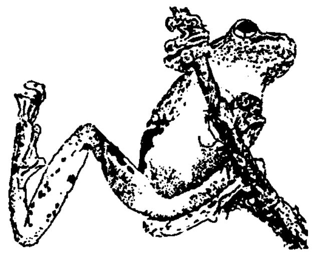

Principles and Strategic Options for the Conservation of Native Grasslands and their Threatened Fauna in Gungahlin, A.C.T.

A report commissioned by the
A.C.T. Planning Authority in February 1995
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Executive Summary

At the time of the first European settlement in Australia, lowland areas of south-eastern Australia had one of the largest areas of native temperate grassland in the world. However these grasslands are now amongst the most endangered natural communities in Australia. The native grasslands in Gungahlin contribute unique elements to the ACT grasslands as a whole, not only floristically, but because of the substantial natural populations of threatened fauna species.

The ACT contains about 8% of the remaining high quality primary native grassland found in south-eastern Australia and of the 26 defined plant communities in this same region, three are found only in the northern Monaro, mainly in the ACT. Gungahlin contains about 10-20% of the ACT's remaining primary and secondary grasslands and has several of the largest remnants in the ACT. The native grasslands remaining in the Gungahlin area are extensive, although the areas of highest quality are considerably smaller.

The significance of these communities at all levels is raised considerably by the fact that they contain extensive populations of the nationally vulnerable species *Delma impar*, as well as having populations of threatened invertebrates such as *Synemon plana* and *Keyacris scurra.* The *D. impar* populations in Gungahlin are the best known and most widespread in the ACT and have the highest capture rates, suggesting that the habitat there is particularly favourable. It is therefore imperative that these values are preserved.

As consultants for the ACT Planning Authority, we were required to assess available information on the spatial extent and quality of lowland native grasslands in the Gungahlin area, including information on species of high conservation concern, and identify those viable areas with the highest priority for conservation. We were also required to develop a set of principles that could be applied during the planning process to lessen the impact of development on the conservation values represented in the Gungahlin area. The principles identified in this report range in scope from the general principles that apply in a regional context to operational principles that apply at the local scale on individual reserved areas.

Specific recommendations are made in Section 6 on the broad regions to contain conservation zones including grassland patches of highest conservation value in a local and regional context. The actual boundaries of the conservation zones and associated buffers require an accommodation of both planning and conservation requirements, subject to the application of the outlined principles.

The nature and location of these conservation zones provides management challenges to all authorities involved, and to the people of Canberra in general. However, when these are successfully met, the Gungahlin Urban Grassland Reserve System will provide an outstanding example of development in partnership with biodiversity protection.

Recommendations

1 The long term conservation of native grassland communities and their threatened fauna in the Gungahlin Central Area should be based around three conservation zones within the identified Gungahlin Central, Gungaderra-Crace and South Mitchell feasible conservation areas. All three sites are necessary to meet the criteria of full representation of Gungahlin grassland values in reserves, to provide adequate diversity in environmental attributes such as topography, vegetation composition and structure (especially that associated with drainage lines) and to meet the requirements for replication of conservation zones.

2 The potential and need for a conservation zone at Kenny should be reassessed when the status of grassland conservation in the ACT and nearby NSW is better known. Until then, the general southern area of the Kenny Block, including patches further east below the 625 m contour, should not be developed. The potential for a conservation zone can be gauged following further survey work in the Kenny Block. The need for one will require assessment of the conservation potential for *D. impar* in grassland areas elsewhere in the ACT.

3 Smaller high quality areas, not able to be included in a conservation zone, such as the presently undeveloped section of Palmerston, should be monitored and used to increase knowledge about the ecology and viability of *Delma impar* populations in small areas of suburbia.

4 Areas finally designated for urban development, but known to contain *D. impar* or other threatened species, should be used to further our knowledge of the species, for example, by trapping out the population to establish population abundance and using these animals for research purposes or translocation trials where justified.

5 The ACT Parks and Conservation Service should develop a Management Plan for the Conservation Zones once they are decided and be provided with adequate resources to implement the plan.

6 Adequate long term management requires understanding of the dynamic processes that operate within native grasslands and knowledge of the ecological requirements of key species of conservation concern. Avenues for funding the necessary tactical research, including a possible levy on new housing blocks in selected regions, should be explored as a high priority.

More specific recommendations are made in Section 6 regarding the spatial extent of conservation zones, compatible activities, linkages between conservation zones and their ongoing requirements for management and research.

The nature and location of these conservation zones provides a management challenge to all authorities involved, and to the people of Canberra in general. However, when successfully met, the Gungahlin Urban Grassland Reserve System will provide an outstanding example of development in partnership with biodiversity protection.

PART A : PRINCIPLES

1. Background

The Limestone and other nearby plains, on which much of Canberra is situated, were a very extensive grassland community prior to European settlement in the 1820's, a prime reason for early settlement of the region. It is probable that the distribution of these grasslands was maintained through the combined effects of low rainfall (less than 600 mm per year), cold air drainage causing an inversion layer in the valleys, periodic drought, cracking clay soils and the low nutrient content of these soils. Grazing by domestic stock, pasture improvement and other disturbances have led to the widespread displacement of native grasses and herbs by exotic species.

Today, partly because of the pattern and timing of urban/industrial development and agricultural practice around Canberra, we still have examples of this native grassland type, albeit small ones, that have undergone varying degrees of alteration since settlement. In areas of floristically comparable grasslands (such as Western Victoria), pasture development has extensively reduced the extent and altered the composition of these communities, and most remaining areas of high conservation value are small (McDougall & Kirkpatrick 1994).

Until recently, the floristic composition and distribution of grasslands in the ACT was not as well known as for other ACT plant communities. Prior to the 1980's there was little mention of native grasslands as a land use issue, other than for their grazing potential. However, since the early 1980's native grassland research and conservation have received increasing attention, in the ACT and in Victoria. Grasslands are increasingly being viewed as comprising a range of distinctive and endangered communities and as the preferred habitats for some threatened plant and animal species.

Research on Australian native grassland plants has established some important features of the biology and ecology of the dominant grass species, with an emphasis on using these in landscape planting, and as a basis for rehabilitation work (see Sharp 1994, Reyenga 1993). The relative abundances of the dominant grass species are strongly influenced by domestic grazing and pasture improvement practices. Grazing causes the demise of *Themeda australis* (kangaroo grass), partly because of its greater palatability compared with that of other native grasses; *Danthonia* species (wallaby grasses) do not grow well where mechanical disturbance or fertiliser application has occurred; *Stipa bigeniculata* (spear grass) is more common in grazed or disturbed pasture partly owing to its unpalatability, and the presence of *Bothriochloa macra* (redleg grass) is often taken to indicate a highly disturbed site.

Some initial studies of the vertebrate fauna and other components of grasslands have been carried out in the ACT. Surveys have been undertaken on several rare or endangered faunal species which are found in grassland communities to determine their general distribution and habitat requirements. These are the pink-tailed legless lizard (*Aprasia parapulchella*), which is found in secondary grasslands dominated by *Themeda australis* (Osborne & McKergow 1993; Osborne *et al.* 1994; Jones 1992), the striped legless lizard (*Delma impar*) (see Rauhala *et al.* 1995), the Morabine grasshopper (*Keyacris scurra*) (Rowell & Crawford 1995), and the golden sun moth (*Synemon plana*) (Edwards 1994). At the community level there have been few surveys of grassland animals, other than for reptiles and frogs. Several invertebrate groups (e.g. springtails, beetles and ants) have been surveyed at a limited number of grassland sites. However, comprehensive surveys are yet to be carried out for most other groups and studies of the physical environment (soils, climate) are at the initial stages.

Fire is believed to be an important factor through its influence on community dynamics. It has been recommended in Victoria that grasslands be burned every two to three years to retain native plant species diversity, but such burning may enable introduced species to become dominant. Additionally, the short and long-term effects of such burning on native plant species other than grasses and the fauna have yet to be fully considered. For instance, it is possible that firing during periods of winter activity could be lethal to the rare grasshopper *Keyacris scurra*. Alternatively, summer fires may reduce the populations of the lizards *D. impar* and *Tympanocryptis lineata pinguicolla* since they may be relying on grass tussocks for shelter. As an alternative to burning, grasslands may be mown to retain species diversity, but it is not known to what extent this practise will alter the overall community composition.

All of the remnant patches of native grassland in the ACT are threatened to some extent by developmental and management pressures (e.g. residential development, livestock grazing, burning, weed invasion). The survival until now of the remaining ACT grassland remnants can be attributed to the removal of grazing in some cases, whilst in others the grazing regime and lack of pasture improvement or cultivation is likely to have been critical. All sites have been subject to some degree of disturbance, including invasion by exotic species.

Between 1970 and 1993, at least three native grassland patches around Canberra have been replaced by development and others have further degraded (Hogg 1990). Some areas are planned for urban development, while many others in and near urban areas are at risk from neglect. Those occurring in rural areas are under invasion pressure from exotic species and are subject to pasture development practices and varying impacts from grazing animals.

The information requirements for native grassland conservation in the ACT were discussed by Williams *et al.* (1991), who recommended that grasslands and *Delma impar* be given a high priority for conservation in the ACT. Williams *et al.* (1991) also proposed the elements of a plan to conserve native grasslands and the information required to implement the plan as well as the scientific studies needed to address deficiencies in knowledge. The current study is a logical extension of this earlier report, with further development of the principles and their specific application to Gungahlin, and it should be referred to for discussion of the more general principles.

A recovery plan for lowland native grasslands in the ACT was prepared in 1991 by the ACT Parks and Conservation Service's Wildlife Research Unit (see ACT Parks & Conservation Service 1992) with funding from the Endangered Species Program of the Australian Nature Conservation Agency. This Agency recognised at that time that grasslands were an endangered community. The recovery plan identified inadequacies in knowledge about the distribution, status and conservation value of grasslands in the ACT, and provided recommendations for survey and research for grasslands and species of concern.

Since then, site-specific management plans have been prepared for urban grasslands and are being implemented (Woodruff & Florence 1992) as part of a broader conservation strategy being prepared (D. Shorthouse pers. comm.). Management practices for grassland conservation are being negotiated for other sites such as Canberra airport, Bellenden St./2CY and the Belconnen Naval Transmission Station (D. Shorthouse pers. comm.). Community groups have shown an increased awareness of the biological value of grasslands, and could become involved in voluntary management of sites in the ACT. More comprehensive protection strategies are being developed (DELP 1994), but as yet no area has been protected (D. Shorthouse pers. comm.).

2. Developing a conservation strategy

2.1. Process and principles

The importance of moves towards a systematic approach to conservation planning, rather than the *ad hoc* approaches which have predominated in the past, has recently been stressed by Pressey (1995). The latter approaches have usually involved land acquisition into reserves using criteria such as availability, aesthetics, lack of demand by other land uses and political pressures generated by community groups (Williams *et al.* 1991). With time, the options available for planning an adequate reserve system are diminished as more land is allocated to uses incompatible with nature conservation. This is particularly critical for lowland grasslands because they are already highly fragmented by agricultural and urban development.

The systematic approach involves recognition of the scientific and political factors that come into play during development, and planning to meet the agreed conservation objectives. Our approach to developing a conservation strategy recognises four main steps, each step having associated principles. As consultants exploring options for the Gungahlin Central Area, we are concerned with the provision of scientific advice to support this approach through the application of the principles.

The main components we recognise are:

- the setting of goals and objectives,
- the assessment of information about the species, communities and sites of concern,
- the delineation of areas for conservation and consideration of their environmental context,
- the formulation of a framework of operational principles to allow flexibility in planning development while preserving key conservation values, and
- the development of management guidelines for grassland areas within and outside reserves.

Selecting among the options that emerge from this process requires political decisions in the knowledge that the environmental costs and benefits of choosing one option over another have been clearly articulated and based on a scientific assessment.

The principles involved with each of the components are now presented and detailed.

2.1.1. Set goals and objectives

Goals and objectives are important for maintaining focus across a diverse range of planning and management activities and in providing a basis for ongoing evaluation of programs.

> *Principle 1: Both regional and local objectives are required for conservation planning on the local scale.*

One reason a conservation plan is required is because the community in general has two potentially conflicting interests; in this case the desire for development to proceed and the desire to see the viability and quality of a natural resource preserved. In developing regional objectives for the conservation of natural grasslands in the ACT, relevant national objectives must be considered, just as national objectives are driven in part by Australia's involvement in international conventions and agreements. At a finer scale, objectives for grasslands of a local area such as Gungahlin are driven by objectives at the regional scale of the ACT.

In developing goals and objectives for the Gungahlin area, it is necessary to clearly identify and articulate the goals and objectives at the broader scale of the region. Achievement of objectives at the more specific levels can then be seen to contribute to objectives at a broader level. Furthermore, decisions on the extent of reservation necessary at the local level to meet regional objectives will depend in part on how well grassland areas at other sites contribute to those regional objectives. Greater attention will need to be paid to conservation within the Gungahlin area, regardless of local objectives, if other areas such as Majura and Jerrabombera Valleys are found to have only low populations of *D. impar*, *Synemon plana* and other grassland species which are well represented at Gungahlin.

It also needs to be appreciated that the task becomes more difficult as the focus of attention becomes more specific because basic information may not be available about the composition, structure and functioning of the smaller areas under consideration; but it is at this level that real conservation is achieved.

Principle 2: Both species and functional communities need to be considered.

Two broad goals are often espoused in nature conservation programs. First is the protection of particular species of interest, often rare or endangered ones. Second is the aim of conserving entire functioning communities. Both approaches are necessary and interdependent. An emphasis on species conservation is required because there will always be species whose population size has been reduced to a low level by human activities.

However, the conservation of such species cannot be done in a context divorced from the community of which they are a part. Indeed the reason for their decline in abundance is most commonly because of changes to the extent or quality of their habitat. Hence conservation of species in nature is achieved only by ensuring the maintenance of suitable environments. To reflect this, the term *biological diversity* has come into use to refer to both species and the processes by which they interact; it encompasses the variety and variability of life and its processes in an area. Implicit in this view of biological diversity is the need to maintain ecosystem processes which have been responsible for the production of species over long time scales. This is now seen as an encompassing conservation goal.

2.1.2. Assess knowledge of the species, communities and sites of concern

Principle 3: Knowledge of key life history properties of species and dynamic processes within the ecological communities is essential for sound conservation planning.

Certain aspects of species biology are more crucial in affecting their population density than others, including rates of fecundity, dispersal abilities, seasonal patterns of habitat use, habitat requirements etc. All have the potential to impinge upon conservation/management options. Some species are habitat generalists, occurring in a range of communities such as grasslands and woodlands, whilst other species are largely confined to just grasslands. For example, for the striped legless lizard (*D. impar*), it is pertinent to ask whether it is vegetation structure or floristics, or both, which are important in determining its abundance and distribution. Is this species highly mobile and possibly able to take advantage of the spatial and temporal mosaic of grassland resources? Are there perhaps specific places favoured for recruitment and/or refuge and which support a population more widely dispersed?

The composition of ecological communities is changing all the time and the changes may be particularly rapid when management and disturbance regimes are altered. Such change always means that some species will increase whilst others decline. It is necessary to gain an appreciation of the scale of these natural fluctuations in community attributes if one is to gauge the human-induced trends in the quality of grassland communities. The temporal dimension to community change will also call into question any "snapshot" assessments of community quality or suitability as a habitat for species of concern. For example, the perennial tussock grass *Themeda australis* is a species that may show a somewhat ephemeral response to seasonal conditions; at times appearing to dominate sites, and in other seasons or years being far less noticeable.

Principle 4: Spatial scale is important when assessing the value of published knowledge of species and communities.

Because we are obliged to sample populations and communities in order to be able to say anything about them, it is necessary to consider the spatial scale at which the sampling was done when interpreting the results. This is illustrated if we consider rarity and habitat association of a species. At the regional level a species may be considered rare and strongly associated with a particular vegetation assemblage, whilst at a local level it may sometimes be common and much less strictly associated with that vegetation. The legless lizard *D. impar* is a good example of this. Its distribution in south-eastern Australia is closely related to areas of native lowland tussock grasslands, but when its distribution is examined closely at the local level, it may be found in grassland sites dominated by exotic species, but usually within dispersal distance of patches of native grassland.

Principle 5: Common as well as rare species have a bearing on conservation planning.

There is seldom justification for being concerned solely with rare species conservation when there still exists habitat in which the species could survive. Just as a species may become less abundant because of environmental factors so also do species increase in abundance. Rare may become common and vice versa over time and at different spatial scales. More importantly, the common and rare species necessarily interact in ecological communities in many diverse ways which reciprocally influence the abundance of each and every species. For example, the native wallaby grass *Danthonia carphoides* is still moderately common in the ACT and provides the principal food source for the rare golden sun moth. The moths however, require extensive patches of *Danthonia* species to maintain their populations for the long term.

Principle 6: The quality of available data and therefore its value to conservation planning, varies depending on its taxonomic and spatial resolution, seasonal biases and temporal representation.

In making assessments for conservation we will always have data sets of varying quality and size. Because much of the most useful information is derived from field surveys of species composition and abundance, such datasets have to be interpreted carefully. For example we now know that to establish the full plant species composition of grassland sites in the ACT one needs to carry out careful plot-based surveys in both spring and summer in a year of adequate rainfall. Similarly, if we repeat such surveys in subsequent years we find there are real changes in the relative abundance of species, and such changes could eventually be related to seasonally varying environmental factors such as weather and management practices. Many of these influences on data quality are discussed more fully in Hone *et al.* (1992).

2.1.3. Delineate possible areas for conservation and consider their environmental inter-linkages

This third step in the development of strategy needs to be carried out at two spatial scales to accord with the two scales of objectives. At the regional scale we first determine why the Gungahlin grasslands (in this case) should be selected for conservation, and what priority should be accorded them. Then, having decided this, we can ask the question at the local scale within Gungahlin. That is, which patches of grassland there have the highest values for conservation and what caveats apply.

Principle 7: Areas considered for conservation should be those of the highest value in terms of meeting local, regional and national objectives.

Principle 8: Conservation value includes concepts of size (viability), diversity, representativeness, distinctiveness (rarity), and naturalness.

Recent developments in the procedures for systematic selection of areas for inclusion in conservation reserves emphasise the need for reserve networks to be representative, that is, to include the range of biological diversity and of other natural features (e.g. earth surface phenomena) within a region. Systematic procedures for designing a reserve system allow a set of representative areas to be identified explicitly and repeatably, provided a set of goals concerning representation and reserve design are given. Some of these tools are flexible enough to provide a variety of possible schemes to meet the same objectives, thus recognising that practically all decisions on the allocation of land for nature conservation are finally made on pragmatic as well as scientific grounds.

Assessing representativeness involves using the criteria of size, diversity, rarity and naturalness (both now and in the future). Ideally we require assessments of all available areas on each of these criteria as inputs to a regional and systematic conservation plan. Some of these criteria relate to the ecological status of places, while others relate to their condition relative to other places in the region under comparison. At the planning stage, additional criteria may also be incorporated into a conservation planning exercise, e.g. such features as amenity or aesthetic value and educational usage.

Rarity in the present context refers to the regional or national rarity of particular vegetation types or habitats. This presupposes a knowledge of the variation in community composition across a region. Often national or state-wide compilations will not be sufficiently detailed when it comes to survey a given region; but the latter surveys must be designed to complement the broad-scale ones in order to give perspective at the various scales. Areas selected to be representative examples of communities need to include both the common and rare communities, even though some species may occur in both.

The criterion of naturalness commonly refers to the degree of modification caused directly or indirectly by human influence. For this assessment in Australia, the usual broad baseline adopted has been the immediately pre-European condition of the vegetation communities, even though the role of Aboriginal people in altering some of these communities is recognised. A national map compilation of such natural vegetation is available, but local work using historical records and remnant vegetation is necessary to delineate even approximate boundaries between say woodland and grassland in a local area.

At the site level, characteristics such as the abundance of exotic species, the reduction of dominant plant species through grazing or pasture improvement and the degree of disturbance by development are all appropriate aspects of naturalness which need to be evaluated. In considering small remnants, the likely extent of physical change imposed on the ecosystem must be carefully evaluated. For instance, spray drift leading to toxic accumulations, the diversion of runoff influencing water balance, and urban heat islands changing the microclimate in terms of frost incidence. Such impacts on small areas are far more likely to bring about major and rapid community change than apparently more subtle effects such as random local extinction of component populations.

Another aspect of naturalness is the potential for areas to be rehabilitated to a more natural condition and/or to be linked to predominantly natural surrounds. If a patch has been altered in the relative abundances of species by e.g. domestic stock grazing, then the removal of grazing will enable some immediate recovery. In contrast, a site which has had nutrient additions will require a much longer time to recover and will require more specific management treatments, e.g. mowing and removal of biomass.

> *Principle 9: Diversity. Conservation areas that possess greater heterogeneity of environmental attributes (floristics, vegetation structure, abiotic components), within the bounds of those conditions known to support lowland grassland communities, are better than those that are largely homogeneous.*

Diversity in this context usually means the number of different species found in an area of defined size. Species diversity should not, however, be an over-riding consideration; other forms of diversity at all levels in the biological hierarchy should be considered. For example, the phenomenon of spatial variation in communities is one that could be incorporated into assessments of conservation significance. This does not deny the importance of species as the carriers of genetic potential, but simply recognises that species are produced and maintained by ecological processes at all levels.

It is also often difficult to identify the areas and components of the environment that are essential to the persistence of a threatened species in the long term. Populations expand, contract and shift spatially in response to seasonal and longer-term environmental variation. Foci for this expansion and contraction may no longer lie within the current range of the species, restricted because of development, bringing populations to crisis infrequently and unpredictably (say once in 75 years).

Even if all that is required for population persistence lies within the Gungahlin area, snapshot studies (those conducted over a few weeks, months or even years) are not guaranteed to yield the information necessary to preserve all essential environmental attributes. For this reason, heterogeneity in topography, soils, moisture regime, floristics and vegetation structure, within the bounds of those known to support lowland native grassland, should be maintained in any proposed conservation area as a high priority.

