Natural vegetation of the southern wheat-belt (Forbes and Cargelligo 1:250 000 map sheets)

Dominic Sivertsen and Lisa Metcalfe

Sivertsen, Dominic and Metcalfe, Lisa (NSW National Parks and Wildlife Service, PO Box 1967, Hurstville, NSW, Australia, 2220) 1995. Natural vegetation of the southern wheat-belt (Forbes and Cargelligo 1:250 000 map sheets). Cunninghamia *4(1):* 103–128. Remnant, native, woody vegetation of the southern wheat-belt on the Forbes and Cargelligo 1:250 000 map sheets is mapped and described. The study area is defined by the Lachlan River and latitude 33°S in the north, longitude 145°30′E in the west, latitude 34°S in the south and by a line which separates the western slopes and the western plains in the east; the study area thus excludes areas of the western slopes and the Western Division of New South Wales. The study area includes the towns of West Wyalong, Condobolin, Lake Cargelligo and Hillston; it also includes all or part of the Bland, Carrathool, Forbes, Lachlan, Parkes and Weddin Local Government Areas. Vegetation delineation, preliminary classification and sampling stratification are based largely on stereoscopic air photo interpretation. Pattern analysis, using data from 290 formal sites, is used to test and refine the above classification and map unit definition is based on the results. Twenty different remnant vegetation map units are described and mapped. Native woody vegetation is dominated by various eucalypt woodlands, the composition of which reflects position in the landscape and soils; *Eucalyptus camaldulensis* and *E. largiflorens* dominate on the floodplains, *E. populnea* subsp. *bimbil*, *E. microcarpa*, *E. conica* and *E. intertexta* dominate on heavier peneplain soils; *E. socialis*, *E. gracilis*, *E. dumosa* and *E. oleosa* dominate on lighter peneplain soils. Hill and footslopes remnants are dominated by *E. dwyeri* and *E. sideroxylon*. White Cypress Pine (*Callitris glaucophylla*) occurs throughout the area.

Of the 582 vascular plant taxa recorded, a high proportion (117 taxa) are exotic and only three are listed as nationally rare or threatened. The amount of native woody vegetation remaining (16% of the area), together with remnant size, threat of clearing, heavy grazing regimes, shape and condition demonstrate serious implications for biodiversity conservation and land management in the area.

Introduction

This is the first in a series of papers, with accompanying maps, delineating and describing the remaining native vegetation in the New South Wales wheat-belt study area (Figure 1). This paper deals specifically with the remnant vegetation of those parts of the Forbes and Cargelligo 1:250 000 map sheets occurring in the study area.

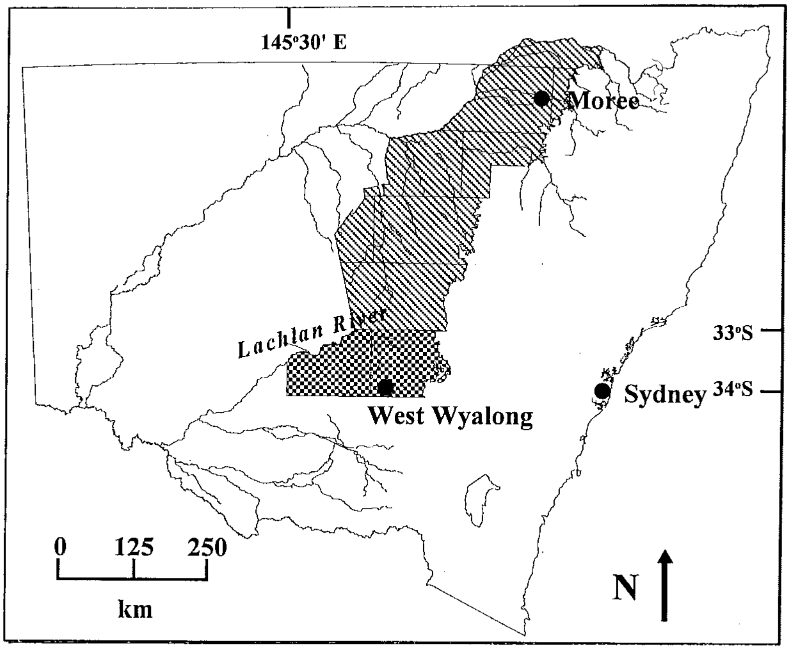

Fig. 1. The entire wheat-belt study area. The combined Forbes and Cargelligo 1: 250 000 map sheet area is indicated by the darker stippling.

The Forbes and Cargelligo areas comprise the southern-most part of New South Wales wheat-belt study area. This area has undergone far-reaching changes since European settlement due mainly to its importance for agriculture (Goldney & Bowie 1990). These changes have included removal of up to 95% of the original native vegetation for cropping and pasture improvement (Murray–Darling Basin Ministerial Council 1987), and widespread removal of native shrub and grass species by domestic and feral grazing animals (Adamson & Fox 1982; Benson 1991).

Land management agencies such as the NSW National Parks and Wildlife Service (NPWS), and community-based land management groups such as Landcare and Catchment Management Committees have a pressing need for information relating to remnant native vegetation. This is particularly true for land-types which have been favoured for agricultural and pastoral development such as the western plains. Native vegetation in the southern wheat-belt has not been well documented and mapped to date (Murray–Darling Basin Ministerial Council 1987). Mapping has either been very broad scale (e.g. Beeston et al. 1980) or of limited extent (Norris & Thomas 1991). Mapping exercises have been mostly based on qualitative assessments. Quantitative data is scarce.

The aims of this project are to map the remnant native vegetation of the study area at a scale of 1:250 000 and to describe those remnants in terms of their floristic assemblages and abiotic environments. Vegetation communities *sens. strict.* are therefore not the mapping units, although the primary breakdown of remnant types will be on floristics. This study is part of a longer-term project to map and describe, quantitatively, the remnant native vegetation of the entire New South Wales wheat-belt.

Limitations of scale

A mapping scale of 1:250 000 was chosen because it allows for a reasonable amount of detail and a rapid coverage of the area. A 1:100 000 scale series of maps covering the same area would take decades to complete, and a large percentage of the vegetation may well have been cleared by that time. However, this scale does present a number of limitations, which are detailed below.

It is important when reading any map to be aware of its scale and hence the level of accuracy that can be expected from it. For example, if a feature on a 1:25 000 scale map is misplaced by one millimetre this will translate to a 25 m displacement on the ground. The same displacement on a 1:100 000 map will be 100 m on the ground. The current maps are published at a scale of 1:250 000. At this scale every millimetre of displacement will translate into a 250 m displacement on the ground. Errors of this magnitude can be expected from the mapping and publishing processes alone. For example, some displacements of up to one millimetre may occur in transferring boundaries from air photographs to maps; and paper stretch during printing may create errors of this magnitude.

Another important aspect of scale which should be borne in mind is the limitation on the effective size of remnants that can be displayed. As the map scale decreases (as the area of land represented by each cm^2 of map increases) it becomes more difficult to map fine detail or small-scale patchiness. For example, whilst it may be quite feasible to map small patches, perhaps consisting of only a few trees of white cypress pine in a mallee community at 1:25 000 scale, it is not practically possible to do so at a scale of 1:250 000. Such patches would be too small to represent on the finished map.

Finally it should be noted that all thematic mapping is somewhat subjective, particularly with respect to placement of boundaries. Boundary lines of remnants should be regarded as falling within interzones and not as depicting immutable lines of change. The possible exception to this is the line between cleared and uncleared land.

Users of these maps are therefore exhorted to bear these limitations in mind. Remnant types are not homogeneous and often include small patches of other vegetation types which are not included in the description and which may appear quite large on the ground. Similarly, hoping to encounter a boundary on the ground exactly where you calculated it to be from the map may be an unrealistic expectation.

Study area

The study is confined to the western plains and isolated ranges on the Forbes and Cargelligo 1:250 000 scale map sheets. The area is bounded by the Lachlan River and latitude 33° to the north, longitude 145°30'E to the west, latitude 34°S to the south and by a line which separates the western slopes and the western plains in the east; an area of 2,400,650 ha (Figure 1). The study area includes the towns of West Wyalong, Condobolin, Lake Cargelligo and Hillston; it also includes all or part of the Bland, Carrathool, Forbes, Lachlan, Parkes and Weddin Local Government Areas.

Whilst these boundaries intentionally exclude the western slopes of the Great Divide and parts of the Western Division of New South Wales that occur on these maps, this is no reflection on the relative importance of these areas, but a way of confining the study to a manageable area with similar ecology and land-use practices throughout. This study will concentrate on the plains, as opposed to the hills, since it is the plains which have undergone the greatest change since European settlement (Murray–Darling Basin Commission 1987) and are most likely to be the subject of conflicting land-use proposals in the future.

Geology

Geologically the study area is complex. Most of the area is mapped as Unconsolidated Cainozoic deposits (fluvial and/or aeolian sand, silt and clay), but many other formations are scattered throughout (Pogson 1967; Bowman 1977). In the far west Dune deposits (clayey sands) and Playa formations (silt and silty clay) appear sporadically throughout the Quaternary deposits. Further east, from about Lake Ballyrogan (Lake Brewster), the study area contains a number of prominent, generally north–south aligned ranges of hills, the geologies of which are diverse. For example, the Lachlan Range is mapped as comprising three different Devonian sedimentary formations overlaying two Silurian sedimentary formations.

Other prominent ranges in the study area are:

- the Ural Range (Silurian volcanics & sediments and Tertiary basalt)
- the Tabbita, Melbergen, Naradhan and Cocoparra Ranges complex (Devonian sediments with some Tertiary basalt)
- the Goobothery Range (Ordovician metamorphics & sediments)
- the Narriah Hills (Devonian sediments & volcanics and Ordovician metamorphics & sediments)
- Mt Tilga and the surrounding hills (Ordovician and Devonian sediments)
- the Wyrra Hills (Silurian sediments)
- the Jemalong, Cordadgery and Gunning Ranges (Devonian sediments)
- the Currawong and Wheoga Hills (Devonian volcanics and sediments).

