

Recovery Plan for the Large Forest Owls



Powerful Owl
Ninox strenua



Sooty Owl
Tyto tenebricosa



Masked Owl
Tyto novaehollandiae

October 2006

Department of Environment and Conservation (NSW), 2006.

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Executive Summary

This document constitutes the formal New South Wales State recovery plan for the three large forest owls of NSW - the Powerful Owl *Ninox strenua* (Gould), Sooty Owl *Tyto tenebricosa* (Gould) and Masked Owl *Tyto novaehollandiae* (Stephens). It considers the ecological requirements of the three species across their known range in NSW and identifies the actions that need to be taken to ensure their long-term conservation as well as the parties who will undertake these actions.

The large forest owls of NSW are each listed as Vulnerable under Schedule 2 of the NSW *Threatened Species Conservation Act 1995*.

They are unique to the Australasian region and represent ancient elements of our fauna. The owls are of great scientific and community interest as flagship species for the conservation and management of mature forest ecosystems. As top order carnivores, they may also play an important role in the functioning of forest ecosystems and may act as indicators for other hollow-dependent and specialised species.

Loss of habitat through extensive forest clearing and fragmentation for agriculture, pine plantations, mining, major infrastructure and urban developments has contributed to permanent regional declines and local extinctions of these large forest owl species across their range.

This recovery plan aims to establish a landscape-scale conservation framework to ensure that all three owl species remain viable in the wild in NSW in each region where significant populations occur. The recovery actions detailed in this plan are directed towards protection and management of the species and their habitats, validation of habitat models, monitoring of owl occupancy of territories and population parameters, increasing community awareness and involvement in owl conservation, and promotion of key research.

It is intended that this recovery plan be implemented over a five year period, by which time the outcomes and/or progress of the proposed recovery actions will be assessed and updated.



Lisa Corbyn
Director General



Bob Debus MP
Minister for the Environment

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1 Introduction

The large forest owls of NSW are the Powerful Owl *Ninox strenua* (Gould) of the family Strigidae, and the Sooty Owl *Tyto tenebricosa* (Gould) and Masked Owl *Tyto novaehollandiae* (Stephens) of the family Tytonidae. These three species present special problems for researchers and forest managers. They are difficult to study because they are nocturnal, wide-ranging and naturally uncommon throughout their distributions. They are considered sensitive to logging and other forms of habitat disturbance since they are among the top order carnivores in the forest ecosystems of eastern Australia and many of their main prey species and nesting requirements depend on elements of old-growth forest (Debus 1994a, Kavanagh 1997, Milledge 2004).

Each of the large forest owls are listed as threatened in NSW. Early assessments of their conservation status by Lunney *et. al.* (2000) suggested that the populations of each species and their current distributions have declined.

Up until 1988 only a small number of records existed for these three species. Systematic surveys for the owls have now been conducted in most forested regions of NSW, with most survey effort concentrated in public forests. Estimated minimum population sizes for each species in NSW are: Powerful Owl 2000 pairs, Sooty Owl 2000 pairs, Masked Owl 1500 pairs, or about 8,000-10,000 individuals of each species, not including non-breeding birds. It is now known that these owls are each widely distributed throughout their ranges in NSW and each occurs mostly within conservation reserves and state forests. Although the majority of broad scale systematic surveys for these species have been undertaken in these areas rather than private lands.

All are currently, or have been threatened by clearing of forest and woodland for agriculture, pine plantations, mining, major infrastructure, urban developments and intensive harvesting practices for wood production in native forests. Logging and assorted management practices potentially remove many of the hollow trees on which the owls and their prey depend.

This recovery plan was prepared in accordance with the requirements of the TSC Act. It describes the biology and ecology of each species and considers the processes threatening their survival and conservation requirements. The plan documents the management and research actions undertaken to date and identifies the actions needed to ensure the long-term viability of the three species in NSW.

2 Legislative Context

2.1 Legal status

In NSW, the three large owl species are listed as Vulnerable on Schedule 2 of the TSC Act. They are not listed nationally under the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act).

2.2 Recovery plan preparation

A draft recovery plan for the large forest owls was prepared and publicly exhibited in May 2005. A report on the submissions made regarding the draft recovery plan was prepared for the Minister for the Environment as required by the TSC Act. This final recovery plan has been amended in response to the public submissions, new information and recent changes to natural resource management in NSW.

Reforms to the threatened species legislation in 2004 established a threatened species Priorities Action Statement (PAS) which sets out the recovery and threat abatement strategies for each threatened species, population and ecological community and key threatening process. This recovery plan identifies priority actions which will be incorporated into the PAS.

2.3 Recovery plan implementation

The TSC Act requires that a public authority must take any appropriate measures available to implement actions included in a recovery plan for which they have agreed to be responsible. Public authorities and councils identified as responsible for the implementation of recovery plan actions are required by the TSC Act to report on measures taken to implement those actions. In addition, the Act specifies that public authorities must not make decisions that are inconsistent with the provisions of a recovery plan.

The public authorities responsible for reporting on the implementation of this recovery plan are the DEC and DPI (Forests NSW). However, a number of proposed actions will assist Local Government and Catchment Management Authorities.

The support and involvement of corporate sponsors, university researchers and community groups in the implementation of this recovery plan is encouraged.

2.4 Critical habitat

The three large forest owls are not currently eligible for declaration of Critical Habitat as they are not listed as Endangered under Schedule 1 of the TSC Act.

2.5 Key threatening processes

The Key Threatening Process (KTP), 'clearing of native vegetation' has been identified as having an adverse effect on the three large forest owls. The Masked Owl was also identified by the NSW Scientific Committee as being potentially adversely affected by the listed KTP 'removal of dead wood and dead trees'. In the longer term, the KTP 'human caused climate change' may also have impacts on the three large forest owls. In addition to these listed KTPs, a range of other processes are recognised as threatening the survival of these species in NSW (see section 7.1).

2.6 Relationship to other state legislation

Large forest owls are broadly distributed and occur across numerous land tenures. NSW legislation relevant to the management of large forest owls include the:

- *National Parks and Wildlife Act 1974 (NPW Act)*
- *Environmental Planning and Assessment Act 1979 (EP&A Act)*
- *Local Government Act 1993 (LG Act)*
- *Native Vegetation Act 2003 (NV Act)*
- *Rural Lands Protection Act 1998 (RLP Act)*
- *Rural Fires Act 1997 (RF Act) and*

- *Forestry and National Park Estate Act 1998 (F&NPE Act)*

Those public authorities and organisations relevant to the management of the three large forest owls are provided in Appendix 3.

2.7 Environmental assessment

When exercising a decision-making function under Parts 4 and 5 of the EP&A Act, decision-makers must consider known and potential habitat of threatened species, biological and ecological factors and the regional significance of individual populations.

Consent and determining authorities are advised that it would be appropriate to give consideration to relevant recovery plans when exercising a decision-making function under Parts 4 and 5 of the EP&A Act. Therefore, consent and determining authorities should take into account the recovery actions outlined in this plan when considering any activity which may affect large forest owls or their habitat. Guidelines for the assessment and mitigation of impacts on large forest owls are to be prepared as an action in this recovery plan. In addition, the plan recommends assessing the effectiveness of mitigation measures that have previously been applied to reduce the impacts of developments on these species.

Any other action not requiring approval or development consent under the EP&A Act or meeting other specified exemptions and which is likely to have a significant impact on the three large forest owls or their habitats, will require a Section 91 licence from the Director General of DEC under the provisions of the TSC Act. Such a licence can be issued with or without conditions, or can be refused. A licence is not required:

- To carry out routine agricultural management activities under the TSC Act and *Native Vegetation Act 2003* (NV Act);
- For actions which are carried out in accordance with a consent or approval under the EP&A Act;
- For actions carried out in accordance with a Property Management Plan approved by the Director General of DEC (section 113B of the TSC Act),
- For actions carried out in accordance with an approved Property Vegetation Plan under the NV Act;
- For emergency actions authorised under the *Rural Fires Act 1997* or *State Emergency and Rescue Management Act 1989*.

Reforms to threatened species legislation in 2004 have enabled the Minister for the Environment to certify Environmental Planning Instruments (EPs). Biodiversity certification will enable local government in areas with high development pressure to provide for the protection of biodiversity, including threatened species at the strategic planning stage.

Certification can switch off the need for threatened species assessment under the *EP&A Act*. Biodiversity must be maintained or improved for certification to be conferred. Certification may be granted for part of a local environmental plan (LEP) or individual species within the LEP, depending on the quality of the available data. Biodiversity certification lasts for up to ten years and can be extended. At the time of writing, no EPs have been certified.

The DEC is developing a Biodiversity Banking and Offset Scheme (BioBanking) to provide a robust method for application of an 'improve or maintain' test to developments under the EP&A Act and formalise arrangements for the use of credits to offset the impact of development. The scheme is likely to commence in 2007.

In NSW, the clearing of native vegetation on private land is subject to either an approved development application or a Property Vegetation Plan (PVP). The PVP is a legal agreement under the *Native Vegetation Act 2003* which details the management of native vegetation on a property. It lasts for 15 years and must “maintain or improve environmental outcomes”. A PVP is developed with and approved by the Catchment Management Authority (CMA) using the PVP Developer (a software program which is designed to assess impacts on threatened species, populations and ecological communities) and provides the basis for financial incentives for landholders and consistent management of native vegetation within CMAs. PVPs should also be consistent with Catchment Action Plans developed by CMAs. The PVP Developer includes a module to assess biodiversity values, including threatened species habitat.

As part of the Integrated Forestry Operations Approvals (IFOAs) held by DPI (Forests NSW), the DEC has issued licences under the TSC Act for the operation of forestry activities within certain regions. These licences set out minimum measures to protect threatened species and protect their habitat from activities associated with timber harvesting. At the time of writing, IFOAs have been signed for the Lower North East Region, Upper North East Region, Eden Region, and South Coast and Tumut subregions of the Southern Region. An action in the plan is to assess the implementation and effectiveness of prescriptions designed to mitigate the impacts on the three large forest owl species.

3 Conservation Status

The three large forest owls all have their NSW distributions centred on, or most concentrated in, the forests of the coast, escarpment and tablelands and are widespread throughout these environments (Debus 1994b, Debus and Chafer 1994, Debus and Rose 1994, DEC Atlas of NSW Wildlife). In addition, the Powerful Owl and the Masked Owl occur at lower population densities in the drier forests and woodlands of the western slopes of NSW (Kavanagh 2002b) and the Masked Owl is sparsely distributed on the western plains.

The first assessments of the distribution, abundance and conservation status of these owls were made only recently. Before 1988, no standardised method existed for surveying populations of large forest owls and no systematic surveys had been conducted in Australia (Kavanagh and Peake 1993a). Since then the numbers of records of these owls, and data about their responses to disturbance, have been increasing rapidly. Most assessments of their conservation status were made in the early-mid 1990's, before the extent of current knowledge became available.

As previously stated, in NSW the owls are all listed as Vulnerable on Schedule 2 of the TSC Act. Lunney (*et. al.* 2000) assessed the conservation status of each of the large forest owls prior to their inclusion on the now defunct *Endangered Fauna (Interim Protection) Act 1991*. Each species was automatically included on the schedules of the TSC Act when it came into effect in 1995.

The reasons contributing to listing the Powerful Owl were: population size between 1,0001 and 10,000 individuals, population suspected to be declining, current distribution within NSW is between 10001 – 100000 Km² and distribution in area has declined by 26-50%. Contributing reasons for listing the Sooty Owl were population size between 1,0001 and 10,000 individuals, population suspected to be declining, current distribution within NSW is between 10001 – 100000 Km² and current distribution has declined by an unknown extent. Lastly, contributing reasons for listing the Masked Owl were: population size between 1,0001 and 10,000 individuals, population suspected to be declining, current distribution within NSW is between 100001 – 400000 Km² and distribution in area has declined by 26-50%.

The Powerful Owl is listed as Threatened in Victoria, Vulnerable in Queensland, and a species of least concern (on a conservation priority scale) Australia-wide (Garnett and Crowley 2000). As it occurs nowhere else in the world, it has been considered globally vulnerable (Collar *et al.* 1994), but Kavanagh and Stanton (2002) considers this to be a misrepresentation.

The southern Sooty Owl, subspecies *tenebricosa*, which occurs in NSW, is considered Threatened in Victoria, Rare in Queensland, and a species of least concern Australia-wide (Garnett and Crowley 2000). The New Guinea subspecies is not listed as threatened.

The southern Masked Owl, subspecies *novaehollandiae*, is considered Vulnerable in NSW and is listed as Threatened in Victoria. The northern subspecies, *kimberli*, is considered Vulnerable in Queensland. The other Australian subspecies are either Near Threatened or Endangered (Garnett and Crowley 2000), although the Tasmanian subspecies *castanops* is also regarded as a pest on Lord Howe Island where it has been introduced. The New Guinea subspecies is not listed as threatened.

3.1 Taxonomic significance

Powerful Owl

The Powerful Owl is a Bassian endemic species, restricted to south-eastern mainland Australia. It is a distinctive member of the *Ninox* genus that is near-endemic to Australasia, with outliers of small, generalised boobook-type *Ninox* owls in South-East Asia and Madagascar. This pattern suggests that *Ninox* originated in, or underwent an ancient radiation in Australia. The closest relatives of *Ninox* may be *Ketupa* (India and Asia) and *Scotopelia* (Africa) (Olsen 1991), indicating a possible Gondwanan origin for this owl group.

Sooty Owl

The southern Sooty Owl is a Bassian endemic, restricted to south-eastern mainland Australia. NSW is a stronghold, as Queensland and Victorian populations are smaller and more fragmented (Higgins 1999.). The Sooty Owl is a member of a distinctive subgenus (*Megastrix*) that is endemic to Australasia. The genus *Tyto* is most diverse in the Australasian region, suggesting that it originated in or underwent an ancient radiation in Australia. The related genus *Phodilus* of Asia and Africa, the only other genus in the family Tytonidae (Schodde and Mason 1997), suggests a possible Gondwanan origin for this owl family.

