

ACT PARKS and CONSERVATION SERVICE



LOWLAND NATIVE GRASSLANDS IN THE ACT AND SURROUNDING REGION:

A REVIEW AND RESEARCH STRATEGY FOR A RECOVERY PLAN

SARAH SHARP

TECHNICAL REPORT 8



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ISSN 1320-1069

ISBN 1 86331 276 5

ACT GOVERNMENT

**Department of the Environment, Land and Planning
ACT Parks and Conservation Service
P.O. Box 1119 Tuggeranong ACT 2901**

Printed on recycled paper

ACKNOWLEDGEMENTS

I wish to thank the following people who provided information related to their work:

Mr John Briggs, CSIRO Division of Plant Industry;
Mr Tony Brownlie, ACT Parks and Conservation Service;
Mr Rob Coorey, ACT Parks and Conservation Service;
Ms Maxine Davis, environmental consultant;
Mr Don Fletcher, ACT Parks and Conservation Service;
Dr Kevin Frawley, National Capital Planning Authority;
Dr Richard Groves, CSIRO Division of Plant Industry;
Mr Frank Ingwersen, ACT Parks and Conservation Service;
Mr Bill Kearney, ACT Parks and Conservation Service;
Mr Phil Kendall, National Capital Planning Authority;
Mr Geoff King, ACT Parks and Conservation Service;
Mr Mark Lodder, Public Works, ACT Department of Environment, Land and Planning;
Mr Ian Lunt, Botany Dept, La Trobe University, Victoria;
Mr Bill Woodruff, ACT Parks and Conservation Service.

I also wish to thank Dr Keith Williams, Mr Don Driscoll, Dr Will Osborne, Mr Frank Ingwersen and Dr David Shorthouse for their helpful comments on the draft.

This report was written as background information for a Recovery Plan for lowland native grasslands prepared in 1991 for the Endangered Species Program, Australian Nature Conservation Agency. It is being published with their permission. The views expressed in this document are not necessarily those of the Australian Nature Conservation Agency.

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ABSTRACT

Lowland native grasslands are a highly modified ecosystem, now remaining only as isolated remnants in the region and throughout Australia. Many of the grasslands are secondary grasslands, having been cleared of trees for pastoral use. Only three grassland sites are reserved in the ACT, none of which are original treeless grasslands. Three nationally rare and endangered plant species occur in the ACT and surrounding region in native grasslands. They are *Rutidosia leptorhynchoides*, *Swainsona recta* and *Thesium australe*. Present management of grasslands generally is not conducive to the long-term sustainability of the communities or the component native flora and fauna.

Major threats to the grasslands are inappropriate management of the sites, their isolation and impacts from external factors including water flow and invasion by exotic species. Limited information is available about how to mitigate these effects and enhance the values of the communities.

There are a number of plants at risk of extinction if native grasslands are not conserved, particularly the nationally endangered plants *Swainsonia recta* and *Rutidosia leptorhynchoides*. There are probably other endangered plants that are restricted to grasslands. Grassland preservation will also secure the habitats of invertebrates and vertebrates.

Recommendations for research related to conserving the communities, habitats and component species are presented. These recommendations form the basis of the Recovery Plan for the lowland native grasslands in the ACT, which is being implemented by the Wildlife Research Unit, ACT Parks and Conservation Service under funding provided by the Endangered Species Program, Australian Nature Conservation Agency.

1. INTRODUCTION

This review was written in 1991 to provide background information for the preparation of a Recovery Plan for lowland native grasslands in the ACT. It defines and describes lowland native grassland communities in the ACT and surrounding region and outlines the studies and findings of relevant research that has been conducted in grassland communities and on groups of species within grasslands in the region up to 1991. The findings of relevant studies related to aspects of grassland ecology from areas elsewhere in Australia and from overseas also are described. Conservation measures outlined in the literature are included and conclusions are drawn relating to implications for requirements for future research to ensure the conservation of lowland native grasslands in the ACT.

Native grasslands include those grasslands that contain predominantly native plant species, both grasses, forbs and other non-woody species. Exotic species (marked in the text with an asterisk) are those species that originated overseas. Throughout the text the lowland grasslands are referred to as communities. A community is defined as an area identified by the characteristic vegetation, containing a variety of species and habitats. The grassland communities are determined by the dominant grass species. 'Ecosystem' is used to describe a more complex group of communities. The higher elevation grasslands, which form a different alliance, are reserved adequately in Namadgi National Park and Kosciusko National Park (Hogg 1990) and are not considered in this report.

The floristic composition and distribution of lowland native grasslands in the ACT is not as well known as other vegetation communities (NCPA 1989; Hogg 1990). Until 1980 there was little interest in native grasslands in the ACT, other than for their grazing potential. Since then, the need to incorporate management plans for grasslands in the ACT has been discussed but none have been implemented (Shorthouse 1991). Grasslands are now being viewed as an important element of ecosystems. They are also recognised as providing habitat for several rare or endangered plant and animal species (Barrett and Mitchell 1984; Hogg 1990; Williams and Kukolic 1991). However, there has been little recognition of grassland communities as a dynamic interaction of faunal, floral and physical site elements.

Lowland grasslands originally covered vast areas of south-eastern Australia (Lunt 1991). Prior to European settlement in the 1820s, the Limestone Plains, Isabella Plains and parts of Belconnen formed an extensive grassland community, merging into woodland on the slopes. The treeless grasslands and open woodlands were favoured for farming and settlement which began in the 1820s. Grazing, pasture improvement and other impacts have led to the replacement of native grasses with exotic species in many areas (Chan 1980). Much of the Limestone Plains and the Isabella Plains have been developed for urban use.

As a consequence of these two major land uses, only fragmented areas of native grasslands now occur in the region. These areas are all subject to differing forms and degrees of continuing disturbance, which is usually active management. Many of the best grasslands remaining are those that were set aside as urban open space or for special purposes prior to the extensive use of superphosphate on pastures in the 1950s. A number of these remnant areas are under threat of further urban development (e.g. in Gungahlin) and many others occur in rural areas, which leave them under continual threat from adverse agricultural practices (Chan 1980; Hogg 1990) or inappropriate management (in terms of their conservation).

The reduction of native grassland communities to remnant patches is widespread throughout southern Australia (Lunt 1991) and correspondingly, there are few lowland grassland communities in reserves anywhere in Australia (Specht 1981). In the ACT, lowland grasslands are inadequately reserved. There are no original treeless grasslands in reserves and only several grassy woodlands or secondary grasslands are represented in ACT parks and reserves. There are also several sites within the National Capital Open Space System (NCOSS). However, these sites are not the most representative or biggest sites, nor the best managed sites.

In order to adequately conserve native grasslands, the ACT requires a number of properly managed reserves and conservation zones which are viable and representative and which conserve and, in some cases re-establish, nationally threatened plant and animal species and locally uncommon species. Additionally there is a need to carry out research relating to conservation management of the grasslands and component species before the remnants become further degraded or are completely destroyed.

2. DESCRIPTION OF NATIVE GRASSLAND COMMUNITIES

The lowland grassland associations in the ACT are considered to be synonymous with the grassland associations on the Monaro Plain and are considered to be very similar to the Basalt Plains associations of Victoria (Costin 1954). There are also many characteristics that grasslands world-wide share.

Native grasslands that exist today may be either 'true' grasslands, grasslands which contain sparsely scattered trees, or grasslands that have been formed as a result of tree and shrub clearance (secondary grassland communities). A true grassland is a community which has a perennial tussock grass cover of native species with a discontinuous layer of smaller forbs and grasses (Barrett and Mitchell 1984) and contains no woody species (R. Groves pers. comm.). Secondary communities or sites that contain very low numbers of trees form communities in which the dominant species are perennial native grasses, with few or no shrubs and with trees either absent or in such low numbers as not to form an open woodland community (Moore 1964).

According to Costin (1954), native grasslands consist of three strata:

- the dominant stratum of perennial tussock grasses, forming a loosely interlacing leaf canopy;
- a discontinuous layer of smaller forbs and grasses below; and
- at ground level a discontinuous stratum of dwarf forbs.

The lowest stratum grows early in the spring season, before being overtopped. Other species in this stratum have low growing vegetative parts and overtop grasses with their reproductive parts (Coupland 1979). Grazing and burning creates a mosaic in native grasslands of tussocks and intertussock spaces in which species typical of the lower two strata can establish (Stuwe 1986). Small wetlands occur in microsites within grasslands (Lunt 1992a). Such 'sub-communities' are considered an integral part of the grassland communities.

Grasses and graminoids (grass-like species such as sedges) typically comprise 30 per cent of species present in grasslands, and up to 90 per cent of the biomass (Coupland 1979). Perennial forbs are the dominant life-forms (Kirkpatrick *et al.* 1988), particularly Asteraceae. The vegetation prior to European settlement was probably more diverse, as many species were presumably eliminated or depleted by overgrazing, changes in fire regimes and isolation. Native orchids, chenopods, lilies and legumes are now particularly rare in Victoria (Lunt 1990a). This is also the case in the ACT (Sharp, unpubl. data).

The native grasslands in the ACT region are dominated by perennial grasses of the genera *Themeda* (kangaroo grasses), *Poa* (snow grasses), *Stipa* (spear grasses) and *Danthonia* (wallaby grasses) (Moore 1970) but introduced species now also form a permanent component of native grasslands (Groves and Lodder 1991). Lowland grasslands were dominated in pre-European times by *Themeda triandra* (Pryor and Moore 1955). As a result of grazing and changes in fire regime *Themeda* was drastically reduced within several years of European settlement (Moore 1959) and *Danthonia* spp., *Stipa* spp. and *Bothriochloa macra* dominated grasslands became more common (Chan *et al.* 1974). In Victoria, areas of grassland typical of the former *Themeda* grasslands now exist only on roadside verges, beside railway lines and in areas that are not grazed (Stuwe and Parsons 1977). In the ACT the same trend is apparent, although they have also persisted in sites that have been subject to low grazing pressure for long periods, particularly in wetter sites (Sharp, unpublished data). Because of permanent changes in ecosystem properties, such as soil characteristics, these grasslands are possibly changing into new, 'metastable' states (Hobbs and Hopkins 1990).

