VII

DISCUSSION OF THE NEW ENGLAND FLORA

The key to species in the preceding chapter included comments on occurrence and distribution of New England grasses. Those notes form a basis for the following general discussion, which also draws on field experience of several years of collecting and travelling through the region.

Aquatic and Semi-Aquatic Grasses

There is a group of grasses found along watercourses, the margins of ponds, and growing in periodically damp or swampy areas. *Potamophila parviflora* is a rare grass growing against rocks or other barriers in the water of flowing streams near the eastern gorges. *Phragmites australis* also occurs in the middle of shallow streams and is particularly prevalent on sandbanks and silted margins throughout the region. *Panicum obseptum, Isachne globosa,* and the introduced *Polypogon monspeliensis* and less common *P. littoralis,* are generally rooted in mud on creek margins, whilst *Tripogon loliiformis, Paspalum paspaloides, Hemarthria uncinata, Glyceria* spp., *Amphibromus* spp. and *Pseudoraphis spinescens* prefer damp and swampy areas or the edges of still ponds, though there is a natural overlap in these two categories. *Tripogon loliiformis* is also frequently found in pastures apparently free from prolonged wet conditions.

Stipa verticillata and *Pennisetum alopecuroides* commonly grow along banks of creeks or on alluvial flats, the former grass appearing only on the western slopes, but both also occur as conspicuous tussocks in more or less well-drained grasslands. *Cynodon dactylon* (couch grass) is one of the most common and versatile grasses, probably introduced but encountered in such widespread circumstances by early pastoralists and botanists as to have been considered indigenous by some authorities. It frequents aquatic and swampy environments and inhabits most terrestrial communities in New England, as well as being a pioneer of wastelands and an ubiquitous grass in townships.

INTRODUCED GRASSES

A little over one third of the New England flora comprises grasses which are not indigenous to Australia. Many of these have been introduced for trial as improved pasture or lawn species, but most have moved into the region adventitiously and are concentrated in and around population centres and along main roadsides. Some have become established as noxious weeds whilst others are useful fodder grasses or soil-binders.

The first introduction was probably *Cynodon dactylon*, and with the search for better pastures in the late nineteenth century a number of European grasses were brought into the district, together with weed species such as *Avena fatua* inadvertently introduced in the process. The proportion of introduced species in the flora is increasing (see Chapter IV) and this is undoubtedly due in most cases to population movements between New England and other parts of New South Wales, though some deliberate introductions to other areas are obviously invading the region (e.g. *Chloris gayana* and *Cenchrus ciliaris*). It is apparent, however, that main roads and stock routes provide the principal avenues of distribution of introduced grasses, and from these ribbons of floristic development they may encroach into indigenous grasslands. The effect of the transport of livestock on grass seed dispersal is illustrated by the number of characteristically western grasses collected from Flemington saleyards, near Sydney, and preserved in the New South Wales National Herbarium.

Cereal grasses

Cereal farming was introduced to New England on a broad scale by freehold settlers in the second half of last century. With the exception of the Inverell district, wheat was abandoned because of low productivity and marketing problems. Other grains such as oats and corn have been cultivated on the tableland to a limited extent and are still grown as a commercial crop or, particularly in the case of oats, for stock feed. The Inverell area, with its fertile black soil and suitable climate, remains, however, the principal cereal production district, and supports crops of rye, barley, sorghum, oats and corn, as well as wheat.

These grasses have frequently escaped from cultivation or been spread by livestock and human agencies, and occur spontaneously along roadsides, on wastelands and near ploughed areas in the countryside surrounding and to the north of Inverell. *Sorghum vulgare* is often encountered along main roads on the tableland plateau, especially near Glen Innes and Armidale, and *Triticum aestivum*, *Avena sativa*, *Secale cereale* and *Hordeum vulgare* also make sporadic appearances near townships and beside highways on the tableland. *Zea mays* is rarely encountered outside field crops.

Improved pasture grasses

The major introduced pasture species in New England are indigenous to Europe and the Mediterranean region, whose climate is somewhat similar to the northern tablelands.

The well-known Ryegrasses (especially *Lolium perenne* and *L. rigidum*), Phalaris (*Phalaris tuberosa*), and Cocksfoot (*Dactylis glomerata*) are widespread throughout the tableland as the result of intensive pasture improvement practices. They do not easily invade native pastures without the prior establishment of clover, but are commonly seen along roadsides and in the vicinity of towns. Tall fescue grasses (strains of *Festuca arundinacea*) are also popular and have spread along main roadsides particularly in the northern half of the tableland. Prairie grass (*Bromus unioloides*) is very palatable to stock and easily eaten out, which coupled with its annual or biennial habit gives it very irregular persistence in pastures. It is very common in the vicinity of habitation. Timothy (*Phleum pratense*) is another introduced pasture species whose high palatability militates against its persistence in improved pastures.

In the early days of pasture improvement *Phalaris* *canariensis* and *P. minor* were tried in a number of sites, but they have been completely superseded by *P. tuberosa. Arrhenatherum elatius* (Tall oat grass) was also introduced in the nineteenth century but failed to persist, and is now an uncommon species in the Glen Innes district.

Africa has been the second major source of species superior to indigenous grasses for primary production, but most of the introductions were designed to cater for warmer conditions and some have invaded New England from the coast or western plains as adventives. *Cenchrus ciliaris* (Buffel grass) and *Chloris gayana* (Rhodes grass) are two examples of South African adventives which occur sporadically along main roadsides. *Brachiaria advena* has been introduced more or less accidentally to the Glen Innes district, but the Veldt grasses, *Ehrharta erecta* and *E. calycina,* have been sown for pasture improvement occasionally with moderate success, or established on dam walls to prevent soil erosion.

Urochloa panicoides (Liverseed) is a useful annual grass from India which is naturalised over much of the State but remains shy of the tableland climate. It has been found a number of times growing in the Inverell district and has been recorded from near Tenterfield.

Some other species introduced as possible pasture grasses have not been adopted for pasture improvement and have become naturalised in varying degrees.

Weed grasses

Several introduced grasses are troublesome weeds of crops or pastures and common components of roadside communities and township parks, gardens and paths.

The Wild oat is a prevalent nuisance in cereal crops and frequents most townships and main roadsides in the region. It is chiefly represented on the tableland by *Avena sterilis*, although *A. fatua* is also present.

Hordeum leporinum (Barley grass) is also a weed of cereal crops and often appears spontaneously in soil cultivated for sowing introduced pasture grasses. The nature of the awns and the ready disarticulation of the rachis provide ideal conditions for seed dispersal by livestock. This annual grass may occur in native pastures, especially if clover has been established and fertilizer applied for a couple of years, and frequently grows along roadsides and in the vicinity of settlements and towns. Barley grass can flower and set seed within 5 cm of the soil surface and reaches maturity quite rapidly, and being palatable only when young it is difficult to control by grazing management alone. The scabrous awns and sharp callus below the spikelets can cause irritation of facial areas of grazing sheep.

In recent years *Cenchrus pauciflorus* (Spiny bur grass) has been found growing in townships and has appeared as a weed in pastures along sandy river flats near Kingstown, and may be spreading elsewhere in the tableland (Walley, 1970b). Like Barley grass it has features which greatly facilitate seed dispersal, in this case in the form of retrorsely barbed spines projecting from the hard bur, each bur usually containing two or three spikelets. Also like Barley grass, it is an annual capable of early flowering close to the soil surface, but its foliage remains palatable. The burs easily catch in the wool of grazing sheep and constitute a serious vegetable fault in the fleece.