Masked Owl

The southern Masked Owl is endemic to temperate mainland Australia. Comments on the Sooty Owl, regarding subgenus and genus, also apply to the Masked Owl.

4 Description

Powerful Owl *Ninox strenua* (Gould, 1838)

Obsolete names: Eagle Owl, Great Scrub Owl are no longer in general use. No subspecies.

An Australian endemic species in a distinct subgenus, *Rhabdoglaux*, with the Rufous Owl *Ninox rufa* (see Schodde and Mason 1997). No geographic variation.

Adult: length 60 cm; male 1100-1700 g, female 1000-1600 g. A very large hawk-like brown owl, finely barred above and coarsely marked with wavy bars or chevrons on white underneath. It has prominent orange-yellow eyes in a flat face, and fully feathered legs with large yellow feet (see Schodde and Mason 1980, Hollands 1991, Higgins 1999). The smaller Barking Owl *Ninox connivens* is spotted rather than barred dorsally, and has vertical streaks not bars (or chevrons) underneath.

Fledgling: the head and underparts are downy white with fine dark streaks and dark ear-patches; the wings and tail are initially shorter than those of adults.

Sooty Owl *Tyto tenebricosa* (Gould, 1845)

No other names in general use. One subspecies in Australia (*tenebricosa*), one in New Guinea (*arfaki*). Recent research by Norman *et al.* (2002) has indicated that *T. tenebricosa* is closer to the Lesser Sooty Owl *T. multipunctata* of North Queensland than to *T. t. arfaki* and these authors suggest that the sooty owl complex is treated as a single species *T. tenebricosa*.

The Sooty Owl is an Australasian endemic species in a distinct subgenus, *Megastrix*, with the Masked Owl and Lesser Sooty Owl (see Schodde and Mason 1997). Geographic variation at a continental scale reflects isolation of the Australian from the New Guinea populations. There is slight north-south clinal variation in size within Australia. There is negligible geographic variation in subspecies *tenebricosa* within NSW, which is contiguous with populations in Queensland and Victoria.

Adult: length 40-45 cm, male 450-700 g, female 750-1260 g. Female larger than male. A medium-sized owl (female is large in *Tyto*), with dark eyes set in a prominent flat, heart-shaped facial disc (see Schodde and Mason 1980, Hollands 1991, Higgins 1999). A dark sooty-grey owl with large eyes in a grey face, fine white spotting above and below, and a pale belly. The feet are large and powerful. It is much greyer than the dark form of the Masked Owl.

Fledgling: the plumage is similar to the adult, but fledglings initially have tufts of down on the head and underparts.

Masked Owl *Tyto novaehollandiae* (Stephens, 1826)

No other names in general use in NSW. Five subspecies in Australia (*castanops*, *galei*, *kimberli*, *melvillensis*, *novaehollandiae*) and one in New Guinea (*calabyi*). The taxonomic status of forms in the Bismarck Archipelago and Wallacea is uncertain; they may be separate species (Mason 1983, Schodde and Mason 1997).

An Australasian endemic species in a distinct subgenus, *Megastrix*, with the two sooty owls (see Schodde and Mason 1997). There is pronounced geographic variation at a continental scale, reflected in island subspecies and tropical versus temperate mainland subspecies. Within subspecies *novaehollandiae* of the southern and eastern mainland, there is slight north-south and east-west clinal variation in size and the degree of sexual size dimorphism (Schodde and Mason 1980, Debus 1993). There is negligible geographic variation in subspecies *novaehollandiae* within NSW, which is contiguous with populations in Queensland and Victoria.

Adult: length 40-50 cm, male 350-650 g, female 550-850 g. Female larger than male. A medium-sized owl (female is large in *Tyto*), with dark eyes set in a prominent flat, heart-shaped facial disc encircled by a dark border (see Schodde and Mason 1980, Hollands 1991, Higgins 1999). The feet are large and powerful, with fully feathered legs down to the toes. The owl exists in several colour forms, with wide variation in plumage. The upperparts are grey to dark brown with buff to rufous mottling and fine pale spots. The wings and tail are well barred. The underparts are white to rufous-brown with variable dark spotting; the spots are fine and sparse to profuse and heavy with fine wavy barring on the flanks. The palest birds have a white face with a brown patch around each eye; the darkest birds have a chestnut face. White-breasted males are similar to the Barn Owl *Tyto alba* which is of lighter build, has smaller feet with the lower part of the legs sparsely feathered, a less prominent dark border to the facial disc, and less barred upperparts. Barn Owls are golden in colour with fine black and white-tipped spots on the back. The dark form of the Masked Owl is much browner than the Sooty Owl.

Fledgling: the plumage is similar to adults of the same colour form, but fledglings initially have tufts of down on the head and underparts.

5 Distribution and Habitat

5.1 Current and historical distribution

Powerful Owl

The Powerful Owl lives in forests and woodlands occurring in the coastal, escarpment, tablelands and western slopes environments of NSW (Kavanagh 2002b, Soderquist *et al.* 2002). The owl occupies the eastern one-third of the State, although records are sparse inland (on the western slopes of the Great Dividing Range) and most concentrated on the coast and tablelands (Debus and Chafer 1994, DEC Atlas of NSW Wildlife). There is no seasonal variation in distribution. A map of the distribution of Powerful Owl records in NSW is provided in Appendix 1. The majority of broadscale systematic surveys for this species and also Sooty and Masked Owls have been conducted on public lands, which reflects the large number of records of the species in these areas. A list of Local Government Areas and Catchment Management Areas with records of Powerful Owls is provided in Appendix 2.

The Powerful Owl is more than twice as abundant in north-eastern NSW as in south-eastern NSW and on the western slopes (Kavanagh and Peake 1993b, Kavanagh 1995, Kavanagh and Bamkin 1995, Kavanagh *et al.* 1995, Kavanagh and Stanton 1998). Although the species is widespread throughout its range, its habitat has been reduced or fragmented by clearing for agriculture, pine plantations, mining and major infrastructure, urban developments, and by reductions in habitat quality. It has been estimated that Powerful Owl populations and the area they occupy may have declined by approximately 20-50% since European settlement, with possible contraction of the inland limits of its range (Debus and Chafer 1994, Lunney *et al.* 2000).

Currently, the majority of potential habitat for this species is restricted to conservation reserves and state forests, although the Powerful Owl also occurs within large areas of forest on other public lands and on private land, including suburban bushland. The Powerful Owl has been recorded in many national parks and state forests throughout its range in NSW (Debus 1994a, NSW NPWS 1994, Kavanagh 1997, DEC Atlas of NSW Wildlife). The eastern NSW population is continuous or almost so, with a slight interruption at the lower Hunter Valley. Some inland populations may be isolated (Debus and Chafer 1994).

There have been no translocations of this species.

Sooty Owl

The Sooty Owl lives in the moist eucalypt forests and rainforests of the coastal, escarpment and eastern tablelands regions of NSW (Kavanagh 2002b). The owl occupies the easternmost one-eighth of NSW (Debus 1994b, DEC Atlas of NSW Wildlife). There is no seasonal variation in its distribution. A map of the distribution of Sooty Owl records in NSW is provided in Appendix 1. The Sooty Owl is more than twice as abundant in north-eastern NSW as in south-eastern NSW and the species does not occur on the western slopes (Kavanagh and Peake 1993b, Debus 1994a, Kavanagh 1995, Kavanagh and Bamkin 1995, Kavanagh *et al.* 1995, Kavanagh and Stanton 1998). The Sooty Owl is widespread throughout its range but within the limits imposed by the distribution of its specialised habitat. Its range has been reduced or fragmented by forest clearing for agriculture and urban developments, and by reductions in habitat quality. It has been estimated that Sooty Owl populations and the area they occupy may have declined, but the extent is unknown (Lunney *et al.* 2000).

Currently, the majority of potential habitat for this species is restricted to conservation reserves and state forests, although there are a few records of the Sooty Owl occurring within the wettest and most fertile areas of forest occurring on private land. The Sooty Owl has been recorded in many national parks and state forests throughout its range in NSW (Debus 1994a, NSW NPWS 1994, Kavanagh 1997, DEC Atlas of NSW Wildlife). A list of Local Government Areas and Catchment Management Areas occupied by Sooty Owls is provided in Appendix 2. Northern and southern NSW populations are disjunct separated by the Hunter Valley (Debus 1994b). Otherwise, there are no isolated populations.

There have been no translocations of this species.

Masked Owl

The Masked Owl lives in eucalypt forests and woodlands from the coast, where it is most abundant, to the western plains (Kavanagh 2002b). Inland records for this species are sparse but, overall, records fall within approximately 90% of NSW, excluding the most arid north-western corner (Debus and Rose 1994). There is no seasonal variation in distribution. A map of the distribution of Masked Owl records in NSW is provided in Appendix 1.

Generally, the Masked Owl appears to be less common than the other two large owls in heavily-forested areas. In such environments, it is more than twice as abundant in north-eastern NSW as in south-eastern NSW and on the western slopes (Kavanagh and Peake 1993b, Kavanagh 1995, Kavanagh and Bamkin 1995, Kavanagh *et al.* 1995, Kavanagh and Stanton 1998). The habitat for this species appears to be widespread throughout its range and there are increasing numbers of records occurring on private land. However, its habitat in woodland and dry forests appears to have been greatly reduced or fragmented by clearing for agriculture and urban developments resulting in widespread local extinctions in the inland regions (Debus and Rose 1994). Its decline in western regions has also been attributed to the collapse of native mammal populations in the inland. In wetter forests, the abundance of this species may have been reduced by intensive logging (Kavanagh and Bamkin 1995). It has been estimated that Masked Owl populations and the area they occupy may have declined by approximately 20-50% since European settlement, with possible contraction of the inland extent of its range (Debus and Rose 1994, Lunney *et al.* 2000).

Potential habitat for the Masked Owl is mostly in conservation reserves and state forests, although this species is also found throughout large areas of forest or woodland on other public lands and on private land, including suburban bushland. The Masked Owl has been recorded in many national parks and state forests throughout its range in NSW (Debus 1994a, NSW NPWS 1994, Kavanagh 1997, DEC Atlas of NSW Wildlife). The eastern NSW population is continuous but some inland populations may be isolated (Debus and Rose 1994). A list of Local Government Areas and Catchment Management Areas occupied by Masked Owls is provided in Appendix 2. There have been no official translocations of wild individuals of the NSW subspecies, although there have been experimental releases of captive-bred juveniles within the owl's historical range. There is high mortality of such juveniles in a rural landscape with high fox density, and low success to independence and dispersal (Debus 1997). Individuals of the Tasmanian subspecies were historically translocated to Lord Howe Island where the owl is now thriving, resisting attempts at eradication, and having an adverse impact on threatened Lord Howe Island endemic vertebrates.

5.2 Significant habitat

Habitat models for large forest owls have been developed for north-eastern NSW (NSW NPWS 1994, Debus 1994a, Kavanagh *et al.* 1995), south-eastern NSW (Kavanagh and Bamkin 1995, Kavanagh 1997) and, more recently, in each of the four areas subject to Regional Forest Agreements (upper north-east NSW, lower north-east NSW, Eden region, and

the south coast and south-western tablelands regions of NSW). Each of these models was based on mapped (remotely-sensed) or visually-estimated variables collected from within specified radii (500-2000m) around each site in the landscape where owl surveys had been undertaken. Some models are better than others, for a variety of reasons, but all are sufficient to obtain a broad understanding of the distribution of important habitat for the owls within coastal NSW and the adjacent escarpment and tableland areas.

Large forest owls respond to geomorphology, moisture regime, vegetation structure and consequent site productivity rather than specific floristics. Using broadscale surveys, owl habitat has been characterised only to the level of broad vegetation systems (rainforest, wet sclerophyll forest, dry sclerophyll forest) rather than to specific forest types. The owls appear to prefer mid to late successional, mixed-age or multi-aged forest greater than 60 years old (Davey 1993), although Powerful and Sooty Owls show no adverse relationship with management history and can forage in forest greater than 20 years old (Kavanagh and Bamkin 1995, Kavanagh *et al.* 1995, Kavanagh 1997). By contrast, the Masked Owl prefers unlogged or lightly logged forest with high densities of old hollow trees and avoids young regrowth (Kavanagh and Bamkin 1995, Kavanagh *et al.* 1995).

Tree hollows used by many of the owls main prey species form in trees greater than 120 years old; those of a size used by owls for nesting and roosting form in trees greater than 150 and probably greater than 200 years old (Mackowski 1984, Lindenmayer *et al.* 1991, Milledge *et al.* 1991). Depending on forest productivity, several major prey species (the gliders and large possums) are each likely to require at least 1-2 hollow trees per hectare, and up to 10-20+ den trees per hectare in the best habitat (Gibbons and Lindenmayer 1997). However, the most important prey species for the Powerful Owl and the Sooty Owl in many areas, the Common Ringtail Possum, does not require tree hollows provided there is a tall, dense shrub layer present in which it can build a drey among the foliage (Kavanagh 1997, Kavanagh 2002b).

Data on specific habitat requirements of the owls presented below are drawn mainly from detailed studies of individual pairs of the owls mostly in coastal eastern and south-eastern NSW (e.g. Kavanagh 1997).

Powerful Owl

Habitat for this species is widespread and primarily tall, moist productive eucalypt forests of the eastern tableland edge and the mosaic of wet and dry sclerophyll forests occurring on undulating, gentle terrain nearer the coast. Optimal habitat includes a tall shrub layer and abundant hollows supporting high densities of arboreal marsupials.

Roosting: groves of dense mid-canopy trees or tall shrubs in sheltered gullies, typically on wide creek flats and at the heads of minor drainage lines, but also adjacent to cliff faces and below dry waterfalls. Species commonly used for roosting include the She-oaks *Allocasuarina* spp., rainforest species such as Coachwood *Ceratopetalum apetalum*, Lilly Pilly *Acmena smithii* and Sassafras *Doryphora sassafras*, Black Wattle *Acacia melanoxylon*, Turpentine *Syncarpia glomulifera* and eucalypts. Roosting sites are commonly among small groves of up to 2 ha of similar-sized trees with dense foliage in the height range 3-15 m. (Kavanagh 1997, Kavanagh 2002b).

