Impacts of Landclearing: the impacts of the approved clearing of native vegetation on Australian wildlife in New South Wales

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IMPACTS OF LANDCLEARING

The Impacts of the Approved Clearing of Native Vegetation on Australian Wildlife in New South Wales

WHEN LAND IS CLEARED, EVERYTHING THAT LIVES IN IT IS KILLED.

– AUSTRALIA STATE OF THE ENVIRONMENT 2006

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CONTENTS

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Dr Hal Cogger is a leading Australian herpetologist and author of the definitive *Reptiles and Amphibians of Australia*. He is a former Deputy Director of the Australian Museum.

Dr Cogger has participated on a range of policy and scientific committees, including the Commonwealth Biological Diversity Advisory Committee, Chair of the Australian Biological Resources Study Advisory Committee and Chair of the Australasian Reptile & Amphibian Specialist Group (IUCN's Species Survival Commission). He also held a Conjoint Professorship in the Faculty of Science & Mathematics at the University of Newcastle (1997-2001).

He is currently the John Evans Memorial Fellow at the Australian Museum.

Hal Cogger's research interests include the systematics and ecology of Australian reptiles and frogs and the role of threatened species in conservation biology and policy development. He is senior author of the Action Plan for Australian Reptiles.

For his contribution to Australian herpetology, Dr Cogger has been awarded an AM, an honorary Doctor of Science from the University of Sydney, and honorary life memberships of the Australian Society of Herpetologists, the American Society of Ichthyologists and Herpetologists and The Herpetologists' League, Inc. He is a recipient of the Whitley Medal of the Royal Zoological Society of NSW.

PROFESSOR CHRIS DICKMAN MAMMALS

Professor Chris Dickman is a highly respected scientist with nearly 30 years' experience of working on the ecology, conservation and management of Australian mammals. Since 1990, he has been Director of the Institute of Wildlife Research at the University of Sydney. In 2004, he was awarded a personal chair in ecology at the university.

For much of the last 20 years, Professor Dickman has studied the factors that influence vertebrate diversity in arid Australia. In this work, he has identified habitat loss, feral cats and foxes as being particularly detrimental to the survival of native fauna.

Professor Dickman is a past President of the Australian Mammal Society and of the Royal Zoological Society of New South Wales, past Chair of the NSW Scientific Committee, and Chair of the Australian Marsupial and Monotreme Specialist Group for the Species Survival Commission of the IUCN.

Professor Dickman currently serves on the national assessment panel for the Threatened Species Network Community Grants Program, the NSW Biodiversity Research Network, and the Scientific Advisory Committee for Earthwatch.

Professor Dickman has written or edited 16 books and monographs and authored a further 220 journal articles and book chapters. He is a recipient of a Bolliger Award and Troughton Medal from the Australian Mammal Society.

In 2001, he was elected a Fellow of the Royal Zoological Society of New South Wales. Professor Dickman is a WWF-Australia Governor and former member of WWF's Scientific Advisory Panel.

PROFESSOR HUGH FORD BIRDS

Professor Hugh Ford is one of Australia's most senior and respected bird scientists. He has over 30 years of experience in the ecology, behaviour and conservation of Australian birds, especially those of eucalypt forests and woodlands.

Until recently, Professor Ford was Head of the School of Environmental Sciences and Natural Resources Management, University of New England.

Professor Ford is the author of *Ecology of Birds: An Australian Perspective.* He has edited two books on Australian birds and authored over 100 (book) chapters and journal articles.

In 1980, Professor Ford and Dr Howe published a landmark study of the long-term conservation status of birds in the Mount Lofty Ranges of South Australia. Using island biogeography principles, the two scientists predicted that of the original terrestrial bird fauna of about 120 species, almost 50 would eventually become extinct. This was the first Australian study alerting us to the problem of an 'extinction debt'. The recently started Mount Lofty Birds for Biodiversity Regional Recovery Project aims to tackle this problem.

In 1993, Hugh Ford was awarded the Serventy Medal for 'Outstanding Services to Ornithology in the Australasian region' by the Royal Australasian Ornithologists Union.

Hugh Ford conducted a major project on the impact of habitat loss, fragmentation and degradation on birds with Professor Harry Recher, Dr Denis Saunders and Dr Geoff Barrett, which was supported by WWF-Australia in the early 1990s.

Professor Ford is a Governor of WWF-Australia and was formerly a member of WWF's Scientific Advisory Panel. He is also a member of the Research and Conservation Committee of Birds Australia.

EXECUTIVE SUMMARY

This report uses the amount of land in New South Wales approved by the State Government for clearing between 1998 and 2005 inclusively to calculate the impacts of land clearing on the State's wildlife.

According to these calculations more than 104 million native mammals, birds and reptiles have died or will die as a result of the clearing of native vegetation in NSW approved between 1998 and 2005.

These include:

- over 11 million mammals with possums and gliders most severely affected as well as many millions of kangaroos, wallabies, bandicoots, koalas and wombats;
- around 13 million birds comprising mostly woodland and forest birds and including species of honeyeaters and babblers that are under threat of extinction in NSW; and
- more than 80 million reptiles such as skinks and geckos.

These estimates are highly conservative and the true mortality is likely to be substantially higher than those estimated in this report.

Due to inadequate or uncertain public data, the figures in this study do not include the numbers of animals killed as a result of illegal clearing that occurred in NSW from 1998 to 2005, or as a result of exempt clearing (ie legally permitted clearing that does not require approval) that occurred during this time. These other clearing activities also result in the deaths of many millions of native animals. For example, around 5 million mammals, birds and reptiles would have been killed by the amount of illegal clearing estimated by the Auditor-General to have occurred in 2005.

This study does not include any estimates of the amphibians, fish and invertebrates that were also killed as a direct or indirect result of the approved clearing of native vegetation.

The study used the known record of approved clearing of native vegetation in NSW from 1998 to 2005 inclusively that was published by the Auditor-General in his 2006 report, *Regulating the Clearing of Native Vegetation: Follow-up of 2002 Performance Audit*. Between 1998 and 2005 inclusively, the NSW Government approved 639,930 hectares for clearing under its native vegetation legislation.

NSW's wildlife is seriously threatened and under increasing pressure from a range of traditional threats, such as the clearing of native vegetation and the impacts of exotic pests, as well as more recent factors, such as climate change. NSW can stop the loss and degradation of valuable habitats immediately by arresting the extent of clearing and fragmentation of native vegetation, particularly west of the Great Dividing Range, and by undertaking the level of research and monitoring that is essential to managing natural resources at sustainable levels. Alternatively, NSW can continue to allow native habitats to be lost or degraded and experience irreversible regional population declines and extinctions.

According to these calculations more than 104 million native mammals, birds and reptiles have died or will die as a result of the clearing of native vegetation in NSW approved between 1998 and 2005.

1. BACKGROUND

1.1 IMPACTS ON WILDLIFE OF LOSS OF NATIVE VEGETATION

The *Australia State of the Environment 2006* report states that when land is cleared "everything that lives in it is killed." [1]

The impacts of the loss of native vegetation on Australian wildlife are well recognised. For example, the 2001 national report, *Australia: State of the Environment 2001*, identified the clearing of native vegetation as the biggest threat to Australia's wildlife. *The Australia State of the Environment 2006* report identifies the clearing of native vegetation as "an ongoing threat to Australia's environment".[2] The 2006 NSW State of the Environment report also concluded that the clearing of native vegetation, with the associated destruction of habitat, is "the greatest single threat to biodiversity in NSW". [3]

In 2003, the WWF-Australia report, *Impacts of Land Clearing on Australian Wildlife in Queensland*, analysed the impacts of the loss of native vegetation on key elements of Queensland's wildlife.[4] That report outlined the profound effects, both immediate and long-term, of the clearing of native vegetation on the survival of Australian wildlife, including the deaths of many millions of native mammals, birds and reptiles.

When an area of native bushland is lost, most of the resident wildlife does not simply relocate. In reality, the vast majority of animals will die. Most will die quickly but others survive for a time before succumbing to starvation, predation or other fates. This can lead to the local and regional extinction of populations and, through successive cycles of local impacts and fragmentation, the decline and, in some cases, extinction of entire species.[5]

A further consequence of this extinction process is that it can take decades or more for the full effects of land clearing to appear – a time lag that is referred to as an extinction debt. The debt arises because we have "borrowed" rich habitats for short-term gains and reduced their diversity, adaptability and long-term productivity through loss of species richness. The resultant debt is likely to fall due in 20 to 50 or more years' time and will therefore be paid by future generations as local extinctions gradually become regional until entire species are made extinct.[6]

As noted by the *Australia State of the Environment 2006* report, the detrimental effects of vegetation change extend "beyond the number of hectares cleared or replanted each year". Any vegetation that regrows or replaces cleared vegetation, whether natural regeneration or planted trees, is rarely like the communities that were previously cleared. For example, dense woody shrubs may form a monoculture in place of a naturally occurring, complex ecosystem.[7] It also takes a very long time for some components of the ecosystem critical to wildlife habitat to be replaced, such as tree hollows, extensive areas of bark and large trees.