> *Principle 10: Size. Larger contiguous conservation zones are superior to smaller zones, or zones of equivalent size that are fragmented, all other considerations being equal.*

> *Principle 11: Shape. Conservation zones that have a large area to perimeter ratio are better than those that are irregular in shape, elongated or whose boundaries project into sub-optimal habitat.*

Areal extent is often used as a key consideration in deciding conservation value. It directly affects the population sizes able to be reserved therein and also the likely extent of external impact in both the short and long term. Much debate has taken place in conservation biology over the relative merits of reserved areas of differing sizes and shapes. However when considering a system of remnants, the size of individual remnants needs to be balanced against the total area and spatial relation of high diversity remnants that can be incorporated by use of buffer zones, corridors etc. into a reserve.

Because population size is the best predictor of extinction probability, reserves should be sufficiently large to preserve large populations of important species (rare and endangered species, keystone species, economically important species, wide ranging species, etc.). Small populations are more vulnerable to extinction due to environmental fluctuations, demographic variation, inbreeding and loss of genetic diversity. The best evidence to date suggests that populations in the order of a thousand reproductive individuals are needed to ensure the long term viability of vertebrates. The reasons for this are summarised below, and lie in an approach for determining minimum viable populations (MVP).

There is no single answer to the problem of what the minimum viable population size is for a species. It depends on the biology of the species and on the options available regarding the quality and extent of habitat which can be preserved. For most species there is virtually no information available that allows us to undertake assessments of population viability. Such approaches require information on population density and fluctuations, life-span, dispersal, lifetime reproductive output and age specific birth and death rates. Thus, in applying a MVP approach (such as has been applied to *D. impar* in Victoria) some educated guesswork about the probabilities of natural catastrophes is required. Moreover, the procedure can be overly time-consuming when conservation decisions have to be made quickly. Demographic and genetic arguments are in general agreement that a minimum viable population should be in the order of a thousand reproductive adults for the population to persist in the longer-term in the absence of environmental catastrophes such as disease and fire.

Existing data for *D. impar,* or indeed any of the species of concern in Gungahlin, is insufficient to allow a full MVP analysis. To attempt one would involve unacceptable guesswork, and, in the absence of the baseline data to enable an evaluation following its implementation, such an analysis would be futile. Instead, for *D. impar* we recommend that conservation effort in the ACT be directed at maintaining several populations that are in the order of one thousand individuals.

If the protected areas are subject to influences which may cause local extinction then we must consider the likely frequency of such events and the possibilities for recolonisation. In this case we will require some replication of these units to reduce the chances of regional extinction.

> *Principle 12: Replication of conservation areas in fragmented habitats is necessary as a hedge against catastrophic and/or stochastic local extinction.*

However, it is generally accepted that larger populations have a greater ability to withstand perturbations and contain higher levels of genetic diversity. The following should be considered when a choice is available between various remnants:

- the smaller and more elongate the remnant the greater the likely influence of external factors on the site;
- larger (and more elongate) remnants potentially contain a greater habitat diversity and therefore a greater diversity of species;
- a collection of smaller remnants may between them contain a greater array of habitats than one larger remnant;
- smaller remnants will not contain viable populations of all species but may be valuable in association with other nearby remnants in a reserve; while
- smaller, isolated remnants will lose species faster from the effects of drought, fire or human related impacts, as no undisturbed areas remain nearby from which recolonization can take place.

> *Principle 13: Regional conservation planning based on remnants must consider the constraints and opportunities provided by the present and future land use patterns.*

As well as selecting remnants to represent a region's biological diversity, a conservation plan must consider the spatial and ecological linkages between them. These will to a large extent influence the conservation value of patches and the reserve system as a whole. The structure of a reserve based on remnants can usefully be focussed on three components:

- the inclusion of a set of replicated patches with the highest conservation value,
- the control of the internal dynamics and external influences on the patches,
- the development of linkages between patches and of connections to other relatively natural communities.

Principle 14: Rehabilitation of fragmented habitats should be considered as a means of increasing overall size, buffering and interconnection.

Buffers and corridors could be developed by rehabilitation management techniques, using existing information on the development and management of native grass swards. While the structure and species composition of such areas will not be identical to that of more natural areas, their general appearance, wildlife habitat values and dynamic character result from similar ecological processes. This creative conservation approach includes planting species on sites which will add to their natural diversity and provide habitat value. Specific management regimes will need to be designed for such areas.

Native grasses are suited for use in rehabilitation since much practical information is already available for establishing the common species, and moreover, the time scale for development of a suitable vegetation structure is probably only a few years. However experience suggests that some exotic plant species will prove difficult to remove and the establishment methods for native species other than grasses are not so well understood.

2.1.4. Develop strategy options and management guidelines

Principle 15: Integration of smaller systems within broader conservation systems increases their conservation value.

A significant trend in conservation management is the extension of conservation programs to include the broader landscape outside of formal reserves. Historically, most conservation plans have assumed that the key to successful management of endangered species or communities is the prohibition of human exploitation or the inclusion of endangered species within a reserve. Legal protection can be a first step towards conservation, but is just the beginning of a sound population and community management program. Even in well-established national parks, human activities may still threaten species and communities, because disturbance and ecological processes continue across artificial boundaries.

The implication is that active management is required following reservation of remnant grassland areas, and management of certain possibly degrading processes, outside the reserved areas, is just as important if the values represented by the grasslands are to be protected.

Principle 16: Consider alternative reserve structures in the light of constraints and opportunities provided by planned development.

As grassland conservation relies largely on remnants, these fragmented systems require planning and management which accounts for the features which distinguish them from larger nature reserves and national parks. These features include the following.

- Remnants are usually a small, non-representative sample of pre-existing communities because of selective patterns of land clearance and impacts due to factors such as grazing; but they may contain most of the species of those prior communities.

- Remnants require ongoing management and monitoring because their small size leads to greater external impacts and likelihood of local extinctions.
- Remnants need to be considered as a system or network because fragmentation produces, firstly, a new biogeographic pattern of populations and communities, and secondly, each remnant has an altered physical environment due to changes in its surrounding conditions.

An evaluation scoring system can be devised to make comparisons between individual patches. Such systems are very dependent on the weighting given to their elements and the way in which these ratings are used to rank sites, however they provide some check on subjectivity in making comparisons. The key considerations on which to compare remnant grassland sites would include the following:

- areal extent and topography,
- number of native and exotic species,
- extent of invasion and modification (various categories),
- recent site history,
- number and priority of plant communities present,
- presence and relative abundance of any rare, endangered or threatened species of plant or animal,
- distance to nearest grassland remnant of a larger size,
- distance to a woodland,
- existing or potential to develop a buffer zone around,
- existing or potential to develop a corridor to other remnants,
- adjacent land use and its likely impacts.

Rating scales for each of these considerations can be developed and sites compared in this way, however this approach may lead to interpretation problems when higher ratings on some criteria compensate for poorer ratings on others in different combinations. Subjective judgement will remain an integral part of such assessments.

Principle 17: Conservation zones are not isolated from external influences and careful consideration needs to be given to compatible adjacent land uses, and moderation of their impacts.

The ecological character and land use of the area adjacent to a patch have significant effects, both direct and indirect, on that area's dynamics. These include variation in solar radiation, hydrological influences and wind patterns. Urban development on sites surrounding native grasslands may increase mean temperatures both diurnally and seasonally within the grassland, affecting reproduction and growth patterns of both plant and animal species. Fire regimes will have altered and require reappraisal. Other less direct influences include increased feral animal and weed infestation and changed nutrient status if there is run-on from adjacent sites. All these effects will lead to change in community composition over time.

The following strategies can be used to try to limit the effects of these influences on the patches and the whole reserve.

- Wherever possible, include patches which are run-off rather than run-on;
- select patches which have an existing or potential buffer around them (see next section);
- plan to reduce the possibility of pedestrian and vehicle desire lines going across patches;
- plan to minimise the fire ignition risk from adjacent land users;

- be particularly vigilant during any land development phase to protect against vehicular, dumping and nutrient impacts, as well as temporary or permanent diversion of run-on water and suspended material.

It is likely that the area immediately surrounding a remnant also has some habitat value, but will be more degraded than the remnant itself. Buffer zones around remnants will act to reduce the incidence and impact of weed and feral animal invasion and other disturbances in general. Buffers include for example, water bodies, rocky outcrops and strips of vegetation containing few introduced plants. They may be under different land tenure but still designed and managed to withstand higher levels of grazing pressure, or trampling, for instance, than the remnant.

One feature that is considered desirable to include in the development of a reserve is the provision of corridors, to reduce barriers for movement between a reserve and other refuges. In this context the term corridor is used to denote a strip of land linking areas which otherwise would be isolated, enabling some plant and animal species to move between refuges. Common corridors include road verges, drainage lines, windbreaks or shelter belts.

The following properties of corridors are commonly cited although not universally demonstrated:

- they may increase or decrease (by acting as a sink) the effective size of plant and animal populations;
- they may facilitate recolonization of a remnant which has been affected by some disturbance, such as fire;
- they support communities of plants and animals in their own right;
- they may form refugia in times of stress, or provide free access to refugia that are not widely available, such as during or after a fire or a drought.

To achieve these benefits, corridors should be as wide as possible to decrease edge effects, should contain native species as much as possible, and be managed in sympathy with the objectives set for adjacent remnants. For key species of concern the net value of corridors needs to be carefully evaluated.

Principle 18: Include research-based management, monitoring and community participation.

Biological resource managers are now realising that their art has to be adaptive, in the sense that we don't have full scientific knowledge at the start, all we need is the information to reach the next few steps towards achieving set goals. Indeed many decisions could not be postponed to await research results even if resources were available for the necessary investigations. To maintain this flow of information it is essential to include a research and monitoring component into any management program. Whereas previously managers could achieve their goals using the flow of general scientific knowledge, the increasing complexity and particularity of management now requires dedicated research focus. For example, tactical research is required to determine the management regimes which would maintain the biodiversity of remnants and to determine the significance of native and exotic grasslands to *D. impar*.

There is a clear need to have research and management integrated so that they guide each other. To do this, management actions have to include the establishment of research and monitoring sites. In time, the interpretation of results from these sites provides evaluative feedback to ongoing research, planning and management programs.

It is desirable that surveys are designed so that indicators can be identified and incorporated in ongoing monitoring programs. This allows population trends to be followed in relation to disturbance events and more gradual change such as may be caused by long-term climatic cycles.

Community perceptions of grasslands also pose some uncommon difficulties for achieving conservation, both in the urban and rural setting (Williams *et al.* 1991):

- grasslands are most commonly thought of as lawn, turf, field or pasture, rather than as a distinctive natural ecosystem;
- grasslands in Australia now usually lack any large native animals, and so have low popular appeal in terms of their conservation; and
- in an urban setting there is often an understandable tendency to plant trees on grassland sites or to see them as convenient areas for the spreading of fill or the stripping of topsoil.

These perceptions emphasise the need for close community involvement in grassland conservation efforts.

2.2. Procedure for grassland conservation analysis for Gungahlin

In the second part of this report we apply the following procedure for developing a conservation strategy based on the principles developed.

1. Develop conservation objectives at regional and local scale.
2. Assess knowledge of the species and communities. Evaluate quality of available information.
3. Assess the value of the Gungahlin grasslands in relation to those elsewhere in the ACT and Australia. What will be lost if they are destroyed or their values are eroded?
4. Decide indicators of conservation value (size, grassland quality, threatened species etc.) and cut-off values defining high conservation value.
5. Define patches on the basis of both natural and human induced boundaries as the smallest discrete mappable units for which data are available.
6. Assess the conservation value of each grassland patch in the Gungahlin Central Area.
7. Group the patches of high conservation value with regard to the nominated criteria, and plot them on a base map.
8. Decide on core conservation areas. These are areas of high conservation value which should be protected from adverse impacts as a high priority.
9. Identify all areas unavailable for inclusion in lowland grassland reserves, such as existing urban, improved pasture and upland areas and mark as excluded.
10. Identify all patches not identified as core but suitable for inclusion in lowland grassland reserves. Assess their value in terms of ensuring or improving the viability of core areas, as judged by application of conservation principles.
11. Explore options involving aggregation of adjacent areas for the protection of the highest ranking sets, paying particular attention to attributes affecting long-term viability such as patch size and connectivity. Give attention to pre- and post- development scenarios. Repeat in a series of steps for lower ranked sites to yield a graded series of options for conserved areas.
12. Explore options for maintaining or increasing connectivity of patches on a broader scale, such as might be possible between the Gungahlin Central Area and areas around Mitchell.

13. Present a series of conservation options which address issues at the regional (ACT), sub-regional (Gungahlin) and local (Gungahlin Central Area) scales, and provide design and management guidelines related to the principles developed.

PART B : STRATEGY

3. Proposed conservation goals and objectives

The World Conservation Strategy was established in 1980 by the International Union for the Conservation of Nature and Natural Resources, stating three main objectives for nature conservation. These were (i) to maintain essential ecological processes and life-support systems, (ii) to preserve genetic diversity, and (iii) to ensure the sustainable utilisation of species and ecosystems.

The UN Convention on Biological Diversity, developed in 1992, came into force in late 1993 after more than 150 States, including Australia, signed it, thus making it an instrument of international law. This is a commitment by these nations to conserve biological diversity, to use biological resources wisely and to share equitably the benefits arising from the use of genetic resources. On the strategic planning side, the Convention creates obligations to develop national strategies and plans, to integrate the conservation and sustainable use of biological diversity into relevant sectoral plans, programs and policies, as well as into national decision-making. Each signatory undertakes to identify important components of biodiversity and to give emphasis to *in-situ* conservation through the maintenance of viable populations of species in natural environments.

The thrust of these international agreements is reflected in Federal Government thinking. In the 1992 Statement on the Environment the Prime Minister stated that "*Our fauna and flora and our climate and landscape are just as much natural assets of Australia as gold or coal or iron ore*". In a further commitment to the environment by the government, the State of the Environment Reporting Framework for Australia was launched in 1994, at which time the Minister for the Environment, Sport and Territories, Senator John Faulkner, stated that "*...we have an undoubted global responsibility to act (on) the conservation and wise management of biological diversity*". Federal responsibilities in the ACT are closely involved in the fate of the

Territory's remnant grasslands, because of its control of a number of important sites such as Bellenden Street/2CY and the Majura Field Firing Range.

At the State level, the ACT Government Environmental Strategy released in January 1995 provides a framework for the development, review and revision of a range of strategies and legislation for effective environmental management. The strategy promotes a holistic, coordinated and comprehensive approach to management of natural resources. Government initiatives in the ACT which affect vegetation and fauna conservation include the *Nature Conservation Act 1980* (responsibility for the ACT to protect its native plant and animal species -- although fish, invertebrates and non-vascular plants have little formal protection unless specifically declared); the *Land (Planning and Environment) Act 1991* (relates to planning, environmental assessments and inquiries, heritage and land administration); the *Nature Conservation (Amendment) Act 1994* (strengthens provisions for the identification and protection of threatened native species and communities); the Territory Plan and the *Commissioner for the Environment Act 1993.*

Native species and sites of ecological significance may be protected under the provisions of the Land (Planning and Environment) Act 1991. Places which may have scientific or natural heritage significance may be placed on the Interim Heritage Places Register, with priority given to places under threat of destruction, disturbance or redevelopment. Gazettal gives legal effect to conservation and management measures as identified in a listing for the site. While numerous sites of cultural significance appear on the register, to date few sites of natural significance, and no sites in Gungahlin, have been listed. However, several natural sites are currently being proposed for listing, including grassland sites supporting significant populations of *Synemon plana* (golden sun moth) and *Tympanocryptis lineata pinguicolla* (southern-lined earless dragon).

The *Nature Conservation (Amendment) Act 1994* established a process for the assessment of the conservation status of both native species and ecological communities by the ACT Flora and Fauna Committee, which provides advice to the Minister. The committee also provides advice on the identification and management of processes that threaten or may threaten native species and ecological communities. Criteria for recommendations on species, communities and threatening processes are in the final stages of drafting, and are currently being circulated for public comment.

In light of the above, we propose the following set of regional and local objectives for conservation of grassland ecosystems in the ACT, with the local objectives being of clear relevance to the Gungahlin area.

Regional Objectives

To conserve the ACT's remnant native grasslands so that the biota and ecological processes they comprise remain viable and well represented in the ACT in perpetuity.

To integrate the ACT's remnant grasslands into broader conservation systems, involving both reserves and areas outside reserves, and their management.

To promote public awareness of the conservation value of grasslands in meeting regional, national and international conservation objectives on biodiversity and the environment.

Local Objectives

To conserve all grassland patches in the sub-region which are of a size and quality to persist indefinitely given a feasible level of active management, and which contribute to meeting regional objectives.

To maintain the spatial extent and integrity of the grassland community and the viability of threatened biota within conserved areas.

To interface the local system of conserved areas with community expectations for use of open space.

It is clear that not all of the remnant grassland in and around Canberra could be incorporated into a viable conservation reserve system. Many sites are extremely small and so isolated that their chances of surviving the effects of adjacent urban land use for any significant length of time are low. It is also recognised that the objectives given above may not be fully realised because planning decisions are made by integrating a range of considerations, of which conservation of the biota is only one. In such cases, planning must be undertaken with a view to minimising the impact on conservation values, even though it is admitted that some detrimental impact will occur.

Often, detrimental impacts can be offset by investment of funds and/or resources to improve the prospects for conservation in adjacent or other regions. Minimising impact or trading off benefits against deleterious impacts requires an assessment of relative value of the resource, either in before and after development comparisons, or in a spatial context. In the consideration of Gungahlin, it is necessary to have an assessment of the value of these remnants in relation to other grassland remnants in the ACT region, and to be able to assess the value of the grassland remnants post-development with those present in Gungahlin now.

4. Assessment of knowledge and significance of species and communities of concern

4.1. Knowledge of native grassland flora

4.1.1. Data sources

The sources of comprehensive, current data which have been used as inputs to analyse grassland conservation options in the ACT and Gungahlin are summarised here in order to highlight the areas surveyed, methods used, and utility or outcomes of each study which are relevant to the present study.

McDougall & Kirkpatrick (1994) coordinated surveys of lowland grassland in south-east. Australia covering the Monaro (NSW and ACT), the Gippsland Plains (Vic.), Western Basalt Plains (Vic.), South Gippsland (Vic.), South Australia and Tasmania. This survey was relatively broad scale, and aimed to cover all regions thought to have supported lowland native grasslands. The analysis of these surveys provides a floristic definition, at a broad level, of remnant lowland grassland communities in south-east Australia.

The Monaro work was further analysed by Benson (1994) who visited sites once in spring or summer 1991/2 to establish plant species present. Representative sites were selected from expert advice and by field searching. This analysis provides a regional context for the ACT and southern tablelands, but cannot be taken as a comprehensive coverage of sites for the ACT.

Sharp and others (see Sharp & Dunford 1994) have surveyed the ACT lowland grasslands (i.e. on the tablelands) and surrounding region by finding sites from satellite imagery and field checking. Floristic composition was recorded both in spring & summer 1991/2, and site management history and soil properties assessed also. This work provides a baseline description of the floristic composition and the delineation of many major high quality sites in the ACT.

The Wildlife Research Unit (1995) has recently surveyed grasslands in Gungahlin southwards from Mulligans Flat Reserve to the Federal and Barton Highways. All grassland types were field mapped in late summer (1995) with the aid of aerial photography. Floristic and conservation ratings were given to units identifiable at 1:10,000 scale for all types of grassland. This provides an assessment of grassland type and conservation rating across the entire area of concern to the present study, however there is no floristic detail available from this survey. The seasonal responses of the grasses and other flora make it difficult to assess the composition of areas which have been heavily grazed or which are only assessed at one time of the year.

These surveys were carried out for slightly differing purposes and although some aspects of the methods were standardised, such as the *a priori* floristic conservation rating, there are some inevitable differences in the level of resolution each provides. Nevertheless they are complementary, as they span the various spatial scales of concern relative to assessing the significance of the Gungahlin remnants. As a consequence of the different scales and objectives of survey, the Gungahlin study (Wildlife Research Unit 1995) is the only one which has been done at a resolution capable of providing a complete map of grasslands (including native and exotic pastures) in any part of the region. The other studies described above have focussed on the generally smaller areas of highest conservation value and provide some of the data necessary for assessing the wider significance of grasslands for conservation.

4.1.2. Extent and quality of grassland types in the ACT region

The Monaro region's grasslands (including some ACT sites) have been surveyed at a broad level. Grasslands in the ACT and nearby NSW represent a northern outlier of an extensive area of cool climate grassland which originally occupied much of the Monaro region (Figure 1) (Benson 1994; Benson & Wyse Jackson 1994). These authors estimated that at the time of European settlement there were some 250,000 hectares of native lowland grassland in this region. Some 20,000 hectares of this total occurred in the ACT.

Only a very small fraction of the Monaro and ACT grasslands remain in close to natural condition. The extent of loss of this community was addressed broadly by Benson and Wyse Jackson (1994) who found that less than one percent of the native grassland in the northern Monaro (excluding the large area of *Poa sieberiana* dominated tussock grassland south of Cooma) remains in good condition.

Our knowledge of the extent of the remaining high quality lowland native grassland in the ACT has been improved by recent surveys (Sharp & Dunford 1994), however there are still some extensive areas, such as the Jerrabombera Valley, requiring further investigation to ascertain their conservation value (DELP 1994). Also unknown is the conservation value of what were once extensive areas of grassland in NSW near Bungendore (refer Figure 1). Grassland remnants in that area could contain communities reasonably similar to those of the ACT, but have apparently not been surveyed.

