SECTION I

ECOLOGY

CHAPTER 1

INTRODUCTION

Ecologists have long been concerned with determining the factors that regulate density levels of animal populations. Many hypotheses have been put forward in an attempt to create a general theory for the problem of natural regulation of populations. These theories can be classified into four broad categories. Early workers in the field of population regulation (e.g. Uvarov, 1931) believed that density-independent factors were of major importance in the regulation of population size. The main factor affecting population size was thought to be weather. The direct effects of weather on survival rates were independent of the size of the population. Nicholson (1933) believed that only density-dependent factors were capable of regulating population size. He considered it essential that a controlling factor should act more severely against an average individual when the density was high and less severely when the density was low. Factors thought to be operating in a density-dependent way were biotic ones such as competition, parasitism or predation.

Andrewartha and Birch (1954) rejected the separation of density-independent and density-dependent factors. They believed that the influences of all components of the environment are likely to be dependent on the density of the population. They divided the environment into four components: (1) weather; (2) food; (3) other animals and pathogens; and (4) a place in which to live. Andrewartha and Birch (1954) believed that an animal's chance of surviving and multiplying depended on all four components of the environment. Numbers of animals could be limited by shortage of resources, such as food, or by inaccessibility of these resources, or by a shortage of time during which conditions are favourable for an increase in the population.

Recently emphasis has been placed on the role of intrinsic changes in populations in controlling population size (e.g. Chitty, 1960; Wynne-Edwards, 1962). Phenotypic and/or genotypic changes in individuals are thought to be responsible for bringing about self-regulation of a population by keeping the density below a level which would result in destruction of the renewable resources of their environment. The role of territorial behaviour in limiting density (e.g. Jenkins, 1963; Carrick, 1963) and changes in the quality of individuals as density rises (e.g. Wellington, 1960, 1964) are examples of the role of intrinsic factors in self-regulation.

It has become clear (e.g. Kikkawa, 1977; Lidicker, 1978) that no one theory will apply to all animal species. It is probable that ecologically similar species are more likely to be influenced by the same kinds of environmental factors. For example, free-flying, terrestrial insects are more likely to be directly affected by changes in weather than are mammals.

Most studies of large mammalian herbivores seem to point to the importance of food quantity and quality in determining population size. Caughley (1970a) has interpreted the eruption, crash and resulting equilibrium of ungulate species after their introduction to new areas as being the result of grazing pressure leading to an equilibrium between animal density and food supply. Many studies (e.g. Taber, 1956; Taber and Dasmann, 1957; Peek *et al.*, 1976) documenting changes in mammalian herbivore density with successional changes in habitat have implicated changes in food supply as being the major cause of these density changes. Correlations have been found between food abundance and density (e.g. Franklin *et al.*, 1975). Food quality has been shown to influence productivity and survival especially in young animals (e.g. Klein, 1970). The influence of climate through its effect on food abundance and quality has been implicated in the control of population density in many mammalian herbivore species (e.g. Sinclair, 1977; Coe *et al.*, 1976; Phillipson, 1975; Myers and Poole, 1963).

Population density in macropods has also been shown to be affected by food quantity and quality. Newsome (1965a,b) concluded that red kangaroo *Macropus rufus* density was determined by the availability of food and shelter. An increase in the abundance of food and availability of water have been postulated as reasons for the suggested increase in numbers of red kangaroo (Newsome, 1975) and euro *Macropus robustus erubescens* (Ealey, 1967a,b; Ealey and Main, 1967) since the introduction of ruminant domestic stock into their environment. Bayliss (1980) found a correlation between density changes and an index of plant growth for the red kangaroo. Main (1970) considered various aspects of food quality as well as abundance of water and shelter to be important determinants of mortality rates in Western Australian herbivorous macropod species. Barker *et al.* (1974) have postulated shortages of water and plant nitrogen as limiting factors for the Rottnest Island quokka *Setonix brachyurus*. Inns (1980) considered a seasonal shortage of good quality food to be a major cause of mortality in a population of tammars *Macropus eugenii* on Kangaroo Island. Correlations between density of animals and abundance of food have been demonstrated in the Rottnest Island quokka (Holsworth, 1967) and the eastern grey kangaroo *Macropus giganteus* (Taylor, 1980). An increase in food abundance due to habitat disturbance by mining activities is thought to have led to an increase in population size for the Barrow Island hare wallaby *Lagorchestes conspicillatus* (Bakker and Main, 1980).

Eastern grey kangaroo and wallaroo *Macropus robustus robustus* are both large herbivorous macropodids. They occur sympatrically over large areas of eastern Australia, although wallaroo are present in an area only when suitable shelter in the form of rocky hills or steep slope is available. Both species feed mainly from late afternoon through to early morning and retire to suitable shelting habitat during the day. Individuals are seen mainly in small groups although fewer grey kangaroo are seen alone and more are seen in larger groups than are wallaroo (Kaufmann, 1974). Reproduction has been extensively studied in the grey kangaroo (e.g. Poole, 1973; Poole and Pilton, 1964) but wallaroo populations in the more mesic areas of eastern Australia have received little attention. Studies on a variety of kangaroo species (e.g. Poole, 1973; Russell and Richardson, 1971; Ealey, 1962; Frith and Sharman, 1964) have shown seasonality of breeding to vary according to the variability in rainfall. Studies in arid and semi-arid areas (e.g. Newsome, 1975) have found rainfall, through its effect on food, to be an important determinant of survival rates of pouch young and juveniles. Survival rate of young animals appears to be the major factor influencing population density changes of kangaroos in these areas (e.g. Bayliss, 1980; Newsome, 1977; Frith and Sharman, 1964). Dietary studies on large macropods (e.g. Griffiths and Barker, 1966; Storr, 1968; Kirkpatrick, 1965a) have usually found grass to be the most important component of the diet. Differences in diet and habitat use have both been found in studies of the ecology of sympatric macropod species (e.g. Caughly, 1962; Griffiths and Barker, 1966).

Until recently most work on the ecology of large herbivorous macropods was concentrated in arid and semi-arid areas. In the New England Tablelands of New South Wales the presence of properties which differ in pasture management, and many areas with sympatric populations of grey kangaroo and wallaroo, allowed a study to be made of the comparative ecology of the two kangaroo species in areas differing in the quality and quantity of food present. Graziers in the New England Tablelands claim an increase in numbers of eastern grey kangaroo and wallaroo occurs after pasture improvement measures are adopted on a property (e.g. Cameron, 1975; Wright, 1975). Since other studies had shown food to be an important factor in the regulation of the density of macropod populations, it was hypothesized that an increase in the quantity and/or quality of food available to kangaroos after pasture improvement would lead to an increase in their density. Since pouch young and juvenile mortality had been shown to be important in determining population density of macropods in arid and semi-arid areas, a study of pouch-young and juvenile mortality rates was also undertaken to assess their role in influencing the increase in population density which occurs after pasture improvement on properties in the New England area.

Habitat use was investigated to compare the influence of selected abiotic and biotic factors in determining the use of an area by the grey kangaroo and wallaroo and to assess the influence of food quality and quantity on the density of kangaroo feeding in a habitat. It was hypothesized that if an area was suitable in all other respects for use by a kangaroo, the abundance of food should influence the degree of use of an area by kangaroos and that for areas with similar food abundances the area with the highest quality pasture would support the greatest density of kangaroos feeding upon it. Since grass was expected to be the major component of the diet of both species it was thought that the quality and abundance of grass would be the most important component of the pasture influencing the use of an area for feeding. Diet was investigated to examine the role of differences in diet in the ecological separation of the grey kangaroo and wallaroo and to investigate differences in the composition of the diet in areas differing in the food resources available. The condition of kangaroos and aspects of their nutrition were investigated to assess the influence of seasonal changes in food availability and differences in the food quality and abundance between areas on the condition, survival and reproduction of populations of eastern grey kangaroo and wallaroo with a view to determining why pasture improvement might lead to an increase in the population density of macropods.

