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Petaurus gracilis (Diprotodontia: Petauridae)

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Abstract: *Petaurus gracilis* (De Vis, 1883) is a gliding possum commonly known as the mahogany glider. This species is endemic to open sclerophyll woodland between Tully and Ingham in North Queensland, Australia. Within its distribution *P. gracilis* occurs in forests dominated by trees of the genera *Eucalyptus*, *Corymbia*, *Melaleuca*, and *Acacia*. This species is recognized as an endangered species because of habitat loss, high degree of fragmentation of the remaining habitat, its naturally limited distribution, lack of habitat protected within national parks, and the degradation of its habitat from the transition to rain forest and thickening of sclerophyllous vegetation in much of its habitat.

Key words: Australia, gliding possum, mahogany glider, marsupial, North Queensland, petaurid glider, sclerophyll forest

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Petaurus Shaw, 1791

Petaurus Shaw, 1791:2, plate 60. Type species *Petaurus australis* Shaw, 1791, by monotypy.
Ptilotus Fischer von Waldheim, 1814:512. Type species *Petaurus australis* Shaw, 1791, by subsequent designation.
Belideus Waterhouse, 1839:151. Type species *Didelphis sciurea* Shaw, 1794, by original designation.
Belidens Wiegmann, 1839:418. Incorrect subsequent spelling of *Belideus* Waterhouse, 1839.
Belidea Gould, 1842:11. Type species *Belidea ariel* Gould, 1842, by monotypy.
Xenochirus Gloger, 1841:85. Type species *Didelphis sciurea* Shaw, 1794, by monotypy.
Petaurula Matschie, 1916:261. Type species *Petaurus breviceps* Waterhouse, 1839, by original designation.
Petaurella Matschie, 1916:261. Type species *Petaurus papuanus* Thomas (1888:158), by original designation.

CONTEXT AND CONTENT. Order Diprotodontia, suborder Phalangeriformes, superfamily Petauroidea, family Petauridae. Petauridae includes 3 genera: *Petaurus*, *Gymnobelideus*, and *Dactylopsila*. Members of the genus *Petaurus* include *P. abidi*, *P. australis*, *P. biacensis*, *P. breviceps*, *P. gracilis*, and *P. norfolcensis*.

Petaurus gracilis (De Vis 1883)
Mahogany Glider

Belideus gracilis De Vis, 1883:619. Type locality "North of Cardwell," North Queensland, Australia.
Petaurus norfolcensis gracilis: Iredale and Troughton, 1934:24. Name combination.

