Recovering endangered populations in fragmented landscapes: the squirrel glider *Petaurus norfolcensis* on the south-west slopes of New South Wales

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ABSTRACT

The squirrel glider *Petaurus norfolcensis* is listed as a vulnerable species across New South Wales. The population in the Wagga Wagga Local Government Area was considered to be at a higher level of threat (*i.e.* in immediate danger of extinction) and was classified as an endangered population in 2000. The determination to list this population was made largely on the basis of limited point locality records of the species and an assessment of the extent of habitat clearing. This decision to designate the population as endangered was valid at the time and we do not dispute the fact that squirrel gliders within the Wagga LGA are at serious risk of extinction. However, recent surveys have revealed that the species is more widespread across the South West Slopes Bioregion of NSW than initially recognised. Despite this situation, the future conservation status of the squirrel glider is still uncertain due to extensive historic clearing and fragmentation of habitat as well as ongoing incremental loss and degradation of key resources. The new information about the distribution of squirrel gliders raises questions about the most effective approach, including the spatial scale, at which to manage and recover widespread but vulnerable species. We recommend that a landscape-scale approach that incorporates metapopulation theory be adopted to define and manage disjunct populations. There are likely to be numerous disjunct populations across the south-west slopes that are as equally endangered as the population(s) in the Wagga LGA. Therefore, a necessary first step in recovering squirrel gliders is to develop habitat models that describe and predict the occurrence of the species and delineate population boundaries. Other critical steps include: (i) reducing threats; (ii) maintaining a perpetual supply of key resources; and (iii) undertaking strategically located revegetation programs to increase total habitat and link isolated populations. Finally, the need to test and potentially revise the feedback process under the *Threatened Species Conservation Act 1995* is also recommended.

Key words: recovery, endangered populations, fragmented landscapes

Introduction

The *Threatened Species Conservation Act 1995* (TSC Act) of New South Wales has, as one of its objectives, to 'prevent extinction and promote recovery of threatened populations' (Appendix 2). A population is eligible to be listed under that Act if 'its numbers have been reduced to such a critical level, or its habitat has been so drastically reduced, that it is in immediate danger of extinction…' (Part 2, Division 2, Section 11). In July 2000, the New South Wales Scientific Committee, constituted under Part 8 of the TSC Act, determined that the squirrel glider *Petaurus norfolcensis* population in the Wagga Wagga Local Government Area (hereafter Wagga LGA) was eligible for listing as an endangered population (see also Appendix 2 for criteria for listing of endangered populations). The Scientific Committee concluded that the population was in immediate danger of extinction because of the extensive loss of habitat from the Wagga LGA and the drastic reduction in population size. It also qualified as an endangered population because it was recognised as a disjunct population that occurred near the western limit of its geographic range. The Scientific Committee based this determination, in part, on a sparse number of records from across the south-west slopes of New South Wales and from within the Wagga LGA. The records within the Wagga LGA occurred as five separate sightings between 1996 and 1998 in Wiradjuri Reserve and Wilks Park along the Murrumbidgee River, and three records from 25–30 km south of the city of Wagga Wagga in 1993, 1994, and 1995. The nearest geographic records of the species from outside the Wagga LGA came from near the township of Cootamundra to the north-east (a single record each in pre-1900, 1954, 1995 and 1999) and Albury in the south (two in 1954).

The squirrel glider has declined in range and abundance in Victoria and New South Wales and is listed as endangered and vulnerable, respectively, in those states (Lunney *et al.* 2000; NRE 2000). Detailed information on its status throughout Queensland is lacking but the species appears

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to be locally common, at least in the southern part of the State, although ongoing persistence of populations is considered questionable given incremental loss of habitat (Rowston *et al.* 2002). The official conservation status of the species in Victoria and New South Wales reflects the fact that, although the species is relatively widespread, much of the preferred habitat has either been cleared or drastically modified. The challenge for relevant land management agencies is to prevent the extinction of the species by arresting its decline and facilitating its recovery.