There are a number of other formations which do not form prominent ranges and are commonly obscured by Cainozoic material. These are most commonly Silurian and Ordovician sediments or Silurian granites.

Topography

Topographically, the study area is also complex. It is a peneplain which dips gently from 250 m elevation in the east to 120 m in the west. This peneplain also changes character from west to east. In the west it is flat to gently undulating and becomes progressively more undulating to rolling in the east. This general trend is locally disrupted by the ranges of hills already discussed, which may exceed 550 m elevation. Many of these ranges rise prominently and steeply from the surrounding plain. For example, the Lachlan Range rises to 362 m from the plain over a distance of only one kilometre.

There are also a number of floodplain zones, most of which are associated with the Lachlan River, although narrow bands of floodplain are recognisable along most tributary streams. The Lachlan floodplain varies in width from about 10 km to about 2 km.

Climate

Average annual rainfall ranges from 526 mm at Forbes to 365 mm at Hillston; a fall of 180 mm/year from east to west over a distance of 260 km (Table 1). Rainfall is distributed more or less evenly throughout the year but is erratic (Bureau of Meteorology 1992). Temperatures vary little across the study area; the hottest month is January with average daily maxima between 33.4° C (Lake Cargelligo) and 32° C (Forbes); the coldest month is July with average daily minima between 2.4° C (Forbes) and 3.7° C (Hillston).

Table 1. Summary of meteorological data for selected weather stations in the study area

	Highest maximum mean daily temperature °C	Lowest minimum mean daily temperature °C	Highest mean monthly rainfall mm	Lowest mean monthly rainfall mm	Average annual rainfall mm
Forbes	32.0 (Jan)	2.4 (July)	49 (Jan)	40 (Feb)	526
Condobolin	32.8 (Jan)	3.6 (July)	43(Jan&Oct)	30 (Sept)	443
Wyalong	32.2 (Jan)	2.6 (July)	46 (Oct)	35 (Nov)	485
Lake Cargelligo	33.4 (Jan)	2.8 (July)	40 (Oct)	31 (Sept)	427
Hillston	32.9 (Jan)	3.7 (July)	35 (Oct)	26 (Feb)	365

Methods

Definition of remnant vegetation

For this project remnant native vegetation was defined as comprising at least 5% native tree or shrub crown cover; where crown cover was <5% the area in question was visited in the field before it was mapped as native vegetation. Treeless remnants were only mapped when observed in the field because native low shrub, herb and grass communities are often difficult to distinguish from exotic pastures, weed infestations and even cropped land on high level aerial photography and satellite imagery.

Since the maps accompanying this report are 1:250 000 scale, it is important to note that mapping of small scale patchiness and very small remnants is not practically possible at this scale. Remnants of less than 10 ha are not mapped.

Sampling

Several possible sampling methods were considered. These included site stratification based on environmental gradients (Gillison 1984; Austin & Heyligers 1989), simple grid survey and random sampling. However, because of the difficulty in applying any of these methods due to the fragmented nature of the vegetation, limited access (sample sites were restricted to public land) and the difficulty in applying a gradient approach on the plains, interpreted high-level aerial photography was chosen. Restriction on access to private land, a government policy of the day, makes quantitative comparisons between remnants on public and private land impossible. This may present a limitation for some users.

Stereoscopic examination of air photos (air photo interpretation or API) allows recognition of vegetation/landform/soil patterns. Such patterns have been used to stratify sampling in vegetation and land resource surveys in Australia as early as 1946 (Christian & Stewart 1953) and are still currently used (e.g. Benson 1992). Using photopattern as a means of observing the effects of environmental gradients is convenient, particularly in a case such as this, where those gradients are not immediately apparent.

High level aerial photography, ca 1:85 000 scale (Commonwealth, 1980 for Cargelligo and 1989 for Forbes), covering the whole of the study area, was examined stereoscopically. Vegetation remnants were delineated and classified into 'phototypes' based on photopattern and position in the landscape. Upon completion of the API the photos were re-examined and possible field site localities were allocated so that all delineated phototypes were sampled, with replication, over the whole of their geographical range where possible. Replication varied according to the size and area of each phototype. For example, the strictly riparian remnant type (R1) was described at a total of 23 sites, whilst the less extensive 'floodplain mosaic' (R2) was sampled only seven times. This sampling of phototypes was applied to both plains and hills, thus all possible combinations of aspect, altitude and geology have not been investigated for the hills. In addition to stratification based on photopattern, sites were located taking into account access and location on public land, predominantly state forest, nature reserve, road reserve and travelling stock reserve.

Each site consisted of a measured 20 x 20 m (400 square metre) quadrat except where the nature of the remnant made this shape inappropriate, e.g. narrow riparian communities. In such cases the length and breadth of the quadrat were altered so that a constant area was sampled. Each site was described in terms of morphological terrain type, landform pattern, soil surface texture and colour, site drainage (run-off), site disturbance (soil erosion and exotic grazers), vegetation structure, floristic composition and species abundance. Vegetation structure was described in the following terms: heights of all strata, crown cover of the upper strata (Walker & Hopkins 1984), an estimate of total ground cover for the lowest stratum, and a cover abundance rating for each species present (Braun-Blanquet 1932). Observations of soil erosion and the effects of exotic grazers were non-quantitative, evidence of sheet, rill and gully erosion was noted (McDonald et al. 1984); grazing by exotic species was inferred from faecal remains, trampling and warrens.

Descriptions of geology, landform, soil and vegetation structure follow the terminology of McDonald et al. (1984). Botanical classification and nomenclature generally follow Jacobs and Pickard (1981) and Harden (1990, 1991–93); any exceptions to this are noted. Primary data were collected in all cases except for cover/abundance ratings of individual plant species which are pre-classified according to the Braun-Blanquet (1932) 1–7 scale.

A total of 290 formal sites were described. These were supplemented by numerous field notations made during the survey. Field work was carried out from October 1991 to February 1992. The study area had been subject to several years of drought before the survey. During the survey, however, the drought was broken by local heavy rains, notably in the east.

Data analysis

Recognition and description of vegetation patterns is integral to this project. Vegetation patterns were first classified intuitively on the basis of API. They were subsequently classified using multivariate analysis, using the PATN software package (Belbin 1988, 1991).

Cluster analysis with a hierarchical classification was used since the main aim was reduction of data to manageable groups and description of the data in terms of those groups (Faith, 1991). The Kulczynski coefficient and flexible UPGMA were used to calculate similarity and to generate the hierarchical classifications respectively (Belbin 1988).

Ephemeral and annual species were eliminated from the analysis because of the 'noise' introduced by sites on the eastern side of the study area. Here, drought-breaking rains produced rapid germination and maturation amongst the ephemerals and annuals. Exotic herbaceous species were also eliminated from the pattern analysis. These species, by virtue of their tendency to grow in a wide range of environments and native communities, also introduce considerable 'noise' into the analysis. All woody species (trees and shrubs) and perennial herbaceous species were included in the analysis. In all, approximately 290 taxa were eliminated from the final analysis.

Groups were defined from the resulting PATN dendrogram by considering as well as species composition, abiotic factors such as soil type, soil surface texture, landform, run-off, slope, geology and altitude. The site groupings so developed were then compared with the original API classification. A final classification was devised which equated site groupings with the map units; API boundaries were then amended as necessary.

Results

Some 84 families, 281 genera and 582 taxa (species and subspecies) of plants were recorded from the 290 formal sites. Of these 465 taxa were native, 117 exotic and three (*Lomandra patens*, *Phebalium obcordatum* and *Stipa eremophila*) are listed as nationally rare or threatened Australian plants [ROTAP] (Briggs & Leigh 1988). The families represented by most species were: Poaceae, 100 species; Asteraceae, 82 species; and Fabaceae and Chenopodaceae each with 32 species. The families Myrtaceae and Mimosaceae, which contain most of the canopy and small tree taxa, had 25 and 23 species respectively. The greatest species diversity is evident among families and genera containing mainly herbaceous species. The importance of the herbaceous components of the vegetation is seen in the full map unit descriptions (Table 2). Genera comprising seven or more species records, and the characteristic life forms of those genera, are shown in Table 3. A list of species recorded and their occurrence by map unit appears on the back of the published maps.

The results of the pattern analysis are expressed as a dendrogram revealing 15 major PATN groups (Figure 2). The initial API recognised 30 phototypes including seven floodplain and wetlands phototypes, 14 hills and footslopes phototypes, and nine plains phototypes. Whilst the disparity in the number of units in these two classifications may appear great, there are in fact many close parallels.

Five Riparian/Floodplain and two Wetland API phototypes were initially recognised based on canopy type, crown separation, position in the landscape and landforms. Of the 59 sites in these phototypes, 26 or 44% belonged to one PATN group (characterised by *Eucalyptus camaldulensis*); 25 or 42% fell into a second distinct PATN group (*E. largiflorens*); the remaining sites fell into other PATN groups because of codominance of another species or because of infrequently occurring species achieving dominance. Based on the analysis, therefore, two riparian map units, characterised by *E. camaldulensis* and *E. largiflorens* respectively, were recognised. Based on the API a third map unit was recognised which contained elements of these two, together with open grassy areas forming a mosaic, the elements of which could not be mapped separately at a scale of 1:250 000. Three additional floodplain units have been described based on photopattern and contain the sites which did not fit into the two main riparian groups. Therefore, the combination of pattern analysis and API has allowed identification of six riparian/floodplain map units.

