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Area Requirements For Viable Populations Of The Australian Gliding Marsupial Petaurus Australis

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Abstract

The yellow-bellied glider Petaurus australis is an arboreal marsupial that has an extensive but patchy distribution in native eucalypt forests along the east coast of Australia. It is considered a vulnerable species due to widespread habitat loss and low population densities resulting from social groups using exclusive homeranges of 25-85 ha. Many of its populations have been reduced in size but there are no data to assess the viability of small populations. We used the computer program ALEX to conduct a preliminary population viability analysis (PVA).The objective was to determine minimum habitat areas that contain viable populations (i.e. populations that had a 95% probability of persistence for 100 years). Life history parameter values were derived from three detailed studies of this species. The model employs an environmental variable that influences breeding success to simulate environmental stochasticity. Parameter values were varied in order to conduct a sensitivity analysis. Each parameter set was simulated 100 times for a 200 year period. The model predicted that areas containing at least 150 glider groups were needed to support viable populations. The sensitivity analysis indicated that the adult mortality rate had the greatest influence on population viability. Varying the settings of rhe environmental variable also showed how important this component is to population viability and highlights the need for studies that specifically address the relationship between environmental variation and breeding success.

Minimum habitat areas were estimated by determining the area of forest that could contain 150 glider groups. Areas were based on the size of a glider group homerange and the proportion of forest in an area that could be occupied. Two scenarios exist for estimating the area of forest that is occupied. In one case, all of the available habitat (usually broad areas containing a highly favoured tree species) is occupied by gliders. This equates to 9750 ha of forest. In the other case, only a proportion (28-54%) of the forest is occupied. This equates to between 18,000 and 35,000 ha of forest to contain viable populations. Such large area requirements and an extensive geographic range suggest that the yellow bellied glider has potential for defining minimum sizes for Australia's forested conservation reserves. Using the above data, we provide a preliminary assessment of the adequacy of the size of forested conservation reserves in New South Wales.

Keywords: area requirements; Petaurus australis; viable populations

INTRODUCTION

Population viability analysis (PVA) is a computer modelling tool that is used to assess the extinction probability of threatened and endangered vertebrates and guide management options (Boyce, 1992). However, as the lists of such species around the world continues to grow, it becomes imperative that consideration be given to preserving functioning ecosystems. One of the most effective ways to achieve this at present is to focus on conserving vertebrates that have large area requirements (Soulé & Simberloff, 1986; Beier, 1993). These species are likely to occur at the lowest population sizes, and be among the most sensitive to extinction, of any species in an ecosystem (e.g. Terborgh, 1992). Thus, these species should be specifically targeted by PVA.

The species typically considered useful in this role have been the large owls, the northern spotted owl *Strix occidentalis caurina* in northwestem USA (Murphy & Noon, 1992) and the powerful owl *Ninox strenua* in eastern Australia (Possingham & Noble, 1991), and large mammalian carnivores such as the mountain lion *Felis concolor* in the USA (Beier, 1993). However, further species should be sought to provide additional assessment of the adequacy of management and conservation programs (Possingham, 1991). The yellow-bellied glider *Petaurus australis* is a forest-dependent arboreal marsupial that can be used to assess the adequacy of conserving forest ecosystems in eastern Australia. It lives in small family groupings that occupy virtually exclusive home ranges of 25-85 ha (Goldingay, 1992; Goldingay & Kavanagh, 1993). Thus, this species typically occurs at low population densities. The yellow-bellied glider has two traits that present advantages over other species if used as a target species for preserving forest ecosystems. First, its geographic range encompasses the entire length of the forests of the Great Dividing Range (Fig. 1), extending from far north Queensland down the eastern Australian coast and along the southern coast to just inside the South Australian border; a distance of approximately 3200 km (Winter, 1979). Other species of forest fauna that may be targeted with the aim of preserving forest ecosystems (e.g. the powerful owl) do not have such an extensive range and therefore may offer fewer opportunities for use in management. Secondly, the yellow-bellied glider is strictly arboreal and unlikely to cross open ground. In the absence of trees, the species is unable to disperse among patches of suitable habitat. Therefore, it is highly sensitive to habitat fragmentation. In contrast, large owls and large mammalian carnivores can readily cross areas of unsuitable habitat and have the capacity to continue to use landscapes containing fragmented habitat (Carey *et al.,* 1992; Beier, 1993).