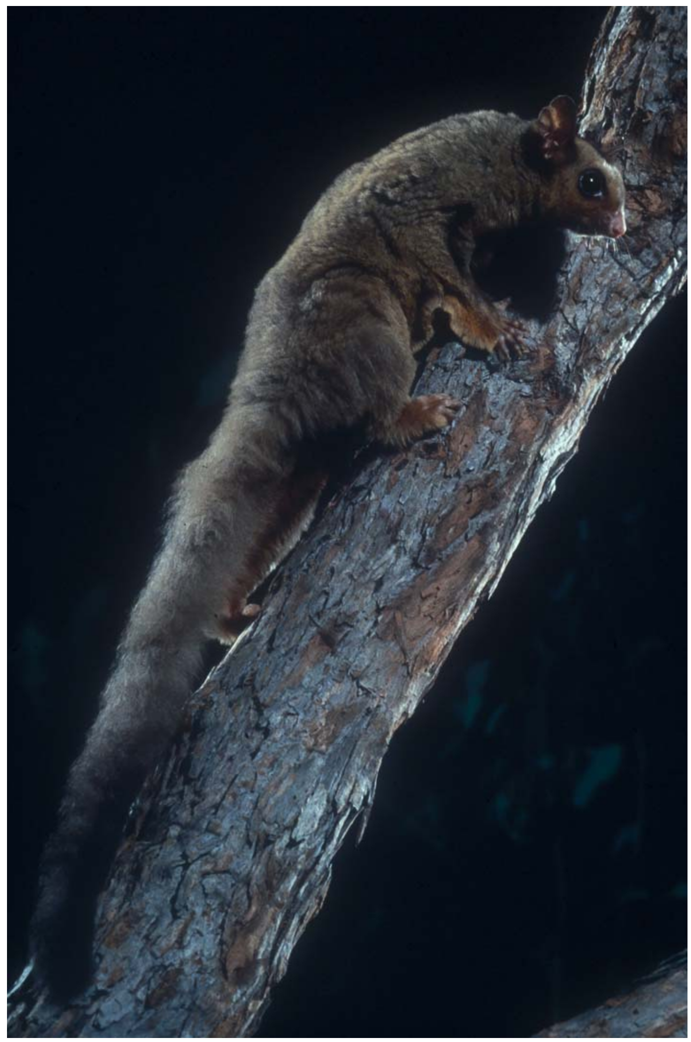

Fig. 1.—An adult *Petaurus gracilis*. Used with permission of the Queensland Museum.

Petaurus gracilis: Van Dyck, 1991:351. First use of current name combination.

CONTEXT AND CONTENT. Context as for genus. *P. gracilis* is monotypic.

NOMENCLATURAL NOTES. The taxonomic status of this species has been the subject of much conjecture after De Vis (1883) 1st described it because he failed to designate a holotype, no specimens are referred to in the literature, and no specimens are known outside the Queensland Museum (Van Dyck 1993). As early as 5 years after its description it was reduced to a synonym of *Petaurus sciureus* (= squirrel glider [*P. norfolcensis*]) by Thomas (1888). Subsequently however, it was elevated to a subspecies of *norfolcensis* by Iredale and Troughton (1934), which was followed by subsequent authors including Tate (1945), Fleay (1947, 1954), Marlow (1965), Troughton (1967), Alexander (1981), Strahan (1983), and Colgan and Flannery (1992), who used allozyme data. This taxon was synonymized within *P. norfolcensis* by McKay (1988) and Van Dyck (1990), who suggested that caution should be exercised in applying subspecies status to animals outside the type locality near Mt. Echo. With the exception of Van Dyck (1990, 1993) and Colgan and Flannery (1992), the earlier classifications were not based on samples or inspections of specimens, because the species had not been formally recorded between 1886 and its rediscovery on 6 December 1989 (when it was found at Barrett's Lagoon near Tully, 24 km north of Cardwell). After it was rediscovered, and the assessment of new samples of *P. gracilis* was undertaken, it was resurrected from synonymy with *P. norfolcensis* to species rank by Van Dyck (1991), with a formal reappraisal by Van Dyck (1993), who found it to be genetically and morphologically distinct. Subsequently, this taxon was recognized as a species by all authors including Flannery (1994), Strahan (1995), and Jackson (2008). Species rank was retained by Malekian et al. (2009), although it was recognized that mitochondrial divergence with *norfolcensis* was less than within *P. australis*. A detailed account of the early taxonomic history is given by Van Dyck (1990, 1993).

DIAGNOSIS

Petaurus gracilis (Fig. 1) is most similar to the squirrel glider (*P. norfolcensis*) but is readily distinguished from this species by its much greater body size. The maximum skull measurements of *P. gracilis* show no overlap with the squirrel glider in the maximum length of skull ($\bar{X}$ = 51.15 mm versus 45.33 mm), zygomatic width ($\bar{X}$ = 34.14 mm versus 30.15 mm), and rostral height ($\bar{X}$ = 14.02 mm versus 11.54 mm—Van Dyck 1993; Fig. 2). *P. gracilis* also has a significantly narrower interorbital width than does the squirrel glider ($\bar{X}$ = 8.59 mm versus 9.60 mm—Van Dyck 1993). *P. gracilis* also is clearly differentiated from the squirrel glider by the external measurements (see "General Characters" below). *P. gracilis* can be distinguished from the sugar glider (*P. breviceps*), with which it lives sympatrically, by size; it is twice the length and more than 4 times the mass of the sugar glider (Jackson 2008).

GENERAL CHARACTERS

Average body mass of *Petaurus gracilis* is 405 g (range 345–500 g) for males and 365 g (range 310–454 g) for females (Jackson 2008), which compares to a body mass of only 230 g (range 130–300 g) for the squirrel glider (van der Ree and Suckling 2008). *P. gracilis* also has much longer body measurements than the squirrel glider, with the head and body length being 254 mm (range 230–275 mm) for males and 248 mm (range 225–270 mm) for females. The tail length is 370 mm (range 335–395 mm) for males and 377 mm (range 345–405 mm) for females (Jackson 2008). This compares with a head and body length of 210 mm (range 180–230 mm) and tail length of 270 mm (range 220–300 mm) in the squirrel glider (van der Ree and Suckling 2008). *P. gracilis* has a long, fluffy tail although the hair at the base is not as long as that found in the squirrel glider (Jackson 2008).