1.2 PROTECTION OF NATIVE VEGETATION IN NSW

It is almost a decade since a NSW Government recognised through legislation that the loss or clearing of native vegetation causes serious loss of biodiversity.[8]

In 1997, NSW passed the *Native Vegetation Conservation Act 1997* with the object of conserving and managing native vegetation.[9] In 2002, the Auditor-General found that "the system for regulating the clearing of native vegetation was ineffective" due to deficiencies in accountability, planning, information, enforceability, monitoring and reporting. As noted by the Auditor-General in 2006, "this regulatory system continued until December 2005 and continued to be ineffective".[10]

In 2001, NSW formally listed the clearing of native vegetation under its *Threatened Species Conservation Act 1995* as a "key threatening process" that harms

When an area of native bushland is lost, most of the resident wildlife does not simply relocate. In reality, the vast majority of animals will die.

threatened species, populations or ecological communities, or could cause other species to become threatened. At the same time, the Scientific Committee established by the *Threatened Species Conservation Act* found that the clearing of any area of native vegetation in NSW, including areas less than two hectares in extent, may have significant impacts on biological diversity.[11]

In 2003, the NSW Government stated its "commitment to end broadscale clearing and maintain productive landscapes" [12] and passed the *Native Vegetation Act 2003*. One of the main objects of the legislation is to prevent the clearing of any native vegetation that has not been cleared since 1 January 1990 (or 1 January 1983 in the case of land in the Western Division) unless it improves or maintains environmental outcomes. [13] This Act did not become operational until 2005.

It is noted that the NSW legislative regime is not supported by a comprehensive mapping of NSW native vegetation although various studies have been made in parts of the State over a long time.[14] Similarly, NSW has not established a comprehensive system for adequately monitoring and reporting changes to the State's vegetation cover. Proper monitoring of all the State's vegetation and a rigorous classification system is essential to enable future planning and management of the State's resources and to ensure that adequate and representative protection of our biodiversity takes place. This is crucial for a wide variety of reasons, not the least to ensure the continued functioning of our landscapes and ecosystems.

1. BACKGROUND

1.3
NATIVE VEGETATION LOSS IN NSW

NSW covers some 800,000 square kilometres of south eastern Australia.

It is a topographically complex region that includes more than one quarter of the nation's plant species and encompasses almost all of the major environments represented in Australia.

NSW has already lost well over half of its native vegetation. Since 1788, at least 61% of the original native vegetation of NSW has been cleared, thinned or substantially or significantly disturbed. This figure exceeds 90 per cent in the case of some types of native environments such as the south east grassy forests.[15]

The following map depicts the existing extent of native vegetation in NSW in 2005.

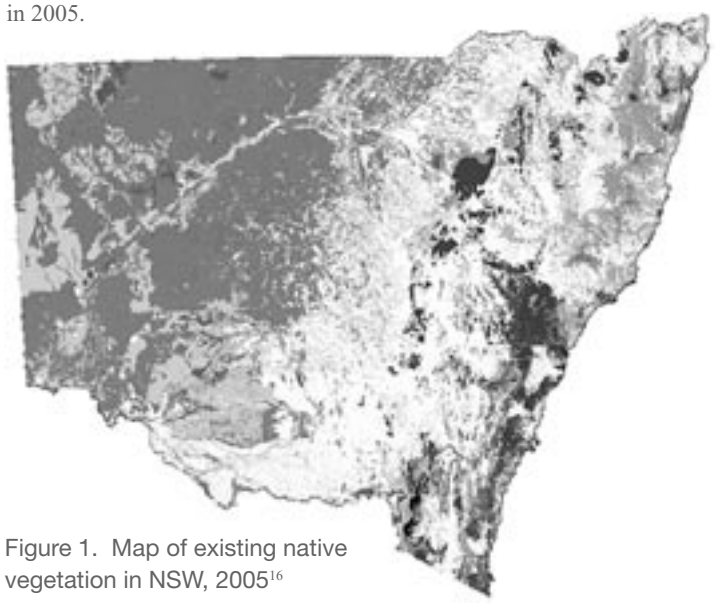

Figure 1. Map of existing native vegetation in NSW, 2005[16]

- Rainforests
- Wet sclerophyll forests (shrubby subformation)
- Wet sclerophyll forests (grassy subformation)
- Grassy woodlands
- Grasslands
- Dry sclerophyll forests (shrub/grass subformation)
- Dry sclerophyll forests (shrubby subformation)
- Heathlands
- Alpine complex
- Freshwater wetlands
- Forested wetlands
- Saline wetlands
- Semi-arid woodlands (grassy subformation)
- Semi-arid woodlands (shrubby subformation)
- Arid shrublands (chenopod subformation)
- Arid shrublands (acacia subformation)
- Cleared land

NSW has already lost well over half of its native vegetation. Since 1788, at least 61% of the original native vegetation of NSW has been cleared, thinned or substantially or significantly disturbed.

During the years 1998 to 2005 inclusively, 639,930 hectares of native vegetation was approved for clearing in NSW. It is noted that these figures do not include areas of native vegetation subject to illegal clearing or exempt clearing (i.e. clearing that may be legally carried out under the *Native Vegetation Act* without approval).[17]

The table below sets out the known record of clearing of native vegetation approved by the NSW Government in NSW from 1998 to 2005. The Auditor-General also estimated that 30,000 hectares of illegal clearing took place in 2005.

Approved clearing has been greatest in areas to the west of the Central Division for agriculture, and in coastal regions for urban development. The greatest area of new clearing of native vegetation in NSW since 1997 has taken place in the central west and north west of the State. Within these western areas, the most intensive clearing has been in the hotspot area around Walgett, Nyngan and Tottenham. New clearing in the State's western areas has been attributed to the development of new strains of wheat suitable for arid climates which have provided a financial incentive for clearing native vegetation in areas previously considered too arid for crops.[19]

In February 2007, the NSW Government reported that, on average, around 16,000-18,000 hectares of woody vegetation had actually been cleared in NSW during a two year period between 2004 and 2006.[20] This compares with the Auditor General's estimate of around 75,000 hectares for 2005 alone. The huge discrepancy between the Auditor-General's figures and these latest findings has not been comprehensively explained. The NSW Government also reported on new clearing approvals for the first six months of 2006.[21]

Year	Hectares (approvals)
1998	73,735
1999	160,863
2000	74,459
2001	90,786
2002	57,753
2003	63,501
2004	73,951
2005	44,882
TOTAL	639,930

Table 1: Known record of approved clearing of native vegetation in NSW, 1998-2005. [18]

1. BACKGROUND

1.4 NSW WILDLIFE UNDER THREAT FROM LOSS OF NATIVE VEGETATION

Significant loss of native vegetation and the associated destruction of habitat continues to occur in NSW despite the fact that NSW wildlife is already under siege.

In NSW, 315 animal species or populations are listed as threatened with Statewide extinction.[22] This comprises:

- amphibians – 27;
- aquatic invertebrates – 3;
- bats – 21;
- birds – 115;
- endangered populations – 36;
- fish – 12;
- invertebrates – 14;
- marine mammals – 7;
- marsupials – 24;
- reptiles – 44; and
- rodents – 12.[23]

Eighty-two per cent of the terrestrial or non-marine species had the clearing of native vegetation listed as a key threatening process under the NSW *Threatened Species Conservation Act.*

The following table sets out the numbers of terrestrial or non-marine mammals, birds and reptiles listed by NSW as threatened with Statewide extinction and the number having land clearing as a key threatening process.