The yellow-bellied glider is also deserving of a PVA because it is presently listed as endangered or vulnerable in three of the four states in which it occurs, totalling more than two-thirds of its geographic range. The aim of this paper is to provide preliminary estimates of the area of forest that contain a minimum viable population (MVP) of the yellow-bellied glider. These estimates enable a preliminary assessment of the adequacy of existing forested areas to conserve this species. We acknowledge that there is no consensus of the most appropriate criteria to define viable populations (Shaffer, 1981; Boyce, 1992). However, we arbitrarily defined populations as viable if they had a 95% probability of persistence for 100 years. Similar criteria have been used in other PVAs (e.g. Burke *et al.,* 1991).

Fig. 1. Distribution of the yellow-bellied glider in eastern Australia. Dashed line indicates the limit to the distribution. Letters identify the location of three studies used to derive the life history parameter values; H, Herberton, Queensland (Russell, 1984), B, Bombala, New South Wales (Goldingay & Kavanagh, 1990), G, Glengarry North, Victoria (Henry & Craig, 1984).

METHODS

Simulation model and data input

The computer program ALEX (Possingham *et al.,* 1992; Possingham & Davies, this issue) was used to carry out the PVA. The model uses information on the life history traits of the female population and environmental variability that influences reproduction. The life history traits include the mortality rates of the various age classes in the population and the probability of producing female young. The input data were derived from several field studies on this species (Henry & Craig, 1984; Russell, 1984; Goldingay &

Kavanagh, 1990). An important component of this PVA was to conduct a sensitivity analysis to explore the influence of the life history parameters and environmental variability on the estimated extinction probabilities. The effects of catastrophes such as fire, which are a component of the environment of this species, were not examined.

Age classes
The yellow-bellied glider has three age classes: newborn, subadult, adult. Observations suggest that young are carried in the pouch for 3.3 months and remain in the den for 1.7-3 months before independent foraging (Russell, 1984; Goldingay, 1992). Subadults disperse from their natal home ranges when 18-24 months of age (Henry & Craig, 1984; Goldingay & Kavanagh, 1990). The model was set so that offspring would become reproductively active in their second year.

Litter size and sex ratio
Yellow-bellied gliders typically give birth to a single young each year (Craig, 1986; Goldingay & Kavanagh, 1990). There are no data available for the sex ratio at birth. We assumed this to be 1:1 so the probability that a female young is produced was 0.5. The few data on the sex ratio of subadults are consistent with this assumption, assuming that there is no differential mortality between birth and the time a subadult becomes trappable.

Mortality and lifespan
Data on mortality are scant for the yellow-bellied glider. Data were summarised (Table 1) from the three field studies listed above. No consideration was given to differences between the sexes because of the small sample size. To determine newborn mortality, only those records were considered where a pouch young or nestling was observed and was known to have become a subadult or had disappeared prematurely. These data showed that five of 16 (approximately 0.30) young did not survive the newborn category.

It was assumed that if' an individual had survived to 18 months of age then it had survived the subadult stage. Data from the three field studies listed above suggest a mortality of two out of five subadults. Thus, based on these data we have assumed that subadult mortality was approximately 0.40.

The maximum observed longevity of this species is 6 years (Russell, 1984, Goldingay & Kavanagh, 1990). Thus, if an adult died in its sixth year, it would have spent 4 years as an adult and average annual mortality would be 0.25. Data for Bombala (Goldingay & Kavanagh, 1990) were calculated by estimating survival in each year an adult was present. Therefore, 10 adults survived for a cumulative total of 15 out of 19 years, which gives a mortality of 0.21. This value was approximated to 0.20 for use as a baseline parameter value in ALEX.