Pennisetum villosum (Feathertop or Squirrel tail), is a noxious weed, principally of townships. It is a caespitose perennial that spreads rapidly by dissemination of the spikelets with the attached involucre of plumose bristles, and being quite unpalatable can invade and dominate wastelands and pastures. At present it is spreading rapidly and causing some concern, since it has the potential of a tenacious and useless intruder onto fertile soils.

Another unwanted grass spreading over the tableland is *Eragrostis curvula*. This species has a number of sub-species or varieties or strains which exhibit considerable variation from one extreme to the other. Many taxonomists have distinguished *E.chloromelas* Steud. and *E.robusta* Stent from *E. curvula*, but Leigh's study of their leaf anatomy has demonstrated that the taxon contains a number of strains which should not be raised to the specific level (Leigh, 1961), and his approach is followed here. Two strains were tested at a research station near Glen Innes and elsewhere in

Australia on the basis of the reputation of *E. curvula* as an excellent fodder species in South Africa (Meredith, 1955). It would appear that either the grasses are not suited to Australian conditions or more likely that unpalatable strains were imported by mistake. They are avoided by livestock and develop large tussocks which can crowd out more useful species.

The two strains of *E. curvula* in New England differ mainly in their foliage. The strain generally called *E. curvula* is a tall erect perennial with long, straight, filiform, subglabrous leaves, light green in colour and often with a yellowish tinge. The strain often called *E. chloromelas* has shorter, filiform, hairy leaves which curl conspicuously and are usually dark green in colour with at times a bluish or glaucous appearance. Both strains are common in Tenterfield township and have been found along roadsides and invading pastures in the neighbourhood (Auld and Scarsbrick,1970). The first strain mentioned is radiating through the tableland along the main roadsides, and is now established almost as far south as Bendemeer.

Sorghum halepense (Johnson grass) is a roadside and township weed which tends to spread into fertile areas. It is moderately palatable as cattle feed but in certain seasons when young or stunted it can be cyanogenetic, forming a toxic principle which releases hydrogen cyanide in the rumen with fatal consequences. The tough rhizomes produced by this perennial sorghum can make eradication difficult. *Cynodon incompletus* also displays this phenomenon to a lesser degree.

A number of annual grasses accidentally introduced have become widespread and are relatively useless as fodder grasses. *Aira cupaniana* is a slender, short-lived annual that has become common in native grasslands. The Rats-tail fescues, in particular *Vulpia bromoides* (but also *V. myuros* and *V. megalura*), are widespread annuals in improved and native pastures and very prevalent along roadsides. They regularly appear densely in the first spring of a freshly sown pasture of introduced grasses, and bestow a browned-off character to the paddock in late spring when they have matured. After a few years, however, they become a very minor component of spring growth under proper management. There is a danger that the sharp callus on mature florets can penetrate tender parts of grazing sheep and cause considerable irritation. Common annual Brome grasses, such as *Bromis mollis* and *B. diandrus*, are conspicuous roadside grasses which lose their palatability as they mature and could be a nuisance in pastures, particularly after fertilization and clover introduction. Livestock usually graze them severely when young, however, and they only inhibit the utilisation of late spring pastures in paddocks perennially understocked. *Holcus lanatus* (Yorkshire fog) is an unwanted and unpalatable grass (except when young) which is established in a few isolated patches and has a sporadic distribution.

Serrated tussock *(Nassella trichotoma)*, from South America, appeared near Rockvale and Hillgrove during the last fifteen years, but it has been erradicated immediately on detection and, unlike the situation on areas of the soutnern tablelands, has never been a menace to New England grasslands.

The Barnyard grasses, *Echinochloa colonum* and *E. crusgalli*, together with *Digitaria sanguinalis* (Summer grass) and *Setaria glauca* (Pigeon grass), are sometimes troublesome in cultivation, especially on fertile soils. In general they are commonly found in and around townships, on waste places, and occasionally along main roads. *Agropyron repens* (English couch), *Eleusine indica* (Crowsfoot) and *Arrhenatherum elatius* var. *bulbosum* (Bulbous oat grass), could develop into weeds of cultivation and neglected pastures, but at present they are rare in New England, occurring near populated areas. Crowsfoot is relatively unpalatable and believed to be cyanogenetic.

Eragrostic cilianensis (Stink grass) can be a nuisance in cultivations and tends to frequent and at times dominate fertile areas in and around townships. It is palatable when young, however, and can be controlled by careful grazing management. *Cynodon dactylon* can also interfere with cultivations, and with its rhizomatous habit is often hard to eradicate.

Other introduced grasses

Species not covered in the above sections are largely common or sporadic adventives of roadsides and townships, such as

Bromus spp., *Poa* spp. (especially *P. annua*), *Briza maxima* and *B. minor* (which has successfully invaded a number of native communities), *Setaria* spp., *Paspalum dilatatum* (often considered a weed in townships), *Festuca rubra, Anthoxanthum odoratum, Lamarckia aurea, Catapodium rigidum, Agrostis gigantea, Koeleria phleoides* and *Alopecurus pratensis*. *Oryzopsis miliacea* and *Cortaderia selloana* grow ornamentally in Armidale, and the Common bent, *Agrostis tenuis*, has been used for lawns in the district.

Trisetum flavescens is a rare introduction near Pt. Lookout, and *Stipa neesiana* and *S. hyalina* are naturalised in the Glen Innes district. *Panicum laevifolium* and var. *contractum* occur in improved grasslands and neglected areas on the tableland.

Eleusine tristachya is found in the vicinity of towns and around sheepyards, and *Pennisetum clandestinum* (Kikuyu grass) is used for lawns and for binding the soil of dam walls. *Chloris virgata* is a roadside and township adventive in the Inverell district, and the more common *Hyparrhenia hirta* is a tall roadside dominant on the western slopes, encroaching onto the tableland plateau (recently found east of Armidale). The latter grass can form very dense strips along road margins and occasionally invades the adjoining grassland.

INDIGENOUS GRASSES

By far the greater part of New England grasslands are dominated by native species. Despite the extensive areas sown to introduced species and the aerial seeding of clover and grasses over the last twenty five years, more than 80% of the region is covered with indigenous grasses (Anon, 1964).

The following commentary on these native species is based on visual and subjective impressions of their frequency, distribution and structural niche in the grasslands, taking into account herbarium records at New England University and the National Herbarium, Sydney. This appraisal was compiled prior to the analysis of the grassland sampling reported in Section C, and provides a limited comparison of subjective and empirical approaches to the assessment of native grassland communities.

Common dominant grasses

The dominant grasses of the region are caespitose perennials, frequently tall-growing. The word "dominant" as used here refers to species which are the conspicuous components that give the grassland its characteristic appearance at first glance and appear to provide the bulk of herbage present. The prominence of inflorescences of specific grasses during their flowering period can easily influence the initial impression, and this bias has been taken into account and ameliorated by walking through the grassland to acquire a vertical perspective.

Tribe Andropogoneae contains the majority of dominant genera, and the reddish-brown colouration of the flat leaves of these genera confers a typical complexion to fields pervaded by

Andropogoneaceous species. *Themeda australis* (Kangaroo grass) is perhaps the best-known and widest-spread dominant. It is believed to be palatable, but its fodder quality is depressed when the foliage is mature or frosted in winter months. It is a very leafy perennial with long blades and forms pronounced tussocks, and in many respects resembles the next two species.

Cymbopogon refractus (Barbed wire grass) and *Sorghum leiocladum* (Wild sorghum) are widespread but not as common as *T. australis*, with which they are often associated and rarely occur as the principal dominant species of a community. *C. refractus* and *T. australis* do not withstand severe defoliation and will decrease under repeated heavy grazing. Annual burning and light grazing, however, can favour *T. australis* almost to the exclusion of other perennial species.