3. DISTRIBUTION OF LOWLAND NATIVE GRASSLAND COMMUNITIES IN THE ACT AND REGION

3.1 Factors Influencing Distribution

According to Chan (1980); Kirkpatrick *et al.* (1988) and Groves and Lodder (1991), in south-eastern Australia, lowland native grasslands occur in:

- sites with low rainfall (less than 600 mm per year) which are subject to periodic drought;
- where low temperatures cause heavy and frequent frosts; and
- where low nutrient and cracking clay soils occur, together preventing the establishment of trees or other woody species.

The B-horizon of the soil is often poorly aerated, preventing native tree establishment but trees such as willows, that can survive in poorly aerated soils, are able to establish (Pryor 1939 in Moore 1959).

Competition from grass species can prevent the establishment of trees (Read and Hill 1983). Grass is not only a strong competitor for nutrients and water, but grass swards enhance the severity of radiation frost (Ellis 1985). Additionally, grasslands attract animals which inhibit the establishment of trees through browsing or trampling.

Soil type appears to have minimal effect on the distribution of grasslands (Chan 1980). However, the distribution of particular species is related to soil type or texture in some cases, such as *Poa* which occurs where soils are of a heavier texture (Pryor 1962) and as Williams (1979) found for several grasses and legumes occurring on the north-west slopes of NSW. Burning by aboriginal people may also have influenced the distribution of grasslands in the ACT (Chan 1980), as is the case elsewhere in Australia (Jackson 1968; Stuwe 1986).

True grasslands occurred on the Canberra Plains, at Ginninderra and the Tuggeranong Plains (Pryor and Moore 1955). Pryor and Moore (1955) referred to a study carried out by Hoddle in 1836 in an area now just north of the airport in which he described a sharp boundary between the trees and an open plain. Other sites, which are or were fringed by *Eucalyptus pauciflora* (snow gum) which occur in sites that are too cold for other eucalyptus species, are also likely to indicate the edge of true grasslands (Pryor 1962). A fringing woodland community with a grassy understorey (grassy woodland) also occurs. Mallen (1986), after surveying vegetation along parts of the Murrumbidgee Corridor, suggested that much of the area she studied had, prior to European settlement, been covered with a sparse, park-like tree cover of woodland tree species, with increasing density on the slopes.

Those grassland areas occurring in the region as a result of clearance of trees for agriculture (secondary grasslands) are maintained through grazing and other management practices. Removal of grazing results in revegetation by woody species, if seed sources are available. Grasslands, both true and secondary, in the ACT and region are now found generally on slopes up to 10 degrees (Holani 1982). While true grasslands generally occur at altitudes of up to 600 metres (Chan 1980), the addition of secondary communities means that they are found also at slightly higher elevations.

Moore (1970) believed that true grasslands within the woodland zone differ little in species composition from the herbaceous communities of the adjacent woodlands, whereas Mallen (1986) suggested that true grasslands and secondary grasslands can be differentiated by species which occur more frequently in grasslands than in woodlands. However, the discrimination of sites based on species composition is not as apparent in sites that have been cleared and grazed over long periods (Sharp unpubl. data).

3.2 Reliability of Existing Mapping

The distribution of grasslands in the ACT, identifying eight grassland types, was mapped in the late 1970s (Chan 1980). These grasslands are shown in a vegetation map of the ACT (NCDC 1989).

The vegetation types of the ACT have been digitised by Ritman and Lees (1990) using Landsat TM (February 1989) for spectral resolution and SPOT Panchromatic (July 1988) for spatial resolution. Overall they found the classification to be extremely reliable in discriminating between major land cover types but reliability was lower within structurally similar land cover types, such as grassland types. Ritman and Lees (1990) work was the first attempt to map grassland types in the ACT using satellite imagery and further assessment of its value is required to validate this technique, which may have a significant role in management, planning and monitoring grasslands over time.

Since 1990 systematic identification of grasslands through extensive surveying has occurred and is being documented currently for publication (Sharp, in prep). It includes a map, showing site boundaries and a description of the sites in terms of their size, dominant species, significant species and tenure.

4. HABITAT LOSS

Communities provide habitat for a number of plants and animals, including invertebrates. Habitat is a complex interaction of space, food and shelter requirements for individual species. Changes occurring in a community will affect the habitat quality. The effects of changes may not be apparent for some time. Species may be weakened gradually over time, for example losing reproductive ability but remaining until senility, or be outcompeted by other species (the lag effect described by Hobbs and Hopkins 1990).

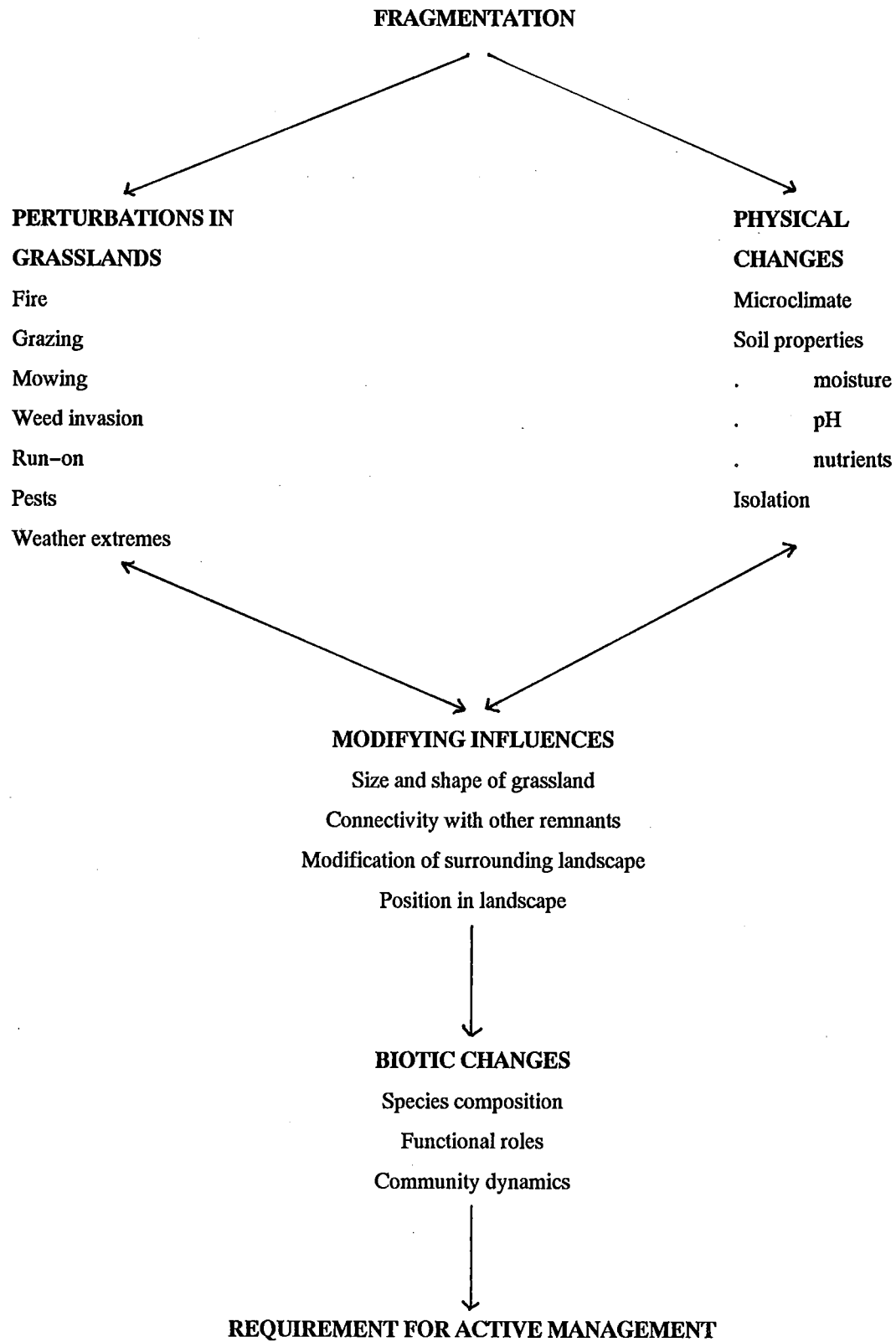
This report describes the modifications that have occurred in grasslands, including fragmentation and management changes and how they have affected habitat quality and diversity with impacts radiating out to other plants and animals. These include changes to food sources, structural modification of the plant species, changes to soil moisture and other soil features.

4.1 Impacts of Fragmentation on Community Habitat

There has been extensive coverage of this topic in general terms (e.g. Saunders *et al.* 1987, Saunders *et al.* 1991). A diagrammatic representation of the interactions of impacts on fragmented grassland communities and their modifying influences (Fig 1) indicates how management may be used to counteract those impacts and to utilise management for the enhancement of conservation values.

Grasslands have been subject to perturbations over a very long period of time, in the form of droughts, floods, fire, whether naturally caused or otherwise, and grazing by indigenous species. However, because grasslands have become further destabilised and modified since European settlement and particularly as they have become more fragmented and invaded by exotic species, these communities require pro-active management to retain their conservation value. Generally, smaller remnants require management related more to their protection from external factors, such as wildfire, water run-on and weed invasion, while in larger remnants, management may be directed more towards retaining species diversity, for example by patch-burning or mowing.

Figure 1. Impacts of fragmentation on grassland communities (adapted from Saunders *et al.* 1991).



4.2 Dynamics of Native Grassland Communities

The major ecological factors affecting community and species dynamics in Australian grasslands are interactions between previous grazing and fire regimes and soil type as it influences the soil moisture regime (Groves and Williams 1981). Modifications to management practices and other disturbances impact the dynamics of the communities through changes that occur in species composition and vegetation structure and in permanent changes to site characteristics, such as soil acidity.