Nesting: old hollow eucalypts in unlogged, unburnt gullies and lower slopes within 100 m of streams or minor drainage lines, with hollows greater than 45 cm diameter and greater than 100 cm deep; surrounded by canopy trees and subcanopy or understorey trees or tall shrubs. Hollow entrances are greater than 6 m above ground, commonly more than 20 m where the forest permits, in trees of at least 80 cm diameter at breast height. A pair is generally faithful to a traditional nesting hollow, but also sometimes uses alternative hollows in the nesting gully. (Data from Schodde and Mason 1980, McNabb 1996, Kavanagh 1997, Kavanagh 2002b, Higgins 1999).

Sooty Owl

Habitat for this species is also widespread but limited mainly to the tall, moist eucalypt forests and rainforests of the escarpment and coastal areas. Sooty Owls occur in both steep and undulating country but are strongly associated with sheltered gullies, particularly those with a tall, rainforest understorey.

Roosting: hollows in live or occasionally dead trees, eucalypt or rainforest species, in moist forest; among dense foliage in rainforest gullies; caves, recesses or ledges in cliffs or banks. Roost sites are in the darkest and most secluded or sheltered positions in the forest. Foliage roosts are typically in narrow, gloomy side-gullies near creek junctions or below dry waterfalls, less than 10 m from drainage lines. Foliage roosts used are rainforest species, tree ferns and vine tangles. Hollows used are usually less than 100 m from streams, and are also used as nest sites or have similar characteristics to those used for nesting (based on data from Hollands 1991, Kavanagh 1997, Kavanagh 2002b).

Nesting: old hollow trees, eucalypt or rainforest species, usually live but stags are occasionally used, in unlogged, unburnt gullies and lower slopes within 100 m of streams, with hollows greater than 40 cm wide and greater than 100 cm deep; surrounded by canopy trees. Also nests in caves. Hollow entrances are at least 16 m above ground, in trees of at least 120 cm diameter at breast height. The pair is faithful to a traditional nesting hollow. (Data from Hollands 1991, Kavanagh 1997, Kavanagh 2002b).

Masked Owl

Habitat for this species is also widespread throughout the dry eucalypt forests of the tablelands, western slopes and the undulating wet-dry forests of the coast. Optimal habitat includes an open understorey and a mosaic of sparse (grassy) and dense (shrubby) ground cover on gentle terrain (Kavanagh *et al.* 1995, Kavanagh 1997).

Roosting: hollows in live or occasionally dead eucalypts; dense foliage in gullies; and caves or recesses in cliffs. Hollow sites can be in a variety of topographic positions, from gully to upper slope, and are also used as nest sites or have similar characteristics to those used for nesting. Roost sites in trees are greater than 5 m above the ground. (Data from Debus and Rose 1994, Kavanagh and Murray 1996, Kavanagh 1997, Kavanagh 2002b, Mooney 1997).

Nesting: old hollow eucalypts, live or dead but commonly live, in a variety of topographic positions from gully to upper slope, with hollows greater than 40 cm wide and greater than 100 cm deep; there is no relationship with distance to streams. Nest sites may be subject to a variety of disturbance regimes, which make nest trees susceptible to loss (wind throw and burning). Hollow entrances are at least 3 m above ground, in trees of at least 90 cm diameter at breast height. The pair is faithful to a traditional nesting hollow, but may also use alternative hollows in the breeding territory in different years. (Data from Schodde and Mason 1980, Kavanagh 1996, Kavanagh 2002, Kavanagh and Murray 1996, Mooney 1997, Higgins 1999).

6 Biology and Ecology

6.1 Life history

Powerful Owl

The Powerful Owl lives as monogamous, sedentary life-long pairs in large permanent home ranges. The social unit is an adult pair and 1-2 dependent young. Age at first breeding is 2 years in captivity, unknown in the wild but probably 3 or 4 years. Most (84%) pairs nest each

year and most of those nesting (93%) produce at least one young (Kavanagh 1997). Laying is strictly seasonal, occurring mainly in June (mid-May to mid-July). The clutch is 1-2 eggs; a single clutch is laid per year although, rarely, a replacement clutch may be laid if the first attempt fails early in the egg stage. The incubation period is 5 weeks. There are no data on egg success. Successful broods fledge 1-2 young.

Fledging rates in NSW are at least 1.2 young per nesting attempt or at least 1.5 young per successful nesting attempt (Kavanagh 1997). Based on fewer data, Debus and Chafer (1994) calculated fledging success at 0.8 young per nesting attempt. In Victoria, McNabb (1996) reported 94% nest success and 1.4 young per pair per year, but Hollands (1991) recorded only 0.4-0.5 young per pair per year in western Victoria.

Young are altricial; the nestling period is 2 months; the breeding cycle occupies 3 months from laying to fledging. The male provides food, while the female provides parental care in the egg and chick stages; both sexes provide food from the late nestling stage to independence of the young. The Powerful Owl is highly sensitive to nest disturbance during the egg and chick stages and will readily abandon the nest if disturbed. There are no data on mortality or survival rates. Causes of juvenile mortality include felling of nest trees, disease, starvation, and predation by the Red Fox. Both adults and juveniles are sometimes killed by motor vehicles, and at least one adult was killed by a falling branch during strong winds (R. Kavanagh, DPI Forests NSW *pers. obs.*).

Juveniles are dependent for 6-7 months post-fledging; thereafter they apparently survive either by remaining within the natal territory or by dispersing to other areas. Dispersal ability is unknown, but expected to be at least 10-20 km which may include partly open country. There are no barriers to dispersal or gene flow other than extensive treeless country. Longevity is 25+ years in captivity; possibly 15 years in the wild. (Data from Fleay 1979, Schodde and Mason 1980, Hollands 1991, Debus and Chafer 1994, McNabb 1996, Kavanagh 1997, Higgins 1999).

Sooty Owl

The Sooty Owl lives as monogamous, sedentary, life-long pairs in large permanent home ranges. The social unit is an adult pair and 1-2 dependent young. Age at first breeding is 1 year in captivity, unknown in the wild but potentially 1 or 2 years. Laying is irregular and unpredictable, occurring in most months with peaks in autumn-winter and early spring. The clutch is 1-2 eggs in the wild; a single clutch is laid per year but sometimes (often?) there is no breeding within a year. In captivity, the owl has a higher reproductive potential when food is unlimited: up to three eggs per clutch and two broods per year, of up to three young each. The incubation period is reportedly 6 weeks, though possibly 5 weeks as for the Masked Owl. There are no data on egg success. Successful broods of 1-2 young fledge; from limited data, fledging success in NSW has been calculated as 0.9 young per attempt (Debus 1994b).

Young are altricial; the nestling period is reportedly 2.5-3 months, though possibly 2 months as for the Masked Owl; the breeding cycle occupies up to 4 months from laying to fledging. The male provides food, while the female provides parental care in the egg and chick stages; both sexes provide food from the late nestling stage to independence of the young. There are no data on mortality or survival rates, or causes of juvenile mortality.

Juveniles are dependent for 3-5 months post-fledging; thereafter dispersal is unknown. Dispersal ability is unknown, but expected to be at least 10-20 km which may include partly open country. One hand-reared immature is known to have dispersed 50km from its point of release in Byron Bay NSW (David Milledge *pers. comm.*) There are no barriers to dispersal or gene flow other than extensive treeless country. Longevity in the closely related Lesser Sooty Owl is 20+ years in captivity; possibly 15 years in the wild. Causes of adult mortality include occasional collisions with motor vehicles. (Data from Fleay 1979, Schodde and Mason 1980,

Hollands 1991, Olsen and Marples 1993, Debus 1994b, Kavanagh 1997, Kavanagh and Jackson 1997, Higgins 1999).

Masked Owl

The Masked Owl lives as monogamous, sedentary life-long pairs in large permanent home ranges. The social unit is an adult pair and 1-3 dependent young. Age at first breeding is unrecorded, potentially 1 year in captivity and 1 or 2 years in the wild (as for the Sooty Owl). Laying is irregular and unpredictable, occurring from late summer to spring but mostly March to July. The clutch is 1-4 eggs in the wild; a single clutch is laid per year or sometimes there is no breeding within a year. In captivity, the owl has a high reproductive potential when food is unlimited: up to seven eggs per clutch and four broods per year, of up to five young each. The incubation period is 5 weeks. There are no data on egg success. Successful wild broods of 1-3 young fledge; fledging success is 1.2 young per attempt (Debus 1993).

Young are altricial; the nestling period is 2 months; the breeding cycle occupies 3 months from laying to fledging. The male provides food, while the female provides parental care in the egg and chick stages; both sexes provide food from the late nestling stage to independence of the young. There are no data on mortality or survival rates; causes of juvenile mortality include felling of nest trees, injury, disease, starvation, and predation by the Red Fox.

Juveniles are dependent for 1-3 months post-fledging; thereafter some disperse to marginal habitats. Dispersal ability is 80+ km over partly open country; there are no barriers to dispersal or gene flow. Longevity is 10+ years in captivity. Causes of adult mortality include road kills, rabbit traps, barbed-wire fences, overhead wires, and wildfire. (Data from Fleay 1979, Schodde and Mason 1980, Hollands 1991, Debus 1993, 1997, Olsen and Marples 1993, Debus and Rose 1994, Kavanagh and Murray 1996, Kavanagh 1996, 1997, Bell and Mooney 1997, Higgins 1999).

6.2 Ecology

Powerful Owl

Diet: the Powerful Owl is a specialist predator of arboreal marsupials, particularly the Common Ringtail Possum in coastal forests and the Greater Glider in escarpment and tableland forests. These two mammals comprise more than 80% of the diet for this owl in most territories in NSW. The Powerful Owl has been found to reduce populations of its preferred prey almost to local extinction (Kavanagh 1988, 1992). Other mammals commonly taken include the Sugar Glider, the Common Brushtail Possum and the Grey-headed Flying-fox. This predominantly mammalian diet is supplemented extensively by diurnal birds, in particular by the Pied Currawong and many parrot species. Some large insects are taken in summer-autumn. Rarely, the owls have been recorded taking some scansorial and terrestrial mammals (mainly rats). (Summarised from Debus and Chafer 1994, McNabb 1996, Kavanagh 1997, Kavanagh 2002a and Higgins 1999).

Predators: eggs and nestlings are possibly taken by goannas. Fledglings are taken by the Red Fox, dogs, and possibly by the Wedge-tailed Eagle (McNabb 1996, Kavanagh 1997).

Behaviour: nocturnal; roosts by day in the leafy canopy of trees or tall shrubs. Forages by hunting from perches within the forest or woodland canopy. Larders excess food (remains of large kills) by holding it in the claws on the roost during the day. Home range has been estimated as 300-1500 ha according to habitat productivity; measured as 800 ha for one non-breeding individual and 350 ha for one breeding female closely associated with the nest tree and new fledgling (Kavanagh 1997). Moist forest in unlogged corridors in gully systems is used for nesting and roosting, and also preferentially for foraging although much foraging is also conducted in dry and regrowth forest (Kavanagh 1997). Breeding pairs use traditional

roost sites; a non-breeding individual used many different roost sites (Kavanagh 1997). There is some seasonal shift in site use within the home range: the breeding area is sometimes not used in the non-breeding season (various studies, summarised by Higgins 1999).

Ecological factors required for reproduction: mature forest stands containing large hollow bearing trees. Dense understorey shrubs for fledglings to climb and shelter within. High density of arboreal marsupials, many of which are hollow-dependent. (From Schodde and Mason 1980, McNabb 1996, Kavanagh 1997, Higgins 1999).

Specific habitat requirements: eucalypt forests and woodlands on productive sites on gentle terrain; a mosaic of moist and dry types, with mesic gullies and permanent streams; presence of leafy sub-canopy trees or tall shrubs for roosting; presence of large old trees to provide nest hollows. (From Debus 1994a, NSW NPWS 1994, McNabb 1996, Kavanagh 1997).

Sooty Owl

Diet: the Sooty Owl is a generalist predator taking almost all arboreal, scansorial and small terrestrial mammals occurring within its more specialised habitat. It particularly favours the Common Ringtail Possum, but it also takes large numbers of the Sugar Glider the Bush Rat, Fawn-footed Melomys and the Brown Antechinus. Bandicoots are also commonly taken. Birds and insects are rarely eaten by the Sooty Owl. (Summarised from Debus 1994b, Kavanagh 1997, Kavanagh 2002a, Kavanagh and Jackson 1997, dietary studies listed by Higgins 1999). Bilney (*et al.* 2006) have shown Sooty Owls to increase their consumption of arboreal prey in East Gippsland, Victoria. They attribute this shift in diet to a reduction in terrestrial prey from predation by the Red Fox and other feral species.

Predators: no information; eggs and nestlings are possibly taken by goannas.

Behaviour: nocturnal; roosts by day primarily in large tree hollows or among the dense foliage of sub-canopy rainforest trees, tree ferns and vine thickets in gullies; in some territories, the owls commonly roost in caves, cliff ledges or crevices, rock or bank overhangs. Forages by hunting from perches within the forest canopy or sub-canopy. Home range has been estimated as 200-800 ha according to habitat productivity; measured as 3000 ha (1000 ha actually used) for one unmated, non-breeding individual in marginal habitat, and 450+ ha for one adult female in continuous habitat of mesic gullies within dry forest (Kavanagh 1997, Kavanagh and Jackson 1997). Moist forest in unlogged corridors in gully systems is used for nesting and roosting, and also preferentially for foraging although foraging is occasionally conducted in regrowth forest (Kavanagh 1997). Established pairs use traditional roost sites (Hollands 1991, Kavanagh 1997), although non-breeding individuals use many different roost sites (Kavanagh and Jackson 1997 and Kavanagh unpublished data).

Ecological factors required for reproduction: mature forest stands containing large hollow trees, in moist gullies. Multi-layered forest containing a distinct “rainforest” element of dense mid-storey trees and shrubs. High density and diversity of small forest mammals, some of which are hollow-dependent or require old-growth forest attributes. (From Schodde and Mason 1980, Debus 1994b, Kavanagh 1997, Higgins 1999).

