

Conservation of a rare arboreal mammal: habitat preferences of the Lumholtz's tree-kangaroo, *Dendrolagus lumholtzi*

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Abstract. Success of conservation efforts of large and cryptic mammals is often limited due to a lack of knowledge of their habitat preferences. This study investigates factors that affect the habitat selection of the rare Lumholtz's tree-kangaroo, *Dendrolagus lumholtzi*, using signs of its activity. The presence and absence of scratch marks on tree trunks and faecal pellets within a 100-cm radius around them were surveyed on 23 ha within a 65-ha large fragment of rainforest on the Atherton Tablelands, north-eastern Australia in order to classify trees as 'actively used' or 'inactive'. Structural features of the 315 surveyed tree trunks were also recorded. Using discriminant function analysis, 'actively used' trees were found to have no epiphytes on the main trunk, less obstruction by neighbouring trees, shrubs or lianas within a 0.5-m radius of the trunk (particularly in the eastern direction), and a smaller diameter at breast height than 'inactive' trees. Smaller tree trunks and less obstruction may facilitate a more rapid movement into the canopy as well as provide potential escape routes from predators. More specific knowledge on factors that affect habitat selection of the Lumholtz' tree-kangaroo will help in a reclassification of the threatened status of this species and assist in more effective conservation efforts.

Additional keywords: arboreal folivore, Macropodidae, predator escape route.

Introduction

The conservation of large mammals can be problematic when species are very cryptic, limiting the options to study their ecology, life histories and habitat requirements. However, this knowledge is essential for conservation priority setting and the success of conservation efforts. For instance, the Red List published by the World Conservation Union (IUCN) demands detailed population and life-history information and its criteria require familiarity and training to ensure consistent assessments (Robbirt *et al.* 2006). Under these conditions, the study of cryptic mammals relies more and more on the use of indirect ecological methods such as the study of faeces and tracks (Triggs 1997; Henderson 2003).

The Lumholtz's tree-kangaroo (*Dendrolagus lumholtzi*) in north-east Australia is one example of a cryptic large mammal that has been placed on the Red List as least concern. Under the *Nature Conservation Act of Queensland*, Australia (QPWS 1992) the species is listed as rare. A revision of its threatened status is therefore needed but requires more detailed studies on its habitat preferences. For better conservation actions, Maxwell *et al.* (1996) recommend the monitoring of its distribution and abundance as well as the study of its habitat utilisation and population dynamics in fragmented and regenerating rainforest habitats.

The natural distribution of Lumholtz's tree-kangaroos is restricted to north-east Queensland between the Carbine

Tableland, north of Cairns (16°55'0"S, 145°46'0"E), and the southern edge of the Cardwell Range near Ingham (18°39'18"S, 146°9'45"E) (Martin 2005). Lumholtz's tree-kangaroos are mainly found on the Atherton Tablelands (Newell 1999a), where notophyll rainforest (Types 5b (Mabi) and 5a, Tracey 1982) has been identified as its prime habitat (Kanowski *et al.* 2001). The species is also found in drier rainforest along the Herberton Range and more rarely in rainforests with higher rainfall near the eastern edge of the Atherton Tablelands (Winter *et al.* 1991). All these habitats have experienced extensive reductions in their natural occurrence due to land clearing for agriculture and urban development (Turton 2008). Mabi forests now exist in only 62 remnant fragments between 2 and 270 ha in size, comprising 4.3% of its original extent (Latch 2008). This has led to the declaration of this rainforest type as an endangered ecosystem under the *Environmental Protection and Biodiversity Conservation Act (1999)* of Australia. Currently, only 12% of this prime habitat for Lumholtz's tree-kangaroo is protected in national parks (Kazmeier 2004), resulting in the classification of the Lumholtz's tree-kangaroo as rare under *Queensland's Nature Conservation Act of 1992* (Latch 2008).