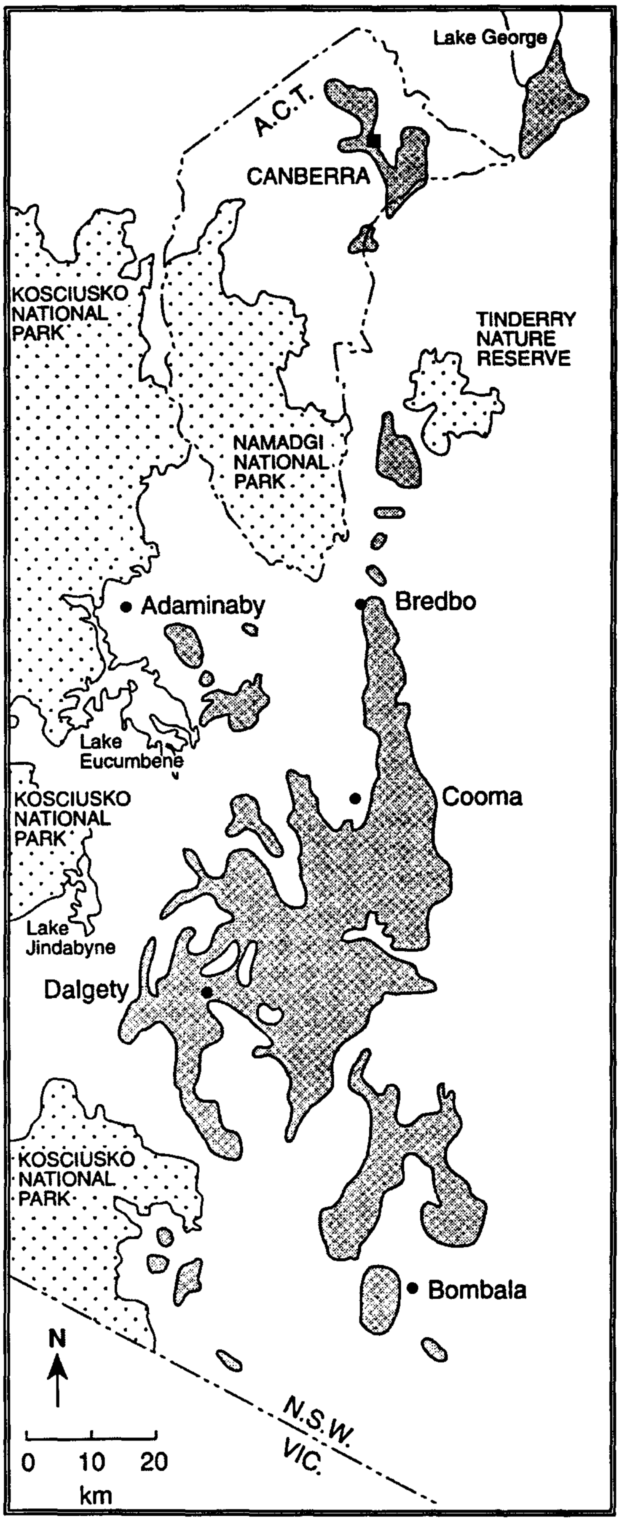


Figure 1. Estimated extent (shaded area) of natural grasslands below 1000 m at the time of European settlement on the Monaro. (Adapted from Benson 1994).

Most of the lowland native grasslands have been affected by heavy grazing, localised cropping, application of fertiliser and introduction of pasture plants and weeds. As a result of this disturbance, the composition of the grasslands is now considerably changed in many sites, with the decline of palatable or sensitive grasses and forbs, including kangaroo grass (*Themeda australis*). The best preserved sites generally occur in small areas fenced off from grazing and/or other disturbance or in areas of light grazing pressure. Large patches of kangaroo grass are now rare in lowland sites and the presence of a *Themeda* or *Danthonia* sward can often be considered to be an indicator of less disturbed native grassland in much of this region (Chan 1980).

The Gungahlin native grasslands include areas dominated by all of the major native grass species of the district, including *Stipa bigeniculata, Themeda australis, Bothriochloa macra,* and several *Danthonia* species (Rauhala *et al.* 1995). Although comparative data on other plant species across the area are not yet available, we can surmise from the range of dominant grasses present, and the conservation ratings, that there are likely to be populations of many other grassland plant species scattered through the area and contributing to overall community diversity.

The diversity of grasses present, including the exotic species such as *Phalaris aquatica,* produces a wide range of possible growth responses in these grasslands to seasonal weather conditions and grazing pressures. This may be an important factor in providing enduring tussock cover for fauna such as reptiles.

4.2. Significance of the grasslands

4.2.1. National significance of ACT native grasslands

At the time of the first European settlement in Australia, lowland areas of south-eastern Australia had one of the largest areas of native temperate grassland in the world. However these grasslands are now amongst the most endangered natural communities in Australia. It is against this background that the value of the native grasslands in the ACT, particularly in Gungahlin, will be assessed.

McDougall and Kirkpatrick (1994) suggested that there are now about 10,000 hectares of lowland native grasslands remaining in south-east Australia compared with an estimated pre-European area of two million hectares. Similarly there were estimated to be approximately 20,000 ha in the ACT (Benson 1994). In the ACT, there is approximately 800 hectares of primary native grassland which is considered to be still in a near to natural condition, i.e. with a conservation rating of 1 or 2 based on component plant species (Sharp & Dunford 1994; DELP 1994). This represents about 8% of the remaining high quality lowland native grassland in south-east Australia and about 4% of the pre-European area in the ACT.

McDougall and Kirkpatrick (1994) also analysed the total floristic pattern across all the regions surveyed and from this they defined 26 different grassland communities. Five of these are confined to the Monaro region including the ACT, indicating that about 20% of the plant community diversity of native grasslands in south-east Australia is presently found on the Monaro.

One of the communities recognised at this broad scale is found only in the Canberra region (Benson 1994). This is the *Danthonia* dominated grasslands at low altitudes (ca. 600 m) on red clays. Two other communities recognized at this broad scale are found only in the ACT and southwards intermittently as far as Bredbo along the Murrumbidgee Valley. These are *Themeda australis* dominated grasslands at low altitudes on loamy clays and another type of *T. australis* dominated grassland at slightly higher altitudes on sedimentary and volcanic soils.

4.2.2. Regional significance of Gungahlin grasslands

To assess the regional significance we have used the data presented by Sharp & Dunford (1994) and the similar DELP (1994) report because these cover the ACT at a consistent level of recent survey. Based on these reports, primary or natural grasslands (i.e. those that were here at the time of European settlement, as opposed to secondary grasslands formed by later clearance of woodlands), occur in only six sites greater than 10 hectares in the ACT, and these total about 795 ha. Sites less than 10 ha total approximately 13 ha (Sharp & Dunford 1994). Of this 808 ha, the Gungahlin area was thought to account for 130 ha (16%) of the remaining high quality lowland native grassland in the ACT (Sharp & Dunford 1994). If we consider all areas of native grassland (but not grassy woodlands) in the ACT, that is, both primary and secondary, there are approximately 1,152 ha of which 145 ha (13%) are in Gungahlin (Sharp & Dunford 1994).

More intensive surveys this year in Gungahlin have demonstrated that there are greater areas of native grassland, native pasture and disturbed grassland in Gungahlin (Davis & Hogg 1992; Rauhala *et al.* 1995; Wildlife Research Unit 1995). These grasslands have been surveyed in a way which might eventually enable detailed comparisons across the ACT, however the rest of the ACT has yet to be surveyed in such detail. Nor are close comparisons possible with the Monaro-wide survey of Benson (1994), although floristic data were collected for many trapping sites in this area (Rauhala *et al.* 1995). The mapping done by WRU (1995) of the Gungahlin study area is best suited to assessing local significance within the surveyed area, and has been so used in Part 5 of this report.

The recent mapping shows that most of the mapped boundaries for native grasslands in Gungahlin have a clear association with fence lines. Therefore the particular set of species dominant in any area is likely to be in part a response to the management history of the site. For this reason it is not considered useful to attach too much importance to the various floristic sub-units of the native grassland category which have been mapped.

The lowland native grassland types occurring in the ACT are extremely poorly protected regionally. In particular, the *Danthonia* spp. – *Asperula conferta* – *Bothriochloa macra* low grassland is apparently found only in the ACT and near Queanbeyan, with the largest site sampled being the Navy Transmission Station in Belconnen (Benson 1994). The *Themeda australis* – *Juncus filicaulis* lowland grassland community (Benson 1994) is also very restricted, occurring mainly in the ACT and northern Monaro. It was recorded at five sites by Benson, (three of which were in the ACT, one of these being the Bellenden Street/2CY site in Gungahlin), though there are other examples of this community within the ACT.

Rauhala *et al.* (1995) recognised five main types of grassland communities in which the striped legless lizard (*D. impar*) has been found in the ACT. These have been defined very broadly as native grassland, rough native grassland, degraded and disturbed grassland, exotic grassland and drainage line and wetland vegetation. The native grassland associations described from sampling at *D. impar* trap sites in the ACT (Rauhala *et al.* 1995) include three communities: *Danthonia caespitosa–Themeda australis* community, a *Themeda australis* community and a *Stipa bigeniculata* community.

The category of rough native grassland should also be considered important here because it is also largely dominated by native species, has a high potential for rehabilitation and some areas contain populations of threatened species (Table 1). The community is described by Rauhala *et al.* (1995) as having a broader, less consistent spectrum of floristic and structural conditions, and is considered to be more disturbed by grazing and has a higher incidence of exotic species. Whilst Rauhala *et al.* do not provide a direct comparison with other ACT grasslands they note that the better quality grasslands of this category in Gungahlin include "significant patches of relatively undisturbed native grassland, with very high native grass and forb component and minimal exotic species frequency".

Table 1. Species thought to be nationally threatened and which are present in ACT grasslands (after Sharp 1994).

Button wrinklewort	*Rutidosis leptorrhynchoides*
Purple pea	*Swainsona recta*
Austral toadflax	*Thesium australe*
Striped legless lizard*	*Delma impar*
Pink tailed legless lizard	*Aprasia parapulchella*
Southern lined earless dragon	*Tympanocryptis lineata pinguicolla*
Golden sun moth*	*Synemon plana*
Morabine grasshopper*	*Keyacris scurra*
Canberra wood cricket*	*Cooraboorama canberrae*

* Known to occur in, but not confined to, the Gungahlin study area.

The larger patches of native grassland in Gungahlin are of undoubted conservation significance in the region. The *Themeda australis – Juncus filicaulis* grassland at the Bellenden Street/2CY site is listed as a site of ecological significance in the ACT (NCDC 1990) and represents a community that is now uncommon and highly threatened in the Southern Tablelands (Benson 1994).

The larger patches of *Stipa bigeniculata* dominated native grassland and native pasture at Gungahlin have a wider distribution in the region (Benson & Wyse Jackson 1994; Benson 1994) and are less significant in an ACT context because large areas of less disturbed examples of this community occur in the Jerrabomberra Valley. Importantly however, they contain significant populations of threatened species which considerably enhances the regional significance of the Gungahlin grasslands.

The Gungahlin native grasslands therefore contribute unique elements to ACT grasslands as a whole, not only floristically, but because of the substantial natural populations of threatened fauna species. It is important to note, however, that reservation of Gungahlin grassland remnants to meet the local objective of conserving the diversity of native grassland communities at Gungahlin, will contribute only partially to a similar objective for the ACT or wider region. This is because other grassland areas also contribute uniquely to grassland values of the ACT (e.g. the presence of the earless dragon in the Jerrabombera Valley grasslands).

4.3. Fauna of conservation concern in Gungahlin

4.3.1. The striped legless lizard *Delma impar*

4.3.1.1. Data sources

Coulson 1990; Williams *et al.* 1991; Department of Conservation and Environment 1992; Kukolic 1992, 1993, 1994; Wainer 1992; ACT Government 1994; Kukolic *et al.* 1994; Osmond 1994; Hadden 1995; Rauhala *et al.* 1995.

4.3.1.2. Biology of *Delma impar*

There has been little research on the biology and ecology of the striped legless lizard *D. impar.* What little information there is has been opportunistically collected during distribution surveys in the ACT and in Victoria. The genetic structure of ACT and some Victorian populations has been examined by Osmond (1994) who confirmed that these populations were very similar.

Diet: *Delma impar* is an invertebrate predator. Preliminary studies in Victoria indicated that the species consumed a range of invertebrate prey items, with the larvae of noctuid moths thought to be particularly important in the diet (Coulson 1990; Wainer 1992). More detailed research in the ACT (Nunan 1995) supports this view, with the main prey taken including cockroaches, crickets, moth larvae and grasshoppers. Nunan's research also indicates that the prey available is considerably less diverse in exotic grasslands, with spiders and crickets being the main prey taken. It is not known if the reduced prey diversity in exotic grasslands has an influence on the long-term survival prospects for the species at such sites.

Reproduction: Little is known of the species' reproductive ecology . Breeding occurs in early summer when a clutch of two eggs is laid in the soil at the base of tussocks or beneath stones embedded in the soil (Kukolic *et al.* 1993). Hatchlings appear in March and it is unlikely that a second clutch is laid. The low clutch size of *D. impar* increases its susceptibility to disturbance because of its effect on the potential rate of population recovery. Reproductive adults have been found in both native and introduced grasslands.

Dispersal: There are indications that the lizards are capable of active and extensive movements above the ground. There have been several sightings of individuals moving rapidly over the tops of dense *Themeda* swards (W. Osborne pers. obs.; D. Nunan pers. comm.). Observations of marked animals by Kukolic *et al.* (1994) recorded maximum movements between pitfall traps of 62 metres in nine days and 60 metres in two days. Similarly, Rauhala *et al.* (1995) recorded potential maximum distances travelled of 52 and 58 metres during two day periods. These movements are about the maximum that could be recorded with the particular trapping layout used by the Wildlife Research Unit, and it is likely that movements involving a greater length would be made by some individuals over a longer period. However, as is discussed below, some of the movements recorded may be in error if the lizards actually climbed over drift fences instead of travelling around their extremities.

The trapping of specimens in very small patches of less-disturbed vegetation in the middle of extensive open areas indicates that the lizards can apparently retreat in to such refuges if available (Kukolic *et al.* 1994). Kukolic (pers. comm.) believes that it is likely that *D. impar* retreats to low-lying ephemeral drainage lines that have a thick residual cover of rushes (*Juncus* spp) and grasses such as *Holcus* or *Phalaris*. Kukolic uses this argument to explain why the species is readily caught in such restricted areas of paddocks that have been overgrazed; the lizards simply congregate in these protected sites during adverse periods and move back into nearby grassland when seasonal conditions improve. Whilst this theory is as yet untested by experimental research, it does provide an explanation for the apparent rapid colonisation of some formerly overgrazed sites (K. Kukolic pers. comm.). Further research on this aspect of the biology of the species is required.

Predation: There is little information available on the natural predators of *D. impar*. In the ACT kestrels (*Falco cenchroides*) have been observed capturing the lizards on several occasions (W. Osborne pers. observ.). Other birds of prey which hunt over grasslands in the ACT include black-shouldered kites (*Elanus notatus*), a species known to capture *Delma inornata,* a related species which does occur in Gungahlin (J. Olsen pers. comm.). Birds of prey frequently utilise powerlines and poles as a vantage point for detecting prey and the placing of such perches in grasslands may lead to an increase in predation.

Cats also frequently capture legless lizards. Following the development of the suburb of North Lyneham, a resident reported that her cat killed 11 *D. inornata* in a fortnight period (pers. comm. to W. Osborne). Recent studies (Barratt 1995) have shown that companion cats in suburban areas will travel up to 900 m from the suburb into grasslands. Their activities taper off with distance from the suburb edge, and the distance travelled is less during the day and apparently also where there are low amounts of cover such as tall tussock grasses. Barratt recommends that buffer zones of 200 m in width be considered to minimize the impact of companion cats on wildlife, in the absence of other effective measures.

4.3.1.3. Floristic composition and habitat structure

Delma impar is restricted to areas of lowland grassland dominated by perennial tussock-forming species. In Victoria the lizards show a preference for native grasslands dominated by *Themeda australis* but there have been records from areas dominated by introduced grasses such as serrated tussock (*Nassella trichotoma*). In the ACT the species has been recorded at many sites dominated by *Themeda australis, Stipa bigeniculata* and taller species of *Danthonia* (e.g. *Danthonia caespitosa*). Most sites have been affected by weeds to varying extents, with some sites being dominated by exotic tussock grasses such as *Phalaris aquatica.* Although *D. impar* has been captured in exotic grasslands (e.g. *Phalaris* and *Festuca*) it is not known if these populations are sustainable in the long term. It is possible that such habitats do not provide a broad enough food base to support viable populations (see comments under diet), and it is also possible that the sites will gradually become rank and unsuitable, particularly without livestock grazing. The use of such exotic dominated sites may be dependent on the presence of other breeding populations occurring in adjacent native pasture. This requires further research.

4.3.1.4. Response to management activities

Field surveys indicate that the quality of suitable habitat is linked to grasses with a particular tussock structure which may be essential for the long term survival of local populations of *D. impar.* Kukolic *et al.* (1994) suggest that intensive grazing and cultivation reduces this tussock structure, causing the eventual disappearance of the lizards. Frequent burning and mowing of sites is likely to have the same effect, although this requires further research.

Whether *D. impar* is able to respond to over-grazing, or other disturbance, by adopting a semi-fossorial existence or retreating into soil via cracks or invertebrate burrows is unknown. The discovery of specimens in freshly ploughed paddocks provides circumstantial evidence that the lizards may be able to seek out sub-surface microhabitats (K. Kukolic pers. comm.). Rauhala *et al.* (1995) also report that in 1994 many specimens were found sheltering in the soil in gaps that had formed on the outside edge of pitfall traps, providing further support for this possibility. If the lizards are able to survive by adopting a semi-fossorial existence, it may explain in part their apparent ability to rapidly recolonise formerly over-grazed areas of perennial tussock grasslands.

Recorded densities appear to be related to ground cover, and it has been indicated that heavily grazed areas have the potential to regenerate following specific management actions such as reduced grazing (Rauhala *et al.* 1995).

4.3.1.5. Distribution of *Delma impar*

Because of its cryptic behaviour and appearance there have been few comprehensive studies of *D. impar,* and its distribution remains poorly known throughout much of its potential range. The lizards have been recorded at an estimated 125 sites in south-eastern Australia, stretching from Bool Lagoon in South Australia, through Victoria and the Tumut region to the ACT and Goulburn (Coulson 1990; Hadden 1995). A single specimen, now in the Macleay Museum Sydney, was apparently collected near Cooma in 1888 (Shea 1993).

Known distribution based on surveys

Numerous trapping surveys have been conducted for the species in both Victoria and the ACT in recent years. The technique of trapping is expensive and causes some disturbance to grassland sites, with each site requiring trapping with pitfall traps set for approximately four consecutive weeks in late spring (November-December).

Most of the previously known *D. impar* sites have now been disturbed and in a recent analysis Hadden (1995) indicated that only about 40 sites remain, mostly near Melbourne, Ballarat, Bendigo and Canberra. Eleven of these sites (broadly corresponding to a grassland locality; not a specific trap site) occur in the ACT, representing 40 per cent of all known *D. impar* sites (unfortunately the eleven sites in the ACT are not listed so it is not possible to judge how representative this is of the actual distribution of currently known sites in the ACT). The high value for the ACT may in part be a result of the substantial survey effort conducted by the ACT Parks and Conservation Service in recent years.

The current distribution of *D. impar* in New South Wales is not known. There are historical records from near Batlow, Tumut and Cooma, and a recent record from Goulburn. In the ACT the species is known from four disjunct areas: the lower Gungaderra catchment (largest population known in the ACT), Yarramundi Reach (very small population), the Majura Valley immediately north of the Canberra Airport (moderate population) and the Jerrabomberra Valley where only preliminary trapping has been undertaken (Rauhala *et al.* 1995). The known altitudinal range in the ACT is 560 metres to 626 metres. Detailed and extensive surveys have been undertaken only at Gungahlin and Yarramundi Reach (Kukolic 1994; Rauhala *et al.* 1995). The broader distribution of the lizards in the Gungahlin area has been determined through the detailed surveys mentioned above. The species has been captured in five main areas: Crace, Lower Gungaderra, proposed Gungahlin Town Centre, South Mitchell and Kenny (Rauhala *et al.* 1995). Additionally, the lizards have been found previously in the grounds of the CSIRO Division of Wildlife and Ecology, and to the east of the Barton Highway in disturbed grassland near Kaleen.

Predicted distribution based on habitat requirements

With the information currently available, it is not possible to predict the distribution of *D. impar* in the ACT or surrounding areas of NSW. Suitable combinations of topography which include naturally treeless grasslands certainly occur elsewhere near Sutton, Gundaroo, Lake George and Goulburn, and it would be surprising if populations did not occur in parts of this region.

Unfortunately, at a regional scale it is difficult to predict the distribution of *D. impar* without a knowledge of grassland floristics and structure. The suitability of sites for occupation may also vary from year to year depending on the extent of ground cover present. It is very likely that the species has disappeared from areas that have been subject to cultivation and improvement to annual pastures. Thus, until surveys are conducted more extensively in the region, including in the Jerrabomberra and Majura valley areas of the ACT, it must be recognised that the only substantial remaining populations, apart from those in Victoria, occur in the ACT at Gungahlin. In order to assist with regional conservation planning for *D. impar*, it is essential that surveys in NSW be funded and undertaken to match the survey effort in the ACT and in Victoria.

The most extensive surveys in the ACT have been undertaken in Gungahlin, thus enabling a greater level of prediction. Within the generally defined possible range of the species in Gungahlin the lizards were captured at 19 of 37 trap sites sampled by Rauhala *et al.* (1995), indicating the likelihood of an extensive distribution throughout much of the area. The highest abundances were generally recorded in native grasslands, however depending on the year of the survey and the current grazing levels, density was found to vary considerably across the area. For example high abundances have been recorded in some areas of exotic grassland in the proposed suburb of Kenny and near the eastern edge of Kaleen.

The upper altitudinal limit of the species appears to be defined as a maximum by the 625 m. contour line, although trapping to the north and east of the Gungahlin Central Area suggests that the species reaches the limit of its geographic extent below the 625m contour (Figure 2) and is not distributed away from the open areas of the former treeless plains. Parts of the Gungahlin area not occupied by the lizards have been subject to considerable cultivation with the result that pastures dominated by perennial grasses have often been replaced by annual pastures which are apparently unsuitable for *D. impar.* In addition, much of the higher ground in the GCA was formerly tree covered and thus may have been originally unsuited to occupation by the species.

Within the GCA the general extent of the distribution of *D. impar* is now fairly well defined, as represented by the known capture sites (Figure 2), and it is likely that the species has an extensive distribution, only avoiding urbanised areas, road surfaces, improved grasslands that lack perennial tussock-forming species, and areas subject to a history of crop production.