In the initial API, ten hills and four footslopes phototypes were recognised based mainly on crown densities and mapped geologies. However, PATN analysis revealed few real differences between most of these phototypes. Based on the analysis, two main groups (mallee and non-mallee vegetation) could be recognised. Amongst the non-mallee vegetation some differences were evident between sites occurring on sedimentary or metamorphic geologies, and those occurring on volcanic geologies. These two groups have therefore been differentiated in the mapping. Amongst the volcanic geologies it was not possible to describe any sites on basalts. However, API and informal observations revealed that areas of basalt tended to be substantially cleared and that, where remnants of native vegetation occurred, they were similar to those described on the sedimentary geologies. The final result is that four Hills map units have been recognised. The four footslopes API types were later reduced to three based on density of woody vegetation cover and floristic composition.

By a similar process of comparison and combination between API and PATN classifications, the nine original phototypes occurring on the Peneplain were reduced to seven map units.

Remnant types containing species with narrow geographical distributions, for example riparian, wetland and hill species, fell into discrete PATN groups. On the other hand, remnant types of the plains and footslopes containing species with broader geographical distributions tended to have sites dispersed among numerous PATN groups (Figure 2). On the peneplain, API allowed two distinct types of box community to be distinguished; an Open Woodland (P3) that shows evidence of having been partially cleared and heavily grazed, and a Woodland or Open Forest (P4) displaying less evidence of clearing and grazing. The difference between these two map units was not immediately apparent from the pattern analysis, although close examination of the site data reveals substantial floristic differences. Conversely, two *Callitris glaucophylla* dominated remnant types were recognised in the initial API which showed no substantial difference either in the pattern analysis or in terms of crown cover. In this instance, therefore, the two initial categories were combined.

PATN analysis and API comparison has resulted in the formulation of 20 map units, the full descriptions of which appear in Table 2.

The four broad geomorphic zones adopted as the primary breakdown for the map units display distinct combinations of environmental factors which are reflected in the floristic composition of the map units (Tables 4, 5, & 6). The Riparian and Floodplain zone is characterised by channels, backplains and floodplains; grey cracking clay soils; very low slopes; and very slow to nil run-off (Table 4).

The Peneplain units fall into three main categories (Table 5). P1, P2, and P5 (mallee units) are characterised by sandy soils; low slopes; very slow to slow run-off; and flat to gently undulating terrain. P3, P4 and P6 are characterised by loamy red earth soils; low slopes; slow run-off; and generally flat terrain. P7 occupies an interzone between the Floodplain and Peneplain units. Landforms tend to be flat, although occupying a higher position in the landscape than surrounding 'R' units. Soils are dark red-brown clayey earths.

The Footslopes zone is characterised by lower slopes and flats; loamy red and red-brown earth soils; slopes of up to 3°; and slow to rapid run-off. The Hills zone comprises upper slopes and crests; shallow (frequently skeletal) brown earth soils; moderate to steep slopes; and rapid to very rapid run-off (Table 6).

Table 2. Map unit descriptions

The following map unit descriptions summarise the landforms, soils, vegetation structures and species occurring in each unit. These remnants are not homogeneous with respect to all of these factors, hence, the descriptions deal with the most common and characteristic features. Variations are discussed in the 'comments' section. Each map unit is described in the following terms:

Name: Map unit code (characteristic vegetation community).

Sites: The number of formal sites described in the mapping unit.

Landforms: Most frequently occurring morphological terrain types.

Soils: Main soil types encountered. This typing of soils is based on field observations (as previously described) and, where available, mapped information; they should not be interpreted as resulting from formal profile descriptions.

Structure: Main vegetation structural types, following Walker and Hopkins (1984).

Species: Dominant and most frequently occurring species in each stratum are listed. For convenience the strata are labelled 'Trees', 'Low Trees', 'Tall Shrubs', 'Shrubs', 'Herbs' and 'Grasses'. Where one or more of these strata do not commonly occur they are omitted.

Comments: This section is devoted to general descriptions of the unit and descriptions of the range of variation expected.

Note: Exotic species are indicated in the species lists on the back of the maps.

RIPARIAN AND FLOODPLAIN REMNANTS

Name: R1. (River Red Gum Forests)

Sites: 23.

Landforms: Banks, channels and backplains.

Soils: Grey cracking clay and polygenetic alluvial soils.

Structure: Tall Open Forest.

Species: Trees *Eucalyptus camaldulensis*; Low Trees *Acacia stenophylla, Acacia saligna*; Shrubs *Muehlenbeckia florulenta*; Herbs *Pratia concolor, Rumex brownii, Echium plantagineum, Sonchus oleraceus, Onopordum acanthium* subsp. *acanthium, Oxalis corniculata, Centipeda cunninghamii*; Grasses *Cynodon dactylon, Paspalidium jubiflorum, Lolium rigidum*.

Comments: This remnant type is characteristic of streamline and river margins. The dominant community most commonly comprises two strata; the canopy and a herbaceous understorey, usually dominated by exotics. The shrub stratum is patchy in occurrence and is frequently absent.

Name: R2. (Floodplain Mosaic)

Sites: 7.

Landforms: Backplains, floodplains and banks.

Soils: Grey cracking soils.

Structure: Tall Open Forests and Closed Grassland.

Species: Trees *Eucalyptus largiflorens, Eucalyptus camaldulensis;* Low Trees *Acacia salicina* and

Acacia stenophylla; Shrubs *Muehlenbeckia florulenta;* Herbs *Carex inversa, Centipeda cunninghamii, Marrubium vulgare, Echium plantagineum*; Grasses *Lolium rigidum, Hordeum leporinum, Phalaris paradoxa, Agrostis avenacea.*

Comments: This remnant type comprises a mosaic of R1, R3 and Grasslands where the individual elements are too small to map separately. It is mainly associated with backplain and floodplain areas of the Lachlan and other major rivers and characteristically contains a network of minor stream channels.

Name: R3. (Black Box Woodlands)

Sites: 23.

Landforms: Floodplains, closed depressions and very gentle rises.

Soils: Mainly grey cracking clays with some red earths and brown clays.

Structure: Mid-High Open Forests, Mid-High Woodlands and Mid-High Open Woodlands.

Species: Trees *Eucalyptus largiflorens, Eucalyptus camaldulensis, Eucalyptus populnea* subsp. *bimbil*; Low Trees *Acacia salicina, Acacia pendula*; Shrubs *Muehlenbeckia florulenta*; Herbs *Einadia nutans, Sclerolaena muricata, Rhodanthe corymbiflora, Oxalis corniculata*; Grasses *Danthonia setacea, Lolium rigidum, Hordeum leporinum, Phalaris paradoxa*.

Comments: Associated with broad floodplain areas and isolated closed depressions which often pond water for several days following rain. *Eucalyptus camaldulensis* tends to replace *E. largiflorens* in about the eastern third of the study area. Minor areas of *E. populnea* subsp. *bimbil* and *Casuarina cristata*, forming a mosaic pattern, occur on higher ground within this unit in the west. Typical Black Box (*Eucalyptus largiflorens*) communities in this area contain either a scattered Lignum (*Muehlenbeckia florulenta*) shrub layer or the shrub layer is absent. The ground cover may vary considerably from site to site and tends to be less dominated by exotics than is the case with river frontage remnants (R1 & R2).

Name: R4. (Lignum Shrublands)

Sites: 1.

Landforms: Flats and Closed Depressions.

Soils: Brown clay.

Structure: Tall Shrublands.

Species: Shrubs *Muehlenbeckia florulenta*; Grasses *Stipa aristiglumis, Enteropogon acicularis, Phyla nodiflora, Lolium perenne*.

Comments: Remnant type of limited extent; associated with the Lachlan River and Lakes.

Name: R5. (Myall Woodlands)

Sites: 1.

Landforms: Gilgaied flats.

Soils: Grey clay.

Structure: Mid-High Woodland to Mid-High Open Forest.

Species: Trees *Acacia pendula*; Shrubs *Amyema quandong, Einadia nutans*; Herbs *Ixiolaena tomentosa, Marsilea hirsuta*, Grasses *Danthonia setacea, Lolium rigidum*.

Comments: This remnant type is difficult to distinguish from grassed land on the 1: 85,000 aerial photography used in this project and hence, may be more common than indicated on the map. However, whilst it is possible to see scattered Myall (*Acacia pendula*) throughout the area, very few sizeable remnants were observed. The mistletoe *Amyema quandong* is a characteristic stem parasite of Myall.

Name: R6. (Yellow Box/River Red Gum Forests)

Sites: 4.

Landforms: Flats, floodplains.

Soils: Brown earthy soils and clays.

Structure: Tall Open Forest to Tall Woodland.

Species: Trees *Eucalyptus melliodora, Eucalyptus camaldulensis*; Low Trees *Acacia stenophylla;* Shrubs *Muehlenbeckia florulenta;* Herbs *Onopordium acanthium* subsp. *acanthium;* Grasses *Lolium perenne, Lolium rigidum, Avena ludoviciana*.

Comments: This remnant is characterised by the presence of Yellow Box (*Eucalyptus melliodora*), usually in combination with River Red Gum

(*Eucalyptus camaldulensis*), and has many features in common with remnant type R1. However, it is does not occur on banks and tends to be confined to low-lying areas on the floodplains. The shrub layer tends to be both patchy and sparse and the ground cover is dominated by exotic species.

UNDULATING PENEPLAINS REMNANTS

Name: P1. (Mallee Woodlands)

Sites: 11.

Landforms: Flats and very gentle rises.

Soils: Sandy red earths.

Structure: Low to Mid-High Mallee Woodlands.