Currently, conservation efforts for this species concentrate on the preservation of its prime habitats. However, limited knowledge of habitat utilisation and microhabitat preferences of this species reduces the success rate of conservation measures

and the development of a long-term conservation strategy for this species (CRC 1999).

Studies on Lumholtz's tree-kangaroos have mainly focussed on its diet (Procter-Gray 1984; Jones 2001), its home range (Newell 1999b) and its behaviour (Procter-Gray and Ganslosser 1986). However, observations indicate that Lumholtz's tree-kangaroos are not using Mabi forest fragments equally (M. Goetz, Directed Research Project, Centre for Rainforest Studies, unpubl. data 2009; Margit Cianelli, pers. comm.), suggesting that factors other than the distribution of preferred food trees influence habitat preferences of this species.

One such factor could be the vegetation density in a forest, which may affect the movement and particularly the antipredatory behaviour of this species. Tree-kangaroos climb trees by grasping around them and using a 'hopping' locomotion to move up the trunk in order to forage and rest in the canopy (Martin 2005). When climbing, the animals cling to the trunk with the sharp claws of their forelegs while moving their hind legs simultaneously upwards (Ganslosser 1991). This way of locomotion suggests that the circumference of trees plays a role in the selection of habitats and those tree trunks with smaller circumference may be preferred for climbing over those with larger circumferences.

Studies on a range of mammalian species indicate that predator defence behaviour can play an important role in habitat selection. For example, *Peromyscus leucopus* is known to select fallen logs as 'runways' because they reduce noise and provide unobstructed paths that can be travelled at more rapid speeds than along the litter of the forest floor (Douglas and Reinert 1982; Barnum *et al.* 1992). Lumholtz's tree-kangaroo, although an arboreal folivore, retreats to the ground when attempting to escape predation (Flannery *et al.* 1996). This unusual behaviour is attributed to its evolutionary link to terrestrial macropodid ancestors, which it shares with the rock wallabies (Flannery *et al.* 1996). It seems likely that this particular escape behaviour would benefit from certain structural traits of tree trunks which may allow a more rapid descent. Small to moderate trunk diameter and absence of large epiphytes may facilitate a timely descent and therefore successful escape from predators. Furthermore, understorey trees, shrubs and other obstructions surrounding the trunk of a tree may potentially hinder escape from predators.

Because of the cryptic habits of Lumholtz's tree-kangaroos, this study uses indirect measurements of its activity (such as faecal pellets and scratch marks) to investigate the role of microhabitat features (circumference and tree obstruction) on its habitat selection.

Based on the above considerations we expected that Lumholtz's tree-kangaroos would prefer areas with smaller and less obstructed trees because they assist them better in both reaching the canopy and escaping from predators.

The results may contribute to a better understanding of the utilisation of microhabitats within highly fragmented primary habitats of Lumholtz's tree-kangaroos and assist in the development of long-term conservation strategies for this rare species.

Methods

The study was conducted in a 65-ha fragment of privately owned 5a complex notophyll vine rainforest on the Atherton

Tablelands, north-east Queensland, Australia (17°24'S, 145°31'E) (Tracey 1982). Here Lumholtz's tree-kangaroos have been observed by the owner on a regular weekly basis. The fragment had been selectively logged in the past until the logging stopped in the 1980s. About 20 ha of the northern part of the fragment are natural regrowth since that time. The surrounding areas had been cleared in the 19th century and up to the 1960s. The nearest town to the study site is Herberton (17°38'S, 145°38'E).

Between March and April of 2009 a 23-ha plot of mature, old-growth rainforest within the 65-ha fragment was investigated for tree-kangaroo activity. In order to obtain random sampling points, a 150- by 150-m grid system was overlaid onto the 65-ha fragment. From the first sampling point, which was chosen randomly (Fig. 1), grid lines were manually flagged and measured using tape and compass navigation. Despite high vegetation density in some parts (particularly at canopy gaps) the accuracy of the established points was estimated to lie within 1–3 m. A confirmation of the position of the points by GPS/GIS (based on a grid development in ARC GIS ver. 3.2, ESRI) was limited as the GPS accuracy of ± 4 m could not be further improved under the forest canopy. A section of 10 grid line intersection points was chosen for this study to assess tree-kangaroo activity within the central part of the 65-ha fragment. The remaining grid line intersection points were investigated in another study on tree-kangaroo activity.

