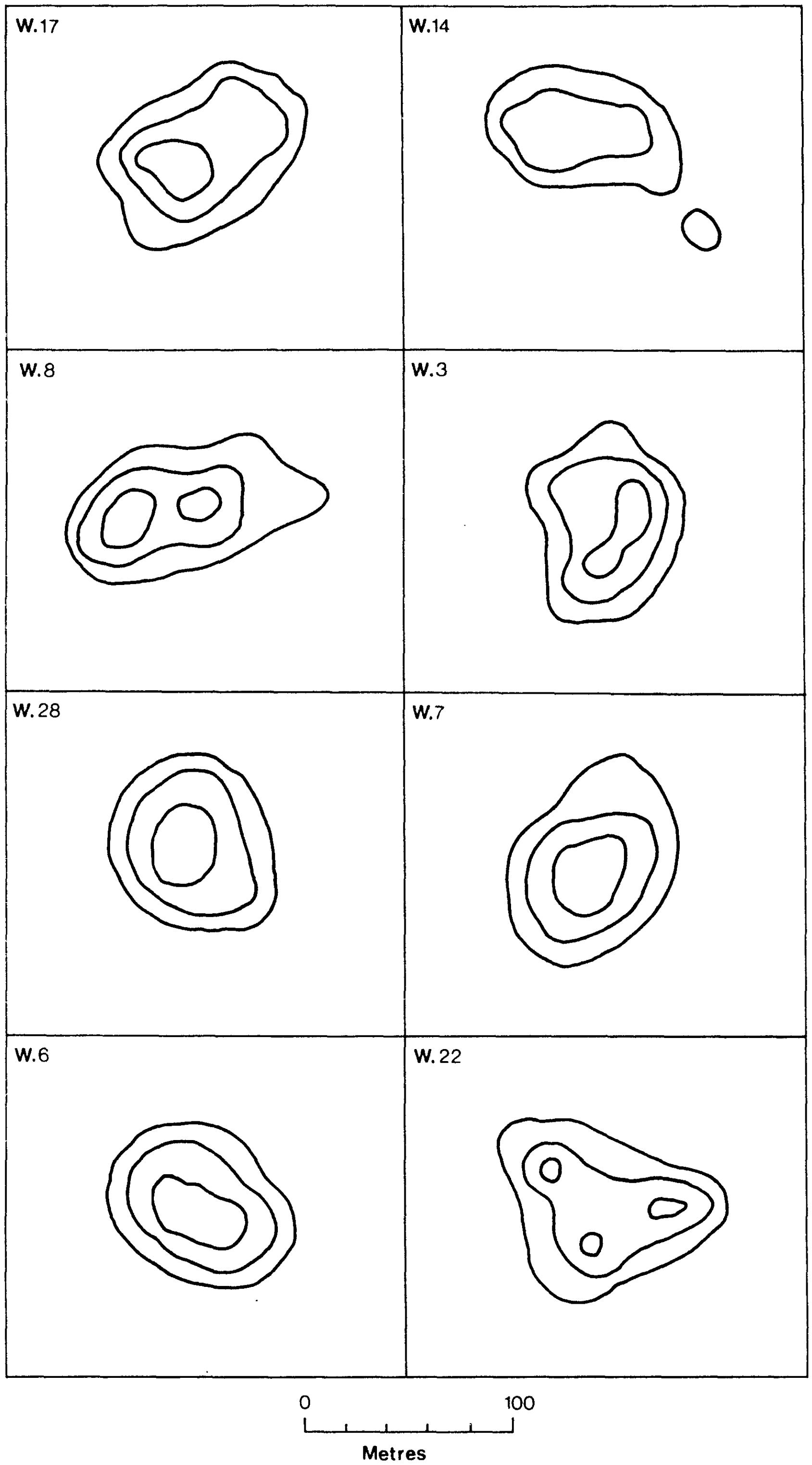



FIGURE 4.24. Harmonic isopleths of activity for the home ranges of 22 singing males. Codes for individuals are shown in the top left-hand corner of each map; e.g. W.17 = Bird 17 at Wiangarie, B.12 = Bird 12 at Barrington Tops. Where three isopleths are shown these are the 20m, 30m and 40m isopleths. Where only two isopleths are shown these are the 30m and 40m isopleths. (Figure is continued on following two pages.)

