HABITAT SELECTION BY THE RARE GOLDEN-TIPPED BAT
KERIVOULA PAPUENSIS

MARTIN SCHULZ AND TERESA J. EYRE


Habitat selection by the golden-tipped bat Kerivoula papuensis was described using presence/absence data from 144 harp trapping sites between Cooktown in north-eastern Queensland and Bulahdelah in central-eastern New South Wales. Logistic regression was used to identify structural, topographic and other attributes of sites associated with the presence of K. papuensis. Occupied habitat was characterised by an abundance of vine drapes, the presence of the yellow-throated scrubwren Sericornis citreogularis, close spacing between stream channels, multiple tree layers, high relief and slope characteristics, westerly aspect, higher elevations, low abundance of large tree epiphytes and proximity to the nearest forest ecotone. However, aspects of habitat selection are poorly known, such as maternity roost selection and foraging habitat by the species. Further study is required to fully understand the habitat requirements of this species.

Key words: Kerivoula papuensis, habitat selection, foraging habitat, rainforest

The identification of habitat requirements of rare species is a key component of conservation management. Bats follow a ‘K-strategy’ life history, displaying low reproductive capacity, long life and high adult survivorship and are therefore likely to maintain relatively stable natural populations (Findley 1993). Consequently, bat populations are unlikely to be able to recover rapidly if declines occur and are particularly vulnerable to environmental changes which lead to reduced longevity or reproductive success (Walsh and Harris 1996). Foraging habitat is difficult to study directly in microchiropteran bats, since members are nocturnal, predominantly volant when feeding, and their echolocation calls are primarily ultrasonic. In recent years it has been possible to study foraging habitat preferences of some species acoustically since the introduction of bat detectors (e.g. Crome and Richards 1988; Rydell et al. 1994; Carmel and Safriel 1998). Bat species can be identified from their calls with varying degrees of certainty (e.g. Fenton 1982; Ahlén 1990; Barclay 1999). However, the effectiveness of acoustic identification of species with low-intensity vocalizations is limited. Such species typically belong to the ‘clutter-tolerant’ bats, which forage within cluttered microhabitats (Norberg and Rayner 1987; Brigham et al. 1997). These bats typically use ultrasonic signals that are short and low in intensity which cannot be detected except at close range (Forbes and Newhook 1990; et al. 1992; O’Farrell and Gannon 1999). The use of broad band, low intensity frequency-modulated calls associated within and around the clutter of understorey vegetation is taken to extremes in the Kerivoulinae (Kingston et al. 1999). Kerivoula papuensis has a call duration of less than 3 msec and a low signal intensity with a maximum detection range of 1 to 1.5 m (Rhodes 1995; Woodside 1995). Similarly, other members of the genus have small detection ranges,
Kerivoula papuensis has been described as a specialist of rainforest and other densely vegetated habitats (Richards 1990). All diurnal K. papuensis roosts located in north-eastern New South Wales (NSW), central- and north-eastern Queensland (Qld) occurred in rainforest or wet sclerophyll forest with a rainforest substorey (Schulz 1995, 2000; Schulz and de Oliveira 1995). Limited observations on light-rainforest substorey (Schulz 1995, 2000; Schulz and de Oliveira 1995). Based on capture records the species is generally considered to frequent rainforest or rainforest-vegetated gullies in wet sclerophyll forest over a range of elevations (Richards 1983; Kennedy 1990; Walton et al. 1992; Rhodes et al. 1993; NSW National Parks and Wildlife Service 1994; Churchill 1998). Kerivoula papuensis seems to prefer ecotonal habitats occurring in tangled rainforest in the vicinity of dry sclerophyll forest or along watercourses (Parnaby 1992; Gilmore and Parnaby 1994; Woodside 1995) or alternatively forest interiors, away from ecotones (NSW National Parks and Wildlife Service 1994). Kerivoula papuensis has also been captured in recently logged dry sclerophyll forest (Lunney and Barker 1986) and dense eucalypt regrowth surrounded by dry sclerophyll forest (Parnaby and Mills 1994). The species is listed as "rare" in Queensland under the Threatened Species Conservation Act 1995 and 'Lower risk (near-threatened)' nationally following IUCN criteria (Duncan et al. 1999). This study investigates habitat selection by K. papuensis, using analysis in which vegetation structure, topography and other variables at sites where this species was recorded are compared with those where it was not trapped.