	No. threatened	No. with land clearing as key threatening process	Percentage of species having land clearing as key threatening process
Mammals (terrestrial)	57	49	86%
Birds (non-marine, not offshore)	88	72	82%
Reptiles (terrestrial)	36	28	78%
TOTAL	181	149	82%

Table 2: Terrestrial or non-marine mammals, birds and reptiles listed by NSW as threatened with Statewide extinction by the end of 2006 and the number having land clearing as a key threatening process under the NSW *Threatened Species Conservation Act* [24]

1.5 METHODOLOGY

• Information on native vegetation change

The calculations in this report are based on the known record of approved clearing of native vegetation between 1998 and 2005 published by the NSW Auditor-General in the 2006 report, *Regulating the Clearing of Native Vegetation. Follow-up of 2002 Performance Audit*. [25]

The figures reported by the Auditor-General are not a complete record of the clearing of native vegetation in NSW for the subject time period. Instead, the Auditor-General's report figures comprise only the area subject to approvals under the previously applicable legislation (being the *Native Vegetation Conservation Act 1997*)[26] and an estimate of illegal clearing in 2005.

• Calculation of wildlife impacts

Given Australia's megadiversity of species and our comparatively small human population and research base, the density (ie number of individuals in a given area) of relatively few species has been determined with precision. In addition, the number of different species, or species richness, occurring in a given area is not known in great detail for many habitats. Estimates of these values must necessarily be extrapolated from a relatively small number of detailed studies. Therefore the authors have deliberately employed highly conservative estimates in making their calculations. The true mortality is likely to be substantially higher than those estimated in this report.

2. MAMMALS

2.1 OVERVIEW

Australia supports a rich and impressive diversity of mammals, with over 300 native species occupying the land.[27] The continent is unique in being dominated by marsupials, and in being the only great land mass to contain representatives of the three major groups of living mammals: the marsupials, monotremes (the egg-laying platypus and echidna) and placentals. About 244 species, or 81% of this distinctive fauna, are found only in Australia, with the others occurring also in the New Guinea region.[28] Some 27 species and subspecies of native mammals have become extinct in Australia over the last 200 years, the highest rate of loss for any region in the world. [29]

A detailed stock-taking in 1992 found records of 130 species of native mammals in NSW.[30] Of these, 63 were marsupials, 28 were rodents and 37 were bats; the two remaining species were the echidna and platypus. Disturbingly, the stock-take found that 27 of the original species no longer occurred in NSW, with eight of these being extinct Australia-wide. An additional 50 species were still present but were threatened with extinction in the future. Several species have since been added to the original stock-take due to more survey work and taxonomic revisions but the perilous state of the majority of NSW mammals remains unchanged.

In general, mammals are more diverse and abundant in the higher rainfall coastal regions of NSW and on the slopes and tablelands of the Great Dividing Range. These regions remain the strongholds for many of the tree-dwelling marsupials, rodents and bats, and provide the major refuges for specialist species such as the platypus and mountain pygmy-possum. With declining rainfall inland, tree cover becomes more sparse and gives way in parts of the far west of the State to arid and semi-arid shrubland and grassland. These drier habitats still provide homes for many species of native mammals, but the low and uncertain productivity of the environment means that these species typically survive 'on the edge' at lower and precariously variable densities. Although there is a lack of detailed information on the types of vegetation that are currently being cleared, the available data indicate that large areas of the central west and Barwon regions are being affected, as well as parts of the eastern catchment of the Darling River. Clearing in these areas removes diverse vegetation types that can be classified broadly as woodland and parkland. Many mammals that already occur sparsely in these vegetation types are being pushed to the brink of regional extinction, and those with bigger populations or broader geographical ranges are being reduced, fragmented and placed at future risk as more vegetation is destroyed. Clearing of vegetation in coastal areas for development can also be expected to have very negative consequences for mammals, but there is no reliable information on how much vegetation is destroyed there.

2.2 NUMBERS OF MAMMALS KILLED BY VEGETATION LOSS IN NSW

- **More than 11 million native mammals died or will die in NSW as a result of the clearing of native vegetation approved between 1998 and 2005.**

It is conservatively estimated that over 11 million mammals will die or have already died as a result of land clearing approved in NSW between 1998 and 2005 inclusively.

As noted previously, this estimate does not include the number of mammals killed by illegal or exempt clearing. For example, around half a million mammals would have been killed by the amount of illegal clearing estimated by the Auditor-General to have occurred in 2005.

It is conservatively estimated that over 11 million mammals will die or have already died as a result of land clearing approved in NSW between 1998 and 2005 inclusively.

Possums and gliders are affected most severely by clearing, with common brushtail possums (*Trichosurus vulpecula*), ringtail possums (*Pseudocheirus peregrinus*), feathertail gliders (*Acrobates pygmaeus*), sugar and squirrel gliders (*Petaurus breviceps* and *P. norfolcensis*) suffering the highest rates of mortality. Small carnivorous marsupials are also killed in large numbers each year, with dunnarts (*Sminthopsis* species) being most at risk in central and western regions and antechinuses (*Antechinus* species) further east.

2. MAMMALS


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2.3 HOW HAVE THESE NUMBERS BEEN ESTIMATED?

The numbers of native mammals killed by approved vegetation clearing were estimated by, firstly, obtaining estimates of mammal population density in NSW and, secondly, multiplying these density estimates by the areas of vegetation approved to be cleared in order to obtain the numbers of mammals impacted by the clearing process.

Estimates of density were obtained from published studies of mammals in NSW and from studies carried out in other parts of Australia in similar habitats to those present in NSW (Table 3). Many of these studies targeted just one or a small number of species of mammals, and these have been grouped for simplicity into the broader categories of possums and gliders, native mice and rats, etc. When averaged across the broad habitat types in which the studies had been conducted, mean densities for each of the different mammal groups ranged from 0.01 – 15.5 animals per hectare, with higher values being obtained usually in studies carried out in coastal regions than on the tablelands, western slopes of the Great Dividing Range, and plains. Because the most clearing occurred in the central and western regions of NSW, only the lower density estimates were used in analyses.

Estimates of population density were based on species-specific estimates as well as broader survey studies that survey a range of species in an area and sample the various habitats that are available.

The following table sets out the estimates of density of native mammals from different habitats and regions in NSW and total numbers that have died or will die as a result of land clearing approved in 2005.

Mammal species/ group	Densities (numbers of animals per hectare) in forest, woodland and scrub: means are shown in bold with range, if available, in brackets*		Numbers killed by approved clearing per year (2005 data)**
	Coast and eastern ranges	Tablelands, western slopes and plains	
Echidna	0.01	0.02	898
Koala	0.05 (<0.01 – 4.4)	0.08 (<0.01 – 2.1)	3,591
Common wombat	0.5 (0.01 – 1.9)	0.1 (<0.1 – 0.4)	4,488
Possums and gliders	15.5 (0.5 – 34.0)	7.0 (0.5 – 26.5)	314,174
Kangaroos, wallabies and rat-kangaroos	0.8 (0.1 – 2.6)	0.5 (<0.1 – 1.0)	22,441
Bandicoots	2.1 (0.1 – 2.7)	1.7	76,299
Antechinuses, dunnarts and other carnivorous marsupials	9.5 (1.5 – 24.9)	3.8 (0.5 – 52.0)	170,552
Native mice and rats	2.9 (0.5 – 20.0)	4.3 (0 – 44.0)	192,993

Table 3: Estimates of density of native mammals from different habitats and regions, and total numbers to be killed annually by land clearing approvals for 2005.