Specific habitat requirements: mosaic of rainforest and moist eucalypt forest in dissected terrain, with sheltered gullies; dense mid-storey; some old hollow bearing trees. (From Debus 1994a, NSW NPWS 1994, Kavanagh *et al.* 1995, Kavanagh 1997, Kavanagh and Jackson 1997).

Masked Owl

Diet: the Masked Owl is a specialist predator of terrestrial mammals, particularly native rodents. Small dasyurids are also important prey in forests; introduced rodents and rabbits are important in disturbed areas. The diet is supplemented by bandicoots, arboreal mammals (Sugar Glider, Common Ringtail Possum), and some birds. (Summarised from Debus and

Rose 1994, Kavanagh 1996, 1997, Kavanagh 2002a, Kavanagh and Murray 1996, dietary studies listed by Higgins 1999).

Predators: eggs and nestlings are possibly taken by goannas. Fledglings are taken by the Red Fox (Debus 1997).

Behaviour: nocturnal; roosts by day in tree hollows, caves, and dense foliage including exotic trees. Foliage roosts can be highly cryptic. Forages by hunting from perches at or near ground level on the forest edge, in woodland or in open country. Larders excess food in caches. Home range has been estimated as 400-1000 ha according to habitat productivity; measured as 1100 ha for one adult female of a resident pair in the non-breeding season, in bushland fragmented by suburban and semi-rural developments (Kavanagh and Murray 1996). Mesic microhabitats, such as gullies, may be used preferentially for nesting and roosting, although upper slopes are also used; ecotones within forests and at forest edges appear to be used preferentially for foraging (Debus and Rose 1994, Kavanagh 1996, Kavanagh and Murray 1996). Established pairs roost in traditional tree hollows, including tree hollow nest sites; in the non-breeding season they use other roost sites away from the nest patch (Kavanagh 1996, Kavanagh and Murray 1996). There is some seasonal shift in site use within the home range: the owls range more widely, and the breeding area is sometimes not used in the non-breeding season (Kavanagh and Murray 1996). Juveniles have been shown to occupy artificial nest boxes, but not adults (Chris Thomson, Sinclair Knight Merz *unpubl. data.*).

Ecological factors required for reproduction: mature forest or woodland stands with large hollow bearing trees. Dense trees or shrubs for fledglings to shelter within. High density of small terrestrial mammals, only few of which have any strong relationships with old-growth forest or woodland attributes. (From Schodde and Mason 1980, Debus and Rose 1994, Kavanagh 1996, Kavanagh and Murray 1996, Debus 1997, Mooney 1997, Higgins 1999).

Specific habitat requirements: dry eucalypt forests and woodlands on productive sites on gentle terrain; high density of old hollow bearing trees; grassy understorey with a mosaic of sparse and dense ground cover. (From Debus and Rose 1994, NSW NPWS 1994, Kavanagh et al. 1995, Kavanagh 1996, Kavanagh and Murray 1996).

6.3 Population structure

It is assumed or expected that:

- (a) for Powerful Owls and Sooty Owls there is long-term population stability with high adult survival and strong fidelity of breeding adults to territories. Confidence in this assessment is lower for Masked Owls because they are less abundant and more difficult to survey
- (b) for all three large forest owl species the numbers are highest immediately post-fledging, with attrition of juveniles by the next breeding season
- (c) for all three large forest owl species the sex ratio is unity
- (d) source and sink populations exist, in terms of sedentary breeding adults in high-quality habitat, juvenile dispersal to low-quality habitat, and persistence of some non-breeding individuals in low-quality habitat lacking nest sites or sufficient prey densities for breeding.

The following population assessments are based on surveys undertaken at 1290 sites at locations in south-east NSW, north-east NSW, south-west slopes and central-west slopes and another 986 sites in north east NSW as part of post graduate research undertaken in the late 1980s and early 1990s by Kavanagh (1997) and Debus (1994b) respectively (Rod Kavanagh DPI (Forests NSW *pers. comm.*). They are based on responses by territorial birds to call

playback and accordingly there would be additional non-breeding birds in the population that were not effectively sampled using this method.

Powerful Owl

Estimated minimum population size in NSW is 2000 pairs (Debus 1994a, Kavanagh 1997) or at least 10,000 individuals.

Sooty Owl

Estimated minimum population size in NSW is 2000 pairs (Debus 1994a, Kavanagh 1997) or at least 10,000 individuals.

Masked Owl

Estimated minimum population size in NSW is 1500 pairs (Debus 1994a, Kavanagh 1997) or at least 8,000 individuals.

7 Management Issues

7.1 Threatening processes

For all three species of large forest owl, threats are listed in perceived order of severity (greatest to least) in NSW.

7.1.1 Habitat clearing and fragmentation

Forest clearing and fragmentation for agriculture, pine plantations, mining, major infrastructure and urban developments permanently removes foraging and breeding habitat, affecting all age classes of owls. Forest clearing is widespread but concentrated in the coastal lowlands and foothills on flatter terrain and on the western slopes. Small (less than 200 ha) forest fragments that are more than 1 km from large areas of forest are not used by Powerful and Sooty Owls, but may provide marginal habitat for non-breeding Masked Owls (Kavanagh 1997, Kavanagh and Stanton 2002). Clearing for agriculture in the mid-west of NSW and the demise of open forest and woodland on the coast are the major threats past and present for the Masked Owl.

The likely ability of the owls to disperse over tens of kilometres through a mosaic of forested and cleared land suggests that there are unlikely to be any barriers to gene flow within NSW. Owl populations are unlikely to have declined or been fragmented to the point where their genetic integrity is threatened. However, loss of habitat may have caused permanent regional declines and local extinctions (Debus 1994, Debus and Chafer 1994, Debus and Rose 1994). The situation has probably stabilised for the Sooty Owl, which now occurs mostly in wet escarpment forests on rugged terrain, or on public land where no further deforestation is taking place.

7.1.2 Logging

Intensive logging of wood-production forests has the potential for removing nest sites and roost sites for owls, and den sites for prey species, unless these trees can be identified and protected. Intensive logging and other silvicultural practices such as timber stand improvement, change the age structure of the forest by removing many of the older, hollow-bearing trees resulting in the development of much younger stands containing as few as 10% of the original number of hollow trees (Gibbons and Lindenmayer 1997).

Research to date has shown logging practices in NSW to have had little adverse effect on the regional distribution or occupancy rates (logged vs unlogged forest) of the Powerful Owl and the Sooty Owl, although occupancy by the Masked Owl appears to be greatly reduced in heavily logged forests (Kavanagh and Bamkin 1995, Kavanagh *et al.* 1995). For the Powerful Owl and the Sooty Owl, this may reflect the existence of undisturbed or less disturbed forest nearby in the landscape providing the essential resources needed (nest sites, roost sites). For the Masked Owl, the reduced numbers occurring in intensively-logged forests may reflect an inability by this species to hunt successfully for small ground mammals among dense logging regrowth. Among the major prey species of the owls, only the Greater Glider is substantially reduced in numbers by intensive logging and some, such as the Common Ringtail Possum, are favoured by regrowth following logging (Kavanagh and Bamkin 1995, Kavanagh 1997). In NSW, logging is regulated by licences issued under the F&NPE Act (section 8.3). This plan aims to test the effectiveness of management conditions relevant to owls in these licences.

Large forest owls have been shown to respond to logging (and wildfire) disturbance by recolonising areas as forest regeneration proceeds. Radio-tracking studies in south-eastern NSW have shown that the Powerful Owl and the Sooty Owl can forage extensively among young regrowth (<20 years) provided there is older-aged forest nearby for roosting and nesting (Kavanagh 1997). Davey (1993) considered that regrowth needed to be at least 60 years of age for occupancy by the Masked Owl. Although they spend some time foraging in regrowth, Powerful Owls and particularly Sooty Owls prefer to forage in undisturbed gullies where they roost and nest (Kavanagh 1997). Under some circumstances, the Masked Owl may be a disturbance opportunist in terms of its ability to forage along roads, tracks, ecotones, and recently harvested forest or cleared land (Schodde and Mason 1980, Hollands 1991, Debus 1993, Debus and Rose 1994, Kavanagh and Murray 1996). However, it is apparently disadvantaged by dense post-logging regeneration (Kavanagh and Bamkin 1995, Kavanagh 1997).

All three owls are well distributed throughout managed forests, but it is important to ensure that some unlogged or undisturbed forest is retained throughout the landscape for these species. Logged forest is not a barrier to owl movement, therefore any effect on the owls' genetic integrity is unlikely. Environmental variables are more important than management history in determining patterns of owl distribution and occupancy rates in forests, particularly for the Sooty Owl (NSW NPWS 1994, Kavanagh and Bamkin 1995, Kavanagh *et al.* 1995, Kavanagh 1997). The situation has probably stabilised for the Sooty Owl, which occurs mostly in national parks, unloggable areas of state forests (rainforest, steep slopes), and those other areas of state forest (such as riparian corridors) that are protected by general and specific harvesting prescriptions.

7.1.3 Fire

Wildfire is part of the natural perturbation regime. It affects all age classes of owls; it is widespread but dispersed in space and time. Besides occasionally causing direct mortality to the owls and their prey, wildfires may reduce the numbers of existing nest and roost trees in the landscape. However, these changes may be offset by the creation of new nest and roost sites (hollows), and changes in understorey characteristics which could improve habitat quality for many prey species (Catling 1991).

The Powerful Owl and the Sooty Owl appear to display a strong association with long-unburnt forest, particularly in their choice of nesting and roosting locations (Kavanagh 1997). However, foraging habitat for both species may be greatly enhanced in some environments by infrequent wildfires that re-set patterns of understorey succession, thus providing good habitat for several important prey species in the medium term (10-40 years post-wildfire) (Kavanagh pers. obs.). The Masked Owl, in contrast, displays a stronger association with forest that has been burnt more frequently (Kavanagh *et al.* 1995). This species appears to forage near ecotones, whether "internal" (i.e. at the boundary of forests of different structural

composition) or “external” (i.e. at the forest edge). The mosaic nature of burnt-unburnt patches in the landscape after fire contributes to structural diversity in forest stands which appears to improve foraging opportunities for the Masked Owl.

Hazard reduction burning (frequent, low-intensity fire), has the potential to simplify forest structure if most areas are burnt. The overall reduction in cover caused by frequent burning, and changes in plant species composition to a “grassy” understorey, reduces habitat quality for many small ground-dwelling mammals (Catling 1991). The foliage roosts of the Powerful Owl (e.g. *Allocasuarina* spp.) are vulnerable to regular hazard reduction burning. Frequent burning can also accelerate the demise of senescent hollow bearing trees through constant burning out of their bases. Further information on the impact of fire on the habitat and prey base of these owls is required.

7.1.4 Grazing

Grazing by cattle and sheep is common in many state forests, Travelling Stock Routes, leasehold and private lands. The main impact on the owls is likely to be the associated annual burning (often illegally) by leaseholders in their efforts to improve feed quality for their stock. The combination of grazing and regular burning is likely to affect habitat quality for owls through its effects on nest and roost site availability and its effect on the quality of ground cover for mammal prey. Grazing is most likely to affect the Masked Owl in grassy open forests. Impacts from grazing on Sooty Owl habitat is likely to be limited although stock can degrade gully areas. Some arboreal prey for the Powerful Owl will be reduced while others should remain unaffected.

7.1.5 Predation

Fledglings of the Powerful Owl and the Masked Owl are susceptible to predation by the Red Fox (McNabb 1996, Kavanagh 1997, Debus 1997). The risk of predation by foxes on fledglings is widespread and likely to be correlated with proximity to disturbed areas (Debus 1997). Lace monitors are known to predate upon the nestlings of Barking Owls (*Ninox connivens*) (Rod Kavanagh DPI (Forests NSW) *pers. comm.*) and are also likely to predate on the eggs and nestlings of Masked Owls and possibly Sooty owls and Powerful Owls (David Milledge *pers. comm.*).

7.1.6 Human hazards

Human hazards are widespread but concentrated in disturbed areas. Masked Owl mortality from road kills is high, but mortality caused by fences, wires, rabbit traps and open-topped water tanks has also been recorded (Debus 1993, 1997, Peake *et al.* 1993, Debus and Rose 1994). The Powerful Owl and the Sooty Owl are much less likely to be killed by vehicles and other accidental deaths are rare (Debus 1994b, Debus and Chafer 1994, Kavanagh 1997, Kavanagh 2004).

7.1.7 Pest control

Pesticide use is widespread in many areas, but localised around plantations and crops subject to rodent damage. The Masked Owl is susceptible to secondary poisoning by brodifacoum-based rodenticides (Young and De Lai 1997), sodium monofluoroacetate (1080) and Pindone. These products should be replaced by coumatetralyl-based rodenticides in integrated pest management programs.

7.1.8 Disease

Little is known of disease in owls. There is an apparently low incidence of natural pathogens in nestling and fledgling Powerful Owls and Masked Owls (Fleay 1979, Debus 1997). A very low incidence of disease has been detected in adult owls (Debus 1997). Botulism has been

recorded in Powerful Owls from eating road-killed animals in suburban areas (CSIRO 1996). One young, but independent Powerful Owl died due to gluttony; it swallowed a young Common Ringtail Possum whole causing a stomach blockage (Kavanagh, pers. obs.). Sooty and Masked Owls may also be susceptible to infection from the black rat lungworm (*Angiostrongylus cantonensis*), which is a parasite of introduced and native rodents (Spratt 2005).

7.1.9 Drought

The Powerful Owl and especially the Sooty Owl are probably buffered against drought by their preference for mesic gullies. All three owls are associated with riparian areas which form source populations for many prey species and thus function as drought refuges for prey (Davey 1993). However breeding success may be reduced in drought years due to reductions in prey availability. The long term impacts of climate change could also result in increased drought and fire frequency.