A comprehension of functional roles of populations, the functional diversity of communities and the effects of disturbances within a community facilitate an understanding of whether perturbations are likely to affect the stability of the community (Main 1987). These include, for example, the role of legumes in releasing available nitrogen into the soil for use by other species and the role of certain soil organisms in decomposition of plant litter. Considerably more research needs to be carried out on the functional roles that individual species play in a community before this approach can be integrated into grassland conservation management. Additionally, further studies of species that represent a range of life strategies is called for to aid in conservation planning (R. Groves, pers. comm.).

4.3 Effects of Disturbance on Grasslands and Grassland Species

Burning

Aboriginal people were known to use fire regularly for many reasons associated with hunting. This took the form of regular and controlled burning of patches of grassland (Nicholson 1981). Frequent firing by aboriginal people in Australia converted large areas of potential or actual forest into grassland plains and savanna woodlands which were maintained as secondary communities (Leigh and Noble 1981, Jackson 1968). Early settlers in eastern Victoria described how the grasslands with scattered trees were kept open by the annual bushfires of the Aboriginal people but reverted to forest after European settlement put an end to aboriginal management (Howitt 1890 in Nicholson 1981). Firing did not only take place in late winter or early spring to encourage the growth of green shoots but also in summer to expose food sources (Mitchell 1848 in Nicholson 1981). Since European settlement, however, fires have tended to be less frequent and more extensive and intense (Christensen and Burrows 1986).

Areas which were subject to the greatest fire frequency contained the highest native species diversity and also a complement of exotic annual species in *Themeda* dominated grasslands in Victoria (Stuwe and Parsons 1977) and in an urban grassy woodland in Hobart, Tasmania (Kirkpatrick (1986). In the absence of fire *Themeda* filled the intertussock spaces, preventing the establishment of other species. In order to retain species richness in *Themeda* grasslands, McDougall (1989) recommended that they be burnt every two to five years. Many endangered plants of grasslands depend on specific burning regimes for regeneration (Lunt 1991). A number of species, for example some orchids and other monocotyledons, are stimulated by fire to flower (Gill 1981).

The soil seed bank determines the likely germinating species after a fire (Lunt 1990b) and the recovery characteristics of the species. If the soil seed bank is dominated by exotic species, as Pavlovic (1982) found in a study of the seed store of a *Themeda* dominated grassland in Smiths Paddock, ACT and Lunt (1990b) found in a reserve in Victoria, it is likely that with fire the exotic species may become dominant. The effects of more frequent fires on the abundance of exotic species is not well known and needs to be assessed (Lunt 1990c).

There is an apparent need to burn certain grasslands in order to maintain species richness. In addition, particular species appear to require burning at particular times of the year in order to survive (e.g. *Rutidosis leptorhynchoides*, the endangered button wrinklewort (Leigh *et al.* 1984)). Seasonality of burning has however significantly different impacts on species within grasslands. Winter burns encourage the germination of forbs which take the place of grasses, whereas spring burning removes the reproductive parts of flowering forbs and cool season grasses (Hastings 1983). In Victorian rail reserves subject to late spring burns some endangered forbs were adversely affected (Stuwe and Parsons 1977), but it is in rail reserves burnt in late spring that several of the rare and endangered species occur in the ACT region (J. Briggs pers. comm.).

Research into the effects of seasonality and frequency of fire on native grasslands and component species in the ACT and region is required. Information derived will enable a sensitive approach to the manipulation of fire for management, relating it to the impacts on particular species. Alternative techniques, in particular mowing and grazing, require comparative research. Many grassland sites in the ACT have not been burnt for a very long time. This may in fact mean that fire will not enhance native species to the extent that it does in sites elsewhere. In some sites in the ACT burning may not be possible due to constraints under air pollution legislation and alternative practices would be required. This includes any sites near the airport and some of the urban sites.

Grazing Effects

While exotic plant species may be adapted to grazing and trampling by ungulates, Australian plant species evolved in the presence of low grazing pressure from soft-footed animals (Hastings 1983). Thus the impact of grazing by domesticated animals on indigenous plant species is substantial. This impact not only relates to the loss of species through direct grazing pressure but also from trampling, the addition and transfer of nutrients through dung and urine and the creation of significant areas of bare ground, which exotic species may be able to colonise before native species can re-establish (Kirkpatrick *et al.* 1988). Significant nutrification and weed establishment occurs in sheep camps on the sides of hills and there is extensive exotic seed spread from undigested seeds from animals fed with hay, particularly horses. Cattle and sheep have similar preferences for forage (Wilson and Hodgkinson 1990) but sheep are generally more destructive to vegetation than cattle (Moore 1959).

Substantial changes also occur to the soil as a result of trampling, creation of bare areas, loss of litter and subsequent erosion. This leads to a loss of soil moisture and subsequently a more arid environment (Moore and Biddiscombe 1964). Grass pastures in Northern Australia responded to overgrazing and burning by the development of areas of bare soil which showed structural collapse and surface scaling (Bridge *et al.* 1983). Changes in plant species composition and cover also can affect populations of ants, termites and topsoil micro-arthropods, leading indirectly to changes in soil structure (Wilson 1990).

Frequent overgrazing in the 1800s (Hancock 1972) and the severe impact of rabbits between the 1880s and the 1950s is likely to have left no pristine grasslands remaining. While the effects of grazing have slowed with a decrease in rabbit populations and greater management of livestock (Wilson 1990), there are still significant areas within the region that are being overgrazed (F. Ingwersen, pers. comm.). The importance of native pasture for agriculture at the present time, however, is indicated by the 60 per cent of pastures on the Southern Tablelands of NSW still dominated by native grasses (Munnich *et al.* 1991).

While it has been suggested that in many cases there will be an increase in plant species diversity from moderate grazing, because the dominant grasses are suppressed and more resources are available for other plants to establish (Kirkpatrick *et al.* 1988; Wilson 1990; Wilson and Hodgkinson 1990), initial grazing pressure is often on the palatable forbs rather than on the less palatable dominant grasses such as *Themeda triandra* (Lunt 1991). At low grazing levels, even though the dominant grasses may show no effects, the more palatable and sensitive species such as *Microseris lanceolata* (yam daisy) can be severely impacted (Lunt 1991). In Victorian grasslands there is a significantly lower species richness in sites that are grazed in comparison to sites that are regularly burned (Stuwe and Parsons 1977). While grazing may maintain the quality of a grassland, it will not improve it (Lunt 1991). Lunt (1991: 59) believed that any site that has never been subject to grazing by domestic stock should not be grazed, as it will "rapidly, and probably irreversibly, lead to a deterioration in vegetation quality". This measure should be applied to any sites that have not been grazed for many years, such as along railway easements.

Botanical composition of the perennial grass component on light and heavy soils respectively is different under light grazing. However, botanical composition becomes similar and almost identical under severe grazing (Moore, 1959). Under heavy grazing *Themeda triandra* and other tall perennials are replaced by the shorter species, such as *Danthonia* spp. which can withstand heavier grazing. Further grazing pressure leads to the replacement of *Danthonia* by unpalatable exotic winter and spring annuals (Moore 1959, Moore and Biddiscombe 1964, Wilson 1990). However, usage has to be both severe and prolonged for permanent changes in grassland vegetation to occur, although exclusion of stock from sites, even for 20 years, may not be long enough to allow the return of species removed by grazing (Groves and Williams 1981). One of the forbs most resistant to grazing is *Chrysocephalum apiculatum* (yellow buttons) which is common, particularly in *Danthonia* grasslands (R. Groves pers. comm.).

A survey of pastures in the Goulburn district (Munnich *et al.* 1991) found a high proportion of *Danthonia* species (wallaby grasses), particularly *D. pilosa*, *D. caespitosa* and *D. racemosa*, and *Microlaena stipoides* var. *stipoides* (weeping grass). The annual grass *Vulpia bromoides** (squirrel-tail fescue) occurred in high proportions. Paddocks containing native species had nearly as high a stocking rate as sown paddocks. While this indicated that it is possible to retain native grasses under grazing, Munnich *et al.* (1991) made no assessment of the diversity of native forbs under grazing in the region. Thus they did not indicate whether the conservation value of grazed native pasture was retained.

Kangaroo grazing in native grassland in Tidbinbilla Nature Reserve in the ACT significantly altered the abundance, height and structure of species (Neave and Tanton 1989). However, kangaroos, while having a significant grazing impact, have a narrower range of preference and create minimal impact from trampling around water sources (Wilson 1990). Nevertheless, high population levels of kangaroos will degrade vegetation, select for unpalatable native and exotic species and restrict the regeneration of rare and threatened plant species (Lunt 1991).

Removal of stock from secondary grasslands may lead to dense regeneration of trees and shrubs (Williams and Ashton 1987), which may conflict with the desire to retain an open woodland or grassland. Tree regeneration may be controlled by burning. Regular mowing of grassy woodlands also prevents tree regeneration (Lunt 1991). This technique could be used to maintain a secondary grassland.

Research and monitoring are required to determine what are the impacts of different grazing regimes on grasslands in this region and under what situations grazing by domestic stock or native species is appropriate as a management technique to retain the conservation value of grassland communities.

Mowing

Mowing trials on the dominant grasses in a *Themeda* dominated grassland and a mixed *Danthonia*, *Bothriochloa* and *Stipa* grassland have been carried out in the ACT (Chan 1980). While mowing *Themeda* before the beginning of growth in spring or after seed maturation increased production, more frequent mowing led to the loss of *Themeda*. In contrast, *Bothriochloa* was unaffected by mowing, and therefore could become a dominant species in sites subject to frequent mowing. *Stipa* was also adversely affected by mowing and *Danthonia* showed mixed responses. While impacts on other individual species were not assessed, it was concluded that species composition could be altered by different mowing frequencies because of differences in response of plants flowering at different times of the year (Chan 1980). Mowing may diminish the diversity of native plants (Kirkpatrick 1986). Too frequent mowing at Yarramundi Reach in the ACT may have led to a significant increase in the abundance of wild oats (*Avena fatua**) (R. Groves pers. comm).

Research is required to determine what effects mowing has on species other than the dominant grasses in grasslands. This includes the effects of removing or retaining the hay, as it is known that dense litter inhibits the establishment of annuals, both exotic and native. Until further research is carried out, the recommendations in Lodder *et al.* (1986) form a conservative approach to the use of this technique.