Table 1. Summary of baseline parameters used as input to ALEX

	Parameter	Value
Probability of annual mortality		
	Newborn	0.30
	Subadult	0.40
	Adult	0.20
	Probability of no female offspring	0.50
	Probability of one female offspring	0.50
	Environmental variation (EV)	0.8 +/- 0.3
	Homerange size (ha)	65

Homerange size
Values of homerange area can be used to estimate habitat areas of specified population sizes because the homeranges of glider groups are virtually exclusive and represent territories (Goldingay, 1994). At two sites in NSW, homeranges of the yellow-bellied glider ranged between a mean of approximately 35 and 65 ha (Goldingay, 1992; Goldingay & Kavanagh, 1993). Less detailed assessment of glider homeranges at two sites in Victoria (Henry & Craig:, 1984; Craig, 1985) provided estimates argued to be equivalent to the larger estimate (Goldingay & Kavanagh, 1993). A recent study near the South Australian-Victorian border provided a preliminary estimate of the homerange size of approximately 60 ha (Gilbert, 1993).

The number of female yellow-bellied gliders that occupy a homerange can vary from one site to another (Goldingay, 1992). At two sites, the number of adult females per homerange varied between one and two but at three other sites there was only a single adult female per homerange (Goldingay & Kavanagh, 1991). In the model, we have allowed for only a single adult female to occupy each home range and have allowed that a subadult female can also occupy each home range.

ENVIRONMENTAL VARIABILITY

The ALEX model uses an environmental variable drawn at random from a normal distribution with a specified mean and standard deviation to simulate environmental stochasticity. This variation influences the proportion of females in the population that breed each year. The model requires a value for the environmental variable to be specified at which all females in the population are able to breed (best conditions) and a value at which no females can breed (worst conditions). The proportion of females that breed if the environmental variable is between the worst and best case increases linearly from 0 to 1. Rainfall data can be used to approximate the environmental variable. Long-term rainfall data supplied by the Bureau of Meteorology for locations near two glider study sites in NSW were equivalent to values with a mean of 0.8 and standard deviation of 0.26-0-28. Environmental variation (EV) was modelled in this analysis by using a mean of 0.8 + 0.3 (SD). Best conditions occurred when this value was 0.6 and the worst when the value was 0.4. Variation in breeding frequency has been recorded for this species (Craig, 1986; Goldingay & Kavanagh, 1990) while adverse environmental conditions have been documented to coincide with a decline in the population density of the species (Goldingay, 1992).

Sensitivity analysis

Because the baseline parameter values for the yellow-bellied glider used in ALEX were derived from limited data, we varied these parameters. This allowed an assessment of the sensitivity of the model's results to slight deviations in these values. For each parameter value used in this study, the population was simulated 100 times for a 200-year period. The results of each set of 100 simulations are expressed by the probability of extinction after 100 years (i.e. the percentage of the 100 simulations when the population became extinct within the 100-year period). Simulations were run for different population sizes so that an assessment could be made of the population size at which the extinction probability was 5% or less after 100 years.

RESULTS

Sensitivity analysis

Using the baseline parameter set (Table 1) for analysis within ALEX, a population containing at least 150 glider groups was required to meet our definition of viability (i.e. less than a 5% extinction probability within a 100-year period). The output of the model was sensitive to varying the mortality of newborn and subadult gliders (Figs 2 and 3). However, varying adult mortality had a pronounced effect on extinction probabilities (Fig. 4). Even slight increases resulted in populations that were demographically unstable.