7.2 Population viability

Empirical data on population parameters are too sparse for confident predictions about population viability analysis (PVA) of large forest owls in New South Wales. A preliminary PVA performed in south-eastern NSW, using the best available demographic data in Australia, suggested a low probability of regional extinction within 200 years for all three species of large forest owls (Kavanagh 1997). This analysis was spatially explicit as it used the results of detailed owl habitat mapping in the south-east forests as the basis for initialisation of the model and successional changes in habitat quality within owl management units. Sensitivity analysis showed that model simulations were sensitive to variation in adult mortality, a very difficult parameter to measure accurately, and in the probability of pairs failing to breed, which is also difficult to measure (Kavanagh 1997). Thus, there was a considerable uncertainty in the predictions. Similar results (i.e. low risk of extinction but also uncertainty in the predictions) were obtained recently for Victoria by McCarthy *et al.* (1999). Both studies considered that a prohibitively large field programme involving monitoring of individually recognisable owls would be required to obtain an improved estimate of adult survival. Thus, without considerable additional resources, it is unlikely that PVA will be useful for these species in terms of assessing the likely consequences of alternative management actions.

In northern NSW, owl population viability is likely to be even more optimistic, with higher owl densities, more diverse forest, and a wider prey base for the owls (Debus 1994b,b, Kavanagh *et al.* 1995). The Powerful Owl, in particular, displays considerable resilience to low level habitat disturbance through its continuing and successful occupancy of bushland among the outer suburbs of major Australian cities (Pavey *et al.* 1994, Pavey 1995, Kavanagh 1997, Lavazanian *et al.* 1994, Webster *et al.* 1999).

7.3 Species ability to recover

The large forest owls have been classified as vulnerable because of the past and continuing human impacts on their habitats. Along with many other species, the clearing of forests and woodland for agriculture has reduced the amount of habitat available for large forest owls. However, much suitable habitat remains within conservation reserves and in wood production forests and to a lesser extent on private forest lands. Recent management initiatives in wood production forests are intended to arrest any further decline in habitat availability for these owls (see sections 8.1, 8.2 and 8.3). Indeed, there is no evidence at present that populations of large forest owls are continuing to decline on public forest lands. This cannot be said for private forest lands. Population stability or increase is dependent on the continued

implementation of the management procedures applied in state forests, and these principles need to be extended to private forest lands.

Recent evidence from south-eastern NSW has shown that, in certain forest types (dependent on the prey base, in this case primarily the Common Ringtail Possum), the Powerful Owl and the Sooty Owl can increase dramatically in abundance within 20 years of intensive logging and wildfire (Kavanagh 1997, and more recent unpubl. data). In this case, several wide riparian reserves were not logged and these are now providing important nesting, roosting and foraging locations for the owls, and radio-tracking studies have shown that the surrounding forest regrowth is also being used as foraging habitat. It is unknown, but less likely (see Kavanagh and Webb 1998, Kavanagh 2000), whether owl populations could recover as quickly following intensive logging in forests where the Greater Glider forms the principal prey base for the owls. Current timber harvesting prescriptions in state forests recognise this and attempt to compensate by reducing logging intensity in forests known to provide good habitat for the Greater Glider. In addition, all riparian zones are protected from logging (see section 8.3.1). While young regrowth appears unsuitable for the Masked Owl (Kavanagh and Bamkin 1995, Kavanagh 1997), it has been estimated that Masked Owls will recover in even-aged forests greater than 60 years of age (Davey 1993).

Population increase, without migration, for large forest owls is likely to be slow because they have low fecundity. However, mortality is not expected to be as high as for many northern hemisphere owls (Kavanagh 1997), and they have a high capacity to disperse and colonise recovering habitat (as discussed above). The Powerful Owl and Sooty Owl are unlikely to move across large expanses of cleared land. Dispersing juveniles and older non-breeding birds are likely to disperse to and occupy suboptimal habitat (e.g. Kavanagh and Jackson 1997). It is likely that populations can be recovered through habitat improvement in both forestry and non-forestry situations, by protecting strategic habitat corridors across the landscape, by protection or improvement of the owls' prey base, and by control of introduced predators. Habitat creation and recovery are prospects for the medium to long term. It is unlikely that recovery will be assisted significantly by *ex situ* programs of captive-breeding, release and reintroduction, because: (a) there are insignificant numbers of captive Powerful and Sooty Owls, and captive Powerful Owls are poor breeders; (b) the owls' core habitats are likely to be already fully occupied; (c) fox predation negates the release of Masked Owls in disturbed landscapes.

7.4 Biodiversity benefits

The Powerful, Sooty and Masked owls are of national and international scientific interest. They are endemic species that represent significant components of genetic diversity in the genera *Ninox* and *Tyto*. The flora and fauna associated with these species, such as the marsupials, endemic rodents and ancient forest eucalypts, are also unique components of the biodiversity of Australia.

As top-order carnivores, the large forest owls contribute to the stability of forest ecosystems (Davey 1993, Debus and Chafer 1994) and function as ecological and management indicator species (Milledge *et al.* 1991, 2004, Debus 1994b, Kavanagh 1991, 1997). The large forest owls and the marsupial gliders they prey upon are among the species regarded as having the closest associations with old-growth forest environments in eastern Australia (Kavanagh 2002b).

Regional conservation of these species will therefore have significant flow-on biodiversity benefits. They are considered able to function as indicators for hollow-dependent and other specialised species disadvantaged by impacts such as intensive logging and frequent fire (Milledge 2004) and have featured prominently in conservation planning on public forest lands in NSW (Kavanagh 2002b).

7.5 Social, economic and cultural issues

Regional conservation of the large owls by implementation of this plan will incur costs and benefits. These impacts would be difficult to quantify and to separate out from the costs and benefits of broader forest management and conservation measures.

The economic impact of conserving large forest owls has been substantial under recent forestry reforms implemented as a result of Regional Forest Agreements. These reforms included many new conservation reserves, reduced levels of timber production, and the adoption of new harvesting prescriptions (conservation protocols) to apply in state forests in NSW. The social and economic impact of these reforms has not been directly assessed. However, DPI (Forests NSW) state that the ongoing cost of putting in place owl landscape prescriptions as part of its management operations on state forests is in the order of \$500K - \$1m annually).

There will be cases when known records of the large forest owls occur in the vicinity of proposed developments and activities. If these proposals are not exempt from the assessment process, the economic and social consequences of protecting the species and its habitat will need to be assessed as part of the normal environmental planning and assessment process.

Economic benefits from owl conservation include revenue from increased ecotourism and park-use fees, income to landholders from agroforestry, and the associated multiplier effect in the economy. Owls do not have commercial value as such, but people such as ecotourism operators and their clients, bird-watchers and other nature-lovers spend money on travel, equipment and accommodation in order to experience these birds and their environment. In a parallel situation in North America it was found that, although there are financial costs to sections of the community connected with the timber industry, conservation of large forest owls has a predicted net national benefit (Rubin *et al.* 1991).

Conservation of the three large forest owls will assist in the conservation of native forests, including old-growth forests and also contribute to enhanced provision of ecosystem services such as water quality and catchment yields in public forest areas where management prescriptions currently apply. As a potential indicator or umbrella species, conservation of the three large forest owls can assist in the conservation of other forest species and communities at no additional cost. This will result in increased aesthetic value and recreational and educational potential of native forests. Conserved owl habitats will provide people with opportunities for education and passive recreation, through increased opportunity to experience and learn about native forests and their fauna. The habitats of the owls are storehouses of genetic diversity, the non-timber elements of which may have economic value in the future. Healthy forests provide ecosystem services to humans, such as water, oxygen, a sink for greenhouse gas (carbon dioxide), and resources. Implementation of this plan will enhance the ability of DPI (Forests NSW) to manage native wood-production forests in an ecologically sustainable manner.

Owls have charismatic public appeal and there is community support for rainforest and old-growth forest, therefore there is likely to be community support for owl conservation. Increased awareness and public profile of threatened forest owls will increase community support for conservation of threatened species and protection of biodiversity.

Owls are popular figures in folk lore and children's stories. However, the cultural significance of large forest owls to indigenous Australians and rural communities is currently unknown.

Without a strategic approach to managing these three species in the present, it is possible that they will be reduced to a level where they risk becoming Endangered in the future. Preventing this from occurring will provide long-term social and economic benefits.

The total cost of implementing the recovery plan is estimated to be \$988,920 over five years, although some synergies between actions is likely to reduce the overall cost of

implementation. Actions identified in this plan will be incorporated into the threatened species PAS. Both DEC and DPI (Forests NSW) have been identified as the public authorities responsible for implementing the plan. Full implementation of the plan is dependent on securing funds additional to current expenditure.

8 Previous Management Actions

8.1 Surveys

Regional surveys for large forest owls have now been completed throughout most of their ranges in public forest lands since 1988 when systematic surveys began (e.g. Binns and Kavanagh 1990a, 1990b, Kavanagh and Peake 1993, Debus 1994, NSW NPWS 1994, Kavanagh 1995, 1997, Kavanagh and Bamkin 1995, Kavanagh *et al.* 1995, Kavanagh and Stanton 1995, 1998, and many surveys undertaken as part of environmental impact statements within state forests or for comprehensive regional forest assessments). These surveys identified the relative importance to owls of different bio-physical features of the landscape, allowing the development of regional-scale owl-habitat models, and provided a means for comparing the relative abundance of the owls between regions. Invariably, however, these surveys provide only a coarse indication of the important habitat features for owls at the scale of individual owl territories. The locations of owl territories have not been mapped. The distribution of owls on privately-owned lands, many national parks, and non-forest environments remains poorly known.

8.2 Reservation

Forest habitat for all three large owls is reserved within many national parks and other conservation reserves in NSW. Very large additions (> 1.5 million ha) to the conservation reserve system, mainly from state forests, occurred during the past five years as a result of Regional Forest Agreements. Key factors used for identifying which areas were to be added to the National Park estate included modelled (mapped) habitat for large forest owls. These owl-habitat models were developed from data collected during the numerous surveys conducted on public forest-land, mainly in state forests (see above). Consequently, significant recent additions of suitable habitat for large forest owls have been made to the conservation reserve system in NSW. Ongoing modelling and mapping of owl-habitat relationships will provide a powerful tool for assessing the distribution, configuration and amount of high quality habitat for each owl species across different land tenures as has previously been demonstrated by Kavanagh (1997), Kavanagh (2002b) and Loyn *et al.* (2002).

8.3 Conservation protocols

8.3.1 Protocols in state forests

Owl management (and management for other species) in wood production forests is regulated by “conservation protocols” that form the terms of licences for forestry operations. For the majority of forests in NSW, these licences are TSC Act licences issued under the *F&NPE Act* 1999 for those areas covered by integrated forestry operations approvals under the same Act. These conservation protocols for timber harvesting within state forests were developed jointly by the DEC, DPI (Forests NSW) and the former NSW Department of Urban Affairs and Planning (now known as Department of Planning).

A summary of the main features of these conservation protocols for owls is given below. Pre-logging surveys are routinely undertaken in areas scheduled for harvesting in state forests. Special protection is given to forests occurring in all riparian zones where owl nests, roosts and prey are most likely to be found. In addition, old hollow trees are retained within logged areas to reduce logging impacts on the owls and their prey. These conditions apply throughout wood production forests, regardless of whether owls are known to occur. Additional conditions apply if an owl is recorded or predicted to occur based on wildlife-habitat models. This can take the form of site-specific management, based on individual owl territories, or landscape management in which large (approx. 10,000 ha) blocks of forest are managed to maintain owl populations.

The conservation protocols consist of: (a) general prescriptions for production forests, applied across the whole landscape irrespective of the known occurrences of threatened owls; (b) species-specific prescriptions when threatened owls are known or predicted to occur.

General prescriptions

Rainforest protocol: all forest types designated as rainforest are excluded from logging.

Old-growth forest protocol: all areas designated as old-growth forest are excluded from logging.

Tree retention: live hollow-bearing trees are retained in regrowth and non-regrowth zones at up to 10 per two hectares, from among the largest trees in the stand. Recruits for a new generation of hollow-bearing trees in the future are also retained in regrowth and non-regrowth zones at up to 10 per two hectares. Most dead trees are retained.

Protection of habitat trees: logging and fire are managed to minimise damage to hollow-bearing trees, recruitment trees and stags.

Riparian buffers: disturbance is excluded from strips 10 m, 20 m, 30 m and 50 m wide on each side of streams for all first, second, third and fourth or higher-order streams respectively. However, many nest and roost trees of the Masked Owl are likely to occur outside such riparian buffers (Mooney 1997).

Connection corridors: each 500 ha block of forest is connected by undisturbed corridors of width 40 m between second-order or 80 m between third-order streams, to link neighbouring catchments.

Burning: prescribed fire is managed to reflect the ecological requirements of threatened species in the area, to maintain an understorey mosaic, and to minimise impact on the understorey and large fallen logs especially in riparian areas.

Pre-logging site inspections: searches are conducted for owl nests, roosts and pellets.

Ground habitat protection: measures are taken to protect understorey, ground cover and large fallen logs during forestry activities.

Specific prescriptions

Protection of known nest and roost sites: owl nest sites or permanent roost sites detected during pre-logging surveys are protected by exclusion zones of 50 m and 30 m radius respectively.

Protection of potential habitat: 300 ha of undisturbed habitat is retained within a 2 km radius of a detection site for the Powerful Owl or a Masked Owl and, in south-eastern NSW, for the Sooty Owl as well.

Protection of prey: eight habitat trees per hectare are retained on logging sites in areas of high arboreal marsupial density (more than one Greater Glider per hectare, within 2 km of a Powerful Owl record).

Landscape approach: for the Powerful Owl and the Masked Owl and, in south-eastern NSW, for the Sooty Owl as well, a predictive landscape approach may be used as an alternative to the record-based prescriptions. Such an approach incorporates retention of large patches of habitat in the logging mosaic. At least 25% of the forest area within the landscape (approx. 10,000 ha blocks), which may include areas of national park, is retained unlogged as owl habitat.

8.3.2 Protocols on other lands

Management of owls and their habitat on privately-owned lands in NSW ranges from non-existent to application of the principles and practices which apply on public forest lands. Few attempts have been made to date to coordinate owl conservation efforts over multiple holdings of private land.

Examples of the ways in which conservation protocols have been applied on development sites include the following.

Highway upgrades: protection of large hollow trees, pre-clearing surveys, and erection of artificial hollows in adjoining forest.

Mining: identification and protection of nest and roost sites; pre-clearing surveys.