Invasion by non-indigenous plant species

While few introduced plant species will invade undisturbed native grassland (Moore 1959, Hastings 1983), communities subject to recurrent disturbance are more prone to invasion by exotic species (Fox and Fox 1986). The soil seed store in a long-grazed grassland in Victoria was dominated by exotic species, with few native species (Lunt 1990b). Thus disturbance to a site, including fire, may increase the dominance of exotic species. Therefore management practices which minimise disturbance should also minimise exotic plant invasion. However, without some disturbance to such species as *Themeda*, species richness declines (McIntyre *et al.* 1988).

Not all invading organisms cause the destruction of native plant communities and it may be possible that they can occur in grasslands and not transform a predominantly native grassland into a predominantly exotic grassland (Christensen and Burrows 1986, Kirkpatrick *et al.* 1988, I. Lunt pers. comm.). The exception is where nutrient levels are high or soil disturbance has been extreme (Kirkpatrick *et al.* 1988).

However, management is required to control the spread of particular exotic species that are known to be actively invasive, preventing the re-establishment of native species, limiting the functional roles in a community or affecting the habitat value for native animals. *Phalaris aquatica** (Toowoomba Canary Grass), for instance, appears to be a very invasive plant, found in both lightly grazed and undisturbed grasslands (Stuwe and Parsons 1977). Additionally, the effects of competition by exotic species on rare plants needs to be considered. As rapid occupiers of soil disturbed sites, invasive exotic species restrict the space for native species to re-establish.

Additionally invading plant species alter stand and fuel fire structures (Hobbs and Hopkins 1990). For instance, many exotics are annuals (e.g. *Vulpia** spp., *Bromus** spp., *Avena** spp.) or spring-growing perennials (e.g. *Phalaris**), so that significant amounts of litter forms in summer. In contrast, *Themeda* and *Bothriochloa* grow in summer and so are green in the most critical period. Other cool season grasses such as *Danthonia* do not produce as much biomass as do many exotic grasses.

Fertiliser application

Growth of some natives in a glasshouse was enhanced by the addition of fertiliser (Groves *et al.* 1973; Hobbs and Atkins 1988). However, in a Californian grassland, an increase in fertiliser caused an increase in the invasion by non-native annual grasses in areas originally dominated by native annual forbs (Huenneke *et al.* 1990), which suggests that selected species are affected detrimentally. Overall, species richness declined when fertiliser was added. If disturbance to the soil occurs at the same time as fertiliser is added, annuals such as *Avena fatua** will establish in native grassland (Hobbs and Atkins 1988). Thus it appears that the exotic species are better able to utilise the nutrients and so outcompete the native species, rather than nutrients *per se* being detrimental to the establishment and growth of native grassland species.

Nutrient addition may in fact be unintentional if run-on to native grasslands occurs from neighbouring fertilised sites. If site disturbance plus nutrient addition occurs, exotic species invasion may have a severe impact.

Cumming and Williams (1983) found that associated with the application of fertilisers over time is an increase in the acidification of soils. The rate of acidification varied considerably depending on the chemical properties of the soil and on the impacts of factors related to land use. Increases in acidity will have a major impact on species composition, depending on the individual species' tolerance to increased acidity. For instance, *Microlaena stipoides* var. *stipoides* can grow in soils that have a pH as low as 3.9, but *Danthonia* species cannot tolerate pH levels that low (Munnich *et al.* 1991).

Soil Disturbance

As is clear from the results of studies on the invasion by exotic species (see above), soil disturbance has a significant impact on native grasslands. The more destructive forms of soil disturbance such as disc or chisel ploughing have a higher impact on the presence or absence of *Danthonia* species than techniques such as scarifying, which merely breaks the surface without turning the soil (Munnich *et al.* 1991).

Use of Herbicides

Studies have been carried out in Britain to determine which herbicides cause minimal damage to the native vegetation and to monitor recovery from damage if it does occur (Marrs 1985). No account was taken of possible damaging effects on ecosystem processes. Marrs recommended that a quantitative approach is needed in order to assess herbicide damage.

In Australia, herbicides may play an important role in the control of selected weeds such as *Rosa rubiginosa* * (Briar rose) and *Phalaris* spp. * (Lunt 1991). Research is currently being carried out on the use of specific herbicides to selectively control weeds in native grasslands. The Victorian Department of Conservation and Natural Resources is trialling Atrazine which is selective for grasses with a C₃ photosynthetic pathway (Arundell 1992).

Urban Development

While urban native habitats are characterised by frequent disturbance (fire, trampling, hydrological changes, nutrient inputs etc), they may still have value as corridors or species reservoirs (Davis and Glick 1978). In the ACT, a number of significant grasslands occur in urban areas, including sites containing the endangered plant species *Rutidosia leptorhynchoides* and *Swainsona recta* and the threatened golden sun moth *Synemon plana*.

Many of the grassland sites in the urban area are very small and many require very intensive management in order to maintain species diversity and minimise weed invasion. In urban ecosystems, the maintenance of habitat diversity requires a combination of "careful planning and benign neglect – the preservation of existing habitats and the abandonment of a 'manicure mentality' " (Davis and Glick 1978).

Run-off from urban sites on to native grassland areas may lead to an increase in soil moisture and may increase nutrient input. This could affect the component species, enhancing opportunities for invasion by exotic species (Clements 1983).

The Use of Disturbance to Enhance Native Grassland Communities

Single disturbance factors in isolation do not necessarily have significant effects on species richness, distribution or function. However, in conjunction with other factors, they have a compounding effect (Kirkpatrick *et al.* 1988).

Due to irreversible changes that have occurred in the past in differing degrees at sites, management cannot try to emulate what is thought to have been the pre-European regimes. It is clear that communities require site specific active on-going management to prevent dominance by certain species, particularly *Themeda triandra* and invasive species, and a loss of species richness.

Until further research and monitoring indicates otherwise, management should take a conservative approach, with a minimum of changes from the present regime. Remnants are like they are because of their past management. If a remnant has high conservation value, it should be assumed as a first step that the management has been at least adequate (Lunt 1992b). Removal of obvious detrimental impacts, such as overgrazing by either domestic animals or macropods, or prevention of run-on from sites subject to nutrient input and irrigation will enhance the sites. Further changes to the particular management regimes that are in use at the present time should be initially treated cautiously.

Periodic burning appears to be the most optimal form of management to retain species richness and diversity. Depending, however, on what species are being actively managed, the appropriate rate and timing of burns differs markedly. Burning may not be appropriate in sites that have not been burnt for a long period, or in sites that have a soil seed store dominated by exotics. Infrequent mowing or light grazing by domestic stock, while impacting some species more than others, may be better than no management at all, unless an area has never been grazed, or not for a long time.

Further long-term research in conjunction with site monitoring is required to determine what grazing pressure or how often burning, mowing or other management techniques should occur, having regard for the life histories of specific plants and animals that are indigenous to a site, to conditions that occur on the sites and the land use of the site and surrounding area. A range of management techniques is required to be developed that can be applied under differing circumstances.

4.4 Rare and Threatened Plant Species

There are three nationally rare and endangered plant species that occur in native grasslands in the ACT and the surrounding region. They are *Swainsona recta* (endangered), *Rutidosia leptorhynchoidea* (endangered) and *Thesium australe* (vulnerable) (Briggs and Leigh 1988). It is considered that the reduction in these species is related to the impacts of management since European settlement and to fragmentation. Additionally there are other species in native grasslands that are locally uncommon. A species may be uncommon because its habitat is uncommon. Other species, however, have had their range and abundance reduced by impacts of fragmentation and management.

The majority of rare, endangered or uncommon species in Victorian and Tasmanian native grasslands are forbs (Lunt 1992a and Kirkpatrick *et al.* 1988). There are 125 plant species which are now uncommon in native grasslands and grassy woodlands in Victoria and further surveys for floristics in Victorian grasslands may find more uncommon species (Lunt 1992a). In comparison, there are six species in native grasslands in the ACT and surrounding region that have been identified as being uncommon (Hogg 1990). This difference in numbers of rare species may well reflect the paucity of surveys that have been carried out in the ACT in the past in comparison to Victoria. In the meantime

there needs to be research carried out on the life history and habitat requirements of these six known species before they too become rare or endangered.

Swainsona recta (small purple pea) is known from three sites in the ACT, on Long Gully Road, in Kambah, neither of which are reserved and Mt Taylor, which is reserved. The numbers of *S. recta* on these sites are extremely low, numbering only several plants. The site in Kambah will not be developed and is being managed by ACT Parks and Conservation Service (Woodruff and Florence 1992). This site was burnt in autumn in 1987 and again in 1990 in order to maintain the species (J. Briggs, pers. comm.). Attempts to establish plantings at Kambah and several other sites have been unsuccessful.

The largest known populations of *S. recta* occur at several sites along the Queanbeyan/Cooma railway line near Queanbeyan. These sites are also unreserved. At the present time they are largely unmanaged due to the closure of the Queanbeyan–Cooma train service, but prior to its closure the site was burnt biennially, generally in late spring (J. Briggs, pers. comm.). There has not been any grazing along the railway line since the railway was built in the early 1900s. There should be every effort made to prevent grazing in this uniquely long–ungrazed area. Grazing in these sites may well cause the demise of *S. recta*.

Rutidosia leptorhynchoidea (button wrinklewort) has been found in a number of sites in the ACT, all within the urban area. Some of these are within National Capital Open Space System areas, but none are in reserves. Two sites are in areas that have been recommended for the Register of the National Estate (Briggs and Leigh 1985). Other occurrences are in the Queanbeyan district (Hogg 1990), including one site found in August 1991 on the western slopes of Mt Jerrabomberra (M. Davis pers. comm.). The species occurs both in the Canberra district and the Basalt Plains in Victoria, but may once have been widespread in *Themeda* grasslands (Briggs and Leigh 1985). It would "appear to be a marker species of considerable importance in any attempt to understand the relationships between the grasslands of these widely separated and ecologically divergent areas" (Gray 1979). Its threats include intensive grazing, fertiliser application, extensive site disturbance and strong competition from other forbs (Leigh *et al.* 1984).