Species: Trees *Eucalyptus socialis, Eucalyptus gracilis, Eucalyptus dumosa, Callitris glaucophylla*; Shrubs *Melaleuca uncinata, Olearia pimeleoides, Eremophila glabra, Acacia* spp., *Halgania cyanea*; Herbs *Chrysocephalum apiculatum, Hyalospermum semisterile, Stackhousia viminea, Lomandra effusa, Dianella revoluta, Daucus glochidiatus*; Grasses *Triodia scariosa* subsp. *scariosa, Stipa elegantissima*.

Comments: This remnant type is characterised by Mallee Woodlands on red sands. These communities support diverse and variable shrub and herbaceous understoreys. Small areas of *Callitris* open woodlands occur on hard-setting red earth soils within the mallee.

Name: P2. (Open Mallee Woodlands)

Sites: 8.

Landforms: Flats and gentle rises.

Soils: Sandy red earths.

Structure: Low Mallee Woodlands and Mid-High Woodlands.

Species: Trees *Callitris glaucophylla, Casuarina cristata*; Low Trees *Eucalyptus socialis, Eucalyptus dumosa, Eucalyptus oleosa, Eucalyptus leptophylla*; Shrubs *Olearia pimeleoides, Geijera parviflora, Acacia* spp., *Hakea tephrosperma, Pittosporum phylliraeoides*; Herbs *Chrysocephalum apiculatum, Dianella revoluta, Vittadinia pterochaeta, Daucus glochidiatus, Echium plantagineum, Hyalosperma semisterile, Hypochaeris radicata*; Grasses *Bromus rubens, Stipa scabra* var. *scabra, Vulpia myuros, Stipa elegantissima*.

Comments: In this remnant type the vegetation communities are structurally diverse. The Mallee communities are frequently more open than in P1 as a result of past clearing and grazing, and are interspersed patches of White Cypress Pine (*Callitris glaucophylla*) and Belah (*Casuarina cristata*) dominated communities.

Where the shrub and grass layers have been removed and disturbed by grazing, exotic species dominate the understorey.

Name: P3. (Open Box Wood-lands)

Sites: 27.

Landforms: Flats and gentle slopes <2 degrees.

Soils: Loamy red earths, minor sandy red earths and brown earths.

Structure: Mid-high Open Woodland, Tall Open Woodlands, Tall Woodlands and Tall Grassland

Species: Trees *Callitris glaucophylla, E. populnea* subsp. *bimbil, Eucalyptus intertexta, Eucalyptus microcarpa, Allocasuarina luehmannii*; Low Trees *Geijera parviflora, Acacia oswaldii*; Tall Shrubs *Dodonaea viscosa, Eremophila mitchellii*; Shrubs *Maireana enchylaenoides, Einadia nutans*; Herbs *Sida corrugata, Echium plantagineum*; Grasses *Danthonia setacea, Enteropogon acicularis, Stipa scabra* var. *scabra, Vulpia myuros, Elymus scaber* var. *scaber, Lolium rigidum*.

Comments: A generally open pattern with scattered denser areas on the aerial photographs. Site descriptions suggest previous clearing and moderate to heavy grazing patterns.

Name: P4. (Box Woodlands)

Sites: 52.

Landforms: Flats, very gentle slopes and minor drainage lines.

Soils: Loamy red earth soils, minor occurrences of sandy and clayey red and brown earths.

Structure: Tall Woodland to Tall Open Woodland and Mid-High Woodland.

Species: Trees *Eucalyptus populnea* subsp. *bimbil, Callitris glaucophylla, Eucalyptus microcarpa, Eucalyptus conica, Eucalyptus intertexta*, and *Allocasuarina luehmannii*; Tall Shrubs *Dodonaea viscosa, Pittosporum phylliraeoides, Acacia deanei, Senna artemisioides* and *Santalum acuminatum*; Shrubs *Einadia nutans, Maireana enchylaenoides*; Herbs *Calotis cuneifolia, Dichondra repens, Sida corrugata, Vittadinia dissecta, Oxalis chnoodes*;

Grasses *Danthonia setacea, Stipa scabra* var. *scabra, Lolium rigidum, Enteropogon acicularis, Vulpia myuros, Elymus scaber* var. *scaber*.

Comments: Very similar to P3 in composition but differing in having a consistently denser and more even canopy. Possibly not thinned as P3 has been. Varying dominance of the main eucalypt species; frequently with *Callitris glaucophylla* co-dominant.

Name: P5. (Mallee/White Cypress Pine intergrade)

Sites: 5.

Landforms: Flats.

Soils: Sandy and loamy red earths.

Structure: Mid-High Mallee Woodland or Tall Woodland to Mid-High Woodland.

Species: Trees *Callitris glaucophylla*; Low Trees *Eucalyptus socialis, Eucalyptus dumosa*; Tall Shrubs *Eremophila glabra, Pittosporum phylliraeoides, Melaleuca uncinata*; Shrubs *Maireana enchylaenoides*; Herbs *Dianella revoluta, Hyalosperma semisterile, Hypochaeris radicata*; Grasses *Danthonia setacea, Triodia scariosa* subsp. *scariosa, Vulpia myuros*.

Comments: Intergrade remnant between White Cypress Pine and Mallee remnants with cypress pine and mallee in discrete communities forming a mosaic, the individual units of which are too small to map separately.

Name: P6. (White Cypress Pine Woodlands)

Sites: 48.

Landforms: Flats and gentle rises.

Soils: Loamy red earth soils.

Structure: Tall Open Woodland, minor Mid-High Open Woodland and Tall Woodland.

Species: Trees *Callitris glaucophylla*, (minor *Eucalyptus populnea* subsp. *bimbil, Eucalyptus microcarpa, Eucalyptus intertexta, Brachychiton populneus* and *Allocasuarina luehmannii)*; Tall Shrubs *Acacia deanei, Dodonaea viscosa, Geijera parviflora, Senna artemisioides* Shrubs *Einadia nutans, Maireana enchylaenoides*; Herbs *Cheilanthes austrotenuifolia, Calotis cuneifolia, Oxalis chnoodes, Sida corrugata, Hypochaeris radicata, Stackhousia viminea, Bracteantha bracteata*; Grasses *Stipa scabra* var. *scabra, Vulpia myuros, Danthonia setacea, Elymus scaber* var. *scaber, Pentaschistis airoides*.

Comments: White Cypress Pine woodlands and forests dominate but contain elements of other plains communities. Eucalypts may be locally dominant or co-dominant and thus this type overlaps with P4. This remnant type often comprises a dense stratum of regrowth pine with Eucalypts as isolated emergents.

Name: P7. (Bull Oak/Belah Woodlands)

Sites: 10.

Landforms: Flats, shallow depressions and minor drainage lines.

Soils: Gilgaied clays and red earths.

Structure: Tall Woodlands (minor Tall Open Woodland and Mid-high Open Woodland).

Species: Trees *Allocasuarina luehmannii, Callitris glaucophylla, Casuarina cristata, Acacia homalophylla*; Low Trees *Myoporum montanum, Acacia deanei*; Shrubs *Einadia nutans, Enchylaena tomentosa*; Herbs *Sida corrugata, Vittadinia dissecta*; Grasses *Danthonia setacea, Lolium rigidum, Vulpia myuros, Stipa wakoolica, Enteropogon acicularis, Elymus scaber* var. *scaber*.

Comments: Confined to the eastern third of the study area, this remnant occupies a zone of transition between the floodplain and peneplain remnants.

FOOTSLOPE REMNANTS

Name: F1. (Grasslands)

Sites: Nil

Landforms: Slopes, low crests and flats.

Soils: Lithosols and colluvial soils.

Structure: Tall Grassland, (minor Mid-High Open Woodland).

Species: Trees *Callitris glaucophylla, E. populnea* subsp. *bimbil*; Grasses *Stipa scabra* var. *scabra, Danthonia setacea*.

Comments: No access was available for formal sites in this remnant type. However, it appears from the API to be mainly cleared and consists of grasslands with clumps of trees remaining; it is otherwise similar to F2.

Name: F2. (Open Pine and Box Wood-lands)

Sites: 18.

Landforms: Footslopes and flats.

Soils: Colluvial red earths.

Structure: Tall Open Woodland, Tall Woodland and Mid-High Open Woodland.

Species: Trees *Callitris glaucophylla, Eucalyptus populnea* subsp. *bimbil, Eucalyptus intertexta, Eucalyptus dwyeri, Eucalyptus sideroxylon, Brachychiton populneus*; Low Trees *Acacia doratoxylon, Acacia deanei, Myoporum montanum, Pittosporum phylliraeoides, Leptospermum divaricatum*; Shrubs *Chenopodium desertorum, Dodonaea viscosa, Cassinia laevis Maireana enchylaenoides, Einadia nutans*; Herbs *Calotis cuneifolia, Hypochaeris radicata, Sida corrugata, Cheilanthes austrotenuifolia*; Grasses *Vulpia myuros, Danthonia setacea, Stipa scabra* var. *scabra, Bromus rubens.*

Comments: White Cypress Pine dominates over most of this remnant type. It displays elements of both hill and plains remnants as is to be expected with an interzone.

Name: F3. (Pine and Box Wood-lands)

Sites: 8.

Landforms: Footslopes and flats.

Soils: Red and brown earths.

Structure: Tall Woodland.

Species: Trees *Callitris glaucophylla, Eucalyptus microcarpa, Eucalyptus populnea* subsp. *bimbil*; Tall Shrubs *Acacia deanei, Hakea tephrosperma, Eremophila mitchellii*; Shrubs *Senna artemisioides, Einadia nutans*; Herbs *Oxalis chnoodes, Cheilanthes austrotenuifolia, Sida corrugata*; Grasses *Danthonia setacea, Stipa scabra* var. *scabra, Vulpia myuros, Pentaschistis airoides.*

Comments: A denser version of F2 with White Cypress Pine dominating overall, although any of the main tree species may be locally dominant.