1.1 Organization of the study

The study was carried out on two properties in the New England Tablelands of New South Wales where grey kangaroo and wallaroo occurred sympatrically and which differed in the degree of pasture improvement which had taken place. The biomass of plants, in different categories of quality and plant type in each habitat and each season, was estimated to compare the food resources on the two areas. Quality measurements were also made of the plants on the two areas. Transect counts of macropods were undertaken to compare the density of grey kangaroo and wallaroo on the two areas and to quantify the use of habitats differing in the biomass of different plant types and selected abiotic and biotic factors such as rock density, slope and tree density. A dietary study enabled a comparison to be made of the use of the pasture on the two areas by the grey kangaroo and wallaroo. A knowledge of the diet was also essential to assess the influence of food in determining the use of an area for feeding and to relate changes in the composition of the diet to changes in the quality of food in the stomach of kangaroos. Examination of the quality and quantity of food in the stomach of kangaroos was used to interpret changes in the condition of kangaroos over seasons and differences in the condition of kangaroos on the two properties.

Ideally, to minimise differences due to seasonal differences between years, the study of habitat use, diet, condition of animals and changes in the pasture should have been carried out simultaneously. However, the time involved in field work necessitated the program being partitioned over several years. Transect counts which involved least disturbance to the population were carried out first. As a collaring program was carried out in conjunction with the transect counts, data were also gathered on movements and home range use as well as other aspects of social organization such as group size and composition. After twelve months of transect counts, the work on diet, condition of the animals and pasture conditions was carried out. This involved collecting a shot sample of kangaroos each three months and sampling pasture biomass and composition. The shot sample of kangaroos was also used to study aspects of reproduction and mortality rates of pouch young. The samples collected in this second phase of field work involved extensive laboratory work most of which had to be done after the field sampling program had been completed.

The thesis is divided into two sections. The first deals with aspects of the ecology of the wallaroo and eastern grey kangaroo and the second concentrates on their social organization.

1.2 Description of the eastern grey kangaroo and wallaroo

(i) Eastern grey kangaroo

The eastern grey kangaroo has a wide distribution over most of eastern Australia (Fig. 1.1) from Cooktown in the north to western Victoria in the south. Its distribution extends west into semi-arid areas but it is usually associated with watercourses in these areas (Frith and Calaby, 1969). Grey kangaroo typically inhabit dry sclerophyll forests and open woodlands.

The general body colour is greyish-brown with the belly fur usually lighter than elsewhere on the body. The paws, toes and terminal third of the tail is usually close to black. There is little difference in coat colour between the sexes but sexual dimorphism in size is marked (Fig.1.2).

Fig. 1.1. Distribution of *Macropus giganteus*. (after Kirsch and Poole, 1972).

Fig. 1.2. Male (right) and female (left) eastern grey kangaroo. (photo P. Jarman)

(ii) Wallaroo

Wallaroo (or euros as they are known in arid areas) are found throughout most of mainland Australia in a variety of habitats, usually in association with mountainous or hilly terrain (Fig. 1.3). The taxonomy of the group has been reviewed by Richardson and Sharman (1976). Thirteen forms have been described and these have been divided by Richardson and Sharman into three species with *M. robustus* being divisible into four subspecies. The subspecies dealt with in this study, *Macropus robustus robustus*, is found along the Great Dividing Range of eastern New South Wales and Queensland. Eastern wallaroo are confined to more mesic areas and do not extend into semi-arid areas.

Wallaroo , especially males, are stockily built in comparison to grey kangaroo . Their forearms are also noticeably shorter. The coat has a shaggy appearance with coat colour varying with region and subspecies. In the eastern wallaroo males tend to be blackish with a rusty red tinge, especially in older animals and during winter, and females are a light blue-grey colour. The sexes differ markedly in size (Fig. 1.4). Adult females usually weigh between 20 and 25 kg whereas males over 45 kg can be found. Males have a marked development of the forearms in comparison to females.

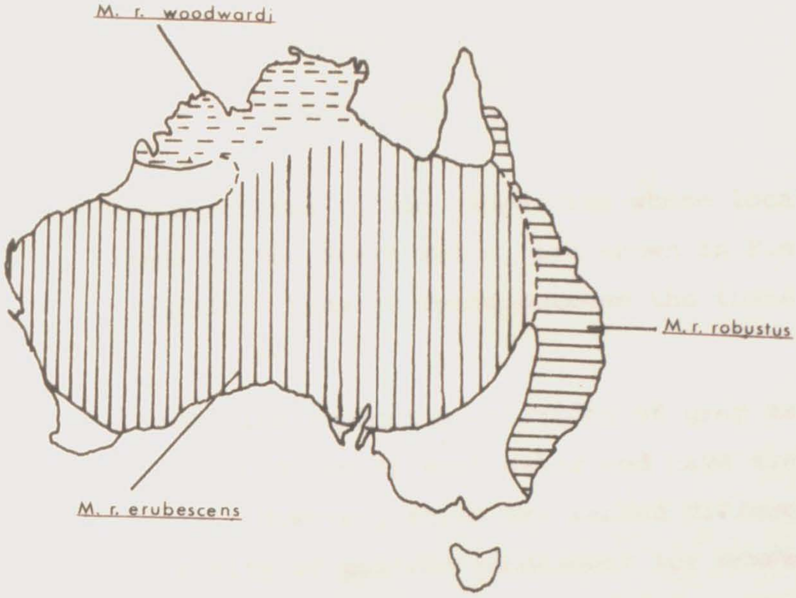


Fig. 1.3. Distribution of the subspecies of *Macropus robustus*. *M. r. isabellinus* occurs on Barrow Island off the coast of Western Australia. (After Richardson and Sharman, 1976).

Fig. 1.4. Male (foreground) and female (background) wallaroo. (photo P. Jarman)

CHAPTER 2

STUDY AREAS

The study was conducted on two properties whose locations, on the New England Tablelands of New South Wales, are shown in Fig. 2.1. Newholme is 9 km north of Armidale. Lana is found between the towns of Kingstown and Uralla.

Both these properties support populations of grey kangaroo and wallaroo. They are within 40 km of each other and have similar rainfall and temperature regimes. However, there are marked differences between the properties in the intensity of pasture management for domestic stock. Lana has been selectively cleared of trees and an intensive program of fertilization of pastures has been carried out. Clover seed has been spread to build up soil nitrogen content and some paddocks have been harrowed and sown with introduced grasses (*Phalaris tuberosa*, *Festuca* spp.). In contrast to Lana, on Newholme no application of fertilizers or ploughing and seeding with exotic pasture plants has been undertaken. Large areas of Newholme remain with a dense tree canopy.