Thesium australe (Austral toadflax) is semi–parasitic on a variety of grassland forbs. A single known population in the ACT occurs near Kambah Pool (Briggs and Leigh 1985). It was once widespread throughout native grasslands in a wide range of habitats in eastern Australia, but it was always rare (Briggs and Leigh 1985). It cannot survive in dense shrub or tree cover and is reduced by heavy grazing and cultivation (Briggs and Leigh 1985). Its status has been downgraded from endangered to vulnerable (J. Briggs pers. comm.) as further populations have been found in northern NSW.

The Kambah Pool site has been fenced and a trial burn was carried out in autumn 1988, but it appeared to have no impact, but not enough is known about the species to know how to manage its habitat effectively (J. Briggs, pers. comm.).

The locally uncommon plant species listed in Hogg (1990) that occur in true grasslands in the ACT and surrounding region are described briefly:

Zornia dictiocarpa (Fam. Fabaceae) is rare in the ACT, but is also found in NSW and Queensland (Burbidge and Gray 1970).

Eryngium rostratum (Fam. Apiaceae) occurs near the *Thesium australe* site at Kambah Pool and at the railway site near Queanbeyan where *Swainsona recta* has been found (J. Briggs pers. comm.). Surveys carried out in grasslands since 1990 have indicated that populations of *E. rostratum* are relatively common in the better grasslands (S. Sharp, unpub. data).

Swainsona monticola (Fam. Fabaceae) occurs south of the *S. recta* site on the railway site (J. Briggs pers. comm.) and at Kambah Pool.

Swainsona sericea (Fam. Fabaceae) occurs south of the *S. recta* site on the railway site (J. Briggs pers. comm.). It has also been found in a site in the Majura valley.

Diuris punctata (Fam. Orchidaceae) also has only been seen at Kambah Pool and at the railway siding (J. Briggs pers. comm.).

Re-classification of locally uncommon species following intensive surveys that were carried out by several researchers in 1991 and 1992 is required.

4.5 Reclamation Research

According to Groves and Lodder (1991), the importance of reclamation of species in native grasslands is related to

- their value in improving or enhancing the habitat in sites that are degraded; and
- the re-introduction of rare, endangered or uncommon species to protect the gene pool before wholesale destruction of these species occurs.

Reclamation may involve a comprehensive and large-scale attempt to re-introduce a diversity of both grass species and forbs. Termed 'creative conservation' by Barrett and Mitchell (1984), this approach aims to parallel natural systems and improve habitat value of the system, without, however, attempting to recreate the complexity of natural systems. Alternatively, reclamation techniques can be used to re-establish particular native species into a site that is degraded. Reclamation, however, should be seen as one aspect in the conservation of species and habitats; it does not provide an alternative to the preservation of remnants (McDougall 1989).

Methods for the re-establishment of native grasses have been under investigation for a number of years. A summary of methods used for establishment of grasses is given below and the reader is directed to the literature for the detailed techniques used.

- 1) From seed, with or without native annual forbs (Hagon *et al.* 1975; Lodder and Groves 1989; McDougall 1989; Jeffersen *et al.* 1991). A variant of *Danthonia richardsonii* from northern NSW is presently being developed to make it available for commercial sales. *Themeda triandra* is also being trialled to determine if it can be produced in commercial quantities (Jeffersen *et al.* 1991).
- 2) Transplantation of divided tussocks (Hagon *et al.* 1975).
- 3) Transference of seed-rich soil: Worthington and Hilliwell (1987) have had success with this method in Great Britain, but the amount of exotic seed that appears to be present in many soils in native grasslands (e.g. Pavlovic 1982, Lunt 1990b) may be too great for this method to be applicable in the ACT.
- 4) Transference of freshly cut hay onto new sites which have had all exotic species removed (McDougall 1989, T. Brownlie, pers. comm.).

Research is also being carried out at present to assess the potential of native grasslands herb species for revegetation. The germination and establishment requirements are being determined for nine herb species that occur commonly in native grasslands in the ACT region (Jeffersen *et al.* 1991). The germination and establishment requirements were established for eight species found near Armidale, including some species that also occur in the ACT (McIntyre 1990). In that study it was found that populations of two species that were collected from two separate sites showed different responses to techniques used to enhance germination, and McIntyre cautioned that this variation in response may have relevance in revegetation and may reflect genetic diversity.

On-going research is required to determine which species are most successful for revegetation work and how to establish them. While the diversity of species of a natural grassland cannot be recreated, the species chosen for restoration and revegetation need to have attributes that confer resilience (Panetta and Groves 1990). These include mechanisms for recovery from disturbance and a degree of tolerance to competition.

5. LIFE HISTORY AND ECOLOGY OF THE COMMUNITIES

Details of studies related to the ecology of particular grassland species are presented below. Research that has been carried out has often not been directly related to native grassland or grassland species conservation. As Williams *et al.* (1991) stated, much research is of general relevance, but often there is a lack of specific data. However, this research has often revealed valuable insights, directly or indirectly, into the ecology of some species and the grassland community.

5.1 Autecological and Phenological Studies

The value of autecological and phenological studies lies in their application to the conservation of species, in population ecology, in an understanding of the dynamics of communities and in the impacts of management and to reclamation research. Studies within the ACT and elsewhere in Australia have established aspects of reproduction biology and the ecology of dominant grass species, but few studies of other components of grasslands have been carried out (Williams *et al.* 1991). Information related to ACT grasslands species is summarised below and implications for further research drawn.

Studies have been carried out in the ACT and elsewhere in Australia on a number of the more common grass species (e.g. Chan 1980, Moore 1959, Biddiscombe *et al.* 1954, Groves 1965, Kakudidi 1982) and on selective grassland forbs (e.g. Jeffersen *et al.* 1989, McIntyre 1990). Germination, establishment and responses to external factors such as nutrients and moisture stress have been addressed. Many of the studies were pursued in order to determine whether the species could be used effectively for establishment in revegetation programmes and also the more useful native pasture species occurring in the region have been studied.

Both warm-season (C_4) and yearlong green species (C_3) grasses occur in the ACT. *Themeda triandra* and *Bothriochloa macra* are major warm-season grasses and *Stipa* spp, *Danthonia* spp, *Microlaena stipoides* var *stipoides* and *Poa* spp are major yearlong green grasses occurring in the ACT region (Lodder *et al.* 1986). The main germination, establishment and growth periods for these two types of grasses differ, creating a distinctive pattern of seasonal changes in grasslands (Chan 1980). The major growth period of warm season grasses is in late spring and summer (Hagon and Groves 1977), which means that they remain green in summer; that of the yearlong green grasses is earlier. The optimal temperature for germination of the warm-season grasses is over 30°C, while for the yearlong green grasses it is lower, at about 25°C, but these latter species can also germinate under lower temperatures (Hagon 1976). For most of the native species there is no difference in growth and survival if nutrients are added (Hagon and Groves 1977), although some grasses can impact on others in the presence of nutrients, due to their superior ability to absorb nutrients (Groves *et al.* 1973). This has implications in regard to the addition of superphosphate in grazed grasslands, as generally the exotic grasses are better able to utilise the nutrients than the native grasses and so will outcompete them (Hobbs and Atkins 1988).

Native grasses tend to be more difficult to establish than exotic species. They are unable to germinate unless: water is applied (rain or irrigation), even in the presence of adequate soil moisture (Hagon and Chan 1977); and there is a reduction in survival of seedlings of all the species in the presence of mature plants (Lodge 1981). They have relatively long dormancy periods (three months in *Danthonia* spp. and *Bothriochloa* and eleven months in *Themeda* and *Stipa* spp. Hagon *et al.* 1975) and relatively limited germination temperatures, particularly in the case of the warm-season grasses. Native grasses also produce less seed per seed head and often the seed shatters, dropping off as it ripens rather than remaining on the plant, as do many commercially available exotic species. However, the native grasses generally survive better in times of drought because they have deeper roots than many exotics and use less soil moisture. Additionally, because they remain greener in summer than most exotics and have a tussocky growth form, they do not create such a fire hazard (Lodder *et al.* 1986).

Investigation into population structure and response of species to disturbance is required to assess the viability of populations. Factors such as disease epidemics, catastrophes, fragmentation and genetic drift have significant influences on the quality of population structure (Williams *et al.* 1991).

5.2 Floristic Surveys

Before 1991 several comprehensive surveys took place in specific areas of grasslands (e.g. Chan 1980, Mallen 1986) and all identifiable native grasslands were mapped from aerial photos (Chan 1980). Since then, the majority of remnant grasslands in the ACT have been identified and comprehensive floristic surveys carried out in about 45 of the sites (Sharp (ed.) 1994). Patterns related to their past and present land use, size, degree of fragmentation, dominant species, proportions of exotic species etc are presently being assessed in order to ascertain short-term and longer-term dynamics of the grasslands under differing conditions (S. Sharp, unpubl. data).

The identification of the species composition and patterns occurring in grasslands sites is a primary goal in the conservation of native grasslands, as it enables further research to be defined (for example, which species appear to be most in need of further research or reservation or what management practices require further study as they relate to certain site conditions). In addition such analyses aid in the assessment of sites for reservation and in the assessment of how different land uses appear to affect particular species and species diversity.

5.3 Genetic Studies

There is a paucity of genetic research carried out specifically on grassland species. However, there is a need to determine the extent of variability within species in the ACT region. At least in some species there is a high degree of variability within different areas (Groves 1975; Scott and Whalley 1982; McIntyre 1990).

Additionally, impacts of disturbances since European settlement (such as increased grazing, changes in soil fertility and pH, changes in fire frequency and seasonal burning) have led to the selection for biotypes better adapted to these changed conditions (Whalley 1990). Genetic differentiation of plants occurs in sheep camps in northern NSW, caused by intensive selection by sheep (Scott and Whalley 1984). *Danthonia caespitosa* showed high variability between areas in NSW; in optimum sites it showed considerable tolerance to heavy grazing, but in marginal areas it grew only in sites protected from grazing, such as cemeteries or roadsides (Hodgkinson and Quinn 1976).