DISTRIBUTION

Despite extensive surveys *Petaurus gracilis* is only known to occur in a narrow band of open, wet sclerophyll woodlands between Ollera Creek (40 km south of Ingham) and the Hull River near Tully; a north–south distance of 122 km, in North Queensland, Australia (Jackson 2008; Fig. 3). Within this distribution *P. gracilius* is known to occur at elevations mostly below 100 m (Jackson et al. 2011). The total area of habitat available to *P. gracilis* before large-scale clearing began in 2007 has decreased by 49% from 276,880 to 141,122 ha (Jackson et al. 2011). The remaining distribution is composed of 9 primary subpopulations that are in turn highly fragmented. Its restricted distribution is determined by very high seasonal rainfall, which has a mean dry quarter precipitation usually greater than 100 mm, and a woodland blend of vegetation that has historically been shaped and maintained by fire (Van Dyck 1993).

Because of the highly limited distribution of *P. gracilis* the known locality records were compared with those of the closely related squirrel glider to predict the distributional limits of each species using the computer program BIOCLIM (Jackson and Claridge 1999). *P. gracilis* was predicted to occur in areas with higher average mean annual temperature, smaller temperature range, higher temperatures throughout the year, higher annual precipitation, higher seasonality of precipitation, higher seasonality of moisture index, and higher precipitation in the wettest quarter and warmest quarter when