HILL AND RIDGE REMNANTS

Sedimentary and metamorphic geologies

Name: H1. (Dwyers Red Gum and Pine Woodlands)

Sites: 30.

Landforms: Upper and mid slopes, crests and ridges.

Soils: Lithosols and shallow brown earths.

Structure: Mid-High Woodland, Mid-high Open Woodland, (minor Tall Open Woodland and Low Open Woodland).

Species: Trees *Callitris glaucophylla, Eucalyptus dwyeri, Callitris endlicheri, Eucalyptus sideroxylon, Brachychiton populneus, Acacia doratoxylon, Allocasuarina verticillata*; Tall Shrubs *Leptospermum divaricatum, Cassinia laevis, Dodonaea viscosa, Calytrix tetragona*; Shrubs *Grevillea floribunda, Hibbertia obtusifolia, Melichrus urceolatus, Platysace lanceolata*; Herbs *Gonocarpus elatus, Cheilanthes austrotenuifolia, Wahlenbergia queenslandica*; Grasses *Vulpia myuros, Danthonia setacea, Pentaschistis airoides, Stipa scabra* var. *scabra.*

Comments: Three main associations are represented: *E. dwyeri/Callitris glaucophylla, E. dwyeri/Callitris endlicheri* and *Callitris glaucophylla/ E. sideroxylon.*

In some areas *Acacia doratoxylon* or *Allocasuarina verticillata* may form the canopy layer but usually form a dense understorey where they occur.

Name: H2. (Green Mallee Woodlands)

Sites: 9.

Landforms: Low crests, gentle hillslopes and flats.

Soils: Lithosols and shallow brown earths.

Structure: Mid-High Mallee Woodland (structurally diverse, varying from Low to Tall formations).

Species: Trees *Eucalyptus viridis, Eucalyptus sideroxylon, Callitris endlicheri, Eucalyptus dumosa, Eucalyptus gracilis, Eucalyptus polybractea, Eucalyptus dwyeri*; Low Trees *Melaleuca uncinata, Acacia doratoxylon, Acacia cultriformis, Santalum acuminatum*; Tall Shrubs *Cassinia laevis, Olearia floribunda, Pultenaea largiflorens, Cassinia uncata, Dodonaea viscosa*; Shrubs *Melichrus urceolatus, Platysace lanceolata*; Herbs *Dianella revoluta, Cassytha melantha, Helichrysum viscosum, Helichrysum obcordatum, Calotis cuneifolia*; Grasses *Danthonia setacea, Vulpia myuros, Stipa scabra* var. *scabra.*

Comments: Mallee on hills, often associated with *E. dwyeri* and Cypress Pine.

VOLCANIC GEOLOGIES

Name: H3 (Pine and Poplar Box Open Woodlands)

Sites: 6.

Landforms: Hillslopes, ridges and crests on granites and volcanics.

Soils: Lithosols and shallow brown earths.

Structure: Mid-High Open Woodland.

Species: Trees *Callitris glaucophylla, Eucalyptus populnea* subsp. *bimbil, Eucalyptus dwyeri, Brachychiton populneus*; Low Trees *Acacia doratoxylon, Allocasuarina verticillata*; Shrubs *Prostanthera nivea, Grevillea floribunda, Hibbertia riparia*; Herbs *Cheilanthes austrotenuifolia, Hypochaeris radicata, Oxalis chnoodes*; Grasses *Stipa scabra* var. *scabra, Pentaschistis airoides, Danthonia setacea, Vulpia myuros.*

Comments: Similar in many instances to H1 but differing in that *E. populnea* subsp. *bimbil or E. intertexta* may dominate or be co-dominant with White Cypress Pine in the canopy. This may reflect the fact that these geologies often display gentler slopes and lower hills than the steeply dipping sedimentaries.

Name: H4 (Cypress Pine Woodlands)

Sites: Nil.

Landforms: Low crests and hillslopes on basalts.

Soils: Basalt-derived clays.

Structure: Mid-High Open Woodland and Grasslands.

Species: Trees *Callitris glaucophylla, Eucalyptus dwyeri*; Grasses *Stipa scabra* var. *scabra, Danthonia setacea.*

Comments: There are very few basalt hills in the study area and most of these have been cleared. What vegetation remains appears similar to that of H1 on the aerial photographs. There was no access to this remnant for formal sites.

Table 3. Genera with the highest species diversity in the study area

T=tree, S=shrub, G=grass, H=herb, P=stem parasite.

Genus Name	No. of species	Growth form/s
Acacia	23	S,T
Eucalyptus	18	T
Stipa	17	G
Danthonia	10	G
Goodenia	10	H
Dodonaea	10	S
Lomandra	9	H
Juncus	9	H
Wahlenbergia	8	H
Chenopodium	8	H,S
Sida	8	H,S
Paspalidium	7	G
Rumex	7	H
Amyema	7	P

Discussion

Native vegetation in the study area has undergone many changes since European settlement in the mid-1800s. The most obvious change has been clearing, although grazing by domestic stock and feral grazers has also had profound effects on the vegetation (Adamson & Fox 1982). Other processes of change include the introduction of exotic species (see Tables 4, 5 & 6); active management of state forests and private woodlots to encourage the growth of some species (e.g. *Callitris glaucophylla*) at the expense of others (for example, eucalypt box species, see remnant type P6); alterations to pre-settlement fire regimes; pollution and damming of waterways; aerial application of pesticides and fertilisers; and isolation of remnant vegetation in time and space; these are the main 'threatening processes' operating in the wheat-belt. Discussion of the full effects of these threatening processes are not within the scope of this paper and are not well understood in all cases (see Saunders et al. 1991 and Bradstock et al. (in prep.) for an introduction to the subject). There seems little doubt that these processes have led to declines in native species diversity and an increase in the likelihood of extinctions in the medium and long term (Adamson & Fox 1982; Benson 1991; Hobbs 1987; Saunders et al. 1991). None of the sites visited during this survey could be described as completely undisturbed. The results clearly demonstrate high levels of grazing (by domestic and feral grazers), widespread soil erosion and partial clearing within the remnant native vegetation.

Clearing is the most readily observable threatening process in the study area. It is not an historical practice that has now ceased, but is continuing in much of the agricultural lands of New South Wales. Between 1974 and 1989, in the area covered by the Condobolin 1:100 000 map sheet (Figure 3), 57 400 ha of the native vegetation were cleared; an average of 3 800 ha per year and a reduction of 61% of the remaining native vegetation over 15 years (Sivertsen 1993). Virtually all this clearing was confined to the plains and the lower footslopes.

Clearing affects all communities described in this paper, with the possible exception of those occurring on steep hillslopes. Most affected are the Riparian communities and Box woodlands which occupy the prime agricultural lands. Box species have also been selectively logged from state forests to encourage White Cypress Pine regrowth.

An important aspect of remnant vegetation management must be an understanding of extent and condition of those remnants. For example, 34 400 ha of River Red Gum (R1) are mapped (Table 7), making it the third most extensive remnant type but, as the map indicates, most of the River Red Gum occurs as narrow bands along the major river corridors and often only as a single line of trees on either side of the channel. This is not the potential extent of the River Red Gum community. In many instances this species will occur as a narrow band adjacent to the channel, but not as a single row of trees with well spaced crowns as is the case currently. Towyal and Cadow State Forests (Lachlan River) and Gunning Gap State Forest on Goobang Creek demonstrate River Red Gum's potential to spread at least a kilometre from the channel under favourable conditions. The narrow corridors which remain are