If it is accepted that local variants should be retained through protection, then comprehensive genetic work is required to be undertaken in order to recognise the variants that occur within the region. Genetic research is also required to be carried out for endangered species management, for revegetation studies and to determine viable population sizes; at the present time the data base of knowledge required for these purposes is largely obtained only from taxonomic descriptions and geographic information (Hopper and Coates 1990).

5.4 Taxonomic Research

Taxonomic research is a continual process of definition of newly discovered species and revision of known species. Many species found in native grasslands are under revision at the present time.

A technique using computers that aids in the identification of grass genera has been developed by Watson *et al.* (1986) and is being further developed to incorporate species (M. Dallwitz, pers. comm.). This technique uses a non-hierarchical key for plant identification and may be of considerable benefit in grassland studies.

6. STATUS OF ACT LOWLAND NATIVE GRASSLANDS

6.1 Status and Reservation

Some lowland native grassland sites in the ACT have limited reservation status, as they are included in The National Capital Open Space System (Hogg 1990), but such status does not guarantee that they will be effectively managed. Many of the larger, more diverse grasslands have no protection through reservation, protection or appropriate management plans.

Sites such as roadsides, railway sidings, corridor reserves and sites used for special purposes such as cemeteries which represent the closest approximation to pre-European grasslands (Specht *et al.* 1974) are of high significance. These require on-going sympathetic management to prevent local extinction of species and weed invasion.

Management plans for all native grassland sites which occur in the urban areas of Canberra have been developed by City Parks, ACT Parks and Conservation Service (Woodruff and Florence 1992). Other sites are being managed in order to retain particular species, such as *Swainsona recta* (Hogg 1990), however this management is not adequate for the long-term protection of the species (J. Briggs pers. comm.). A conservation strategy which provides recommendations for appropriate management and adequate protection for all the identified sites in the ACT is currently being developed (Sharp, in prep).

6.2 Rare and Endangered Species

The classification of species as being uncommon in the ACT requires revision. Certain species that have been considered rare or uncommon may in fact not be and conversely, many more plants may be found to be rare or uncommon in the ACT and region. The surveys that have been carried out and on-going surveys will reveal the distribution of species which can be used to ascertain the distribution and

abundance of species in the ACT. Additionally the most appropriate methods of management need to be determined in order to retain these species.

6.3 Effects of Management Practices

Grasslands consist of a mosaic of species that require different management strategies in order to maintain structural and functional diversity. Mismanagement of sites from a conservation point of view may lead to the loss of species richness and loss of habitat value, no matter how many are reserved. In order to retain their value, the grasslands with highest conservation value that remain require adequate long term protection and these and the other sites need to be managed for their conservation values.

Additionally the most appropriate management regimes are not yet clearly known, and a range of techniques require extensive research to be carried out into their effects when applied in isolation and in combination. In order to maintain species richness and diversity, both in terms of structure and floristics, active management is required to prevent dominance by one or several species (native or exotic), which prevent the establishment and growth of other species.

7. EXISTING CONSERVATION MEASURES IN THE ACT

Some grasslands in the ACT occur within the Public Land System, both within the city of Canberra, on the edges of the surrounding hills within the Canberra Nature Park and along the river corridors. While this gives some degree of protection, at least to the sites themselves, it gives no guarantee that appropriate management to retain or enhance the species composition contained within them will occur. The relevant managers are attempting to retain the integrity of these sites, within the bounds of available information, but without plans of management for native grasslands, the grasslands are unlikely to be managed adequately. Maintenance of sites containing rare species is the responsibility of the particular managers of the sites in question. This may have the effect of quite different management practices being (or not being) carried out.

The sites which contain rare and endangered species require specific management plans with on-going monitoring to identify if these species are being adversely affected over time.

Several sites which have special uses are subject to minimal disturbance, such as occasional mowing or very light grazing (for instance the *Danthonia* grassland in the Belconnen Naval Station, the Bellenden St 2CY site containing a *Themeda* grassland, the *Themeda* grassland site on Majura Road that contains a communication beacon and road sides). However, several of these sites, including the Belconnen Naval Station have been listed for potential future development (ACT 1993).

Native grasslands are considered a threatened community under the Commonwealth's *Endangered Species Protection Bill 1992*, which gives specific obligations for Commonwealth land, including the preparation and implementation of Recovery Plans and Threat Abatement Plans, conservation agreements and interim conservation orders. It does not have the same obligations for state or territory land, however. The Nature Conservation (Amendment) Bill 1994, passed in September 1994 and in force in October 1994 establishes a listing process and assessment of the conservation status of species and communities in the ACT. At the present time, however, no original treeless native grasslands under the control of the ACT government are adequately protected. Their preservation is subject to the particular leaseholders and managers, who may at any time destroy the grasslands, intentionally or otherwise.

8. RESEARCH STRATEGY

A research strategy for the conservation of native grasslands in the ACT and region is based on the overall objectives of:

- 1) identifying sites for reservation;
- 2) identifying additional sites that are managed for purposes other than conservation, but which are maintained as native grassland communities; and
- 3) determining, then implementing, the ways to best manage and enhance those sites.

The following conservation principles are inherent in the research strategies that are recommended in this report.

- Replicate samples of all species, subspecies and habitats are required in reservation. Ideally reserves should be near or alongside sites containing native vegetation and be as large as possible, to extend and enhance the habitat values and ability to withstand disturbances such as accidental or extensive fire and to minimise weed invasion.
- Reservation/conservation should be on the basis of integrated ecosystems incorporating forest, woodland, grassland and wetland (Hogg 1990). Conservation should involve more than reservation and include communities under leasehold or special use, which are then managed sympathetically. Rather than being managed separately, these grassland sites should be seen as an integrated network of reserves (Lunt, 1992a).

- Native grassland communities at some sites may be restored to contain a diversity of species and to re-establish rare and threatened species.
- Research and management should be integrated in order to guide each other (Williams *et al.* 1991).

In order to retain the remaining native grasslands until further research is carried out, the following actions are recommended:

- No significant native grasslands should be destroyed until their value is fully assessed in terms of habitat and species composition.
- Until medium to long term research shows otherwise, grasslands should be maintained either by infrequent mowing or light grazing (if this is already being used), or if already subject to a burning regime, the same regime be continued. Conservation plans should be based on what is already known, but be carried with a cautious approach. Management should integrate applicable techniques.
- Management regimes should reflect explicitly stated objectives for reservation and preservation of a particular community. If a site is being preserved for particular species, its appropriate management must be a priority.
- The concept of financial incentives for rural landholders to manage significant native grasslands that occur on their properties sympathetically needs to be developed and implemented.
- The broad community (including land users, developers, bureaucrats, field naturalists and politicians) should be educated in the significance of native grasslands. This may include the publication of information on grasslands in the form of booklets and the publication of a field guide to native species in grasslands.

Research on lowland native grasslands should be applied, with the objectives being to determine how best to conserve and preserve representative remnants, with their component habitats and plant and animal species. This must involve mapping and surveying the communities, studies of the species composition, the interactions and dynamics of flora and fauna and the impacts of land use and management on both the communities and on the species within the community. Researchers should be encouraged to publish their results in readily available journals or reports and make available their data for other studies (in the form of a central data-base).

REFERENCES

- Arundell, M. 1992 Good works for grasslands. *Indigenotes* 5(7): 6.
- Australian Capital Territory (1993) The Territory Plan.
- Barrett, S. and Mitchell, L. 1984. Nature Conservation in the ACT. Conservation Council of the South East Region.
- Beadle, N.C.W. 1981. The Vegetation of Australia. Cambridge University Press, Cambridge.
- Biddiscombe, E.F., Cuthbertson, E. G. and Hutchings, R. J. 1954. Autecology of some natural pasture species at Trangie, NSW. *Aust. J. Bot.* 2: 69 – 98.
- Bridge, B J., Mott, J.J., Winter, W.H. and Hartigan, R.J. 1983. Improvement in soil structure resulting from sown pastures on degraded areas in the dry savanna woodlands of Northern Australia. *Aust. J. Soil. Res.* 21: 83–90.
- Briggs, J.D. and Leigh, J.H. 1985. Delineation of important habitats of rare and threatened plant species in the Australian Capital Territory. Report to the Australian Heritage Commission.
- Burbidge, N.T and Gray, M. 1970. Flora of the Australian Capital Territory. Australian National University Press, Canberra.
- Chan, C.W. 1980. Natural Grasslands in Canberra: Their Distribution, phenology and effects of mowing. MSc thesis, Australian National University.
- Chan, C.W., Totterdell, C.J. and Groves, R.H. 1974. Natural grasslands in Canberra. CSIRO Division of Plant Industry, Canberra. Report to National Capital Development Commission.
- Christensen, P.E. and Burrows, N.D. 1986. Fire: An Old Tool with a New Use. Pp 97–105 in Groves R.W. and Burden J.J. (eds.) *Ecology of Biological Invasion: An Australian Perspective*. Australian Academy of Science, Canberra.
- Clements, A. 1983. Suburban development and resultant changes in the vegetation of the bushland in the northern Sydney region. *Aust. J. Ecol.* 8: 307–19.
- Costin, A.B. 1954. A study of the ecosystems of the Monaro Region of New South Wales. Government Printer, Sydney.
- Coupland, R.T. 1979. The nature of grassland. Pp. 23–29 in R.T. Coupland (ed.) *Grassland Ecosystems of the World IBP18*. Cambridge University Press, Cambridge.
- Cumming, C.W. and Williams, C.H. 1983. Soil pH in the Pejar Catchment Area, Goulburn. *J. Soil Cons.* 39(1): 106–112.
- Davis, A.M. and Glick, T.F. 1978. Urban ecosystems and island biogeography. *Env. Cons.* 5(4): 299–304.
- Ellis, R.C. 1985. The relationships among eucalypt forest, grassland and rainforest in a highland area in north-eastern Tasmania. *Aust. J. Ecol.* 10: 297–314.
- Fox, M.D. and Fox, B.J. 1986. The susceptibility of natural communities to invasion. Pp 57–66 in R.H. Groves and J.J. Burdon *Ecology of Biological Invasions: An Australian Perspective*. Australian Academy of Science, Canberra.
- Frawley, K.J. 1991. The Conservation of Remnant Woodland and Native Grassland in the ACT. Report for the National Parks Association (ACT).