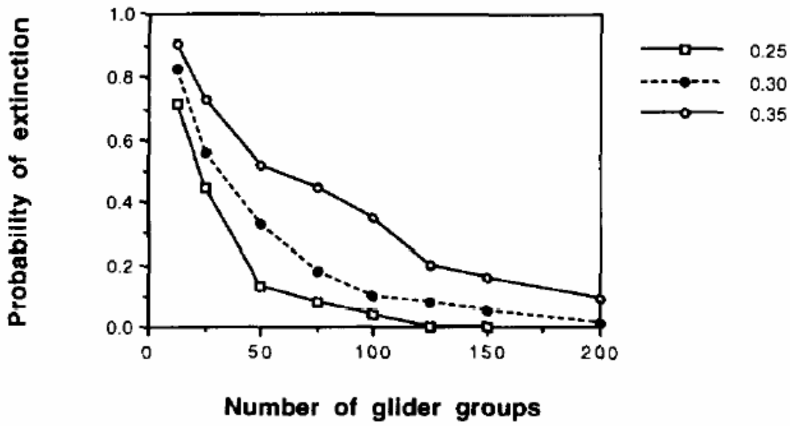

Fig. 2. Probability of extinction when the annual mortality of female newborn yellow-bellied gliders is varied.

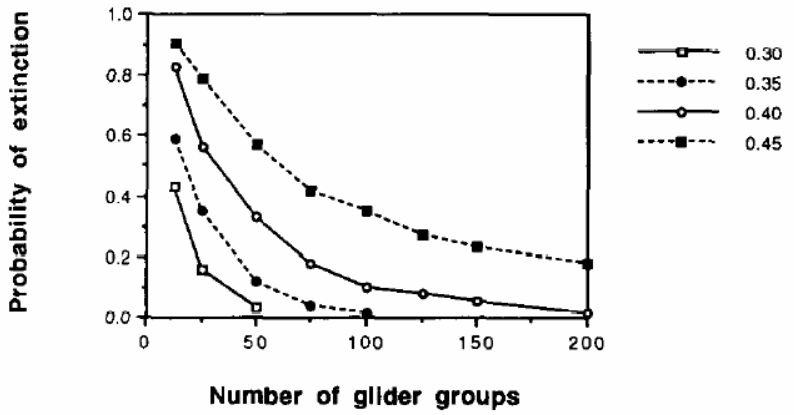

Fig. 3. Probability of extinction when the annual mortality of female subadult yellow-bellied gliders is varied.

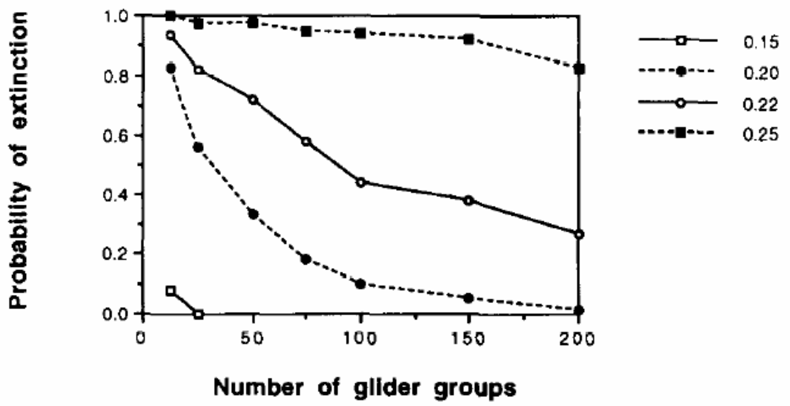

Fig. 4. Probability of extinction when the annual mortality of female adult yellow-bellied gliders is varied.