Bothriochloa macera (Red-leg or Red grass) is a very common species usually with more cauline foliage than *T. australis* and lower palatability. It readily assumes dominance under heavy grazing and on fertilised areas free of introduced species, and its somewhat geniculate-ascending habit may be reduced to a mat of leaves hugging the soil surface. The grass is hardy and persistent and often found in association with *Sporobolus elongatus*.

Red-leg and *Eulalia fulva* (Silky browntop) resemble one another in normal growth habit, but the latter is far more palatable, less common, and suffers population decline under heavy grazing. It favours sandy granitic soils, especially on the western slopes where its persistence may be due to lower stocking rates commensurate with the lower fertility. *Dichanthium sericeum* (Queensland blue grass) is also found chiefly on the western slopes and may become dominant on the fertile soils of the Inverell district and western slopes. It is a palatable, frequently glaucous perennial, popular as a fodder grass.

The seventh dominant in tribe Andropogoneae is the weed grass *Imperata cylindrica* var. *major* (Blady grass), which develops strong rhizomes well below the soil surface. Its foliage is usually erect, very scabrous on the blade margins and unattractive as fodder. Burning the topgrowth as a control measure simply allows the rhizomes to spread, and it can become dominant of large patches of grassland. Deep cultivation followed by dense seeding with clover and vigorous grasses can eventually choke it out.

The scabrous, narrow-leafed Tussocky Poas, *P. labillardieri* and especially *P. sieberana,* dominate widespread areas of native grassland, particularly on the tableland plateau and eastern highlands. The dark green colour of the spring growth and the bleached appearance of the mature and frosted, fine-leafed foliage produces a characteristic visual impression of *Poa* grasslands, contrasting with Andropogoneaceous communities. Only the young growth is palatable, and this factor has promoted the practice of early spring burning to hasten new growth. The mature tussocks are very dense but usually well-spaced, allowing other grasses to prosper in the substratum. Frequently *Poa* is the only dominant present, but in the western half of the area it is often associated with *Themeda* or *Aristida* spp.

Two Wire grass species, *Aristida ramosa* and *A. vagans*, are prevalent in many areas, particularly on the western slopes. *A. ramosa* is the more common species, and develops a large bulk of topgrowth arising from a comparatively small crown. This growth habit is achieved by the geniculate-ascending culms branching readily at the nodes and producing mainly cauline leaves. The blades are narrow, short, stiff, convolute for the most part, and the stems hard and wiry, producing herbage unattractive and unpalatable to livestock. The florets bear a sharp callus which can penetrate the skin of sheep and cause intensive irritation. Where the Wire grasses dominate the community they often form a closed canopy and allow only decumbent species or loosely tufted grasses in the basal layers, or even eliminate inter-tussock ground cover altogether. In general, they are very undesirable species whose establishment is thought to have been favoured by annual burning and overstocking. These practices will reduce litter and compact the soil surface, leading to greater run-off of rainwater and microclimatic extremes that allow wire grasses to compete successfully with softer and less hardy grasses.

Danthonia spp. (Wallaby grasses) are widespread throughout the region and highly regarded as fodder grasses, producing soft flat or rolled leaves in relatively short tussocks. They sometimes attain dominance in fertile soils on the tableland plateau and Inverell district, usually in association with co-dominants such as *Bothriochloa macera* and *Poa* spp. Usually they regularly occur as subdominants and minor species, and can be selectively depressed with continuous grazing. The principal New England species are *D. linkii, D. laevis, D. purpurascens, D. pilosa* and *D. racemosa*. Their persistence on low fertility soils is favoured in lightly grazed timbered areas free from annual burning. *D. pallida* is a tall robust perennial conspicuous on the rocky slopes of timbered hillsides.

Often associated with *Bothriochloa macera, Sporobolus elongatus* (Slender rats-tail grass) achieves co-dominance and sometimes exclusive dominance in moderately continuous or heavily grazed pastures on granitic and poor sedimentary soils. It is more palatable than Red-leg grass, however, though generally considered undesirable as a major component of the grassland. The tussocks are usually loosely tufted and readily choked by dense clover or early-growing introduced grasses.

Species of *Eragrostis* can sometimes occur as co-dominants in well-grazed pastures, though their tussocks are not conspicuous and their foliage is usually decumbent. *E. leptostachya* and *E. trachycarpa* are the most common representatives of the genus, but they rarely persist in high density.

Arundinella nepalensis (Reed grass) is a tall-growing, erect, densely caespitose and unpalatable grass occasionally dominant in patches on granitic soils, and is confined to the western side of the Divide.

Common sub-dominant grasses

The sub-dominant species are often decumbent, low-growing or stoloniferous, but in this category are also included caespitose grasses that contribute to the upper stratum of foliage as minor members of the community. All the grasses classified as dominants in the preceding section can occur in this capacity as secondary components sparsely distributed. The group of sub-dominants prevalent chiefly in open fields or savannah-type grasslands will be considered first.

Chloris truncata (Windmill grass) is a nutritious perennial often reduced to an annual condition by severe frosts in winter. Its high palatability leads to selective defoliation and it is usually maintained in a semi-prostrate habit. Windmill grass prospers in grazed and fertilised areas and is one of the most useful native species in the understory of tussock grasslands and is common in all districts apart from the eastern highlands.

Hairy panic grass, *Panicum effusum,* is an ubiquitous perennial in New South Wales with soft, light-green foliage particularly palatable when young. Unfortunately the immature leaves can cause photosensitisation in sheep, but its sparse occurrence in New England would not warrant any anxiety.

Digitaria brownii (Cotton panic) and the introduced *Cynodon dactylon* (Couch) are decumbent and stoloniferous species respectively, commonly growing in the lower foliage strata and frequently occurring in association. Of the two, Couch grass is the more tenacious and prevalent, occasionally dominating neglected fields after cultivation and capable of withstanding heavy grazing.

Three *Eragrostis* species, *E. brownii*, *E. elongata* amd *E. molybdea*, sometimes rank as sub-dominants. *E. brownii* is the most common, and, like *E. trachycarpa*, it often appears in association with *Bothriochloa macera* and *Poa* spp. These Love grasses are moderately palatable perennials rarely developing a densely tufted habit.

Dichanthium setosum is a relatively common, erect perennial found in lightly grazed pastures, though never observed in high density. The same may be said of the somewhat decumbent *Agropyron scabrum* (Common wheat grass). *Dichelachne sciurea* also remains an insignificant member of grassland communities, but it is conspicuously widespread and occurs in practically every New England grassland examined.

As stated in the previous section, many *Danthonia* spp. grow as sub-dominant tufted grasses in the region. To those already mentioned could be added *D. induta* and *D. richardsonii*. In growth habit and frequency the sub-dominant *Danthonia* plants resemble the Corkscrew grasses (or Spear grasses) of the *Stipa* *variabilis* complex, the latter being more common on the western slopes with narrow, often filiform leaves of lower palatability. *Stipa* spp. provide useful fodder, however, due in particular to their drought resistance and hardy character, but the sharp callus on their florets can be as irritating to sheep as that of *Aristida* spp., if not more so, and this detracts from their pastoral value.

A couple of spring annuals are very common in native pastures. These are the indigenous *Agrostis avenacea* and the introduced *Aira cupaniana*. Neither is a valuable fodder grass.