METHODS

Choice of sites

Eighty-four known K. papuensis sites were selected for obtaining detailed habitat information. These sites extended from Barretts Lagoon (15°25', 145°09''), north of Cooktown in north-eastern Qld south to Wang Wauk State Forest (32°14', 152°12'') near Bulahdelah in central-eastern NSW (Appendix 1). Kerivoula papuensis sites selected encompassed the core area of the distribution of the species in Australia, accounting for 83% of documented records up to December 1998 (NSW National Parks and Wildlife Service 1994; Forest Assessment Unit 1998; Schulz 1999). Site selection was based on sampling all known capture sites located in the central and northern parts of the species’ range, where accurate location descriptions enabled precise re-location of the sites.

All sites selected were restricted to locations in which free-flying K. papuensis were captured in harp traps. Locality records based on road fatalities, cat kills or deaths inside buildings from ceiling fans were not included. Where records from other sources were used, the accuracy of the location of capture sites was confirmed through discussions with the original researchers. To maintain independence between sites, a minimum straight-line distance of 1.5 km separated K. papuensis sites selected. This distance was based on the maximum recorded movement of 1.1 km in radio-tagged individuals and 1.2 km in recaptured banded individuals in the Richmond Range (Schulz 1999).

Sixty absent sites were randomly selected in locations from the Cooktown area (15°25', 145°07'') south to Bulahdelah State Forest (32°19', 152°14'') (listed in Appendix 1). These sites were selected on the basis of representing harp trap locations in forested habitat situated within the predicted distribution of the species generated from BIOCLIM analysis (Walton et al. 1992; Parnaby and Mills 1994; Mills and Schulz, unpubl. data). All sites were in rainforest, wet sclerophyll forest with a rainforest substorey or in other forest types situated within 500 m of the first two habitats. Each absent site was sampled by the senior author for a minimum of two to three consecutive nights with two or more harp traps using the modified trapping technique outlined in Schulz (1999). The sampling period used was suggested to be adequate to provide a reliable estimate of bat species present in a forest area (Mills et al. 1996), with three consecutive nights of trapping accounting for 64% of K. papuensis captured in the Richmond Range, north-eastern NSW and 69% in Mt Baldy State Forest, north-eastern Qld (Schulz 1999). Trapping was restricted to the period from September to April, which coincided with the highest capture rates of the species in known localities, such as the Richmond Range (Schulz 1999). The sampling effort was assumed to be adequate to detect the presence of K. papuensis in most sites. However, the probability of detection using this method will depend on a range of factors, including harp trap placement, climatic conditions and the habitat. These limitations need to be considered when interpreting the results.
Habitat measurements

Twenty-three habitat variables were measured in all sites between December 1995 and December 1998 (Table 1). The habitat variables were chosen after consultation with biologists familiar with the ecology of bats and rainforest fauna and were assumed to represent various characteristics important in maintaining Kerivoula papuensis populations. Measurements of the habitat variables were predominantly made on a 50 m by 50 m sampling plot, centred on the location of the harp trap site. Two variables, relief and stream spacing, were measured from topographic maps in a 2 km radius centred on the trap site. In non-rainforest sites, an additional measurement was made, the distance from the capture site to the nearest rainforest patch >1 ha in area, which included sclerophyllous forest types with a rainforest substorey.

Kerivoula papuensis sites from other sources were re-visited to measure site variables up to six years after the original capture date, with one site (Barretts Lagoon, north-eastern Queensland) re-visited eleven years after the original capture. Consequently, some sampling biases may have been introduced. Such biases were minimised through discussions with the original researchers and land managers or property owners regarding broad habitat characteristics of the sites at the time of the capture and subsequent vegetation changes. Locations where forest characteristics had changed in the intervening period, such as through disturbances associated with forest harvesting or wildfire were excluded from the analyses.