Habitat utilisation by Lumholtz's tree-kangaroos at each of the 10 intersection sampling points was assessed using the regularised, grid-based spot-assessment technique developed by Phillips and Callaghan (1995) for assessing habitat use in koalas (*Phascolarctos cinereus*). The nearest tree to the sampling point was identified as the central tree. The 29 trees nearest the central tree were flagged and incorporated into the sampling. Trees less than 9 cm diameter at breast height (DBH) were excluded from the study (because of personal observation by wildlife rescuer Margit Cianelli that tree-kangaroos generally avoid trees below this size). If trees had

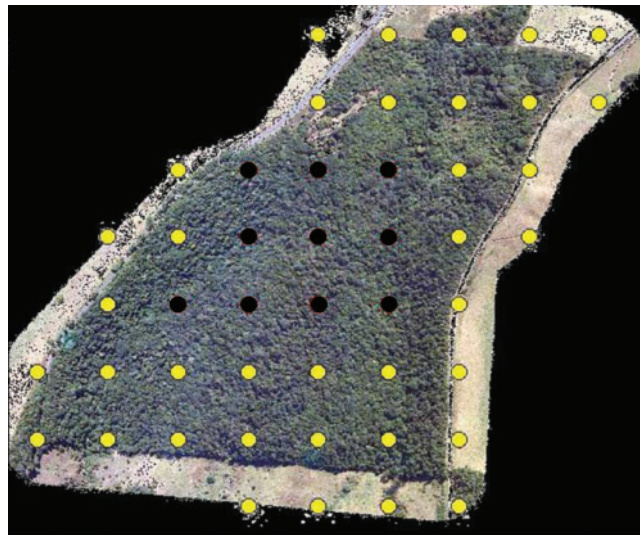


Fig. 1. Study area with intersection point of the overlaid 150 × 150 m grid system. Black dots show sampling points of present study.

multiple trunks, measurements of each trunk larger than 9 cm DBH were taken.

At each tree, DBH, presence and absence of tree-kangaroo signs of activity (including scratch marks and faecal pellets), and the amount of obstruction was recorded using the following methods. DBH was measured using a DBH measuring tape (Forestry Supplier Inc., Australia) at a height of 1.30 m. Trees were grouped according to DBH in intervals of 10 cm starting at a minimum size of 9 cm.

Scratch marks made by Lumholtz's tree-kangaroos consist of three distinctively long (~15 cm), parallel lines on the bark of the tree (Fig. 2). They are mainly made when animals descend from the canopy using the claws to reduce the speed of the descent. Although other arboreal mammals such as possums can leave scratch marks, the Lumholtz' tree-kangaroo is the only arboreal animal of its size on the Atherton Tablelands with three claws on its hind feet. Scratch marks are visible for a long time (pers. comm., Margit Cianelli). However, the bark type may affect their longevity.

Faecal pellets are the most accepted indicator of whether a tree has been used recently by this arboreal folivore. However, no detailed information on the longevity of faeces of Lumholtz's tree-kangaroo are available and it is likely that weather conditions have a profound impact on the rate of their decomposition. Tree-kangaroo faeces can mostly be distinguished from faeces of other arboreal mammals (Fig. 3) (Triggs 1997) by their size and shape. Trees were scored for the absence or presence of faecal pellets based on a 2-min search for pellets within a 100-cm radius around the base of the tree. Previous studies using the spot-assessment technique for koalas have found that this radius encompasses

50% of the total number of faecal pellets beneath a tree canopy (Phillips and Callaghan 1995).