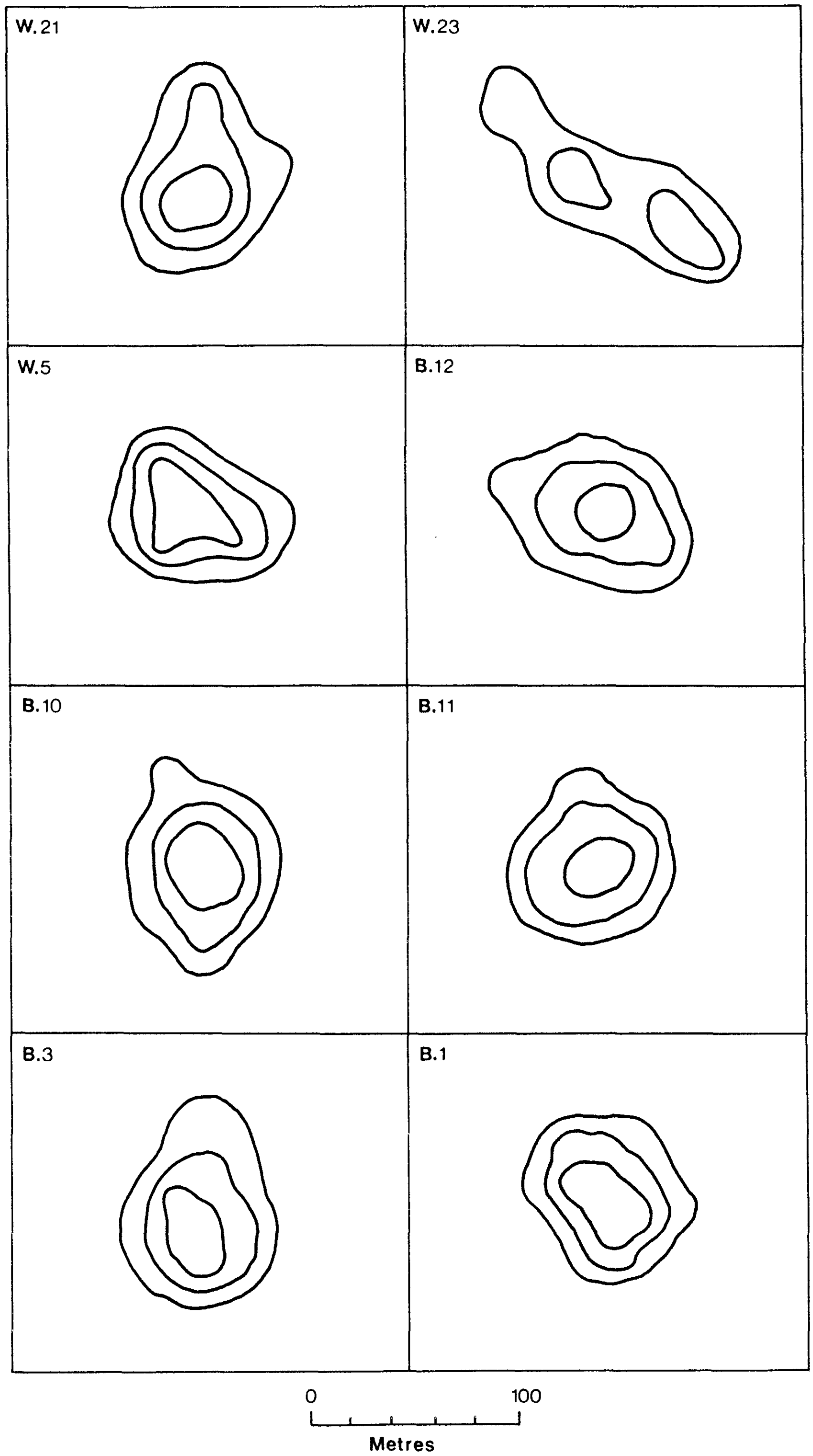



FIGURE 4.24 (cont.)

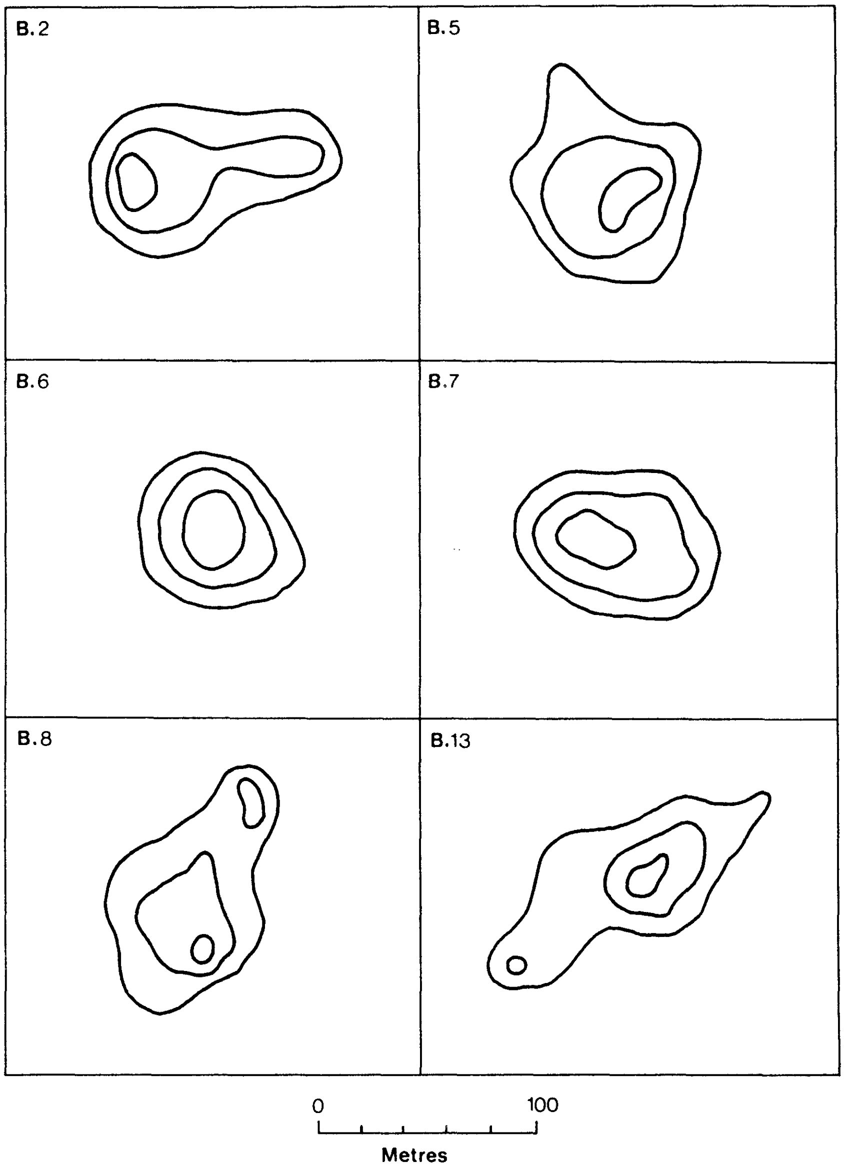



FIGURE 4.24. (cont.)

4.3.2.4 Absolute Estimates of Home Range Size

While relative home range indices, such as those discussed above, are useful for studying variation in the size of home ranges, they are generally of little value in the estimation of absolute home range size - i.e. the actual area used by an individual. This information is vital for the purposes of habitat assessment and management.