This chapter brings together recent (post-2000) information about the distribution of the squirrel glider that was not available to the New South Wales Scientific Committee at the time of listing. Surveys and records of the species within the Wagga LGA, and more generally across the south-west slopes of New South Wales collated after 2000, demonstrates that it is more widely distributed than previously recognised. Furthermore, the distribution of records from numerous fragments of habitat allows the prediction to be advanced that the species is likely to occur as numerous disjunct populations over a much broader area. Therefore, we ask four questions that need to be answered to increase the likelihood that the population in the Wagga LGA, and the species as a whole can be conserved. First, how should the boundary of local populations be defined? Second, at what spatial scale should recovery and management actions occur? Third, is the listing of endangered populations the most effective approach to conservation? Finally, what is the most efficient manner in which new information can be incorporated into the listing process?

Distribution and habitat requirements

The squirrel glider is a medium-sized (190-300g) arboreal marsupial whose primary method of travel is by gliding between trees using a flap of skin that extends between its arms and legs. Squirrel gliders are sparsely distributed in eastern Australia from Cape York Peninsula to western Victoria, mainly inland of the Great Dividing Range. A separate population band occurs on the coastal side of the Great Dividing Range between southern Queensland and southern New South Wales (Menkhorst *et al.* 1988). The species is found inland as far as the Grampian Ranges in Victoria and the Pilliga Scrub and the Coonabarabran areas of New South Wales (Quin 1995). Squirrel gliders typically occur in dry sclerophyll forests and woodlands below about 300 m in elevation (Menkhorst *et al.* 1988; Bennett *et al.* 1991; Rowston *et al.* 2002; Smith and Murray 2003), extending into coastal forests and slightly wetter swamp forest in northern New South Wales and Queensland (Rowston *et al.* 2002; Smith and Murray 2003). Trees with hollows are an essential habitat component because they are used as dens for shelter and raising young (Traill and Lill 1997; van der Ree 2000; Gibbons and Lindenmayer 2002).

Major threats to the species

The primary threats to the persistence of squirrel gliders across their range relate to the loss and degradation of habitat. Habitat loss and fragmentation has occurred because the preferred habitat often occurs on soils suited for agriculture (*e.g.* van der Ree 2002), in areas mined for gold (Traill 1991), or in coastal areas favoured for human settlements (*e.g.* Rowston *et al.* 2002; Smith and Murray 2003). Habitat has been degraded through the loss of key shelter and dietary resources. Trees containing hollows are typically less abundant in forest stands (*e.g.* State Forests) managed for timber than in remnants in road or travelling stock reserves (*e.g.* van der Ree and Bennett 2001). The net decline in abundance of large and hollow-bearing trees without adequate rates of replacement is also likely to be a major long-term threat to the persistence of squirrel gliders. The senescence or intentional removal of mid- and understorey species of plants that provide food resources (Holland 1998; Sharpe and Goldingay 1998) further degrades habitat quality. This may occur in rural landscapes where uncontrolled grazing by stock limits regeneration, as well as in urban areas that are cleared for human use. Other threats include mortality from collision with vehicles along roads and entrapment in barbed wire fencing (van der Ree 1999).

Recent surveys

We have compiled and mapped records of squirrel gliders from across the south-west slopes of New South Wales up to the end of 2003 (Table 1, Figure 1). This includes records available to the New South Wales Scientific Committee at the time of listing the endangered population (indicated by triangles in Figure 1), as well as more recent information (squares). Records were collated from numerous trapping and spotlighting surveys and incidental sightings from various sources (see Table 1). The squirrel glider was detected in a range of woodland types (Table 1) in both the Wagga LGA and many adjacent LGAs (Figure 1). This widespread distribution, utilisation of a range of eucalypt species and the lack of targeted survey effort to date, lead to the conclusion that the species may be more widely distributed than initially thought. However, there is still uncertainty about actual distribution, size and density of populations, and hence the long-term viability of the species across the highly fragmented landscapes of the south-west slopes.

Reassessing the status of the Wagga LGA population

In light of the new information, how well does the endangered population of squirrel gliders for the Wagga LGA still meet each of the three possible criteria for listing?