* Data sources: Abensperg-Traun, M. 1990. Patch selection and patch use in the echidna, *Tachyglossus aculeatus* Shaw 1792 (Monotremata: Tachyglossidae), in Western Australian wheatbelt reserves. PhD thesis, University of Western Australia; Barrott, E. 1999. Census techniques, habitat use and distribution of koalas in the Pilliga State Forests. Hons thesis, University of Sydney; Dickman, C.R. 1980. Ecological studies of *Antechinus stuartii* and *Antechinus flavipes* (Marsupialia: Dasyuridae) in open-forest and woodland habitats. *Australian Zoologist* 20: 433-446; Dickman, C.R. 1993. The biology and management of native rodents of the arid zone in New South Wales. *New South Wales National Parks and Wildlife Service Species Management Report* 12: 1-149; Dickman, C.R. and Read, D.G. 1992. The biology and management of dasyurids of the arid zone in New South Wales. *New South Wales National Parks and Wildlife Service Species Management Report* 11: 1-112; Hartley, M. 2002. *Sarcoptes scabei var. wombati* infection in the common wombat (*Vombatus ursinus*). M.Appl. Sci. thesis, University of Sydney; Kerle, J.A. 2001. *Possums: the Brushtails, Ringtails and Greater Glider*. University of New South Wales Press: Sydney; Martin, R.W. 1985. Overbrowsing, and decline of a population of the koala, *Phascolarctos cinereus*, in Victoria III. Population dynamics. *Australian Wildlife Research* 12: 377-385; Skerratt, L.F., Skerratt, J.H.L., Banks, S., Martin, R. and Handasyde, K. 2004. Aspects of the ecology of common wombats (*Vombatus ursinus*) at high density on pastoral land in Victoria. *Australian Journal of Zoology* 52: 303-330; Southwell, C. 1987. Macropod studies at Wallaby Creek II. Density and distribution of macropod species in relation to environmental variables. *Australian Wildlife Research* 14: 15-33; Tasker, E.M. 2002. The ecological impacts of cattle grazing, and associated grazier burning in the eucalypt forests of northern NSW. PhD thesis, University of Sydney: Sydney; and numerous chapters in books edited by Goldingay, R.L. and Jackson, S.M. (eds). 2004. *The Biology of Australian Possums and Gliders*. Surrey Beatty & Sons: Sydney; Grigg, G., Jarman, P. and Hume, I. (eds). 1989. *Kangaroos, Wallabies and Rat-kangaroos*. Surrey Beatty & Sons: Sydney; Jones, M.E., Dickman, C.R. and Archer, M. (eds). 2003. *Predators with Pouches: The Biology of Carnivorous Marsupials*. CSIRO Publishing: Melbourne; Lunney, D. (ed.). 1991. *Conservation of Australia's Forest Fauna*. Royal Zoological Society of New South Wales: Sydney; Lunney, D. (ed.). 2004. *Conservation of Australia's Forest Fauna*, 2nd edition. Royal Zoological Society of New South Wales: Sydney; Lunney, D., Urquhart, C.A. and Reed, P. (eds). 1990. *Koala Summit: Managing Koalas in New South Wales*. NSW National Parks and Wildlife Service: Sydney; Seebeck, J.H., Brown, P.R., Wallis, R.L. and Kemper, C.M. (eds). 1990. *Bandicoots and Bilbies*. Surrey Beatty & Sons: Sydney; Smith, A. and Hume, I. (eds). *Possums and Gliders*. Surrey Beatty & Sons, and the Australian Mammal Society: Sydney.

** Calculated using mean density estimates of each mammal species / group from the tablelands, western slopes and plains.

2. MAMMALS

2.3 HOW HAVE THESE NUMBERS BEEN ESTIMATED?

Continued

Several decisions were taken that have led to very conservative estimates of numbers being made. Specifically:

- Many species were excluded from estimates because there is insufficient information on their abundance. The largest omission is the entire NSW bat fauna (37 species), for which no information on density could be found.
- Many small mammals in semi-arid and arid regions exhibit large fluctuations in density depending on the prevailing weather. For example, historical accounts of the long-haired or plague rat (*Rattus villosissimus*) suggest that densities well in excess of 1000 animals per hectare can be attained after years of good rain[31], with the species virtually disappearing again during drought. For such eruptive species, only the low-density population estimates were used.
- The densities of several common species, such as the brown antechinus (*Antechinus stuartii*), agile antechinus (*A. agilis*), yellow-footed antechinus (*A. flavipes*) and brushtail possum (*Trichosurus vulpecula*) have been measured in several studies, with most yielding low to moderate densities but small numbers of studies yielding very high estimates. To reduce bias arising from these rare high values, means for each species were first calculated as log-transformed densities and then back-transformed to produce normal values. This method was used also by Cogger *et al*.[32]
- Several species were omitted from consideration due to uncertainty about how vegetation clearing would affect them. Exclusions included red kangaroos (*Macropus rufus*), eastern grey (*M. giganteus*) and western grey kangaroos (*M. fuliginosus*), which can flee clearing operations that are in progress; rock-wallabies (*Petrogale species*), platypus (*Ornithorhynchus anatinus*), the water rat (*Hydromys chrysogaster*) and the dusky hopping-mouse (*Notomys fuscus*), as these species occupy habitats not directly subject to clearing; and species that are largely restricted to arid desert country with few trees and shrubs (three species were in this category, the planigales, *Planigale gilesi* and *P. tenuirostris*, and Forrest's mouse *Leggadina forresti*). Although these latter species sometimes occur in wooded habitats, most records in NSW are from open habitats that are not likely to be cleared.[33]
- As noted, the usually lower densities obtained from studies carried out in the tablelands, western slopes and plains were used in preference to the higher estimates obtained in surveys further east.

Despite the uncertainties inherent in extrapolating numbers of animal mortality over large areas, the above points ensure that the estimated numbers are conservative. Omission of the bat fauna alone will lead to a substantial underestimation of the true impact of vegetation clearing, even though it is known to be a highly destructive process for many species[34]. In addition, habitats near cleared areas are usually reduced in quality due to the effects of fragmentation and processes that occur along the boundary of the cleared area, including increased access by pests and feral predators such as foxes.[35] Although these indirect effects of vegetation clearing are less obvious and longer-term, they highlight the conservative nature of the estimates that we provide here.

2.4 DO MAMMALS DIE WHEN THEIR NATIVE HABITAT IS CLEARED?

Does vegetation clearing actually kill mammals, or simply displace them? From an ecological perspective, clearing of vegetation has several immediate effects on the mammals that use it. Some individuals can be expected to die of injury or trauma sustained during the clearing process. For survivors, clearing removes shelter from the extremes of weather, cover from predators, depletes or destroys food resources, and disrupts the familiar home range and social environments that individuals experienced pre-clearing. The cleared environment is therefore inimical to the survival of mammals. Some species such as large kangaroos make use of open pastures, but still need some remnants of scrubbier vegetation for shelter.

If mammals cannot survive in a newly-cleared environment, can they survive if they move to uncleared areas of vegetation? The answer is 'no', for several reasons. Firstly, except for some desert-dwelling species most native mammals are sedentary, and many will even 'home' back to a familiar location if they are displaced.

Within Australia, NSW has a particularly poor conservation record for its mammals, with the worst-affected regions lying west of the Great Dividing Range

Secondly, uncleared areas of vegetation will be occupied by resident animals. In the short-term, residents will often repel intruders and prevent them from relocating. In the longer term, if displaced individuals do settle, they will increase demands on scarce resources in the reduced areas of uncleared land, and population numbers in the fragments will decline. Thirdly, even if unoccupied land is available, there is no guarantee that it will be suitable for displaced individuals to use. For example, Tyndale-Biscoe and Smith experimentally removed greater gliders (*Petauroides volans*) from a block of forest and then waited to see if gliders from a logged block next to it would use it.36 They did not; animals moved in at the same very low level as they did into fully occupied forest. Finally, a serious problem for mammals displaced by vegetation clearing is that they face a very high risk of being taken by predators such as red foxes (*Vulpes vulpes*), feral cats (*Felis catus*) and dogs (*Canis lupus familiaris*). For example, a study of ringtail possums (*Pseudocheirus peregrinus*) released experimentally into Ku-ring-gai Chase National Park, near Sydney, Augee *et al*. (1996) found that 110 of 118 animals whose fates they could determine were killed by predators. The impacts of predators on displaced mammals have been documented in several studies.37

2.5 FUTURE OF MAMMALS IN NEW SOUTH WALES

As well as Australia having the world's highest extinction rate for native mammals in the last 200 years, a further 83 terrestrial species and subspecies are currently listed as being at risk of extinction.[38] Within Australia, NSW has a particularly poor conservation record for its mammals, with the worst-affected regions lying west of the Great Dividing Range[39]. These regions are where much vegetation clearing now occurs. Clearing of vegetation and subsequent land uses such as grazing and cropping have been identified previously as major threats for mammals in these regions.[40] Looking to the year 2038, Dickman constructed three scenarios for NSW mammals.[41] The first scenario predicted increased mammalian diversity due to discoveries in fauna surveys and research, and the second foresaw no change. In both scenarios, no further extinctions were envisaged. In the third scenario, land clearing and other threatening processes were seen as continuing without check, and reducing the State's mammal fauna from its original 130 species to just 53 species by 2038. The destruction of some 60% of the State's native mammals would be unprecedented on a world scale. Continued land clearing has the potential to push us closer to this apocalyptic scenario.

2.6 CASE STUDIES:

THE EFFECTS OF CLEARING ON POSSUMS AND GLIDERS

Surveys in recent years have shown that over 300 species of native vertebrates use tree hollows for shelter, with 83 of these species (31%) being mammals.[42] Many more species use trees and shrubs as arenas for social interactions, to move about in the canopy, to escape predators and other enemies on the ground, to search for insects and other foods, or to eat the leaves, buds and flowers on the plants directly.[43] For slow-moving species, such as koalas and possums, we can expect many individuals to be killed by the trauma of tree fall or by associated injuries sustained in the clearing operation.[44] If animals do survive the process of clearing, what prospects do they have afterwards? Quantitative information from two case studies of possums and gliders shows that most will die.