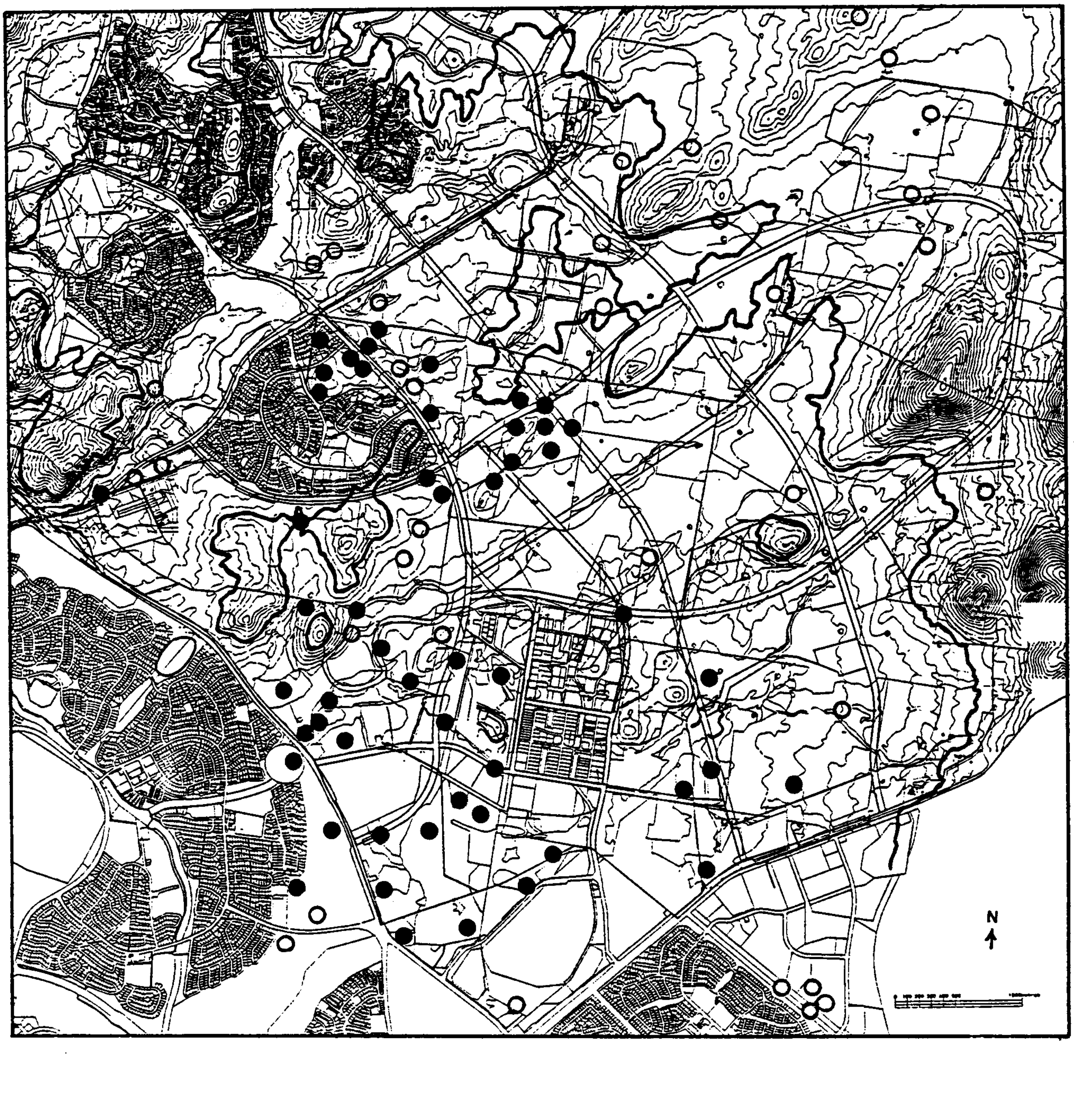


Figure 2. Location of sites that have been trapped for *Delma impar* at Gungahlin by the ACT Parks and Conservation Service. Closed circles represent trap sites where *D. impar* has been caught, open circles represent sites where trapping occurred but the species was not found. Also shown is the 625 m contour.

4.3.1.6. Abundance of *Delma impar*

Relative abundance estimates

Relative abundance of *D. impar* is currently measured as catch rate (usually as the number of individuals caught per 1000 trap nights). There have been no attempts to estimate population size based on mark-release-recapture methods. November/December catch rates for a site in the ACT that has been monitored for several consecutive years range from 4.7 to 56.5 per 1000 trap nights (Rauhala *et al.* 1995). In 1993 Kukolic *et al.* (1994) recorded the highest catch rate recorded for the ACT of 57.1. The mean catch rate over all years for all successful trap sites in Gungahlin is 6.2 (median 9.6), whereas in 1994, a drought year, the mean catch rate was 2.9. High catch rates for the species have been recorded patchily throughout much of the inner Gungahlin area making it difficult to map specific areas with higher abundances. As was mentioned above, this approach should be treated cautiously.

The use of capture success as a means of measuring true relative abundance is compromised by the likely differential trappability of the species when grassland condition changes with drought or grazing. Rauhala *et al.* (1995) caution that it is unsound to postulate a significant change in population size for any location on the basis of results obtained only twice. This means that the reduced abundance of *D. impar* at Gungahlin in the last summer of trapping (Nov/Dec 1994) should not be taken to mean that the sites are no longer suitable. Most individuals may well have stayed in the over-grazed drought affected paddocks by sheltering in burrows, and by retreating into remaining areas of ground cover.

4.3.1.7. Population density and dispersal ability:

Population density can be defined as the number of individuals per unit area. Lizards that occur in relatively unproductive environments occur in the lowest densities. Population densities are not static and are known to vary among locations and years in the same species. Unfortunately there are few estimates available of the density of grassland reptiles (Heatwole 1987). There are no estimates of population density for *D. impar* and the information available is based on capture frequency based on captures of individuals during standard pitfall trapping (20 traps in a cross pattern linked by two drift fences, each 50 metres long) by the ACT Parks and Conservation Service.

During the 1994 trapping season a total of 72 individuals were caught at 25 sites. The density at many sites was thought to be low during this season because of the drought and sparse ground cover (Rauhala *et al.* 1995). The mean catch rate at sites with *D. impar* was 6.2 per 1000 trap nights, with a range from 1.4 to 11.5. Trapping during the same period by D. Nunan (pers. comm.) at four ungrazed sites for which previous years trapping results were available at Gungahlin gave a mean of 8.9, with a range from 5.3 to 12.5. In fact trapping by Nunan indicated an increase in catch rate in 1994 compared to 1993 (see Table 8 of Rauhala *et al.* 1995). Thus, the drought may have depressed catch rates for *D. impar* but perhaps only substantially in the over-grazed paddocks. These differences in catch rate and their interpretation present difficulties in assigning a significance value to a site where the species has been trapped. This is further discussed later in relation to assigning a ranking value to sites where the species has been trapped.

There is little information available on the distances moved by *D. impar*. Ten animals were caught more than once, with the period between release and recapture varying from two to 20 days. The maximum recorded distances of 52 and 58 metres were moved during two day periods, while another individual was recaptured less than five metres away after 20 days. These movements are the maximum that can be detected by the trapping array, and it is quite likely that some specimens actually cross over the tops of the fences, or burrow underneath them, giving an incorrect measure of distance moved (Rauhala *et al.* 1995). There have been no cases of specimens being detected as moving between trap sites (K. Kukolic and M. Rauhala pers. comm.).

Estimating the size of viable areas of grassland for *D. impar*

As is discussed in detail by Williams *et al.* (1991), to assess the viability of populations requires extensive and detailed knowledge of population structure (e.g. sex ratio, age structure, age at first breeding, mortality rates, etc.) and its response to disturbance. This includes genetic variation within and between populations, reproduction rates and dispersal patterns in relation to patches. This information is clearly not known for *D. impar.*

In determining the size of areas of grassland needed to support *D. impar* in the long-term it is not possible to use a rigorous quantitative approach based on population demography. Instead, a conservative approach has been employed which assumes that the trapping array used in reptile surveys detects all adults living within the 0.25 ha area that the traps are laid out in. Because the capture rate of new individuals reaches an asymptote after two to four weeks continuous trapping at a site (K. Kukolic and W. Osborne unpublished data) it can be assumed that most trappable individuals have been caught in four weeks trapping. Using a mean catch of six adults per site for Gungahlin, a conservative estimate of an area for supporting 1000 breeding individuals can be calculated as being approximately 42 hectares. This estimate of course assumes that suitable grassland is evenly distributed throughout the area under question. However, in reality it is likely that in some patches density may be higher or lower. Also, trapping sites were generally located in patches of grassland assumed to be more suitable for the species. Despite these limitations to determining population density, we suggest that the estimate still has merit because it is likely to still be an under-estimate of population density. After suitable management of the grasslands, their structure should recover, so providing a greater area of better quality habitat in the longer-term. Thus the estimates based on the mean trapping results are likely to be conservative, and, following habitat recovery, the density of adults per hectare is likely to increase above the estimate of 24/ha used here.

In summary, the approach suggested above is not based on population demographic analysis, instead it is based on an estimate of the mean number of adults occurring within the 0.25 ha. area sampled by the trapping array. A safeguard of this approach is that there are likely to be more individuals in each area than were actually caught. What must be added to this minimum area for population conservation are sufficient buffers against adjacent land use, and additional areas to include habitat heterogeneity as some protection against environmental catastrophes such as droughts, floods and fires.

4.3.2. Significant invertebrates

The following invertebrate species of conservation significance have been located within the Gungahlin grasslands, though little information is available on their biology or distribution. Like all invertebrate species they are not on any threatened species list at present, although significant concern has been expressed about their status.

4.3.2.1. The golden sun moth (*Synemon plana*)

Information sources: The overall distribution of *Synemon plana* is poorly known, although with increased survey effort in the ACT region in the last few years, many more sites have been found here. A systematic survey for the species in the ACT has not been conducted. Edwards (1994) found the species in the Gungahlin Town Centre area in 1994, recording both males and females. During *D. impar* trapping in 1994, some were found in pitfall traps (Rauhala *et al.* 1995). It is not possible with the available data to model the possible distribution of the species in the Gungahlin area because the grassland mapping does not resolve sufficiently the *Danthonia* species which *Synemon plana* apparently feeds upon (Driscoll 1994; Edwards 1994).

Habitat requirements: The native grass species *Danthonia carphoides*, *D. auriculata* and *D. setacea* provide food for the moth larvae and are essential for the long-term persistence of the moths at each site (T. Edwards pers. comm.). Grasslands dominated by other taller species are unsuitable. It is able to survive light grazing or mowing and may be resistant to fire (Edwards 1994).

Reproductive biology: The length of the life cycle is unknown. The egg stage probably lasts about one month, and the pupal stage about six weeks. However the duration of the larval stage is not known, with Edwards (1994) suggesting that it could be 42 weeks or even up to several years (146 weeks). During this time larvae live in the soil and feed on the underground parts of *Danthonia* spp.. Adults emerge from the soil to fly during November and December, but only survive up to three days. Adults have no mouthparts and so do not feed.

Population density: Estimates of the male population are available for York Park (Edwards 1994), with populations of 520 and 456 in consecutive years, in and area of 0.35 hectares.

Dispersal ability: Females have reduced wings and will only fly when disturbed for distances of a few metres. This suggests evolution under conditions not requiring colonisation of disjunct areas. Males are active fliers and given continuous habitat could cover relatively large distances. When they fly away from their grassland site they usually turn back after about 50 m, implying that they can recognise suitable habitat. The flight activity of males is decreased by wind exceeding about 20 km/h, and those that do fly tend to accumulate near a down-wind boundary of the site (Edwards 1994). This may explain why some individuals have been found in pitfall traps used for reptile trapping.

Known distribution: Once widely distributed throughout south-eastern Australia, *S. plana* is now only known from fourteen sites in the ACT (DELP 1994) and three in Victoria. There is a single record from S.A. and, apart from a site near Queanbeyan ("The Poplars"), there are no records of the species in NSW since the 1940's (Edwards 1994). Some of the ACT sites are small and their long term survival is unlikely. *Danthonia carphoides* grasslands are not represented in any nature reserves, however some urban sites are being managed by the ACT Parks and Conservation Service to improve the survival of the moth at those locations (Woodruff & Florence 1992).

Many sites where the species was recorded in Gungahlin are not dominated by *Danthonia carphoides*, although the grass is often present as a minor component. The site labelled Palmerston 5 was the only new area where the moths were recorded last year, although the method of trapping used for *D. impar* is not intended for invertebrate surveying (Rauhala *et al.* 1995).

There is a distinct tendency for sites to be located on low ridges, hillocks or low hills, which may be due to loss of the food species in more moist, lower lying areas. This should be considered in any reservation site (Edwards 1994).

4.3.2.2. Morabine grasshopper (*Keyacris scurra*)

Information sources: (Driscoll 1994); A. Rowell pers. comm.

Habitat requirements: Tall herbaceous vegetation used for shelter (*Themeda australis* frequently used, though others include *Chrysocephalum semipapposum*).

Diet: Preferred food plants are *Chrysocephalum semipapposum* and *C. apiculatum*, although others have been recorded.

Reproductive biology: Eggs are laid in the soil from August to October, and adults die during that period. Eggs hatch around February, with males maturing by March or April and females by August or September.

Dispersal ability: Limited, as all life stages are wingless.

Known distribution: Occurs in woodland and grassland providing its food and shelter requirements. It was once widely distributed throughout south-eastern Australia, although the species is now restricted to the few areas that have never been severely stocked. Rowell and Crawford (pers. comm.) surveyed approximately 600 ha around Canberra and found the species at only seven sites totalling about 25 ha. Of these, one population near Gibraltar Rocks is in Tidbinbilla Nature Reserve, a second is within Mulligans Flat Nature Reserve in Gungahlin, and a third is at Kambah Pool within the Murrumbidgee River Corridor and proposed nature reserve. The other known site in Gungahlin is at the relatively large Bellenden Street/2CY *Themeda* grassland patch.

4.3.2.3. Canberra wood cricket (*Cooraboorama canberrae*)

Information sources: (Driscoll 1994; Rauhala *et al.* 1995). Little is known of the biology and ecology of this rare cricket.

Habitat requirements: Shelter probably provided by bark and litter associated with grasslands and woodlands. It has been found in suburban gardens (Driscoll 1994).

Reproductive biology: The only available information is that adults have been collected from December to March, and one nymph collected in May matured in December (Driscoll 1994).

Dispersal ability: Unknown.

Known distribution: Prior to pitfall trapping in November and December 1994, *C. canberrae* was only known from individual specimens collected from urban areas in Canberra (Driscoll 1994). It is now thought that a population may exist at the Majura Field Firing Range and possibly at the Belconnen Naval Base grassland (Rauhala *et al.* 1995). The only known location in Gungahlin is from Area A, at the site of the proposed Town Centre. Intensive collecting outside the ACT has failed to uncover any specimens. The species also appears to have declined in abundance since the holotype was collected in 1981 (Driscoll 1994).

4.4. Conclusions

4.4.1. Quality of information for conservation planning

For this Gungahlin area we now have a useful map of all grasslands and an assessment of their overall floristic type and *a priori* conservation rating. Whilst this provides a basis for comparisons between the larger areas in terms of dominant grass species, it is not possible from these data to delineate any areas of concern for particular plant species. This arises because the survey was based on a single visit during late summer, in drought conditions, when many of the non-grass species are dormant. Follow-up surveys in promising areas are warranted.

Limited though these data are, they are the best and only available for any comparably sized area of lowland grassland in the region. This has meant that to evaluate the significance of the Gungahlin grasslands we have had to use the published site-based data from broader scale surveys. The latter have focussed on the higher conservation quality sites only. These sites are mostly too small to have viable populations of vertebrate fauna and hence the need for a wider habitat view when considering vertebrate fauna.

Surveys for threatened grassland invertebrates have also not been systematic across the landscape, so that our information is mainly of the presence of given species in selected sites. This tells us little about likely distribution or habitat requirements. Some abundance estimates for *Synemon plana* are available and represent the beginning of the necessary studies to determine population viability.

For *Delma impar,* the vertebrate of most concern in Gungahlin, we have good distribution data based on surveys undertaken since 1990 across a range of known and potential habitats. However, it is not possible to calculate estimates of true population density from the present data because it is not known what proportion of the population at a given site is trapped. Using the approach outlined earlier we estimate that long-term population viability is likely to be maintained in relatively heterogenous conservation areas with a minimum size of about 40 ha. However, to this minimal area must be added suitable refuge areas for survival during severe conditions, in order to achieve effective *Delma impar* conservation.

4.4.2. Conservation significance

Because of their small size and isolation from other native grasslands, small remnants are likely to have lost species of plants and animals that require larger areas for population maintenance. Despite this, the ACT's grasslands contain some 130 native plant species, and provide habitat for a number of nationally threatened species of both plants and animals.

The ACT contains about 8% of the remaining high quality primary native grassland found in south-east Australia. Of the 26 defined plant communities in this same region, three are found only in the northern Monaro, mainly in the ACT.

Gungahlin contains about 10-20% of the ACT's remaining primary and secondary grasslands and has several of the largest remnants in the ACT. The native grasslands remaining in the Gungahlin area are extensive, although the areas of highest quality (conservation rating 2) are considerably smaller. By contrast, Victoria's single large grassland reserve at Derrimut contains an area of only 130 ha of native grassland. Some of the Gungahlin communities are examples of distinctive species associations of the northern Monaro, e.g. the *Themeda australis* community found at the Bellenden Street/2CY site.

The significance of these communities at all levels is raised considerably by the fact that they contain extensive populations of the nationally vulnerable species *D. impar*, as well as having populations of threatened invertebrates such as *Synemon plana* and *Keyacris scurra. D. impar* is presently known only from scattered sites in Victoria, a single site near Goulburn and three other ACT locations. The *D. impar* populations in Gungahlin are the best known and most widespread in the ACT and have the highest capture rates, suggesting that the habitat there is particularly favourable.

From what we know about native grassland floristic composition and conservation priority in the Monaro, the lowland native grasslands occurring in the ACT have major regional significance. They are important biodiversity storehouses for grassland species, representing, in some cases, communities which are unique to the Canberra-Queanbeyan region and all of which are poorly protected. The high degree of reduction in area, continuing threats, general vulnerability, still developing knowledge base, presence of threatened species and lack of protection of native grasslands in the ACT clearly indicate a high conservation priority for this community.

5. Delineation of areas for conservation in Gungahlin

5.1. Terminology

The terminology used to describe areas delineated is illustrated in Figure 3 and the terms defined therein.

Core Conservation Area: defined as contiguous areas, greater than 20 ha in size, formed by the amalgamation of grassland patches with one or more of the following characteristics:

- grassland conservation rating of 1, 2, 2/3 (a mosaic) or 3 (see Table 4);
- maximum catch rate of *Delma impar* greater than 10 animals/1000 nights and/or evidence of breeding;
- presence of *Synemon plana* and/or *Keyacris scurra*.

Associated or enclosed drainage lines, thought to be important as drought refugia for *Delma impar* (Kukolic *et al.* 1994), were included in core conservation areas. Narrow projections into areas of incompatible land use or exotic vegetation were not included in the delineation of the core conservation areas.

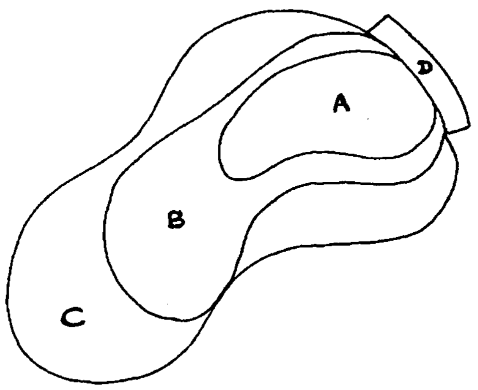
Maximum Feasible Conservation Area: defined as the maximum extent of a contiguous area of native grassland of some conservation value or potential for rehabilitation including one or more Core Conservation Areas, but excluding:

- exotic grasslands,
- suburban areas and other existing development, and
- areas above the 625 m contour.

Conservation Zone: defined as a contiguous area set aside for conservation of native grassland and associated threatened species and based on a Core Conservation Area plus any required Buffer Zones. The boundaries of such zones are not specified in this report, but it is anticipated that they will be determined by accommodating the needs of conservation and planning, through the application of the principles stated herein.

Buffer Zone: defined as an area (usually linear) which separates an area of low compatibility in terms of land use from a conservation zone, so as to minimize the indirect influence of the former on the latter. Buffer zones may be in exotic grassland, and would not normally be incorporated in the Conservation Zone. As such, they are available for low impact use, provided their buffering function is not compromised. Note that areas of lower value native grassland, contained within a Conservation Zone, may serve to buffer the Core Conservation Area, but under this definition, would not be regarded as buffer zones.

Figure 3 Diagram illustrating key terms defined for describing land for conservation.



A: Core Conservation Area

A+B: Conservation Zone

A+B+C: Maximum Feasible Conservation Area

D: Buffer Zone

5.2. Establishing a base spatial unit (patch)

Two spatial scales were recognised in the process of assigning conservation values at a local level, that is, within Gungahlin. Major non-urbanised Blocks were defined on the basis of the known presence of threatened species and communities within areas largely defined by existing infrastructure and degree of isolation. These blocks are shown on Figure 4 and their attributes are described in Table 2. Similar land entities were recognised in Rauhala *et al.* (1995).

It should be noted that there are some large areas of native grassland in the Kenny block which are in the north-east, along the boundary of the mapped area. These are all above 625 m altitude and almost certainly lack *D. impar*. Much of this area is likely to have once supported open woodland.

Table 2. Land area, native grassland area and *Delma impar* trapping in Gungahlin Blocks.

	Gungahlin Central *	Gungaderra - Crace	South Mitchell	Kenny*	Remainder of study area
Land area (ha)	774	337	162	1230	90
Area of native grassland sens. lat. (ha)	257	203	111	518	24
Area of grassland with conservation rating 1, 2 or 3	174	41	51	143	1.2
Number of trap sites at which *D. impar* has been found	12	15	9	6	6

* The Gungahlin Central and Kenny blocks are arbitrarily separated by the Gungaderra drainage line.