Data analysis

A Pearson correlation matrix was initially generated so that intercorrelation between the predictor variables could be identified. Canopy and emergent heights (correlated with vegetation type) were consequently removed from the data set. Logistic regression (S-Plus Version 3.3 for Windows, Mathsoft, Seattle, WA, USA) was used to determine habitat variables significantly associated with sites occupied by Kerivoula papuensis. This analysis procedure is particularly suitable for habitat association studies with habitat and geographical variables often having non-normal distributions, predominantly categorical, and the sampling design is retrospective (Ramsey et al. 1994; Sedgeley and O’Donnell 1999). The majority of variables used were either continuous or categorical, with the exception of altitude, distance to nearest water, canopy and emergence height, and the distances to the nearest ecotone and cleared land (Table 1).

Variables recorded for each site were analysed using a Generalised Linear Model assuming binomial distribution with a stepwise forward regression process (Hastie and Pregibon 1992) to develop a model of the relationship between K. papuensis and the measured variables. This procedure selects the variable or variables that contribute the most to predicting habitat selection in the species. Four outlier K. papuensis sites were excluded from the analyses, since they were not located within the forest types targeted for sampling i.e. rainforest, wet sclerophyll forest with rainforest substorey or open forests located within 500 m of the previous two forest types.

RESULTS

Kerivoula papuensis was predominantly recorded from rainforest (90.5% out of 84 sites), dominated by rainforest structural types lacking sclerophyllous emergents (47.6% out of 84 sites) and rainforest with a well-developed overstorey of Eucalyptus species or brush box Lophostemon confertus (39.3% out of 84 sites) (Table 2). The remaining sites were located in tall open forest with or without a dense sclerophyllous substorey and riparian forest lacking rainforest elements. The mean distance (± SD) of these non-rainforest sites to the nearest rainforest patch of > 1 ha area or sclerophyll forest with rainforest substorey was 505 ± 322 m, with a maximum distance of 1,300 m recorded on privateland adjacent to Mt Mistake, south-eastern Queensland. No K. papuensis sites in non-rainforest habitats were separated from the nearest rainforest patch by treeless habitats, with sites either connected by continuous forest (67%, n = 6) or a narrow riparian strip of vegetation in a landscape modified into pastureland (33%, n = 3). The latter situation accounted for the largest distance movements of banded individuals recorded from the nearest rainforest patch, such as on privateland near Mt Mistake.

Ten variables significantly contributed to the explanatory power of the logistic regression examining specific habitat preferences in Kerivoula papuensis (Table 3). The variables identified were vine drapes, yellow-throated scrubwren Sericornis citreogularis, tree layers, stream spacing, relief, large tree epiphytes, slope, aspect, distance to ecotone and altitude. Therefore the model indicated that the probability of Kerivoula papuensis occurring in a site increased with the abundance of vine drapes, presence of S. citreogularis, multiple tree layers, high relief and slope characteristics, westerly aspect and a higher altitude. Additionally, the probability of the species occurring within a site increased with three variables decreasing: stream channel spacing, abundance of large tree epiphytes and proximity to the closest forest ecotone.
(1) Altitude (m).

(2) Slope, using the categories of Speight (1990): 1, level; 2, very gently inclined (0.35°-1.45°); 3, gently inclined (1.45°-5.45°); 4, moderately inclined (5.45°-18°); and 5, steep (18°-30°).

(3) Aspect (approximated to nearest cardinal point).

(4) Relief within 2 km radius of the capture site, using the categories of Speight (1990): 1, very high (>300m); 2, high (90-300 m); 3, low (30-90 m); and 4, very low (9-30 m).

(5) Landform, using the categories of Speight (1990): WC, watercourse; LS, lower slope; MS, midslope; US, upper slope; RI, ridge; FL, flat; and CD, closed depression.

(6) Distance to nearest water from the trap site (m).

(7) Stream channel spacing within 2 km radius of the capture site, using the categories of Speight (1990): 1, numerous (<150 m); 2, very closely spaced (150-250 m); 3, closely spaced (250-400 m); 4, moderately spaced (400-625 m); and 5, widely spaced (>625 m).

(8) Broad structural vegetation type based on the tallest stratum, excluding emergents (Specht 1970). The following categories of rainforest based primarily on leaf size (after Webb 1978) were used: MEVF (mesophyll vine forest), NVF (notophyll vine forest), MIVF (microphyll vine forest) and SEVT (semi-evergreen vine thicket). Two categories of other forest types based Specht, Roe and Boughton (1974) were used: TOF (tall open forest) and OF (open forest). Additional categories: rainforest types with sclerophyllous emergents were identified separately; RPRF, riparian forest with well-defined vine scrub elements present; RFSR, riparian forest with no or sparsely scattered rainforest elements; STOF, tall open forest with sparse substorey; and DTOF, tall open forest with a dense substorey.