1 GREATER GLIDER (*PETAUROIDES VOLANS*)

Occurring broadly in forest and woodland in eastern Australia, this large gliding possum depends on hollows in old trees for shelter and specialises in eating the leaves of a small number of *Eucalyptus* species. During clearing operations animals may escape being crushed by gliding as trees fall. In a detailed study by Tyndale-Biscoe and Smith[45], near Canberra, the authors captured and marked every glider that escaped tree fall. Although the study extended for five years, more than three quarters of the marked gliders were never seen again after being marked. Of the few survivors, almost three quarters were recaptured within eight days of tree clearing; these had lost weight and the females had lost their pouch young. The very few animals that survived to the following year typically had home ranges that overlapped a block of forest that had not been felled. Is it possible that the animals that disappeared had simply moved somewhere else? In this particular study the cleared forest was mostly surrounded by pine plantations and open farm land where gliders cannot live. Searches for marked animals failed to find any there. Greater gliders are typically sedentary and are reluctant to move even if unoccupied forest is available.

The authors concluded that, while few greater gliders are killed during tree fall, over 90% remain in their destroyed home range and die soon after. The immediate causes of death are not known, but most likely include starvation, exposure and predation. Some animals can survive, but only if at least part of their home range remains uncleared.

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2 EASTERN PYGMY-POSSUM (*CERCARTETUS NANUS*)

This diminutive possum lives in forest and heath-dominated habitats in south-eastern Australia, and visits flowers to obtain nectar, pollen and occasional insects. It is listed as a vulnerable species in NSW. In the Dorrigo region on the New England Tablelands, eastern pygmy-possums can sometimes be found in scattered remnants of forest that has otherwise been cleared for cattle grazing. Studies of this species in a small (4 hectare) remnant by Bladon *et al*[46] found that possums took readily to nest boxes that were placed in trees, and used them to rear their young. Eighteen months after the studies began, a substantial portion of the remnant (1.4 hectares, 35%) was cleared without warning by the land's new owner. Although two-thirds of the original habitat remained, monthly capture rates of pygmy-possums fell from 33.5% to just 7.8%, and the population from 15-20 animals to only 5-8. In percentage terms, these population reductions were much greater than might have been expected from the loss of habitat. The authors concluded that the population crash was due to immediate losses of possums (i.e., deaths), loss of habitat, and time taken for surviving pygmy-possums to relocate and begin using nest boxes again. There was no evidence that the missing possums had relocated elsewhere. Apart from being surrounded by open pasture, no marked animals were found in other forest remnants around the disrupted one, despite intensive searching.

There were two other unexpected findings in this study. Firstly, the effects of the clearing appeared to be much greater on females than on males. Prior to clearing females comprised about 60% of the adult animals in the population, but in the six months post-clearing the sex ratio fell so dramatically that just one animal out of every five captured was female. Secondly, females that had been carrying young before the clearing event were not seen again, and recruitment of young to the population over the breeding season was zero. These results suggest that even partial clearing can have large and disproportionately negative effects on pygmy-possums and (to quote the authors) "support concerns that the long-term survival of the eastern pygmy-possum in New South Wales is threatened by continued land clearing throughout much of its present range."

3. BIRDS

3.1 OVERVIEW

Some 450 species of birds regularly occur in NSW and about half of these may be found in the eucalypt forests and woodlands of the Great Dividing Range, western slopes and plains. Some 115 species of birds (i. e. about 25%) in NSW are considered to be threatened with extinction in the State. Twenty seven of these threatened species may be found in the woodlands and open forests west of the Great Dividing Range, that is in the habitats that have been most extensively cleared in the last 10 years. Most significantly, the loss and fragmentation of habitat, due to clearing, has been listed as a key threatening process for all of these species. Many of these birds are characteristic of the western slopes woodlands, such as the endangered regent honeyeater (*Xanthomyza phrygia*), swift parrot (*Lathamus discolor*) and black-throated finch (*Peophila cincta*). The box-ironbark forests of the slopes are also the major habitats for vulnerable species such as the grey-crowned babbler (*Pomatostomus temporalis*), diamond firetail (*Staganopleura guttata*) and black-chinned honeyeater (*Melithreptus gularis*).[47]

In addition to these threatened species there is accumulating evidence that many other birds of the inland woodlands and forests are declining and disappearing locally. A continuation of broad-scale clearing of native vegetation will mean that they may soon join the list of threatened species in the State.

3.2 NUMBER OF BIRDS KILLED BY NATIVE VEGETATION LOSS IN NSW

- **Some 13 million native birds died or will die in NSW as a result of the clearing of native vegetation approved between 1998 and 2005.**

It is conservatively estimated that around 13 million birds have died or will die as a result of the clearing of native vegetation approved between 1998 and 2005.

As noted previously, this estimate does not include the number of birds killed by illegal or exempt clearing. For example, over half a million birds would have been killed by illegal clearing in 2005 as estimated by the Auditor-General.

Although the birds that have died or will die will of course include numerous common species, such as noisy miners (*Manorina melanocephala*) and striated pardalotes (*Pardalotus striatus*), they will include a number of species that are threatened in NSW such as regent honeyeaters (*Xanthomyza phrygia*) and grey-crowned babblers (*Pomatostomus temporalis*). Furthermore, an increasing number of woodland birds in NSW are known to be declining, with a likelihood that they will become threatened in the near future, if current threatening processes, such as loss of their habitat, continues.

It is conservatively estimated that around 13 million birds have died or will die as a result of the clearing of native vegetation approved between 1998 and 2005.

3. BIRDS

3.3 HOW HAVE THESE NUMBERS BEEN ESTIMATED?

The estimates have been calculated by multiplying a mean value for bird density by the number of hectares known to have been approved for clearing by the NSW Government.[48]

Birds occur at different densities in different natural habitats, reaching their highest densities in wet forests and their lowest densities in grassland. The available evidence suggests that most recent clearing has been in the Barwon and central west regions of NSW and the eastern parts of the far west. Broadly, this consists of woodland and parkland. In actual fact, vegetation in this region ranges from open eucalypt forests and woodlands, as well as open forest and woodland with varying amounts of *Callitris* pine and *Casuarina*, plus small areas that are dominated by *Acacia*. Some woodlands, for instance those with poplar box (*E. populnea*) contain quite low densities of trees. Generally, birds become less abundant as the density of trees and shrubs declines. Consequently, studies have been sought that estimate the densities of birds in a range of vegetation types that occur in the region of NSW where clearing has been most prevalent.

Table 4 lists the results from a range of locations, mostly in NSW, where bird densities have been estimated. These range from the Tablelands to the eastern part of the Western Plains, and from south of the Murray in Victoria to central Queensland. They include all of the major vegetation types in the region, from woodland to forest, and dominated by gums, boxes, stringybarks and ironbarks (*Eucalyptus*), as well as *Callitris* and *Casuarina*. The density of birds in these sites range from under 10/ha in degraded woodlands in Victoria, poplar box woodland and tablelands woodland after a severe drought, to over 30/ha in white box (*E. albens*) remnants and mixed open forest with many ironbarks near Bundarra. The overall mean value is 20.7 birds/ha.

Therefore some 13 million woodland and forest birds have been or will be affected by the clearing of all vegetation that had been approved by the NSW Government from 1998 to 2005 (640,000 x 20.7 = 13,250,000).

The following table lists the results of estimates of bird densities from a range of locations.