Trees were classified as 'actively used' or 'inactive' based on the presence or absence of scratch marks and/or faecal pellets. Absence of activity signs does not necessarily prove that trees are not used, so these trees are referred to as 'inactive'.

Obstruction, such as the trunk or branch of an adjacent tree, lianas or shrub within 0.5-m radius of the main tree trunk, was scored as present or absent in all four cardinal directions so that each tree could range from a score of 0 (no obstruction in any direction) through a score of 4 (obstruction in all directions) (Table 1). Epiphytes growing on the main trunk were noted as present or absent since their structure could inhibit a rapid descent. As most of them encompassed the tree trunks entirely, epiphytes were not recorded in the cardinal directions.

SPSS (ver. 9) statistical software was used for all statistical analyses. Mean DBH of 'actively used' trees and 'inactive' trees were compared using a *t*-test. Total obstruction, irrespective of direction, of 'actively used' and 'inactive' trees was compared using a *t*-test. A discriminant function analysis was used to determine how all of the independently measured variables of obstruction collectively separate the overall structure of 'actively used' trees from those not used by tree-kangaroos ('inactive' trees). This multivariate technique creates a new composite



Fig. 2. Scratch marks made by Lumholtz's tree-kangaroos on tree trunks.



Fig. 3. Fresh Lumholtz's tree-kangaroo scat (measurements: 2.5 cm × 1.5 cm).

Table 1. Habitat variables used in the analysis

Abbreviation	Variable	Sampling method
DBH	Diameter at breast height	DBH of trunks at least 9.0 cm in diameter
EPIPH	Presence/absence of epiphyte	Epiphyte visible on main trunk from the forest floor
NORTH	Northern obstruction	Any obstruction within 0.5 m of the northern vertical quadrant of trunk below the canopy
SOUTH	Southern obstruction	Same as NORTH
EAST	Eastern obstruction	Same as NORTH
WEST	Western obstruction	Same as NORTH
TOTOB	Total obstruction	Combined obstruction along all quadrants

variable or discriminant function from the original directly measured variables in order to best separate the groups studied. The significance of this type of analysis is determined by considering reclassification into 'actively used' or 'inactive' trees. If structural variables of obstruction, as shown in Table 1, do explain this classification, then based solely on these variables (in the combined form as a discriminant score) trees should be reclassified at a higher degree of accuracy than random reclassification.

Results

Each of the 10 sampling points used in the study contained signs of activity by Lumholtz's tree-kangaroos by the presence of scratch marks and/or faecal pellets. The sampling point with the least activity had seven 'actively used' trunks of the 30 sampled trees while the two points with the highest activity had signs for 16 out of the 30 trees sampled.

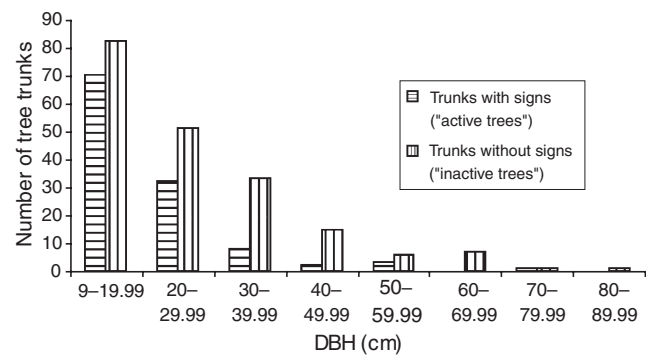
DBH and selected structural variables of obstruction were measured for 315 tree trunks, with 117 trunks allocated to the class of 'actively used' trees (with signs of tree kangaroo activity) and 198 trunks showing no signs of activity by the tree-kangaroos ('inactive' trees). Only in five cases were trunks classified as 'actively used' only because of the presence of faecal pellets. All other 'actively used' trunks were classified as such because of the presence of scratch marks visible on the base of the trunk. Table 2 shows the mean and standard error of all structural variables of the 315 tree trunks measured in this study.