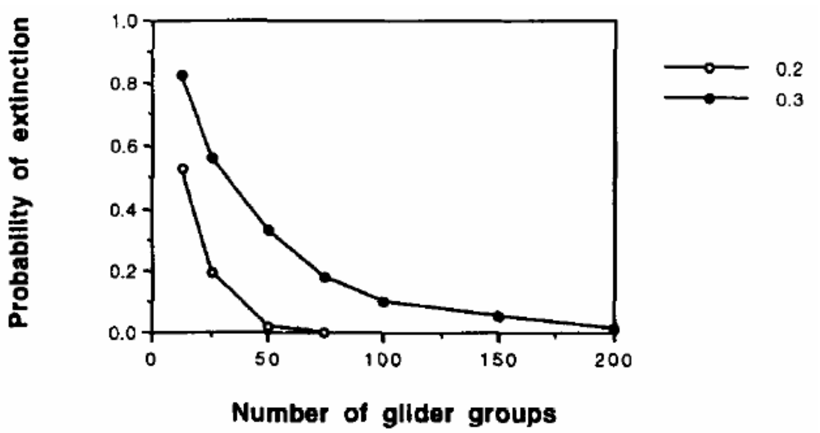

Fig. 5. Probability of extinction when the standard deviation in the environmental variation is varied.

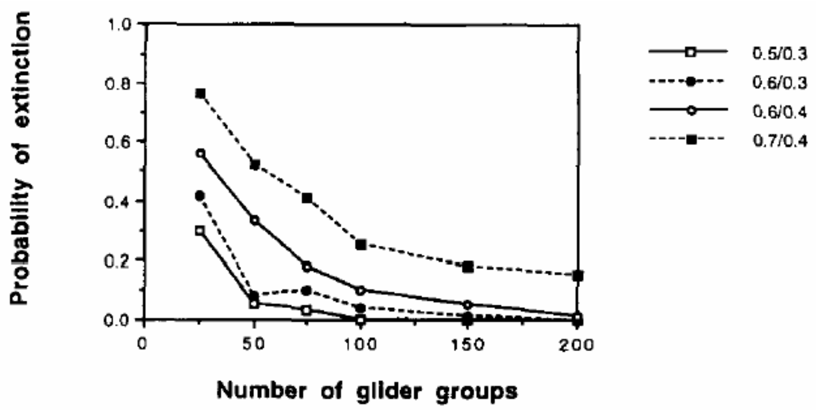

Fig. 6. Probability of extinction when the settings for the best and worst environmental conditions are varied.

An important component in the model is the setting for the environmental variable because it regulates the proportion of females in the population that breed. Using a lower value for the standard deviation in the environmental variable indicated that populations containing at least 50 glider groups were viable (Fig. 5).

Varying the thresholds of the best and worst environmental conditions for breeding while using the baseline life history parameters and *EV* required a population containing at least 150 glider groups to remain viable in two of the four scenarios (Fig. 6). The predictions from the model were very sensitive to this variable, indicating the need for data on year-to-year variation in fecundity in response to a variation in climatic variables such as rainfall.

This sensitivity analysis has demonstrated that caution should be shown in deciding which parameter values to use in this PVA. Slight changes in some of the model's parameters above the baseline data resulted in large increases to the estimates of the extinction probability. In particular, slight increases in adult mortality resulted in substantial increases in extinction probability and the population size required to remain viable, suggesting the need for more precise estimates of this parameter.

Habitat areas

This PVA has relied on a simple habitat configuration, namely a single patch of suitable habitat. This approach was chosen in order to reduce the number of assumptions that are used in the model such as those associated with the dispersal behaviour of subadults (see Lamberson *et al.*, 1992; Harrison *et al*, 1993). A single patch of suitable habitat is not an unrealistic scenario because the yellow-bellied glider occurs in many areas where suitable forest habitat has become isolated by roads and clearing for agriculture and housing (Goldingay, personal observations). The results of this PVA indicate that a population needs to contain at least 150 glider groups to be viable. It should be noted that this PVA has not modelled catastrophic events such as wildfire and drought which commonly affect parts of the range of this species. Again, this approach was adopted to reduce the number of assumptions in the PVA. If catastrophes were included, even larger population sizes are likely to be required to remain viable. To estimate the forest area needed to sustain a viable population of the yellow-bellied glider required two pieces of information, the area required by a single glider group and the amount of suitable habitat in a particular area. The home ranges of gliders are virtually exclusive to a single glider group and represent territories (Goldingay & Kavanagh, 1993; Goldingay, 1994). Therefore, estimating the amount of habitat required to support a specified number of glider groups simply involves multiplying the average homerange size by the number of groups required. The largest average homerange size that has been estimated (65 ha) is used to ensure that the habitat area is not underestimated. Thus, the habitat area that is required to support 150 glider groups is 9750 ha.