In 1972 the University of New England purchased Newholme as a field research station for the School of Natural Resources. Throughout the study the area was run as a grazing property. Newholme is dominated topographically by Mt. Duval and adjoining smaller hills (Fig. 2.2). Most of the area south and south-east of Mt. Duval has been extensively cleared but the mountain and adjoining hills remain relatively well timbered. Only a small portion of the cleared pasture was included in the study area as most of this treeless area was not utilized by macropods. The pasture on the hills was dominated by *Poa* tussock grasses. Small areas on the hills have been cleared but these now support a good regrowth of saplings. Cattle grazing ($\simeq$ 0.2 animals/ha) is mainly confined to the cleared pasture to the south and south-east of the hills. Sheep grazing ($\simeq$ 1.9 animals/ha) occurs over the whole property. Fencing on the property is poorly developed on the hills and sheep are free to graze over the whole of Mt. Duval. Stock water dams are present on the flat country but are not on the hills where many small creeks, which contain some water for most of the year, are present. Many small "camps", maintained by the sheep, have an abundant cover of short green grass due to continual grazing and deposition of faeces and urine by sheep. Small natural clearings can be found in drainage lines on the hills.

Lana is managed as a grazing property for sheep ($\simeq$ 3.1 animals/ha)

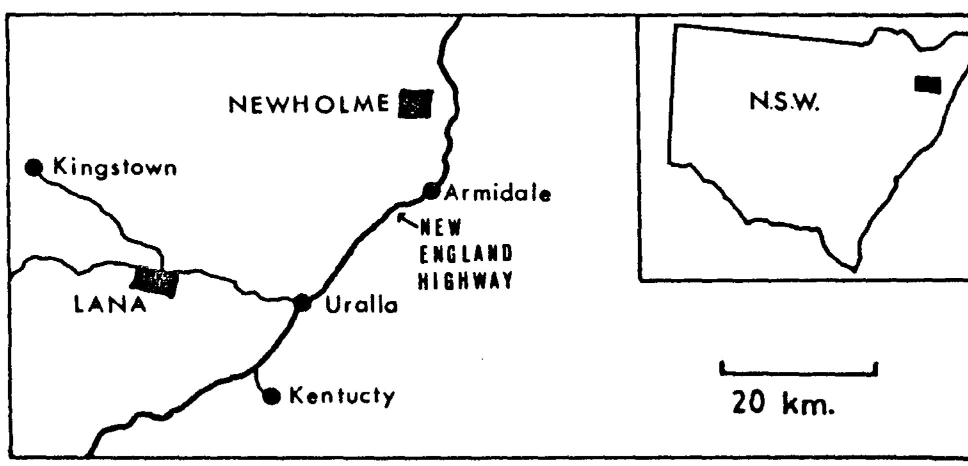


Fig. 2.1. Map showing the location of the study areas.

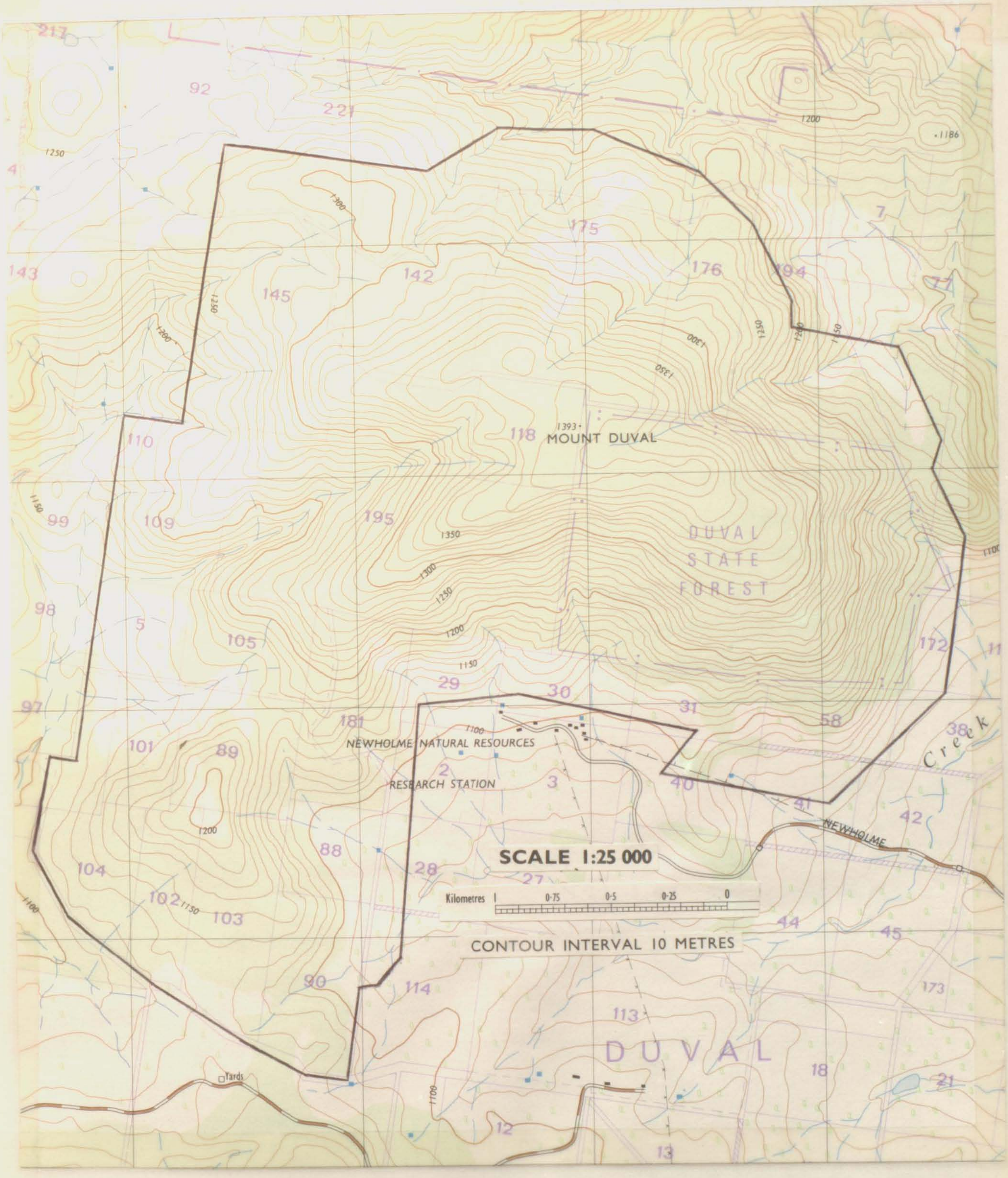


Fig. 2.2. Topographic map of the Newholme study area. ——— delineates the study area.

and cattle (≈ 0.3 animals/ha). Only the northern portion of the property was used as a study area. This is bounded by a main road to the north and by Roumalla Creek to the south. A string of rocky outcrops runs across the centre of the area. These rocky outcrops are broken by an area of woodland where a public road runs through the study area (Fig. 2.3). A pasture improvement program has been carried out over the last twenty years. Aerial spreading of superphosphate usually occurs on a yearly basis. During the early stages clover seed was spread. Exotic grasses have also been introduced into some paddocks (mainly to the east of the public road). Fencing is well maintained and paddock size is on the whole smaller than occurs on the Newholme study area. Stock water dams have been provided in all paddocks. The tree cover on the rocky hills has largely been maintained and a few patches of dense woodland remain. However most of the area has been selectively cleared of dead and young green timber resulting in an open savanna woodland. Cattle usually avoid the rocky hills but sheep utilize most areas. No sheep are run in the paddocks with improved pasture. Sheep "camps" and other areas of pasture intensely affected by sheep grazing can be found associated with the hills. At the request of the owner, Mr. P.A. Wright, Lana was designated as a Wildlife Refuge by the New South Wales National Parks and Wildlife Service in 1968.