'Actively used' trees had a smaller mean DBH than inactive tree trunks ($t=3.836$, $d.f.=313$, $P<0.001$) (Table 2). Total obstruction, irrespective of direction, was significantly greater surrounding 'inactive' trees than 'actively used' trees ($t=3.092$, $d.f.=313$, $P=0.02$) (Table 2). There were more trees measuring 9–29 cm in DBH with scratch marks than trees of larger size (Fig. 4) although no statistical test was performed on the data.

Structural variation of trees was partitioned between 'active' and 'inactive' trees using a two-group discriminant function analysis. The discriminant function analysis, which considered all variables collectively, had one significant discriminant function ($\chi^2_6=34.04$) (Table 3). All of the variables were significantly and positively correlated with activity (Fig. 5). 'Actively used' trees were less likely to have epiphytes, had a smaller DBH and fewer obstructions in each of the four cardinal directions. The discriminant function significantly separating 'actively used' and 'inactive' trees was most strongly correlated with obstruction along the eastern portion of the trunk ($r=0.634$)

Table 2. Means (\pm s.e.) of each structural variable for tree trunks with and without signs of activity of Lumholtz's tree-kangaroo
n = no. of trees

Variable	'Actively used' trunks (<i>n</i> = 117)	'Inactive' trunks (<i>n</i> = 198)
DBH (cm)	19.8 \pm 1.01	25.9 \pm 1.07
EPIPH (presence = 1, absence = 0)	0.085 \pm 0.026	0.176 \pm 0.027
Obstruction NORTH (presence = 1, absence = 0)	0.214 \pm 0.033	0.323 \pm 0.033
Obstruction SOUTH (presence = 1, absence = 0)	0.214 \pm 0.038	0.328 \pm 0.033
Obstruction EAST (presence = 1, absence = 0)	0.145 \pm 0.032	0.338 \pm 0.033
Obstruction WEST (presence = 1, absence = 0)	0.248 \pm 0.040	0.298 \pm 0.032
Total obstruction (0 = no obstruction, to 4 = obstruction in all cardinal directions)	0.821 \pm 0.094	1.29 \pm 0.10

**Fig. 4.** Distribution of diameter at breast height (DBH) of tree trunks with and without signs of activity by Lumholtz's tree-kangaroo.

and DBH ($r=0.637$). The presence of epiphytes as well as obstruction from the north and south also contributed to the discriminant function. Obstruction from the west was the least strongly correlated with the function (Table 3). The discriminant function analysis reclassification correctly matched original groupings in 64.8% of the cases. 'Actively used' trees were reclassified as such in 76.1% of the cases. Only 58.1% of

Table 3. Summary statistics for a discriminant function analysis and the linear correlations between measured variables and the discriminant function

*, Significance level $P < 0.01$

Statistic	Discriminant function
Eigenvalue	0.116
Chi-square test	34.04*
Degrees of freedom	6
Linear correlation (r) with:	
DBH	0.637
EAST	0.634
EPIPH	0.373
SOUTH	0.363
NORTH	0.348
WEST	0.159

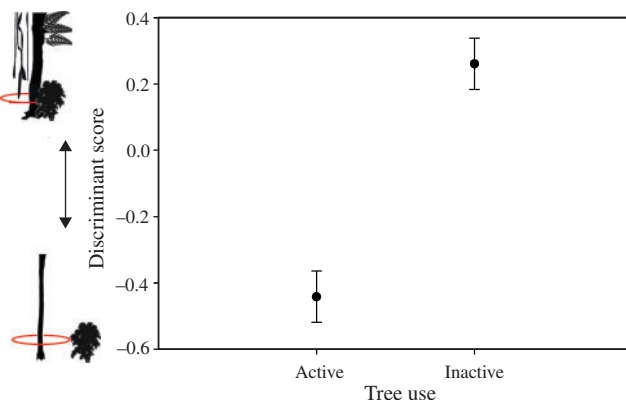


Fig. 5. Mean (\pm s.e.) discriminant scores from an analysis of trees.