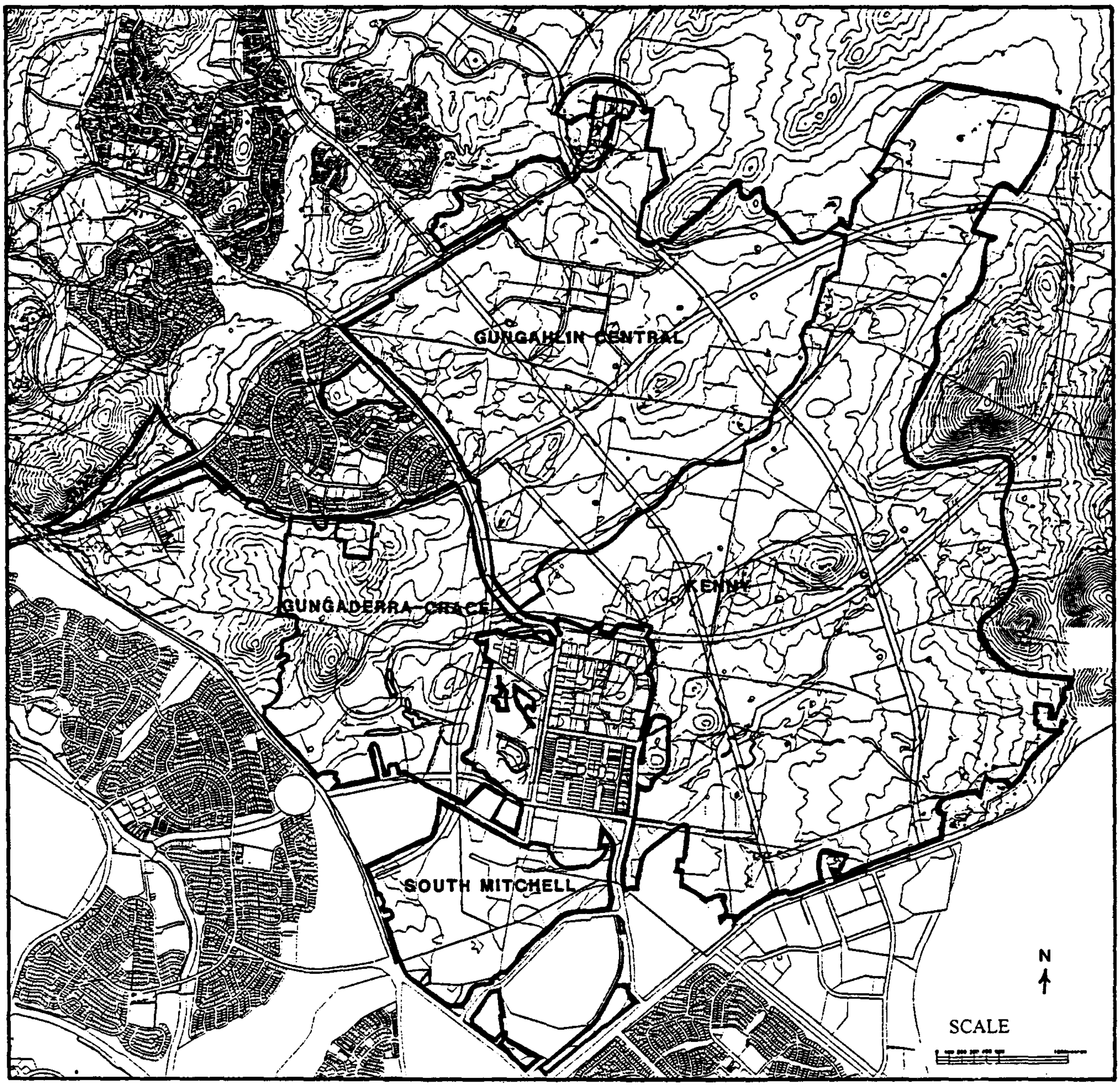


Figure 4. Boundaries of blocks delineated for planning and analysis purposes.

Grassland Patches were delineated by overlaying the land units defined by grassland type (Table 3) with the units defined by grassland conservation rating (Table 4) based on the recent Gungahlin grassland survey by the Wildlife Research Unit (1995). That is, the map units established from data on floristic composition were further subdivided wherever different conservation ratings had been applied to sub-areas within a grassland type unit. The resulting basic unit of analysis (Patch) was thereby defined as an area of a particular grassland type with a particular conservation rating applying to the grassland within it. Some areas were rated as containing a mixture of sub-areas with two different ratings. All patch areas were calculated using an electronic planimeter on the digitised version of the Gungahlin grasslands map (WRU 1995).

This procedure yielded 260 Patches in the four Blocks of the Gungahlin study area. The total area of these patches for different grassland types and conservation rating values in each Block is compared in Tables 5 and 6.

Table 3. Definition of grassland types in Gungahlin as mapped by the ACT Parks and Conservation Service (Wildlife Research Unit 1995).

Type	Description
Native — *Stipa*	Relatively undisturbed native grassland community, with very high native grass and forb and minimal exotic species frequency. *Stipa bigeniculata* and/or *S. falcata* dominated, hillsides and lower slopes.
Native — *Danthonia*	As above. *Danthonia* spp. (esp. *D. caespitosa*) dominated, hill slopes and lower slopes.
Native — *Themeda*	As above. *Themeda australis* dominated, run-on sites.
Native — Mixed	As above. Co-dominated by *Themeda australis*, *Danthonia* spp., *Bothriochloa macra* and *Stipa* spp.
Native — Rough	Modified native grassland. Dominated by native grass and/or forb species with moderate to high frequency of exotic species.
Degraded & Disturbed	Degraded or poor condition native or exotic grassland. Weed and/or pasture improvement species frequent with native species frequency typically low.
Exotic	Exotic species dominate. Commonly includes pastures improved for grazing purposes. Native forb and grass frequency is minimal.
Drainage & Wetland	Native or exotic wetland species and grassland species typical of wetter sites dominate. Exotic and/or native species diversity ranges from low to high. Includes dams, wetlands and ephemerally wet drainage lines.

Table 4. Grassland conservation floristic rating scale applied to patches of grassland in Gungahlin by the ACT Parks and Conservation Service (Wildlife Research Unit 1995).

Rating	Native species number, cover & frequency	Introduced species cover & frequency	Comments
1 Very high	High to very high	Very low	This rating implies the most natural of grassland communities. Generally of national significance.
2 High	Many	Low to moderate	Implies grassland from which a number of native species have been replaced by introduced plants due to disturbance or management practices. Generally of national significance.
3 Moderate	High for grass species but fewer other species.	Moderate	Implies grassland largely altered from the pre-European state yet valuable for rehabilitation etc. Generally of local to regional significance.
4 Low	Low numbers grass spp., relatively moderate cover other spp.	Moderate to high	Implies grassland that may have utility as animal habitat, for wildlife buffers or corridors, as potential rehabilitation sites or for research.
5 Minimal	Patchy distribution	Very high	—
0 None	Very infrequent or none.	—	—

Table 5. Total area (ha) of grassland patches of differing floristic type within each Gungahlin block.

Grassland Type	Gungahlin Central	Gungaderra - Crace	South Mitchell	Kenny	Misc.	TOTAL
Native- *Stipa*	9.7	14.9	3.4	1.7	0	**29.7**
Native- *Danthonia*	12.1	0	0	22.5	0	**34.6**
Native- *Themeda*	0	13.4	0	0	0	**13.4**
Native- Mixed	130	0.5	8.6	94	1.2	**234.3**
Native- Rough	105.1	178.5	99.2	399.3	22.9	**805**
Degraded & Disturbed	215.3	70	47.5	276.6	56.9	**666.3**
Exotic	248.7	20	2.7	392.6	8.1	**672.1**
Drainage & Wetland	52.8	39.9	0.8	43.2	1.1	**137.8**
TOTAL	**773.7**	**337.2**	**162.2**	**1229.9**	**90.2**	**2593.2**

Table 6. Total area (ha) of grassland patches of differing conservation rating within each Gungahlin block.

Conservation rating	Gungahlin Central	Gungaderra - Crace	South Mitchell	Kenny	Misc.	Total
1	22	0	0	0	0	**22**
2	10.2	28.3	8.6	46.2	1.2	**94.5**
3	141.7	12.3	42.2	96.3	0	**292.5**
4	111.1	167.3	46.4	265.9	26.5	**617.2**
5 & 0	488.7	129.3	65	821.5	62.5	**1567**
TOTAL	**773.7**	**337.2**	**162.2**	**1229.9**	**90.2**	**2593.2**

5.3. Assessing the *a priori* conservation values of patches

Several criteria were used to establish an *a priori* set of values for each patch considered before urban development, namely:

- the *a priori* grassland conservation rating of WRU (1995) (Table 4);
- the maximum catch rate of *D. impar* for all trapping sites (if any) within a patch across all years of trapping;
- the presence of *Synemon plana* or other significant invertebrates; and
- evidence of breeding for *D. impar*.

The data for each patch are tabulated in Appendix 1 and for each trap site in Appendix 2.

Clearly the basic spatial units identified here are not viable conservation areas because of their small size. Overall they have a median area of 3.75 ha and a mean area of 10.2 ha. A procedure for aggregating them into viable areas is presented in the following sections.

5.4. High priority inclusions : Core areas for conservation

Core conservation areas have been defined as contiguous areas, greater than 20 ha in size, formed by the amalgamation of grassland patches with one or more of the following characteristics:

1. grassland conservation rating of 1, 2, 2/3 (a mosaic) or 3 (see Table 4);
2. maximum catch rate of *Delma impar* greater than 10 animals/1000 nights and/or evidence of breeding;
3. presence of *Synemon plana* and/or *Keyacris scurra*.

Associated enclosed drainage lines, thought to be important as drought refugia for *Delma impar* (Kukolic *et al.* 1994), were included in core conservation areas. Narrow projections into areas of incompatible land use or exotic vegetation were not included in the delineation of the core conservation areas.

The particular catch rate (10 per 1000 nights) for *D. impar* was chosen as there was a median catch rate of 9.6 for those sites where animals where caught. *Synemon plana* was in most cases associated with *Delma impar* trap sites (as an incidental catch), and so provides relatively little extra information for judging the value of patches. Records for other invertebrates are too few to consider representative of those species distributions.

On the basis of the above definition of core conservation areas, present data allow the delineation of three such areas in Gungahlin; one in each of the Gungahlin Central, Gungaderra-Crace and South Mitchell blocks. At this stage the Kenny block does not have a single high quality area greater than 20 ha. Figures showing the core conservation areas are presented and discussed after the next section, which addresses the areas we have excluded from consideration for conservation purposes.

Note that core conservation areas, though high priority inclusions in any proposed conservation zone, may not on their own be viable. They are not necessarily of a size to be viable in the long term without the incorporation of further adjacent areas of some conservation value, nor are they necessarily buffered from adverse external influences. They are not, on their own, to be considered proposals for conservation zones or reserves.

5.5. Exclusions: Areas of low compatibility with conservation zones

We have used an exclusion process applied to the entire area to provide a view of the maximum possible area available for conservation zones, buffers and corridor linkages.

The exclusion process was based on the following rules.

1. Exclude areas above the 625 m contour. Analysis of the *D. impar* trap sites showed that the species is restricted in Gungahlin to an absolute maximum altitude of 626 m ASL (Figure 5). This would also be above the approximate upper elevation limit of the natural grasslands (Chan 1980) and hence could also include some secondary grasslands (Sharp *et al.* 1995).
2. Exclude areas of existing development.
3. Exclude areas of exotic grassland. It is likely that extensive areas of exotic grassland are not suitable *D. impar* habitat and would be expensive to rehabilitate. However it is noted that there are some areas where *D. impar* was found in exotic grassland and these are reassessed in the later phases of the analysis.

The areas excluded by the application of these rules are shown on overlays provided with this report and for key parts of the study area are shown in Figures 6 to 9.

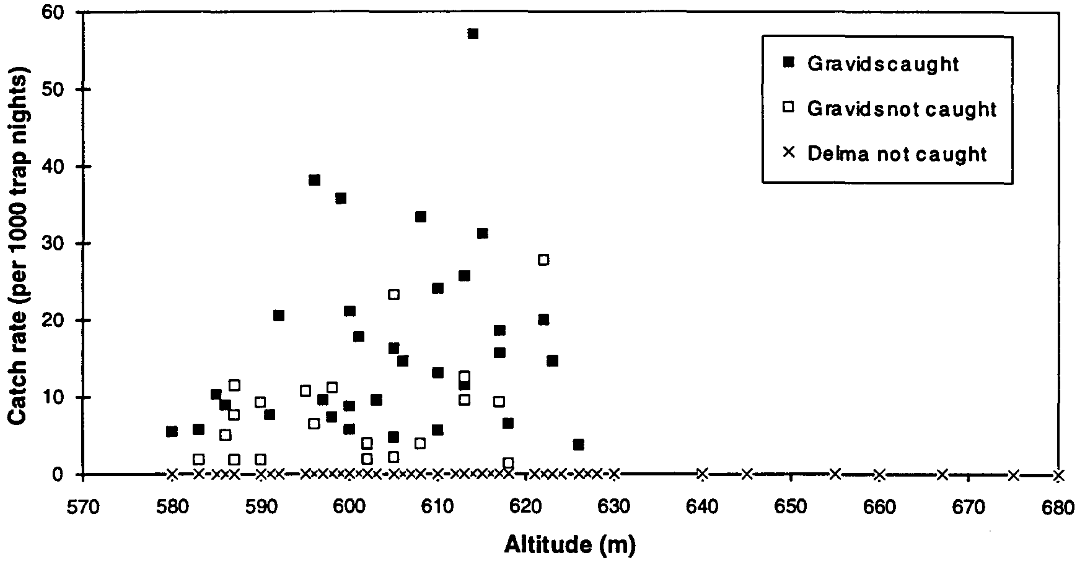


Figure 5. Maximum catch rate for *Delma impar* in Gungahlin (1989-94) and the altitude of *D. impar* trapping sites, including sites where *D. impar* was not found by trapping.

6. Development of strategy options and management guidelines

6.1. Developing conservation strategy options

6.1.1. Defining conservation zones

We have defined previously a conservation zone as a contiguous area comprising (i) a core conservation area, and (ii) associated adjacent areas of lesser conservation value that are included because of their contribution to the long term viability of the zone through either additional area added, environmental heterogeneity or buffering.

On the basis of the distribution of core conservation areas within Gungahlin, there is the possibility of establishing three conservation zones, one within each of the blocks Gungahlin Central, Gungaderra-Crace and South Mitchell (Figure 4). The locations of the associated core conservation areas are shown in Figures 6 to 8. Desirably, the boundary chosen for a conservation zone would lie between the boundary of the core conservation area and the surrounding boundary of definite excluded areas, although in some cases we recognised that the maximum feasible conservation area would not extend to the exclusion boundary because of the large area and/or low quality of the grasslands so included.

Measured attributes of each of these feasible areas within which a conservation zone could be established are listed in Table 7. Qualitative features of these areas are summarised in Table 8 and described in detail below in relation to grassland conservation objectives. Further information on land use, physical characteristics and vegetation of these sites is provided by Rauhala *et al.* (1995).

Table 7. Measured attributes of the maximum feasible conservation zones divided between the core and extra-core areas.

	Gungahlin Central	Gungaderra - Crace	South Mitchell	Kenny	Total (excluding Kenny)
IN CORE CONSERVATION AREA					
Area (ha)	92	244	77	—	413
Area of native grassland of rating 2-3 (ha)	88	41	51	15	180
Known area* of *D. impar* habitat (ha)	79	167	56	32	302
Potential additional# area of *D. impar* habitat (ha)	13	77	21	—	111
OUTSIDE CORE, INSIDE FEASIBLE AREA					
Area (ha)	61	61	85	—	207
Area of native grassland of rating 2-3 (ha)	23	0	0	—	23
Known area* of *D. impar* habitat (ha)	15	0	32	—	47
Potential additional# area of *D. impar* habitat (ha)	46	61	53	—	160
Size of maximum feasible conservation area (ha) (<625m alt.)	153	305	162	—	620
Significant invertebrates recorded	*Synemon plana* *Cooraboorama canberrae*	*Synemon plana* *Keyacris scurra*	—	—	

* Area based on total area of patches containing a successful *D. impar* trap site.

\# Potential area includes those patches not trapped, occurring below 625 m, and with, at most, scattered timber cover.

Table 8. Assessment of the features of maximum feasible conservation areas ranked on a subjective high/medium/low scale.

	Gungahlin Central	Gungaderra - Crace	South Mitchell	Kenny
D. impar habitat quality	H	H	H	M
Grassland quality	H	H	H	M
Other species quality	H	H	L	L
Degree of disturbance	M	M	L	H
Rehabilitation need	M	M	L	H
Rehabilitation potential	H	H	H	M
Site integrity and manageability	H	H	H	M
Drainage and pollution exposure	L	M	M	M
Predation exposure, ferals	M	M	L	M
Educational/research value	H	H	H	H
Likely boundary conditions	roads suburb Town Centre open space	roads Reserve industrial cemetery urban	roads CSIRO industrial	industrial roads suburb NEC

6.1.1.1. Gungahlin Central

Gungahlin Central (Figure 6) has the second largest core conservation area (92 ha), and contains an extensive patch of relatively undisturbed mixed native grassland of high quality. The highest catch rates of *D. impar* have been recorded in the south-east portion of the area within the proposed suburb of Franklin (Kukolic *et al.* 1994; Rauhala *et al.*, 1995). *Synemon plana* and *C. canberrae* have also been recorded in this area.

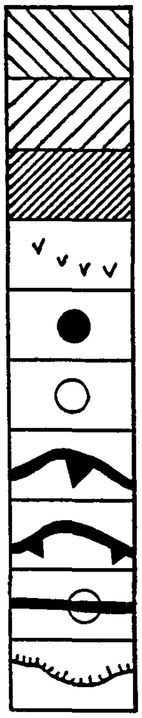
Most of the high quality grassland occurs in a large area covering the central and eastern half of the area and designated as the core area, being separated from the *Stipa* and *Danthonia* dominated areas in the west by some Degraded and Native-Rough grasslands. Some of these areas have been heavily grazed in recent years but are recovering following progressive withdrawal of livestock in 1994 (Rauhala *et al.*, 1995). *D. impar* have also been captured in rushes in the drainage line in the western portion of this area (Kukolic *et al.* 1994). This may be important in providing refuge for *D. impar* during drought conditions, when tall tussock grasses are less abundant, and the depression increases the likelihood of rehabilitation of the population within this area.

There has been conservation planning for *D. impar* in the western portion of the area (ACT Government 1994; Rauhala *et al.*, 1995), which emphasised the importance of rehabilitating habitat between the small patches of higher quality *D. impar* habitat in the west (referred to as Area A in previous planning) and the extensive patch of high quality grassland in the east. Whilst this action is desirable its effectiveness is compromised by the remoteness of Area A and the management difficulties involved in rehabilitating and maintaining a grassland linkage. The narrowing of the feasible area in this western end also increases the susceptibility of the area to external impacts by increasing an otherwise low edge to area ratio for the core area as designated here.

The south-western edge of the potential area is bounded by a major road, which would provide a buffer. Other boundaries correspond with the existing Wells Station Road and areas of improved arable pastures which do not contain native grasses and are not likely to support *D. impar*.

An adjacent smaller area of *D. impar* habitat now within the suburb of Palmerston (Area F; Rauhala *et al.*, 1995) has not been included in this potential area as it has been completely isolated by Gungahlin Drive and should be managed as a separate unit (see later).

<u>Legend for Figures 6 to 9.</u>



Grassland Patch with conservation rating of 2 or 3

Grassland Patch with high *D. impar* catch rate (>10 per 1000 trap nights)

Grassland Patch with *D. impar* breeding population caught

Drainage lines and wetlands

Trap site — *D. impar* caught

Trap site — *D. impar* not caught

Core Conservation Area boundary (green)

Maximum Feasible Conservation Area boundary (red)

Indicative location of suggested Buffer Zones (yellow)

625 m contour line

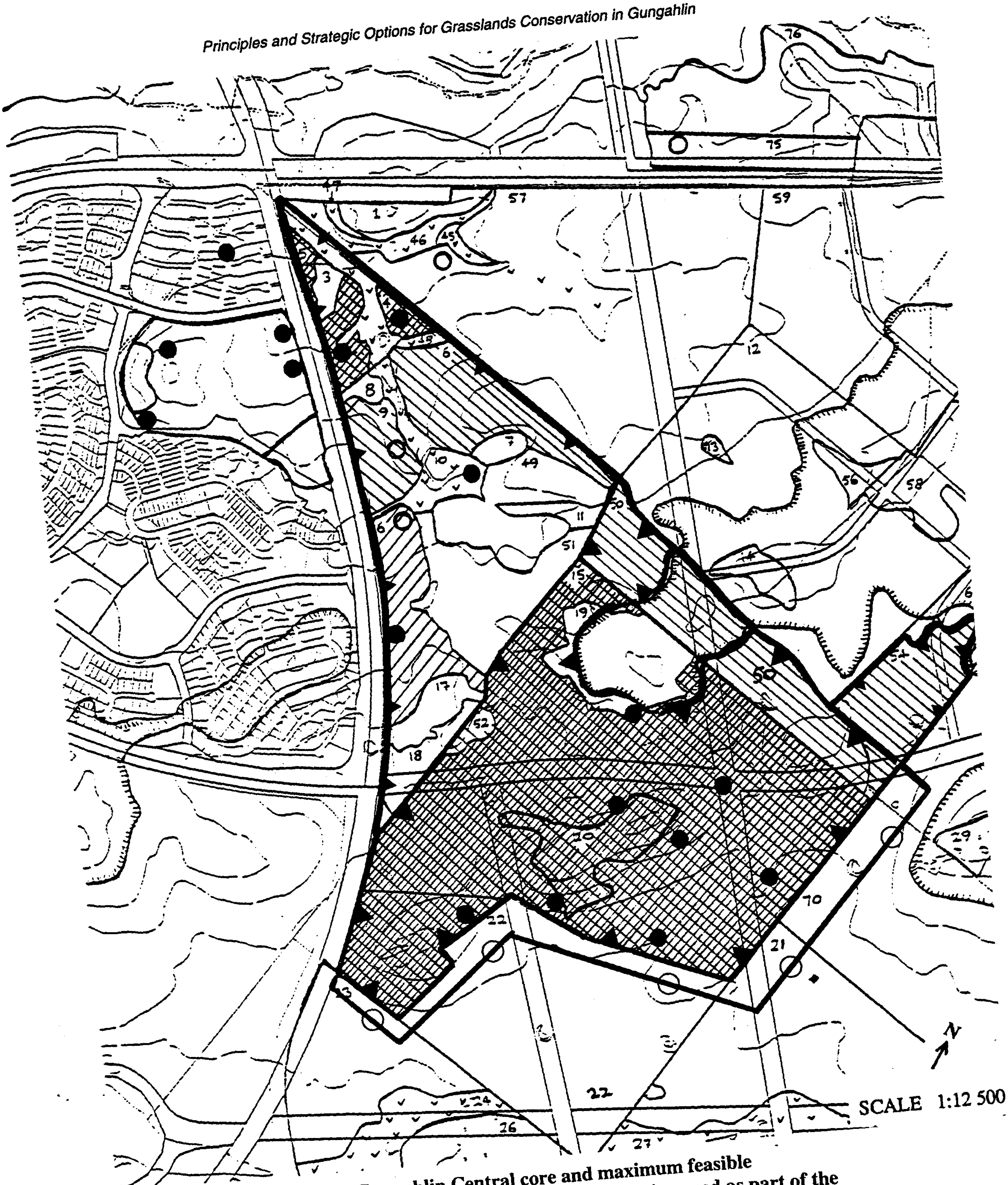


Figure 6. Location of Gungahlin Central core and maximum feasible conservation areas, showing thematic information used as part of the delineation process. Refer page 51 for legend.