Habitat	Region	Density - Birds/ha	Reference	Notes
Coastal and Range Forests		**Mean = 30.4**		
Open forest and woodland	SE Queensland	9.9 summer, 25.5 winter	Catterall et al. 1998[49]	
Dry sclerophyll forest	Coastal NSW	23.6-51.3	Milledge and Recher 1985[50]	
Wet sclerophyll forest	Coastal NSW	36.8-54.1	Milledge and Recher 1985[51]	
Dry sclerophyll forest	Coastal NSW	31.5	Shields et al. 1985 [52]	
Wet sclerophyll forest	Coastal NSW	25.9-35.5.	Shields et al. 1985 [53]	
Open forest	Sydney	23.3	Keast 1985 [54]	
Silvertop ash, stringybark	Eden	25.6	Kavanagh and Stanton 2003	Unlogged sites only
Tableland Woodlands		**Mean = 19.5**		
Stringybark woodland	New England	21.5-23.6	Ford and Bell 1982 [55]	Large remnant
Stringybark woodland	New England	9.7	Ford et al. 1985 [56]	Same as above but after severe drought
Stringybark, gum, box woodland/ open forest	New England	18.2 breeding, 32.5 winter	Howe 1984 [57]	Continuous forest
Stringybark, gum, box woodland/ open forest	New England	16.1 breeding, 16.6 winter	Howe 1984 [58]	Remnants
Tablelands woodland	S NSW	16.4-20	Recher and Holmes 1985[59]	
Tablelands open forest	S NSW	15-27.6	Recher and Holmes 1985 [60]	
Blakely's red gum, yellow box	ACT	22.8	Er and Tidemann 1996	
Slopes Woodland and Open Forest		**Mean = 35.1**		
Open forest	NW Slopes of NSW	42.8	Oliver et al. 1999 [61]	
Box, stringybark, gum, pine	Pilliga Scrub	25.9	Date, pers comm	
White box woodland	Gunnedah	36.6	Martin et al. 2004	
Plains Woodland and Scrub		**Mean = 13.8**		
Box, gum, pine woodlands	Northern Plains, Victoria	8.2	Antos and Bennett 2004	
Box, gum, pine	Murray Plains	19.7	Oliver and Parker 2006	Mature only – excl. replanted
Eucalypt woodland, brigalow	Emerald, Queensland	21.7	Woinarski et al. 2006	Average of 1973-6 and 2001-2 counts
Poplar box	Central Queensland	9.2	Gilmore 1985 [62]	Number of pairs x 4
Gidgee	Central Queensland	10.2	Gilmore 1985 [63]	Number of pairs x 4
Grassland		**Mean = 1.3**		
Grassland	New England	0.8	Ford and Bell 1982 [64]	Native grassland, scattered trees
Grassland	New England	1.9	Barrett 1995 [65]	Native or Exotic Pasture, Scattered Trees
Rainforest		**Mean = 33.0**		
Rainforest	Coastal NSW	33.0	Shields et al. 1985 [66]	

Table 4: Estimates of the density of birds from a variety of habitats.

3. BIRDS

3.4 WHAT HAPPENS TO BIRDS WHEN THEIR HABITAT IS CLEARED?

Somewhat surprisingly, there seem to have been few studies on the direct impact of vegetation clearance on birds. Birds are considerably more mobile than most mammals and reptiles, and many will survive the immediate clearing and even the burning of wind-rowed vegetation. Eggs and nestlings, and most recently fledged young will probably die immediately. Ludwig et al. (2000)[67] studied the impact of clearing of eucalypt woodlands near Emerald in central Queensland. Four of the six most common bird species were significantly less common in cleared land, and a fifth probably was also negatively affected by clearing. Only the red-backed fairy-wren (*Malurus melanocephalus*) increased in cleared sites, because it prefers dense grassy habitat. Fulton and Majer (2006)[68] looked at the effect of chaining of *Allocasuarina* shrubland in the Western Australian Wheatbelt. They compared sites in uncleared shrubland, in chained but unburnt shrubland and in dead stubble. Again, most woodland birds declined or disappeared after chaining, including two species that are regarded as near threatened, the crested bellbird (*Oreoica guttaralis*) and the white-browed babbler (*Pomatostomus superciliosus*). A few species became more common in the chained site or stubble, for example the willy wagtail (*Rhipidura leucophrys*), and the Richard's pipit (*Anthus novaeseelandiae*) which only moved in after chaining.

The longer term effects of clearing or chaining of woodland, burning of the debris and conversion to pasture of crops can be seen from examining birds in grassland (Table 4). There are typically only one or two birds per ha in grassland, i. e. 90-95% fewer than in intact woodland. It should also be noted that these are mostly not woodland species, such as the pipit.

Therefore, it is reasonable to conclude that almost all woodland birds either die or leave the area after it has been cleared, though some may stay for some time. We can only surmise what happens to birds that leave when their home ranges are destroyed. Those that survive may move into neighbouring habitat or cross open areas to other remnants. This may put them at greater risk of predation (see section 3.4). If they reach suitable habitat this is likely to be occupied by, and defended by, other members of the same species. More likely, they will have to settle for inferior habitat. Although they may survive here for some time, they are unlikely to breed successfully and replace themselves before they die. This could be because safe nest sites such as tree hollows or dense shrubs are lacking or because predators are more common. Also, important foraging sites or foods, such as large tree trunks and nectar may be scarce. Consequently, even though clearing may not kill the majority of the woodland birds directly, over the longer term they will be lost from the landscape.

3.5 FUTURE IMPACTS OF CLEARING OF NATIVE VEGETATION ON BIRD POPULATIONS

Whereas, there may be a direct decline in the populations of woodland birds due to loss of their habitat, what is now becoming clear is that for many species the decline in these populations is actually far greater than simply the proportion of habitat that has been lost.[69] Clearing of native vegetation, especially in those regions where only a small proportion is left, will lead to remnants that are smaller, and more isolated from each other, and also, because they have more edge are likely to be more degraded than continuous woodland. Many woodland birds avoid, or soon disappear from, smaller patches. Furthermore, they may be unwilling to disperse to isolated remnants. Most species are absent from sites smaller than

It is reasonable to conclude that almost all woodland birds either die or leave the area after it has been cleared, though some may stay for some time.

10 ha, but also quite a few species tend to be less frequent in sites less than 100 ha in area. There are many reasons for this, and they interact in complex ways. As well as the chance loss of small populations and difficulties experienced in dispersing, birds in highly fragmented and degraded landscapes may suffer higher rates of predation, especially on their nests, and also competition from aggressive species, such as noisy miners. We perhaps know best what is happening in the case of the robins (see case study).

Taken overall, the impact of clearing and loss of a substantial proportion of the native vegetation may lead to the decline of many woodland birds, and even the regional extinction of some species. This is most evident when only about 10% of the native vegetation remains. This is the case in the Mount Lofty Ranges of South Australia, where the long-term effects of extensive clearing over a century ago are still being felt. As a result, as many as 50 of the 120 native bird species are predicted to eventually disappear as a result of the reduction of habitat area to ten per cent of its former extent.[70] The impact of removing 90% of the native vegetation is also clear in the Western Australian Wheatbelt, and parts of Victoria. Within NSW, critical levels of habitat loss have been reached on parts of the Tablelands. Although we may not yet have reached these critical levels throughout parts of the western slopes and adjoining plains, if we continue to clear at current rates, we shall soon reach the point at which many bird populations move into regional decline and extinction. It is imperative that we limit the amount of clearing of native vegetation in NSW to prevent any further declines and extinctions of our native birds. Unless we do this, any efforts to revegetate will be in vain.

3.6 CASE STUDY:

WHAT IS HAPPENING TO ROBINS?

Robins are a brightly coloured group of birds with two or three species often found in most wooded areas. They have been the subject of many studies and these together provide a clear indication of how the loss, fragmentation and degradation of habitat can affect our woodland birds. Birds Australia conducted its second bird atlas from 1998 to 2002, some 20 years after the first atlas was completed.[71] The atlases have provided one of the few sources of quantitative information on how the abundance of some woodland birds has changed. The robins have fared worse than most, with several species showing a decline in detection rate of 40% or more in NSW (Table 5).

Studies in Western Australia, Victoria and NSW have documented the loss of hooded and yellow robins from vegetation remnants. The Armidale area provides an excellent example. Hooded robins had gone from three patches in the early 1980s, and from three more by 2006. Eastern yellow robins in this time had vanished from two patches. Although these are probably random losses of very small populations – often single pairs, what is worrying is that they are not rescued by immigrants from other patches.

So, are robins unable or unwilling to disperse among isolated patches? Debus[72] moved eastern yellow robins to one patch, which had lost the species in the early 1990s. Some of the birds stayed and even bred successfully, suggesting that the habitat was satisfactory for them, but that they had not been able to reach it. However, two birds travelled 7 km to the reintroduction site from another patch unaided. So yellow robins can move between remnants. Scarlet robins also arrived in another site every spring, probably from over 10 km away. Further translocations have provided less clear-cut results. Few birds stayed in their new locations for long, and in fact, several translocated birds were killed by predators, probably grey butcherbirds (*Cracticus torquatus*). So robins can disperse, but it is a risky exercise, and perhaps they often choose not to cross cleared country.

Whether or not robins can disperse among vegetation remnants may be irrelevant if there are too few young birds available to disperse. Debus found that young fledged from only about 9% of scarlet robin nests in one woodland remnant, a figure very similar to that found by Robinson in more continuous woodland in southern NSW.[73] Yellow robins were more than twice as successful, but even so they barely produced enough young to replace local deaths, let alone provide new dispersers. Scarlet robins only maintained themselves due to the immigrants. The main nest predators were pied currawongs (*Strepera graculina*), which have increased due to the winter supply of exotic berries. However, there are plenty of other nest predators from possums to shrike-thrushes and kookaburras.