- Gill, A.M. 1981. Post-settlement fire history in Victorian landscapes. Pp. 77–98 in A.M. Gill, R.H. Groves and I.R. Noble (eds.) *Fire and the Australian Biota*. Australian Academy of Science, Canberra.
- Gray, M. 1979. The protection of an endangered species – *Rutidosia lephorrhynchoides* F. Muell. *Bull. Ecol. Soc. Aust.* 9(4): 5–8.
- Groves, R.H. 1965. Growth of *Themeda australis* tussock grassland at St. Albans, Victoria. *Aust. J. Bot.* 13: 291–302.
- Groves, R.H. 1975. Growth and development of five populations of *Themeda australis* in response to temperature. *Aust. J. Bot.* 23: 951–63.
- Groves, R.H., Keraitais, K. and Moore, C.W.E. 1973. Relative growth of *Themeda australis* and *Poa labillardieri* in pots in response to Phosphorus and Nitrogen. *Aust. J. Bot.* 21: 1–11.
- Groves, R.H. and Lodder, M. 1991. Flora of the ACT's Natural Grasslands. In *The ACT's Native Grasslands Workshop Proceedings*. Conservation Council of the South East Region and Canberra.
- Groves, R.H. and Williams, O.B. 1981. Natural Grasslands. Pp 293–316 in R.H. Groves (ed.) *Australian Vegetation*. Cambridge University Press, Cambridge.
- Hagon, M.W. 1976. Germination and dormancy of *Themeda australis*, *Danthonia* spp, *Stipa bogeniculata* and *Bothriochloa macra*. *Aust. J. Bot.* 24: 319–27.
- Hagon, M.W. and Chan, C.W. 1977. The effects of moisture stress on the germination of some Australian native grass seeds. *Aust. J. Exp. Agr. Anim. Husb.* 17(84): 86–89.
- Hagon, M.W., Groves, R.H. and Chan, C.W. 1975. Establishing native grassland in urban parklands. *Aust. Parks and Rec. Nov.* 1975: 11–14.
- Hagon, M.W. and Groves, R.W. 1977. Some factors affecting the establishment of four native grasses. *Aust. J. Exp. Agric. Anim. Husb.* 17: 90–96.
- Hancock, W.K. 1972. *Discovering Monaro. A Study of Man's Impact on his Environment*. Cambridge University Press, London.
- Hastings, I. 1983. Management Plan (1983) for the Cobra Killuc State Wildlife reserve: with notes on grassland ecology. Fisheries and Wildlife Service, Vic. Resources and Planning Bureau. Technical Report Series No. 2.
- Hobbs, R.J. and Atkins, L. 1988. Effects of disturbance and nutrient addition on native and introduced annuals in plant communities in the Western Australian wheatbelt. *Aust. J. Ecol.* 13: 171–179.
- Hobbs, R.J. and Hopkins, A.J.M. 1990. From frontier to fragments: European impact on Australia's vegetation. *Proc. Ecol. Soc. Aust.* 16: 93–114.
- Hodgkinson, K.C. and Quinn, J.A. 1976. Adaptive variability in the growth of *Danthonia caespitosa* Gaud. Populations at different temperatures. *Aust. J. Bot.* 24(3): 381–96.
- Hogg, D.McC. 1990. The Ecological Resources of the ACT. A review of recent information. Report to the National Capital Planning Authority.
- Holani, T. 1982. The ecology of plant communities of the Canberra region. Grad Dip (Sc) thesis, Dept Botany, Australian National University.

- Hopper, S.D. and Coates, D.J. 1990. Conservation of genetic resources in Australia's flora and fauna. *Proc. Ecol. Soc. Aust.* 16: 567-577.
- Huenneke, L.F., Hamburg, S.P., Koide, R., Mooney, W.A., Vitousek, P.M. 1990. Effect of soil resources on plant invasion and community structure in Californian serpentine grassland. *Ecology* 71(2): 478-491.
- Jackson, W.D. 1968. Fire, air, water and earth – an elemental ecology of Tasmania. *Proc. Ecol. Soc. Aust.* 3: 9-16.
- Jeffersen, E.J., Lodder, M.S., Willis, A.J. and Groves, R.H. 1991. Establishment of natural grassland species on roadsides of south eastern Australia. Pp 333-339 in D.A. Saunders and R.J. Hobbs (eds.) *Nature Conservation 2: The Role of Corridors*. Surrey Beatty and Sons, Chipping Norton.
- Kakudidi, E.Z.K. 1982. A survey of the grass flora of the Canberra region. Grad Dip (Sc) thesis, Dept Botany, Australian National University.
- Kirkpatrick, J.B. 1986. The viability of bush in cities – ten years of change in an urban grassy woodland. *Aust. J. Bot.* 34: 691-708.
- Kirkpatrick, J., Gilfedder, L. and Fensham, R. 1988. City Parks and Cemeteries. Tasmania's remnant grasslands and grassy woodlands. Tasmanian Conservation Trust, Hobart.
- Leigh, J. Boden, R. and Briggs, J.D. 1984. *Extinct and Endangered Plants of Australia*. McMillan Australia, South Melbourne.
- Leigh, J.H. and Noble, I.R. 1981. The role of fire in the management of rangelands in Australia. Pp 471-495 in A.M. Gill, R.H. Groves and I.R. Noble (eds.) *Fire and the Australian Biota*. Australian Academy of Science, Canberra.
- Lodder, M., Groves, R.H. and Wittmark, B. 1986. Native grasses – the missing link in Australian landscape design. *Landscape Aust* 1/86: 12-14.
- Lodge, G.M. 1981. Establishment of warm- and cool-season native perennial grasses on the north-west slopes of New South Wales. II Establishment and seedling survival in the field. *Aust. J. Bot.* 29: 121-33.
- Lunt, I.D. 1990(a). A floristic survey of the Derrimut Grassland Reserve, Melbourne Victoria. *Proc. R. Soc. Vic.* 102(1): 41-52.
- Lunt, I.D. 1990(b). The soil seed bank of a long-grazed *Themeda triandra* grassland in Victoria. *Proc. R. Soc. Vic.* 102: 53-57.
- Lunt, I.D. 1990(c). Impact of an autumn fire on a long-grazed *Themeda triandra* (Kangaroo Grass) grassland: implication for management of invaded, remnant vegetation. *Vict. Nat.* 107(2): 45-51.
- Lunt, I.D. 1991. Management of remnant, lowland grasslands and grassy woodlands for native conservation: a review. *Vict. Nat.* 108(3): 56-65.
- Lunt, I.D. 1992(a). Rare or threatened plants of lowland grasslands and grassy woodlands in Victoria. *Advances in Native Conservation* 1: 7-13.
- Lunt, I.D. 1992(b). The plains wanderer. *Indigenotes* 5(6): 2-3.

- Main, A.R. 1987. Management of remnants of native vegetation: a review of the problems and the development of an approach with reference to the wheatbelt of Western Australia. In D.A. Saunders, G.W. Arnold, A.A. Burbidge and A.J.M. Hopkins (eds.) *Nature Conservation: The Role of Remnants of Native Vegetation*. Surrey Beatty and Sons, Chipping Norton.
- Mallen, J. 1986. A report on the existing and pre-European vegetation of the east bank of the Murrumbidgee River: Point Hut crossing to Tuggeranong Creek. Report to Margules and Partners, Kinston, ACT.
- Marrs, R.H. 1985. The effects of potential bracken and scrub control herbicides on lowland *Calluna* and grass heath communities in East Anglia, UK. *Biol. Cons.* 32(1): 13–32.
- McDougall, K.L. 1989. The re-establishment of *Themeda triandra* (Kangaroo Grass): Implications for the Restoration of Grassland. Arthur Rylah Institute for Environmental Research. Tech. Report Series No. 89. Dept of Conservation, Forests and Lands, Melbourne.
- McIntyre, S. 1990. Germination of eight native species of herbaceous dicots and implications for their use in revegetation. *Vic. Nat.* 107(5/6): 154–158.
- McIntyre, S., Ladiges, P.Y. and Adams, G. 1988. Plant species richness and invasion by exotics in relation to disturbance of wetland communities on the Riverine Plain, NSW. *Aust. J. Ecol.* 13: 361–373.
- Moore, C.W.E. 1964. Distribution of grasslands. Pp 182–205 in C. Barnard (ed.), *Grasses and Grassland*. Macmillan, London.
- Moore, R.M. 1959. Ecological observations on plant communities grazed by sheep in Australia. Pp 500–13 in A. Keast (ed.) *Biogeography and Ecology in Australia*. Junk, The Hague.
- Moore, R.M. 1970. *Australian grasslands*. Australian National University Press, Canberra
- Moore, R.M. and Biddiscombe, E.F. 1964. The effects of grazing on grasslands. Pp 221–235 in C. Barnard (ed.) *Grasses and Grasslands*. Macmillan, London.
- Munnich, D., Simpson, P.C. and Nicol, W.I. 1991. *Native grasses of the Goulburn District*. NSW Agriculture and Fisheries.
- National Capital Planning Authority 1989. *Canberra's Environment 1989*. Environmental Planning Branch, Canberra.
- Neave, H.M. and Tanton, M.T. 1989. The effects of grazing by kangaroos and rabbits on the vegetation and the habitat of other fauna in the Tidbinbilla Nature Reserve, ACT. *Aust. Wildl. Res.* 16: 337–51.
- Nicholson, P.H. 1981. Fire and the Australian aborigine – an enigma. Pp 55–76 in A.M. Gill, R.H. Groves, I.R. Noble (eds.) *Fire and the Australian Biota*. Australian Academy of Science, Canberra.
- Panetta, E.D. and Groves, R.H. 1990. Weed management and revegetation programmes. *Proc. Ecol. Soc. Aust.* 16: 537–543.
- Pavlovic, N.B. 1982. The variation in seed banks on Black Mountain. Grad Dip (Sc) thesis, Dept. Botany, Australian National University.
- Pryor, L.D. 1962. *Trees in Canberra*. Dept of the Interior, Canberra.
- Pryor, L.D. 1986. *Plant species study: National Museum of Australia*. Report to National Capital Development Commission.