6.1.1.2. Gungaderra - Crace

The Gungaderra-Crace core conservation area has been defined as a single, large unit (244 ha) which occupies most of the maximum feasible area because of the contiguous nature of the grassland and broad linking drainage line in this area. The area of high quality native grassland is an important *Themeda australis* site. This area is smaller than that in the Gungahlin Central area, and is divided by a major drainage line, but when combined with the known area of suitable *D. impar* habitat, the core conservation area is extensive (Table 7; Figure 7).

The occurrence of *D. impar* is well defined in the southern section of the core area where the species occurs in large patches of high quality *Themeda* and *Stipa* as well as in less natural grasslands. In the northern half of the area, known *D. impar* sites are mostly around the extremities of the area (Figure 7), though two unsuccessfully trapped sites more centrally placed may have been influenced by the drought conditions of 1994 and the overall low catch rates recorded during that period. It is expected that if the native pasture in this area is allowed to recover, *D. impar* populations would slowly recover and disperse into newly created favourable habitats.

The presence of an extensive drainage basin through the area adds considerably to its vegetation heterogeneity and, as previously stated, may be important for *D. impar* as a refuge and in forming an integral link within the area during drier conditions.

Some areas of former development in the southern end of the area, such as radio towers, have been included in the core conservation area as compatible land uses. Others, such as the cemetery and crematorium, have been excluded as incompatible largely due to tree planting and other intensive land uses. Existing woodland on Gungahlin Hill is also not included within the area, though it provides a logical extension of any potential reserved areas (see also discussion in Rauhala *et al.* 1995).

The conservation value of the Gungaderra-Crace area is increased by the presence of an extensive patch of high quality *Themeda* grassland at the National Transmission Agency facility near Bellenden Street (see Rauhala *et al.* 1995 for details). The threatened grasshopper *K. scurra* also occurs at this site, one of the few known occurrences close to Canberra's suburbs. *S. plana* has also been recorded in the area, but its distribution has not been surveyed (Rauhala *et al.*, 1995).

Natural boundaries for the core area have been difficult to define, and in places existing infrastructure such as buildings has created an irregular edge. Overall though, the core and feasible area has a low edge to area ratio favourable to conservation management.

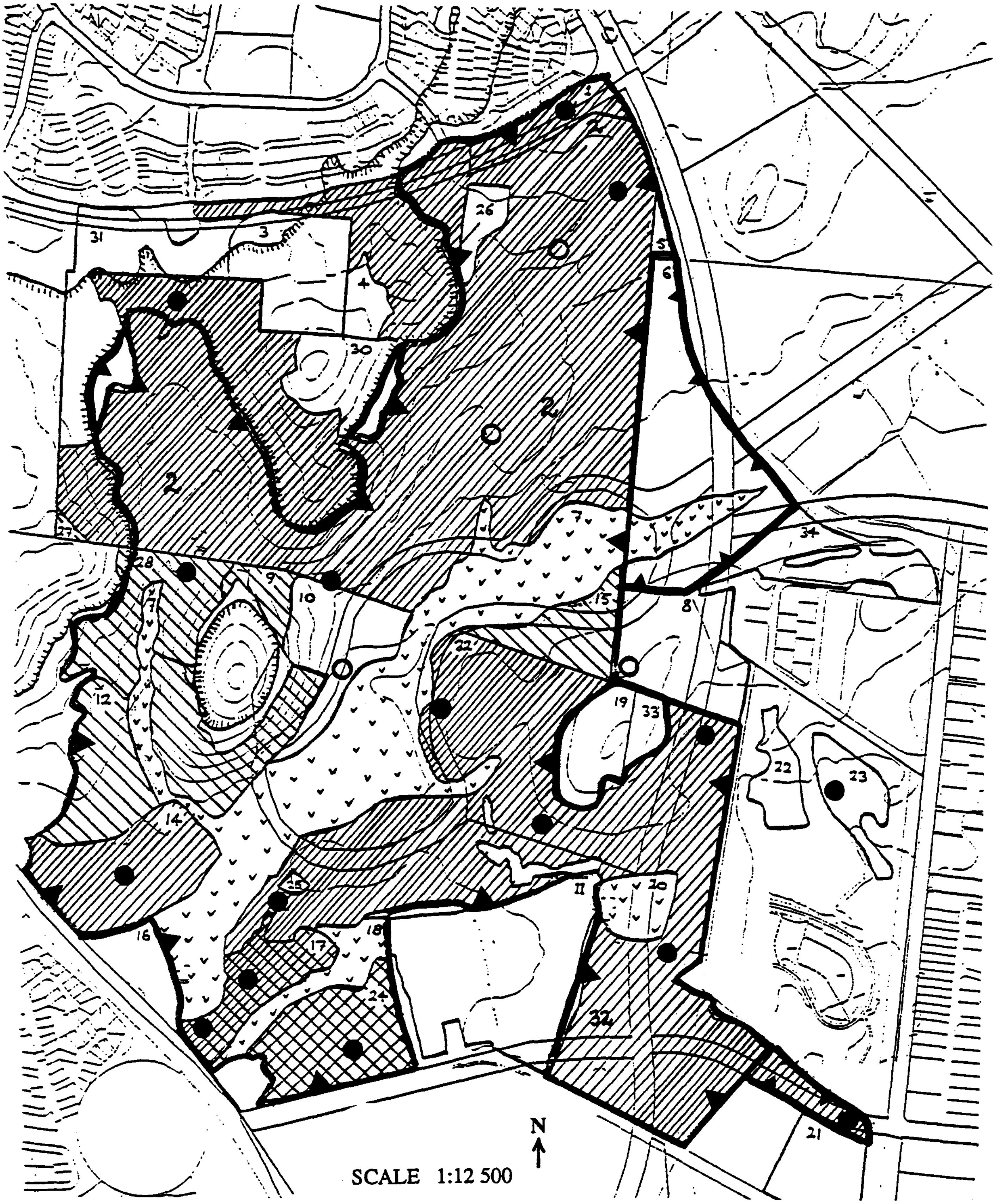


Figure 7. Location of Gungaderra-Crace core and maximum feasible conservation areas, showing thematic information used as part of the delineation process. Refer page 51 for legend.

6.1.1.3. South Mitchell

The South Mitchell core conservation area (77 ha, Figure 8) contains 51 ha of high quality grassland and suitable *D. impar* habitat (Table 7). There are no records of threatened plants or invertebrates from this area, although there have been no surveys of the block for these species. The presence of large patches of *Danthonia* species increases the likelihood of the occurrence of *S. plana*.

Most of the high quality grassland and *D. impar* habitat designated as the core area is located in a broad central strip within the block (Figure 8), thus allowing the placement of effective natural buffer zones within the maximum feasible area boundary.

The degree of disturbance is generally low, although the area contains tree planting, and a large City Parks landscape materials depot on the north-east edge of the core may be an undesirable source of nutrients in leachate from stockpiles of organic debris. Low-lying areas on the western side include both drainage line vegetation and large patches of exotic grass, including *Phalaris*, which provides potential *D. impar* habitat. However, these areas will require active management to prevent weed spread.

Although much of the eastern part of the feasible area has been subject to heavy grazing over many years, it should rehabilitate to a better quality grassland with appropriate management. *D. impar* occurs in this area and with rehabilitation the populations should recover in this area.

The entire block is surrounded by major roads which restrict the dispersal potential for *D. impar* but may reduce incursions by cats and dogs. The block also has quite a low edge to area ratio.

Figure 8. Location of South Mitchell core and maximum feasible conservation areas, showing thematic information used as part of the delineation process. Refer page 51 for legend.

6.1.1.4. Kenny

There is almost 500 ha of quality native grassland located within the Kenny block. Most of this occurs in the north-east of the block. It should be noted that this area has not been considered within the scope of this study since the extent of most patches are unmapped, they located above the 625 m contour and no *D. impar* has been recorded within them. The extent of these areas should be further studied and their value compared to similar areas in Mulligans Flat Reserve, with the possibility of incorporation as the lower slopes of hill reserves and other open spaces.

The Kenny block contains only a relatively small area of quality native grassland associated with *D. impar* (15 ha). However, the presence of *D. impar* populations was only found during the 1994 survey, with most trap sites being successful and collecting some of the highest catch rates for the season (Rauhala *et al.* 1995).

Most of the this high quality grassland occurs on the north-eastern edge of Mitchell. The high rating *D. impar* areas are mostly east of Mitchell. The spatial arrangement of the high quality areas is not as well proportioned as those of the other blocks, with a high edge to area ratio. Only a narrow linkage joins the north and south sections, although this could be extended further east into the exotic grassland of zero conservation rating if it was thought that this could be rehabilitated for *D. impar* conservation. Near to the high quality grasslands in Kenny is a proposed low hill reserve with scattered trees, and along the eastern edge is a drainage line, providing a variety of linked habitats.

Most of the western edge of the feasible area is bounded by the industrial area of Mitchell, although the eastern side is connected to extensive exotic and degraded grasslands. It is considered that the open paddocks east of Kenny to the 620 m contour have high potential for maintaining *D. impar* populations, and could provide a valuable area for some research studies.

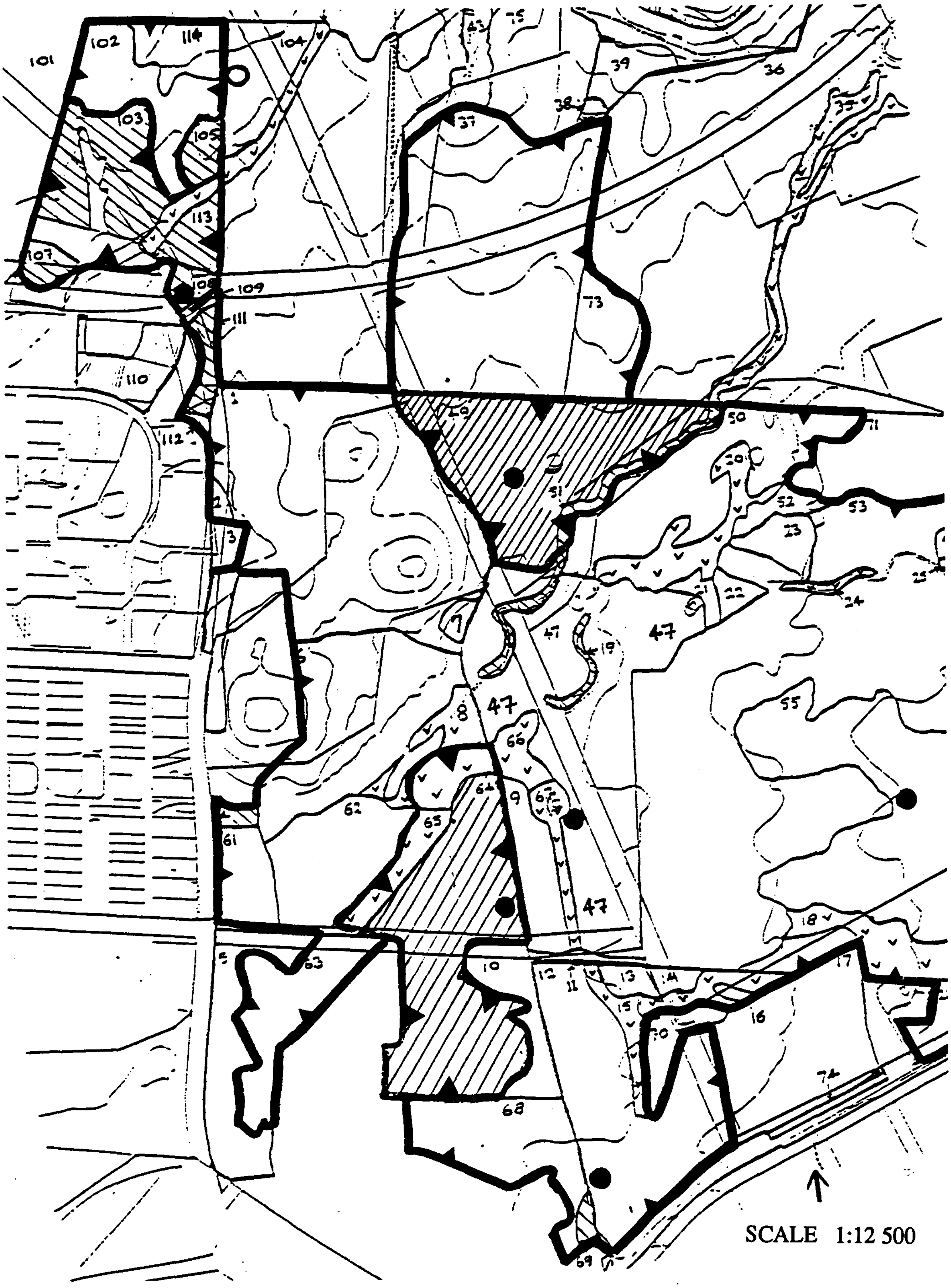


Figure 9. Location of Kenny high quality areas, showing thematic information used as part of the delineation process. Refer page 51 for legend.

6.1.2. Delineating actual conservation zones

Two key considerations remain in deciding what areas to set aside as conservation zones. There needs to be a decision on how many zones are required to be established and a series of decisions are required to establish the spatial extent of each zone.

6.1.2.1. The number of conservation zones

Two zones would meet the absolute minimum requirements for replication at the sub-regional level and four is the maximum number feasible within the Gungahlin area studied. A decision on the number of zones should be guided by the principles relating to representativeness, replication and connectivity.

The areas set aside should be representative of the grassland communities in Gungahlin. No one site meets this criterion. Spatial replication of conservation zones is necessary to better ensure long-term viability both at local and regional levels. With replication, there is the possibility of repopulating an area from nearby populations should local extinction occur. The number of replicates required at Gungahlin will depend on the potential to replicate *D. impar* populations and grassland communities in reserves elsewhere in the ACT.

Recommendations

With these principles in mind, we strongly recommend that three conservation zones be established within the Gungahlin Central, Gungaderra-Crace and South Mitchell feasible conservation areas. All three sites are necessary to meet the criteria of full representation of Gungahlin grassland values in reserves, to provide adequate diversity in environmental attributes such as topography, vegetation composition and structure (especially that associated with drainage lines) and to meet the requirements for replication of conservation zones. Kenny cannot at this time be considered as a viable conservation area because of the fragmented arrangement and small size of the quality areas. However this may be partly attributable to the relatively low trapping effort for *D. impar* in this area (1994 season only).

6.1.2.2. Spatial extent of conservation zones

Because of the comparatively small size of the areas of native grassland and, in some cases, of *D. impar* habitat, in the core conservation areas, there is a need for additional areas of poorer quality grassland to be included around the core areas. These additional areas provide some protection against the incursion of fire, and minimise the risk of herbicides or other pollutants affecting the core area. They also provide the potential to establish buffer zones where more invasive management activities can be located (eg. fire trails, access tracks, paths, materials storage areas). Without buffer zones or the addition of adjacent areas of poorer grassland, the periphery of core areas of high conservation value is likely to deteriorate, particularly if development occurs up to the edge of the core areas.

When considering the ways in which the core areas can be buffered and increased in area to more viable sizes, we use many of the principles developed earlier. Some of the most pertinent we have translated into decision guidelines which we present here before discussing the main considerations in defining an actual conservation zone in each block.

Decision guidelines based on Principle 10 : Larger contiguous conservation areas are better than smaller contiguous areas or areas of equivalent size that are fragmented.

1 Roads, retention ponds, artificial drains, power-line easements and other such structures should be located to lie adjacent to grassland areas of conservation value, rather than through them.

2 If structures must run through a grassland conservation area, special consideration should be given to ensuring that they minimise obstruction to dispersal and survivorship of key grassland species. The placing of poles and other elevated structures in grassland areas may also attract increased numbers of birds of prey, increasing predation on lizards.

3 If contiguous conservation areas are to be effectively divided, (that is, 1 above cannot be met) the viability and values of the resulting fragments will need to be reassessed.

Notes: Roads are considered to be effective barriers to dispersal by *Delma impar*. Concrete drainage channels may also be an effective barrier and also serve as a source of mortality for *Delma impar*.

Decision guidelines based on Principle 11 : Conservation areas that have a large area to perimeter ratio are better than those that are irregular in shape, elongated or whose boundaries project into surrounding sub-optimal habitat.

1 Small isolated areas of say, less than 20 ha, are likely to be profoundly affected by external influences through soil nutrient enrichment, weed invasion, incursions by companion cats, and fire, such that their values are unlikely to be sustainable in the longer term. The level and cost of management required to preserve them would lead to unacceptable compromises elsewhere.

2 The boundaries of conservation areas can be considered flexible for planning purposes provided any changes can be seen to reduce the severity of "edge effects" (that is, reduce perimeter to area ratio) and not to compromise the areas designated as core in terms of conservation value.

Decision guidelines based on Principle 9 : Proposed conservation areas that possess greater heterogeneity of environmental attributes, within the bounds of those known to support lowland grassland communities, are better than those that are largely homogeneous.

1 Designated conservation areas should be extensive enough to include a range of topographies and associated mosaic variation in grassland composition.

2 Designated conservation areas should be large enough that they will not be universally influenced by single events, such as fire; rather, such events should produce a mosaic.

3 The added dimensions in terms of floristics, vegetation structure and soil moisture that accompanies the presence of natural drainage lines is of particular value and should be preserved where possible.

Decision guidelines based on Principle 16 : Conservation areas are not isolated from external influences and careful consideration needs to be given to compatible adjacent land uses, and moderation of their impacts.

1 The periphery of core areas of high conservation value would soon deteriorate were we to reserve them alone and allow development to proceed up to their boundary. This can be avoided by including buffer zones of poorer quality grassland around the core conservation areas. Consideration of the scale of nutrient-bearing runoff, weed dispersal and companion cat movements suggests that 200 m would provide adequate buffering. Existing infrastructure dictates that in some places the available buffer would be zero.

2 Where such buffer zones are located in native grassland they should be of the minimum width required to maintain operational vehicle access trails and fired or mown fire breaks.

3 Where buffer zones include exotic grasslands or degraded grasslands of little conservation value, they could support low impact developments that are carefully managed to prevent erosion, nutrient runoff and weed spread.

4 Where buffer zones abut housing areas, their width should be increased to reduce human impact on the native grassland area, and to reduce the likelihood of companion animals, particularly cats, from moving into the core conservation areas. In such situations a width of 200m is desirable based on the home range of cats (Barratt 1995). If a wide buffer is not possible some form of fencing and control of drainage may be required to reduce disturbance to the core areas.

6.1.2.3. Gungahlin Central

The Central Gungahlin core conservation area is defined in Figure 6. The core of 92 ha contains a large area (88 ha) of contiguous high quality native grassland (patches 15, 20 & 50) and supports a dense population of *D. impar* and the most substantial populations of *Synemon plana* yet found in the Gungahlin region. A small area of native grassland at the extreme west of the area (patches 4 and 5) also supports a breeding population of *D. impar* but is not suitable as conservation core area. It is smaller in extent than the recommended 20 ha minimum size for core areas, has a very large perimeter to area ratio, and is largely separated from the large defined core area by disturbed and degraded patches (11, 17 and 51). Even with the inclusion of the drainage line (patch 10) between patches 6 and 9 this area only totals approximately 15 ha. In applying our decision guidelines based on Principles 9, 10, 11 and 16 these areas are not considered viable in the long term. However, such small isolated patches should not be destroyed without considering their very high potential for research on grassland communities and the ecology of *D. impar*. Such sites would be particularly useful for undertaking removal sampling to determine the true population size of the species in different-sized grassland areas.

In applying decision guidelines based on Principle 11, the majority of patch 54 at the north-eastern edge of the core, although of high quality grassland, has been excluded from the core as it protrudes into low quality habitat. Similarly, the southern protrusion of patch 15 would also have been excluded, however it should be maintained within the core area because it provides the only potential connectivity to Gungaderra-Crace conservation area, and also includes a small rocky knoll with a quartz outcrop that provides habitat for a colony of the skink *E. cunninghami* (Kukolic 1993).

Areas to the south and east have negligible conservation value but are essential for buffer needs, particularly if suburban development is proposed adjacent to the conservation area. North of the core area much of the land rises above the 625 m contour. A ridge of this higher area extends into the core area, and is considered suitable for inclusion in the final conservation area, as development in this area could impact into the core area.

In considering the location of suitable buffer zones we have applied Principle 16. We recommend that a buffer be developed on the western side of the core area and extended as far as possible to the west for *D. impar* conservation. This could include encompassing the degraded patches and preferably including some of the drainage line and adjacent *Danthonia* grassland. On the southern and eastern perimeter of the core area a buffer zone should be established in the adjacent exotic grassland, and not within the core area (Principle 16). The buffer zone along the northern edge of the core could be located in the core area in patch 50, which is rough native grassland.

Recommendations:

(a) That a conservation zone (Gungahlin Central) be declared to include an intact core conservation area comprising patches 15, 20, 50 and 52, and parts of 19 and 54 of Figure 6, but not the majority of patch 54 which projects into areas of no conservation value.

