Patterns of decline in the native mammal fauna of the north-west slopes of New South Wales

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ABSTRACT

Twenty-one species of non-flying native mammals were positively identified during a systematic fauna survey of forest, woodland and scrub habitats in State Forests on the north-west slopes of New South Wales (1993–95). This is about 50% of the known historical diversity of mammal species from this region (43 recorded species), with 11 considered extinct and 12 species known from the region, but not recorded during the survey. Of the species detected during the survey, 10 can be considered as common or widespread, while 12 species can be considered rare or under-recorded. The specific identity of two species detected from hair and scat samples, *Notomys* sp. and *Rattus* sp., remain unclear as do observations made of rat-kangaroos. This paper presents the results of the mammal survey and analyses the habitat/resource preferences and weight ranges of the extant, declining and extinct species from the region. The results of this analysis suggest that grass-dependent species and species between 50 g and 6 kg have suffered most from extinction. Species currently considered under threat or whose status remains unclear generally have shrubby understorey and mature tree/log preferences and weigh between 10 g and 1.5 kg. Mammals still common in State Forests of the region are generally mature woodland (tree and log dependent) or shrubby understorey species over 1 kg. Patterns of cultural disturbance are compared to these trends.

Key words: Extinction, Species decline, Habitat, Disturbance, Resources.

INTRODUCTION

A study of the fauna and habitats in State Forests of the north-west slopes of New South Wales was undertaken over two spring/summer seasons (1993–94 and 1994–95). This was undertaken to assist conservation manangement of the North-west Cypress and Ironbark Management Area, for the State Forests of New South Wales. Threatened species were targeted for the surveys, though during the course of the study a systematic survey of all vertebrate fauna groups, except fish, was undertaken. The objectives of the study were to attempt to investigate forestry impacts upon the vertebrate fauna, as well as investigate their patterns of distribution and relative abundance. This study is an important part of a baseline of biological information that currently exists for the north-west slopes of New South Wales. The data from the study, with all locations of mammals encountered, has been entered in several databases (NPWS Atlas, Australian Museum, State Forest records).

This paper places the results of the non-flying mammal surveys within a broader context of native mammal decline on the north-west slopes of New South Wales. A survey of bats conducted by Coles (1995) revealed 19 species present in State Forests from a known diversity of 22 species for the region (Date and Paull 1996).

The woodland, forest and scrub habitats surveyed during the study are often referred to as part of the North-west Cypress and Ironbark Belt, reflecting biogeographical and commercial aspects of the region, mainly by the presence of the two most important timber species, Narrow-leaf Ironbark *Eucalyptus crebra* and White Cypress Pine *Callitris glaucophylla*. Both species dominate many areas of State Forest in the study area. This region forms a unique biogeographical zone, generally regarded as a transitional zone between Bassian and Eyrean faunas, with some Torresian species present. There are some similarities with the zoogeography of the south-west slopes (Caughley and Gall 1985; Bauer *et al.* 1996) though the north-west slopes have a higher faunal diversity, as well as a suite of endemic fauna and unique vegetation characteristics, such as the dominance of White Cypress Pine (Date and Paull 1996).

There has been a low level of scientific scrutiny of the fauna on the north-west slopes in historic and recent times though the level of mammal extinction appears to be high (11 spp.) as does the historical mammal diversity when compared with other areas of Australia (Date and Paull 1996). Lunney *et al.* (1997a) found that the most common ecological attributes of threatened mammals throughout New South Wales were a seed/vegetarian diet, a large body size, or ground-dwelling, burrowing and rock/cave dwelling habits. This study will look at these factors with respect to the extinct, declining and common native mammal species on the north-west

slopes, particularly their weight class and habitat resource or sub-habitat preferences.

THE STUDY AREA

The North-west Cypress and Ironbark State Forest Management Area was used as the study area for this study. It encompasses an area of approximately 125 000 km^2 from the New South Wales-Queensland border south to Dubbo and from Coonamble in the west to Gunnedah in the east. Figure 1 gives the locations for all study sites assessed during the study. The highest number of sites was in the Pilliga State Forest.

The study area covers most of the north-west slopes region of the Great Dividing Range, including the bioregions of the Nandewar Range, the Brigalow Belt South and the eastern edge of the Darling River Plains (Thackway and Cresswell 1995). Elevation ranges from 800 m a.s.l. in the east to 200 m a.s.l. in the west. Several major rivers, which

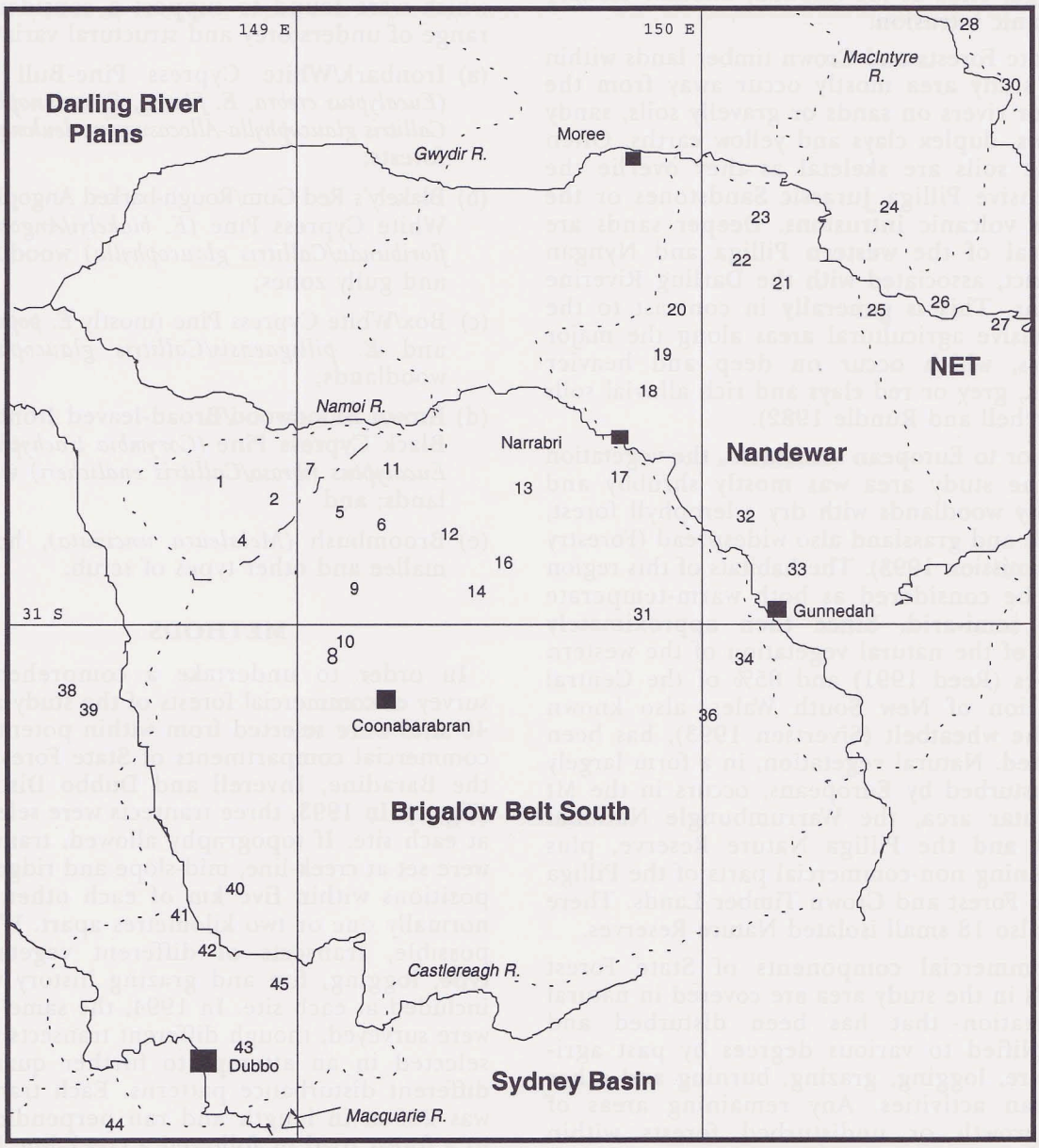

Figure 1. Map of study area showing State Forest sites and bioregional boundaries. Legend: (NET: New England Tablelands. Dash-dot line shows easternmost extent of deep sands between the Namoi and Castlereagh Rivers).