Yellow-bellied gliders typically show a patchy distribution, even in large areas of continuous forest (Braithwaite, 1983; Lunney, 1987). This results from gliders showing a preference for particular tree species and associated forest types (Kavanagh, 1984, 1987; Braithwaite *et al.*, 1988; Goldingay & Kavanagh, 1993). This indicates that for many large patches of forest, only a proportion of the forest offers suitable habitat. For some habitat types such as that dominated by the grey gum *Eucalyptus punctam,* surveys indicate that large patches of forest may be occupied throughout by the yellow-bellied glider (R. Goldingay, unpublished data). Thus, there are two scenarios to consider when estimating forest areas that contain viable populations of this species -- that all of the available forest is occupied or only a proportion of the available forest is occupied. Regional surveys of arboreal marsupials have been conducted that allow an estimate of the proportion of suitable habitat in areas where not all of the forest is occupied. The most definitive was that by Braithwaite (1983), who used logging crews to record the number and species of arboreal marsupials that were displaced from trees during clear-felling operations when large areas of native forest in the south-east corner of NSW were being converted to exotic pine plantations. This study recorded yellow-bellied gliders from only five of eight State Forests that each had more than 200 ha of habitat removed. Most of the records were obtained from two State Forests on the tablelands, one of which was close to a site where detailed studies were conducted on the ecology of the yellow-bellied glider (see Goldingay & Kavanagh, 1990, 1993). In these two State Forests, Braithwaite recorded 30 yellow-bellied gliders from 1389 ha of forest cleared. This area contained an abundance of favoured tree species. The average group size of gliders on the tablelands was 2.6 individuals per group (Goldingay & Kavanagh, 1991). Thus, 11.5 glider groups were censused by Braithwaite. If each had a home range size of 65 ha (the estimate for this area) then 748 ha of suitable habitat were censused in the total forest cleansed. This equates to approximately 54% of the forested area sampled being occupied by gliders. Therefore, the size of a block of forest needed to contain 150 glider groups in this type of forest would be approximately 18,000 ha.

Two further regional surveys recorded data on yellow- bellied glider distribution. Kavanagh and Bamkin (1995) surveyed 200 site~,; in the south-eastern region of NSW where Braithwaite conducted his study. This recent study relied on spotlighting and the broadcast of owl calls to detect the presence of yellow-bellied gliders. Kavanagh and Bamkin recorded this species at 29% of their survey sites. A similar type of survey in the mountain ash *E. regnans* forests in the Victorian central highlands recorded yellow-bellied gliders at 28% of 130 survey sites (Milledge *et al.*, 1991). If we again assume a home range of 65 ha, these values indicate that a block of forest in the area of these surveys may need to be as large as 35,000 ha in order to contain a viable population of yellow-bellied gliders.

DISCUSSION

Estimates of MVP using ALEX

Using plausible assumptions in the simulation model indicated that a population containing approximately 150 glider groups is needed to have a 95% probability of persistence for over 100 years. This estimate is based on life history parameters derived from three field studies conducted throughout the range of the yellow-bellied glider. A sensitivity analysis showed that the model's output was particularly influenced by the value used for adult mortality. This parameter is difficult to determine accurately because gliders live for at least 5-6 years, a period exceeding the duration of most studies on this species. Long-term studies are required to provide more precise estimates of all the life history parameters.