Criterion (a) it is disjunct or near the limit of its geographic range:

Squirrel gliders are more widespread within the Wagga LGA and across the south-west slopes than previously recognised. While the new records have extended the western limit of the species by approximately 50 km, the Wagga LGA population can still be considered to be near the western limit of its geographic range. Given the extent of loss and fragmentation of habitat within

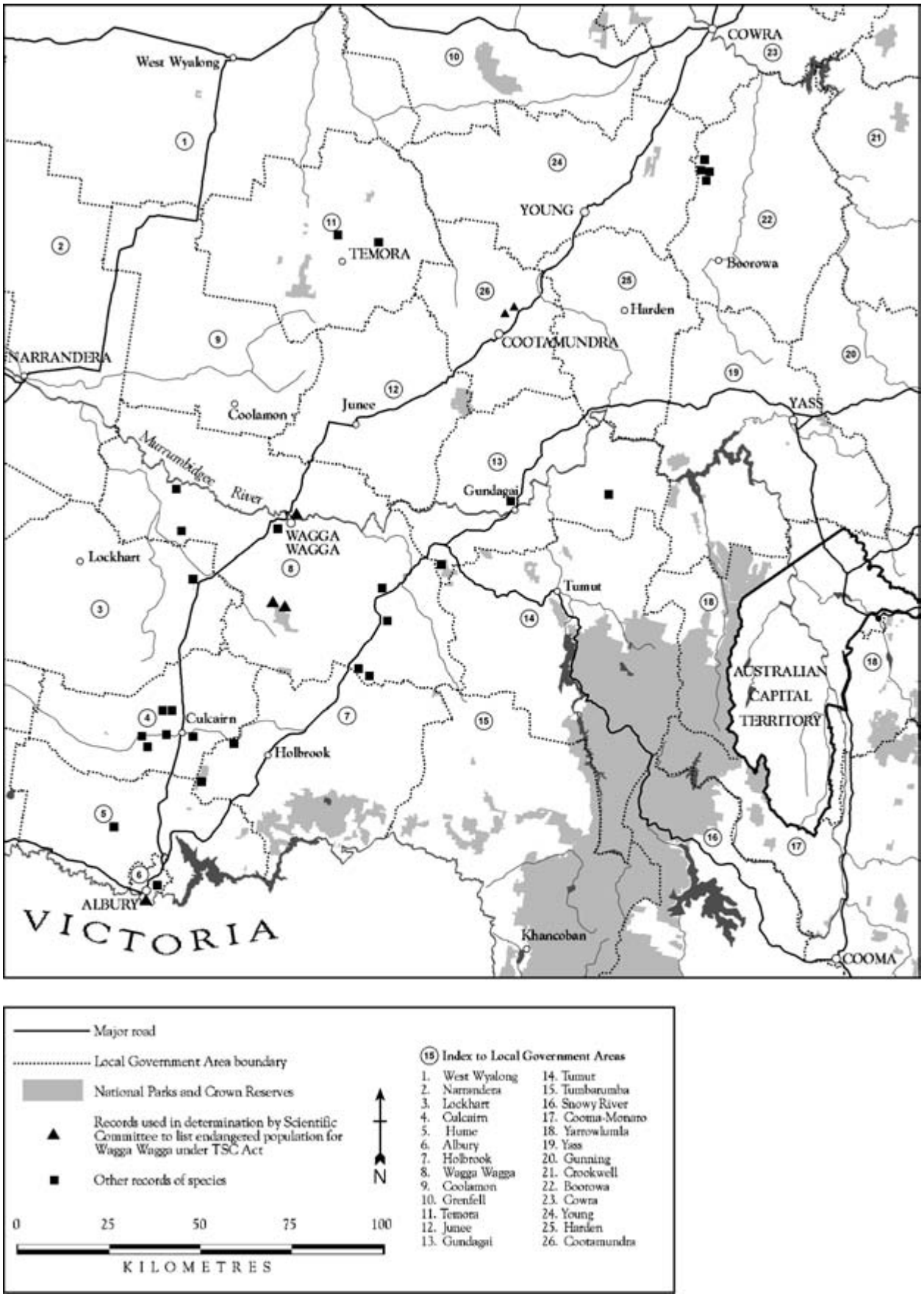

Figure 1. Locality records for the squirrel glider *Petaurus norfolcensis* on the south west slopes of New South Wales. Records are current to end 2003.

Table 1. Records for the squirrel glider *Petaurus norfolcensis* on the south-west slopes of New South Wales. Records are current to end 2003.