Species	Decline in Australia	Decline in NSW
Flame robin	51%	56%
Scarlet robin	31%	55%
Hooded robin	27%	41%
Jacky winter	19%	21%
Crested shrike-tit	25%	18%
Dusky woodswallow	28%	41%
White-browed woodswallow	38%	61%
Black-faced woodswallow	36%	65%
Masked woodswallow	22%	46%
Bush stone curlew		63%

Table 5. Declines in recording rates of robins, and some other woodland birds, in Australia and NSW, between the first and second bird atlas. [75]

Even if they manage to escape nest predators, robins may still struggle to feed their babies. Zanette found that there are fewer ground invertebrates in some smaller remnants, and chicks and incubating females were fed less often in such sites.[74] Fertilised soils also may mean denser grass cover, which can make capture of food difficult for the pouncing robins.

Robins even in extensive eucalypt woodlands are found in much lower densities than in rainforest. This is probably due to lower food abundance, most likely due to the scarcity of leaf litter and perhaps because there is less fallen timber. To some extent this is natural, and to some extent because people have collected firewood.

So, robins are affected by a host of problems as they struggle to survive in their highly modified landscapes. Quite likely other birds, which have not been studied as well, are influenced in the same way.

It is noted that for almost all species the decline has been greater in NSW than in Australia as a whole.


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4. REPTILES

4.1 OVERVIEW

About 830 species of non-marine reptiles are found in Australia - of these, 227 (27%) occur in NSW.

4.2 NUMBER OF REPTILES KILLED BY THE CLEARING OF NATIVE VEGETATION

- **80 million reptiles died or will die in NSW as a result of the clearing of native vegetation approved between 1998 and 2005.**

It is conservatively estimated that more than 80 million reptiles have died or will die as a result of the clearing of native vegetation approved in NSW between 1998 and 2005. In 2005 alone, it is estimated that at least 9.7 million reptiles perished.

However, the actual mortality is likely to be much higher because a conservative population density has been used.

Furthermore, as noted previously, this estimate does not include the number of reptiles killed by illegal or exempt clearing. For example, the level of illegal clearing estimated by the Auditor-General to have occurred in 2005 would have resulted in the deaths of more than 3 million reptiles.

In NSW the highest numbers of reptile species are found in the moister forests of the coast and ranges. This region suffered high levels of clearing of native forest in the nineteenth and early twentieth centuries, so that current clearing rates represent a relatively small proportion of the total native vegetation clearing being undertaken in NSW at the present time. Consequently, though estimates of the number of reptiles perishing as a result of native land clearing in the State have been estimated for all of NSW, the highest annual levels of clearing, and thus the greatest numbers of reptile deaths, are occurring in the approximately three quarters of NSW extending from the western slopes of the Great Dividing Range

It is conservatively estimated that more than 80 million reptiles have died or will die as a result of the clearing of native vegetation approved in NSW between 1998 and 2005.

4.3 HOW HAVE THESE NUMBERS BEEN ESTIMATED?

In the absence of any reliable studies of the total numbers of all reptiles occurring in any given site in Australia, estimates were made by modifying the method developed by Ehmann & Cogger[76], in which they concluded that, on average across Australia, the density of reptiles in any given area was about 200/ha, based on the average presence of about 20 species with a mean density per species of 10 individuals/ha.

However, because an Australia-wide estimate must take into account large areas of reptile-rich desert lands and those of the wet and seasonally-wet tropics, this approach has been modified here to take into account the known distributions of NSW reptiles across various vegetation zones and to estimate the number of species occurring in each zone.

First, each of the major plant associations found in NSW and their original geographic distributions were extracted from a vegetation map in which the 17 vegetation associations defined by Williams[77] that occurred in NSW were later aggregated by Williams[78] into nine broader associations. The approximate areas in which each of these plant associations occur within NSW were estimated, together with the total number of species of reptiles occurring in each association (Table 6).

The resulting species-richness numbers were then weighted to take into account the total areas of each zone in order to arrive at a mean species richness per zone, with the further assumption made (based on qualitative observations) that in any given hectare of any zone, at least 25% of the species found in that zone are likely to be present.

Table 6: Major vegetation associations in NSW and the number of species of reptiles recorded from each association

Vegetation Association	Area of potential occurrence (ha approx)	Reptilian Species Richness	Area x richness weighting
1. Rainforest	1,200,000	33	39,600,000
2. Evergreen sclerophyll forest	14,500,000	124	1798,000,000
3. Woodland & parkland	31,600,000	116	3665,600,000
4. Grassland & savannah	3,000,000	64	192,000,000
5. Malee Scrub & heath	3,300,000	58	191,400,000
6. Mulga & other arid scrub	20,200,000	100	2020,000,000
7. Saltbush & other shrub steppe	7,500,000	71	532,500,000
8. Semi-desert steppe	200,000	56	11,200,000
Total	**81,500,000**	**622**	**8,450,300,000**
Mean	**10,187,500**	**77.75**	**1,056,287,500**

Mean species richness = 77.5
Mean weighted species richness/vegetation type (mean area richness weighting/mean area of potential occurence) = 103.7
Mean weighted species richness/ha = 25.9

4. REPTILES

4.3 HOW HAVE THESE NUMBERS BEEN ESTIMATED?

Continued

Finally, to take into account the lower productivity of NSW's temperate climatic zone, the mean individual species density/ha was reduced from 10^{79} to 5. This reduction is arbitrary, but is intended to demonstrate that when using a very conservative estimate, the deaths of large numbers of reptiles have resulted from the clearing of native vegetation in NSW during the past decade (Table 7).

Year	Approved clearing (ha)	Reptile mortality
2005	45,000	5,827,500
2004	74,000	9,583,000
2003	64,000	8,000,000
2002	58,000	7,511,000
2001	91,000	11,784,500
2000	74,000	9,583,000
1999	161,000	20,849,500
1998	74,000	9,583,000
Total	641,000	82,721,500

Table 7: Estimates of reptile mortalities resulting from the approved clearing of native vegetation in NSW, 1998-2005. Clearing rates, to the nearest thousand, are those recorded by the NSW Auditor-General.[80] Mortality numbers were calculated using the formula N= total area cleared (ha) x mean species richness (25.9) x mean individual species density (5)

4.4 WHAT HAPPENS TO REPTILES WHEN THEIR HABITAT IS CLEARED?

It is commonly, but erroneously, believed that reptiles (and many other animals) displaced by clearing native vegetation will simply 'move on' to the next available patch of suitable habitat. However, reptiles are surprisingly sedentary. Smaller lizards such as many skinks, geckos and dragons usually have home ranges measured in the hundreds of square metres or less. Even many snakes and larger lizards have similarly small home ranges and it is only individuals of some of the larger goannas, snakes, turtles and crocodiles that may range over many hectares or even square kilometres.

Following clearing of native vegetation, crossing areas of hostile habitat to reach other patches of suitable vegetation is therefore not an option for most reptiles. Few would attempt it and those that did will quickly die from predation or exposure to unsuitable climatic conditions.

And so, unlike birds (and other flying organisms), the vast majority of reptiles whose habitats are disturbed by clearing of native vegetation have nowhere to go unless the area cleared is part of a larger, continuous patch. In this case, some of the displaced reptiles may be able to make their way into the remaining remnant.

However, if the area being cleared is an isolated patch that has no direct link - a habitat corridor – to other patches of the same habitat, the majority of reptiles will simply die or be eaten immediately after clearing has occurred. The exceptions are those few species that might have been exploiting disturbed sites in the original habitat (road, track and stream edges, patches of invasive weeds, clearings caused by humans or tree falls) and which may not only survive but also thrive in the remaining habitat. If the clearing is undertaken in stages, some species may survive for a time in windrows prior to burning, but their reprieve is likely to be temporary.

Further, it is often argued that biodiversity loss resulting from native vegetation clearing is a reversible process – that natural regeneration or active rehabilitation by humans can result in recolonisation by those species that constituted the original biodiversity of an area. In reality it is nearly always only a smaller subset of the original species that can successfully recolonise the area, and then only if the rehabilitated vegetation is continuous with an intact, uncleared area of the original habitat. The latter is essential as a source of recruitment of the species originally present. Consequently, the clearing of any *isolated* remnants of native vegetation permanently reduces or eliminates most of their reptile fauna.