Key. (State forest): 1. Pilliga west; 2. Pilliga west; 4. Pilliga west; 5. Euligal; 6. Pilliga east; 7.Etoo/Quegobla; 8. Yarrigan; 9. Baradine/Orr; 10. Wittenbra; 11. Pilliga east; 12. Pilliga east; 13. Pilliga east; 14. Yaminbah; 16. Pilliga east/Rutley; 17. Jack's Creek; 18. Killarney; 19. Bobbiwaa; 20. Moema; 21. Montrose/Campbell; 22. Irrigappa; 23. Terrie Hie Hie; 24. Warialda; 25. Bingara; 26. Mehi; 27. Sepoy; 28. Bebo; 30. Severn; 31. Kerringle; 32. Leard; 33. Kelvin; 34. Goran; 36. Trinkey; 38. Tallegar; 39. Sandgate/Bourbah; 40. Yalcogrin; 41. Gilgandra; 42. Breelong/Eura; 43. Beni; 44. Momo; 45. Goonoo.

form part of the Murray-Darling System, flow from east to west within the area. They include, from north to south, the MacIntyre, Gwydir, Namoi, Castlereagh and Macquarie Rivers. A western extension of the Great Dividing Range, the Liverpool Range, transects the area from east to west, south of Tamworth and Coonabarabran and joins the Warrumbungle Range, an ancient volcanic outlier in otherwise gently undulating and flat country. A second western extension of the Great Dividing Range, the Nandewar Range, ends at Mt Kaputar, another tertiary volcanic intrusion.

State Forests and Crown timber lands within the study area mostly occur away from the major rivers on sands or gravelly soils, sandy loams, duplex clays and yellow earths. Often these soils are skeletal as they overlie the extensive Pilliga Jurassic Sandstones or the later volcanic intrusions. Deeper sands are typical of the western Pilliga and Nyngan district, associated with the Darling Riverine Plains. This is generally in contrast to the extensive agricultural areas along the major rivers, which occur on deep and heavier black, grey or red clays and rich alluvial soils (Mitchell and Rundle 1982).

Prior to European settlement, the vegetation of the study area was mostly shrubby and grassy woodlands with dry sclerophyll forest, scrub and grassland also widespread (Forestry Commission 1993). The habitats of this region can be considered as both warm-temperate and semi-arid. Since then approximately 50% of the natural vegetation of the western slopes (Reed 1991) and 85% of the Central Division of New South Wales, also known as the wheatbelt (Sivertsen 1993), has been cleared. Natural vegetation, in a form largely undisturbed by Europeans, occurs in the Mt Kaputar area, the Warrumbungle National Park and the Pilliga Nature Reserve, plus adjoining non-commercial parts of the Pilliga State Forest and Crown Timber Lands. There are also 18 small isolated Nature Reserves.

Commercial components of State Forest lands in the study area are covered in natural vegetation that has been disturbed and simplified to various degrees by past agriculture, logging, grazing, burning and other human activities. Any remaining areas of old-growth or undisturbed forests within commercial areas of State Forests are small and/or fragmented by cultural disturbance patterns. In fact few areas can be described as "undisturbed". Nevertheless, in the North-west Cypress/Ironbark Belt relatively undisturbed old woodlands and forests of low commercial value remain, particularly associated with the larger Pilliga, Goonoo and Bebo State Forests.

Floristically mixed woodlands, usually containing several species of eucalypt, were frequently encountered during the study. However, vegetation types appear to be influenced principally by soil type and depth, rainfall and soil moisture. Vegetation structure has been influenced by past fire, grazing and logging regimes, and site floristics have been found to be highly correlated with disturbance history (Date and Paull 1996).

The overstorey vegetation identified during this study includes the following associations, which were found to support a considerable range of understorey and structural variation:

(a) Ironbark/White Cypress Pine-Bull Oak *(Eucalyptus crebra, E. fibrosa, E. melanophloia/ Callitris glaucophylla-Allocasuarina leuhmannii)* forests;

(b) Blakely's Red Gum/Rough-barked Angophora/ White Cypress Pine *(E. blakelyi/Angophora floribunda/Callitris glaucophylla)* woodlands and gully zones;

(c) Box/White Cypress Pine (mostly *E. populnea* and *E. pilligaensis/Callitris glaucophylla*) woodlands;

(d) Brown Bloodwood/Broad-leaved Ironbark/ Black Cypress Pine *(Corymbia trachyphloia/ Eucalyptus fibrosa/Callitris endlicheri)* woodlands; and

(e) Broombush *(Melaleuca uncinata)*, heath, mallee and other types of scrub.

METHODS

In order to undertake a comprehensive survey of commercial forests of the study area, 40 sites were selected from within potentially commercial compartments of State Forests in the Baradine, Inverell and Dubbo Districts (Fig. 1). In 1993, three transects were selected at each site. If topography allowed, transects were set at creek-line, mid-slope and ridge-top positions within five km of each other, but normally one or two kilometres apart. Where possible, transects of different vegetation type, logging, fire and grazing history were included at each site. In 1994, the same sites were surveyed, though different transects were selected in an attempt to further quantify different disturbance patterns. Each transect was 200 m in length and ran perpendicular to a forest road or followed a creek-line from the road. A 5 km road transect, connecting some or all of the fauna transects was also included at each site.

For large and medium-sized mammals, detection was based primarily on spotlighting along the 240 vegetation and 80 road transects, identification of scats, opportunistic sightings

and the setting of two hair-tubes per transect on the ground for 10 or more days. Hair-tubes were placed at the roadside and 100 m from the road along each transect. In 1993, meat fat, rolled oats and peanut butter were used as bait. In 1994, a broader selection or mixture of bait ingredients was introduced, including sardines, honey, apricots, aniseed and almond oil. In addition, one cage trap per transect was set for three consecutive nights in 1994. Microhabitat features, particularly tree species, were recorded if an arboreal mammal was sighted. Playback of Koala *Phascolarctos cinereus* and Squirrel Glider *Petaurus norfolcensis* calls were used at all sites.

For small mammals, small Elliott traps were set for three consecutive nights at each transect. In 1993 eight traps per transect were set on the ground, but in 1994, for each transect, eight traps were set on the ground and eight were mounted on tree brackets. Baits used were similar to those for hair-tubes. Predator scats (fox and dog) and any small mammal scats were collected along transects, roads and opportunistically. Four dry pit-traps were used for three days at all transects in 1993. They were connected by a low, plastic drift fence in a cross formation covering an area of approximately 100 m^2. These pit-traps were a bucket-sized (approximately 26 cm deep × 23 cm in circumference) and did not catch any mammals.

Analysis of hair from feral mammal scats and hair-tubes was undertaken by Barbara Triggs. Compilation of historic records of mammal fauna of the region was achieved by consulting the NPWS Atlas, the Australian Museum, as well as other sources (see Tables 2 and 3).

RESULTS

Species detected during survey

All mammal species detected during the study are presented in Table 1 which also shows the frequency with which each was detected, their observed habitat preferences, their maximum (if available) or average recorded weights and their conservation status. Frequency counts were tallied from all observations and scat identifications, trap results and hair-tube samples were identified for each species during the course of the surveys. If currently listed under the *Threatened Species Conservation Act 1995*, species here are given endangered or vulnerable designations. If recorded five times or less, a species was regarded as "rare" though this may also be a reflection of their level of detectability and not of their relative abundance. However, most species regarded as rare here are also species which we know little about, particularly in the Northwestern Cypress/Ironbark Belt. Two species, the Yellow-footed Antechinus *Antechinus flavipes* and the Sugar Glider *Petaurus breviceps* were detected less than twenty times, but were found to be widespread in State Forests of the Cypress/Ironbark Belt.

Though listed as a threatened species, the Koala *Phascolarctos cinereus* is common and probably secure in the Pilliga but remains vulnerable in the Gunnedah area, mainly due to high levels of habitat fragmentation and destruction. Of the mammals detected on

Table 1. Results of non-flying, native mammal survey (1993–95).