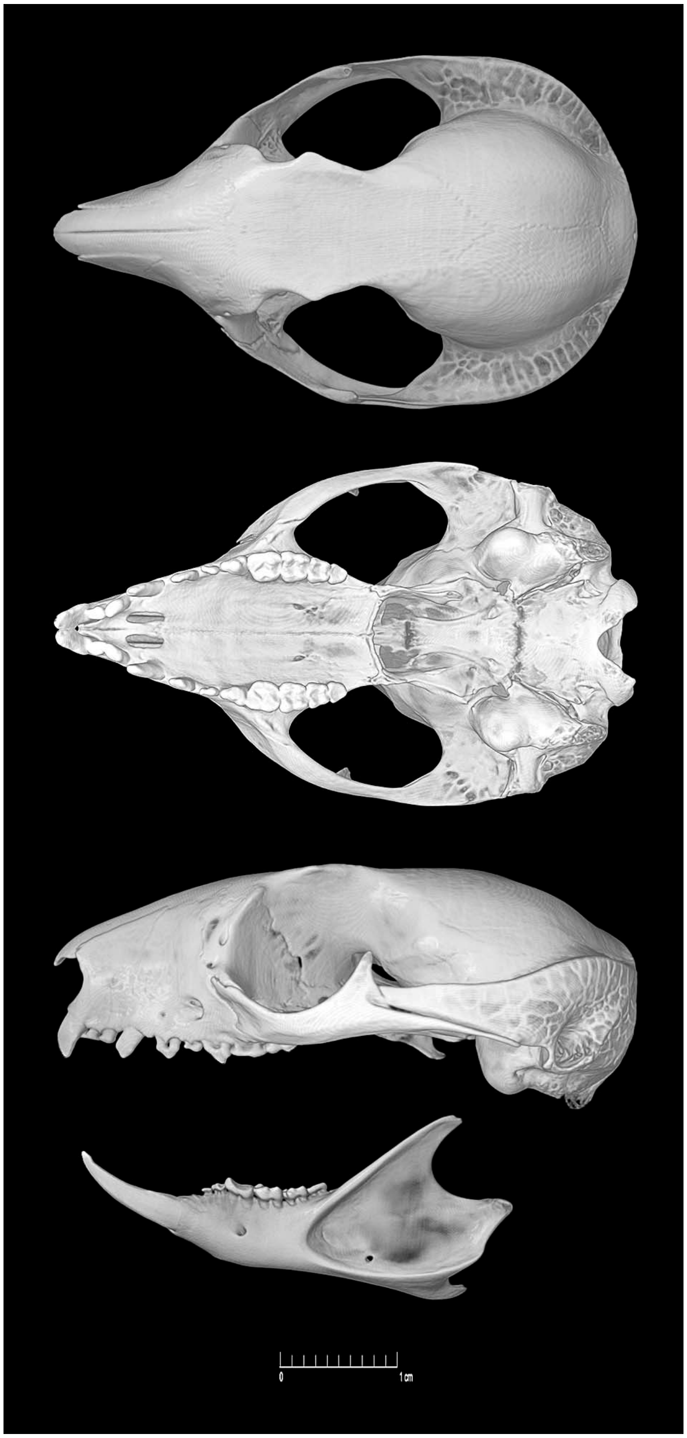

Fig. 2.—Dorsal, ventral, and lateral views of skull and lateral view of mandible of an adult *Petaurus gracilis*. Scale is 1 cm.

compared with the predicted distribution of the squirrel glider. The distribution of *P. gracilis* was predicted to occur above 500 m elevation in some areas within the known range but did not extend outside the known area on the mainland. However, BIOCLIM did predict that the species might occur on Hinchinbrook Island and the Palm Islands, which are located off the coast nearby. In contrast to *P. gracilis*, the squirrel glider was predicted to occur well outside of its known distribution, including all the area predicted to be habitat for the former species. Despite this predicted overlap, the closest these 2 species are known to occur to each other is 25 km (Jackson and Claridge 1999). There are no known fossils recorded for *P. gracilis*.

Fig. 3.—Geographic distribution of *Petaurus gracilis*. Map redrawn from Jackson (2008).

FORM AND FUNCTION

The dental formula is i 3/1, c 1/1, p 3/3, m 4/4, total 40 (Fig. 2). The pouch of female *Petaurus gracilis* is well developed and includes 2 teats. The reproductive system of *P. gracilis* has not been examined in detail. This species possesses a well-developed gliding membrane that extends from the 5th finger of each manus to each ankle. The gliding membrane allows them to glide an average of 30 m per glide, although the longest glide recorded is 60 m (Jackson 2000b). In undertaking these glides *P. gracilis* achieves an average glide ratio of approximately 2:1, so that for every 1 m it loses in elevation it gains 2 m in horizontal distance (Jackson 2000b). To achieve this efficiency it has to use a glide angle of approximately 28°, which begins from launching points with an average height of nearly 20 m above the ground and ends at an average of 4.5 m above the ground.

The digestive tract of *P. gracilis* is relatively simple and resembles that of the sugar glider (Van Dyck 1993). In 1 specimen that was dissected, the small intestine was 44 cm in length and gradually tapered from 1.3 cm diameter below the duodenum to 2.9 cm diameter at the point of junction with the hindgut and cecum. The cecum was 7.8 cm long and 1.5 cm wide at the broadest point. The colon was 25 cm long (Van Dyck 1993).

ONTOGENY AND REPRODUCTION

Petaurus gracilis shows a distinct breeding season, with 1 or 2 young being born in the drier months between April and October, which results in the young being weaned during the wet season when there is more insect food available (Jackson 2000c). Observations suggest that all adult females breed each year, with an average litter size of 1.55 and a natality rate of 2.09 young per year. *P. gracilis* only appears to be able to raise a 2nd litter within a year if the 1st one is lost before leaving the pouch or potentially if they breed early in the year (Jackson 2000c). The young are weaned at 4–5 months of age and sexual maturity occurs at 12–18 months of age (Jackson 2008).

ECOLOGY

Population characteristics.—Little is known of the population characteristics of *Petaurus gracilis*. It is nocturnal and typically lives in socially monogamous pairs (see "Space use" and "Behavior"). The limited information on the densities of *P. gracilis* has revealed that it has an average density of 0.24 individuals/ha in continuous forest and 0.16 individuals/ha in fragmented habitat (Jackson 2000c). Longevity of *P. gracilis* is approximately 5–6 years (Jackson 2008).