Metzgar and Sheldon (1974) have described a very useful technique for estimating absolute home range size based on the assumption that, as observations of an animal accumulate, the area where it has been observed increases asymptotically (Hayne 1949; Stickel 1954; Odum and Kuenzler 1955). This asymptote represents the total area of an animal's home range. Metzgar and Sheldon's technique involves estimating an "average" asymptote based on pooled data from a number of individuals. In the present study pooling of data from all studied territoires seemed justified as variability in home range size was relatively small (see above analysis).

Metzgar and Sheldon measured home range area in terms of number of trap grid stations. In the present study three estimates of home range area were used.

1. Number of 10 metre squares containing one or more records, multiplied by 0.01 to give an area in hectares (a 10 metre grid was placed over each bird's territory map).
2. Area (hectares) enclosed by the minimum convex polygon.
3. Length; i.e. Maximum distance (metres) between any two points in the home range.

These three estimates are intended to fulfill different needs in the assessment of status and management of the Rufous Scrub-bird. The first two estimates yield a model describing the home range requirements of a male scrub-bird as: X hectares of suitable habitat patches contained within an area of Y hectares. This model can be used for refining the assessment of habitat suitability (see Table 4.5) and as a guide for artificial creation of scrub-bird habitat. The third estimate can be used to determine the circular area required to exclude disturbance from a known territory. These uses are discussed in greater detail in Chapter 7.

Metzgar and Sheldon (1974) used the following function to describe the relationship between mean home range area and sample size:

$$S_c = S_\infty(1 - e^{-kc})$$

where $S_c$ = home range area after c observations.

$S_\infty$ = home range area after an infinite number of observations (i.e. the asymptote of the function).

$e^{-k}$ = a constant computed from the data.

A closer fit to the scrub-bird data was achieved using a closely related monomolecular function derived from plant growth analysis (Hunt 1982):

$$S_c = S_\infty(1 - be^{-kc})$$

where b = a measure of the starting size of the system.

This function was fitted to the data using an iterative procedure described by Hunt (1982).

The estimated asymptotes for the three home range measures should be interpreted with caution (see Figs.4.25, 4.26, and 4.27). All three measures approached an asymptote slowly and therefore required extrapolation well beyond the limits of the data. The following asymptotic estimates of average home range size must therefore be regarded only as "best available estimates":

1. Number of 10 metre squares = 37.2 (an area of 0.37 ha).
2. Minimum convex polygon = 1.17 ha.
3. Length = 331 metres.

Based on these estimates, an "average" male scrub-bird requires at least 0.37 ha of suitable habitat (i.e. combined area of suitable patches) contained within an area of 1.17 ha. A circular reserve designed to exclude disturbance from a known territory should be at least 331 metres in diameter.

The slowness with which the three home range measures approached an asymptote may reflect a basically unimodal distribution of activity, in which frequency of occurrence drops off gradually with increasing distance from the home range centre (see Ford and Myers 1981; Schoener 1981). For this type of distribution it may be more appropriate to express home range size in probabilistic terms; e.g. the size of an area within which an animal spends 95% of its time. The probabilistic model most frequently used to describe home range size is the bivariate normal distribution (Jennrich and Turner 1969; Koeppl *et al.*1975). This model is only appropriate for describing home ranges with a bivariate normal structure.

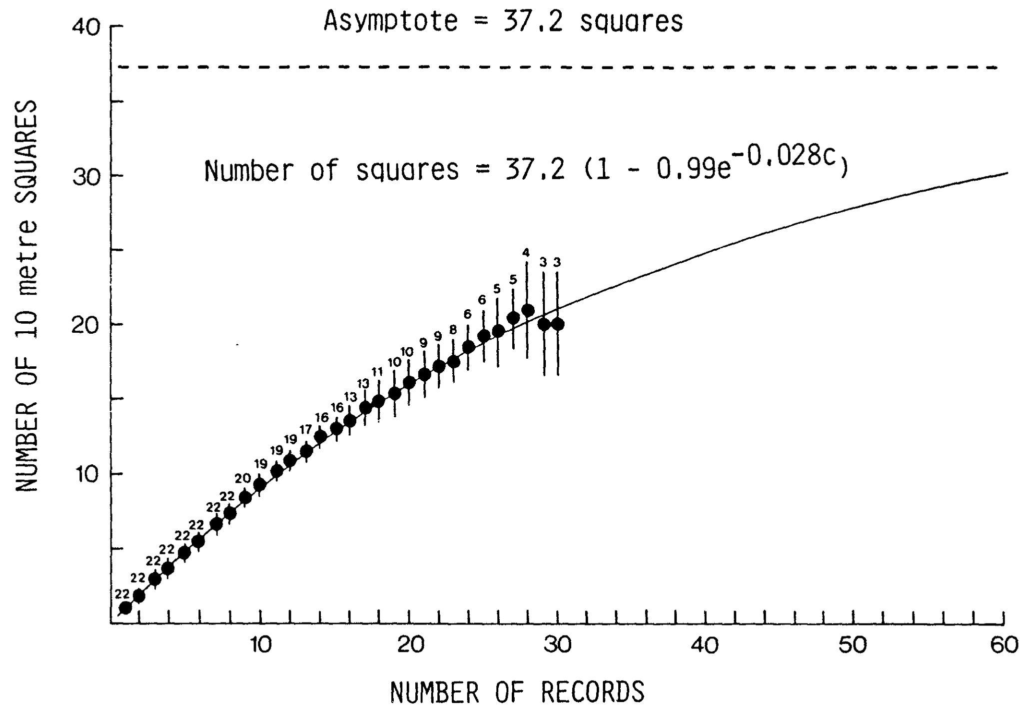



FIGURE 4.25. Mean number of 10 metre squares containing records plotted against number of records. Sample size (i.e. number of birds) and 95% confidence interval are shown for each mean value. (c = number of records)