Several sub-dominants comprise a small group found principally in wooded and protected areas. Many *Danthonia* grasses occur in such habitats, together with *Microlaena stipoides* and *Echinopogon* spp., especially *E. caespitosus* and *E. intermedius*. Like their uncommon and rare fellow-inhabitants of protected areas, these grasses are generally soft-leaved palatable species with geniculate-ascending culms not forming dense tussocks.

Uncommon and rare grasses

All the species considered in the above discussion of common grasses are more or less widespread in other regions of New South Wales, apart from *Dichanthium setosum* and *Danthonia induta*, which are both generally confined to the northern tablelands. Unlike the bulk of common grasses, many of the uncommon and rare New England species are more sensitive to environmental conditions and unable to survive the warmer habitats on the coast or western plains. These characteristically tableland grasses belong to genera such as *Deyeuxia, Festuca, Echinopogon, Danthonia* and *Poa.*

On the other hand, some uncommon New England grasses are principally species of the coastal districts of New South Wales that encroach onto the high rainfall areas in the eastern half of the tableland (e.g. *Entolasia* spp. and *Oplismenus* spp.), or whose distribution is discontinuous, by-passing the eastern high altitudes and re-appearing on the western slopes (e.g. *Alloteropsis semialata* and some *Digitaria* spp.). Similarly, a proportion of minor members of the New England grass flora are typical western plains grasses whose eastern limit reaches the western slopes and tablelands (e.g. some *Chloris* spp. and some *Aristida* spp.).

The distribution behaviour of New England grasses facilitates classification based on geographical divisions in an east-west rather than north-south direction, i.e. along the steepest climatic gradient. Generalised differences in gross morphology can be associated with this gradient insofar as uncommon and rare species in the eastern half of the region are frequently soft-leaved, decumbent or loosely caespitose (with notable exceptions in the form of *Poa* spp. and some *Stipa* spp), whilst those in the western half of the region are usually densely caespitose and more rough and coarse (apart from such species as *Digitaria ramularis* and *Eremochloa bimaculata*). In the following notes, the rare and uncommon indigenous grasses are considered in more detail in terms of distribtuion patterns from the western plains to the coast.

By extending the New England region to Inverell and the western slopes north and south of the town, a number of grasses are included in the flora which are common species on the drier and warmer western plains. Some of these grasses encroach onto the western margin of the study area but are unknown at higher altitudes or in coastal districts. *Leptochloa digitata, Themeda avenacea* and *Diplachne fusca* are caespitose perennials that fall into this category. The same applies to *Panicum decompositum, Aristida leptopoda, Agropyron scabrum* var. *plurinerve, Digitaria coenicola, Chloris acicularis, C. divaricata, Paspalidium globoideum* and *Enneapogon gracile.*

On a narrow stretch of soil derived from serpentine parent material near Woods Reef, outside the study area, an isolated patch of *Triodia irritans* var. *laxispicata* may be found, at times the exclusive herbaceous perennial occupying the manganiferous soil. This grass occurs on similar soil types to the south and also on the western plains.

Several characteristically near or far western plains species penetrate further onto the slopes and/or tablelands, such as *Tragus australianus,* species of *Aristida* (except *A. warburgii*), *Paspalidium constrictum, P. gracile, Chrysopogon fallax, Cymbopogon obtectus* (rare), *Danthonia eriantha, Stipa setacea* and *Dichanthium affine.*

Digitaria coenicola var. *ramosa* and *Bothriochloa bilboa* have a range restricted to the north west slopes, but *Bothriochloa bladhii, B. decipiens, Eragrostis parviflora, Echinopogon ovatus, Paspalidium aversum* and *Panicum queenslandicum* are distributed from the western plains through the northern tablelands to the coastal districts.

Understandably, a substantial portion of the uncommon species are typical tableland grasses sparsely ranging along the Great Divide and often extending to the western slopes. Species in this group are *Danthonia carphoides, D. monticola, Dichelachne crinita* and *D. rara* (both also occurring on the coast), *Poa sieberana* var. *hirtella, P. costiniana, Festuca eriopoda, Agrostis hiemalis* and the less common *A. venusta*. In addition there are *Echinopogon cheelii, Enneapogon nigricans, Pentapogon quadrifidus, Amphipogon strictus, Stipa mollis,* and *Deyeuxia* spp., apart from *D. acuminata* which is confined to the northern tablelands.

Other grasses found in New South Wales only on the northern tablelands of New England are *Echinopogon phleoides, E. mckiei, E. nutans* var. *major,* and *Festuca asperula. Danthonia racemosa* var. *obtusata* and *Panicum queenslandicum* var. *acuminatum* are typically New England grasses radiating westward.

Alloteropsis semialata, Hyparrhenia filipendula and *Digitaria diffusa* are coastal grasses occurring rarely in the western half of New England. *Chloris ventricosa* is by no means rare on the western slopes, but has a similar pattern of distribution, as does *Eriochloa procera* which grades into *E. pseudoacrotricha* west of the tableland. Other coastal grasses extending onto the tablelands are *Cenchrus australis*, *Digitaria ramularis*, *D. diminuta*, *Panicum simile*, the rare *Arthraxon hispidus*, *Eremochloa bimaculata*, *Eragrostis philippica*, *Aristida warburgii*, *Dichanthium tenue*, *Heteropogon contortus*, *Sacciolepis indica*, *Leptochloa decipiens*, *Hierochloe rariflora*, *Capillipedium spicigerum*, *C. parviflorum*, *Stipa ramosissima*, *Danthonia longifolia*, *Panicum bisulcatum*, *Deyeuxia quadriseta* and *Agrostis aemula*. This group also includes *Entolasia* spp., *Oplismenus* spp., *Setaria australiensis*, *Poa queenslandica* and *Stipa pubescens*, which are all found in the eastern half of the region in high rainfall timbered areas.

SECTION C

'NATURAL' GRASSLANDS

In the absence of subsequent reports, Roe's preliminary survey of grazed native pastures in the Armidale district (Roe, 1947) remains the principal authority on the structure and composition of New England grasslands. The following study is an attempt to broaden existing knowledge of the region by selecting study sites over a wide area, and by concentrating on communities which appear to persist in their 'natural' state. It is difficult to imagine that any areas have completely escaped the influence of pastoral management, and in the context of this report 'natural' grasslands are deemed to mean communities least affected by pastoral interests.

An account of the survey is preceded by a short review of literature undertaken to assess the relative merits of methods used in grassland analysis, with particular attention given to the point quadrat technique.

VIII

POINT QUADRAT ANALYSIS

- A REVIEW -

Introduction

Quantitative analysis of vegetation has become an increasingly important tool in the study of plant communities, particularly with regard to methods other than separating and weighing clipped samples. There has been considerable development in this field since 1907, when Armstrong reported percentage cover determined with a foot square grid divided into square inches, showing a high correlation with weight analysis. The various techniques that have evolved for the measurement of plant cover frequency and density have been reviewed by Tansley and Chipp (1926), Gates (1949), Brown (1954), Kershaw (1964), Cain and Castro (1959), Tothill and Peterson (1962), Branson (1962) and Greig-Smith (1965).

Apart from charting, weighing, and square quadrat assessments, the most popular methods for estimating ground cover and frequency are the line transect of Canfield (1941) and the point quadrat of Levy (Levy and Madden, 1933). Variations of these methods have led to individual approaches, such as the Percentage Absence Method of Blackman (1935), the Point-Observation-Plot technique of Stewart and Hutchings (1936) and the loop method used by Short (1953) and Sharp (1954).