Grey kangaroo are regularly culled on Lana but no wallaroo are shot. Neither grey kangaroo nor wallaroo are harvested on Newholme. Swamp wallaby *Wallabia bicolor* are present on hilly areas on both Lana and Newholme but they are more abundant on Newholme. Rabbits (*Oryctolagus cuniculus*) are present only in small isolated areas on Newholme, whereas on Lana they are widespread but heavily controlled. There is a general lack of predators on both properties. However, foxes (*Vulpus vulpus*) are numerous on both properties and wedge-tailed eagle (*Aquila audax*) are occasionally seen. Dingoes (*Canis familiaris dingo*) have been eliminated from both properties.

2.1 Climate

The New England Tableland is an area of warm summers and cool to cold winters. Maximum and minimum temperatures typical of the area are given in Fig. 2.4. Severe frosts are normally experienced during the winter months. Snow-falls in winter are irregular and normally last for only a few hours on the ground surface. Occasionally snow may persist for two days or more on Mt. Duval on Newholme. Annual rainfall averages for the past twenty years are 781 mm for Lana and 812 mm for Armidale (9 km from Newholme). Fig. 2.5 shows the mean rainfall per month averaged over a

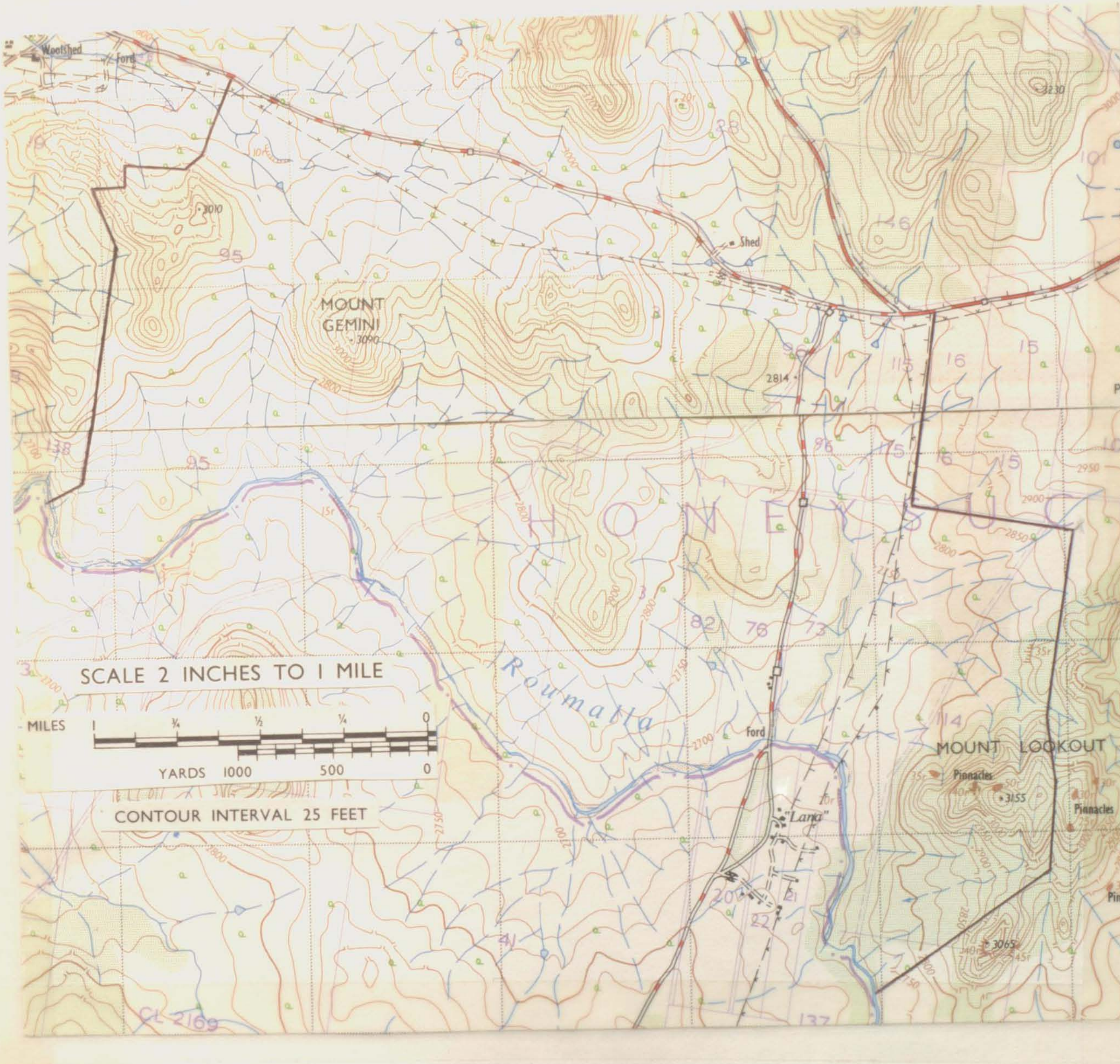


Fig. 2.3. Topographic map of the Lana study area. ——— delineates the study area to the east and west. To the noth the study area is bounded by the main road and to the south by Roumalla Creek.

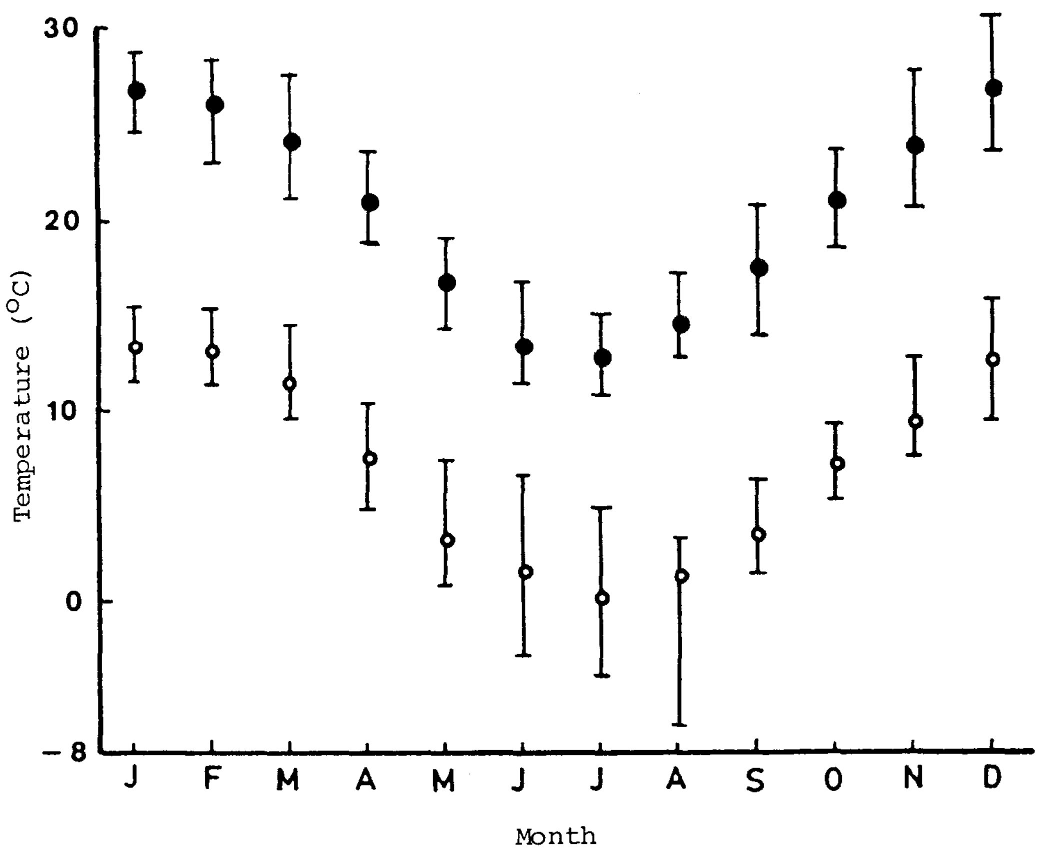


Fig. 2.4. Maximum and minimum temperatures recorded at Armidale. Values are means averaged over 1957 to 1979. I represents the range of values.