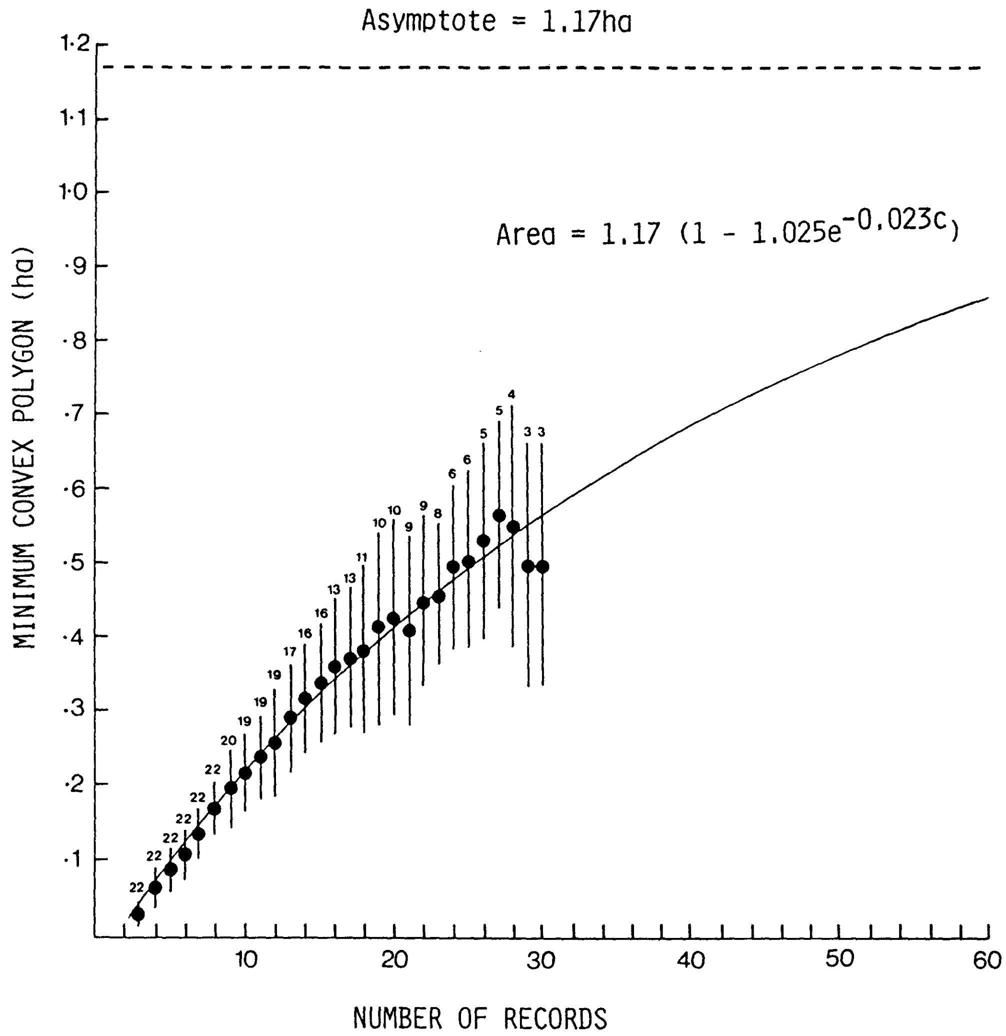



FIGURE 4.26. Mean minimum convex polygon area plotted against number of records. Sample size (i.e. number of birds) and 95% confidence interval are shown for each mean value. (c = number of records)