Adaptations of point sampling procedure are demonstrated by (i) Bitterlick's plotless method for estimating timber and shrub cover (Grosenbaugh, 1952), slightly modified by Cooper (1957,1963) as the variable plot technique, and utilised for grassland community analysis by Hyder and Sneva (1960), (ii) the point-centred quarter method developed by Cottam and Curtis (1956) for sampling tree and sapling vegetation and applied to grassland by Dix (1961) and Heyting (1968), (iii) the wandering quarter method of Catama (1963) derived from the point-centred quarter approach, and (iv) the contact sampling method (Yarranton, 1966) for measuring spacial inter-specific association patterns.

Evaluation of Methods

The validity of several sampling techniques relies on random distribution of individuals in a community, but as early as 1936 Clapham showed that distribution tended to become non-random at high densities, and Pidgeon and Ashby (1940) reported that although species of moderate density were randomly distributed, a species with random distribution in one area may be aggregated in another. Goodall (1952b) and Kershaw (1964) pointed out with substantial evidence that an aggregation pattern of species distribution will always be present in vegetation, particularly for the common species, due to environmental and sociological factors.

Crocker and Tiver (1948) deduced that non-randomness of the spatial distribution of individuals in the population demerits the value of the Percentage-Absence method of detecting plant density. The same aggregation factor will produce misleading results from the point-centred quarter method (Cottam and Curtis, 1956), and led Risser and Zedler (1968) to discourage its use unless data are checked against quadrat density counts.

Through their investigation of the loop method for measuring plant cover, Hutchings and Holmgren (1959) discovered bias could occur with varying plant sizes and shapes, as well as due to species aggregation. Kinsinger et al (1960) and Cook and Box (1961) found that the loop method over-estimated cover of shrubs, but the latter authors reported that it under-estimated grass cover compared to point quadrat sampling. A contrasting conclusion was presented by Johnson (1957) who discovered that measurements of basal cover in grasslands by the loop method were two or three times the values obtained by vertical point sampling. In general, the reliability of the method for grassland analysis is questionable (Hutchings and Holmgren, 1959).

The variable plot technique is rapid with a low coefficient of variability (Schultz et al, 1961), but for grassland analysis it can only readily be applied to measuring cover of clumps of tussock grasses (Hyder and Sneva, 1960), and its accuracy is dependent upon a regular circular shape for each clump (Cooper, 1963).

Basal cover in a grassland community determined by Bitterlick's plotless method was considerably faster than the line intercept technique but produced a far higher value (Hyder and Sneva, 1960). Though speed is also the main advantage of the Point-Observation-Plot method, the subjectivity involved in its application (Smith, 1944) has, however, excluded it from standard range survey procedures.

The wandering quarter method is a specialised technique for measuring population density and the distribution pattern of a species.

Like the contact sampling method for assessing inter-specific associated, it gives no assessment of plant cover.

The three principal methods by which plant cover can be determined are the grid quadrat, line transect (intercept) and point quadrat. Winkworth et al (1962) compared these three techniques on an arid grassland and found that they provided comparable and equally reliable estimates. Parity between line transect and clipped quadrats in plant density evaluations was obtained by Evans and Cain (1952), whilst Heady et al (1959) reported matching values for plant cover determined by charting, line transect and point sampling. In a study comparing a number of methods for assessing botanical composition of Mediterranean grassland, Naveh et al (1963) found that point quadrat estimates approximated weights of hand-separated samples. The similarity of data from the line transect and point quadrat methods was noted by Brun and Box (1963) with a botanical composition study, by Whitman and Siggeirson (1954) with results of a plant density analysis, and by Johnson (1957) in terms of basal area assessment. Kinsinger et al (1960) found that point quadrat measurements over-estimated plant cover when compared to the line transect method, using "true cover" of charted crowns as a standard. In a theoretical study of plant cover analyses, however, Schultz et al (1961) reported that point quadrat data deviated only 1.2% from the true value, whilst results obtained by the line intercept method had an error of 2.5%.

Assuming approximately equivalent accuracy for the three methods, the question of suitability for survey work was considered, particularly with regard to efficiency of sampling. Since the grid quadrat technique is known to be slower than other methods (Winkworth et al, 1962; Naveh et al, 1963; Penfound, 1963), the selection of a suitable technique was confined to a choice between line interception and point quadrat. For Heady et al (1959), line intercept measurements took less time than point samples, but other workers have found that the reverse is the case, especially when studying grassland vegetation (Crockett, 1963; Johnson, 1957) as opposed to shrub communities (Brun and Box, 1963). Though it may be slower, Johnson (1957) reported that the line interception method detected more species than the point quadrat technique, which was subsequently confirmed in relation to species with less than 3% ground cover (Heady et al, 1959).

An appraisal of the literature cited above favours the point quadrat method for reliable and efficient estimation of plant cover, and particular aspects of the technique are considered in more detail.

Point Quadrat Analysis

The point quadrat method of analysis was developed in New Zealand in the 1920's by Levy (1927). As acknowledged by Levy and Madden (1933), the method derives from Cochayne's technique for studying tussock grassland, which employed a point on the toe-cap of one boot as the sampling point (a convenient method which has persisted in range studies, e.g. Evans & Love 1957). The apparatus they devised consisted of a frame holding a row of ten pins, 2 in. apart, which were lowered vertically into the foliage, a "hit" occurring whenever a pin connected with a leaf but only one hit per species being recorded for each pin. The set of ten pins were "read" at randomised sites over the study area. Levy and Madden found that 400 to 500 points were sufficient for a valid estimation of cover for both dominants and minor constituents of the grassland, which was supported by Crocker and Tiver (1948).

Modifications of the technique have been to sample with only one pin, to use an inclined rather than a vertical setting, to reduce the area of the pin point, and to increase the information obtained from the sample.

i Single pin sampling

Blackman (1935) suggested that sampling with only one pin would give a more accurate assessment of plant cover than the results from a frame of ten pins, for the same number of points. This was confirmed by Goodall (1952a), who showed that the probability of a strike varies less within frames than between frames, and though single pin sampling demanded more time per point, 670 samples gave the same precision as 2000 frame points.

Goodall was concerned by the scope for subjectivity in the placement of a single pin, and recommended using a randomly selected pin from a frame of ten. Objectivity was achieved without compromise by Tidmarsh and Havenga (1955) by spacing the samples systematically over the study area from a randomly chosen starting point. Provided the distance between points exceeded the average diameter of individual plants, the data conformed to a binomial distribution, which is what Kemp and Kemp (1956) obtained from Goodall's (1952a) results.

Broembsen (1964) has since tested the relationship between pattern, size of individual and spacement of sampling points using analogous situations in electronic circuits. He found that variance decreased as point spacement increased, and that the distribution of sample data was binomial in random populations where the point spacement exceeded the average size of individuals.

ii Inclined pins

An inclination of 45° was used by Tinney et al (1937) for point quadrat analysis, and this modification has been followed by others (e.g. Arny and Schmid, 1942; Hein and Henson, 1942; Leasure,1949; Musser, 1948; Kim,1964,1967). Drew (1944) found that when the vegetation was only 4 in. high inclined pins were more accurate than vertical pins, but that with foliage 6 in. high the latter gave better results. Drew's data was tested by Winkworth(1955), who discovered that the difference between pin settings was not significant and regarded Drew's conclusion as invalid. He went on to compare vertical and inclined pin sampling in detail with a percentage cover analysis of heath vegetation in Victoria and found that though inclined pins made more contacts with the foliage, there was no appreciable difference between the methods for estimating the percentage contribution of each species.