Species	Frequency	Observed habitat	Weight (kg)	Status[1]
Tachyglossus aculeatus	139	ubiquitous	7	common
Dasyurus maculatus	1	mixed eucalyptus. woodland	7	vulnerable
Antechinus flavipes	16	woodlands, rocky complex	.05	widespread
Sminthopsis murina	5	shrubby woodlands	.025	rare
Macropus rufus	3	grassland/savanna/edge	65	rare
Macropus giganteus	277	ubiquitous	60	abundant
Macropus robustus	40	rocky complex, ridge	45	common
Macropus rufogriseus	68	shrubby woodland, scrub	19	common
Wallabia bicolor	169	shrubby woodland, scrub	17	common
Macropus dorsalis	1	tall acacia woodland	16	endangered
Phascolarctos cinereus	74	mature, mixed woodlands	6.5	vulnerable
Trichosurus vulpecula	160	ubiquitous	4	common
Pseudocheirus peregrinus	42	mature woodlands	1	common
Petaurus norfolcensis	5	mature woodlands	.23	vulnerable
Petaurus breviceps	13	mature woodlands	.14	widespread
Cercartetus nanus	5	shrubby woodlands	.024	rare
Acrobates pygmaeus	2	mature woodlands	.014	rare
Pseudomys pilligaensis	3	shrubby woodlands	.012	vulnerable
Notomys sp.	1	scrub?	?	?
Rattus sp.	1	riparian grassy woodland	?	?
Hydromys chrysogaster	1	permanent river	0.75	rare
Canis familiaris dingo	2	scrubby open woodland	19	rare

[1]Status as listed under the *Threatened Species Conservation Act, 1995.*

the survey, 10 can be regarded as common and widespread, while the other 12 can be regarded as rare or poorly known.

a) Habitat preferences

The habitats identified in Table 1 also reflect the resource requirements of each species. Most species in the study area seem to be reliant on either of two main resource types/habitats. Mature woodland species primarily require tree and log resources (e.g., foliage, hollows) and may be found in shrubby or grassy woodlands and forest, wherever there is adequate resource. Shrubby understorey is a common habitat component throughout the Cypress/Ironbark Belt and is an important food and shelter resource for most terrestrial species encountered during the study. In many areas of shrubby understorey, trees are often scattered and stunted, unsuitable for arboreal mammals. Other identified habitat types which are important for some species are scrub (vegetation dominated by growth between two and four metres high), rocky complex, aquatic (for the Water Rat *Hydromys chrysogaster*) and grasslands.

Three species, the Eastern Grey Kangaroo *Macropus giganteus,* the Echidna *Tachyglossus aculeatus* and the Common Brushtail Possum *Trichosurus vulpecula,* were found to be common and widespread in the study area. The Eastern Grey Kangaroo, a grass dependent species, ranges widely throughout most habitats, but tends to avoid rocky areas (the habitat of the Wallaroo *M. robustus*) and thick scrub (which is the preferred habitat of the smaller macropods, the Red-necked Wallaby *M. rufogriseus* and the Swamp Wallaby *Wallabia bicolor).* Both wallabies are also found wherever there is extensive understorey cover. The Echidna is also ubiquitous, although it seems to avoid areas where there is no rock or log cover. The Brushtail Possum is the most common arboreal species in the study area, occurring widely throughout wooded habitats as well as in town trees and roofs. In the bush it avoids areas where there is little tree cover, such as scrub, as it is essentially hollow dependent.

The Dingo *Canis familiaris dingo* was recorded from observations made of two sandy-coloured pups in Goonoo State Forest in scrubby open woodland.

b) Weight ranges

The species most commonly detected, including the macropods, the larger arboreal marsupials and the Echidna, all weigh 1 kg or more. The Sugar Glider and the Yellow-footed Antechinus are the only two species detected during the study weighing under a kilogram that can be regarded as common. Of the 11 species rarely encountered during the study, four were over a kilogram; the Tiger Quoll *Dasyurus maculatus,* the Black-striped Wallaby *Macropus dorsalis,* the Red Kangaroo *Macropus rufus* and the Dingo. The rest are small species, weighing between 12 gm and 750 gm (see Table 1).

Species not detected during the survey

Table 2 lists native mammals that have previously been positively identified from the study area, as recorded in current databases, but were not detected during these surveys. This may be because the surveys did not cover preferred habitats for these species or these species are very rare or absent in the study area.

There are three and perhaps four species of dunnart known from the Pilliga. A dunnart described as *Sminthopsis* sp. nov. was identified by Lim (1992) during small mammal surveys in the Pilliga Nature Reserve. He regarded it as closely resembling *S. ooldea.* The Stripe-faced Dunnart *S. macroura,* is known from the northern parts of the study area with another record from Rocky Glen, east of Coonabarabran in 1979 (Australian Museum Records). Old records show the Fat-tailed Dunnart *S. crassicaudata* was once widespread across the study area, yet there is only one recent record from Sandgate State Forest (Clive Barker, pers. comm. 1998) as well as other observations of this species near the Macquarie Marshes (pers. obs. 1992). The Common Dunnart *S. murina* was commonly recorded in old records, however, none was trapped during this study.

No planigales have been recorded from State Forests of the Cypress/Ironbark Belt to our knowledge, though the Narrow-nosed Planigale *Planigale tenuirostris* and the Paucident Planigale *P. gilesi* may occur in suitable wetlands or cracking clay habitats. The Brush-tailed Rock-wallaby *Petrogale penicillata* is thought to be extinct in State Forests of the study area, though a population still survives in the Warrumbungle National Park. The Western Grey Kangaroo *Macropus fuliginosus* is regarded as common, though only an occasional visitor to the north-west slopes of New South Wales, as is the Red Kangaroo (Johnson *et al.* 1989). Another macropod, the Rufous Bettong *Aepyprymnus rufescens* is known from throughout the region from historic and database records, though not positively identified for over 50 years from the study area. It is known to prefer a grassy understorey habitat (Johnson 1980; Pople 1989).

Table 2. Native mammal species not detected during surveys (1993–95).

Species	Habitat[1]	Weight (kg)	Records[2]	Status
Phascogale tapoatafa	mature forest	.2	Singleton, 1969 (AM) Cobar, 198? (NA) Pilliga, 19?? (SFR)	vulnerable
Sminthopsis macroura	shrublands, shrubby woodland, scrub	.02	Many records from northern part of study area (AM)	vulnerable
Sminthopsis crassicaudata	grassland, shrubland, open woodland, scrub	.015	Throughout study area (Marlow, 1958)	rare
Sminthopsis sp. nov. (Lim)	shrubby woodland	?	Pilliga NR, 1990 (Lim 1992)	rare
Antechinomys laniger	grassland, shrubland, scrub	.03	Western edge of study area (AM)	vulnerable
Aepyprymnus rufescens	grassy understorey, woodland edge	1.6	Many records throughout study area, north of the Castlereagh R. (A.M., Rolls 1981)	vulnerable
Petrogale penicillata	rocky complex	7	Warrumbumgles (NA), Coolah, 1887 (AM), Pilliga, 1992 (NA; Rolls 1981), Mt Kaputar, 1975–81 (NA), (Lunney *et al.* 1997b)	vulnerable
Macropus fuliginosus	grassland/ woodland	50	many recent records	occasional
Petaurus australis	mature forest	.7	Mt Kaputar (Marlow 1958; NA)	vulnerable
Petauroides volans	mature forest	1.5	Mt Kaputar (Marlow 1958)	rare
Rattus villosissimus	grassland, shrubland	.15	Merriwa, 1980 (AM), Coonamble, 1943 (AM)	vulnerable
Rattus tunneyi	grasslands, shrubby understorey	.075	Duck Creek 18?? (Marlow 1958)	endangered

[1]Sources: Flannery 1990; Fox 1982; Marlow 1958; Pople 1989; Strahan 1995; Troughton 1941.
[2]Sources are given in brackets. Abbreviations: A.M.: Australian Museum records; N.A.: New South Wales National Parks and Wildlife Service Atlas; SFR: State Forest Records.