Quarries: protection of large hollow trees; pre-clearing surveys.

Bushland residential subdivisions: protection of nest and roost sites, patches of habitat and prey bases.

Vegetation clearance applications: Clearing of native vegetation that may provide habitat for large forest owls is regulated by the *Native Vegetation Act 2003*. Catchment Management Authorities can refuse applications for clearing where they affect threatened species.

8.4 Translocations and captive breeding programs

Powerful Owl

There have been no translocations and no official captive breeding programs. Small numbers of individuals are held at Taronga Zoo and Featherdale Wildlife Park, Sydney; their origin is central or southern NSW. This owl is a poor breeder in captivity; nothing useful has been published on captive birds since Fleay (1979).

Sooty Owl

There have been no translocations and no official captive breeding programs. Small numbers of individuals are held at Taronga Zoo and Featherdale Wildlife Park, Sydney; their origin includes northern NSW. This owl is a good breeder in captivity; nothing useful has been published on captive birds other than the limited data cited by Debus (1994a).

Masked Owl

There have been no official programs. Small numbers of individuals of the NSW subspecies are held at Featherdale Wildlife Park, Sydney, and probably other public and private zoos or wildlife parks including (or formerly) the Reptile Park, Gosford. The origin of Featherdale birds was captive-bred stock from Fleay's Fauna Park, Gold Coast (Qld); descendants of wild birds from south-east Qld and NSW border region, and the north coast of NSW. This owl is a prolific breeder in captivity.

An experimental program has been conducted by the Division of Zoology, University of New England, Armidale (NSW), of hack-release of dependent juveniles from captive rearing by two pairs. The origin of parental stock was (a) a captive-bred pair from Featherdale (descendants of Fleay stock), whose ancestral genetic provenance was the SW north coast and adjoining Qld border region (probably F2 or F3 generation captive); (b) a wild adult pair from north-eastern NSW (Hunter region and Northern Tablelands). This project provided knowledge and understanding of feeding and breeding requirements; potential productivity on unlimited food; breeding biology (incubation and nestling periods, growth, age and sex characters); parental behaviour including fostering of a wild orphan; morphology; vocalisations; and fledgling behaviour, requirements (roost sites), ranging behaviour, foraging and independence, and mortality factors including predators (see Debus 1997).

The results of these experimental releases of captive-bred juveniles within a rural landscape has been high mortality due to fox predation and low success to independence and dispersal (Debus 1997). Individuals of the Tasmanian subspecies were historically translocated to Lord Howe Island where the owl is now thriving, resisting attempts at eradication, and having an adverse impact on threatened Lord Howe Island endemics.

9 Recovery Objectives, Actions and Performance Criteria

9.1 Overall objectives

The overall objective of the NSW Large Forest Owl recovery plan is to ensure that viable populations of the three species continue in the wild in NSW in each region where they presently occur. Depending on the full implementation and success of the proposed actions, a further objective is to reassess the conservation status of the species and downlist from Vulnerable to secure if appropriate.

9.2 Overall performance criterion

The overall performance criterion of the recovery plan is that the status of these three species in the wild stabilises or improves as a result of protection and successful management of sufficient good quality habitat on and off-reserve.

9.3 Specific recovery objectives, actions and performance criteria

9.3.1 Model and map owl habitat and validate with surveys

Objective 1: Assess the distribution and amount of high quality habitat for each owl species across public and private lands to get an estimate of the number and proportion of occupied territories of each species that are, and are not, protected.

Major new additions to the conservation reserve system have been made recently as a result of Comprehensive Regional Assessments and the Regional Forest Agreement process. Models of owl-habitat relationships were used to map the distribution of potential habitat for the owls and these maps had a significant influence on the allocation of public forest lands to the conservation reserve system. However, there still remains large areas of privately owned forest that are at risk of further clearing, and where there are no estimates of the number of owl territories present. An assessment of the distribution, configuration and amount of high-quality habitat for each owl species across different land tenures and an estimation of the number of owl territories supported within this habitat is required.

Recovery actions:

Recovery actions will be directed towards updating existing owl habitat models, mapping modelled habitat across public and private lands, and carrying out field surveys to validate models and enable estimation of the number of territories for each species supported by public versus private land.

Action table

No.	Specific actions	Responsibilities	Timeframe
1.1	Update and refine existing owl habitat models using the best available information.	DEC/DPI (Forests NSW) with the assistance of owl experts.	Year 1

1.2	Map the amount of modelled habitat across forested land in NSW.	DEC/DPI (Forests NSW) with the assistance of owl experts.	Year 1
1.3	Design a sampling strategy to test the modelled habitat for the presence of owls and locate identified sites.	DEC/DPI (Forests NSW) with the assistance of owl experts.	Year 1
1.4	Field validation of modelled habitat for the presence of owls.	DEC/DPI (Forests NSW).	Years 2-3
1.5	Estimate the areal amount of mapped modelled habitat for each owl species that is occupied (based on the proportion of sample sites with owls in them) and use this estimate to further estimate the number of owl territories present within different land tenures (based on home range data).	DEC with the assistance of owl experts.	By end of Year 5 if surveys are funded.

Performance criterion:

Within five years of the start of this recovery plan, high-quality habitat for each species will be mapped across forested land in NSW and an estimate of the number of occupied territories for each species within each land tenure obtained (including the number of pairs that may be at risk from further development). Field validation actions will require the provision of significant additional funding.

Outcomes:

An accurate estimation of the true conservation status of each species within NSW and knowledge of whether sufficient areas of high-quality habitat exist within conservation reserves to maintain at least 1000 territories for each species throughout the State, and that these territories are occupied by the owls. This information is needed to guarantee long-term viability of owl populations in NSW.

9.3.2 Monitor owl population parameters

Objective 2: To monitor trends in population parameters (numbers, distribution, territory fidelity and breeding success) across the range of the three species and across different land tenures and disturbance histories.

Critical to the success of any recovery plan is data for population trends across the range of a species. Implementation of a comprehensive monitoring programme is fundamental to achieving the overall objective of the recovery plan. Important recovery actions include the establishment of regional monitoring programmes to assess occupancy of potential owl territories, the fidelity to occupied territories and breeding success. Monitoring programmes should be designed to encompass a range of land tenures and disturbance history classes. Monitoring protocols should include the application of standardised sampling methods including sampling techniques and the frequency and season of visits.

Recovery actions:

Recovery actions will be directed towards developing and implementing a set of regional monitoring programs for the three species throughout their ranges in NSW that assess occupancy of potential habitat, fidelity to occupied territories and breeding success across a

range of land tenures and disturbance histories. Synergies with the field validation component of modelled habitat and monitoring actions will be investigated.

Action table

No.	Specific actions	Responsibilities	Timeframe
2.1	Develop a sampling methodology stratified across different land tenures and disturbance histories, as well as a set of standardised regional monitoring protocols.	DEC/DPI (Forests NSW) with the assistance of owl experts.	By end of Year 2
2.2	Seek cooperative involvement of other agencies, researchers and the community in the implementation of the regional monitoring program.	DEC/DPI (Forests NSW).	By end of Year 2
2.3	Implement a regional monitoring program.	DEC/DPI (Forests NSW).	Years 3, 4 and 5

Performance criteria:

Within two years of the start of this recovery plan the DEC will have coordinated the development and implementation of the monitoring program. Within five years of the commencement of the monitoring program, trends in population parameters (numbers, distribution, territory fidelity and breeding success) across the range of the three species and across different land tenures and disturbance histories will be determined. Monitoring actions will require the provision of significant additional funding.

Outcome:

Knowledge of owl population trends throughout their ranges in NSW and comparisons across different land-use categories.

9.3.3 Audit forestry prescriptions

Objective 3: To assess the implementation and effectiveness of forest management prescriptions designed to mitigate the impact of timber-harvesting operations on the three owl species and, (if necessary), to use this information to refine the prescriptions so that forestry activities on state forests are not resulting in adverse changes in species abundance and breeding success.

The preferred approach to owl conservation in wood-production forests is generic, pro-active and operates at a landscape scale, and is predictive rather than record-based (Anon. 1999, Kavanagh 2002b). However, confidence in this approach is dependent on a good understanding of the habitat requirements of the owls and, most importantly, on the effectiveness of owl conservation protocols (TSL conditions; see section 8.3.1) to ameliorate the impacts of forestry practices on owl habitat quality.

Large forest owls are known to utilise logged forests, but limited radio-tracking suggests that the owls require a core area of unlogged or relatively undisturbed forest within their home-ranges for nesting and usually also for roosting and some foraging (see section 7.1.2). The TSL conditions recognise this requirement and prescribe the retention of linear and other unlogged reserves within the known or predicted habitat of the owls (see section 8.3.1). Confirmation is required that these conditions are achieving the desired result; that is, the maintenance of successfully breeding owl populations throughout wood production forests.

Currently, the TSL conditions for regions other than south-eastern NSW provide no species-specific consideration for the Sooty Owl. These conditions assume that the requirements of

this owl are already protected adequately by reservation of all rainforest areas and linear riparian forest strips in wood production forests. Tests of the effectiveness of these conditions may take several forms, including pre and post harvest surveys, nest site monitoring, radio tracking of owls within mosaics of logged and unlogged forests and results from regional monitoring programmes.

In south-eastern NSW, the requirements of the Sooty Owl were considered explicitly and additionally by the TSL conditions on the basis that rainforest is an uncommon element of the south-east forests yet the Sooty Owl is widespread, particularly throughout the coastal and foothills forests of the region. The validity of the above assumption also needs to be tested.

The TSL conditions specify minimum buffers of undisturbed forest surrounding known owl nest sites and roost sites. The effectiveness of these prescriptions also needs to be tested.

Recovery actions:

Recovery actions will be directed towards assessing the implementation and effectiveness of forest management prescriptions, and if necessary, refining them so that forestry activities on state forests are not resulting in adverse changes in species abundance and breeding success.

Action table

No.	Specific actions	Responsibilities	Timeframe
3.1	Investigate the implementation by DPI (Forests NSW) of the forestry TSL owl prescriptions by carrying out proactive audits targeting these prescriptions (DEC) and through IFOA monitoring and reporting DPI (Forests NSW).	DEC/DPI (Forests NSW).	Years 1-5
3.2	Carry out post harvest surveys in locations where owls were detected prior to logging to determine if they are continuing to occupy the habitat.	DEC/DPI (Forests NSW).	Years 1-5
3.3	Encourage post-graduate student radio tracking projects examining the use of logged and unlogged forest by the three owl species.	DEC/DPI (Forests NSW).	Years 1-5
3.4	Make an assessment of the implementation and effectiveness of forestry owl prescriptions using data collected in this action and if necessary refine the prescriptions and negotiate changes to the forestry TSLs.	DEC/DPI (Forests NSW).	Year 5

Performance criterion:

Within five years of the start of this recovery plan the implementation and effectiveness of forest management prescriptions will have been assessed and if necessary, refined.

Outcome:

Confidence that forestry practices on state forests do not result in adverse changes in species abundance and breeding success.

9.3.4 Manage and protect habitat off reserves and state forests

Objective 4: Ensure the impacts on large forest owls and their habitats are adequately assessed during planning and environmental assessment processes.

Forest clearing and fragmentation is recognised as the greatest ongoing threat to the three large forest owls in NSW (see section 7.1.1). Clearing permanently removes foraging and breeding habitat affecting all age classes of owls. This threat is greatest on private lands subject to ongoing development pressures. Strategic land use planning and local assessment of clearing and development applications and their impacts on large forest owls on these lands therefore needs to be adequately informed and mitigated.

Recovery actions:

Recovery actions are directed towards the development, maintenance and evaluation of tools used by consultants, consent and determining authorities for assessing and mitigating the impact of development activities on large forest owls and their habitats.

Action table

No.	Specific actions	Responsibilities	Timeframe
4.1	Prepare and disseminate environmental impact assessment guidelines to assist consent and determining authorities and environmental consultants to assess and mitigate the impacts of developments on the large forest owls and their habitats.	DEC	Year 1
4.2	Monitor and report on the effectiveness of concurrence and licence conditions that have previously been applied to reduce the impacts of developments on the three large forest owl species or their habitats. This will involve keeping a record of such conditions, selecting case studies and then checking for the presence of owls at long intervals post development.	DEC	Years 2-3
4.3	Use this information to develop a set of prescriptive guidelines that may be used to mitigate the impacts of developments on the three large forest owls.	DEC	Years 3
4.4	Provide up-to-date and accurate large forest owl and habitat information in the 'PVP Developer – Threatened Species Tool'. This will ensure that broadscale clearing is only approved under the NV Act if the 'improve or maintain' test is met.	DEC	Years 3 and 5
4.5	Facilitate the adequate consideration of large forest owls during biodiversity certification of environmental planning instruments. This may include ensuring that correct survey methods are used, informed habitat assessments are undertaken and adequate conservation measures are included in EPIs to assist the recovery of the owls.	DEC	Years 2, 4 and 5
4.6	Provide up to date information and data for the BioBanking assessment methodology.	DEC	Year 2

Performance criterion:

All guidelines and support material required to adequately assess and mitigate development activities on large forest owl habitat on lands off reserves and state forests will be prepared and disseminated.

Outcome:

Adverse impacts of developments on owls will be avoided or minimised, and amelioration measures will be refined.

Objective 5: Minimise further loss and fragmentation of habitat by protection and more informed management of significant owl habitat (including protection of individual nest sites).

The protection and management of large forest owl habitat can also be facilitated through the proactive involvement of government agencies, community groups and individual landholders. Catchment Management Authorities (CMAs) in particular, play an important role in providing incentives to landholders to deliver natural resource management on the ground. Investment in the maintenance and restoration of large forest owl habitat on private lands needs to be informed by practical information on habitat management.

Recovery actions:

Recovery actions will be directed towards encouraging the protection and management of significant habitat.