For measurement of foliage areas as opposed to percentage cover, Wilson (1959a) has demonstrated that vertical points underestimate erect foliage. He was able to minimise distortion of the value for leaf area index caused by differing leaf angles by using pins inclined at 32.5° (Wilson, 1959b), and was able to determine foliage density and average leaf angle by relating data from pins at differing inclinations (Wilson, 1963a).

iii Size of point area

In his discussion of the use of point quadrats for vegetational analysis, Goodall (1952a) concluded that the smaller the pin diameter the more accurate were the estimates of percentage cover. Wilson (1963b) supported a theoretical study with field tests to show that the error of over-estimation of relative frequency is doubled by doubling the pin diameter for a given leaf width. He had pointed out, however, that the error can be avoided by recording only contacts with the sharp point and ignoring contacts on the sides of the pin (Wilson, 1959b). As leaf width decreases, the tendency toward over-estimation of cover increases proportionately, and measurement with a point of minimal area becomes more important.

An optical point quadrat employing the cross-wires at each end of a tube (Winkworth and Goodall, 1962), or an ocular point frame of 2 sets of cross-hairs (Stant, 1960), completely avoids errors arising from the point area of a pin, but this refinement can prove difficult where foliage overlaps (Winkworth, 1955).

iv Detail of sampling records

The simplest estimate of plant cover is basal area, as used by Coupland (1950), Robinson (1955) and Tidmarsh and Havenga (1955). Rapidity, ease of measurement and relative independence of seasonal and annual fluctuations in perennial herbage are the advantages of basal data, but low-growing species tend to be over-estimated (Nagel, 1967). Likewise, recording only the first species with which contact was made (e.g. Tinney et al, 1937) underestimates the percentage cover of lower-growing species (Goodall, 1952a).

Recording all contacts made by the pin-point has been used to estimate productivity and herbage weight (Drew, 1944; Hughes, 1962; Olusuyi and Raguse, 1968), though some have found the correlation unsatisfactory (Sprague and Myers, 1945; Arny and Schmid, 1942). Goodall (1952a) used all-contacts data to estimate cover repetition and the percentage each species contributed to the pasture sward.

Using pins graduated in inches, Spedding and Large (1957) recorded every contact of the pin-point, and once the pin had reached the ground they noted the number of hits for each inch, recording the species separately. In this way they estimated plant height and density of species in a grassland sward.

Roux (1963) was able to estimate canopy spread as well as basal and canopy cover by recording a "strike" when the point descended within the perimeter of a plant's canopy but failed to make contact with it. A graduated pin enabled him to evaluate the height of the densest stratum of vegetation and assess layering in the community.

v Conclusion

For satisfactory utilisation of the point quadrat method to determine plant cover, apparatus employing a single pin is preferable to a frame of ten pins. An inclined pin provides no appreciable advantage over a vertical pin for plant cover estimation. Care must be taken to maintain a point of minimal area, and only contacts with the pin-point are recorded as "hits". In order to avoid bias in the data, each sample record should register foliage between the first hit and the basal strike.

IX

EXPERIMENTAL

Method

The apparatus and procedure employed are described for a survey of ten areas of 'natural' grassland. The sites were sampled in late spring and early summer of 1970, at the end of an unusually favourable spring season.

i Sites

Suitable areas of 'natural'grassland in the region were sought to provide sites for a point quadrat study. The aim was to locate grasslands which did not appear to have been cleared of timber, which showed little or no evidence of grazing or burning, and which were free of exotic species. It was believed such areas would bear the greatest possible resemblance to the vegetation as it existed at the time of European settlement.

A careful survey of the region indicated that grasslands approaching these specifications could generally be found in fenced-off stock routes, which are now neglected for livestock movement as droving has been superseded by motor transport. Eight of the ten sites selected are on stock routes, the other two (sites 1 and 3) being areas lightly grazed by cattle. In general, patches of 'natural' grassland are widespread in New England, apart from the Walcha district where each possible site investigated had been invaded by clover and/or introduced grasses.

The localities of the ten sites chosen are illustrated in

FIG 4

SITE LOCALITIES

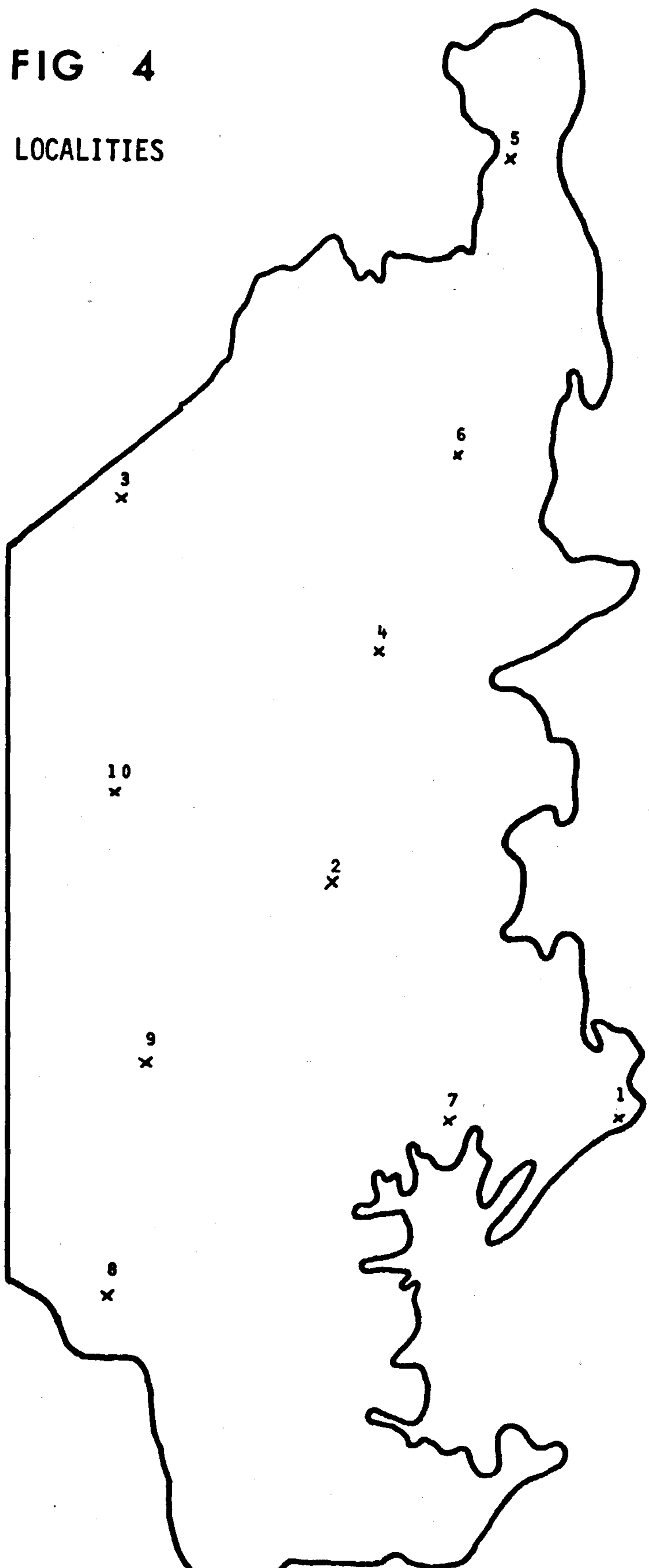


Plate 1: Site 7

Plate 2: Site 8

Fig. 2b and Fig. 4. They occur on the main soil types in the region, and range from the high lands to the western slopes. The elevation, aspect, parent material, soil type and dominant tree species for each sample area are presented in Table VIII. The sites are all woodland communities with a dense herb stratum, a closed to moderately open tree canopy, and a sparse shrub layer. Typical examples of the study areas are illustrated in Plates 1 and 2.

ii Apparatus

The principal features of the sampling device, illustrated in Fig. 5, are derived from Roux (1963), who attached a supporting bracket to one side of a wheel for carrying and operating the sampling pin. For the present survey, a frame was fitted to the fork of a 24 in. bicycle wheel so that the pin is borne in front of the wheel.