The analyses using the ALEX program incorporated a component of environmental variation. Changing the variance in the environmental variable and the thresholds that govern breeding success increased the MVP. Further research is needed to determine the most appropriate values to be used and how environmental variation may influence breeding success. Until these data are available, values must be used that allow for a moderate influence of environmental variation. Employing such values in this PVA required populations to contain at least 150 glider groups to remain viable. Habitat areas required for a minimum viable population The objective of the present study was to provide preliminary estimates of the area of habitat that contain MVPs of yellow-bellied gliders. This requires consideration of the proportion of a forested area that is suitable to this species. In some locations, all of the forested area will offer suitable habitat and the area required to contain a MVP will be the average home range size per glider group multiplied by 150 glider groups. Such a scenario occurs in areas where favoured tree species or forest types are widespread (R. Goldingay, unpublished data). At other locations, regional surveys have demonstrated that only 28-54% of the total forested area may be occupied by gliders (Braithwaite, 1983; Milledge *et al.*, 1991; Kavanagh & Bamkin, 1995). This results because a regional survey samples a much wider array of tree species than those favoured due to variations in topography and soil fertility (Braithwaite, 1983; Braithwaite *et al.*, 1988). The minimum habitat areas that have been estimated include 9750 ha where all the forest is suitable but between 18,000 and 35,000 ha where only a proportion is suitable. The intermediate value (indicating 54% of forest occupied) is based on a subset of the total data of Braithwaite (1983) for forest blocks where most yellow-bellied gliders were recorded. If all of Braithwaite's data are used then only 17% of the total forest was occupied by gliders. The largest area estimate above was based on two studies, one in NSW and the other in Victoria, that conducted nocturnal surveys of animals. They each recorded yellow-bellied gliders at approximately 29% of 100-200 survey sites. The NSW study (Kavanagh & Bamkin, 1994) was conducted in the same region as Braithwaite's study and included forested areas where Braithwaite recorded few yellow-bellied gliders.

Adequacy of existing reserves to conserve yellow-bellied gliders

Estimates of the area of forest required to support a MVP of yellow-bellied gliders allows a preliminary assessment of the adequacy of existing conservation reserves to conserve this species. This may provide some insight into whether a large enough area has been preserved to support a functioning forest ecosystem. The conservation reserves in the south-east corner of NSW can be used to illustrate a situation where only a proportion of the forested area contains suitable habitat. The estimate for the size of forest needed to support a MVP of yellow-bellied gliders in such a case is 18,000-35,000 ha (see above).

Within the last few years eight new conservation reserves have been declared for this region. The original reserve system was considered inadequate because most of the reserves were less than 4000 ha, isolated from each other and centred on low-quality fauna habitat (Recher *et al.,* 1980). Only one of 15 conservation reserves in this region now contains more than 18,000 ha of forest. That is, if these reserves became isolated many of them would not contain enough suitable habitat to support a viable population of yellow-bellied gliders. All the conservation reserves in this region are contained within a matrix of State Forests that are managed primarily for their timber production values but which also have considerable wildlife value. This highlights the need for integrated management across administrative boundaries (Norton & Lindenmayer, 1991) within the south-east forests of NSW because the reserve system by itself may not be adequate. Perhaps of greater concern is that only 20% of forested conservation reserves in NSW are larger than 10,000 ha (Resource Assessment Commission, 1992). Thus, the majority of these reserves will not be large enough to support a viable population of yellow-bellied gliders. This requirement for large areas of forest identifies the yellow-bellied glider as a species that should be targeted to provide a means of assessing whether conserved areas are large enough to preserve functioning forest ecosystems. Moreover, a sound conservation strategy for forest ecosystems should anticipate further fragmentation and should not rely on sufficient habitat being reserved in just a single area but within several across the landscape. This will provide some security against wildfire, disease or predation affecting all areas simultaneously. Similar spreading of the extinction risk has been advocated for the northern spotted owl (Thomas *et al.* 1990; Murphy & Noon, 1992).

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