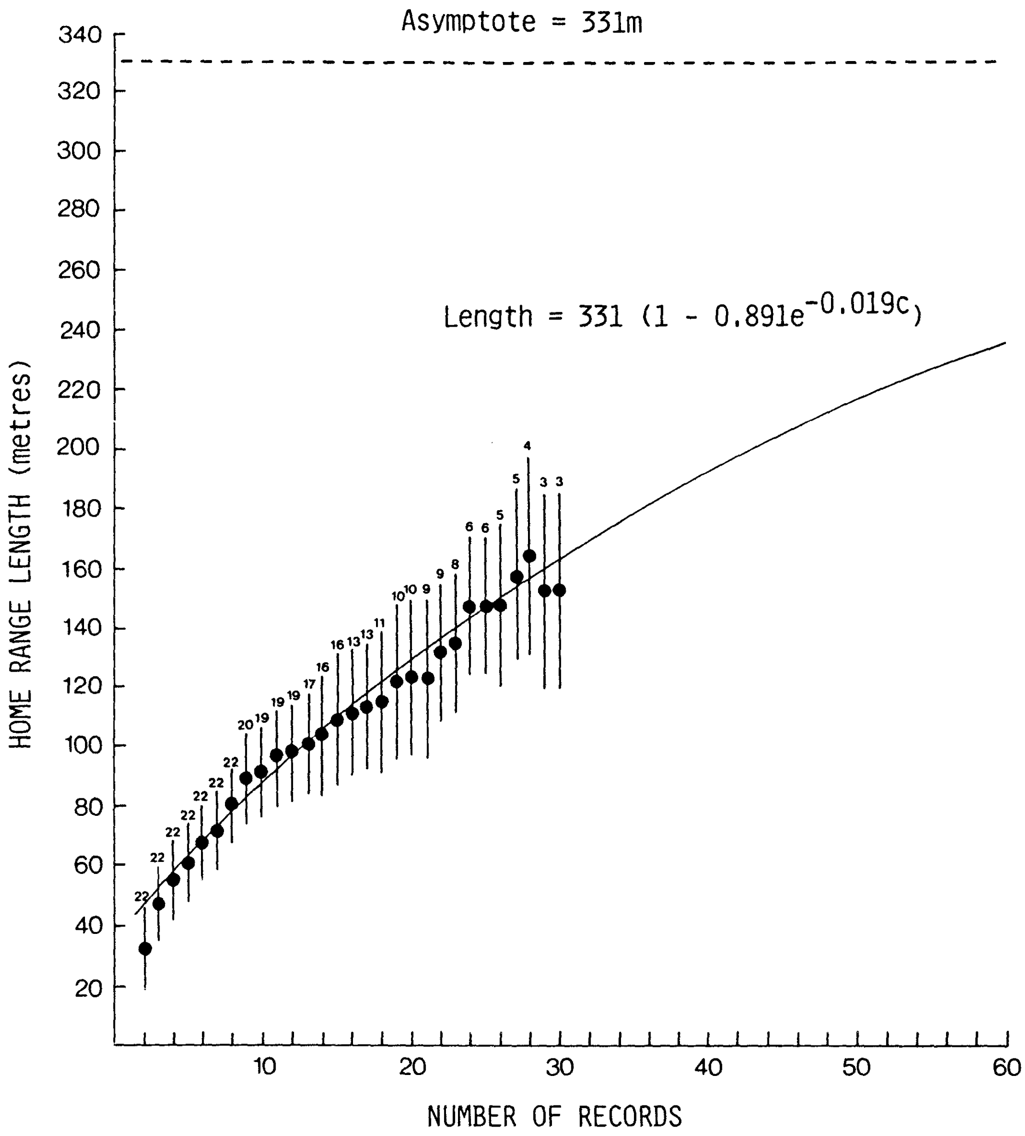



FIGURE 4.27. Mean home range length plotted against number of records. Sample size (i.e. number of birds) and 95% confidence interval are shown for each mean value. (c = number of records)

Departures from bivariate normality will result in either over-estimation or under-estimation of home range size. This problem was encountered when using the bivariate normal distribution to estimate the relative size of individual scrub-bird home ranges. In Fig.4.22b it can be seen that some estimates were inflated whereas others were deflated due to non-normality. Would these effects cancel each other out if an "average" bivariate normal estimate was calculated from all territories combined? This possibility was tested using a paired t-test to compare the adjusted minimum polygon and probability ellipse estimates in Table 4.7. The two samples were found not to differ significantly ($t = 0.49$; $df = 21$; $p>0.05$) suggesting that the average ratio between the two estimates was close to 1.0, that expected for a bivariate normal distribution (see Schoener 1981 for the basic principles underlying this test).

An "average" bivariate normal distribution was fitted to the home range data using the technique developed by Koeppl *et al.* (1975). This method enables the calculation of probability ellipses at any specified probability level. The model used was of the following form:

$$Ap = \frac{\pi(\lambda_x)^{\frac{1}{2}} (\lambda_y)^{\frac{1}{2}} \, 2(n-1) \, F_{\alpha(2,n-2)}}{(n-2)}$$

where Ap = the area of the ellipse within which an average male scrub-bird spent p% of its time.

$\lambda_x, \lambda_y$ = eigenvalues averaged over the 22 home ranges (see Koeppl *et al.* 1975).

n = mean sample size for the 22 home ranges.

$F_{\alpha(2,n-2)}$ = the F-statistic with 2 and n-2 degrees of freedom, at a probability level of $\alpha = (1-p)/100$.

The equation describing the home range size of an average male scrub-bird is:

$$Ap \text{ (hectares)} = 0.314 \left[ F_\alpha(2,17) \right]$$

The length and width of this home range ellipse can be calculated as follows:

$$\text{Length (metres)} = 98.3 \left[ F_\alpha(2,17) \right]^{\frac{1}{2}}$$

$$\text{Width (metres)} = \frac{\text{Length}}{2.43}$$

The average 95% ellipse is 187m long, 77m wide and covers an area of 1.13 ha. The 99% ellipse is 244m long, 100m wide and covers an area of 1.93 ha.

Home range ellipses calculated at various probability levels are depicted in Fig.4.28, along with the combined home range data from all 22 birds. The combined data are also presented in three-dimensional form in Fig.4.29.

4.3.2.5 Roost Sites

Roost sites were usually difficult to locate. Occasionally a male would continue vocalizing while proceeding to its roost, allowing the location of the site to be determined. The locations of 13 roost sites are shown in Fig.4.30. Note that these sites generally lie within the average 99% home range ellipse but well away from the home range centre.

4.3.2.6 Female Home Range

Females rarely vocalized and were therefore extremely difficult to locate. The locations of 15 detections of females are shown in Fig.4.30. All of these detections lie within the average male's 99% home range ellipse but usually well away from the male's home range centre.