The Brush-tailed Phascogale *Phascogale tapoatafa* has been recorded from the Pilliga (State Forest records) and from an unidentified State Forest near Cobar (NPWS Atlas). The large gliders have only been identified from the Mt Kaputar/Nandewar area. The Kultarr *Antechinomys laniger* once occurred throughout the Liverpool Plains as did the Long-haired Rat *Rattus villosissimus*. The Kultarr and the Pale Field Rat *Rattus tunneyi* are both thought to be extinct in the study area (with most recent records over 100 years ago), while the most recently recorded possible irruption of the Long-haired Rat in the study area was in 1980 (Australian Museum record).

a) Habitat preferences

These unrecorded species are mostly reliant upon tall woodland/forest tree resources, scrub, and shrubby and grassy understoreys. Tall woodland/forest was a habitat encountered extensively in the deep sands of Pilliga West State Forest and adjacent areas which were, and still are, prime timber-producing compartments (Forestry Commission 1993). Today much of this habitat is highly structurally altered. The Kaputar/Nandewar system still contains significant stands of taller wooded habitat and has not received much scientific investigation. Most of the species in Table 2 can be regarded as specialized in their habitat requirements and sensitive to disturbance, except for the Long-haired Rat, which tends towards generalism, particularly during irruptive periods (Redhead 1995).

b) Weight range

With the exception of the Western Grey Kangaroo and the Brush-tailed Rock Wallaby, all species in this group are about one kilogram or less. There is a strong similarity between weight classes of this group and those rarely detected during the surveys, most being small (<1 kg). Of the 14 small terrestrial mammals ever recorded from the study area, four are extinct, one is secure and the other nine are rare, little known or declining species. Of these only the Pilliga Mouse *Pseudomys pilligaensis,* the Long-haired Rat, the Stripe-faced Dunnart and the Kultarr are listed as threatened species in New South Wales.

Extinct species

All species listed in Table 3 are known to have once occurred in the study area but are

Table 3. Extinct mammals of the study area.

Species	Habitat preferences[1]	Weight (kg)	Records[2]
Dasyurus viverrinus	grassland/woodland edge, heath	1.3	Singleton, 1895 (AM)
Dasyurus geoffroii	semi-arid habitats, inc. forests	1.3	Liverpool Plains 18?? (Marlow 1958)
Perameles bougainville	shrubland, scrub, rocky complex	.22	Liverpool Plains, 1863 (NA)
Macrotis lagotis	grassland, shrubland, grassy woodland	2.5	Gilgandra, 1899 (AM)
Bettongia lesueur	grassland, shrubland	1	Macquarie R. 18?? (Marlow 1958)
Bettongia penicillata (tropica?)	scrub, woodlands	1.3	Liverpool Plain, 1863 (NA)
Lagorchestes leporides	grassland, grassy woodland	4	Liverpool Plain, 1863 (NA)
Onychogalea fraenata	shrubby, grassy woodland	6	Manilla, 1840 (NA), Pilliga (Rolls 1981)
Pseudomys australis	grassland	.065	Manilla, 1840 (NA)
Pseudomys gouldii	grassland	.05	Liverpool Plain 18?? (Marlow 1958)
Conilurus albipes	mature forest, woodland	.2	Macquarie River? 1846 (NA)

[1]Sources: Flannery 1990; Fox 1982; Marlow 1958; Pople 1989; Strahan 1995; Troughton 1941.
[2]Sources are given in brackets. Abbreviations: AM: Australian Museum records; NA: New South Wales National Parks and Wildlife Service Atlas.

currently listed (in the *Threatened Species Conservation Act 1995*) as species probably extinct (not positively identified in the last 50 years). The identity of the "Brush-tailed Bettong" from the Cypress/Ironbark Belt is uncertain at present, as it may have been either *Bettongia penicillata* or *B. tropica* (C. Dickman, pers. comm.).

Historical fauna records from this region of Australia are few and restricted to reports from early European pioneers, some species being recorded only once or twice from imprecise locations. It is impossible to say precisely when, or even if, any of these species became extinct in the study area.

a) Habitat preferences

Habitat categories assigned to the extinct fauna here are based on old and new sources (see Table 3). The main difference between the habitat preferences of this group compared with the others is that out of twelve species which may have been present in the study area, nine (including both the Eastern and Western Quolls *Dasyurus viverrinus* and *D. geoffroii*) are known to have been dependent upon grassy groundcover for forage, cover and/or nesting resources. The only tree-dependent species regarded as extinct is the White-footed Rabbit-rat *Conilurus albipes*. Based on available sources the Brush-tailed Bettong and the Western Barred Bandicoot *Perameles bougainville* seem to have preferentially selected shrubby understoreys, though habitat preferences were never noted in detail for most of the extinct fauna in the study area. The degree of habitat specialization for these animals can only be speculative.

b) Weight range

All species regarded as extinct in the study area at present fall into a weight range between 50 gm and 6 kg, with seven of those 11 species weighing between 1 and 6 kg, the other four below 1 kg. So in contrast to the other groups, extinct mammals were mostly medium-sized (1–7 kg) along with four small rodents and a small bandicoot.

Significant records from the study

a) Quolls

Hair collected from a hair tube at Quegobla State Forest (Site 7) was identified to the genus *Dasyurus*, probably the Tiger Quoll *D. maculatus* (B. Triggs, pers. comm.). This is the first positive identification of this genus from the Pilliga. The quoll was detected in December, well outside the known breeding season for this species (Mansergh 1983a,b). This points to the possibility that there is a relict population of quolls in the Pilliga, at least in the northern section, whose status urgently needs assessing.

Three species of *Dasyurus* (*D. maculatus, D. viverinnus* and *D. geoffroii*) have been described from the north-west slopes area in historic times, making this the only region in Australia in which the three species had sympatric ranges. The Tiger Quoll, the most frequently recorded species, has been recorded in the study area near Coolah in 1887 and 1973,

Dubbo in 1985, Gilgandra 1957, near Mt Kaputar in 1972, 1977 and 1982 (NPWS, Australian Museum databases) with only unconfirmed reports from the Pilliga prior to this study. Recent specimen-based identifications of this species have also come from Walgett and Carroll, New South Wales (T. Mazzer, NPWS, pers. comm. and *The Northern Daily Leader,* September, 1997). Judging by the spread of recent and historical records of the Tiger Quoll, it was once found throughout the North-west Cypress/Ironbark Belt.

The known distribution of the Tiger Quoll is along the eastern escarpment and its eastern and western ranges, also occupying nearby coastlands and river flats, wherever there is mature forest. It seems to depend on the oldest forest communities, with high levels of moisture retention, prey availability and suitable refugia (old trees and logs). The Quegobla forest is a much drier environment than expected for the Tiger Quoll. This forest is characterized by a structural and floristic complexity with relatively low levels of human disturbance, with some evidence of old logging activity (50–100 years ago), old bushfires, feral rabbits and goats, as well as the presence of an exotic carnivore (dog scats were found along roads in this area). There were high numbers of mature Ironbarks, Red Gums and Box species, a very diverse understorey of White Cypress Pine, Bull Oak, grasstrees *Xanthorrhoea* sp., and *Acacia* spp. as well as patches of low shrubs. Moisture and nutrient levels within this habitat were thought to be relatively high, due primarily to its good understorey and groundcover and overall structural complexity. The area could be classed as a mature, mixed eucalypt tall woodland with a developed shrubby/grassy mosaic understorey. The extent of such habitat within the Pilliga forests is uncertain, though may be helped by forthcoming vegetation survey information (State Forests of New South Wales, in prep.). Data from this study showed that mixed eucalypt/cypress pine habitats are often characterized by a diverse vertebrate fauna (Date and Paull 1996).

b) Rat Kangaroos

In Pilliga East State Forest, near Gilgai FR, a sighting of two small macropods, closely resembling bettongs or rat-kangaroos was made during this study. Another observation was made of one individual in the vicinity of Dandry Creek on private land near the Pilliga Nature Reserve (pers. obs. 1994). Identification to species level was not possible due to the fleeting nature of the observations and could have been any species of bettong. All individuals were flushed from shrubby understorey woodland, and moved rapidly in front of slow moving vehicles at night.

Three species of potoroid macropods have been recorded from the region historically (Gould 1841; New South Wales NPWS database). These are the Brush-tailed Bettong, the Burrowing Bettong and the Rufous Bettong. Both the Brush-tailed and Burrowing Bettongs were once common in the study area. John Gould reported Brush-tailed Bettongs on the Liverpool Plains and the Namoi River in 1863 (Marlow 1958) and the Burrowing Bettong once occurred on the western edge of the study area (Robertson 1981; Seebeck *et al.* 1989). There are claims of sightings of Brush-tailed and one of a Burrowing Bettong in the Pilliga area during the 1980s (NPWS database), though positive identifications are lacking. Information on their habitat and behaviour is also limited (Stoddart 1966; Christensen 1980; Johnson 1980; Robertson 1981).