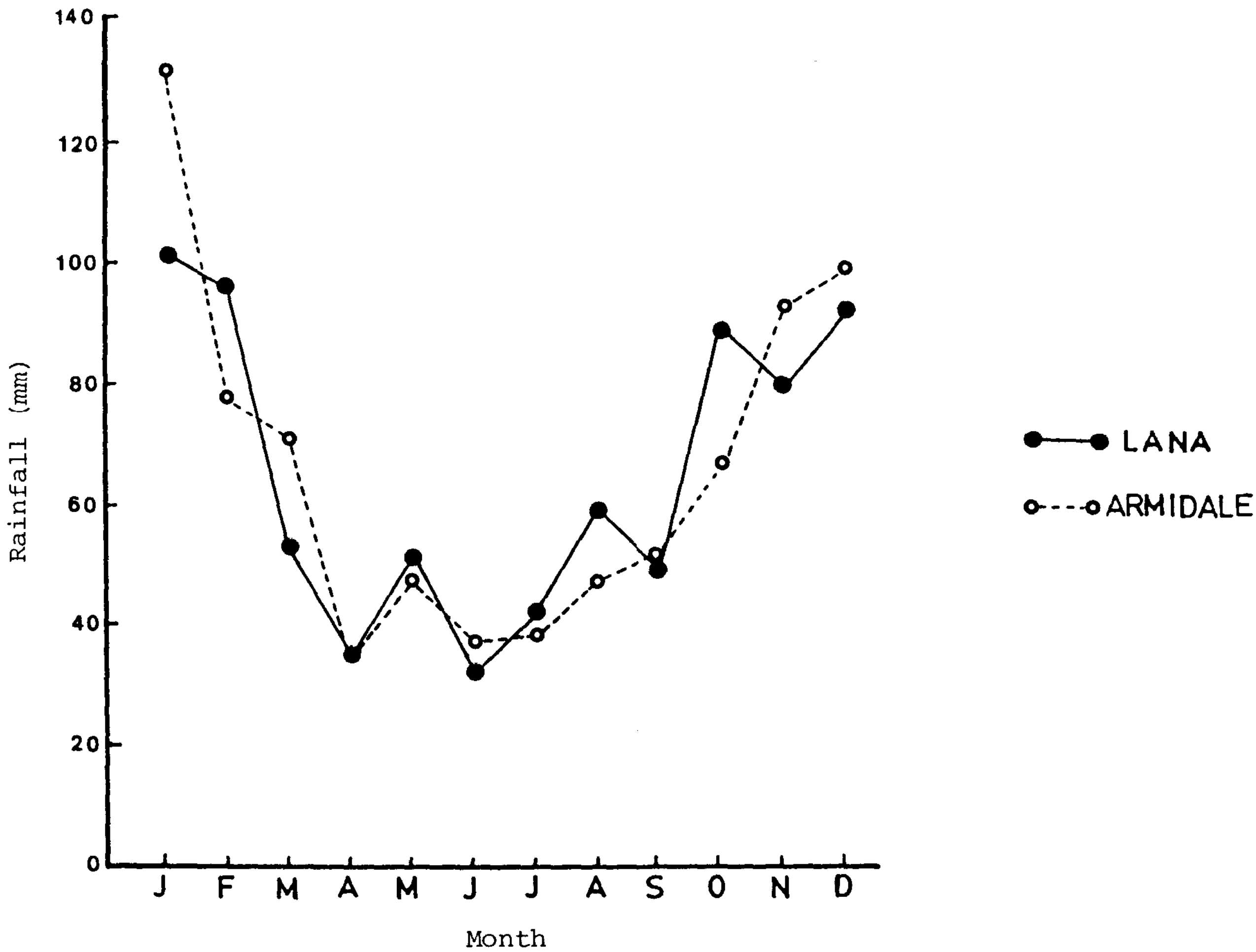


Fig. 2.5. Mean rainfall for each month on Lana and Armidale. The data for Lana are the means for the years 1953-1973. The data for Armidale are the means for the years 1957-1979.

twenty year period for Lana and Armidale. The monthly rainfall for Lana and Armidale in the years 1976 to 1979 during which the present study was conducted are shown in Fig. 2.6.

2.2 Effect of Climate on Plant Growth

Pasture growth is greatest in spring and summer due to the high rainfall and warm temperatures. In autumn and winter cool to cold temperatures and lower rainfall causes a drop in pasture production. The cold weather also causes wilting and death of many individuals of some plant species. Frost can have a devastating effect upon pastures although cool season perennials (e.g. *Danthonia*, tussock grasses) and introduced grasses are somewhat resistant to frosts.

2.3 Habitats

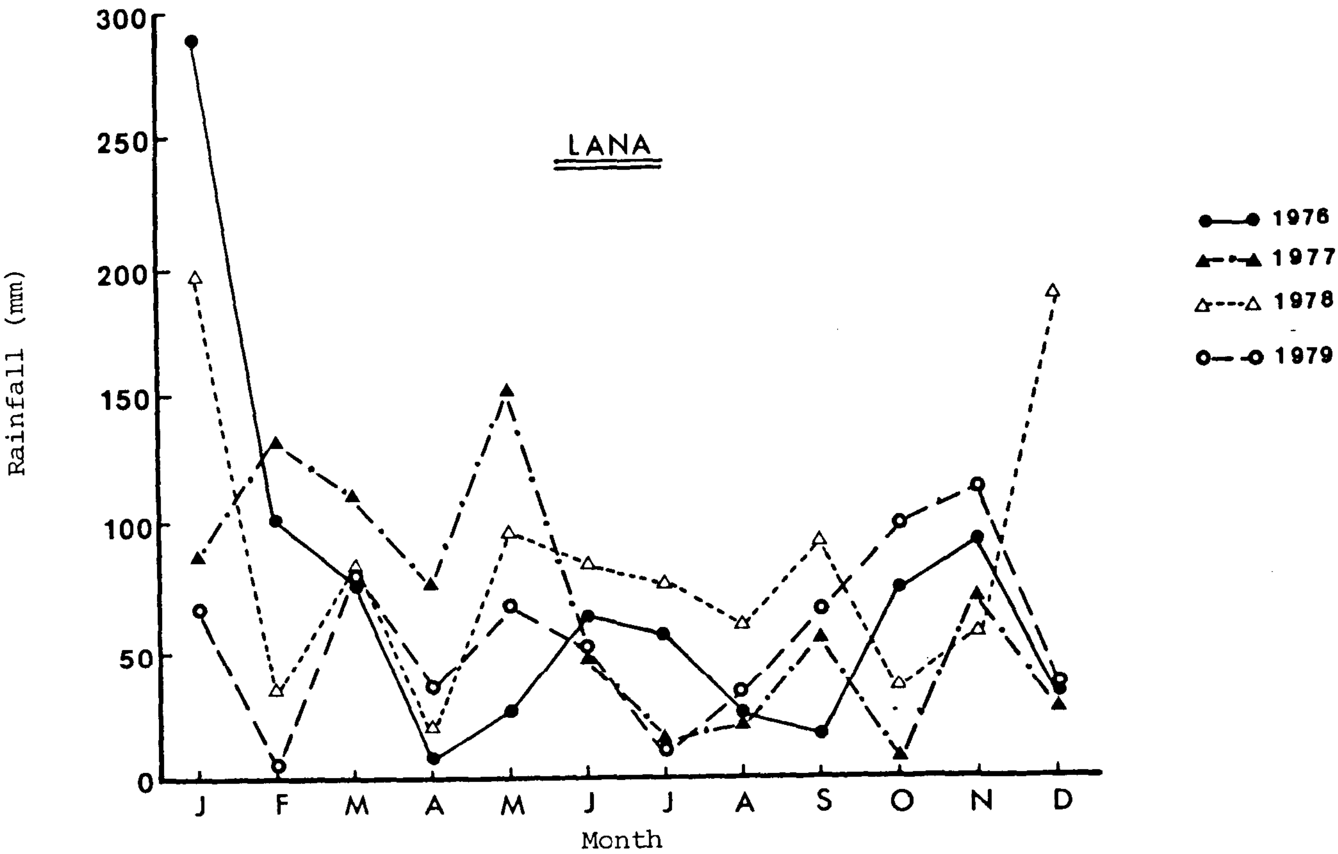
The study areas were subdivided into habitat types based on slope, tree cover, size and density of rocks, species composition and biomass of the pasture, and shrub density. These factors were chosen as being the most likely to influence kangaroo distribution and abundance. Grasses were divided into species with a high or low fibre content in order to categorize them in terms of their quality and hence palatability to kangaroos (see Chapter 3). Species included in the high-fibre grasses were *Imperata cylindrica*, *Danthonia pallida*, *Pennisetum alopecuroides*, *Cymbopogon refractus*, *Aristida* spp. and *Poa* spp.