Space use.—*Petaurus gracilis* has a large home range that is an average of 19.25 ha for males and 20.34 ha for females in continuous habitat, with male and female pairs occupying a combined area of 23.15 ha. In contrast to these observations, the average home range in fragmented habitat has been recorded to be much less at 11.05 ha for males and 6.80 ha for females, with a combined home range of male and female pairs being 11.60 ha (Jackson 2000e). The average overlap of the home ranges of paired males and females is approximately 86%, compared with approximately 11% for nonpaired individuals, which suggests that *P. gracilis* is socially monogamous. This species is also highly mobile, traveling an average distance each night of 1,500 m (range 600–3,400 m) with no significant difference between males and females in either continuous or fragmented habitat. The distance traveled at different times of the year does show a significant difference, with individuals traveling longer distances during late dry season–wet season and shorter distances during the early to middle dry season (Jackson 2000e). Another study found an adult female to have a home range of 23 ha and 2 subadult females had home ranges of 9 and 14 ha (Van Dyck 1993). A 3rd study in fragmented habitat revealed a home range of about 20 ha for males and only 9 ha for females (Asari et al. 2010).

Studies of the home range and movement of *P. gracilis* suggest that when food is readily available, *P. gracilis* is more likely to travel farther than when there is less food available, which may be due to the greater abundance of food to defend (Jackson 2000e). When there is less nectar available it may be energetically more feasible to go directly to the few trees in flower, whereas when there are only a few trees in flower (that are often clumped) within a glider's home range it may be easier to defend them than to attempt to defend those that are more widely distributed. Direct observations suggest that both male and female *P. gracilis* travel along a foraging loop at least every 2–3 nights, which appears to serve 2 purposes. Firstly, a foraging loop may serve to maintain the defense of the home range. Secondly, it may serve to locate trees that will soon be in flower or fruiting. Because their food is patchily distributed (because even ubiquitous species such as Clarkson's bloodwood [*Corymbia clarksoniana*] and poplar gums [*Eucalyptus platyphylla*] have many plants that do not flower), *P. gracilis* can use these foraging loops to find new food sources and remember their location, so that when its current feed trees finish flowering or fruiting it can move to a new food source (Jackson 1998). In addition, by foraging solitarily, pairs of gliders can double their exploration potential, increase the defense of their combined home range, and decrease the risk of being preyed upon (Jackson 2000e).

Within its home range *P. gracilis* has been observed to utilize 3–9 dens each, with a total of 6–16 dens for a socially monogamous pair (Jackson 2000e). Den trees utilized by *P. gracilis* always appear to be of the family Myrtaceae, which includes poplar gums and forest red gum (*Eucalyptus tereticornis*), which are used preferentially; Clarkson's bloodwood is often used but in proportion to its high availability (Jackson 2000e). Other species that occasionally have been used for dens include the pink bloodwood (*Corymbia intermedia*), Moreton Bay ash (*Corymbia tessellaris*), red mahogany (*Eucalyptus pellita*), swamp mahogany (*Lophostemon suaveolens*), cloudy tea-tree (*Melaleuca dealbata*), long-leafed paperbark (*Melaleuca leucadendra*), and broad-leafed teatree (*Melaleuca viridiflora*—Jackson 2000e). Dead trees are only rarely used as den sites. Observations of den tree height vary greatly, ranging from 6.5 to 61.6 m with nest entrances 7–33 m from the ground. The aspect of the den entrance appears to be an important characteristic of den trees, with a clear majority facing either west or south. Because poor weather comes from the east to northeast, a southern or western den entrance may reduce the risk of rain entering the den (Jackson 2000e). An assessment of the most important factors explaining variation in daytime temperature in nest sites found aspect and the amount of canopy cover directly above the nest site to be important, because den entrances that face north and have greater canopy cover are up to 7°C cooler than those that face south or have little cover (Isaac et al. 2008).

The vegetation composition of home ranges and the observed diet (Jackson 1998, 2000e) clearly show that rain forest is rarely traversed or utilized by *P. gracilis*. The only rain-forest species known to be utilized is nectar and pollen from the cadargi (*Corymbia torrelliana*) and euodia (*Melicope elleryana*) on the edge of rain forest and in riparian forest (Jackson 1998, 2001; Van Dyck 1993).

Diet.—The diet of *Petaurus gracilis* is similar to that of other petaurid gliders and includes primarily nectar, pollen, and invertebrates (Goldingay and Jackson 2004). Unlike most other petaurid gliders, however, dietary studies have revealed that nectar and pollen are the most utilized food items available and are obtained primarily from trees of the genera *Eucalyptus*, *Corymbia*, and *Melaleuca* of the family Myrtaceae (Jackson 2001; Van Dyck 1993). One study found nectar and pollen typically comprise between 50% and 99% ($\bar{X}$ = 72.8%) of the observed feeding time when available (Jackson 2001). A different study of fecal and intestinal samples discovered that 30–74% consisted of pollen with 13–79% of the contents ingested (Dettman et al. 1995). These observations suggest that up to 80% of pollen grains are digested and that pollen is a major source of protein.