Previous records of the Rufous Bettong in the study area are old. They include one near Coonabarabran in 1906, one from Narrabri in 1927 (Marlow 1958) and seven from the Manilla area during the 1920s (Australian Museum database). Rolls (1981) records several first-hand accounts of rat-kangaroos (probably Rufous Bettongs) over many years in the Pilliga, with an observation of their decline in more recent times.

c) Wallabies

A Black-striped Wallaby *Macropus dorsalis* was spotlighted as it crossed a road in Euligal State Forest, near Etoo Creek. This observation was made in an Ironbark/Cypress forest with a dominant, tall acacia understorey. This habitat type is consistent with known preferences for this species, which inhabits scrubby or vine wet forest in north-east New South Wales and Brigalow scrub in Queensland (Kirkpatrick 1995). Though a social species (Kirkpatrick 1995), the individual sighted in Euligal State Forest was probably a solitary male, standing over one metre tall, with a prominent hip-stripe and a conspicuous vertebral stripe, visible as it moved into the scrub in an unhurried way, with its head held low and its tail held aloft (pers. obs. 1993). The Black-striped Wallaby may be easily confused with the Red-necked Wallaby, however, the vertebral stripe is a distinctive feature of the Black-striped Wallaby and is the basis of identification in this instance.

The Black-striped Wallaby is distributed from Townsvilles, Queensland, south along the coast, ranges and inland slopes and into northeastern New South Wales west of the

ranges (Kirkpatrick 1995). It is regarded as common in Queensland, even a pest (Calaby and Grigg 1989; Pople 1989), but has declined over most of its range (Calaby and Grigg 1989), especially in New South Wales (Marlow 1958; Johnson *et al.* 1989). Previous records in the study area include 11 near Manilla, registered in 1910 and 1929 (Australian Museum database), four near Narrabri in 1978, 1986 and 1991, one from the Ban Baa area on the eastern side of the Pilliga, one near Tambar Springs in 1979 and some from the Brigalow Nature Reserve in 1979 (NPWS database). Most of these records are from areas now largely altered for stock and cropping agriculture. The Brigalow Nature Reserve is still thought to support a population of this species. As far as we are aware, this Nature Reserve is the only protected patch of Brigalow habitat in New South Wales, though unprotected patches of mixed Brigalow also occur in the northern Pilliga and surrounding region. Due to its size, the Pilliga may represent one of the last important refuges for the Black-striped Wallaby in New South Wales.

d) Gliders

Two unconfirmed observations were made of a large glider (Family: Petauridae) during the surveys. One was made by spotlight in Mehi State Forest, in Grey Box/Red Gum woodland near the Gwydir River. It was a large, dark glider though the specific identity remains inconclusive because the individual glided about 40 m from its tree position to the ground and escaped (Clive Barker, pers. comm.). The other unconfirmed record comes from a hair tuft collected at a dry creek near Gwabegar, Pilliga West State Forest (Site 2). The hair filaments were considered too thick to be those of the Squirrel Glider *Petaurus norfolcensis* or the Sugar Glider *P. breviceps,* it was considered more likely to be hair from a Yellow-bellied Glider *Petaurus australis* or a Greater Glider *Petauroides volans* (B. Triggs, pers. comm.). The southern subspecies of the Yellow-bellied Glider *P. a. australis* has disjunct populations in coastal western Victoria and from the Nandewar Range (1991, NPWS Atlas records). The Greater Glider was also known from the Kaputar/Nandewar area (Marlow 1958). A follow-up survey to the Pilliga West site failed to detect any evidence of either glider (R. Kavanagh and G. King, State Forests of New South Wales, pers. comm.) and neither has been identified previously from the Pilliga forests.

e) Native Rodents

Possibly the most unexpected discovery of the surveys was that of a hair sample taken from a fox scat near Lanes Mill Flora Reserve in the central Pilliga. The hair was identified as belonging to the genus *Notomys,* resembling, in cross-section, a hair from *N. mitchelli* (B. Triggs, pers. comm.). However, there is some conjecture as to the identity of this hair sample at present, particularly whether it can be distinguished from hair of a species of *Pseudomys*. There are no other records of this genus from the study area, apart from an earlier report by Rolls (1981) of possible *Notomys* footprints from somewhere in the central Pilliga area. Hopefully future small mammal surveys in the Pilliga will clarify this record.

Scats thought to belong to a native species of *Rattus* were discovered at a creekside location in Kelvin State Forest, a mountain/forest isolate north of Gunnedah. The scats, uncovered from shallow burrows in and near a creek bank, appear to resemble those of the Bush Rat *R. fuscipes,* (B. Triggs, pers. comm.), much larger than a *Pseudomys* yet not exhibiting features typical of introduced Black Rat *R. rattus* scats, having a brown colour and thicker shape. The Bush Rat is not generally found more than 100 km from the coast (Lunney 1995). The local vegetation was a grassy Red Gum/White Box/Cypress woodland surrounding a shallow, intermittent tributary.

Though tenuous, a positive identification of this rat species needs to be the focus of future research. Two *Rattus* species are known historically from the north-west slopes of New South Wales, however, neither has been observed recently. The Pale Field-rat *R. tunneyi* is known only from black soil country west of the study area (Marlow 1958) and also from north-east New South Wales (Redhead 1995). The Long-haired Rat *R. villosissimus* has been recorded from the Liverpool Plains area (see Table 2). Fluctuations in the distribution and abundance of the Long-haired Rat seem to correspond to cycles of wet seasons (Redhead 1995) and recent drought may account for its apparent scarcity in the study area. However, its presence may be overlooked or confused with introduced species.

Predation by feral species

Feral predator (fox and dog) scats were collected for hair analysis (B. Triggs) to investigate their diets particularly with relation to mammal prey (Table 4). Only one cat scat was located and it contained insect material. Dog and fox scats were usually found along roads and tracks and around dams, but fox scats were also detected away from roads in a variety of situations, but usually found on or near logs and other landmarks. It is not

Table 4: Feral carnivore prey items collected from fox and dog scats (from Date and Paull 1996).

Species	Fox	Dog	Total
Bos taurus	5	9	14
Capra hincus	1	6	7
Ovis aries	4	7	11
Oryctolagus cuniculus	5	8	13
Felis cattus	2	—	2
Rattus rattus	1	3	4
Large *Macropus* spp.	3	14	17
Small *Macropus/Wallabia*	6	11	17
Trichosurus sp.	14	9	23
Phascolarctos sp.	—	1	1
Tachyglossus sp.	—	5	5
Petaurus sp.	1	—	1
Antechinus flavipes	5	—	5
Cercartetus nanus	1	1	2
Notomys sp.	1	—	1
Sminthopsis murina	1	—	1
Acrobates pygmaeus	1	—	1
Totals	51 items 15 species	74 items 11 species	125 items 17 species

known whether the dog scats come from feral or domesticated dogs or Dingos which were only positively identified in Goonoo State Forest.

Dogs took fewer native mammal species than foxes (5 spp), with a greater reliance on stock, feral herbivores and large macropods. The most favoured items for dogs were large macropods and the Swamp Wallaby, with the Echidna, cattle, sheep, goats and rabbits also favoured. Only dogs were found to prey on the Echidna. Other interesting species found in dog scats were the Eastern Pygmy-possum *Cercartetus nanus* and the Koala. Despite their willingness to come to the ground, Koalas did not form a large part of the diet of these carnivores (1 item out of 125).

Foxes took a wider range of native mammals (10 spp.), including five small species. This evidence, along with the fox's willingness to hunt widely away from roads, suggest the fox is a more effective hunter of small native mammals than the dog. How much these species rely on scavenging is unclear. In this study the preferred prey species of the fox was the Brushtail Possum, with the Swamp Wallaby, Yellow-footed Antechinus, cattle and rabbits also important. Interestingly, two fox scats were found to contain cat *Felis cattus* hair, suggesting possible predation.

Overall, the most favoured food items of the feral carnivores were the large native mammals, with predation/scavenging of cattle, sheep and rabbits also important. Small mammals seem to be more important for the fox. Of a possible six species of *Macropus* from the study area, only two, the Eastern Grey Kangaroo and the Wallaroo, were positively identified from hair samples (B. Triggs, pers. comm.).