(i) Lana

Eucalypts are the dominant trees on both study areas. On Lana scattered *Acacia* and Callitris pine are also present. The study area on Lana covers approximately 995 ha. Nine basic habitat types are recognized. These are:

(1) Savanna woodland (SAV). This habitat covers 60% of the study area on Lana; it is characterized by a scattering of eucalypts giving a "parkland-like" appearance. Open woodland on rocky hills was not included in savanna woodland. Grasses and forbs predominate in the pasture. Grasses are mostly low-fibre species such as *Bothriochloa*, *Eragrostis* and *Vulpia*; however high-fibre grasses, such as *Aristida* and *Poa*, are abundant in patches (Fig. 2.7(a)).

(2) Dense woodland (DW) has a good canopy of trees (60-80%). It is found mainly in small patches around the base of hills. Pasture biomass is less here than in savanna woodland. Pasture species present are similar to those in SAV but are in different proportions (Fig. 2.7(b)).



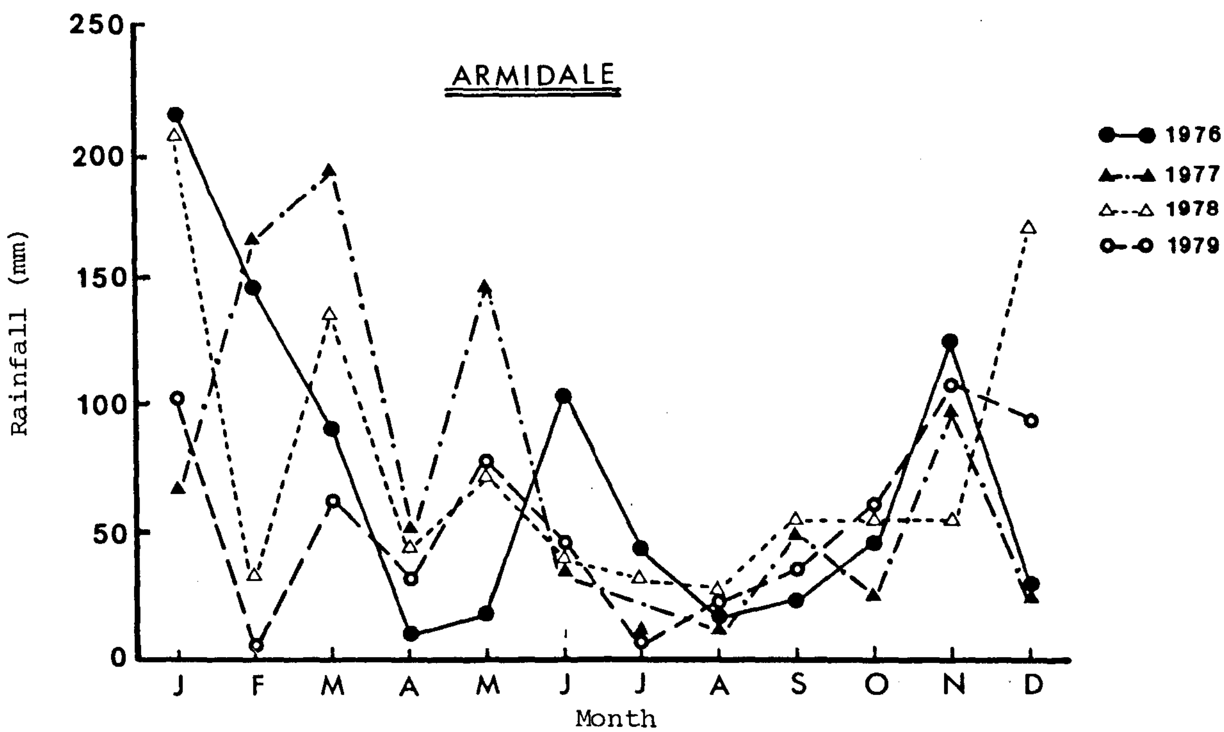


Fig. 2.6 Rainfall recorded at Lana and Armidale for years 1976 to 1979.

Fig. 2.7. Some of the habitat types present on Lana.

(A) Savanna woodland	(B) Dense woodland
(C) Large boulder slope	(D) Rocky slope (background)
(E) Small dense rock slope at base of hills	(F) Small dense rock slope at base of hills
(G) Low-sight-distance slope	(H) Gentle slope

A

B

C

D

E

F

G

H

(3) *Imperata* woodland (IW). This is a dense woodland with the pasture being dominated by blady grass *Imperata cylindrica*. It is found along creeks where a "swampy" pasture dominated by sedges develops in patches. This habitat represents only a small part of the study area and was not sampled to any great extent. Small patches of *Imperata* exist in other habitats but these are not included in *Imperata* woodland habitat.

(4) Large boulder slope (LBS). This habitat is only present on Mt. Lookout to the east of Lana and on a small area of Mt. Gemini (see Fig. 2.3 and Fig. 2.9). There is usually a dense tree cover present. Large boulders (around three metres high) are abundant and the pasture is dominated by high-fibre grass tussocks (*Poa* spp., *Danthonia pallida*). Bare gravelly soil is abundant in places. Very few low-fibre grasses are present (Fig. 2.7(c)).

(5) Rocky slope (RS). This habitat consists of rocky hills where medium sized rocks are frequent and the slope is usually greater than 35 degrees. A medium to dense tree cover is present. Pasture composition is similar to savanna woodland but biomass is reduced (Fig. 2.7(d)).