Action table

No.	Specific actions	Responsibilities	Timeframe
5.1	Prepare guidelines addressing issues associated with habitat protection and management, and survey and assessment. The guidelines are to provide detailed information on the identification of significant habitat for owls, appropriate strategies for its protection, and for habitat creation as part of revegetation programs. The guidelines will be published on the DEC threatened species website and link to species profile information.	DEC	Year 1
5.2	Encourage CMAs to invest in actions that actively manage and/or conserve large forest owl habitat as part of their Catchment Action Plans. In addition, seek other funding opportunities in partnership with community groups, to promote owl conservation on private lands.	DEC	Years 1-5
5.3	Encourage private landholders to undertake management options to conserve and/or actively manage large forest owl habitat (and particularly nest sites) through incentive Property Vegetation Plans, Voluntary Conservation Agreements or other management initiatives.	DEC	Years 1-5

Performance criterion:

Key groups such as Catchment Management Authorities will be better informed and involved in the protection and management of significant habitat for the large forest owls resulting in increases in the amount of protected habitat outside conservation reserves and state forests each year. Management incentives are investigated and applied resulting in increases in the conservation of owl habitat on private land which would otherwise be lost or remain degraded.

Outcome:

Owl habitat outside conservation reserves will be more adequately protected and patches of habitat restored.

9.3.5 Undertake research

Objective 6: To improve the recovery and management of the three large forest owls based on an improved understanding of key areas of their biology and ecology.

In addition to those areas dealt with by the above actions, there are significant gaps in knowledge that limit our efforts to conserve populations of large forest owls. Research is required to:

- identify owl habitat requirements in parts of the State where the owls have not been studied e.g. north-eastern NSW and western slopes of NSW
- improve our understanding of owl population demography, and
- explore the potential for creating owl habitat.

To date, virtually all research on the detailed habitat requirements of large forest owls in NSW has been conducted in far south-eastern NSW and near Sydney (Kavanagh 2002b). The total numbers of nest trees known for the Powerful Owl throughout Australia (all records) is estimated to be less than 100 for the Powerful Owl and the Masked Owl (most of the latter are in Tasmania), and less than 25 for the Sooty Owl. There is an urgent need to obtain data on owl nest-site characteristics in other parts of the State, in particular, in north-eastern NSW and on the western slopes of NSW. These data are required to ensure that owl conservation protocols are targeting the right parts of the landscape in these poorly known regions. Radio-tracking studies are also needed to determine the reliance of the owls on undisturbed patches within mosaics of disturbed and undisturbed forest environments.

There is an almost complete lack of knowledge about the demography of wild owl populations, with the possible exception of breeding success for the Powerful Owl. Critical variables needed for owl population viability analysis include mortality rates (particularly those of adults), and dispersal. The only way to gather these and related data is to establish several major field studies in which efforts are made to trap, band and radio-track large numbers of owls. The demographic data needed for more reliable modelling of owl population viability may take 10 years to collect (Kavanagh 1997).

Nest-boxes have been used extensively, and with great success, in the Northern Hemisphere to increase owl populations where nest sites are limited or absent. The potential for nest-boxes to create habitat or to fast-track the development of owl habitat in young forests and/or plantations in Australia is unknown. Considerable scope exists for trialling nest-boxes for owls and their prey in disturbed environments. The potential for artificial hollows (nest-boxes) to fast-track habitat development for owls should also be investigated.

Owls are popular charismatic animals in folk lore and children's stories in Australia and throughout the world. However, the cultural significance of large forest owls to indigenous Australians and rural communities is unknown and requires investigation.

Recovery actions:

Recovery actions will be directed towards encouraging and facilitating scientific investigation into key aspects of the biology and ecology of the three large forest owls that are likely to provide information that is valuable to the recovery and/or management of these species.

Action table

No.	Specific actions	Responsibilities	Timeframe
6.1	Seek an Australian Research Council (ARC) Linkage grant or other joint funding opportunity to initiate research into identified key areas of the biology and ecology of the large forest owls.	DEC	Year 1
6.2	Promote awareness and involvement of the research and management needs of the three large forest owls among the scientific and academic community.	DEC	Ongoing
6.3	Seek scholarship funds for an aboriginal student to investigate the cultural and historic significance of the three species.	DEC	Year 2

Performance criterion:

More informed recovery and management strategies are developed as a result of increases in knowledge about the biology and ecology of the three species.

Outcome:

Development of new tools for the management of owl populations, and confirmation of the efficacy of conservation protocols.

9.3.6 Increase community awareness and involvement in owl conservation

Objective 7: To raise awareness of the conservation requirements of the three large forest owls amongst the broader community, to involve the community in owl conservation efforts and in so doing increase the information base about owl habitats and biology.

The general community represents a large resource that can be used to provide broadscale information on such things as owl locations, territory fidelity, breeding success and mortality. In addition to special interest groups and interested individuals, animal care groups (who receive injured birds) are an important source of information (eg on reproductive success, dispersal, mortality and longevity). Targeting these groups for involvement in the recovery effort is a key aspect of this recovery plan.

Recovery actions:

Recovery actions will be directed towards raising awareness within the community about the conservation requirements of the three large forest owls and encouraging community involvement in recovery actions and information gathering. These actions will also support actions outlined in Objective 5.

Action table

No.	Specific actions	Responsibilities	Timeframe
7.1	Encourage and coordinate the involvement of community-based groups (eg the Australian Bird and Bat Study Association) and animal care	DEC	Ongoing

	groups (eg WIRES) in the implementation of recovery actions.		
7.2	Ensure the DEC threatened species website provides current information on owl identification (including photographs and samples of calls), habitat identification and protection, any current activities the community can be involved in, as well as information on how and where to report sightings and other relevant information. Ensure the site has links to other key internet sites such as the Australasian Raptor Association.	DEC	Ongoing

Performance criterion:

The broader community is more informed and involved in the conservation of the three large forest owls and the information base increases as a result.

Outcome:

Broadscale information on owl habitat and biology increases over the life of the recovery plan.

9.3.7 Provide organisational support and integration

Objective 8: To coordinate the implementation of the recovery plan and continually seek to integrate actions in this plan with actions in other recovery plans or conservation initiatives.

Effective implementation of a recovery program for a threatened species, population or ecological community is a complex task. A coordinated approach is essential to oversee and assist in the implementation of the actions outlined in this recovery plan including a review of the plan in the final year of its operation and a reassessment of the conservation status of the three large forest owls upon implementation of the recovery actions. A key aspect of this coordination is to continually seek to integrate the recovery actions in this plan with those in other recovery plans (eg the Yellow-bellied Glider) and other conservation initiatives (eg the Marsupial CRC *Nightstalk* program- which monitors the prey base of owls).

Recovery actions:

Action table

No.	Specific actions	Responsibilities	Timeframe
8.1	Coordinate implementation of actions.	DEC	Years 1-5
8.2	Review plan and rewrite in final year.	DEC	Year 5
8.3	Convene a threatened owl workshop with relevant experts and stakeholders to reassess the NSW conservation status of the three large forest owls. This action will be undertaken upon conclusion of the implementation of all of the above actions.	DEC	Year 5

Performance criteria:

The DEC co-ordinates the implementation of the actions in this recovery plan and carries out a review of the plan in its final year. The state conservation status of each of the three large forest owls is reassessed.

Outcome:

The recovery actions outlined in this plan are carried out in a timely, cost-effective and efficient manner that integrates these actions with those of other recovery plans and existing programmes as much as possible. The state conservation status of each species will be based on the most up-to-date and accurate information available.

10 Preparation Details

An early draft of this recovery plan, initially for north-eastern NSW, was prepared by Mr Stephen Debus, Division of Zoology, University of New England. Dr Rod Kavanagh, Science and Research Division, DPI (Forests NSW) then substantially revised and extended the plan to a state-wide context.

The final draft was prepared by Mr Ron Haering and Dr Deborah Ashworth of the DEC Biodiversity Conservation Unit based largely on Dr Rod Kavanagh's earlier draft. Dr Jim Shields of DPI (Forests NSW) contributed to a re-working of some of the actions. Thanks are extended to those people who provided comments on the draft plan which was publicly exhibited in 2005.

11 Review Date

This recovery plan will be reviewed within five years of the date of publication. The review will include an assessment of the progress and/or success of the actions against the criteria in the recovery plan.

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13 Acronyms and Abbreviations

CMA – Catchment Management Authority

DEC – NSW Department of Environment and Conservation

DPI (Forests NSW) – NSW Department of Primary Industries (Forests NSW)

EP&A Act – NSW *Environmental Planning and Assessment Act 1979*

EPBC Act – Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*

F&NPE Act – *Forestry and National Park Estate Act 1998*

IFOA – Integrated Forestry Operation Approval

LG Act – *Local Government Act 1993*

NP – National Park

NPW Act – NSW *National Parks and Wildlife Act 1974*

NPWS – NSW National Parks and Wildlife Service (now known as DEC)

NSW – New South Wales

NV Act – NSW *Native Vegetation Act 2003*

PVA – Population Viability Analysis

RF Act – *Rural Fires Act 1997*

SIS – Species Impact Statement

TSC Act – NSW *Threatened Species Conservation Act 1995*

TSL – Threatened Species Licence

VCA – Voluntary Conservation Agreement

14 Implementation Costs

The recovery actions and recommendations identified in this plan state what must be done to ensure the recovery of the three large forest owls. Table 1 identifies the costs needed to implement recovery actions.

Table 1. Estimated costs of implementing the actions identified in the Large Forest Owls Recovery Plan

Action No.	Action	Priority	Year 1	Year 2	Year 3	Year 4	Year 5	Total Cost	Responsible Agency	In-Kind (DEC)	Cash (DEC)	External funds required (DEC)
1.1	Update owl habitat models	1	\$57,000					\$57,000	DEC	\$8,400		\$48,600
			\$7,350					\$7,350	DPI (Forests NSW)	\$7,350		
1.2	Map modelled habitat	1	\$2,800					\$2,800	DEC	\$2,800		
			\$700					\$700	DPI (Forests NSW)	\$700		
1.3	Design sampling strategy	1	\$14,105					\$14,105	DEC	\$3,500		\$10,605
			\$7,595					\$7,595	DPI (Forests NSW)	\$7,595		
1.4	Field validation of modelled habitat	1		\$169,000	\$169,000			\$338,000	DEC			\$338,000
				\$91,000	\$91,000			\$182,000	DPI (Forests NSW)			\$182,000
1.5	Estimate number of owl territories	1					\$9,100	\$9,100	DEC	\$9,100		
							\$4,900	\$4,900	DPI (Forests NSW)	\$4,900		
2.1	Develop sampling strategy and regional monitoring protocols	1		\$3,500				\$3,500	DEC	\$3,500		
				\$1,750				\$1,750	DPI (Forests NSW)	\$1,750		
2.2	Investigate cooperative involvement of other agencies etc in monitoring	3							DEC			
2.3	Implement regional monitoring program	2			\$22,670	\$22,670	\$22,670	\$68,010	DEC			\$68,010
					\$12,210	\$12,210	\$12,210	\$36,630	DPI (Forests NSW)	\$36,630		
3.1	Investigate implementation of forestry TSL conditions	2	\$3,500	\$3,500	\$3,500	\$3,500	\$3,500	\$17,500	DEC	\$17,500		
3.2	Carry out post harvest surveys	2	\$700	\$700	\$700	\$700	\$700	\$3,500	DEC	\$3,500		
			\$10,500	\$10,500	\$10,500	\$10,500	\$10,500	\$52,500	DPI (Forests NSW)			\$52,500
3.3	Encourage student radio tracking projects	3							DEC			
3.4	Assess forestry TSL owl conditions	3					\$5,250	\$5,250	DEC	\$5,250		
							\$5,250	\$5,250	DPI (Forests NSW)	\$5,250		
3.5	Refine and negotiate changes to TSLs	3					\$3,500	\$3,500	DEC	\$3,500		
4.1	Prepare and disseminate EIA guidelines	1	\$3,500					\$3,500	DEC	\$3,500		
4.2	Monitor effectiveness of	1		\$5,230	\$3,500			\$8,730	DEC	\$8,730		