DISCUSSION

For the purposes of indicating the decline in native non-flying mammal species in the study area, rare species detected during the survey and those species not detected but not considered extinct in the study area were lumped together as "rare or unsure status" species. Figures 2 and 3 compare the relative number of common, declining and extinct non-flying native mammal species according to resource/habitat preferences (grass-, shrub-,

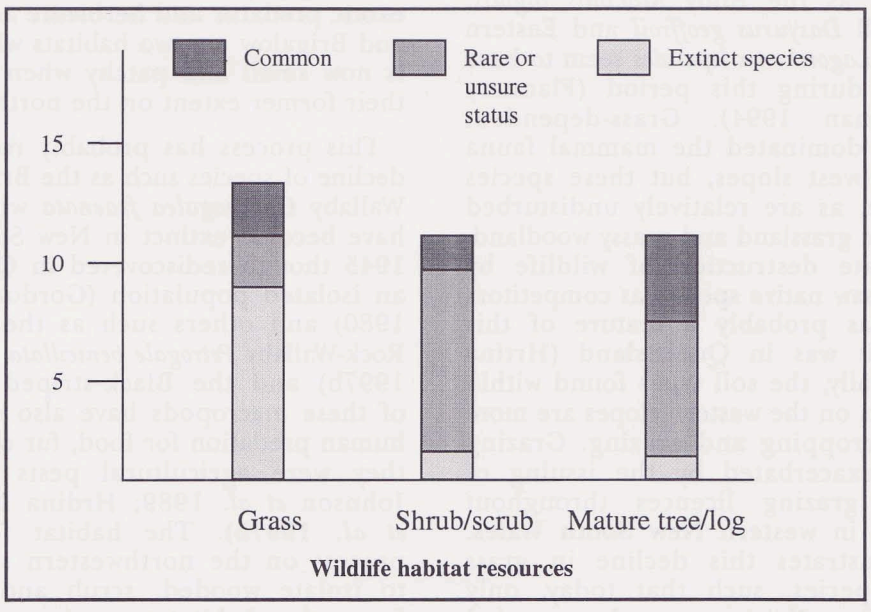

Figure 2. Relative decline in wildlife habitat resources on the western slopes of New South Wales.

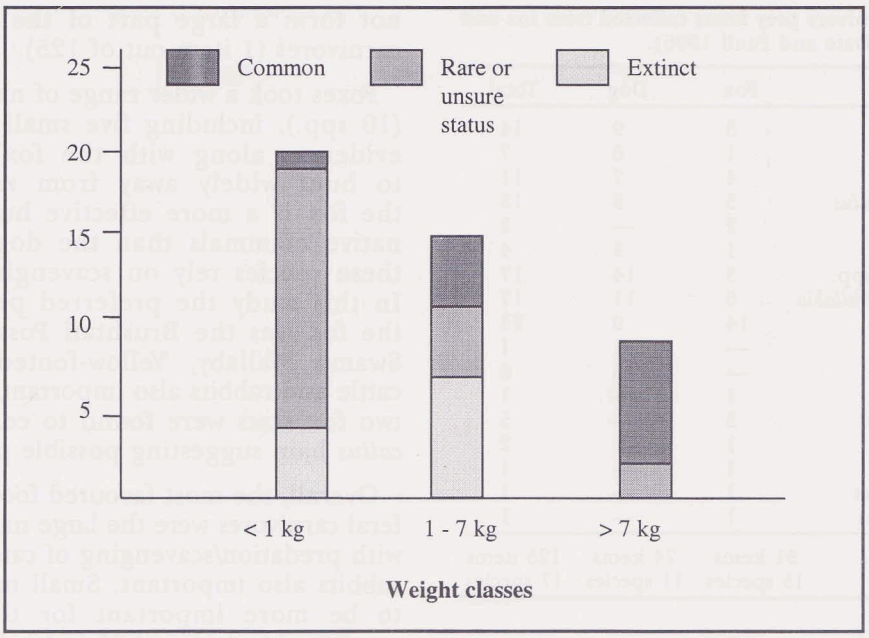

Figure 3. Patterns of native mammal decline according to weight class.

scrub-, or mature tree/log-dependent) and weight class.

Patterns of habitat decline

Declines in species dependent upon certain types of resources is usually indicative of significant decline in habitats containing those resources (Saunders 1977, 1994; Traill 1993; Bennett *et al.* 1994). A significant extinction and decline of grass-dependent species seems to have occurred in conjunction with the expansion and intensification of the pastoral industries in western New South Wales largely by the turn of the last century. Species such as the Bilby *Macrotis lagotis,* Western Quoll *Dasyurus geoffroii* and Eastern Hare-wallaby *Lagorchestes leporides* seem to have disappeared during this period (Flannery 1990; Dickman 1994). Grass-dependent species once dominated the mammal fauna of the north-west slopes, but these species are now rare, as are relatively undisturbed areas of native grassland and grassy woodland. The deliberate destruction of wildlife by farmers who saw native species as competitors for stock, was probably a feature of this process, as it was in Queensland (Hrtina 1997). Generally, the soil types found within grassy habitats on the western slopes are more suitable for cropping and grazing. Grazing pressure is exacerbated by the issuing of unrestricted grazing licences throughout Crown lands in western New South Wales. Figure 2 illustrates this decline in grass dependent species, such that today, only the Eastern Grey Kangaroo can be regarded as common. The Western Grey and Red Kangaroos may be regarded as secure but with vastly fluctuating populations on the north-west slopes.

As with the more open grassland ecosystems, scrub and shrubby understoreys once occurred extensively outside the current Crown lands or reserve systems and have suffered from clearing to a greater extent than the woodland/forest habitats. The clearing, cropping, grazing, hunting and fire management in the more marginal lands further disadvantaged species found in scrub, shrubland, shrubby woodland and remaining grassland habitats, isolating populations and increasing levels of exotic predator and herbivore activity. Mallee and Brigalow are two habitats whose coverage is now small and patchy when compared to their former extent on the north-west slopes.

This process has probably resulted in the decline of species such as the Bridled Nail-tail Wallaby *Onychogalea fraenata* which seems to have become extinct in New South Wales by 1945 though rediscovered in Queensland in an isolated population (Gordon and Lawrie 1980) and others such as the Brush-tailed Rock-Wallaby *Petrogale penicillata* (Lunney *et al.* 1997b) and the Black-striped Wallaby. All of these macropods have also suffered from human predation for food, fur or just because they were agricultural pests (Rolls 1981; Johnson *et al.* 1989; Hrdina 1997; Lunney *et al.* 1997b). The habitat fragmentation process on the northwestern slopes tended to isolate wooded, scrub and rocky areas from other habitat types, increasing levels of "edge-effect" and distances between remnants

(Saunders 1994). The effect of these processes has been a decline of shrub-dependent species so that now there are few common species. The Red-necked Wallaby and the Swamp Wallaby were only species found to be common in shrubby understorey. Scrub habitats were not sampled to any great extent in this study and may turn out to be significant refuges for small mammals throughout the study area and warrant closer scientific investigation. Though less extensive, clearing of natural habitat still occurs on the western slopes, largely for irrigation cropping and rangeland stock. Species dependent upon shrub understorey resources are those currently most in decline in the study area.

Species dependent upon mature tree and log resources seem to have fared better than the other groups, this habitat exhibiting the highest proportion of common species, but also with one extinct and six declining or little known species (Fig. 2). The establishment of State Forests early this century was accompanied by intensive logging regimes which has reduced the average age and changed the structure of many commercial native forests. As a result, the condition of wildlife habitat in State Forests surveyed was found to be variable.

Some of the natural vegetation in State Forests was characterized by a high level of biodiversity with high mature tree retention, a diverse shrub understorey and groundcover of old logs, litter and grasses. Others areas were native mammal poor except for the most ubiquitous mammals; these habitats had low mature tree retention levels, high numbers of dead trees, poor understorey, often dominated by White Cypress Pine or Bull Oak regrowth and a ground cover of cut logs, stumps, and often bare or disturbed ground (Date and Paull 1996). Grazing of stock in many commercial timber areas also had reduced the grass and litter cover.

The fact that understorey resources are so important for mammals, and that their availability is regulated largely by land use regimes, such as fire and grazing, points to the need for further study into these parts of the region's ecology. The decline in both understorey and tree resources is facilitated by interruptions to natural germination and regeneration cycles in the vegetation. However, the role that fire may have played in the study area is little understood, although it is thought by some to be a significant factor in the decline of fauna (Short and Turner 1994) and is a key area of future research. Logging activity and other wood removal has been found to affect the occurrence and habitat selection of hollow-dependent species in temperate woodland habitats in Victoria (Bennett *et al.* 1994; Traill 1993).