(6) Dense rock slope (DRS). This class of habitat is dominated by the presence of abundant rock (usually greater than 65% of the ground cover). There is usually a medium to dense tree cover present. Three major types of dense rock slope are recognized. These are:

(A) Small dense rock slope at the base of hills (SDRb). There is usually a dense regrowth of small eucalypt saplings present here. This habitat is represented by a few small patches at the base of rocky slope. The rocks in this habitat are mainly small (≃ 30 cm across) and densely dispersed (Fig. 2.7(e));

(B) Small dense rock slope at the top of hills (SDRt). The density and size of rocks is similar to SDRb but this habitat is located at the top of some rocky slopes. *Acacia* is sometimes the most abundant over-storey species here (Fig. 2.7(f));

and (C) Dense medium rock slope (DMR). This habitat is found around the tops of some rocky slopes as is SDRt but the rocks are larger. The rocks tend to be similar in size to ones found on rocky slopes but they are much more densely dispersed.

Sparse grasses and forbs are usually scattered among the rocks but scattered dense patches of *Microlaena* also occur probably due to high sheep usage.

(7) Low-sight-distance slope (LSD). This habitat is found around the tops of some rocky hills. Tree cover is usually high. Dense shrubs or saplings are present but passage through this habitat is usually not restricted. Visibility is low. Pasture present varies from dense *Aristida* to small patches of dense *Microlaena* (Fig. 2.7(g)).

(8) Gentle slope (GS). The slope of this habitat is less than for rocky slope and the rocks tend to be less common on most areas compared to rocky slope. Tree cover is usually moderate. These areas can be found at the base of rocky slopes or as the whole of the slope along a chain of rocky hills. Pasture is mostly similar to savanna woodland although biomass is less (Fig. 2.7(h)).

(9) Sheep-affected pasture (SAP). As the name suggests the biotic characteristics of these areas were probably created and are maintained by high usage by sheep (and cattle?). The areas have an abundant growth of short green grass (usually *Microlaena* but *Cynodon*, *Agropyron*, and others in places) and a high leaf-to-stem ratio in comparison to other pastures. Sheep-affected pasture is found in small patches on rocky slope, gentle slope and at the base of some hills in savanna woodland. Tree cover varies depending on where the sheep-affected pasture is located. These areas are sometimes referred to as "camps" in the text.

Fig. 2.8 shows the distribution of habitat types on the study area on Lana. Fig. 2.9 gives a schematic representation of the spatial relationships between the various habitats.

(ii) Newholme

The study area on Newholme covers an area of approximately 970 ha. Fifteen habitat types are recognized on Newholme. These are:

(1) *Microlaena* pasture (MP). This habitat is similar to sheep-affected pasture on Lana. But, on Newholme, the sheep camp pasture is always dominated by *Microlaena stipoides* whereas on Lana only some camps are *Microlaena*-dominated. Areas of dense *Microlaena* in drainage areas which probably were not created by sheep activity were also included in this habitat. Tree cover is usually dense although one small drainage area has no trees present.

(2) *Eragrostis* grassland (EG). The trees have been removed from these areas. *Eragrostis* is abundant in the pasture.

(3) *Poa-Pennisetum* grassland (PPG). This grassland pasture association occurs mostly in drainage areas. The soil here usually remains soggy during most of the year. *Poa costiniana* and *Pennisetum alopecuroides*

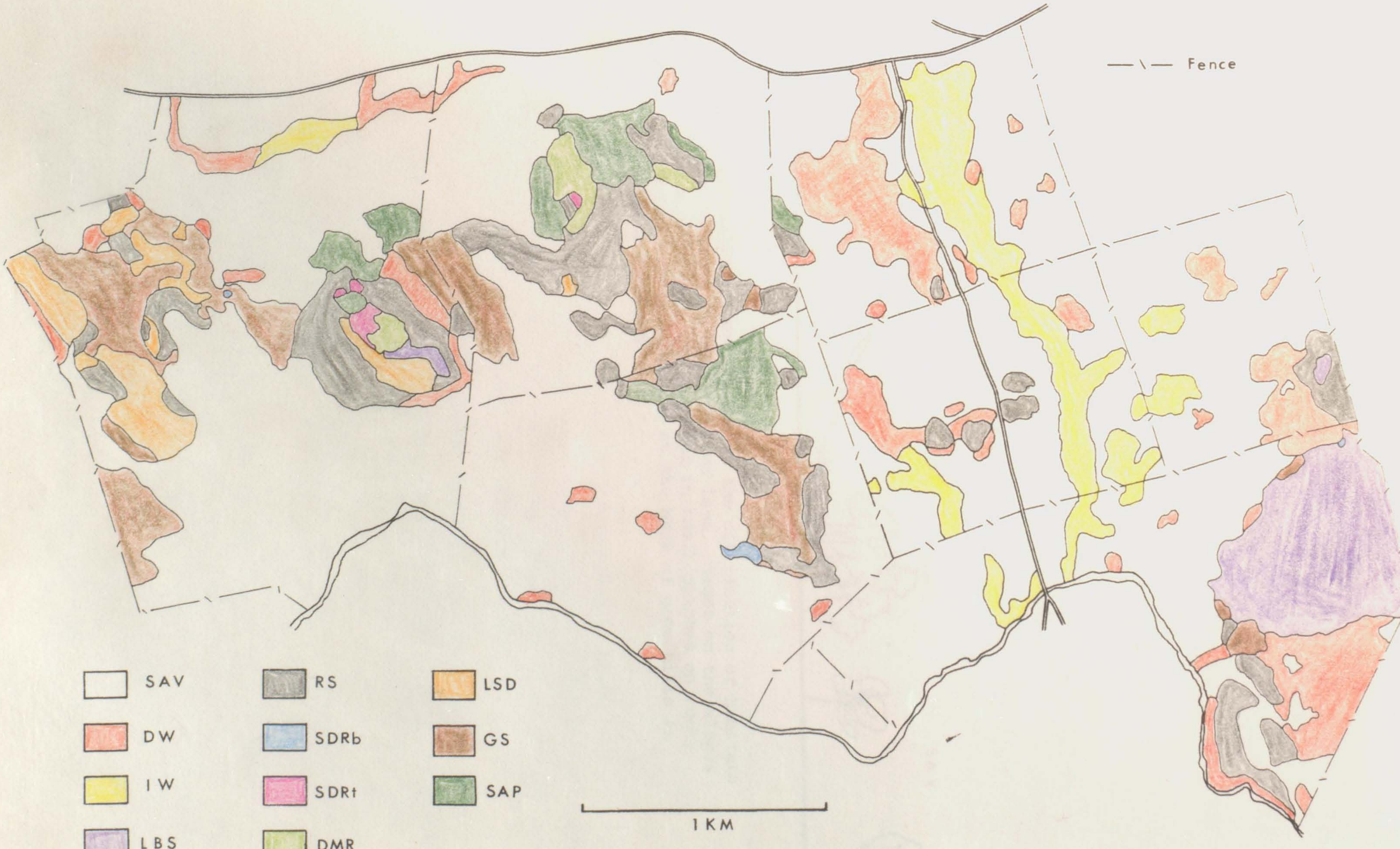


Fig. 2.8. Distribution of habitats on Lana.