Location	Year of sighting	Dominant eucalypt species	No. animals (record type in superscript)	Reference
Albury LGA				
	1954	*E. blakelyi*	*1[t]	Atlas of NSW Wildlife
Thurgoona	2003	*E. albens*, *E. melliodora*, *E. camaldulensis*, *E. blakelyi*	26[t] 3[o] 2[h]	van der Ree (2003) Craig Grabham (unpubl. data) Damian Michael (unpubl. data)
Hume Highway	2002		3[k]	Peter Merritt (unpubl. data)
Boorowa LGA				
Yellow Waters TSR	2001	*E. blakelyi*	1[o], 1[k]	Atlas of NSW Wildlife
Private Property	1999	*E. sideroxylon*	2[o]	Gaia Research Pty Ltd (1999a,b)
Dananbilla NR	1999, 2001	*E. sideroxylon*, *E. blakelyi*	1[o], 1[o]	Gaia Research Pty Ltd (1999b), Atlas of NSW Wildlife
Cootamundra LGA				
Private Property	1954	*E. blakelyi*	*1[t]	Atlas of NSW Wildlife
Jindalee SF	1995	*E. sideroxylon*	*1[o]	Bos and Lockwood (1996)
Jindalee SF	1999	*E. microcarpa*, *E. sideroxylon*	6[o]	NPWS Wildlife Atlas, Claridge (D.L.) and Tidemann (2001)
Culcairn LGA				
Private Property	2000	*E. camaldulensis*	5[t]	Atlas of NSW Wildlife
Billabong Creek	2001	*E. camaldulensis*, *E. melliodora*	1[o]	Craig Grabham (unpubl. data)
Kings TSR	2001	*E. camaldulensis*	6[t]	Matt Haering (unpubl. data)
Walla Swamp	2001	*E. melliodora*, *E. microcarpa*	1[t]	Matt Haering (unpubl. data)
Comer TSR	2002	*E. microcarpa*	1[o]	Atlas of NSW Wildlife
Kirndeen TSR	2002	*E. bridgesiana*, *E. camaldulensis*, *E. melliodora*	9[t]	Matt Haering (unpubl. data)
Morgans Lookout	2002	*E. bridgesiana*, *E. camaldulensis*	2[t]	Matt Haering (unpubl. data)
Gundagai LGA				
Bungongo SF	1979	*E. globulus*	4[o]	Gall (1982)
Ellerslie NR	2002	*E. microcarpa*, *E. melliodora*	2[o]	Atlas of NSW Wildlife
Hume Highway	2002		1[k]	Gaia Research Pty Ltd (unpubl. data)
Holbrook LGA				
Billabong Creek	2002	*E. bridgesiana*, *E. camaldulensis*	3[t]	Matt Haering (unpubl. data)
No Mans Land	2002	*E. albens*	3[o]	Matt Haering (unpubl. data)
Hume LGA				
Unnamed TSR	2002	*E. albens*, *E. blakelyi*, *E. melliodora*	3[t]	Craig Grabham (unpubl. data)
Jindera-Burrumbuttock Rd	2002	*E. albens*, *E. blakelyi*, *E. melliodora*	5[t]	Craig Grabham (unpubl. data)
Lockhart LGA				
The Rock NR	1994		1[o]	Atlas of NSW Wildlife
Burkes Creek	1999	*E. camaldulensis*	1[o]	Channing (2000)
Temora LGA				
	1999		1[o]	Channing (2000)