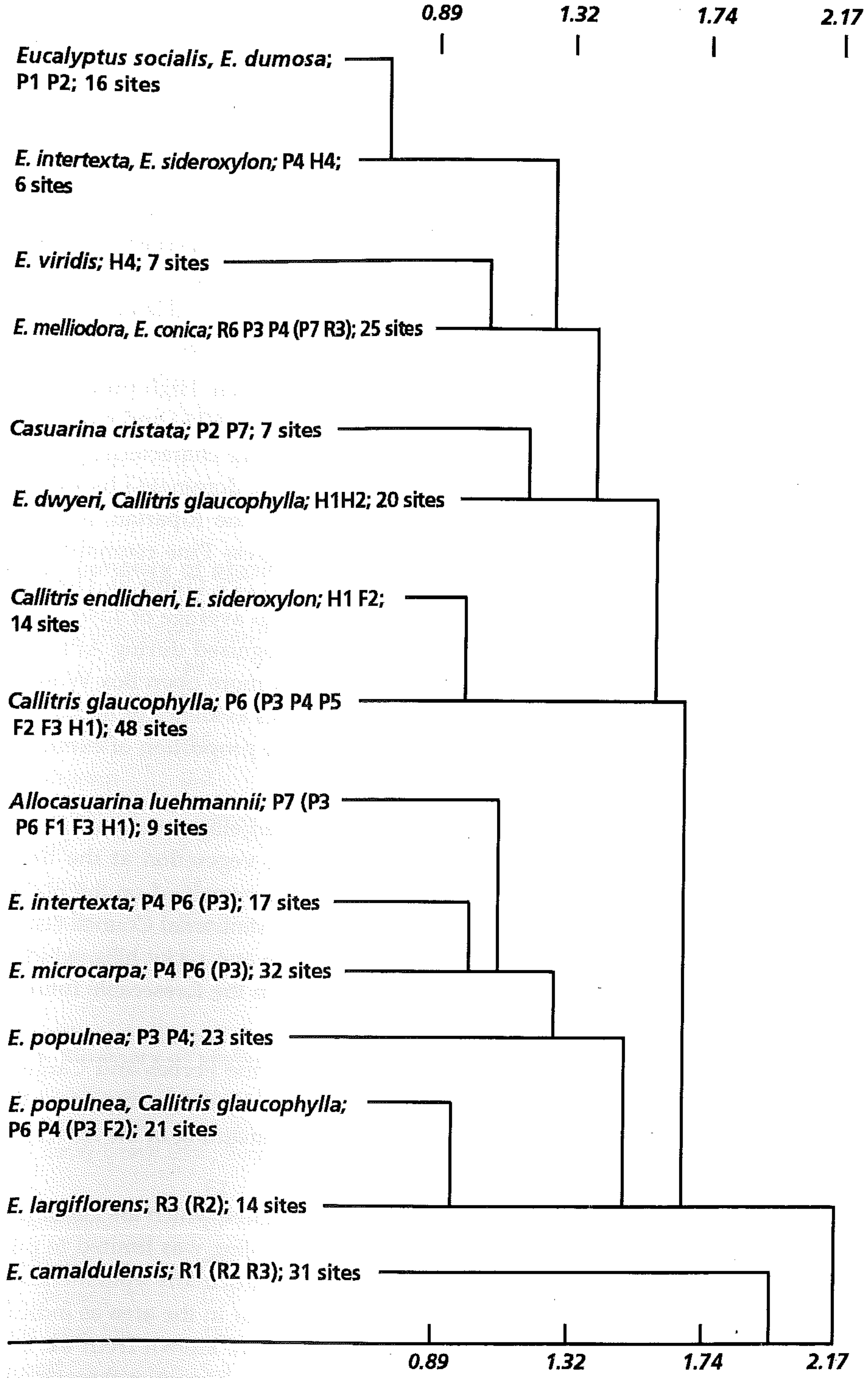

Fig. 2. Dendrogram showing the major group boundaries from the southern wheat-belt survey. The species shown are the major tree species only. Alphanumeric codes show the remnant types associated with each group. Brackets indicate minor occurrences in groups. The vertical scale of the dendrogram is proportional to the number of sites in each group.

also frequently isolated from other remnant vegetation (again as indicated by the maps) and, therefore, present many management difficulties. They have very high boundary length to area ratios and are therefore more prone to weed infestations and the adverse effects of altered light, water and wind regimes. Loss of this vegetation type comprises a substantial loss of habitat for native plants and for both vertebrate and invertebrate native fauna and indicates the possibility of increased soil erosion, degraded water quality and loss of natural flood mitigation. The riparian community is no longer there to filter pollutants and suspended solids from local runoff and to reduce and baffle over-bank flow rates. Mallee (P1 & P2), Box Woodland (P3 & P4) and Dwyers Red Gum/Pine Woodlands (H1) remnants are also frequently long and narrow, thus presenting similar management problems.

Tables 4, 5, 6 and 8 give some indication of remnant condition. High proportions of sites display evidence of grazing (83%), feral animal damage (60%) and partial clearing (70%) (Table 8). The Riparian/Floodplain remnants have characteristically high levels of site disturbance and exotic species and tend to be dominated by exotics in the herb layer. About 40% of plant species recorded for the Riparian/Floodplain remnants are exotics (Table 4), among the Box and Cypress Pine remnants of the Peneplain and Footslopes this figure falls to an average of 22% (Table 5). The Mallee and Hills remnants have the lowest exotic components, an average of 13% and 14% respectively. Thinned and unthinned remnants were recognised during API. P2 is a more open form of mallee than P1; and P3 is a generally more open Box Woodland than P4. In both cases the more open remnant type shows evidence of higher levels of grazing and feral animal damage and support a higher proportion of exotic plant species.

Very little native vegetation remains in the Forbes and Cargelligo study area. A total of 16% (376 800 ha) of the area remained under native vegetation at the time of survey. Of the total study area less than 10%, 230 800 ha, remained on the plains, a figure in close agreement with the Murray–Darling Basin Ministerial Council (1987); a further 145 700 ha supports native vegetation on the steep and rocky hills, which are unlikely to be subjected to further major habit disruption in the foreseeable future.

The results of this study demonstrate that there is a very small, dwindling and degraded native vegetation resource to be conserved in the Forbes and Cargelligo area, particularly on the plains. However, the results also show how important these remnants are in the conservation of native biodiversity remaining in the agricultural lands of New South Wales.

This study recorded 465 taxa of native plants, including three which are classified as rare or threatened nationally (Briggs & Leigh 1988). Sampling was limited to public lands and by drought conditions. Many other species, particularly ephemerals and those with restricted distributions, can be expected to occur in the area as indicated by the work of Fox (1990). A total of 12 ROTAP species are known from the study area (Briggs & Leigh 1988). Many other species are likely to be rare or threatened, at least in the regional context; 41% of the plant species recorded during this study occurred only once or twice (Sivertsen 1993). Whilst this alone cannot confer rare or threatened status, it does indicate that more detailed investigations of the status of

Table 4. Summary of physical and species count data for riparian and floodplain remnants

Landforms: B=Bank, Ch=Channel, BP=Backplain, CD=Closed Depression, F=Flat; Soils: AS=Alluvial Soil, GCC=Grey Cracking Clay, BC=Brown Clay, BE=Brown Earths; Runoff: 0=Nil, VS=Very Slow, S=Slow.

	R1	**R2**	**R3**	**R4**	**R5**	**R6**
Main landforms	B, Ch, BP	B, F	F, BP	F, CD	F	F
Main soil types	AS, GCC	GCC	GCC	BC	GCC	BE
Slopes (degrees)	0	0	0	0	0	0
Altitude range (m.a.s.)	130–250	120–185	100–230	207	190	200–240
Site runoff	0-S	VS	0-S	VS	VS	VS–S
Total species	183	91	185	20	28	65
Exotic species	67	38	59	11	7	28
% exotic species	37	42	32	55	25	43

Table 5. Summary of physical and species count data for Peneplain remnants

Landforms: S= slope, F=Flat; Soils: sRE=sandy Red Earth, lRE=loamy Red Earth, lRBE=loamy Red-Brown Earth; Runoff: 0=Nil, VS=Very Slow, S=Slow.

	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**
Main landforms	F	F	F	F	F	F, S	F
Main soil types	sRE	sRE	lRE	lRE	sRE	lRE	lRBE
Slopes (degrees)	0–2	0–1	0–1	0–1	0	0–2	0
Altitude range (m)	120–200	100–155	110–270	170–185	140–260	190–325	215–235
Site runoff	S	S	VS–S	S	S	S	S
Total species	93	70	173	249	64	218	105
Exotic species	8	12	39	53	16	40	20
% exotic species	9	17	22	21	25	18	19

Table 6. Summary of physical and species count data for footslope and hills remnants

Landforms: LS=Lower Slope, MS=Mid-Slope, UP=Upper Slope, C=Crest, S=Slope (unspecified), F=Flat; Soils: RE=Red Earth, RBE=Red-Brown Earth, BE=Brown Earth; sBE= Sandy Brown Earth; Runoff: S=Slow, R=Rapid, VR=Very Rapid.

	F2	**F3**	**H1**	**H2**	**H4**
Main landforms	LS	LS, F	MS-C	US, C	F, S, C
Main soil types	RBE	RE, BE	BE	BE	sBE
Slopes (degrees)	0–3	0–3	2–6	2–19	1–4
Altitude range (m)	180–330	180–335	210–380	280–320	275–310
Site runoff	S–R	S–R	R–VR	R–VR	S–R
Total species	130	87	164	79	81
Exotic species	23	24	23	13	9
% exotic species	18	28	14	16	11

those populations is warranted. The conservation of all native plant and animal species in the region hinges on the management and protection of vegetation remnants.

The current criteria which define rare or threatened plant species are now well established (Briggs & Leigh, 1988) although refinement of techniques for classification continues (Chalson & Keith, 1995). There is a well recognised procedure for classification and listing of rare or threatened plant species. However, the same cannot be said for plant communities. There is difficulty in achieving an accepted definition of 'community' amongst ecologists; the debate over what constitutes a plant community and even whether or not such concepts have any ecological meaning has spanned many years (e.g. Beadle, 1948 to Austin, 1991). If, however, we can agree that there exist assemblages of species which form recognisable entities, called communities in the absence of a better term (e.g. Poplar Box woodlands, Brigalow, Belah, River Red Gum forests), we can then recognise and define levels of threat facing these communities.

The dominant species in many communities are trees or shrubs which tend to be long-lived by human standards. Hence, changes may occur over a long period of time and so go relatively unnoticed or be accepted as natural. The historical record is very poor in providing information on past crown and stem densities, recruitment rates, tree age and tree size. As a result there is no adequate standard against which to judge modern conditions (Walker et al. 1993). However, introduced grazers, notably sheep, rabbits and goats are capable of preventing effective recruitment amongst long-lived species by grazing seedlings very efficiently (Robertson et al. 1987). Considering the long-term effects of clearing, reduced or zero recruitment amongst canopy species and the already well established changes in the shrub and herb layers (*sensu* Adamson & Fox 1982, Hobbs 1987, and Saunders et al. 1991) it seems likely that most of the communities in the study area face a very uncertain long-term future and could be legitimately regarded as 'threatened'. Grazing affects all communities. Little recruitment was observed in the riparian (*Eucalyptus camaldulensis, E. largiflorens, Acacia pendula*), and Box communities. However, there is an urgent need for more flora and fauna population and community based research and for development of appropriate landscape management procedures.

Conservation

Acknowledging the need for more research should not be a recipe for inaction. Conservation planning is imperative if we, as a society, hope to maintain the systems and processes which support our native plants and animals, and which allow the continued functioning of our agricultural and pastoral industries.