Other wildlife resources not depicted in Figure 2 are aquatic and rocky habitats. Rocky areas may prove to be significant refuges for mammal species, and warrant further investigation in the study area. There is a variety of parent materials which form rocky outcrops in the study area. Species with a known tendency to inhabit these areas are the Echidna, the Wallaroo, the Brush-tailed Rock-wallaby, the Yellow-footed Antechinus, the Common Dunnart, the Tiger Quoll and a number of bats.

Critical weight ranges

Figure 3 classes all mammals identified from the northwestern slopes into three weight categories to compare the relative decline in mammal species between small (<1 kg), medium-sized (1–7 kg) and large species (>7 kg) groups. The unidentified *Rattus* sp. and *Notomys* sp. are not included in this analysis.

Most small mammals are currently in decline, with four extinct species and two secure. This weight category has always been the most diverse in the north-west slopes with at least 19 species. However, more medium-sized species, most of which are grass- and shrub-dependent, have become extinct. Other rare medium-sized terrestrial species still present in the study area, i.e., the Tiger Quoll, the Greater Glider, the Yellow-bellied Glider and a species of bettong, seem to be very rare or elusive to detection. Common medium-sized species are the larger arboreal marsupials and the Echidna. All of the large common species are macropods.

Burbidge and McKenzie (1989) first identified a critical weight range for extinct and declining mammal species as between 35 and 5 500 gm. This study supports an association between this weight range and declining fauna groups in the study area, with extinct species weighing between 50 and 6 000 gm and declining species between 12 and 1 000 gm. Lunney *et al.* (1997a) found that large size was a strong correlate for mammal decline across New South Wales, however, the pattern of size-class decline in the study area is different, with most extinct species being medium-sized and most currently threatened, declining species being small native mammals (<1 kg). Few species in this small weight range are thought to be secure, in contrast to the pattern found across the whole state. Most extant, common species are over 1 kg, except for the Sugar Glider and

the Yellow-footed Antechinus. Interestingly, these species are rare on the south-west slopes of New South Wales (Bauer *et al.* 1996).

CONCLUSIONS

Based on these results, the decline of non-flying native mammals in the North-west Cypress/Ironbark Belt can be traced along the following path:

1. Grass-dependent medium-sized and small mammals seem to have been disadvantaged the most with a longer period of species decline initiated by agricultural impacts since the first European settlement of the Liverpool Plains in the 1850s.
2. Native mammals more reliant on shrubby understorey appear to have suffered a similar though perhaps later or less intensive decline such that today, small and medium-sized shrubby understorey species are the group with the most number of species currently under threat from human activity.
3. Though to a less extent, arboreal species have also declined, primarily from clearing and a prolonged usage of native hardwood and softwood timber as a building and fencing resource since first settlement of the north-west slopes of New South Wales.

Laurance (1991) found that the non-flying mammals most prone to extinction in tropical Queensland forest were those most strongly K-selected (having a low reproductive potential and usually associated with more stable ecosystems) or with a level of dietary specialization. This is pertinent to the native mammal fauna of the study area, where animals with a low fecundity and dietary specialization seem to have declined (e.g., quolls, bettongs). It is suggested that two over-riding pressures have been exerted upon the fauna of the region, widespread habitat loss and fragmentation and the effects of feral animals. This has severely tested the resilience of the native fauna.

Habitat and diet specialization can be detrimental to the survival of those most specialized species in the face of widespread habitat loss, particularly if the overall mobility of species is low. The less mobile small and medium-sized terrestrial species have suffered marked declines when compared to the more mobile species such as the Echidna and the larger macropods, most of which are better able to traverse areas of unsuitable habitat and are less susceptible to predation. The medium-sized Black-striped Wallaby, the Bridled Nailtail Wallaby and the Brush-tailed Rock-wallaby are the exceptions. They are also relatively habitat specialized, generally avoiding open ground.

The magnitude of the threat of exotic predators on small and medium-sized native mammals in the study area is probably great, particularly as most habitats in the region are highly fragmented and isolated, with often high levels of and internal habitat simplification and connectivity. During this study, the penetration of foxes was found to be linked to road networks, and into those areas most disturbed by human activity (Date and Paull 1996). Foxes were found to be a predator of small native mammals in the study area, taking the Yellow-footed Antechinus, the Common Dunnart, the Feathertail Glider *Acrobates pygmaeus,* the Eastern Pygmy-possum and the *Notomys* sp. though probably relying more upon larger prey such as macropods, possums and rabbits. No *Pseudomys* hairs were detected in fox scats.

Dog *Canis familiaris* scats were common in State Forests though it is not clear whether these belong to Dingos or feral dogs. Dingos were only positively identified from one State Forest (Goonoo) though recent sightings have been made in the Pilliga (pers. obs.). It appears that dogs/dingos in the study area do not prey extensively upon small native mammals. The impacts of feral domestic cats in the study area is still largely unknown. They were detected mostly from hair tube samples, though occasional individuals were observed crossing roads, both at night and during the day.

Before European arrival, vegetation communities of the region were diverse, as was the fauna they supported (Aust. Mus. Records; NPWS Atlas; Marlow 1958). The non-flying mammal fauna which has survived can be grouped into three types:

(a) Large, mobile species, e.g., kangaroos, wallabies and the Echidna;

(b) Arboreal species, restricted to remnant woodland/forest habitats; and

(c) Isolated/relict populations of small and medium-sized terrestrial species, still found in relatively undisturbed areas, particularly where there are native grass and shrub communities.

Based on this pattern of habitat and species decline, an assessment of the regional threats to the north-west slopes fauna has highlighted a number of human activities to be important factors in the decline of the slopes mammal fauna. Some have received some research in western New South Wales and are generally considered to be known threatening processes:

(a) Stock grazing, pasture improvement, clearing and understorey removal;

(b) Broad-scale dry cropping; and

(c) Predation by foxes.

Others have received little scientific scrutiny, particularly in western New South Wales, and are important areas of future research:

(a) Removal of hardwood trees and logs for timber and firewood;

(b) Removal of mature White Cypress Pine;

(c) The disruption of natural fire cycles through inappropriate fuel reduction regimes;

(d) Irrigation cropping;

(e) Understorey and groundcover destruction and removal by feral herbivores, particularly the rabbit, goat and pig;

(f) Predation by other exotic predators, particularly the dog and cat; and

(g) Effects of past bounties paid for native mammals killed for fur and as pests in New South Wales.

In summary, 12 mammals are presumed extinct, 21 rare or threatened species and ten species are probably secure on the northwestern slopes of New South Wales. Two species of native mammals await an identification and one, the Pilliga Mouse, is an endemic species which highlights the bioregional uniqueness and conservation significance of the Pilliga mammal fauna in particular. Few native mammal taxa have not suffered some sort of decline or habitat loss since European settlement in the study area. The status of most of those remaining are rare and declining, with a high number whose status is uncertain. Based on the evidence presented here it is likely that any further decline in habitats suitable for small and medium-sized mammals within remnant native vegetation may be a prelude to further native mammal population and species decline.

As most wooded and mixed understorey habitat within this area is now incorporated in State Forests, National Parks, Nature Reserves or on other Crown Timber Lands, the implication for the conservation of regional threatened, protected and declining fauna and their habitats is for an integrated approach from all of these land managers and leaseholders. The proportion of the study area dedicated to nature conservation (National Parks and Nature Reserves) is about 1.6% of the total study area, far less than levels that are generally considered regionally acceptable. The protection of representative examples from the range of habitats in the region has yet to be achieved. The current evidence shows that woodland/forest habitats, particularly those with good hollow-development or those with developed, natural shrubby or grassy understorey, offer the prime refuges for the remaining north-west slope fauna communities, including many rare understorey-dependent species. These habitats warrant a more thorough regional assessment process in order to identify areas critical for regional biodiversity.

Dickman (1994) painted three possible future scenarios for the future of the native mammal fauna in New South Wales. In the optimistic view, an improved knowledge of our fauna may increase the number of species found in this state, but it would be a tragedy if we were to lose further species and populations, particularly ones we know little about.

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REFERENCES

Bauer, J., Bryant, A., Schrader, N., Goldney, D. Stone, B. and Paull, D. C., 1996. Draft Fauna Impact Statement for Proposed Forestry Operations in the South western Cypress Pine forests of New South Wales. Johnstone Centre of Parks, Recreation and Heritage: Charles Sturt University.

Bennett, A. F., Lumsden, L. F. and Nicholls, A. O., 1994. Tree hollows as a resource for wildlife in remnant woodlands: spatial and temporal patterns across the northern plains of Victoria. *Pac. Cons. Biol.* **1:** 222–35.