Location	Year of sighting	Dominant eucalypt species	No. animals (record type in superscript)	Reference
Wagga Wagga LGA				
	1993		*1[t]	Atlas of NSW Wildlife
Livingstone NP	1995	*E. sideroxylon*	*2[t]	Atlas of NSW Wildlife
Wiradjuri Reserve	1996, 1997	*E. camaldulensis*	*1[t], *1[m]	Atlas of NSW Wildlife
Wilks Park	1997, 1998	*E. camaldulensis*	*2[o], 1[o]	Atlas of NSW Wildlife
Roaches Road	2000	*E. camaldulensis*	1[o]	Atlas of NSW Wildlife
Tarcutta Hills	2000, 2001	*E. albens*, *E. sideroxylon*	1[o], 4[t]	Traill (2000) van der Ree (2001)
Berry Jerry SF	2001	*E. camaldulensis*	1[h], 1[o]	Atlas of NSW Wildlife
Eight Mile Road	2001	*E. albens*, *E. polyanthemos*	1[o]	Atlas of NSW Wildlife
Murraguldrie SF	2001, 2003	*E. albens*	12[t], 12[t]	van der Ree (2001) van der Ree (unpubl. data)
Mates Gully TSR	2001, 2003	*E. sideroxylon*	17[t], 13[t]	van der Ree (2001) van der Ree (unpubl. data)
Silvalite Reserve	2003	*E. albens*	2[t]	Bruce Mullins (unpubl. data)
Private Property	2003	*E. albens*	1[t]	Bruce Mullins (unpubl. data)
Kyeamba TSR	2003	*E. albens*	4[t]	van der Ree (unpubl. data)
Young LGA				
Grogan TSR	2000	*E. camaldulensis*	1[o]	Atlas of NSW Wildlife

* Records considered in New South Wales Scientific Committee determination under the *Threatened Species Conservation Act* 1995. LGA = Local Government Area. General Location: NR = Nature Reserve; TSR = Travelling Stock Reserve; SF = State Forest.

Record Type: H = Hair Sample; K = Killed Animal; M = Miscellaneous; O = Observed; T = Trapped

the Wagga LGA, there are likely to be numerous groups of squirrel gliders that are geographically separated, effectively acting as disjunct populations. For example, recent vegetation modelling for the Wagga LGA indicates that of 18 recognised major plant communities present, 7 qualify as being classified as 'endangered' and 7 as 'vulnerable' according to the criteria of Benson and Ashby (2000) – meaning that they have been, to varying degrees, extensively cleared. Furthermore, most of these at risk vegetation communities are considered to be poorly reserved (only 1-5% of extant distribution represented in formal conservation reserves - see Priday 2004).

Criterion (b) it is or is likely to be genetically, morphologically or ecologically distinct:

There is no evidence to suggest that squirrel gliders within the Wagga LGA differ markedly either genetically, morphologically or ecologically from individuals of the same species elsewhere on the south-west slopes (and perhaps across the State). Relevant research would be required to qualify the situation.

Criterion (c) it is otherwise of significant conservation value:

There is no information that could allow assessment of the relative conservation value of squirrel gliders within and outside of the Wagga LGA. More information about the relative size and viability of populations within the Wagga LGA and across the south-west slopes is required to determine the conservation value of particular populations.

Although the squirrel glider is more widespread across the south-west slopes of New South Wales than previously thought, past clearing means that remaining habitat is often made up of few large fragments, interspersed by single trees and small patches of trees occurring in cleared paddocks (Gibbons and Boak 2002). This pattern appears typical for much habitat of the squirrel glider in south-eastern Australia (van der Ree *et al.* 2003) Thus, the survival of many populations of squirrel gliders, particularly those occurring on the inland slopes of the Great Dividing Range is reliant on a mosaic of woodland fragments of varying size and levels of connectivity, set within a cleared agricultural landscape. While squirrel gliders have been detected in some small or linear remnants of woodland throughout their range (Table 1, van der Ree 2002), the long-term viability of these small or isolated populations is unknown.

Positive outcomes from listing the endangered Wagga population

From a recovery planning perspective, the listing of the Wagga LGA squirrel glider population in 2000 has had a number of positive spin-offs. First, the endangered population listing has been useful from the point of view of delimiting a finite area in which to undertake recovery actions – that is, the population is demarcated by the administrative boundary of the LGA. This boundary allows for relevant parties involved in the recovery process to be more easily identified and may lead to more rapid focussing of recovery efforts. The listing has also stimulated parties to conduct further targetted survey for the species

both within and adjacent to the Wagga LGA. Raising the profile of the species, by way of listing the endangered population, has helped in the quest to secure funding for initiatives to benefit recovery of its habitat within the Wagga LGA. The endangered status of the population should also lead to a higher level of consideration during environmental assessment of proposed developments and activities. Finally, the management and ultimately the recovery of the population are guided by a recovery plan, which is currently in preparation. The object of a recovery plan under the TSC Act is to document the research and management actions required to promote the recovery of a threatened species, population or ecological community and to ensure its ongoing viability in nature.