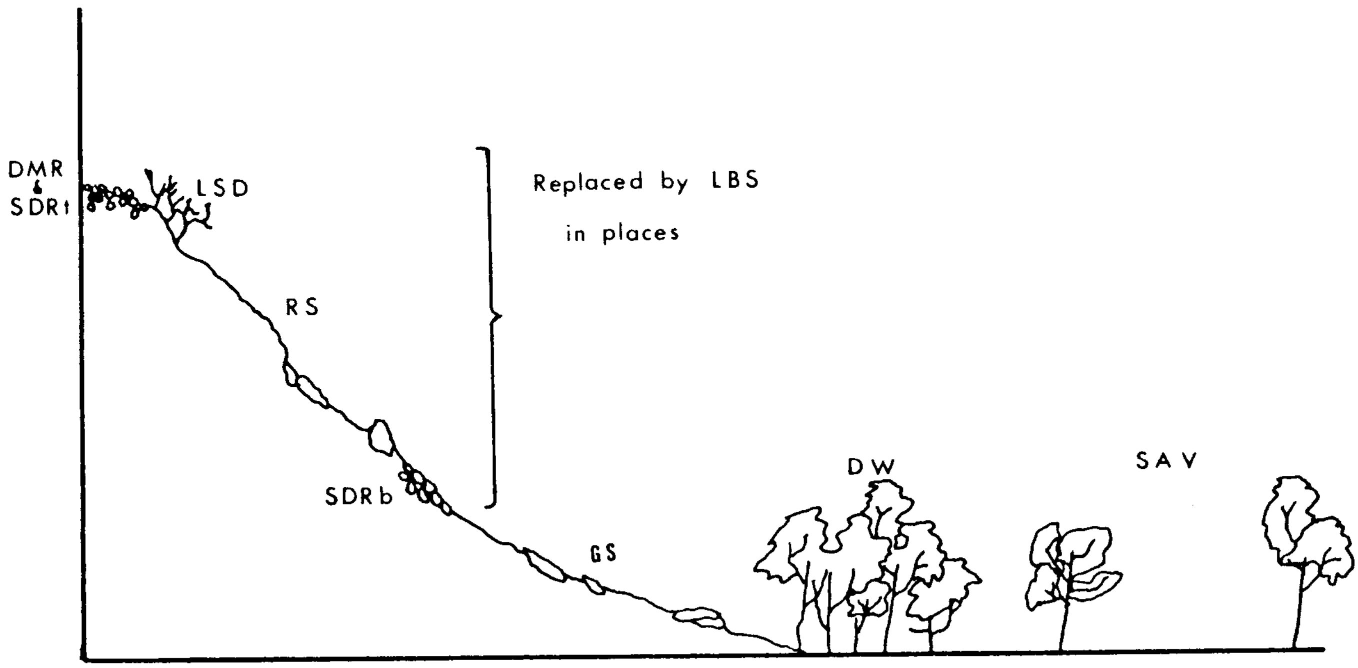


Fig. 2.9. Schematic representation of the distribution of habitats in relation to each other on Lana. Trees on the slopes are not shown. SAP is found in small patches on rocky slope, gentle slope and at the base of some hills in savanna woodland.

tussocks are frequent to abundant. In some small areas sedges (e.g. *Carex gaudichaudiana*) dominate. This habitat can be found as small clearings in woodland, in large areas on the side of gently sloping hills, along small creeks or at the base of hills. In woodland clearings *Eragrostis* tends to dominate around the edges of these areas.

(4) *Poa sieberana* slope (PS). This habitat makes up 30% of the study area. It usually has a dense tree canopy. *Poa sieberana* tussocks dominate the pasture. The slope is usually steep. Medium sized rocks are common (Fig. 2.10(a)).

(5) *Poa costiniana* slope (PC). This habitat is found at the base of some *Poa sieberana* slopes. It is similar in appearance to *Poa sieberana* slope but *Poa costiniana* is the dominant tussock grass. The shrub *Bursaria spinosa* is common in some areas. There is a moderate to dense tree canopy present.

(6) *Poa labillardieri* slope (PL). *Poa labillardieri* is the dominant grass tussock in this habitat. The appearance of these areas is similar to *Poa sieberana* slope and *Poa costiniana* slope. The tree canopy is medium to dense.

(7) Grassy slope (GrS). This habitat is similar to the *Poa* slopes but *Poa* tussocks tend to be small and scattered and other short grasses (e.g. *Bothriochloa*, *Microlaena*) tend to dominate visually. The tree canopy is dense (Fig. 2.10(b)).

(8) *Cymbopogon* slope (CS). *Cymbopogon* and *Poa costiniana* tussocks dominate the pasture in this habitat. Small dense rocks are also frequent to abundant in most areas. The tree canopy is usually dense but one area had been ringbarked and now small saplings are common.

(9) Shrub slope (ShS). The shrub *Bursaria spinosa* is abundant on these slopes. This habitat is found around the base of hills in certain areas. The slope is gentler than the *Poa* slopes and visibility is low. Small to medium rocks are common. The tree canopy is moderate. The pasture consists of scattered *Poa* tussocks with short grasses between (Fig. 2.10(c)).

(10) Savanna slope (SvS). The tree canopy is very open in these areas due to extensive clearing. *Poa* tussocks are frequent to scattered with a very short grass cover (e.g. *Bothriochloa*, *Eragrostis*, *Panicum*) between the tussocks. The slope is not steep. Rocks are not abundant (Fig. 2.10(d)).

(11) Dense rock slope (DRS). These areas are found around the tops

Fig. 2.10. Some of the habitat types present on Newholme.

(a) PS

(b) GrS

(c) ShS

(d) SvS

(e) DRS

(f) PGW

Fig. 2.10. (cont.)

(g) AcW

(h) PF

(i) PFAc

of some slopes. They are characterized by dense small rocks. Small, common to sparse *Poa* tussocks occur with a short grass cover (usually *Microlaena*) between (Fig. 2.10(e)).

(12) *Poa* grassy woodland (PGW). This woodland has a dense tree canopy cover. The pasture is dominated by frequent *Poa costiniana* tussocks with a good broad-leaf grass cover (e.g. *Bothriochloa*, *Echinopogon*) between the tussocks. This woodland is found on very gentle slopes or flat areas (Fig. 2.10(f)).

(13) *Acacia* woodland (AcW). This woodland is found in places on the top of Mt. Duval. Short grasses dominate the pasture and *Acacia dealbata* is a common understorey shrub. The tree canopy cover is usually dense although small scattered open areas are present (Fig. 2.10(g)).

(14) Hilltop *Poa sieberana* forest (PF). This habitat is found on the summit of Mt. Duval. The area is flat or gently undulating. Abundant *Poa sieberana* tussocks dominate the pasture. Dense tall trees are present (Fig. 2.10(h)).

(15) Hilltop *Poa sieberana* forest with *Acacia* (PFAc). This habitat is essentially the same as *Poa sieberana* forest except for the presence of a shrub layer of *Acacia dealbata*. This habitat is found on the edge of some areas of *Poa sieberana* forest before it drops away to form *Poa sieberana* slope (Fig. 2.10(i)).

Fig. 2.11 shows the distribution of habitat types on the Newholme study area.

Most of the Lana study area is savanna woodland which has an open canopy of trees. On Newholme, however, habitats with little tree cover (e.g. EG, PPG, SvS) make up a small proportion of the study area, most areas having a dense tree canopy cover. High-fibre tussock grasses tend to dominate the pasture in most habitats on Newholme, whereas on Lana low-fibre grasses, such as *Bothriochloa*, *Vulpia*, *Eragrostis* and others, make up a greater proportion of the pasture biomass. Although tussock grasses are present on Lana they occur as localized clumps or as scattered individual tussocks in comparison to most Newholme habitats where they are the dominant feature of the pasture. Areas of abundant, short, high quality grass, created by sheep grazing and "camping" activities, are present on both properties. However, these areas are more extensive and occupy a greater percentage of the area on Lana than on Newholme (see Table 5.1), even though on Lana sheep grazing only occurs on approximately two-thirds of the study area and on Newholme it occurs over the whole of the study area.

Fig. 2.11. Distribution of habitats on Newholme.