Thus, for the great majority (ca. 90%) of native reptiles clearing is a death sentence. Even for those individuals that can make their way to adjacent areas of suitable habitat, the carrying capacity of that habitat is more or less stable and relatively inflexible. Despite seasonal variations in its carrying capacity (for example, as a result of flowering events or drought), it can rarely accommodate a new wave of consuming migrants without serious impacts on its ecological integrity. Therefore new immigrants, if they survive, will do so at the expense of existing residents. The net effect will be the deaths of old and new residents roughly equivalent to the numbers migrating from the original clearing event. Those individuals that fail to migrate to nearby suitable habitat will die.

4.5 THE FUTURE OF REPTILES

The majority of reptiles are declining in numbers, but those at the greatest risk of extinction are those whose declines are driven largely by the loss of native vegetation and the consequent fragmentation of their populations.

4.6 CASE STUDY:

MALLEE/ SPINIFEX – A CASE STUDY IN PERMANENT LOSS OF SPECIES FOLLOWING CLEARING

In a long-term study commenced in 1967[81] and monitored periodically to the present, Cogger studied trends in a population of mallee dragons (*Ctenophorus fordi*) at Round Hill Nature Reserve in mid-western NSW, an area dominated by a rich mallee/spinifex plant community.[82] Other species of reptiles were concurrently recorded within the reserve and, more intensively, in the 3 hectares study plot. Over this same period, large tracts of mallee on adjacent private lands were cleared (mostly for cereal production) and provided an opportunity to study the effects of clearing on the original reptilian residents of the cleared land.

Reptile Species	Regional Generalist	Regional Specialist	Exploits disturbed (post-clearing) habitats
Byrne's gecko (*Diplodactylus byrnei*)	•		
Southern spiny-tailed gecko (*Strophurus intermedius*)	•		
Eastern stone gecko (*Diplodactylus vittatus*)	•		
Beaded gecko (*Lucasium damaeum*)	•		
Beaked gecko (*Rhynchoedura ornata*)	•		
Dtella (*Gehyra variegata*)	•		•
Thick-tailed gecko (*Underwoodisaurus milii*)	•		
Unpatterned delma (*Delma inornata*)	•		
Burton's snake-lizard (*Lialis burtonis*)	•		
Eastern hooded scaly-foot (*Pygopus schraderi*)		•	
Common scaly-foot (*Pygopus lepidopodus*)	•		
Nobbi (*Amphibolurus nobbi*)	•		
Mallee dragon (*Ctenophorus fordi*)		*	
Painted dragon (*Ctenophorus pictus*)	•		
Central bearded dragon (*Pogona vitticeps*)	•		•
Gould's goanna (*Varanus gouldii*)	•		•
Lace monitor (*Varanus varius*)	•		•
Carnaby's snake-eyed skink (*Cryptoblepharus carnabyi*)	•		•
Ctenotus allotropis	•		
Ctenotus atlas		•	
Robust ctenotus (*Ctenotus robustus*)	•		
Schomburg's ctenotus (*Ctenotus schomburgkii*)	•		
Desert skink (*Egernia inornata*)		•	
Tree skink (*Egernia striolata*)	•		•
Mueller's lerista (*Lerista muelleri*)	•		
Spotted lerista (*Lerista punctatovittata*)	•		
Gray's four-toed skink (*Menetia greyi*)	•		
Boulenger's morethia (*Morethia boulengeri*)	•		•

Table 8: The reptile species permanently extirpated from native mallee/spinifex plant communities following clearing for cereal production – vicinity of Round Hill Nature Reserve, NSW.

Reptile Species	Regional Generalist	Regional Specialist	Exploits disturbed (post-clearing) habitats
Dull morethia (*Morethia obscura*)		•	
Western blue-tongue (*Tiliqua occipitalis*)		•	
Eastern blue-tongue (*Tiliqua scincoides*)	•		•
Shingleback (*Tiliqua rugosa*)	•		•
Southern blind snake (*Ramphotyphlops australis*)	*		
Prong-snouted blind snake (*Ramphotyphlops bituberculatus*)		•	
Carpet python (*Morelia spilota*)	•		
Western brown snake (*Pseudonaja nuchalis*)	•		•
Coral snake (*Simoselaps australis*)	•		
Dwyer's black-headed snake (*Parasuta dwyeri*)	•		
Bandy-bandy (*Vermicella annulata*)	•		

Species present = 39

Mallee specialists = 7 (18%)

Regional generalists (found in a range of regional vegetation associations) = 32 (82%)

Exploiters of post-clearing habitats = 10 (26%)

Of the 39 reptile species recorded from the reserve (Table 8), 7 (18%) are essentially mallee specialists that were not or rarely encountered outside intact mallee/*Triodia* habitats within the region. A further 32 species were regional generalists in that they also occurred in a range of vegetation associations – *Callitris* and other native parklands and woodlands, and in rocky outcrops, stony hills and lightly-wooded grazing lands within the region.

Only 10 species – generally snakes and larger lizards such as the western brown snake (*Pseudonaja nuchalis*), shingle-back lizard (*Tiliqua rugosus*) and Gould's goanna (*Varanus gouldii*) – readily exploited cleared land and regrowth. Some of the arboreal generalists – for example the Dtella (*Gehyra variegata*) and the tree skink (*Egernia striolata*) - continued to occupy isolated trees and copses left after clearing has occurred. This group represented 26% of the species present in the undisturbed mallee.

But for the majority of species in this study, clearing resulted in their permanent extirpation from the areas in which they originally occurred. Twenty-nine species (74% of the 39 species found in the intact mallee/spinifex community) were lost. Using the conservative calculation shown above/below (assigning a mean density per species of 10 individuals/ha) indicates that at this study site at least 290 reptiles are killed for every hectare cleared for commercial production, and that the 'standing crop' or biomass of each of these native species is not only permanently reduced, but the ecosystem services and productivity of the cleared land are also permanently compromised.

Accurate figures on past and recent mallee clearing rates in NSW are unavailable, although the Australian Natural Resources Atlas[83] estimates that of the 36,746 km^2 of mallee woodlands and shrublands present in pre-European NSW, 92% (33,889 km^2) remained uncleared in 1997. Yet in 1974 Specht *et al*. (basing their calculations on Williams' 1955 vegetation map of Australia) estimated the area of semi-arid mallee in NSW as 25,000 km[84]. These differences reflect differences in both the vegetation classifications used over time and the unreliability of available estimates of mallee distribution and clearing rates.

This case study is not intended to imply that no mallee should ever have been cleared, or should not be cleared in the future, for commercial production. Rather, it is argued that the long-term impacts of clearing of any native vegetation can vary widely in its impacts on regional and national biodiversity. Such clearing should be part of a well-developed regional plan that aims to optimise the retention of viable wildlife corridors and to set aside other areas for sustainable biodiversity conservation. In other words, every hectare of surviving mallee is not of equal value for biodiversity conservation purposes. Cairnes (1989) suggested a set of land use planning policies for mallee ecosystems in NSW that could as well serve as a guide for all native ecosystems.[85]

However policies to date, even when developed and implemented through legislation, have been shown by the NSW Auditor-General[86] to fail miserably unless the Government of the day is prepared to rigorously police its own legislation.

5. CONCLUSION

WWF called on a team of specialists to provide this estimate of the impact of the rates of clearing of native vegetation in NSW on mammals, birds and reptiles approved between 1998 and 2005 inclusively. The figures are clearly dire and show that the long-term impacts of clearing native vegetation are disastrous for wildlife in NSW.

More than 104 million native mammals, birds and reptiles have died or will die as a result of the clearing of native vegetation approved by the NSW government between 1998 and 2005.

Despite a decade of native vegetation legislation, NSW has implemented no Statewide system of monitoring changes to its vegetation, recording the amount of vegetation being lost or even comprehensively classifying its vegetation types.

These impacts are additional to the many millions of native animals that have died or will die as a result of other clearing activities in NSW, such as illegal clearing and exempt clearing during this period. Furthermore, enormous loss of native wildlife has occurred in NSW as a result of the clearing of native vegetation prior to 1998 and since European settlement. For example, figures for the previous decade 1988-1998 suggest that annual native vegetation clearing rates have long been substantial, though variable, and of a similar order to those that occurred in the period 1998-2005.

In addition, the full impact of NSW's past land clearing on native animal populations is still to be felt. The native vegetation already lost in NSW has created an extinction debt that is yet to be paid and has set in train a process of regional and ultimately Statewide extinctions of entire populations.

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...the long-term impacts of clearing native vegetation are disastrous for wildlife in NSW.

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