A conservation strategy for squirrel gliders in the Wagga LGA and the south-west slopes of NSW

Is the listing of the endangered population the most effective strategy to conserve the species in the Wagga LGA and, more broadly, across the south-west slopes of New South Wales? In hindsight, there appears to be little difference in the risk of extinction between the animals living in the Wagga LGA and elsewhere on the south-west slopes. This is because squirrel gliders appear to be widely distributed across the region as a series of mostly small and fragmented populations. Furthermore, the extent of habitat loss and fragmentation within the range of squirrel gliders on the south-west slopes is likely to be similarly extensive. Therefore, the level and type of threat facing most populations of the species is probably comparable.

Squirrel gliders, like all species of native wildlife, are legally protected under the *National Parks and Wildlife Act 1974*. Its status as a vulnerable species under the TSC Act confers extra protection or consideration, however, in practice not necessarily to the same extent as that provided to endangered populations. Therefore, it is possible that people without an adequate understanding of the legislative framework may assume that all populations outside the Wagga LGA may be more secure and less in need of recovery effort. A similar situation may occur for squirrel gliders that occur outside the Barrenjoey Peninsula on the northern Sydney Metropolitan Region, which is where the only other listed endangered population of this species occurs. Should recovery planning focus solely on endangered populations, to the exclusion of other populations that are likely to be similarly threatened? Similarly, does the listing of multiple endangered populations potentially divert conservation effort from recovering the species across the state, where it is classified as vulnerable? Is the most effective conservation strategy to identify, list and manage numerous endangered populations?

We believe that the most effective strategy to recovering the squirrel glider is to take a landscape scale approach. The current known distribution of the species indicates that, prior to clearing for agriculture, squirrel gliders were probably relatively common in woodland habitats below 300 m altitude across the south-west slopes of New South Wales. Indeed, squirrel gliders across the region would probably have interacted as a single population unit, extending into northern Victoria and central New South Wales. Therefore, managing squirrel gliders across the south-west slopes is likely to be a more ecologically defensible management unit than a political LGA boundary.

Steps to achieve recovery across the south-west slopes

Determining the current distribution and habitat requirements of squirrel gliders across the south-west slopes is critical to the effective management of the species. This information can be obtained from surveys that incorporate potential habitat on public land (*e.g.* roadside and travelling stock reserves, State Forests, conservation reserves) as well as on private land. The survey must aim to model and predict the distribution of squirrel gliders across the south-west slopes, taking into account habitat type and quality, patch size and levels of landscape connectivity. Other records may be sourced from environmental impact studies, road kill and opportunistic sightings. It should be recognised that more information about the distribution of many species is likely to exist than is currently indicated in databases, such as the Atlas of New South Wales Wildlife, that was developed in 1992 by the National Parks and Wildlife Service. That this is the case was demonstrated after the Wagga population was listed.

Implicit in determining the distribution of gliders across the south-west slopes is the need to delineate the boundaries of populations. This is essential in identifying the extent to which populations are interconnected via the dispersal of individuals and flow of genes. Information is available on the gaps between woodlands in northern Victoria that gliders are willing to cross during their nightly foraging (van der Ree *et al.* 2003), but the propensity to move across cleared land during dispersal is unknown. Genetic techniques are now able to directly measure dispersal through the identification of dispersing individuals by assignment testing and parentage analysis (*e.g.* Goudet *et al.* 2002). Furthermore, restriction of the movement of individuals between populations is likely to be reflected in the genome of the species, with populations on each side of the potential barrier (cleared farmland) being genetically differentiated (*e.g.* Gerlach and Musolf 2000).

Threat abatement is likewise a high priority for managing and recovering squirrel gliders across the landscape. Most threats to the persistence of squirrel glider populations relate to the loss, fragmentation and degradation of habitat. While broadly similar issues may threaten all populations, certain threats are likely to differ in emphasis across the landscape. In one area, the loss of large hollow-bearing trees and scattered trees in paddocks may be prolific due to changing agricultural practices (Ozolins *et al.* 2001). In another area, the widening of roads resulting in clearing of vegetation may be the major process threatening the species. Regardless, major threats to the persistence of squirrel glider populations need to be identified at a landscape scale once distributional data on the species are obtained.