'inactive' trees were reclassified as 'inactive' while 41.9% were incorrectly classified as 'actively used'.

Discussion

The results of this study show that there are structural differences between tree trunks showing signs of being used by Lumholtz's tree-kangaroos (*Dendrolagus lumholtzi*) (presence of either scratch marks or faecal pellets or both) and those without signs, classified as less active ('inactive') trees. Lumholtz's tree-kangaroos seem to select trees with a smaller DBH, absence of epiphytes on the main trunk of the tree, and limited obstructions by neighbouring trees, shrubs or lianas within a 0.5-m radius of the tree.

Trees with smaller DBH may be selected because they are easier to grasp when climbing. Tree-kangaroos are well adapted to an arboreal lifestyle, with strong forearms and well developed, curved claws combined with shortened but broad hind feet, enabling them to climb into the canopy (Kazmeier 2004; Johnson and Newell 2008). Besides a better ability to climb smaller tree trunks, the nutritional content of the foliage on younger trees may contribute to the selection of trees with smaller DBH. Lumholtz's tree-kangaroos are folivores and their diet consists of a wide variety of foliage from rainforest trees and vines (Procter-Gray 1984; Jones 2001). Younger trees in a rainforest may have more rapid growth rates and consequently a proportionally higher

amount of young leaves than larger canopy trees. Some arboreal folivores, including coppery brushtail possums (*Trichosurus vulpecula*) prefer younger leaves (Monks and Efford 2006), while other species such as the green ringtail possum (*Pseudochirops archeri*) prefer mature leaves (Jones *et al.* 2006). Younger trees may also be preferable because of fewer defence mechanisms against herbivory. Eucalyptus trees with a smaller DBH have been found to contain lower concentrations of plant secondary metabolites (Moore and Foley 2005) and it has been shown that koalas (*Phascolarctos cinereus*) avoid feeding from eucalypts belonging to a size class that contains higher concentrations of secondary metabolites.

Procter-Gray (1984), however, showed that Lumholtz's tree-kangaroos prefer mature leaves, and the species is also known to consume noxious leaves or foliage with low palatability (Johnson and Newell 2008). It has been shown that only 51 of 127 'actively used' trees (trees with tree-kangaroo scratch marks) belonged to known food species of Lumholtz's tree-kangaroo (C. Chan, Centre for Rainforest Studies, unpubl. data 2008). In that study, two of the three most 'actively used' tree species (based on the presence of scratch marks) were not known food species. This suggests that over half of 'actively used' trees may have been used exclusively for climbing up to canopies and branches for reasons other than foraging. Other studies have observed tree-kangaroos sitting in the crown of large trees while scratch marks had been found only on neighbouring trees with smaller DBH (E. Floore, Centre for Rainforest Studies, unpubl. data 2008). Individuals have also been observed crossing from smaller trees to larger trees using closely adjoining branches. These results indicate that tree-kangaroos use smaller tree trunks to reach the crowns of larger trees.

Besides a smaller DBH of 'actively used' tree trunks, structural variables of tree trunks that can be related to the predator escape behaviour of Lumholtz's tree-kangaroos seem to play a role in the selection of trees used by this species. The predator-avoidance behaviour of this species includes the rapid descent from the canopy and an escape on the ground applying a kangaroo-like hopping gait (Ganslosser 1991). This escape tactic is utilised for radio-tracking studies in which individuals are forced to retreat to the ground by shaking the tree they are sitting in (Procter-Gray 1984). The strategy proved to be effective for its natural predators such as pythons (Martin 1995) and raptors, but is highly ineffective against introduced predators such as dingoes and domestic dogs. A survey of the Tree-kangaroo and Mammal Group in 2000 reported that, of more than 300 dead tree-kangaroos over the last 15 years, ~10% were killed by dogs (75% were road kills) (Tree-kangaroo and Mammal Group 2000a).