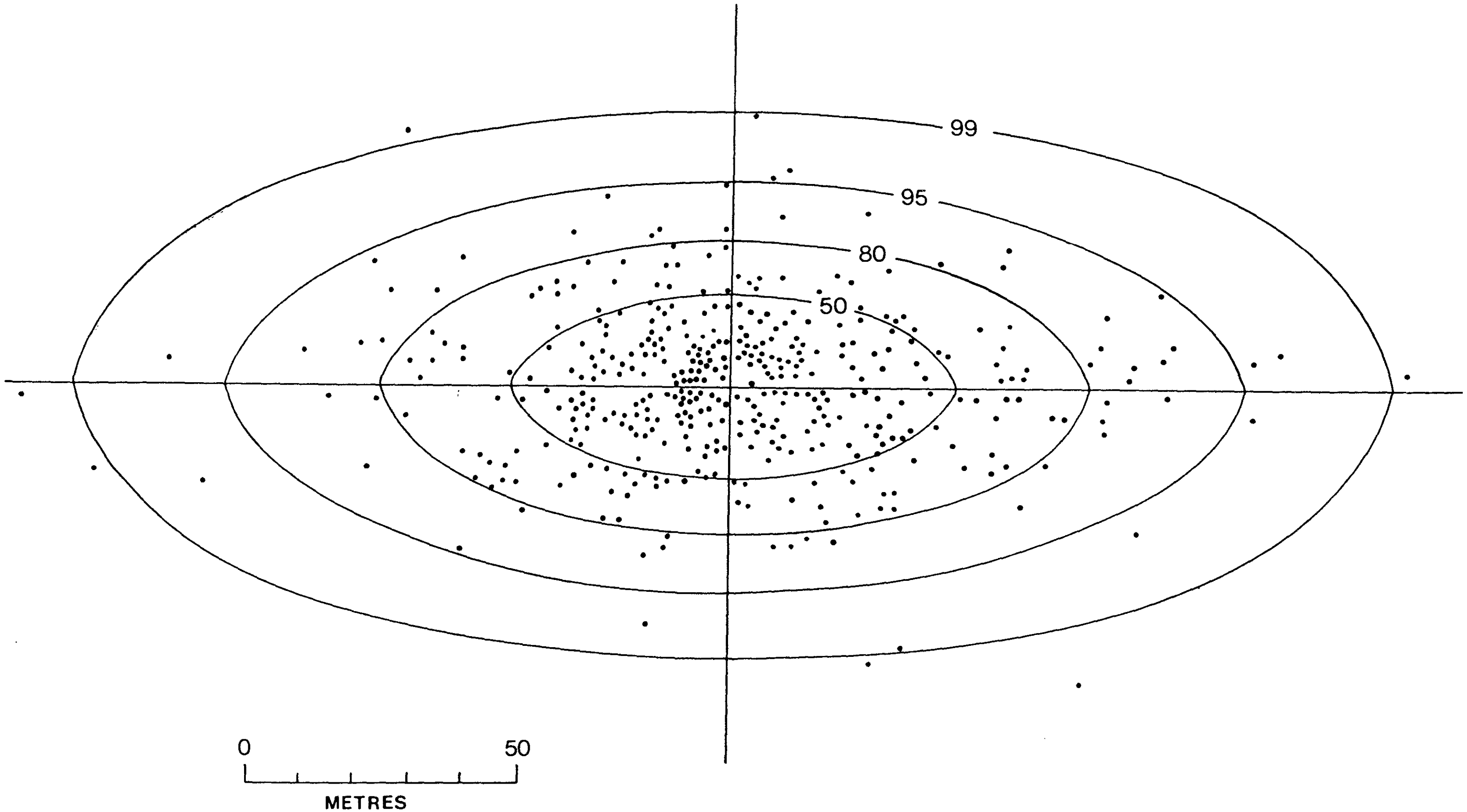



FIGURE 4.28. Combined home range data from 22 singing males (417 points), aligned according to major and minor axes. Average home range ellipses are shown at the following probability levels: 50%, 80%, 95%, 99%.

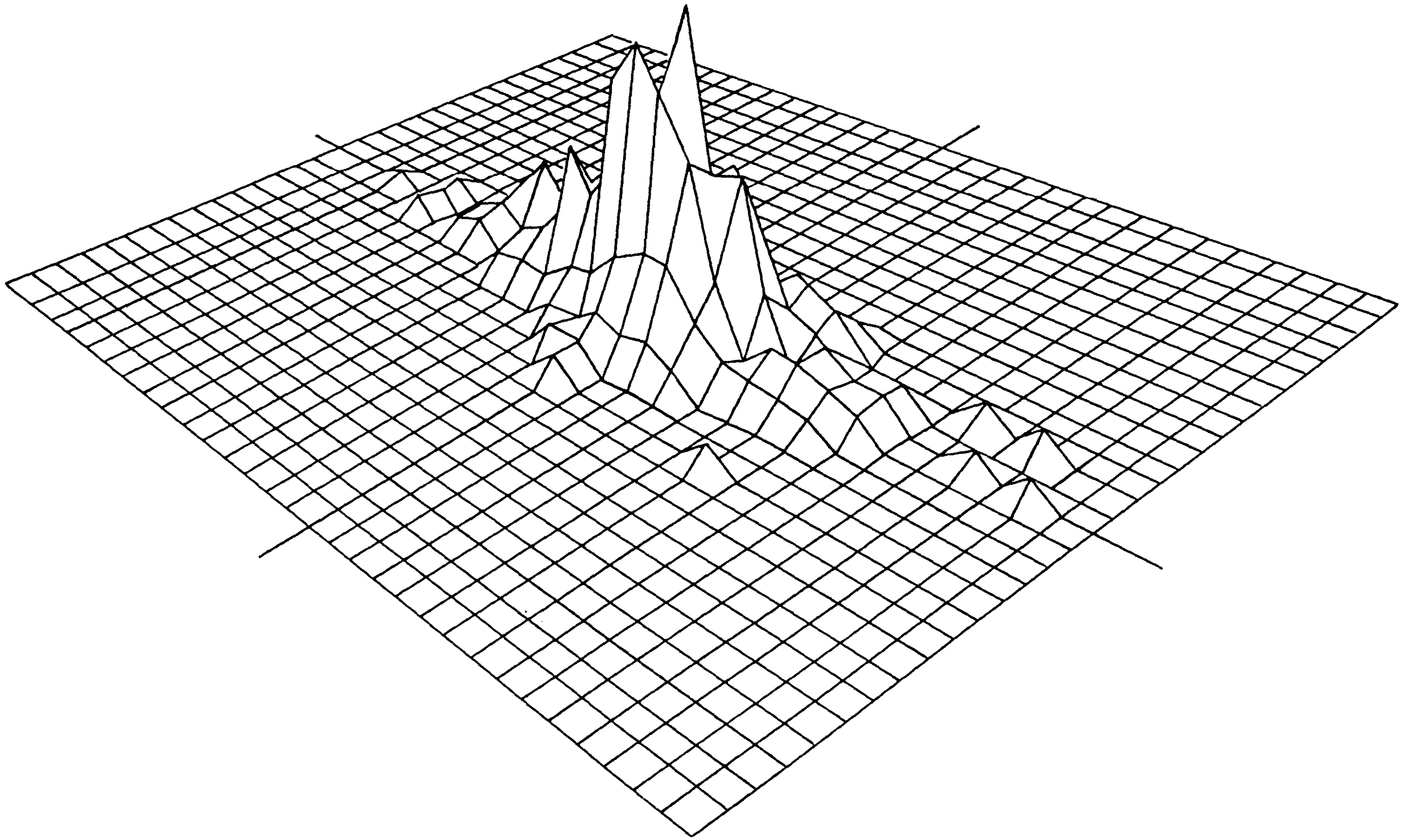


FIGURE 4.29. Three-dimensional view of combined home range data from 22 singing males (417 points) aligned according to major and minor axes. The grid spacing is 10 metres.