The degree of reliance of agricultural and pastoral systems on fully functional natural ecosystems is clearly demonstrated by Davidson and Davidson (1992). The role of native predators, parasites and diseases in routinely controlling populations of agricultural pests is clearly established in this work, as is the role of native fauna, particularly invertebrate fauna, in nutrient cycling and in maintaining healthy soil environments. Davidson and Davidson argue that the continued functioning of rural systems relies ultimately on the maintenance and conservation of remnant native vegetation in the rural landscape. It is not only species and communities which are in need of conservation. It is the natural processes that sustain them.

The largest remnants are in state forests (Crown land) and the steep ranges of hills (Crown and private land) whilst smaller remnants occur on various Crown tenures

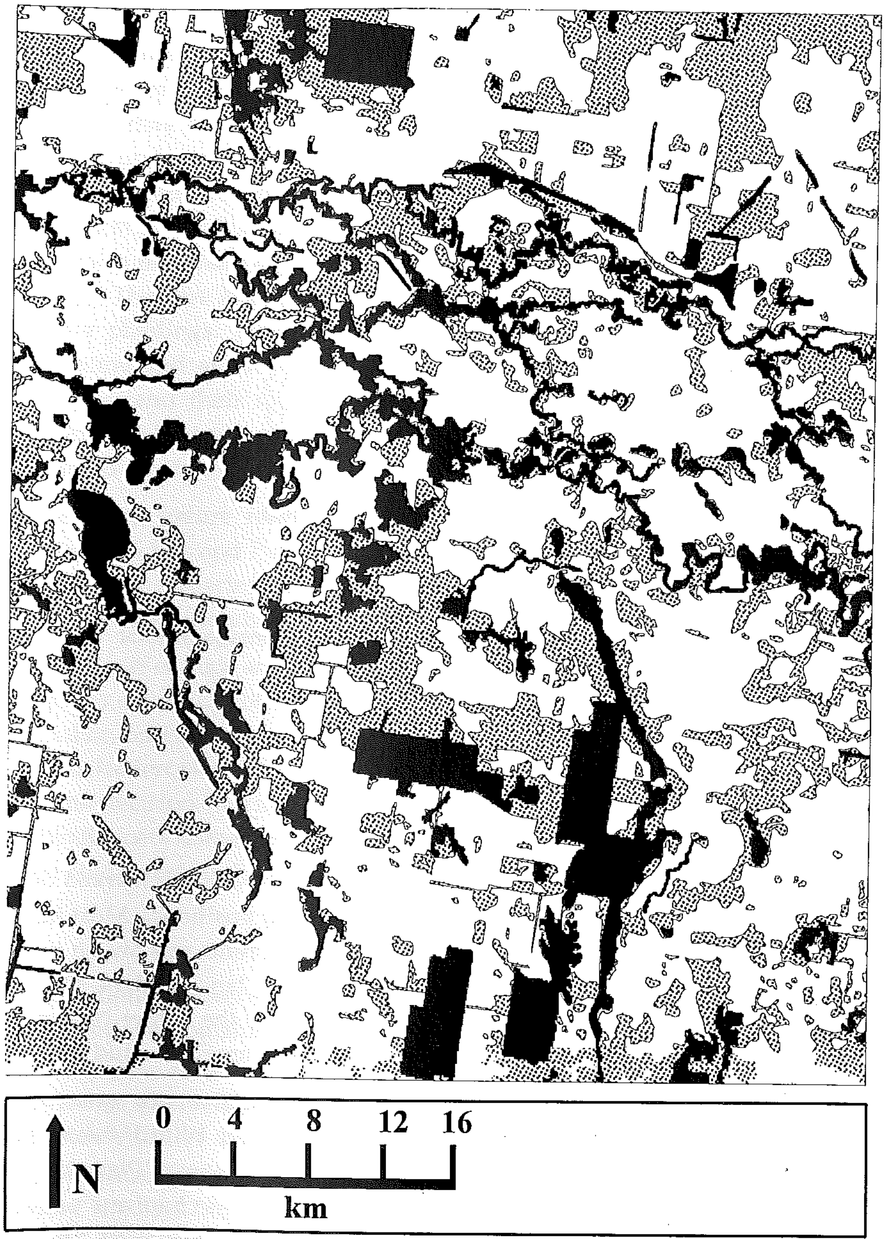

Fig. 3. The Condobolin 1:100 000 map sheet area. The native woody vegetation present in 1974 is represented by ▨ + ■. In 1989 only the ■ area remained.

Table 7. Area of each map unit shown on Forbes/Cargelligo map sheets

Map unit code	Remnant area (ha)	%of study area
R1	34 400	1.4
R2	16 400	0.7
R3	24 200	1.0
R4	1 400	0.1
R5	200	<0.1
R6	2,100	0.1
P1	15 300	0.6
P2	24 700	1.0
P3	39 200	1.7
P4	24 800	1.0
P5	4 400	0.2
P6	33 000	1.4
P7	14 800	0.6
F1	3 600	0.2
F2	21 100	0.9
F3	9 700	0.4
H1	79 400	3.3
H2	20 600	0.9
H3	600	<0.1
H4	10 700	0.5
Total	**380 600**	**16.0**

Table 8. Summary of site disturbance data

Type of disturbance	No. of sites affected	Percentage of total
Soil erosion	151	52
Logging/clearing	203	70
Feral animal damage	175	60
Grazing (exotics)	241	83

such as road reserves and travelling stock reserves. (State forests are marked on the maps and road reserve remnants can be inferred from road positions). Most land in the study area is held in freehold title and many individual remnants are on private land. The inference to be drawn from this is that private land-holders, the local community and the government all share responsibility for the future of remnant native vegetation and associated fauna in the Forbes and Cargelligo study area.

Existing State legislation provides the legal framework for biodiversity conservation either by addressing the issue directly (National Parks and Wildlife Act, 1974; Endangered Fauna [Interim Protection] Act, 1989; Environmental Planning and Assessment Act, 1979; Forestry Act, 1916), or by containing mechanisms whereby biodiversity conservation can be approached indirectly (Soil Conservation Act, 1938; Crown Lands Act, 1989; Pastures Protection Act, 1934). This subject is dealt with more fully by Farrier (1989), who discusses the scope and applications of each relevant piece of legislation. However, effective biodiverstiy conservation need not be constrained by a legislative framework.

Two complementary strands of conservation effort are applicable in this area: reservation, and off-park conservation. These are discussed separately so that the issues involved in each remain clear, but remain two aspects of a single conservation effort.

Reservation

Most remnants in the study area are small and often made up of narrow corridors. The majority of remnants are not suited to reservation although a number of the larger ones may be. The largest remnants on the plains are state forests, some of which are undergoing assessment for their economic viability. Should any state forest be identified for disposal, there would be a strong case for it to be considered for inclusion in the National Parks and Wildlife Service reserve system. These areas already form important core areas for broader, human community-based conservation initiatives. They are important refugia in their own right. They can provide seed for local tree plantings. They are important sources for recolonisation by beneficial native fauna and are repositories of genetic diversity. The long-term survival of these areas, and their regeneration to something approaching their original and more biological diverse state, is most assured under the statutory protection such as that offered by the National Parks and Wildlife Act, 1979.

Some existing nature reserves in the study area, for example, Gubatta (162 ha); Loughlan (385 ha); and Pulletop (145 ha), may be too small for the long-term survival of many of the species they contain. Any opportunity to expand these reserves would be of considerable long-term ecological advantage.

Given the cost of land acquisition and management, decisions relating to the choice of areas for expansion of the reserve network must be taken carefully. The map and information bases produced by this study will make it possible to apply systematic reserve selection techniques (*sensu* Pressey & Nicholls 1989; Bedward et al. 1992) to aid in the decision-making process. These techniques are equally applicable to off-park biodiversity conservation planning. Analysis of this type is yet to be undertaken for the study area and will be the subject of future papers.

Off-park conservation

Most additional conservation efforts in the New South Wales wheat-belt are likely to be undertaken outside the formal reserve network primarily due to the cost and lack of suitable land for reservation. Local resistance to formal reserves is often very strong and is also a reason for trying a less formal approach. Off-park conservation can be of two main types:

- that initiated by Local or State government authorities (Protected Lands Mapping under the Soil Conservation Act; State Environmental Planning Policies under the Environmental Planning and Assessment Act; and Local Environmental Plans)
- community-based consultation (Landcare, Greening Australia, Australian Association of Bush Regenerators and Trees on Farms) through mechanisms such

as Conservation Agreements (National Parks and Wildlife Act), covenants on title (Conveyancing Act, 1919) and Farm Plans. These are important aspects of off-park conservation which can be explored on a case-by-case basis.

In off-park conservation, the unit of action is likely to be an individual paddock or farm, the scale at which most people operate. However, it is increasingly evident that the processes which determine the long-term viability of our conservation efforts operate at landscape or regional levels (Friedel & James in prep.; Noss 1990). These processes, such as movement of nutrients and pollutants, runoff, groundwater movement and nutrient cycling are usually only partly within a single landholder's sphere of influence. In order to be successful in the long term it is essential for off-park conservation to be planned at the regional level and implemented locally. For example, no amount of farm planning will solve a salinity problem if the source of that salinity is not addressed. Similarly, on-farm conservation may not save individual species if primary habitat sources are destroyed elsewhere in the landscape.

Effective Landcare and Total Catchment Management groups are already functioning in the area and issues such as water quality, soil conservation, private forestry and drought relief lands are already on their agendas. These very important agenda items dovetail neatly with nature conservation and can complement more formal conservation practices.

Although degraded, the ecological infrastructure exists for effective bush regeneration. This affords the opportunity to re-establish riparian and dryland corridors and other important repositories of native biodiversity using material of local provenance.