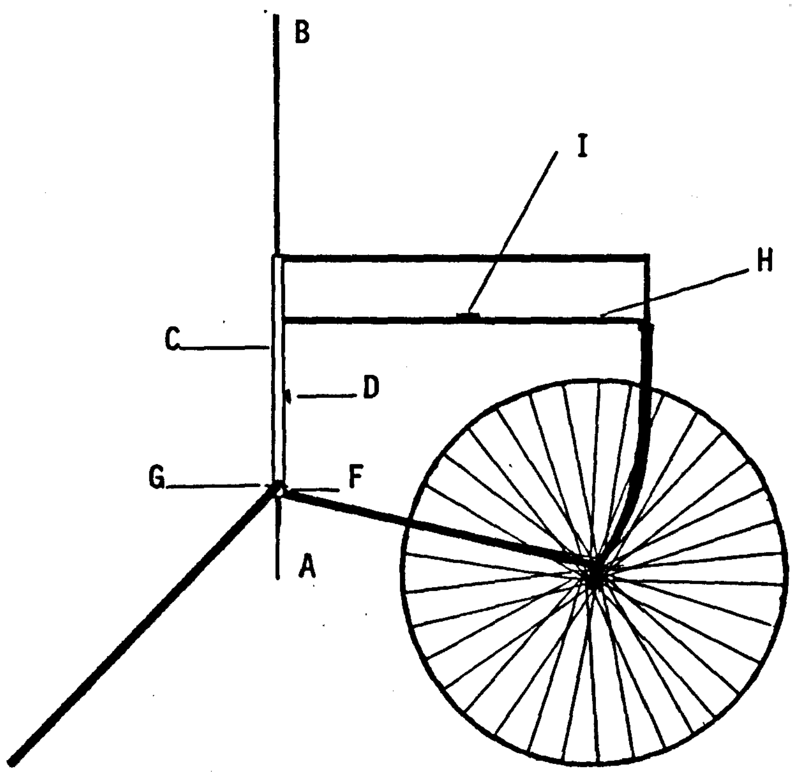
The 3 mm sampling pin (A) is welded to a steel rod (B), 9 mm in diameter, which freely slides down the shaft (C) and may be fixed in position or its movement restricted by the thumb screw (D). The shaft is firmly held to the fork of the wheel by a metal frame, and may be supported in an erect position by two front legs which spread at an angle from the pivot point (F). For ease of conveyance, the legs may be swung back to the wheel rim or up to the shaft. While operating the pin on a transect, the legs

TABLE VIII

FEATURES OF SAMPLE AREAS

Site No.	Locality	Approx. Elevation (ft.)	Aspect	Parent Material	Soil Type	Dominant *Eucalyptus* sp.
1	1 m. south-west of Point Lookout	4,500	Northern	Basalt	Red loam	*E. fastigata* *E. viminalis*
2	$8\frac{3}{4}$ m. north of Guyra	4,300	(flat)	Basalt	Chocolate	*E. pauciflora*
3.	11 m. east of Ashford	2,200	(flat)	Basalt	Black earth	*E. melliodora*
4.	$8\frac{1}{2}$ m. north of Glen Innes	3,400	Western	Porphyry	Podsolic	*E. melliodora*
5.	26 m. north of Tenterfield	3,300	North-eastern	Granite	Podsolic	*E. caliginosa*
6.	$1\frac{1}{2}$ m. north of Bolivia	3,300	Eastern	Granite	Podsolic	*E. rubida*
7.	19 m. east of Armidale	3,300	Northern	Granite	Podsolic	*E. caliginosa*
8.	6 m. north-east of Bendemeer	3,100	North-eastern	Granite	Podsolic	*E. laevopinea* *E. maculosa*
9.	5 m. north-east of Yarrowyck	3,100	Northern	Granite	Podsolic	*E. blakelyi*
10.	$3\frac{1}{2}$ m. North of Tingha	2,000	(flat)	Granite	Solodic	*E. blakelyi*

FIG 5 WHEEL-POINT APPARATUS



Scale: 1 mm = 2·1 cm

are fixed in the correct position with thumb screws (G). With the bar (H) constructed perpendicular to the shaft, a spirit level (I) on the bar facilitates front leg adjustments in order to keep the pin vertical.

Two marks on the inner side of the wheel rim allow two point quadrats to be sampled for each revolution of the wheel, i.e. once every 90 cm.

iii Procedure

The apparatus described above allows samples to be taken at regular intervals along a straight line transect. Since sample points are spaced at a distance exceeding the average diameter of grass plants, any distortion of a possible binomial distribution of data is avoided. Prior to operating the pin, the point was sharpened with a file, and maintained in a sharp condition with repeated filing whenever necessary.

Within each site a relatively uniform area was selected, free from any roadside effects with regard to sites on stock routes along roadways. Two transects were sampled in the selected area, each transect providing 100 points (i.e. 89.1 metres long). The starting point was chosen at random by an assistant, or in the absence of a companion a stick was thrown over one shoulder to fix the first point. The direction of the transect was at right angles to the avenue of access to the study area. The distance between transects was between 10 and 15 metres.

At each sampling point, the pin was lowered onto the vegetation and encounters with plants were recorded in the following way. If the point descended within the perimeter of the canopy of a plant, a spread, "S", was recorded. A contact with a leaf or stem was noted as a canopy hit, "C", only one hit being recorded for each plant. In the event of a hit occurring, any "S" record was negated for that plant. Should the pin-point descent within the rooted crown of the plant, a basal strike, "B", was recorded. A "B" score for a plant cancelled any previous "S" or "C" record. Frequently, the canopies of two or more plants overlapped at the sampling point, and in such cases a record was taken for each plant.

The sampling procedure described above is largely adapted from Roux (1963).

For each grass plant recorded the species was noted; non-gramineaceous plants were classed together as "herbs". The determination of grasses which were not in flower required practice and experience before the survey was attempted. For this purpose thirty sites were roughly sampled between Armidale and Inverell using a mark on the toe-cap of a boot as the sampling point, along the lines of the method employed by Evans and Love (1957). In this way, familiarity with the vegetative characters of common species was obtained, but occasionally in the survey the identification of species encountered proved difficult. When no nearby flowering grasses corresponded with the unknown plant, a sample of a shot was collected and preserved, and subsequently the site was re-visited until the specimen could be matched with a species in flower.

Point quadrat sampling in the manner described becomes difficult during windy weather. Fortunately, this factor was insignificant during sampling periods.

Results

The data obtained at site for basal hits, canopy contacts and canopy spread are presented in Tables X to XIX in Appendix III. The Total Canopy Spread for each species has been obtained by summing the records of basal hits, contacts and spread, and expressing the sum as a percentage of the number of points sampled at each site. Table IX gives the site figures for Total Canopy Spread for herbs and grass species recorded in the survey. In order to highlight high-scoring species, percentages over 25 have been underlined.