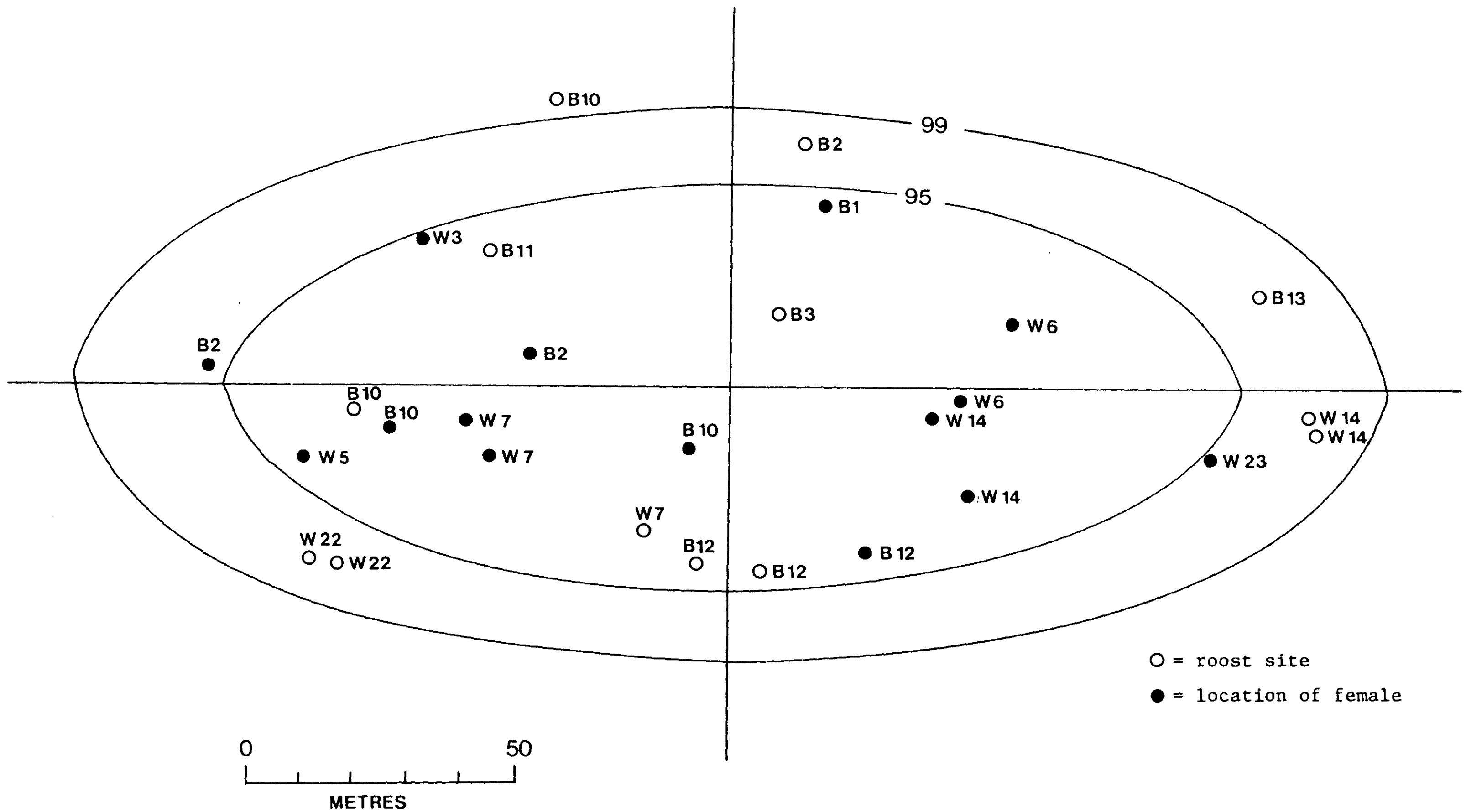



FIGURE 4.30. Combined locations of females and roost sites, aligned according to the major and minor axes of the territories with which they were associated. Male territory codes are indicated; e.g. W6 = Bird 6 at Wiangarie, B10 = Bird 10 at Barrington Tops. Also shown are the average 95% and 99% male home range ellipses.

## 4.4. DISCUSSION

### 4.4.1 Critical Habitat Factors

The availability of each aspect of habitat at Wiangarie and Barrington Tops determined whether it was identified as a critical requirement. For example, density of cover 2-50cm above the ground was identified as a critical habitat factor only at Wiangarie (Table 4.4). This was probably because dense ground cover was generally scarce at Wiangarie, but relatively common at Barrington Tops. This situation highlights an important problem associated with field study of habitat requirements. A habitat requirement can only be identified as a critical factor if it limits the amount of suitable habitat occurring within the area under study. The extent of the area studied will therefore influence the identification of critical habitat factors (Wiens 1981). A small study area may not encompass sufficient variation in certain habitat factors and these may therefore fail to be identified. Furthermore, those variables that are identified may not accurately represent actual critical habitat factors. For example, the abundance of shrubs was closely correlated with scrub-bird presence at Barrington Tops (Table 4.3). If the study had been conducted only at Barrington Tops shrub abundance may have been identified as a critical habitat factor. In reality, preliminary observation at Barrington Tops and Wiangarie led to the idea that the type of ground cover was not important, only its density, and eventually to the identification of cover density as the critical habitat factor.