(b) That additions to the conservation area be made along the western border, or the core conservation area, to increase heterogeneity of environmental attributes within the conservation zone. The size of the additions will be determined largely by the competing pressures on land use but should include substantial elements of patches 11, 16, 17, 18, 49 and 51. Depending on trade-offs to do with the cost of active management and potential for rehabilitation (particularly in relation to weeds and exotic grasses), areas of the buffer comprising Patches 11, 49 and 51 may be released for low impact development (ovals, playing fields).

(c) Narrow buffer zones should be established in the adjacent exotic grassland along the southern and eastern boundaries of the core conservation area as a hedge against fire, weed invasion, eutrophication and impacts of companion animals, especially cats (see page 27). The nature of the adjacent land use and the management actions implemented to minimise their impacts will determine the optimal width of the buffers (in the range 0 to 200 m).

(d) On the northern edge of the proposed conservation zone a buffer should be established which could be located within Patch 50.

(e) The tongue of land above the 625 m contour and adjacent patch 19 could either be included in the reserve or set aside for a compatible use.

(f) Patches 4 and 5 should be made available for intensive study of the population density and life history of *D. impar*, to provide strategic information useful for the future management of the grassland reserves.

6.1.2.4. Gungaderra-Crace

The Gungaderra-Crace core area (Figure 7) comprises approximately 244 ha. Much of the grassland in this area is included in the core area because of its large and contiguous nature (decision guidelines for Principle 10) and because it possess greater heterogeneity of environmental attributes (Principle 9). The core area includes a large and important area of *Themeda australis* grassland, substantial areas of degraded *Stipa* grassland and an extensive low-lying area of ephemeral wetland along a seepage line that centrally bisects the block. *Delma* *impar* has been trapped throughout much of the core area, except in heavily-grazed paddocks in the north-east portion.

A protrusion in the south-eastern corner has not been included in the core because of its extension into surrounding incompatible habitat (Principle 11). A substantial area in the north that occurs above the 625 m contour is also excluded from the core area (this area had low quality grasslands and is above the predicted altitudinal limit of *D. impar*. Any development should be considered carefully when land uses are planned for this area, as some activities could have a significant influence on the conservation area occurring down slope (Principle 17). Specifically, there is a potential for development in this area to affect the core through runoff carrying pollutants and nutrients down slope into the grassland area.

The southern portion of the core contains both high quality grassland and many sites where *D. impar* has been recorded. It includes a wide drainage depression and is connected by grassland to the existing Gungahlin Hill Reserve. The northern portion has little grassland of significance, but scattered *D. impar* records and the upper extension of the drainage depression. It should be noted that the two nil catch trap sites in the middle of patch 2 were recorded in 1994 when overall trapping success was lower than usual and heavy grazing pressure was evident.

The core area is totally surrounded by low quality habitat, with few available areas to extend the conservation area. The three major areas to consider are patch 6 on the north-eastern side, patches 19 & 33 comprising an old sheep camp on a low rise and patch 11 in the south. Patch 6 should be at least partially incorporated as a buffer, and the drainage line protected from pollutants and excessive water runoff from urban areas that could impact downstream through the centre of the conservation area. Patches 19 & 33 should not be further alienated because the slopes surrounding the low rise contain high quality *D. impar* habitat in grassland dominated by *Stipa* (Principle 11). Finally, although patch 11 is an area with exotic and disturbed grassland which contains roads and buildings, it is likely that *D. impar* will move through the area, as is currently the case in the adjacent grounds of CSIRO Division of Wildlife and Ecology. Gungahlin Drive as proposed on the Territory Plan would remove about 50% (30 ha) of the area of Patch 32 from the core and leave a non-viable fragment on the east.

Recommendations:

(a) That a conservation zone (Gungaderra-Crace) be declared to include an intact core conservation area comprising the shaded patches of Figure 7 and enclosed drainage lines 7, 18 and 20, but not including the protrusion of Patch 32 into surrounding incompatible habitat.

(b) In the Gungaderra-Crace Block the core conservation area extends to the boundary of excluded areas with the exception of Patches 6 and 11, unlike the other blocks considered for conservation zones. This limits planning flexibility. However, should the core area need to be compromised by e.g. road alignments, it should preferably involve reduction of Patches 1 and 2 from the north or 32 from the east (which are extensive and similar Native-Rough grassland of Conservation Rating 4 with breeding *D. impar* populations) rather than patches in the south and west, taking into account the principles outlined earlier. Therefore Gungahlin Drive should be placed as far east as possible. An eastward shift of approximately 200 m from the Territory Plan alignment would retain the bulk of Patch 32.

(c) The drainage lines (Patch 7) should be left in as close to natural condition as possible, regardless of the increased flows likely to accompany development. Concrete channels, drains and pipes are likely to present a barrier or source of mortality for *D. impar*, and altered drainage patterns may degrade the values of drainage lines as refugia during times of drought.

(d) Buffers are less of an issue in Gungaderra-Crace as the highest value patches already or will eventually abut roads or areas of urban development. Areas of lower quality grassland included in the core because of their contribution as *D. impar* habitat can also be considered to effectively buffer the high quality areas.

6.1.2.5. South Mitchell

The core area defined within the South Mitchell block (Figure 8) has a total area of approximately 77 ha of which 51 ha are high quality grassland. *Delma impar* potentially occurs throughout the entire area. The area is highly heterogeneous containing a complex mosaic of grassland types and some intrusive developments including a number of buildings and tree plantations. Low-lying areas and seepage lines contain a mix of wetland plants and the exotic grass *Phalaris*, but provide potential refuges and movement corridors for *D. impar*.

The core has been mapped as having some narrow projections away from the major unit on the western edge near the Barton highway, which are retained in the core as they are not surrounded by incompatible habitat (Principle 11).

The large patches along the western edge of the core should all be incorporated as buffers, especially the rest of patch 8 adjacent to the Barton Highway (Principle 17). The road alignment on the north-west side should preferably be as close to the edge of this block as possible. The patches immediately east of the core (patches 11, 18 and 32) should also be incorporated as buffers (Principle 17). The landscaping materials storage facility should be assessed as to its possible long-term impacts on the surrounding area and managed appropriately or removed and rehabilitated.

The eastern portion of the South Mitchell block (patches 33 to 36 etc.) would form a valuable extension of the conservation area due to the presence of *D. impar* and of grasslands still dominated by native grasses. The majority of this area (excluding the protrusion consisting of patches 13, 37, 38 and parts of patch 43) should be reserved from development in the short term until a better estimate of minimum viable area required for conservation of the lizards is determined.

Recommendations:

(a) That a conservation zone (South Mitchell) be declared to include an intact core conservation area as shown in Figure 8. Retention of the narrow projections (Patches 3, 6 and 7) depends upon land use decisions for adjacent patches.

(b) That substantial elements of Patches 1, 4, 40 & 42 be included in the declared conservation zone to act as buffers for the high quality grasslands of the adjacent core conservation areas.

(c) That the western portion of Patch 8 be included in the conservation zone to buffer high quality Patches 7 and 41, and to provide an expanse of low lying moister grassland habitat to adjoin the drainage line in the rest of Patch 8.

(d) That substantial elements of Patches 10, 11, 14, 16, 18, 32, 33 & 34 be included in the conservation zone to buffer the core area and increase the overall size of the conservation zone. This addition would ideally extend to the east at least as far as the boundary of Patches 33/35.

(e) That the City Parks materials storage facility, which is a potential source of invasive plants and nutrients, be assessed as to its impacts on surrounding areas and managed properly or removed and rehabilitated.

6.1.2.6. Kenny

There are few grassland patches below 625 m of high quality within the Kenny block. The major group of these, adjacent to the north-east corner of Mitchell, forms a core of only approximately 16 ha, with *D. impar* known from one small ungrazed patch (Figure 9).

The other two possible core areas (patches 49 and 64), include lower quality grassland but support populations of *D. impar.* The addition of adjoining drainage lines to each small potential area adds habitat heterogeneity to these areas (Principle 9). However the small size of both areas is likely to affect their long-term viability. The southern-most potential core area just exceeds 20 ha, although it has an elongated shape, thus violating decision guidelines based on Principle 10. The maximum feasible area is extensive although patches 9 and 47 are included islands of exotic grassland.

With the current level of information it is not possible to designate core conservation areas in Kenny based on the decision guidelines. It is likely that more extensive trapping in this area may increase the number of quality patches identified, particularly if a reduction in grazing pressure was made.

While much of this area may never recover to quality native grassland, it currently has some conservation value due to the presence of *D. impar.* It is proposed that the general area, including patches further east but below the 625 m contour, be protected from development in the short term, say 5 years, until more is known about the distribution of *D. impar* in the ACT and surrounding region. The Kenny area could also be very useful for studies into grassland rehabilitation and provide an excellent area for further research into the ecology of *D. impar.*

<u>Recommendations:</u>

(a) That the general southern area of the Kenny Block, including patches further east below the 625 m contour, not be developed until the potential and the need for a fourth conservation zone in the Gungahlin area can be assessed. Its potential can be gauged following further survey work in the Kenny Block. There is also a need for an assessment of the conservation potential for *D. impar* in grassland areas elsewhere in the ACT.

6.1.2.7. Compatibility of adjacent land use and activities

Determining the compatibilities of activities and land uses with the objectives of these small grassland conservation areas is not something that can be determined fully in advance. Ongoing management will be needed to continue to refine the interaction of conservation objectives with other land users. However we can suggest the following broad levels of compatibility and the possible impacts that may arise from adjacent land uses (Table 9). Some of the undesirable impacts can be avoided or reduced at the planning stage whereas others may not be apparent for some time, and hence will only be detected and addressed by careful monitoring.

Table 9. General levels of compatibility between grassland conservation zones and some different kinds of adjacent land uses.

Adjacent land use	Compatibility	Possible impacts	Restriction on *Delma* dispersal
Nature reserve	Very High	Fire spread	Low
Rural grazing (low rate)	High	Weed sources, fertiliser transfer	Low
Urban open space-rough	High	Weeds, fire ignition	Low
Urban open space-smooth	Medium	Nutrient input	Medium
Major road	High	Pollutants in run-off	High
Minor road	High	Off-road traffic	High
Horse holding	Medium	Sediment runoff and weed sources	High
Suburb	Medium	Cat/fox predation, vandalism, weeds	High
Arable agriculture	Medium	Foxes, Fertiliser transfer	Medium
Playing fields	Medium-High	Nutrient input	Medium
Town centre	Medium	Pollution, trampling	High
Powerline easement	High	Predation, soil disturbance, vehicles	Low
Stormwater drains	Medium	Mortality factor, run-off	High

As can be seen in the table above, each land use has a characteristic set of possible impacts on an adjacent reserve. In principle, the main factors causing impacts on plant populations and the communities they form will be:

- any alteration to the soil water and nutrient balance,
- undue soil surface disturbance by mechanical means, or fires, which will alter seed beds,
- alterations in grazing/mowing/trampling regimes, which will change species composition; and
- input of the propagules of weedy species, be they herbs, shrubs or trees.

A sound monitoring program will be needed to detect any such changes, as they may occur over the medium term. In turn, animal populations will be most affected by changes in plant communities, in the degree of exposure to predators and by increased mortality from interactions with structures such as roads, gutters and drains. These mortality factors may only operate at certain times of the year or in particular years.

Certain activities within the conservation areas would be compatible with their primary purpose. The major one that will need to be carefully evaluated is the use of stock; which may be needed at low average rates of stocking, to reduce grass biomass and so to minimise fire risk and suppression of smaller plant species by rank growth. Weed introduction by stock would also be a major consideration for management and special conditions may be needed.

Other compatible uses could include low impact recreation such as model aeroplane fields, bicycle paths, walking and riding trails, etc. as well as organised research and education activities, these preferably in designated areas and providing feedback to ongoing management. However, it is not yet known precisely what structures constitute a barrier to the movement of *D. impar,* hence some caution is necessary in siting and building paths and mown areas. To give some design scale to this factor, standard concrete guttering is likely to be a barrier to their dispersal and a cause of mortality.

In principle, activities within the conservation zone would be compatible if they result in (i) no nutrient, pollutant nor seed input sufficient to alter floristic composition over measurable time scales, nor cause deaths of vertebrate animals, and (ii) minimal soil and vegetation damage such that germination is not enhanced nor lizards disturbed from egg-laying or over-wintering sites.

6.1.2.8. Options for linking conservation areas

Each conservation zone is examined briefly here to determine where it could be linked to urban open space, other conservation zones or to Canberra Nature Park. The location of each core and maximum feasible conservation area within Gungahlin is shown in Figure 10.

Linking the conservation areas with each other and with existing reserves is a favourable conservation strategy to allow genetic exchange between populations. At the regional scale there would be advantages in linking some of the areas identified in this study with Mulligans Flat Reserve, thus providing a gradation of different habitats from grassland to woodland. However, given that *D. impar* and primary lowland grassland communities do not extend above 625 m, the linkage would not substantially benefit the values being conserved by the proposed conservation zones. This linkage could be formed as a corridor either north from the Gungahlin Central potential area, or through the Gungaderra Creek drainage line to the proposed hill reserve further east. The linking of the Gungaderra-Crace conservation zone with the Gungahlin Hill Reserve could be readily achieved and is recommended to provide a transition of habitats from woodland to grassland in at least one of the grassland conservation zones.

Within the Gungahlin Central Area the advantages of connecting each of the conservation areas are compromised by existing and proposed infrastructure and expanses of degraded and exotic pasture. Possibilities for connections include:

1. The relatively broad potential contact between Gungaderra-Crace and Gungahlin Central, which is separated by a major road.
2. The current narrow connection across Bellenden Street between Gungaderra-Crace and South Mitchell is not considered suitable for most species, and these areas should be considered as isolated units.
3. There is potential for a corridor involving an wide expanse of degraded native pasture between Gungahlin Central and Kenny across the Gungaderra drainage. This would have significance for *D. impar* mainly. This option could be explored when planning the associated suburbs and open space, particularly if a chain of ponds is located along Gungaderra Creek.

Whilst there are some good theoretical arguments for linkages between conservation areas their practical value in particular instances is difficult to predict without knowledge of the movement behaviour and possible resultant mortality rates of fauna. There may be over-riding negative effects on the value of corridors, such as fire and disease spread, and it is evident that what is a corridor for some species is a barrier for others. It is possible that in some cases active management could facilitate successful recolonization of a conservation zone following local extinctions, provided not all local populations went extinct at the same time. Such management could also be contemplated for countering any detected genetic effects of small population sizes within a zone.

Recommendations:

(a) The Gungaderra-Crace conservation zone be extended to adjoin the Gungahlin Hill Reserve.

(b) The potential for an open space corridor between Gungahlin Central and Kenny across the Gungaderra drainage be considered when planning the associated suburbs and open space.

(c) Given the suggested sizes and nature of the conservation zones, there is insufficient justification, and a low possibility of success, for trying to connect the Gungahlin Central conservation zone with either of the other two, across what will inevitably be large road alignments.

Figure 10. Locations of core (stippled) and maximum feasible conservation areas for grasslands in the Gungahlin Central Area.

6.2. Management guidelines

Because of their small size and urban location the conservation areas will require specialised management. This in turn requires provision for research to resolve the major unknowns about *D. impar* and grassland habitats, as well as community education to maximise the protection that the community can provide.

During the urban construction phase, particular care is needed to avoid unnecessary degradation of grasslands by building activities, including littering and dumping. Enduring impacts on grassland quality will arise from actions such as (i), excessive vehicle overpasses which would compact and bare the soil, encouraging weed spread and germination, (ii) trenching for utilities could alter slope drainage as well as the more obvious soil disturbance, (iii) enhanced run-on, especially of nutrient or sediment-rich water will alter grassland composition in favour of wetland and exotic species and so change the habitat. However, in some places increased trickle flow in drainage lines may be able to be used to improve habitat diversity for *D. impar* by encouraging the development of taller tussock grasses and rushes, but this would not be advisable where high quality native grassland exists.

Guidelines for managing these activities need to be developed in the form of prescriptions for contracts and should include adequate prior site survey with the requirement for marking and flagging work areas carefully to confine impact.

Management of these areas will need to consider:

- appropriate grazing/mowing/firing regimes applied in a chequered pattern across each area, with specific regimes for the core and buffer units;
- community education and involvement;
- appropriate boundary delineation, signs and viewpoints;
- control of drainage and pollutants;
- removal of tree regeneration and shrub invasion in some areas to maintain grassland values;
- provision of fire and drought refuges for *D. impar*, perhaps artificial to some degree;
- appropriate compensatory use of any animals or habitats which do become subject to urban development.

Monitoring will best be directed at detecting the following:

- density of key native species on a 2-3 year basis to ensure that local extinction, should it occur, can be appropriately managed;
- vegetation change related to seasonal, annual and longer term effects.

Research priorities for ongoing conservation management will include the investigation of :

- home range, seasonal influences and population density of *D. impar*,
- dispersal capabilities and barriers to movement of *D. impar* and *Synemon plana*,
- habitat use (vegetation structure, composition, soil conditions) and refuge requirements of *D. impar*,
- predation impact of urban foxes and companion cats,
- population management by mowing, firing etc.,
- weed control and reduction, and

- grassland management and rehabilitation.

Recommendations:

(a) That the ACT Parks and Conservation Service develop a Management Plan for the Conservation Zones once they are decided and that it be provided with adequate resources to implement the plan.

(b) Adequate long term management requires understanding of the dynamic processes that operate within native grasslands and knowledge of the ecological requirements of key species of conservation concern. Avenues for funding the necessary tactical research, including a possible levy on new housing blocks in selected regions, should be explored as a high priority.

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Appendices

Appendix 1. Summary of features of Gungahlin grassland patches.

Appendix 2. Summary of features of Gungahlin *Delma impar* trapping sites.

Appendix 1: Grassland Patches

GRASSLAND PATCHES IN GUNGAHLIN
260 PATCHES; 240 IN 4 BLOCKS AND 20 MISCELLANEOUS

CODING

Delma :

N - Not trapped | x - trap within 100m of patch (animals not caught)
X - Trapped, none found | y - trap within 100m of patch (animals caught)

Vegetation:

N-R	Native - Rough	W	Wetlands and Drainage Lines
N-M	Native - Mixed		
N-T	Native - Themeda	D	Disturbed and Degraded
N-D	Native - Danthonia	E	Exotic
N-S	Native - Stipa		

GUNGAHLIN CENTRAL

Patch no.	Area (ha)	Veg. type	Cons. rating	Delma max rate	breed. pop'n	S. plana record?	Keyacris record?	Coorab. record?	Adjacent habitat Native	Adjacent habitat Other	Adjacent land use
T67	22	N-M	1	N					M,S	W	MFRes
T52	0.9	N-M	2	N					R,M		
T54	8.6	N-M	2	N					R,M	E	
T66	0.7	N-M	2	N					M	W,E	MFRes
T15	71.3	N-M	2,3	57.1	Y	Sp			R	D,E	Rd
T5	3	N-S	3	24.1	Y	Sp			R	W,D	Rd
T4	0.9	N-S	3	13	Y					W,D	
T6	8.2	N-D	3	Ny					R	W,D	
T20	6	N-R	3	38.1	Y				M	W,D	
T50	14.1	N-R	3	N					R,M	D	
T74	6.7	N-M	3	N					D		
T65	0.7	N-S	3	N					M	E	MFRes

Appendix 1: Grassland Patches

T69	7.7	W	3	N					M	W,E	MFRes
T75	5.1	N-S	3	X					R	D	
T72	4.9	N-M	3	X						D	MFRes
T9	3.9	N-D	3	X						W,D	Rd
T62	9.2	W	3	X					R	W,D	
T16	7.4	N-R	4	27.8					M	W,D	Rd
T46	4.3	W	4	N		Sp			R,S	W,D	Rd
T13	0.4	W	4	N					R		
T49	7.7	N-R	4	Ny					D	W,D	
T12	44.6	N-R	4	N					R	W,D	
T18	2.4	N-R	4	N					M	D	Rd
T1	2.5	N-R	4	N						W	Rd
T63	1.6	N-R	4	N						W,D,E	MFRes
T76	14.9	N-M	4	Nx					S	D	
T60	15.7	N-R	4	Nx						W,D,E	
T19	7.6	D	4	14.6	Y				M,R		
T7	1.1	D	4	N					D,R	W	
T11	0.9	D	4	N					R	D	
T3	1	N-R	5	N					S	W	
T10	4	W	5	9.3					D,R	D,W	
T48	0.4	W	5	Ny					S,D	W,D	
T24	6.6	W	5	N						D,E	Rd
T27	8.5	W	5	N						D,E	
T78	4.8	W	5	N						W,D	Farmhouse
T47	0.4	W	5	N					R	W	Rd
T28	0.2	W	5	N						D,E	
T45	0.7	W	5	Nx						W,D	
T68	5.6	W	5	X					M	W,E	
T58	12.1	D	5	N					R	D,E	
T73	10.4	D	5	N					M	R	
T77	7.8	D	5	N					M		House, Map edge
T17	2.3	D	5	N					R,M		Rd
T29	2.9	D	5	N						E	

Appendix 1: Grassland Patches

T51	8.8	D	5	Nx					R,M	W	
T57	49.4	D	5	X					S,D,R	W	Rd
T61	5.1	E	5	N					M,R	D,E	
T64	2.3	E	5	Nx					S,M,R	W	MFRes
T42	13.5	D	5&0	N					R	W,D	Pond
T70	209.7	E	5&0	X		Sp			M,R	W,D,E	
T25	2.1	N-R	0	N						D	
T8	0.6	D	0	Ny					S,D	W	Rd
T59	43.7	D	0	N					R,S	D	
T23	13.1	D	0	N					M	W,E	Rd
T21	2.3	D	0	N					M	W,E	
T14	1.9	D	0	N					R		
T56	0.9	D	0	N					R	D	
T30	22.5	D	0	N						W,E	
T71	13.5	D	0	Nx					R,M	W,D	MFRes
T22	31.6	E	0	Ny					M	W,D	
	778.5										
GUNGADERRA-CRACE											
Patch no.	Area (ha)	Veg. type	Cons. rating	Delma max rate	breed. pop'n	S. plana record?	Keyacris record?	Coorab. record?	Adjacent habitat Native	Other	Adjacent land use
C17	5.1	N-T	2	56.5	Y		Ks		R	W,E	Rd
C24	8.3	N-T	2	27.3			Ks			W	Rd,2CY,Trees
C12	6	N-S	2	Ny					R,S	W,D	Res.
C9	1.6	N-S	2	Ny					R	D	
C13	7.3	N-S	2	N					R	W,D	
C28	7.2	N-R	3	4		Sp			R,S	W	Res.
C5	0.5	N-M	3	Ny					R	D	Rd
C27	0.3	N-R	3	N					R		Res.
C15	4.3	N-R	3	Nx					R	W,E,D	
C2	101.4	N-R	4	18	Y				M,S	W,D	Sub,Rd,Q,Res,Field
C32	57	N-R	4	19.2	Y				R,T	W,E,D	Cem./Trees
C20	2.7	W	4	Ny					R	D	Trees

Appendix 1: Grassland Patches

C29	6.2	N-R	4	N					R,S	D	
C1	3.2	D	5	11.4		Sp			R		Sub
C7	34	W	5	Ny					R,T,S	D,E	Trees
C31	9.5	D	5	Ny					R		Q, Sub.
C18	3.2	W	5	Ny					T,R		Rd,Trees
C26	2.1	N-R	5	N					R		
C11	15.2	D	5	N					R	W	Rd,Trees
C4	1.6	D	5	N					R		Quarry
C19	3.7	D	5	N					R	E	
C16	2.8	E	5	Ny					T	W,D	Rd
C14	9.1	D	0	8.7	Y				S	W,E	Rd
C10	6.7	D	0	Ny					R,S	W	
C33	1.4	D	0	Ny					R	D,E	
C25	0.4	D	0	Ny					R		
C6	14.4	D	0	N					R,M	W,E	Rd,Ind,Trees
C30	4.8	D	0	N					R	D	Q, Trees
C21	4.7	E	0	Ny					R		Rd
C34	4.4	E	0	N						D	Rd, Ind
C8	8.1	E	0	X					R	D	Ind,Trees/Cem.
SOUTH MITCHELL											
Patch no.	Area (ha)	Veg. type	Cons. rating	Delma max rate	breed. pop'n	S. plana Y/likely?	Keyacris Y/likely?	Coorab. Y/likely?	Adjacent habitat Native	Adjacent habitat Other	Adjacent land use
S3	1.1	N-M	2	N						D,E	CSIRO
S7	5.6	N-M	2	10.3	Y				R	D	Rd
S6	1.9	N-M	2	N					R,M	D,E	
S22	32.4	N-R	2,3	23.3					R	D,E	Rd, Trees, S10=?
S23	2.4	N-R	2,3	5.1					R	D	
S24	3.1	N-R	2,3	5.1					R	D	
S17	3.4	N-S	3	N					R	D	Rd
S31	0.9	N-R	3	N					R,S		
S26	6.9	N-R	3,4	9	Y				R		Rd, Trees/S10=?