Other than nectar and pollen, food items consumed by *P. gracilis* include sap from albizia (*Albizia procera*) and hickory wattle (*Acacia mangium*; family Mimosaceae); arils from the seed pods of *Acacia* trees including thick-podded salwood (*A. crassicarpa*), red wattle (*A. flavescens*), and *A. mangium*; insects; lerps (coverings or testa excreted by the nymphs of psyllids, under which they shelter and feed); honeydew (sugary waste excreted by psyllids on the leaves and other parts of the plant on which they feed); and fruit from mistletoes of the family Loranthaceae (Jackson 2001; Van Dyck 1993). Sap from the flower spikes of the grass tree (*Xanthorrhoea johnsonii*; family Xanthorrhoeaceae) is important, as are the resulting flowers that provide plentiful nectar (Van Dyck 1993). In using these food items, *P. gracilis* relies on complex seasonal cycles of food availability, requiring a high diversity of plants, with each species having distinct periods when it provides food during the year (Jackson 2001).

Interspecific interactions.—Within its distribution *Petaurus gracilis* is sympatric with the sugar glider. Field studies using trapping and vegetation structure data show that the presence of *P. gracilis* is significantly correlated with the presence of *Corymbia clarksoniana* and *Eucalyptus platyphylla*, the absence of *Corymbia intermedia* and *Acacia mangium*, and a small middle and upper canopy cover. In contrast, the presence of sugar gliders is most correlated with a large number of stems, suggesting a more closed canopy preference. When the presence of *P. gracilis* was compared with that of the sugar glider with respect to various habitat variables for the entire study area, *P. gracilis* was most associated with the presence of *C. clarksoniana*, *Eucalyptus pellita*, *Lophostemon suaveolens*, *Melaleuca dealbata*, and a reduced lower and upper canopy. In contrast, the sugar glider was most associated with *C. intermedia*, *A. mangium*, a large number of potential food species, rain-forest species, and a dense middle and upper canopy cover (Jackson 2000d). Observation also suggests that *P. gracilis* does not tolerate sugar gliders if they are in the same tree; I have observed *P. gracilis* chasing sugar gliders out of trees that they both occupied.

There are several key predators of *P. gracilis* that include scrub python (*Morelia amythstina*), rufous owl (*Ninox rufa*), barking owl (*Ninox connivens*), masked owl (*Tyto novaehollandiae*), and lesser sooty owl (*Tyto multipunctata*). Feral and domestic cats (*Felis catus*) have been recorded as predators of *P. gracilis* (Jackson 2000c).

HUSBANDRY

Petaurus gracilis has been held successfully in captivity at David Fleay Wildlife Park in West Burleigh, Queensland, since 1997 when an injured male was obtained. This was followed by the addition of several more animals (Muller et al. 2010). This species readily adapts to captivity and breeds consistently, resulting in the population reaching 11 males and 7 females by 2004 at David Fleay Wildlife Park (Muller et al. 2010). *P. gracilis* is a relatively easy species to maintain in captivity with its husbandry being similar to that required for other petaurid gliders, especially the squirrel glider (Jackson 2003).

BEHAVIOR

Studies of the time budget of *Petaurus gracilis* revealed that the amount of time spent active each night throughout the year ranges from 8.0 to 10.1 h (or 63% ± 80% of the dark phase) and does not change significantly between the wet and dry seasons (Jackson and Johnson 2002). Although *P. gracilis* generally has 1 continuous period of activity, individuals have been observed to return to their dens during the night for a mean of 85 min, with mean entrance and exit times at 2259 h and 0025 h, respectively. The amount of time spent foraging (i.e., feeding and traveling) has been observed to range from 40% of the time outside the den in January to 77% in September. The overall foraging time per night has been calculated to be 61.1%, with the remainder of the night spent either stationary ($\bar{X}$ = 24.3%), grooming ($\bar{X}$ = 11.8%), in the den and then reemerging ($\bar{X}$ = 2.5%), or vocalizing ($\bar{X}$ = 0.3%). Activity comprised mostly behaviors associated with foraging and included feeding (44.9%), climbing (13.2%), and gliding (3.0%—Jackson and Johnson 2002).