For the purposes of the present study it was essential that as many as possible of the Rufous Scrub-bird's habitat requirements be accurately identified. Effort was made to alleviate the problems discussed above through the use of two study areas instead of only one. These areas represented two extreme types of forest known to support the Rufous Scrub-bird (see Chapter 2). The study of these two areas has clearly enabled the identification of critical habitat factors that would otherwise have been overlooked had only one of the areas been studied. Nevertheless it seems unlikely that the present study has identified all of the critical factors determining the suitability of habitat for the Rufous Scrub-bird. Some potentially critical factors may not have varied sufficiently throughout the study areas to have placed limitations on habitat suitability. Altitude-related factors may fall into this category. Over the last few decades the Rufous Scrub-bird has rarely been found below an altitude of

600 metres (Roberts 1979; Morris *et al.* 1981) despite the fact that it was once relatively abundant within lowland rainforests such as the Big Scrub near Lismore (Chisholm 1951; Smith 1977). The cause of this retreat is unknown. Both the Wiangarie and Barrington Tops study areas lay above 600 metres and therefore the present study could not determine the influence of altitude-related factors (the altitudinal distribution of the Rufous Scrub-bird is discussed in detail in Chapter 6).

Critical habitat factors could also have been missed as a result of oversight in the initial selection of habitat variables. Selection of variables was based largely on previous literature, intuition, and preliminary observation of scrub-bird and non-scrub-bird habitat. This process may have rejected variables that displayed no apparent (i.e. univariate) difference between habitats, but that nevertheless may have been important when considered in association with other variables. A good example of this type of variable in the present study was leaf litter volume at Barrington Tops. This variable was not identified as being significant in the univariate analysis (Table 4.3) yet was highly significant when its relationship with other variables was taken into account in the multivariate analysis (Table 4.4). This example not only demonstrates the usefulness of multivariate techniques but also the need for both care and imagination in the initial selection of habitat variables.

It is interesting to note that the habitat requirements of the Rufous Scrub-bird described in this chapter closely resemble those of the Noisy Scrub-bird as revealed by intensive study of that species in Western Australia (Robinson and Smith 1976; Smith 1976a; Smith and Robinson 1976; Smith 1979; Davies *et al.* 1982; G.T. Smith pers. comm.). Davies *et al.* (1982) have summarized the habitat requirements of the Noisy Scrub-bird as:

> ".....damp, dense vegetation adjacent to an accumulation of deep litter with a moderately dense understorey...."

This description encompasses all of the habitat factors identified for the Rufous Scrub-bird. The relationship between the described requirements of the two species is as follows:

| Rufous Scrub-bird | | Noisy Scrub-bird |
|---|---|---|
| 1. Extremely dense cover 2-50cm above the ground. | = | "dense vegetation" |
| 2. Moderately dense cover 50-100cm above the ground. | = | "moderately dense understorey" |

3. Moist microclimate 2cm above the ground. = "damp.....vegetation"
4. Ample volume of leaf litter per unit area. = "an accumulation of deep litter"

4.4.2 Effects of Logging

The influence of logging on habitat suitability cannot be simply classified as either "good" or "bad". Results presented in this chapter suggest that logging affects suitability in different ways in different types of forest. The suitability of habitat also changes with time following logging. Furthermore, to assess the net impact of logging on the Rufous Scrub-bird we need to consider not only the effects on habitat suitability but also the immediate effects on existing territories. Logging within an existing territory is likely to have a deleterious influence on the occupants of that territory, regardless of the long term influence on habitat. The net impact of logging in any particular area will be a function of at least four factors:

1. The type of forest logged.
2. The intensity of logging.
3. The time since logging.
4. The number of existing territories destroyed during the logging operation.

Dogmatic statements concerning the influence of logging on the Rufous Scrub-bird should, at this stage, be avoided. What is required is an awareness of the complexity of the situation and the need for further research. The effects of logging and other land-use practices are discussed further in Chapter 6.

4.4.3 Home Range

The results obtained using different relative indices of home range size demonstrate the need for caution in the application and interpretation of such measures. Different indices not only measure different home range properties but are also based on different assumptions. The choice and interpretation of indices must therefore be based on careful consideration of what an index is actually measuring and the influence of departures from any underlying assumptions.

The overall size of male scrub-bird home ranges as indicated by the minimum polygon and probability ellipse indices, appeared to vary little in relation to habitat quality, proximity of neighbours, song output, and geographical locality. This suggests that the absolute home range estimates derived in this chapter are probably applicable in a wide variety of situations. The reliability of these estimates obviously depends on the distribution of a male's singing activity throughout its true home range. The assumption was made that a male will sing from all parts of its home range and that a bird's home range and territory are therefore equivalent. This is difficult to prove without the use of techniques such as radio telemetry. This problem of not knowing what silent individuals are doing is shared by all aspects of research on this species. The home range estimates presented in this chapter must therefore be regarded as conservative.

The home range data for the Rufous Scrub-bird conform closely to results obtained for the Noisy Scrub-bird in Western Australia (Smith 1976a; Smith and Robinson 1976; Smith 1979; Davies *et al.* 1982; G.T. Smith pers. comm.). Similarities between the two species are as follows:

| Rufous Scrub-bird | Noisy Scrub-bird |
|---|---|
| 1. Territory area = 1.17 ha (minimum convex polygon). | "about 1 ha" (Davies *et al.* 1982). |
| 2. Distribution within territory: generally unimodal, spending most time near territory centre. | "within the territory the male spends most of his time in one or two small areas" (Smith and Robinson 1976). |
| 3. Territory shape: varies in accordance with distribution of suitable habitat. | Smith's (1976a) Fig.3 depicts similar phenomenon. |
| 4. Roost sites: located near periphery of male's territory. | "usually situated on the periphery of their territory" (Smith 1976a). |
| 5. Female: most detections near periphery of male's territory. | "at the edge of the male's territory" (Smith and Robinson 1976). |