As hypothesised, tree-kangaroos seem to select for trees with less obstruction, which may allow them a more rapid descent to the ground. Many other studies have found evidence of mammalian prey species selecting habitat sites because of superior predator escape routes. Zollner and Crane (2003) found that eastern chipmunks (*Tamias striatus*) use coarse woody debris (such as logs and branches) more frequently when in habitats with a greater risk of predation. Fan and Jiang (2008) concluded that black crested gibbons (*Nomascus concolor jingdongensis*) selected the tallest trees with the thickest canopies near steep slopes primarily as an adaptation to avoid detection by predators,

to increase the difficulty of attack by predators and to provide an easy escape route.

The results of the study show different correlations of structural features of obstruction with trees exhibiting signs of tree-kangaroos. This indicates that the preferred structure hypothesised to provide a better predator escape route may also serve additional roles for Lumholtz's tree-kangaroos. The strong correlation with lack of obstruction from the eastern portion of the trunk than from other directions indicates that this variable may be selected for an additional purpose such as morning sun exposure, slope aspect or protection from westerly winds.

'Actively used' trees were reclassified as such in 76.1% of the cases on the basis of their structural features of obstruction, indicating that the trees 'actively used' by Lumholtz's tree-kangaroos shared strong similarity in structure. In contrast, more variation in structure was observed in trees less actively used (so-called 'inactive' trees). A proportion of 41.9% of 'inactive' trees sampled had a similar structure to trees 'actively used' by Lumholtz's tree-kangaroos. This suggests that the trees 'actively used' by Lumholtz's tree-kangaroos shared additional characteristics not studied, that contrasted them with 'inactive' trees. Lumholtz's tree-kangaroos may be selecting only a subset of trees that meet the structural requirements of a predator escape route based on other variables that have yet to be studied. Based on observations of the movement of Lumholtz's tree-kangaroos in the canopy (E. Floore, Centre for Rainforest Studies, unpubl. data 2008), the branching pattern of trees as well as the proximity of food trees of certain sizes may affect the selection of trees. The proximity of food trees may also cause a seasonal variability in the selection of trees used to climb into the canopy. Harper *et al.* (2008) showed discrepancies between the 'human' perception of a 'patchy' environment and the actual utilisation of this environment by the common brushtail possum (*Trichosurus vulpecula*) and common ringtail possum (*Pseudocheirus peregrinus*) in relation to the distribution of shelter and food variables. This emphasises the need for more studies on the role of microhabitat features in habitat selection of folivores.

The present study used indirect signs to assess the habitat use of Lumholtz's tree-kangaroos. The sampling points contained far more scratch marks than faecal pellets. Scratch marks are mainly formed when the tree-kangaroo is gripping the tree trunk as it descends with its head facing the canopy and its feet towards the forest floor in order to reduce the speed of descent. Scratch marks may also be means of social communication. However, scratch marks are not equally visible on all bark types and may be obscured on rough-barked trees. It is likely that rough and flaky bark will scratch off when tree-kangaroos ascend or descend trees. The resulting small patches of missing bark would be very difficult to identify as a tree-kangaroo sign and thus may have caused an underestimation of the amount of trees used by tree-kangaroos for climbing. This limitation was taken into account under the assumption that unrecorded, but used trees will be unlikely to have very different DBHs. However, the presence of epiphytes may differ between rough barked and smooth-barked trees.

Scratch marks remain on a tree until the bark is shed, heals over the markings, or is damaged in a way that makes the original markings unrecognisable. During the study old scratch marks could be distinguished from more recent ones. However, the

durability of scratch marks may have resulted in a discrepancy between the structural variables from the time when the tree-kangaroo used the tree and when the variables were actually measured. The rainforest fragment has not experienced any substantial damage within the past year that would have reduced the obstructions measured in the study. Growing maturity of a rainforest, which may result in a decrease of structural obstructions (lianas and shrubs are out-shadowed by large trees, and epiphytes may grow closer to the canopy: Richards 1998) takes time. Therefore, the difference between 'actively used' and 'inactive' trees will be obvious as structural changes apply to both types of trees.