- Pryor, L.D. and Moore, R.M. 1955. Plant communities, in H.L. White (ed.) The Australian Capital Territory as a Region. Halstead Press, Sydney.
- Read, J. and Hill, R.S. 1983. Rainforest invasion onto Tasmanian old fields. *Aust. J. Ecol.* 8: 149–61.
- Ritman, K. and Lees, B. 1990. Landsat Thematic Mapper and SPOT panchromatic assessment of open space in the ACT for NCPA Geographic Information System. Dept. Geog., School of Environmental and Resource Management, Australian National University.
- Saunders, D., Arnold G., Burbidge A. and Hopkins A. (eds) 1987. Nature Conservation: The Role of Remnants of Native Vegetation. Surry Beatty & Sons, Clipping Norton.
- Saunders, D.A., Hobbs, R.J. and Margules, C.R. 1991. Biological consequence of ecosystem fragmentation: a review. *Cons. Biol.* 5: 18–32.
- Scarlett, N.H. and Parsons, R.F. 1982. Rare plants of the Victorian plains. Pp 89–105 in R.H. Groves and W.D.L. Ride (eds.) *Species at Risk: Research in Australia*. Australian Academy of Science, Canberra.
- Scott, A.W. and Whalley, R.D.B. 1982. The distribution and abundance of species of *Danthonia* Dc on the New England Tablelands (Aust). *Aust. J. Ecol.* 7: 239–248.
- Scott, A.W. and Whalley, R.D.B. 1984. The influence of intensive sheep grazing on genotypic differentiation in *Danthonia linkii*, *D. richardsonii* and *D. racemosa* on the New England Tablelands. *Aust. J. Ecol.* 9: 419–429.
- Shorthouse, D. 1991. ACT Grasslands – Planning and Management. In The ACT's Native Grasslands Workshop Proceedings, Conservation Council of the South-East Region and Canberra, in preparation.
- Specht, R.L. 1981. Conservation of Vegetation Types. Pp 393–410 in R.H. Groves (ed.) *Australian Vegetation*. Cambridge University Press, Cambridge.
- Specht, R.L., Roe, E.M. and Boughton, V.H. (eds) 1974. Conservation of major plant communities in Australia and Papua New Guinea. *Aust. J. Bot. Suppl.* 7: 1–667.
- Stuwe, J. 1986. An Assessment of the Conservation Status of Native Grasslands in the Western Plains, Victoria and Sites of Botanical Significance. Arthur Rylah Inst. for Environmental Research. Tech. Report Series No. 48. Dept of Conservation, Forests and Lands, Melbourne.
- Stuwe, J. and Parsons, R.F. 1977. *Themeda australis* grasslands on the Basalt Plains, Victoria: floristics and management effects. *Aust. J. Ecol.* 2:467–476.
- Watson, L., Dallwitz, M.J. and Johnston, C.R. 1986. Grass genera of the world: 728 detailed descriptions from an automated data base. *Aust. J. Bot.* 34: 223–30.
- Whalley, R.D.B. 1990. Native Grasslands in Pastures in NSW. Pp 95–101 in P.M. Dowling and D.L. Garden (eds.) *Native Grass Workshop Proceedings*. Australian University Corporation, Melbourne.
- Wildlife Research Unit 1991. Lowland native grassland communities in the ACT and surrounding region: a recovery plan. Report to the Australian National Parks and Wildlife Service, Endangered Species Program.
- Williams, A.R. 1979. A survey of the natural pastures in the north-west slopes of New South Wales. Tech. Bull. 22, CSIRO, Canberra.

- Williams, D.G., Georges, A., Dearn, J. and Sharp, S. 1991. Information requirements for native grassland conservation in the ACT. Report for ACT Planning Authority.
- Williams, K. and Kukolic, K. 1991. Fauna of the ACT's Grasslands. The ACT's Native Grasslands. Workshop Proceedings. Conservation Council of the South-East Region and Canberra, in preparation.
- Williams, R.J. and Ashton, D.H. 1987. Effects of disturbance and grazing by cattle on the dynamics of heathland and grassland communities on the Bogong High Plains, Victoria. *Aust. J. Bot.* 35:413-31.
- Wilson, A.D. 1990. The effect of grazing on Australia ecosystems. *Proc. Ecol. Soc. Aust.* 16: 235-244.
- Wilson, A.D. and Hodgkinson, K.C. 1990. The responses of grasses to grazing and its implications for the management of native grasslands. Pp 47-57 in P.M. Dowling and D.L. Garden (eds.) *Native Grass Workshop Proceedings*. Australian University Corporation, Melbourne.
- Woodruff, B. and Florence, R. 1992. *City Parks:- Management Guidelines for Specific Sites*. Prepared by Technical Services Unit, ACT Parks and Conservation Service.
- Worthington, T.R. and Hilliwell, D.W. 1987. Transference of semi-natural grassland and marshland onto newly created landfill. *Biol. Cons.* 41(4): 301-11.

APPENDIX

The following research, surveys and other actions were recommended in the 1991 Recovery Plan as actions required to adequately conserve lowland grasslands in the ACT. They were superseded by the Progress Report in 1992 (Sharp, ed. 1994). However, they are reproduced here as they are more comprehensive than those that were finally adopted. Since 1991 these actions have been addressed and some have been completed or are in progress. A summary of all research completed or in progress may be obtained from the Grasslands Project Officer, Wildlife Research Unit, ACT Parks and Conservation Service.

1. Inventory of native grasslands in the ACT and region

A: Objectives:

- To determine the extent and location of remaining native grasslands in the ACT.
- To identify the flora present in the native grasslands and the characteristics of the grasslands.

B: Description of Research Actions:

- 1.1. Map all the remnant grasslands
 - 1.1.1. Map the grasslands and their relationship with other native communities.
 - 1.1.2. Computerise the map for use in a data base.
 - 1.1.3. Assess the alternative mapping techniques for planning, management and monitoring.
 - 1.1.4. Identify land tenure, usage and past management of the grasslands.
- 1.2. Survey all the remnant grasslands
 - 1.2.1. Survey plant species in the grasslands for distribution, abundance, seasonal development of plants in spring and again in summer. Repeat in following years if possible.
 - 1.2.2. Survey soil and site characteristics
 - 1.2.3. Enter all physical and historical site information onto a data base for ready access and manipulation by researchers, planners and managers.
 - 1.2.4. Produce a field guide to the floristics of native grasslands to aid in the identification of species.

2. Determination of community ecology

A: Objectives:

- To assess the patterns and dynamics of native grasslands.

B: Description of Research Actions:

- 2.1. Characterise correlations between species and the physical conditions of the site and surrounding area in order to determine patterns of interactions and plant structure using relevant statistical methods.
- 2.2. Identify indicator species which appear in grasslands subject to different impacts and management and monitor the population trends of these species on an ongoing basis.
- 2.3. Assess the dynamic patterns relating to recruitment and stability in grasslands.
- 2.4. Determine the impacts of the site variables, such as size, isolation, invasive species, which influence grassland community ecology.
- 2.5. Assess if sites can be ranked on their conservation value based on the above.

3. Effects of management

A: Objectives:

- To determine how management practices impact native grasslands.
- To assess how management can be used to conserve and enhance the species diversity and habitat of native grasslands.

- B. Description of Research Actions:**
- 3.1 Identify and manipulate the impacts of management practices (e.g. burning season, frequency and intensity, mowing frequency, grazing impacts) on the community to assess the impacts and determine how they can be used to enhance the grasslands.
 - 3.2 Determine a strategy for preserving grasslands of varying sizes and degrees of isolation and give prescriptions for management.
 - 3.3 Monitor the effects of management practices in terms of their effects on abundance and distribution of species.
- 4. Phenological and autecological research of individual species**
- A. Objectives:**
- For nationally endangered and vulnerable species, potentially rare species (section 4.4) and a selection of functionally diverse species:
- To identify habitats for the species under study.
- To determine their life history strategies.
- To determine the response of the species to impacts and management practices such as nutrient input, competition, mowing, burning and grazing.
- B. Description of Research Actions:**
- 4.1. Survey and map potential habitats of the species under study.
 - 4.2. Study the life cycle of the species.
 - 4.3. Determine the germination, establishment and maintenance requirements for the species.
 - 4.4. Determine the population ecology of the species:
 - 4.4.1. Habitat and specialisation of the plant in its niche including functional roles.
 - 4.4.2. Study of spatial and temporal dynamics of the species
 - 4.4.3. Comparison of the species in different communities.
 - 4.5. Determine the impacts of site factors and management on the individual species.
- 5. Genetic research**
- A. Objectives:**
- To assess the genetic variability within component species.
- To determine the role of genetic variability in population survival
- B. Description of Research Actions:**
- 5.1. Study genetics of species in order to determine the variability within species.
 - 5.2. Determine the role of genetic variability in population survival for application in species preservation and reserve design.
- 6. Taxonomic research**
- A. Objectives:**
- To determine the taxonomy of new species and species whose taxonomy require revision, including those species found to have high genetic variability.
- To research computerised techniques to aid in identification of species in native grasslands.
- B. Description of Research Actions:**
- 6.1. Carry out taxonomic studies on species with high variability, new species or variants and species requiring revision.
 - 6.2. Using a range of data related to species identification, create a computerised identification key for grassland species.

7. Reclamation research

A. Objectives:

To determine strategies to revegetate native grassland sites on a large or limited scale for site reclamation and species re-establishment.

B. Description of Research Actions:

- 7.1 Research specific techniques to establish and maintain rare and endangered species in protected native grasslands.
- 7.2 Assess the germination and establishment requirements for native species used for reclamation.
- 7.3 Assess and research known and alternative techniques to reclaim areas of land with native grassland species (grasses and forbs)
- 7.4 Research techniques used to enhance establishment, such as herbicide applications, soil disturbance.
- 7.5 Monitor the species when re-established in communities

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