TABLE IX

Total Canopy Spread For Species At Each Site

	1	2	3	4	5	6	7	8	9	10
Poa sieberana	92	75.5		7.5	2.5		8.5	5.5	9	
Themeda australis	32	64.5	2	89	104.5	21.5	117.5	4.5	62.5	37
Danthonia racemosa	10.5		1.5		5	0.5		2.5	5	
Dichelachne sciurea	9.5	10.5	2.5	4.5	2.5	3.5	0.5		2	3.5
Danthonia pilosa	4			6		0.5	0.5	11.5		
Eragrostis leptostachya	1.5			1		1				
Danthonia laevis		11						0.5		
Agropyron scabrum		8.5	1.5	2				3.5		
Danthonia purpurascens		6								5.5
Agrostis aemula		5								
Sorghum leiocladum		4	0.5	28	5.5	85	3.5		5.5	3
Microlaena stipoides		2		1.5	9	3	3	4.5		1.5
Sporobolus elongatus		0.5		2		4.5	3.5	3.5	4	
Bothriochloa macera		0.5	4.5	7		8.5		3		
Dichanthium sericeum			37							
Bothriochloa biloba			17							
Aristida ramosa			13.5	2		0.5	3.5	58	56.5	28
Poa sieberana var. *hirtella*			9					1		
Danthonia racemosa var. *obtusata*			7.5							
Danthonia linkii			5.5							
Cymbopogon refractus			3						3	
Chloris acicularis			1							
Chloris truncata			0.5							
Eragrostis brownii			0.5			0.5	0.5	4.5	1	0.5
Panicum effusum				0.5		1		1		
Vulpia bromoides				0.5						
Imperata cylindrica var. *major*					3.5		1.5			
Poa labillardieri					3				17.5	
Echinopogon caespitosus					1.5		0.5			2
Deyeuxia mckiei					1					
Aristida vagans						1.5		5	0.5	
Digitaria brownii							0.5			
Aira cupaniana							0.5	4	0.5	
Danthonia eriantha								8.5		
Tripogon loliiformis								6	0.5	
Vulpia myuros								1.5		
Eulalia fulva								0.5	1	13.5
Echinopogon intermedius									0.5	
Arundinella nepalensis										43.5
Eremochloa bimaculata										25.5
Aristida warburgii										5
Herbs	27	33.5	19.5	37	20.5	33.5	17	16.5	21	38
Bare ground (percentage points)	6.5	4	12.5	6.5	6.5	5	4.5	4.5	4	5

Discussion

The principal feature of the data in Table IX is the prevalence of *Themeda australis*, *Poa sieberana* and *Aristida ramosa*. Apart from the Wire grass, the other two species are rated in a minor class in Roe's survey (Roe, 1947).

The author appreciates the need for caution in making conclusions on the basis of the data collected. Two hundred points per site is not regarded as a sufficient record for valid statistical analysis. A sample of 500 (Crocker and Tiver, 1948), or preferably 1000 points (Roux, 1963), would have provided an adequate sample for establishing statistical relationships between the species in each grassland and between types of grassland. In particular, the data provide too few foliage contacts, and interpretation of results relies heavily on records of canopy spread. Though this limitation is acknowledged, the differences in canopy spread between various components of the grassland are so pronounced that a useful indication of grassland composition may be deduced from the survey. Observations are mainly confined to species with high scores for canopy spread.

Themeda australis is clearly the most common species encountered, both on basaltic and granitic soils and irrespective of elevation. *Poa sieberana*, on the other hand achieves its strongest representation on sites over 4,000 on basaltic soils, whilst *Aristida ramosa* is a common species of western slopes communities, especially on podsolic and solodic soils. *Sorghum leiocladum* contributes substantially to grasslands on the main tableland plateau, even ranking as a dominant on some poorer soil types.

The *Poa sieberana* grasslands contain *Themeda australis* as a major component, and *Sorghum leiocladum* is also a common companion species of *Themeda australis.*

A familiar grass to the west of the region, *Dichanthium sericeum,* can predominate on fertile soils on the low western slopes of New England. The tall-growing *Arundinella nepalensis* flourishes in patches of solodic soil west of the Divide, particularly in damp areas (such as site 10), where *Eremochloa bimaculata* may make a significant contribution to the ground stratum.

In structure, the 'natural' grasslands are dominated by caespitose perennials, often one species being the sole dominant, with a mixture of short tufted or decumbent perennials and annuals between the dominant tussocks. The communities are strongly perennial in character. Various herbs, in particular members of the Cyperaceae and Compositae, occur in relatively high frequency. This perennial character and strongly developed herb layer resembles the native pastures examined by Roe.

Of the lesser species, the results reveal a high site frequency for *Dichelachne sciurea* and *Microlaena stipoides.* Though the former appears to occur randomly in the grassland communities, *Microlaena stipoides* tends to aggregate within the shelter of trees, and registered its scores as the transects passed near the trees on a site.

A number of *Danthonia* spp. are recorded in the survey, but in general they occur in a minor category. This evidence contrasts markedly with Roe's conclusions, in which a pasture type is characterised by the dominance of Wallaby grasses. Similarly, though Roe recognised a Red-leg type pasture, *Bothriochloa macera* received low scores in the present study. The difference in the results between the two surveys is further highlighted by the high specific frequencies in Roe's pastures of *Chloris truncata, Panicum effusum* and *Eragrostis trachycarpa,* all of which are insignificant in, or absent from, the 'natural' grasslands examined. Even Roe's Wire grass dominant pasture contained high proportions of species which are insignificant in the 'natural' pastures.

The profound differences between Roe's description of native pastures and the results obtained for 'natural' grasslands could be due to the influence of pastoral management practices on native pastures in the Armidale district. The discussion of the grass flora in Chapter VII specifies an increase under grazing management in the frequency of species such as *Bothriochloa macera, Sporobolus elongatus* and *Chloris truncata,* which corresponds to the pasture compositions reported by Roe.

By inference, the effect of grazing management, at least in some areas, has been to depress the original perennial dominant in favour of formerly minor species in the community. Moore (1964) denotes a change of this kind as the first step in a pattern of community adjustment to grazing pressure. Though the effects of light stocking may be absorbed with little disturbance, a heavy stocking rate is likely to alter pasture composition substantially (Gillard, 1969). Moore (1953) has reported a response to grazing in terms of promotion of *Bothriochloa macera* dominance, and related it to the competitive advantage of the low-palatable Red-leg under heavy grazing (Moore 1959).

In addition to grazing by domestic livestock, native pastures could be severely affected by other factors associated with pastoral management. Clearing the timber or ringbarking will limit the favoured habitats of species such as *Microlaena stipoides* and *Echinopogon* spp. A reduction in infiltration (Costin, 1962) and an increase in water stress (Story, 1967) are likely to follow in the wake of clearing.

The effects of burning native grasslands in late winter or early spring, as practised on a regular basis by some graziers, are difficult to assess. Norton and McGarity (1965) and Tothill and Peterson (1968) have shown that grass fires produce a negligible rise in surface soil temperature, and, though root-death may occur (Tainton and Booysen, 1965), the main effects of fire on grasses is conveyed indirectly through successive changes in the top cm of soil (Stephenson and Schuster, 1945).

Fires reduce or remove litter and mulch (Ahlgren, 1960; Dix, 1960), which will allow the soil surface to dry out (Glendening, 1944), lead to compaction (Flory, 1936; Shaw, 1956), lower infiltration rates and encourage erosion (Beutner and Anderson, 1943; Dyksterhuis and Schmutz, 1947). Livestock tend to concentrate their feeding on the accessible early growth that appears on burned areas (Shaw and Bisset, 1955). The increase in run-off and consequent reduction in effective rainfall, with heavy defoliation of spring shoots, can understandably upset the ecological balance of grassland communities (Ehrhenreich, 1959). Some authors have reported promotion of *Aristida* spp. as a result of burning (Henderson, 1949; Reynolds and Bohning, 1956), and it is possible that this hardy and low-palatable genus owes its high frequency in New England grasslands to the effects of annual fires on grazed pastures.

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