Faecal pellets (scats) are the only passive way of determining recent tree-kangaroo activity and thus estimate population size (Phillips and Callaghan 2000). Phillips and Callaghan (2000) determined tree species preferences of koalas based on the presence/absence of faecal pellets. Lumholtz's tree-kangaroos, like koalas and other herbivorous animals, produce a large amount of scats (Phillips and Callaghan 1995). The low nutrient content of leaves in rainforests makes it necessary for tree-kangaroos to consume large quantities of plant matter every day. As a result they can defaecate up to 40 times daily. It can be assumed that the half-life time of tree-kangaroo scat in this fragment of rainforest is three weeks (S. Phillips 2009, pers. comm.). However, the area receives an annual average rainfall of 2500 mm with most rain received during the summer months between January and April. Heavy rain increases the decay rate of fresh pellets and may wash faeces away from the site of their deposition. The steep terrain in the study area is likely to impact on this de-location of scats. Additionally, more scats may be deposited under food trees while the animal is feeding. This may be the reason for the discrepancy between the number of trees with scratch marks (exclusively used for climbing) and the number of trees with scats.

Only six faecal pellets were found in the 23 ha covered in this survey. This indicates a low tree-kangaroo activity in this section of the fragment at the time of the study. A subsequent search for scats in the remaining parts of the fragment two weeks later showed a large amount of scats along the southern boundary of the fragment. This suggests that increased decomposition rate and/or relocation of faeces due to the wet weather did not cause the lack of faeces in the study site. The habitat of the study site appears to be suitable, but only low recent activity was recorded. This suggests that tree-kangaroos do not use the fragment equally. A range of factors may determine the use of microhabitats within the larger 65-ha fragment, such as the availability of attractive food (young foliage, fruits, and flowers) or the presence of predators. However, the present study shows that tree-kangaroos may use microhabitats based on structural features linked with their foraging and predator-avoidance behaviour.

The results of this study seem to be contradictory to the preference of complex types of rainforests by tree-kangaroos (Kanowski *et al.* 2001). The complex structure of these rainforests does not provide the simple, unobstructed structure seemingly preferred by Lumholtz's tree-kangaroos. The distribution of many other endemic folivorous marsupials has been explained by the better nutritional quality of foliage on basaltic soils (Kanowski *et al.* 2001). Lumholtz's tree-kangaroos may select the Mabi 5b and 5a rainforests as its macrohabitat for the nutrient-rich foliage

from trees growing on the rich basaltic soils, but actually avoid at a microhabitat scale the structural complexity that defines these rainforests (Tracey 1982). Fragmentation of these complex rainforests may increase their complexity by allowing more vines and epiphytes to grow due to an increase of sunlight from the edges of fragments. This may lead to a decrease in the usability of the fragments by tree-kangaroos with consequent effects on their population size.

Conservation efforts for Lumholtz's tree-kangaroos should therefore not only preserve existing fragments, but also consider their enlargement and connectivity to enable tree-kangaroos to reach other, less complex structured fragments. Due to the extensive loss of its prime habitats and the threat to tree-kangaroos by introduced predators, restoration efforts should focus on the establishment of less complex ecosystems on basalt-rich soils as suitable habitats for tree-kangaroos. There is currently no recovery plan in place for Lumholtz's tree-kangaroos. The Tree-kangaroo and Mammal Group has developed a local strategic plan for the management of Lumholtz's tree-kangaroos on the Atherton Tablelands, focusing on the management of rainforest fragments as habitat and the reduction of threatening processes (Tree-kangaroo and Mammal Group 2000b).

This study contributes to a better understanding of the habitat utilisation of Lumholtz's tree-kangaroos and may help in a better classification of threats to this species. It also shows that more detailed investigations are required to allow the implementation of management strategies that can assist in more effective conservation efforts for this species.

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