The high degree of overlap between the home ranges of paired males and females, the comparatively low overlap with gliders from adjacent groups, the sharing of dens with only 1 individual of the opposite sex, and the observed aggressive behavior toward gliders from other groups indicate that *P. gracilis* is socially monogamous (Jackson 2000e). This contrasts with the view of Van Dyck (1993), who proposed that *P. gracilis* was pseudopolygynous.

The socially monogamous mating system in *P. gracilis* appears to be due to the males being able to defend only enough resources to attract 1 female without reducing their reproductive success (Jackson 2000e). The defense of resources also may help to explain why male and female *P. gracilis* often den apart, because this increases their ability to defend their territory (Van Dyck 1993).

Although *P. gracilis* typically exists as pairs, solitary animals do occur, and appear to be primarily males, which is consistent with examination of trap data, which suggests that the adult population is slightly male biased (Jackson 2000c). Male and female den mates generally forage apart and do not den together every night; they may spend at least 1–2 days at a time in separate dens in different parts of their home range. Therefore, opportunities for extrapair mating are available. The occurrence of extrapair mating in *P. gracilis* is supported by Van Dyck (1993), who observed a female *P. gracilis* mating with a male known not to be her den mate. It is suggested that *P. gracilis* is most likely to be aggressive toward members of the same sex because of the potential for extrapair mating with the opposite sex (Jackson 2000e).

Petaurus gracilis rarely vocalizes and typically limits calls to only 1 or 2 calling episodes per night that typically consist of a single or small number of calls, although calling bouts have been observed to continue for up to 9.5 min (Jackson and Johnson 2002; Van Dyck 1993). Both sexes appear to vocalize and when undertaking their calls usually make a deep, nasal, course grunt "na-when, na-when" that is most often made between 2200 and 0100 h. Several other vocalizations are known that include a soft "tock-tock" when handled for a period of time and a soft "tzzz" call that a young is known to have made after a brief separation from its mother (Van Dyck 1993). The distress call includes a loud grinding noise that sounds like "na-when, na-when" being continually and loudly repeated, reminiscent of a lawn-mower, and can be heard when most individuals are trapped and initially handled (Jackson 2000e; Jackson and Johnson 2002; Van Dyck 1993).

GENETICS

Although allozyme data were limited, Colgan and Flannery (1992) found that *Petaurus gracilis* and the squirrel glider were genetically distinct but they only recognized *P. gracilis* as a subspecies of the squirrel glider. A more recent phylogenetic analysis of all known species and subspecies of *Petaurus* (with the exception of the Biak glider [*P. biacensis*]) sequenced for 2 mitochondrial genes (ND2 and ND4) and 1 nuclear marker (omega-globin gene—Malekian et al. 2009). This analysis revealed that from the sequence divergence values obtained the smallest differences were between the squirrel glider and *P. gracilis* (1.8–2.2%) and the maximum divergence was between the yellow-billed glider (*P. australis*) and the sugar glider (35–45.2%). The single representative of *P. gracilis* grouped closely with the squirrel glider with high bootstrap (99%) and posterior probability (1.00) when using mitochondrial DNA. Because of the low variation of the ω-globin marker in nuclear DNA the phylogenetic relationships between sugar glider, squirrel glider, and *P. gracilis* were unresolved, with each of the species sharing a number of haplotypes. Examination of the allozyme data revealed 3 fixed differences between squirrel glider and *P. gracilis*, suggesting distinction of both species, the divergence of these 2 species based on mitochondrial DNA data was low (2.2%), and similar to the level found within other species of *Petaurus* (e.g., yellow-billed glider—Brown et al. 2006). However, the separate species status of *P. gracilis* was supported by morphometric analyses that show a clear difference between these 2 species (Jackson 2008; Van Dyck 1993).

CONSERVATION

Petaurus gracilis is one of Australia's most threatened species and is listed as "Endangered" under the International Union for Conservation of Nature and Natural Resources (Maxwell et al. 1996). The key threats to *P. gracilis* include habitat loss, limited distribution, lack of habitat protected within national parks, and degradation of its habitat from the transition to rain forest and sclerophyll thickening (Harrington and Sanderson 1994; Jackson et al. 2011). A population viability assessment of this species suggests that an area of up to 8,000 ha containing approximately 800 animals is required to maintain a stable population (Jackson 1999). Jackson (1999) also highlighted the sensitivity of this species to habitat fragmentation because these animals do not readily come to the ground, and if they do they are prone to predation from cats or being hit by cars.