Habitat restoration has the potential to contribute greatly to the future conservation of squirrel gliders in highly cleared agricultural landscapes. For example, plantings undertaken in the 1970s at Thurgoona north of Albury are currently being utilised by squirrel gliders where large remnant trees occur amongst the young regrowth (Rod van der Ree, 2003 unpublished data). However, a limitation of many revegetation programs is that they do not explicitly incorporate the needs of fauna. Consequently, they are unlikely to provide significant long-term benefits for species that have specialised requirements as effectively as plantings that provide for fauna. As a minimum, plantings for squirrel gliders should include a mix of preferred overstorey and shrub species, and incorporate standing (dead or alive) trees for hollows. Artificial nest boxes may also be useful in providing a temporary hollow resource. However, it is preferable to retain existing trees to provide future hollows because of the many years it takes for newly planted trees to develop hollows (upwards of 100–150 years, depending on the species of tree, Gibbons and Lindenmayer 2002). Once the distribution of gliders across the landscape is known, planting can be strategic to link or expand existing habitats, depending on the particular situation. The need to expand or connect habitat in particular areas would be based on habitat modelling that incorporated an assessment of the need to increase population size through habitat expansion or increase viability by linking populations. Local revegetation and landcare staff could access this information in a recovery plan and associated documentation, as well as through consultation with a zoologist or officers from a relevant land management agency such as the Department of Environment and Conservation. Revegetation and enhancement will be most effective when current losses can be controlled and threats are managed.

Future recovery efforts need to be allocated across the entire south-west slopes and not necessarily focused within the Wagga LGA because pressures facing both the species and its habitat are acute across the broader landscape. Recovering the Wagga LGA population must take into account the fact that animals do not recognise political planning boundaries. Managing the population in isolation from all other populations in the region is unlikely to maximise the population's long-term survival. Furthermore, the regional viability of the species, and indeed the viability of each disjunct population, is reliant on the survival of adjacent populations. Current ecological paradigms suggest that metapopulation theory is potentially an effective approach to conserving species (Opdam 1991). A metapopulation can be described as a set of discrete populations that interact with each other via dispersal of individuals (Hanski 1999). The viability of each discrete population, and therefore the metapopulation as a whole, is dependent on maximising the size and number of each connected sub-population. Therefore, managing a single population in isolation from all adjacent populations is likely to be ineffective in the long-term.

One possible way forward is to expand the geographic coverage of the endangered population listing to at least encompass the South West Slopes Bioregion. A supporting argument could be based on the premise that squirrel gliders probably operated as a single population on the south-west slopes before clearing took place. In reality, squirrel gliders probably occurred in a continuous band from northern Victoria, through the south-west slopes of New South Wales and further northwards. In addition, achieving conservation goals at a regional scale will depend on a strategy that maximises the number and size of populations within the metapopulation. Regardless of the approach taken, the process to modify the current listing to increase the geographic extent is non-trivial and involves delisting the Wagga LGA population and re-nominating the (meta) population of the south-west slopes. Further, it is unclear if the legislation allows for listing of populations on the basis of it being a previously continuous population or a currently endangered metapopulation. Nevertheless, the listing of the Wagga LGA population has set a benchmark in accepting, and hence defining, the number of records required to determine a disjunct population of a species within a pre-determined boundary.

Conclusion

We have proposed, as part of the immediate recovery process, a number of ways in which the endangered squirrel glider population in the Wagga LGA and its habitat might be best conserved and, in time, rehabilitated. Conservation actions for the Wagga LGA population must recognise that (a) there are probably numerous disjunct populations that are equally threatened within and outside the Wagga LGA and that (b) the probability of persistence of each disjunct population is related to the size and persistence of adjacent populations and the rate of transfer of individuals. Thus, we question whether the concept of managing an endangered population, in relative isolation to adjacent populations that do not occur within the Wagga LGA, is the most efficient and effective approach to conserving a widespread but highly vulnerable species. Conservation must take a landscape-scale approach that extends beyond the boundaries of a single LGA and incorporate multiple disjunct populations. This raises the issue of how to efficiently refine existing conservation arrangements within the existing legislative framework in light of the new information. While a mechanism is available, it appears cumbersome because it amounts to delisting and relisting the population and no precedent has been set. Nevertheless, a responsive feedback procedure is required to formally integrate new data and ecological paradigms into the official conservation process.