Approved Recovery Plan for Large Forest Owls

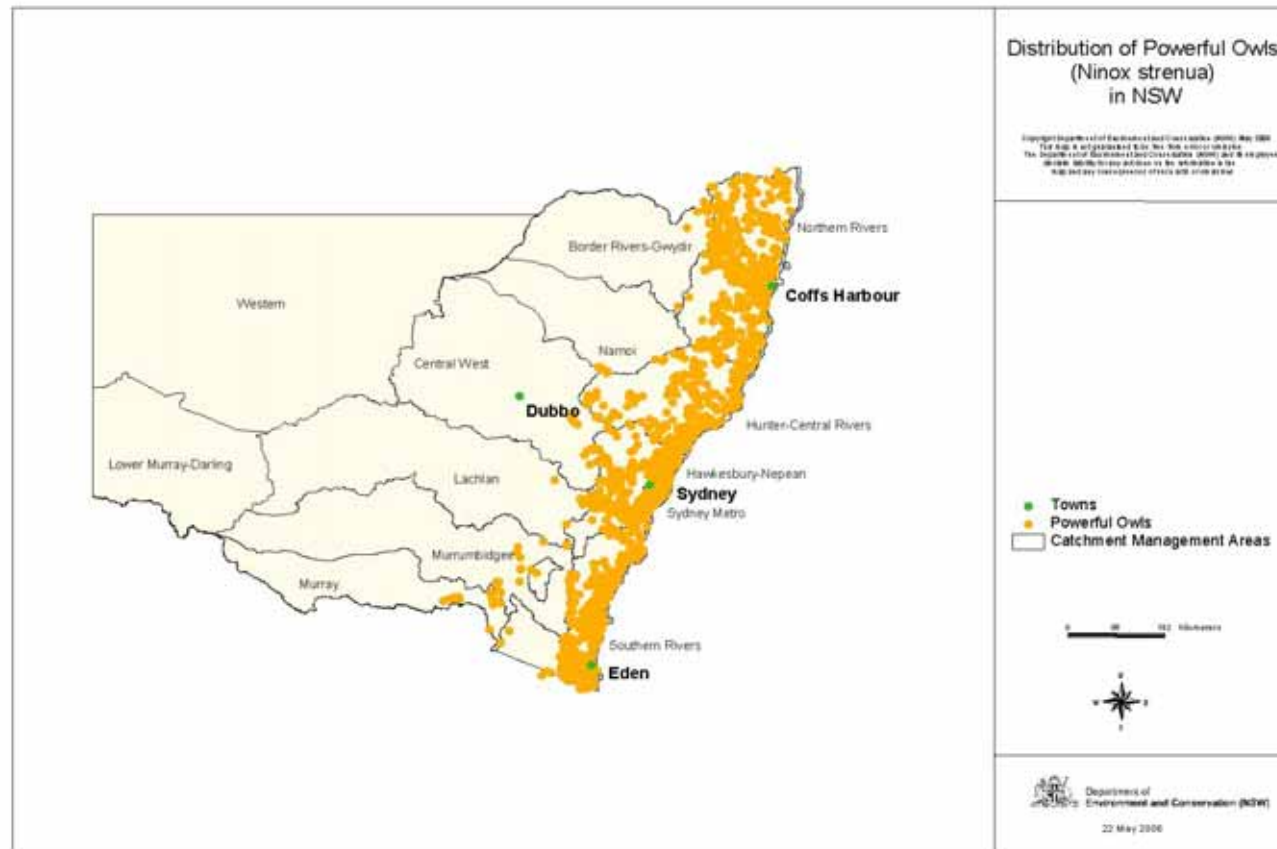
Action No.	Action	Priority	Year 1	Year 2	Year 3	Year 4	Year 5	Total Cost	Responsible Agency	In-Kind (DEC)	Cash (DEC)	External funds required (DEC)
	concurrence and licence conditions											
4.3	Develop prescriptive guidelines	1				\$3,500		\$3,500	DEC	\$3,500		
4.4	Provide accurate owl information for PVP tool	2							DEC			
4.5	Facilitate consideration of large forest owls during biodiversity certification assessments	2							DEC			
4.6	Inform Biobanking site assessments	2							DEC			
5.1	Prepare guidelines for habitat protection, management and survey	1	\$3,500					\$3,500	DEC	\$2,500	\$1,000	
5.2	Encourage CMAs to participate and invest in owl conservation actions	1							DEC			
5.3	Encourage landholders to undertake owl management on private lands	1							DEC			
6.1	Seek and contribute too ARC Linkage grant to initiate research into owl biology and ecology	2	\$37,000	\$37,000	\$37,000			\$111,000	DEC	\$18,000	\$18,000	\$75,000
6.2	Promote awareness of research needs	2							DEC			
6.3	Investigate cultural significance	3							DEC			
7.1	Encourage and coordinate involvement of community groups	3							DEC			
7.2	Ensure DEC website contains current owl information	3							DEC			
8.1	Coordinate implementation of recovery actions	1	\$5,250	\$5,250	\$5,250	\$5,250	\$5,250	\$26,250	DEC	\$25,250	\$1,000	
8.2	Seek to integrate recovery actions	3							DEC			
8.3	Review and rewrite plan	1					\$8,750	\$8,750	DEC	\$8,750		
8.4	Convene threatened owl workshop	1					\$2,750	\$2,750	DEC	\$1,750	\$1,000	
	TOTAL							\$998,920		\$193,205	\$21,000	\$774,715

Priority ratings are: 1- Action critical to meeting plan objectives, 2 - Action contributing to meeting plan objectives, 3 - Desirable, but not essential action.

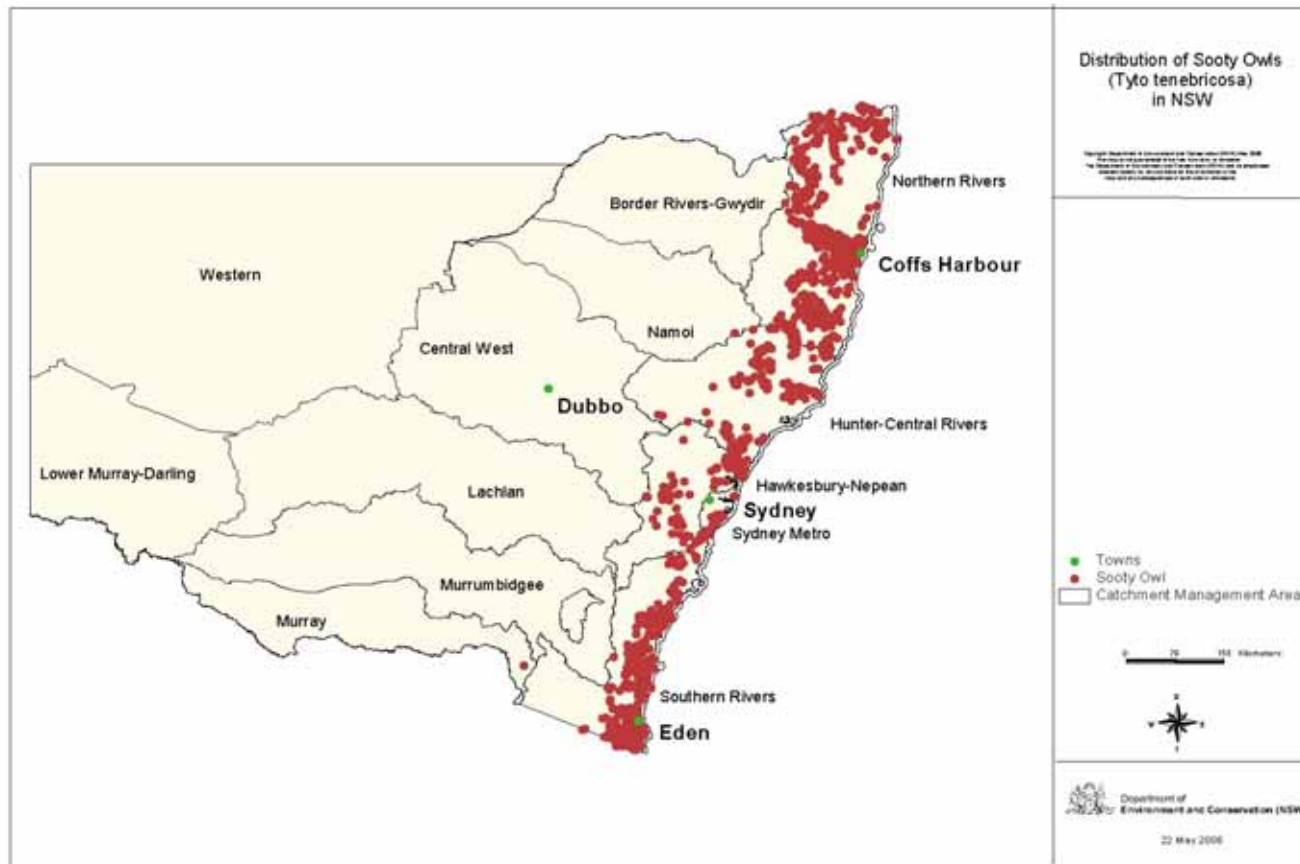
- 'In-Kind' Funds represent actions that are DEC core duties and are covered by current resources eg salary component of permanent staff and travel. (NB A pay rate of \$350 per day is used for coordination and includes on-costs.
- 'Cash' Funds are required for those actions that require a capital expense such as printing.
- External Funds include volunteer's in-kind time or cash grants. These actions will proceed when funds are secured.
- costs incorporated into time of recovery plan coordinator.

Appendix 1: Distribution Maps for Large Forest Owls

(a) Distribution of Powerful Owls (*Ninox strenua*) in NSW



(b) Distribution of Sooty Owl (*Tyto tenebricosa*) in NSW



(c) Distribution of Masked Owl (*Tyto novaehollandiae*) records in NSW



Appendix 2: Catchment Management Areas and Local Government Areas records of Large Forest Owls

Catchment Management Areas

Data compiled from DEC Atlas of NSW Wildlife records. CMAs with five or less records are indicated by a *.

Masked Owl	Sooty Owl	Powerful Owl
Border Rivers-Gwydir	Hawkesbury-Nepean	Border Rivers-Gwydir
Central West	Hunter-Central Rivers	Central West
Hawkesbury-Nepean	Murray*	Hawkesbury-Nepean
Hunter-Central Rivers	Namoi*	Hunter-Central Rivers
Lachlan*	Northern Rivers	Lachlan
Murray	Southern Rivers	Murray
Murrumbidgee*	Sydney Metro	Murrumbidgee
Namoi		Namoi
Northern Rivers		Northern Rivers
Southern Rivers		Southern Rivers
Sydney Metro		Sydney Metro
Western		

Local Government Areas

Note: Data compiled by from DEC Atlas of NSW Wildlife records. LGAs with five or less records are indicated by a *.

Masked Owl	Sooty Owl	Powerful Owl
Armidale Dumaresq	Armidale Dumaresq	Armidale Dumaresq
Ballina*	Ballina*	Ballina*
Bathurst Regional*	Baulkham Hills*	Bankstown*
Baulkham Hills	Bega Valley	Bathurst Regional*
Bega Valley	Bellingen	Baulkham Hills
Bellingen	Blue Mountains	Bega Valley
Bland*	Bombala*	Bellingen
Blue Mountains	Byron	Blacktown*
Bombala	Cessnock	Blue Mountains
Brewarrina*	Clarence Valley	Bombala*
Byron	Coffs Harbour	Botany Bay*
Canada Bay	Cooma-Monaro	Byron*
Canterbury*	Dungog	Campbletown
Carrathool*	Eurobodalla	Cessnock
Central Darling*	Glenn Innes Severn	Clarence Valley
Cessnock	Gloucester	Coffs Harbour
Clarence Valley	Gosford	Cooma-Monaro
Cobar*	Great Lakes	Cowra*
Coffs Harbour	Greater Taree	Dungog
Coonamble*	Hastings	Eurobodalla
Corrowa*	Hawkesbury*	Fairfield*
Dubbo*	Hornsby*	Glenn Innes Severn
Dungog	Kempsey	Gloucester
Eurobodalla	Kiama	Gosford
Gilgandra*	Kyogle	Great Lakes
Glenn Innes Severn	Lake Macquarie	Greater Hume
Gloucester	Lismore	Greater Taree
Gosford	Manly*	Gundagai*
Goulburn Mulwaree	Mid Western Regional*	Guyra*
Great Lakes	Muswellbrook*	Hastings*

Masked Owl	Sooty Owl	Powerful Owl
Greater Taree	Nambucca	Hawkesbury
Gunnedah*	Oberon*	Hornsby
Guyra*	Palerang	Hunters Hill*
Gwydir	Richmond Valley	Hurstville
Hastings	Shellharbour*	Kempsey
Hawkesbury	Singleton	Kiama*
Hornsby	Sutherland	Ku ring gai
Inverell*	Tenterfield	Kyogle
Jerilderie*	Tumbarumba	Lake Macquarie
Kempsey	Upper Hunter	Lane Cove
Kyogle	Walcha	Lismore
Lachlan	Wingecarribbee	Liverpool Plains*
Lake Macquarie	Wollondilly	Maitland
Leeton*	Wollongong	Manly*
Lismore	Wyong	Mid Western Regional
Lithgow*		Muswellbrook
Liverpool*		Nambucca
Liverpool Plains*		Newcastle
Maitland*		North Sydney*
Moree Plains*		Oberon
Muswellbrook		Palerang
Nambucca		Pittwater
Narrabri		Port Stephens
Narromine*		Randwick
Newcastle*		Richmond Valley
Palerang*		Ryde
Parkes*		Shellharbour
Penrith		Shoalhaven
Pittwater*		Singleton
Port Stephens		Snowy River
Richmond Valley		Sutherland
Shellharbour*		Sydney*
Shoalhaven		Tamworth Regional

Masked Owl	Sooty Owl	Powerful Owl
Singleton		Tenterfield
Snowy River*		Tumbarumba
Sutherland*		Tumut
Tamworth Regional*		Tweed
Tenterfield		Unincorporated Area*
Tumbarumba		Upper Hunter
Tweed		Upper Lachlan
Unincorporated Area		Uralla*
Upper Hunter		Walcha
Upper Lachlan*		Warringah
Walcha		Willoughby
Warringah*		Wingecarribbee
Warrumbungle		Wollondilly
Wingecarribbee		Wollongong
Wollondilly		Woollahra
Wollongong		Wyong
Wyong		Yass Valley

Appendix 3: Public Authority Responsibilities Relevant to the Management of Large Forest Owls

Public authority	Relevant responsibilities
Catchment Management Authorities	<ul style="list-style-type: none"> • Preparation of Catchment Action Plans • Developing and approving both offset and incentive Property Vegetation Plans
Department of Planning	<ul style="list-style-type: none"> • Development of policy and strategies for land use planning and environmental assessment • Advice and assistance on environmental planning matters • Assessment and determination of major development applications under Part 3a of the EP&A Act
Department of Lands	<ul style="list-style-type: none"> • Management of crown land with potential habitat
NSW Department of Primary Industries (Forests NSW)	<ul style="list-style-type: none"> • Implementation of prescriptions detailed in IFOA terms of licence granted under Part 4 of the <i>Forestry and National Park Estate Act</i> 1998
NSW Department of Environment And Conservation	<ul style="list-style-type: none"> • Assessment of Section 91 licence applications under the TSC Act • Assessment of Section 120 licence applications under the NPW Act • Advice to determining and consent authorities, with a concurrence role under the EP&A Act • Management of reserved lands • Granting certification to Environmental Planning Instruments • Co-ordination of recovery plan implementation • Development of threatened species Priorities Action Statement • Development of BioBanking tools
Other State government agencies	<ul style="list-style-type: none"> • Management of public lands with potential habitat • Approval authorities for activity proposals under Part 5 of the EP&A Act
Relevant local governments	<ul style="list-style-type: none"> • Preparation of Local Environmental Plans under Part 3 of the EP&A Act • Consent authorities for development proposals under Part 4 of the EP&A Act • Approval authorities for council works under Part 5 of the EP&A Act • Responsibilities under the <i>Rural Fires Act</i> 1997 • Management of council reserves with potential habitat • Consideration of the content of recovery plans when preparing plans of management for community land under the <i>Local Government Act</i> 1993
Rural Fire Service	<ul style="list-style-type: none"> • Preparation of Bush Fire Risk Management Plans and Plans of Operations • Fire management