Appendix 1: Grassland Patches

S33	21.6	N-R	3,4	1.9					R	D	Rd, S10=?
S21	3	N-R	3,4	Ny					R	D	Rd, Trees
S28	0.1	N-R	3,4	N					R		
S29	1.1	N-R	3,4?	N					R		S10=?
S32	5.5	N-R	4,2	1.9					R,S	D	
S35	5.2	N-R	4	1.9					R	E,D	Rd
S13	1.6	N-R	4	N						D	Ind
S39	0.6	N-R	4	N						D	Ind, Trees
S10	0.8	W	4	N					R	D	Ind
S1	6.2	D	4,5	N					R		Rd,CSIRO
S41	2	D	5	5.8	Y				R	D	Rd, Trees
S25	3.2	N-R	5	5.1					R,M	D	
S27	4.8	N-R	5	Ny					R		
S16	2.7	D	5	Ny					R		
S42	1.6	D	5	Ny					M,R	E	
S36	3.8	N-R	5	N						E	Rd
S34	2.7	N-R	5	N					R		Ind, Trees, S10=?
S30	0.3	N-R	5	N					R		
S43	4.3	D	5	N					R	D,E	
S11	4.3	D	5	N					R		S10=?
S12	0.6	D	5	N					R		
S14	0.8	D	5	N						D	
S4	6	D	5&0	Ny					M	E	Rd,CSIRO
S8	10.5	D	0	Ny					R,M	E	Rd
S40	4.1	D	0	Ny					M,R	D	CSIRO, Trees
S37	0.9	D	0	N					R	D	Rd, Ind, Trees
S18	3	D	0	N					S,R		Rd
S38	0.5	D	0	N						D	Rd
S5	0.9	E	0	20.5	Y				M	D	
S9	0.4	E	0	N					R	D	
S15	1.4	E	0	N					R	D	near Rd
	162.2										

Appendix 1: Grassland Patches

KENNY											
Patch no.	Area (ha)	Veg. type	Cons. rating	Delma max rate	breed. pop'n	S. plana record?	Keyacris record?	Coorab. record?	Adjacent habitat Native	Other	Adjacent land use
K108	0.5	N-M	2	9.6					D	W,D,E	Ind?
K111	1.3	N-M	2	Ny					M,R	E	Ind
K43	12.3	N-D	2	N					D	E	Map edge, K44&K45
K103	4.4	N-D	2	N					R	W,D	
K113	1.7	N-D	2	N					M	W,E	Ind
K105	1.3	N-D	2	N					R	W,E	Trees
K89	1.2	N-M	2	N						D,E	Pond
K78	23.5	N-M	2	X					R	D,E	Map Edge
K80	44.7	N-M	2,3	X					R,M	W,E	Map Edge
K48	10.7	N-M	3	N					D	E	Map edge, K44&K45
K82	0.6	N-M	3	N					M	W,E	
K83	0.7	N-M	3	N						W,E	Map Edge
K2	0.4	N-M	3	N					R	E	Ind
K96	1.6	N-D	3	N					R	D,E	Map Edge
K107	1	N-S	3	N						D	near Ind
K69	0.3	N-R	3	Ny					R	D	Rd/Trees
K79	30.7	N-R	3	N					R,M		
K51	2	N-R	3	N					R	D,E	
K4	0.6	N-R	3	N						D	Rd, Trees
K11	0.7	N-S	3	N					R	W,E,D	
K19	0.6	N-R	3	N						E	
K41	1.7	D	3	N						E	
K50	11	N-R	3,4	N					R	W,E	
K49	14.1	N-R	3,4	7.7	Y				R	D,E	
K10	3.4	N-R	3,4	N					S	D,E	
K55	20	N-R	4	3.8					R	W	
K1	26.7	N-R	4	Ny					R,M	E,D	

Appendix 1: Grassland Patches

K68	7	N-R	4	Ny					R	D	NEC
K110	2.9	N-R	4	Ny					M	D	Ind,Rd
K92	6.1	N-R	4	N					D	D,E	
K56	1.3	N-R	4	N					R	W	
K54	1	N-R	4	N					R	W,E	
K77	49.7	N-R	4	N					M	D,E	Map Edge
K42	9.5	N-R	4	N						E,D	
K102	5.8	N-R	4	N					D	W,D,E	Trees
K34	3.8	N-R	4	N						E	Hill, Mapped edge
K30	1.2	N-D	4	N						W,D	Rd
K52	0.9	N-R	4	N					R	W,E,D	
K29	0.5	N-R	4	N						W,D	Rd
K84	8.2	N-R	4	Nx					M,R	W,E	
K86	25.3	N-R	4	Nx					M	W,D,E	
K91	10.4	N-M	4	Nx		Sp			D	E	
K57	4.9	N-R	4	X					R	W,E	
K81	1.3	W	4	N					M	E	
K18	4.4	W	4	N					R,D	E,D	
K93	4.2	W	4	N						D,E	
K8	3.9	W	4	N					S	W,D	
K20	3.5	W	4	N					R	D,E	
K35	3.2	W	4	N					R,D	E,D	
K15	2.5	W	4	N					S,R	D,E	
K67	1.4	W	4	Ny						W,E	
K24	0.3	W	4	N					R	D	
K98	2	W	4	N						D,E	Rd
K85	4.6	W	4	X					R	E	
K6	12.5	D	4	N					R	W,E	
K63	5.7	D	4	N						W,E,D	NEC?
K39	1.8	D	4	N					R	E,D	
K60	0.9	N-R	4	N					R	D	
K53	68	N-R	4,5	Ny					R,S	W,E,D	
K72	20.2	E	4,5	N					D,M	E	K45 = ?

Appendix 1: Grassland Patches

K59	9.9	N-R	4,5	Nx				R	W,E	
K58	0.5	N-R	4,5	Nx				R	E	
K13	0.6	E	5	N				S	W,D	
K65	2	W	5	N					W,D	
K106	1.9	W	5	N				R,D	E,D	Trees
K70	2.4	E	5	N					W,E,D	
K46	24.6	D	5	N				R,D	E	Map edge
K40	23.7	D	5	Nx				R	E	Trees/hill on site
K64	17.1	D	5	11.5				R	W,E,D	
K12	14.2	D	5	N				S,R	W,E	Rd
K62	7.1	D	5	N					W,E,D	
K73	4.3	D	5	N				R	D,E	
K114	2.3	D	5	Nx				R	D,E	
K23	1.8	D	5	N				R	W	
K14	0.7	D	5	N				R	W,E	
K7	0.7	D	5	N				R	E	
K16	0.3	D	5	N				S,R	D,E	
K21	0.8	D	5	N				R	W,E	
K88	6	D	5	N				M,R	E	
K22	0.5	E	5	N				R	W,D	
K25	1.4	W	5	Nx				R	D	
K74	0.7	D	5	N					E	Rd
K31	3.1	W	5	N					D	House, Field
K33	2.2	W	5	N					E,D	
K66	1.3	W	5	N					W,E	
K71	8.7	E	5	N				R	E	
K87	24.7	E	5	N				M,R	W,D	
K3	1	E	5	N				M,R		Ind
K27	40.5	D	5	Nx				R,D	W,E	Rd, House, Field, Tr
K26	1	E	5	Nx				R		
K90	20	E	5	Nx				M,D,R	D,E	
K75	26.7	E	5	X				R	D,E	Farmhouse
K94	83.7	N-R	5&0	N				D,R	W,D,E	

Appendix 1: Grassland Patches

K61	3.4	D	0	N					R	D,E	Rd
K109	0.4	D	0	Ny					M,R	E	Ind?
K112	0.3	D	0	N					M,R		Ind
K5	5.9	E	0	N						D	Rd, NEC
K9	3.1	E	0	Ny					R,S	W,D	
K17	9.7	E	0	N						E	Rd, House
K95	2.1	E	0	N						D	
K101	83.1	D	0	N					R,D,S	W,E	Rd,Ind,Trees
K28	2.1	D	0	N					R	W	Rd, House
K37	20.8	D	0	N					R	E	House
K76	31.2	E	0	Nx					M,D,R	W,D,E	
K36	202.9	E	0	X					R,D,M	W,D	Trees
K47	22.6	E	0	7.7					R,S	W,D	
K104	4.5	E	0	X					R,D	W,D	Trees
K97	4.8	E	NONE	N					R	D	
	1229.9										

MISCELLANEOUS

Patch no.	Area (ha)	Veg. type	Cons. rating	Delma max rate	breed. pop'n	S. plana record?	Keyacris record?	Coorab. record?	Adjacent habitat Native	Adjacent habitat Other	
M8	1.2	N-M	2	Ny					R		Sub
M13	1.6	N-R	4,3	N						D	Rd, Racecource
M7	13.2	N-R	4	12.5	Y				M	D	Sub., Rd
M1	4.3	N-R	4	N						D	Trees, Hill
M14	2.5	N-R	4	N						D	Rd, Racecource, Trees
M2	1.3	N-R	4	N						D	Hill
M18	2.5	D	4	N						D	Rd, Trees
M11	1.1	W	4	N						D	Rd, Racecource, Trees
M9	1.6	D	5	Ny					R		Sub., Rd

Appendix 1: Grassland Patches

M10	7.2	D	5	N						W	Rd, Racecource, Trees
M4	5.9	D	5,3	X						E	Rd, Sub.
M3	26.3	D	5	9.3					R		Dam Wall, Rd
M12	1.8	D	0	N					R	W	Rd, Racecource
M15	5.9	D	0	N					R		Rd, Racecource
M17	0.2	D	0	N						E	Rd, Racecource
M16	0.5	E	0	N					R		Rd, Racecource
M6	4.7	E	0	N						D	Sub.
M5	2.9	E	0	Nx						D	Sub.
C23	3	D	5,3	9.6	Y				trees		Trees/Cem.
C22	2.5	D	5,3	N					trees		Trees/Cem.

Appendix 2: *Delma impar* trap site summary.

Gungahlin Valley Delma Study
Sites listed in order of I.D. No. to complement trap site map.

I.D. No.	Site Name	Area	Grid Ref	Alt. m	Mod. trap period	Catch rate
DPF90	CSIRO 1	LOWER GUN.	935010	605	1/11-21/12/91 *	16.2
	"	"			1/11-31/12/94 *	7.4
DPF9002	2CY1	"	928007	600	27/11-20/12/90*	56.5
	"	"			1/11-21/12/91 *	23.5
	"	"			12/11-18/12/92*	11.4
	"	"			15/11-10/12/93	4.7
	"	"			1/11-31/12/94 *	10.7
DPF9006	OAK HILL	N&E GUNG.	948084	675	15/2-16/3/90 **	-
DPF9007	Mulligans Top	"	976067	680	16/2-16/3/90 **	-
DPF9008	Mulligans Bottom	"	975060	645	16/2-16/3/90 **	-
DPF9009	SITE1	OTHER	929038	606	22/11-20/12/90 *	14.6
DPF9010	SITE 2	"	911026	590	23/11-20/12/90	9.3
DPF9011	SITE 3	"	913027	610	30/11-23/12/90	-
DPF9012	SITE 4	"	916028	600	5/12-28/12/90	-
DPF9013	SITE 5	GTC F	932036	613	4/12-28/12/90 *	12.5
DPF9014	SITE 6	N&E GUNG.	934041	613	4/12-28/12/90	-
DPF9015	SITE 7	"	938047	616	4/12-28/12/90	-
DPF9016	SITE 8	LOWER GUN.	925010	600	5/12-28/12/90	8.7
DPF9017	SITE 9	"	931016	605	5/12-28/12/90	2.2
DPF91	CSIRO 2	LOWER GUN.	933013	601	12/11-21/12/91*	19.2
	"	"			12/11-16/12/92	16.2
DPF9101	SITE 10	"	938014	607	9/1/91-8/2/91 **	-
DPF9102	SITE 11 (CEM1!)	CEMETERY	942011	596	9/1/91-8/2/91 **	6.5
DPF9104	MITCHELL (orig.)	CRACE	938025	617	1/11-21/12/91 *	18.0
	"	"			12/11-16/12/92	13.2
DPF9109	GOLD CREEK	N&E GUNG.	921054	640	19/11-18/12/91	-
DPF9110	HORSE PARK 1	"	946066	628	27/11-23/12/91	-
DPF9111	HORSE PARK 2	"	940066	645	19/11-17/12/91	-
DPF9112	Mulligans Flat 1	"	954052	624	19/11-17/12/91	-
DPF9113	Mulligans Flat 2	"	960054	630	19/11-17/12/91	-
DPF9114	Mulligans Flat 3	"	973064	667	19/11-16/12/91	-
DPF9115	N 1	"	928045	612	1/11-13/12/91	-
DPF9116	N 2	"	929046	608	1/11-13/12/91	-
DPF9117	BORDER 1	"	964079	660	19/11-16/12/91	-
DPF9118	BORDER 2	"	967079	655	19/11-17/12/91	-
DPF9119	DAM WALL	"	916036	595	20/11-18/12/91	-
DPF9201	2CY2	LOWER GUN.	930005	-	26/11-18/12/92	27.3
	"	"			12/11-10/12/93	1.9
	"	"			1/11-31/12/94 *	4.1
DPF9203	FRA1 (GTC1, 1992)	GTC C	942026	-	25/11-16/12/92	57.1
DPF9204	FRA2 (old GTC2)	"	945028	-	25/11-16/12/92	38.1
	"	"		-	19/11-16/12/93	24.1
DPF9204	"	"	944028	616	14/11-10/12/94	-
DPF9205	FRA3 (old GTC3)	"	947028	-	26/11-16/12/92	33.3

Appendix 2: *Delma impar* trap site summary.

DPF9301	KALEEN 1	OTHER	926004	596	29/10-10/12/93	38.1
DPF9302?	KALEEN 2	"	929999	605	29/10-10/12/93	4.8
DPF9302*	2CY4	LOWER GUN.	929009	-	27/11-18/12/92	35.7
DPF9303	KALEEN 3	OTHER	926994	-	29/10-10/12/93	10.7
	"	"		-	1/11-31/12/94	3.3
DPF9304	KALEEN 4	"	928992	590	29/10-26/11/93	-
DPF9305	KALEEN 5	"	925989	597	29/10-26/11/93	-
DPF9306	KALEEN 6	"	916980	605	29/10-26/11/93	-
DPF9307	TP1 TREE PLANTATION1	S. MITCHELL	932998	592	1/11-10/12/93	20.5
DPF9308	TP2 TREE PLANTATION2	"	939000	605	1/11-1/12/93	23.3
DPF9309	STUART 1	"	936997	586	1/11-10/12/93	5.1
DPF9310	STUART 2	"	941999	586	1/11-10/12/93	9.0
DPF9311	RAAF	"	933993	585	1/11-10/12/93	10.3
DPF9312	STOCKPOUND	OTHER	943990	580	1/11-10/12/93	5.1
	"	"			1/11-31/12/94	5.8
DPF9313	RACECOURCE	"	943984	600	10/11-10/12/93	-
DPF9316	PAL1 (old GTC13)	GTC F	931037	-	23/11-14/12/93	9.5
DPF9317	GTC1 (old GTC4)	GTC A	932037	-	19/11-16/12/93	24.1
DPF9317	"	"	932036	608	14/11-10/12/94	1.9
DPF9318	GTC2 (old GTC5)	"	934039	-	19/11-16/12/93	13
DPF9319	GTC3 (old GTC6)	GTC E	937036	-	19/11-14/12/93	9.3
DPF9320	GTC4 (old GTC7)	GTC D	937032	-	19/11-16/12/93	27.8
DPF9321	GTC5 (old GTC8)	GTC B	943033	-	23/11-14/12/93	14.6
DPF9322	MUL1 (old SITE 12)	GTC C	949032	-	30/11-16/12/93	25.7
DPF9322	"	"	949031	613	14/11-10/12/94	-
DPF9323	FRA4 (old GTC9)	GTC C	944031	-	27/11-16/12/93	20
DPF9324	FRA5 (old GTC10)	"	947031	-	19/11-16/12/93	18.5
DPF9325	FRA6 (old GTC11)	"	947032	-	23/11-14/12/93	6.5
DPF9401	GND1 GUNGADERRA 1	N&E GUNG.	952041	627	15/11-11/12/94	-
DPF9402	GND2 GUNGADERRA 2	"	953045	621	15/11-11/12/94	-
DPF9403	GND3 GUNGADERRA 3	"	960047	627	15/11-11/12/94	-
DPF9404	GND4 GUNGADERRA 4	"	979056	630	15/11-11/12/94	-
DPF9405	GND5 GUNGADERRA 5	"	977048	626	15/11-11/12/94	-
DPF9406	GND6 GUNGADERRA 6	"	978045	628	15/11-11/12/94	-
DPF9407	GND7 GUNGADERRA 7	"	978041	623	15/11-11/12/94	-
DPF9408	SUL1 SULLIVANS 1	"	976024	618	15/11-11/12/94	-
DPF9409	SUL2 SULLIVANS 2	"	976019	618	15/11-11/12/94	-
DPF9410	WS1 WELLS STATION 1	KENNY	945996	583	14/11-10/12/94	5.8
DPF9411	WS2 WELLS STATION 2	"	957001	587	14/11-10/12/94	11.5
DPF9412	WS3 WELLS STATION 3	"	958003	587	14/11-10/12/94	7.7
DPF9413	WS4 WELLS STATION 4	"	959010	591	14/11-10/12/94	7.7
DPF9414	WS5 WELLS STATION 5	"	970006	598	14/11-10/12/94	-
DPF9415	WS6 WELLS STATION 6	"	966001	602	14/11-10/12/94	3.8
DPF9416	WS7 WELLS STATION 7	"	955020	607	15/11-11/12/94	-
DPF9417	PAL1 PALMERSTON 1	CRACE	937026	613	14/11-19/12/94	11.4
DPF9418	PAL2 PALMERSTON 2	"	936023	615	14/11-10/12/94	-
DPF9419	PAL3 PALMERSTON 3	"	935020	612	14/11-10/12/94	-
DPF9420	PAL4 PALMERSTON 4	"	928023	626	14/11-10/12/94	3.8
DPF9421	PAL5 PALMERSTON 5	LOWER GUN.	927016	608	14/11-10/12/94	4
DPF9422	PAL6 PALMERSTON 6	"	931014	597	14/11-10/12/94	-
DPF9423	PAL7 PALMERSTON 7	GTC E	936035	613	14/11-10/12/94	-
DPF9424	PAL8 PALMERSTON 8	"	935037	617	14/11-10/12/94	-
DPF9425	CEM1 CEMETERY 1	CEMETERY	942011	597	14/11-10/12/94	9.6
DPF9426	CEM2 CEMETERY 2	"	939012	602	14/11-10/12/94	1.9

Appendix 2: *Delma impar* trap site summary.

DPF9427	CEM3 CEMETERY 3	"	939012 *	602	14/11-10/12/94	4
DPF9431	HOS HOSKINS ST	"	941003	600	14/11-10/12/94	5.8
DPF9432	MIT MITCHELL	KENNY	954014	603	15/11-11/12/94	9.6
DPF9433	CRA1 CRACE 1	S. MITCHELL	939990	590	14/11-10/12/94	1.9
DPF9434	CRA2 CRACE 2	"	944993	587	14/11-10/12/94	1.9
DPF9435	CRA3 CRACE 3	"	945996	583	14/11-10/12/94	1.9
DPF9436	KOS1 KOSCIUSKO 1	GTC F	929039	618	14/11-19/12/94	1.4
DPF9437	KOS2 KOSCIUSKO 2	"	929036	610	14/11-19/12/94	5.7