Although legislation has been developed to protect this species from further decline there is an urgent need to identify strategies to manage and extend the remaining habitat to increase the chances of survival of the species over the long term. Of the habitat remaining only 51,870 ha consists of the most structurally diverse habitat management type "Mixed Open Forest" that contains a number of species of Myrtaceae and Mimosaceaea; 55,760 ha is the more open and less diverse "Mixed Woodland" that contains at least 3 of the species of trees that provide food and shelter for *P. gracilis*, but may not have the complete variety required to provide a year-round food supply; 29,988 ha consists of "Monotypic Stands" that contain only 1 or 2 species that are used by *P. gracilis* for food and shelter such as monotypic stands of *Eucalyptus platyphylla*, *Melaleuca viridiflora*, or broad-leaved paper bark

(*Melaleuca quinquenervia*); and 3,504 ha of "Emergent" trees such as *Eucalyptus torelliana* that are suitable for *P. gracilis* but occur in habitat dominated by unsuitable species (such as rain forest—Jackson et al. 2011).

The land tenure that contributed the largest loss of habitat through clearing was freehold land, which decreased from 129,435 to 26,852 ha. Of the habitat cleared within freehold land, 41,275 ha was Mixed Open Forest, which equates to 73% of all that habitat management type cleared during the review period. Within the remaining Mixed Open Forest habitat, 45% was considered to have decreasing resources for *P. gracilis* as a result of sclerophyll thickening or rain-forest expansion, compared with 26% of Mixed Woodland habitat, 33% of Monotypic Stands, and 8% of Emergent trees. These results reveal that a large reduction in habitat area and quality has occurred since broadscale clearing began, which has been magnified by extensive habitat fragmentation.

The limited information available suggests that *P. gracilis* can live within fragmented habitats as long as they are sufficiently wide (about 60 m), and contain sufficient food tree species to provide a year-round supply of food (Jackson 2000e). Habitat along creeks offers some advantages with respect to food tree species diversity, with species such as *Corymbia intermedia*, *C. tessellaris*, *Lophostemon suaveolens*, *Eucalyptus tereticornis*, *Melaleuca dealbata*, and *M. leucadendra* being relatively more common along creek lines than in open areas. There are, however, a number of disadvantages for gliders living within wildlife corridors along creek lines. These include: the occurrence and spread of rain forest; potentially higher predation due to increased exposure to predators such as pythons and owls, which appear to occur there in greater abundance; the lower number of individuals of each tree species (even though tree species diversity is high) for food and dens due to the smaller area available and competition with rain-forest species; the higher canopy cover from rain-forest species and acacias such as *Acacia flavescens*, which is abundant in disturbed habitat (such as along corridor edges) and which favors sugar gliders (Jackson 2000d); the lower recruitment of food and den species due to higher canopy cover and competition from rain-forest species and weeds; and the lower availability of dens. Therefore, long-term persistence of *P. gracilis* within corridors appears to be difficult, even in areas with fairly wide corridors (Jackson 2000d). When crossing small gaps in habitat, *P. gracilis* was observed to use the tallest trees on the edge of the gap to gain the maximum distance from the glide. However, because *P. gracilis* is strictly arboreal and appears reluctant to cross open ground if the gaps between patches of suitable habitat are much greater than can be traversed by gliding, these animals will be unable to disperse between patches of suitable habitat. Other observations suggest that males are more likely to cross gaps in their habitat than are females (Asari et al. 2010).

Significant efforts must be undertaken to conserve and manage the remaining habitat of *P. gracilis* at the landscape level to ensure that it does not further decrease in its usefulness to *P. gracilis*. Various conservation actions include retaining as much habitat as possible, and using fire to maintain and, where necessary, expand the open woodland, where rain forest has encroached. Strategic expansions of habitat within the known distributional limits by conversion back to native forest and establishing corridors between fragments of habitat are also important conservation actions required (Jackson 2000a, 2000d; Jackson et al. 2011). Results of consecutive surveys suggest that education of the public increases their willingness to pay for the conservation of *P. gracilis* (Tisdell et al. 2005).

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