A large number of animal species are already extinct in this part of New South Wales and there is a trend towards substantial additional extinctions in the near future (Goldney & Bowie 1986; Dickman 1994). This trend, observable in the New South Wales wheat-belt, is a common trend throughout the world. As early as 1948 Fairfield Osborn maintained that: 'The tide of Earth's population is rising, the reservoir of Earth's living resources is falling...' (Osborn 1948). Expansion of the human population and sphere of influence and the attendant loss of habitat has grave implications for species extinctions. Modern extinction rates, calculated on a per species basis, may be as high as those which existed in the 'great extinction events' of the Paleozoic and Mesozoic (Wilson 1989). This means a rate of extinction not seen on Earth for 65 million years, and all due to the activities of one species — *Homo sapiens*. Wilson (1989) also points out one very important difference between the ancient and modern extinction events. In the past these events have tended to affect mainly faunal species, and usually particular taxonomic groups (echinoderms, cephalopods and reptiles), whilst the modern event is universal in its application. Plants, invertebrates and vertebrates are all affected. 'The ultimate result of this is impossible to predict, but it is not something, I think, with which humanity will want to gamble' (Wilson 1989). If May (in press) is correct and 'something like half of all terrestrial species are likely to become extinct over the next 50 years' then we have precious little time to reverse some frightening trends in our agricultural heartlands.

Acknowledgements

We are indebted to a great many people for helping to bring this project to completion. We wish to thank the Australian Nature Conservation Agency for funding the project under Save The Bush. Elizabeth Ashby ably assisted in all aspects of planning, field work and mapping; counter identification staff and various specialist botanists from the Royal Botanic Gardens have, as usual, provided unstinting and valuable expert taxonomic opinion; and numerous, enthusiastic volunteers made the field work easier and more entertaining. We also wish to thank David Keith, Elizabeth Ashby, Janet Cohn and Andrew Denham for providing valuable comments on earlier drafts of this paper.

References

Adamson, D.A. & Fox, M.D. (1982) Change in Australasian vegetation since European settlement. In J.M.B. Smith *A history of Australasian vegetation*. (McGraw Hill: Sydney.)

Austin, M.P. (1991) Vegetation theory in relation to cost-efficient surveys. In C.R. Margules & M.P. Austin (eds.) *Nature conservation: cost-effective biological surveys and data analysis* (CSIRO: Australia.)

Austin, M.P. & Heyligers, P.C. (1989) Vegetation survey design for conservation: gradsect sampling of forests in north-eastern New South Wales. *Conservation Biology* 50: 13–33.

Beadle, N.C.W. (1948) *The vegetation and pastures of western New South Wales with special reference to soil erosion*. (Department of Conservation of New South Wales: Sydney.)

Bedward, M., Pressey, R.L. & Keith, D.A. (1992) A new approach for selecting fully representative reserve networks: addressing efficiency, reserve design and land suitability with an iterative analysis. *Biological Conservation* 62: 115–125.

Beeston, G.R., Walker, P.J., Purdie, R. & Pickard, J. (1980) Plant communities of the Poplar Box (*Eucalyptus populnea*) lands of eastern Australia. *Australian Rangelands Journal* 2(1): 1–16.

Belbin, L. (1988) *PATN Reference manual*. (CSIRO Division of Wildlife and Ecology: Canberra.)

Belbin, L. (1991) The analysis of pattern in bio-survey data. In C.R. Margules & M.P. Austin (eds.) *Nature conservation: cost-effective biological surveys and data analysis*. (CSIRO: Australia.)

Benson, D.H. (1992) The natural vegetation of the Penrith 1:100 000 map sheet. *Cunninghamia* 2(4): 541–596.

Benson, J. (1991) The effect of 200 years of European settlement on the vegetation and flora of New South Wales. *Cunninghamia* 2(3): 343–370.

Bowman, H.N. (1977) *Forbes 1:250 000 Metallogenic map: mine data sheets and metallogenic study*. (NSW Dept. Mineral Resources: Sydney)

Bradstock, R. (in prep.) *Conserving biodiversity: threats and solutions*. Conference proceedings. R. Bradstock (ed.) (NSW National Parks & Wildlife Service: Sydney.)

Braun-Blanquet, J. (1932) *Plant sociology*. (McGraw Hill: New York.)

Briggs, J.D. & Leigh, J.H. (1988) *Rare or threatened Australian plants*. Special Publication 14. (Australian National Parks & Wildlife Service: Canberra.)

Bureau of Meteorology (1992) Climatic data for selected weather stations in western New South Wales. (Bureau of Meteorology: Melbourne.)

Chalson, J. M. & Keith, D.A. (1995) A risk assessment scheme for vascular plants: pilot application to the flora of New South Wales. (NSW National Parks Service: Hurstville.)

Christian, C.S. & Stewart, G.A. (1953) *General report on survey of Katherine–Darwin region, 1946*. Land research series No. 1 (CSIRO: Melbourne.)

Davidson, R. & Davidson, S. (1992) *Bushland on farms: do you have a choice?* (Australian Government Publishing Service: Canberra.)

Dickman, C.R. (1994) Native mammals of western New South Wales: past neglect, future rehabilitation? In D. Lunney, S. Hand, P. Reed & D. Butcher (eds.), Future of the fauna of Western New South Wales, transactions of the Australian Zoological Society. (Australian Zoological Society: Sydney.)

Faith, D.P. (1991) Effective pattern analysis methods for nature conservation. In C.R. Margules & M.P. Austin (eds.) *Nature conservation: cost-effective biological surveys and data analysis.* (CSIRO: Australia.)

Farrier, D. (1989) *Environmental law handbook: planning and landuse in New South Wales.* (Redfern Legal Centre Publishing: Sydney.)

Fox, M.D. (1990) Composition and richness of New South Wales mallee. In J.C. Noble, P.J. Joss & G.K. Jones (eds.) *The mallee lands: a conservation perspective.* (CSIRO: Melbourne.)

Friedel, M.H. & James, C.D. (in prep.) How does grazing of native pastures affect their biodiversity? In R. Bradstock (ed.) *Conserving biodiversity: threats and solutions.* (NSW National Parks and Wildlife Service: Hurstville.)

Gillison, A.N. (1984) Gradient oriented sampling for resource surveys. In K. Myers, C.R. Margules & I. Musto (eds.) *Survey methods for nature conservation, vol. 2.* (CSIRO: Canberra.)

Goldney, D.C. & Bowie, I.J.S. (eds.) (1986) *The National Trust (NSW) scenic and scientific survey of the Central West (draft report).* (National Trust of NSW: Sydney.)

Goldney, D.C. & Bowie, I.J.S. (1990) Some management implications for the conservation of vegetation remnants and associated fauna in the central western region of New South Wales. *Proceedings of the Ecological Society of Australia* 16: 427–440.

Harden, G.J. (ed.) (1990–1993) *Flora of New South Wales, vol. 1–4.* (New South Wales University Press: Kensington.)

Hobbs, R.J. (1987) Disturbance regimes in remnants of natural vegetation. In *Nature conservation: the role of remnants of native vegetation.* (Surrey Beatty: Sydney.)

Jacobs, S.W.L. & Pickard, J. (1981) *Plants of New South Wales.* (Government Printer: Sydney.)

May, R.M. (in press) Past efforts and future prospects towards understanding how many species there are. In *Biological diversity and global change,* a symposium at the 24th General Assembly of IUBS, Amsterdam.

McDonald, R.E., Isbell, R.F., Speight, J.R., Walker, J. & Hopkins, M.S. (1984) *Australian soil and land survey field handbook.* (Inkata Press: Melbourne.)

Murray–Darling Basin Ministerial Council (1987) *Murray–Darling Basin environmental resources study.* (SPCC: Sydney.)

Norris, E.H. & Thomas, J. (1991) Vegetation on rocky outcrops and ranges on central and south-western New South Wales. *Cunninghamia* 2(3): 411–442.

Noss, R.F. (1990) Indicators for monitoring biodiversity: a hierarchical approach. *Conservation Biology* 4(4): 355–364.

Osborn, F. (1948) *Our plundered planet.* (Little, Brown: Boston.)

Pogson, D.J. (1967) *Cargelligo 1:250 000 Geological series explanatory notes.* (NSW Dept. Mines: Sydney.)

Pressey, R.L. & Nicholls, A.O. (1989) Efficiency in conservation evaluation: scoring versus iterative approaches. *Biological Conservation* 38: 199–218.

Robertson, G., Short, J. & Wellard, G. (1987) The environment of the Australian sheep rangelands. In G. Caughley, N. Shepherd & J. Short (eds.) *Kangaroos: their ecology and management in the sheep rangelands of Australia.* (Cambridge University Press: Melbourne.)

Saunders, D.A., Hobbs, R.J. & Margules, C.R. (1991) Biological consequences of ecosystem fragmentation. *Conservation Biology* 5: 18–32

Sivertsen, D.P. (1993) Conservation of remnant vegetation in the box and ironbark lands of New South Wales. *The Victorian Naturalist* 110(1): 24–29.

Walker, J., Bullen, F. & Williams, B.G. (1993) Ecohydrological changes in the Murray–Darling Basin. I. The number of trees cleared over two centuries. *Journal of Applied Ecology* 30, (2): 265–273.

Walker, J. & Hopkins, M.S. (1984) Vegetation. In R.C. McDonald, R.F. Isbell, J.G. Speight, J. Walker, & M.S. Hopkins (eds.) *Australian soil and land survey field handbook.* (Inkata Press: Melbourne.)

Wilson, E.O. (1989) Conservation: The next hundred years. In *Conservation for the twenty-first century.* eds. D. Western & M. Pearl. (Oxford University Press: Oxford).

Manuscript received 29 March 1994
Manuscript accepted 25 July 1995