In the meantime, we have emphasised the need to carry out a survey for the species and build a model that describes and predicts suitable habitat across the south-west slopes. An integral part of the survey would be to delineate population boundaries and estimate the extent to which individuals or genes are moving between populations. Habitat protection and restoration must occur at a landscape scale, recognising the need to manage habitats and threats that occur over large areas or originate from the cleared matrix. The loss of large trees from substantial areas of the landscape will result in a reduction in the hollow resource, utilised by squirrel gliders and a wide range of other species. The lag-time of more than 100–150 years from when trees are planted to when they are large enough to develop usable hollows will limit population sizes when other resources, such as food, are available.

This review of the management and recovery of the endangered population of squirrel gliders in the Wagga LGA has provided an uneasy glimpse of the future. Will state governments or their agencies continue to identify and classify multiple endangered populations of widespread but vulnerable species without taking a more holistic approach? The process of official listing followed by determined efforts to prevent extinction is likely to become more commonplace with time. Therefore, the final lesson to be learned from the endangered Wagga LGA population of squirrel gliders is to critically examine species and landscapes that appear in no immediate need of conservation and consider what options for management will conserve the last stands of forests and woodlands to prevent extinction.

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APPENDIX 1

The Squirrel Glider *Petaurus norfolcensis* is a medium-sized arboreal marsupial from the woodlands and forests of eastern Australia. Due to extensive loss and fragmentation of habitat, it now occurs as many geographically isolated populations and is at risk of extinction across its range. The species is listed as vulnerable in NSW, and two populations (Wagga Wagga LGA and Barrenjoey Peninsula) are considered at greater risk and are listed as endangered. The challenge is to recover the listed endangered populations, as well as manage the species across its range to prevent further decline and enhance prospects for survival. Managing multiple endangered populations in isolation from other populations may ultimately do little to enhance the long-term survival prospects for the species.

APPENDIX 2

Appendix 2

Objects of the *Threatened Species Conservation Act 1995*

The TSC Act came into legislative effect in January 1996. The objects of the Act are:

(a) to conserve biological diversity and promote ecologically sustainable development, and;

(b) to prevent extinction and promote recovery of threatened species, populations and ecological communities, and;

(c) to protect the critical habitat of those threatened species, populations and ecological communities that are endangered, and;

(d) to eliminate or manage certain processes that threaten the survival or evolutionary development of threatened species, populations and ecological communities, and;

(e) to ensure that the impact of any action affecting threatened species, populations and ecological communities is properly assessed, and;

(f) to encourage the conservation of threatened species, populations and ecological communities by adoption of measures involving co-operative management.

APPENDIX 2

Criteria for Endangered Population Listing

To qualify as an endangered population, the Wagga population must, in the opinion of the New South Wales Scientific Committee, have had its numbers reduced to such a critical level, or its habitat so drastically reduced, as to place it in immediate danger of extinction. It also had to meet at least one of the following three criteria:

a) it is disjunct or near the limit of its geographic range, or;

b) it is or is likely to be genetically, morphologically or ecologically distinct, or;

c) it is otherwise of significant conservation value.

APPENDIX 3

Appendix 3

Criteria for assessing conservation status of vegetation communities in the Wagga LGA, applied by Priday (2004) based on system modified from Benson and Ashby (2000).

ENDANGERED: vegetation community was formally widespread (>10000 ha) and >85% has been cleared or severely degraded, or; vegetation community was naturally restricted (1000 to 10000 ha) and >70% has been cleared or severely degraded.

VULNERABLE: vegetation community was formally widespread (>10000 ha) and >60-85% has been cleared or severely degraded, or; vegetation community was naturally restricted (1000 to 10000 ha) and >50% has been cleared or severely degraded.

LEAST CONCERN: vegetation community was formally widespread (>10000 ha) and <50% has been cleared or severely degraded, or; vegetation community was naturally restricted (1000 to 10000 ha) and <25% has been cleared or severely degraded.