Burbidge, A. A. and McKenzie, N. L., 1989. Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. *Biol. Conserv.* **50:** 143–98.

Calaby, J. H. and Grigg, G. C., 1989. Changes in macropodoid communities and populations in the past 200 years, and the future. Pp. 813–20 in *Kangaroos, Wallabies and Rat-Kangaroos* Vol. 2 ed by G. Grigg, P. Jarman and I. Hume. Surrey Beatty & Sons Pty Limited: Chipping Norton, New South Wales.

Caughley, J. and Gall, B., 1985. Relevance of zoogeographical transition to conservation of fauna: amphibians and reptiles in the south-western slopes of New South Wales. *Aust. Zool.* **21:** 513–30.

Christensen, P. E. S., 1980. The biology of *Bettongia penicillata* Gray, 1837, and *Macropus eugenii* (Desmarest, 1817) in relation to fire. *Forest Dept. West. Aust. Bull.* No. 91(9), 90 Pp.

Coles, R. B., 1995. Results of bat survey for the Northwest Cypress-Ironbark Fauna Impact Statement. Report to State Forests of New South Wales, Western Region, Dubbo.

Date, E. M. and Paull, D. C., 1996. Draft report on the fauna survey of the North-west Cypress and Ironbark Belt (1993–95) — Results of surveys, implications for conservation. Report to State Forests of New South Wales, Western Region, Dubbo.

Dickman, C. R., 1994. Native mammals of western New South Wales: Past neglect, future rehabilitation. Pp. 81–91 in *Future of the Fauna of Western New South Wales* ed by D. Lunney, S. Hand, P. Reed and D. Butcher. Royal Zoological Society of New South Wales: Mosman, Australia.

Flannery, T., 1990. *Australia's Vanishing Mammals*. Reader's Digest Press: Sydney. 192 Pp.

Forestry Commission of New South Wales, 1993. Proposed Forestry Operations in the Cypress Pine/Ironbark Forests of North-western New South Wales. Fauna Impact Statement Draft. Forestry Commission of New South Wales, Sydney.

Fox, B. J. 1982. A review of dasyurid ecology and speculation on the role of limiting similarity in community organisation. Pp.97–116 in *Carnivorous Marsupials* Vol. 1 ed by M. Archer. Royal Zoological Society of New South Wales: Mosman, Australia.

Gordon, G. and Lawrie, B. C., 1980. The rediscovery of the Bridled Nailtail wallaby (*Onychogalea fraenata* Gould) in Queensland. *Aust. Wildl. Res.* **7**: 339–45.

Gould, J., 1841. On five new species of kangaroos. *Proc. Zool. Soc. Lond.* **1840**: 92–94.

Hrdina, F. C., 1997. Marsupial destruction in Queensland 1877–1930. *Aust. Zool.* **30** (3): 272–86.

Johnson, K. A., Burbidge, A. A. and McKenzie, N. L., 1989. Australian Macropodoidea: status, causes of decline and future research and management. Pp. 641–57 in *Kangaroos, Wallabies and Rat-Kangaroos* Vol. 2 ed by G. Grigg, P. Jarman and I. Hume. Surrey Beatty & Sons Pty Limited: Chipping Norton, New South Wales.

Johnson, P. M., 1980. Observations on the behaviour of the Rufous Rat-kangaroo, *Aepyprymnus rufescens* (Gray), in captivity. *Aust. Wildl. Res.* **7**: 347–57.

Kirkpatrick, T. H., 1995. The Black-striped Wallaby. P. 238 in *The Australian Museum Complete Book of Australian Mammals — The National Photographic Index of Australian Wildlife* ed by R. Strahan. Angus and Robertson: Sydney.

Laurance, W. F., 1991. Ecological correlates of extinction proneness in Australian tropical rainforest mammals. *Cons. Biol.* **5**: 79–89.

Lim, L., 1992. Conservation and biology of the rare Pilliga Mouse, *Pseudomys pilligaensis* Fox and Briscoe, 1980, (Muridae: Conilurini). Report to the Zoological Parks Board of New South Wales, Mosman, Australia.

Lunney, D., 1995. The Bush Rat. Pp. 443–45 in *The Australian Museum Complete Book of Australian Mammals — The National Photographic Index of Australian Wildlife* ed by R. Strahan. Angus and Robertson: Sydney.

Lunney, D., Curtin, A. L., Fisher, D., Ayers, D. and Dickman, C. R., 1997a. Ecological attributes of the threatened fauna of New South Wales. *Pac. Cons. Biol.* **3**: 13–26.

Lunney, D., Law, B. and Rummery, C., 1997b. An ecological interpretation of the historical decline of the Brush-tailed Rock-wallaby *Petrogale penicillata* in New South Wales. *Aust. Mammal.* **19**: 281–96.

Mansergh, I., 1983a. The status, distribution and abundance of *Dasyurus maculatus* (Tiger Quoll) in Australia, with particular reference to Victoria. *Aust. Zool.* **21**: 109–22.

Mansergh, I., 1983b. The capture period of the Tiger Quoll *Dasyurus maculatus* in Victoria. *Vic. Nat.* **100**: 32–33.

Marlow, B. J., 1958. A survey of the marsupials of New South Wales. *CSIRO Wildl. Res.* **3**: 71–114.

Mitchell, P. B. and Rundle, A. S., 1982. Land systems of the Pilliga region, NSW. Report to NSW NPWS, Macquarie University.

Pople, A., 1989. Habitat associations of Australian Macropodoidea. Pp. 755–66 in *Kangaroos, Wallabies and Rat-Kangaroos* Vol. 2 ed by G. Grigg, P. Jarman and I. Hume. Surrey Beatty & Sons Pty Limited: Chipping Norton, New South Wales.

Redhead, T. D., 1995. The Long-haired Rat. P. 450 in *The Australian Museum Complete Book of Australian Mammals — The National Photographic Index of Australian Wildlife* ed by R. Strahan. Angus and Robertson: Sydney.

Reed, P., 1991. An historical analysis of the changes to the forests and woodlands of New South Wales. Pp. 393–406 in *Conservation of Australia's Forest Fauna* ed by D. Lunney. Royal Zoological Society of New South Wales: Mosman.

Robertson, G., 1981. Bettongs. Pp. 9–14 in *Kangaroos and Other Macropods of New South Wales* ed by C. Haigh. NSW National Parks and Wildlife Service: Sydney.

Rolls, E., 1981. *A Million Wild Acres*. Penguin: Sydney.

Saunders, D. A., 1977. The effects of agricultural clearing on the breeding success of the White-tailed Black Cockatoo. *Emu* **77**: 180–84.

Saunders, D. A., 1994. The effects of habitat reduction and fragmentation on the mammals and birds of the Western Australian Wheatbelt: lessons for New South Wales. Pp. 99–105 in *Future of Fauna in western New South Wales* ed by D. Lunney, S. Hand, P. Reed and D. Butcher. Royal Zoological Society of New South Wales: Mosman, Australia.

Seebeck, J. H., Bennett, A. F. and Scotts, D. J., 1989. Ecology of the Potoroidae — a review. Pp. 67–88 in *Kangaroos, Wallabies and Rat-Kangaroos* Vol. 1 ed by G. Grigg, P. Jarman and I. Hume. Surrey Beatty & Sons Pty Limited: Chipping Norton, New South Wales.

Short, J. and Turner, B., 1994. A test of the vegetation mosaic hypothesis: a hypothesis to explain the decline and extinction of Australian mammals. *Cons. Biol.* **8**: 439–49.

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

Stoddart, E., 1966. Observations on the behaviour of the marsupial *Bettongia lesueur* (Quoy and Gaimard) in an enclosure. *CSIRO Wildl. Res.* **11**: 91–99.

Strahan, R. (ed), 1995. *The Australian Museum Complete Book of Australian Mammals — The National Photographic Index of Australian Wildlife*. Angus and Robertson: Sydney.

Thackway, R. and Cresswell, I. D., 1995. An interim biogeographic regionalisation for Australia: A framework for setting priorities in the National Reserves System Cooperative program. Version 4.0. Australian Nature Conservation Agency, Canberra.

Traill, B. J., 1993. Forestry, birds, mammals and management in box and ironbark forests. *Vic. Nat.* **110**(1): 11–14.

Troughton, E., 1941. *Furred Animals of Australia*. Angus and Robertson Pty Ltd: Sydney. 314 Pp.