(9) Narrowest vegetation width within which capture sites were located using three categories: 1, <100 m; 2, 100-500 m; and 3, >500 m.

(10) Canopy height (m): height of the tallest canopy tree in the sample plot.

(11) Emergents using six categories: NO, none present; AA, non-sclerophyllous emergents only; EA, sclerophyllous emergents of one species; EB, sclerophyllous emergents of two or more species; MEA, mixed emergents, with only one species of sclerophyllous emergent; and MEB, mixed emergents with two or more species of sclerophyllous emergents.

(12) Emergent height (m): height of the tallest emergent tree in the sample plot (where present).

(13) Projective foliage cover of understorey stratum (< 3 m) using four categories: 1, <25%; 2, 25-50%; 3, 50-75%; and 4, >75%.

(14) Tree layers, using three categories: 1, one layer obvious; 2, two layers obvious; and 3, more than two layers.

(15) Large tree epiphytes, using four categories: 0, none; 1, few; 2, common; and 3, abundant.

(16) Vine drapes on the tallest stratum, using four categories as for (15).

(17) Vine abundance, using four categories as for (15).

(18) Distance to nearest ecotone (m).

(19) Large-scale forest disturbance, including regeneration following clearfell harvesting; recorded as the presence or absence of evidence.

(20) Distance to nearest cleared land (km), calculated from 1: 25 000 or if unavailable 1: 100 000 topographic map.

(21) Presence or absence of selected hanging nest builders or users (based on Schulz 2000) in the sample plot. 
(i) yellow-throated scrubwren Sericornis citreogularis.
(ii) brown gerygone Gerygone mouki.
(iii) large-billed scrubwren Sericornis magnirostris.

Table 1. Variables measured at all K. papuensis present and absent sites
Table 2. Broad habitat types of *K. papuensis* sites.

<table>
<thead>
<tr>
<th>Broad Habitat Type</th>
<th>% Occurrence (n = 84)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainforest</td>
<td>47.6</td>
</tr>
<tr>
<td>Rainforest with scleroxyllous overstorey</td>
<td>39.3</td>
</tr>
<tr>
<td>Riparian forest with rainforest elements</td>
<td>3.6</td>
</tr>
<tr>
<td>Tall open forest with dense scleroxyllous substorey</td>
<td>3.6</td>
</tr>
<tr>
<td>Tall open forest with sparse substorey</td>
<td>3.6</td>
</tr>
<tr>
<td>Riparian forest lacking rainforest elements</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Table 3. Significant variables from the generalised linear model describing habitat selection in *K. papuensis*.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficients</th>
<th>S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>−4.915</td>
<td>2.222</td>
</tr>
<tr>
<td>Stream spacing</td>
<td>−1.026</td>
<td>0.397</td>
</tr>
<tr>
<td>Relief</td>
<td>−0.806</td>
<td>0.404</td>
</tr>
<tr>
<td>Large tree epiphytes</td>
<td>−0.582</td>
<td>0.388</td>
</tr>
<tr>
<td>Distance to ecotone</td>
<td>−0.003</td>
<td>0.001</td>
</tr>
<tr>
<td>Altitude</td>
<td>+0.002</td>
<td>0.001</td>
</tr>
<tr>
<td>Aspect</td>
<td>+0.005</td>
<td>0.003</td>
</tr>
<tr>
<td>Slope</td>
<td>+0.649</td>
<td>0.365</td>
</tr>
<tr>
<td>Tree layers</td>
<td>+1.307</td>
<td>0.564</td>
</tr>
<tr>
<td>Presence of <em>Sericornis citreogularis</em></td>
<td>+1.685</td>
<td>0.539</td>
</tr>
<tr>
<td>Vine drapes</td>
<td>+1.889</td>
<td>0.434</td>
</tr>
</tbody>
</table>

**DISCUSSION**

The results must be interpreted with caution given that even the smallest microchiropteran can travel some distance in one night, making definitive interpretation of habitat use by trapped individuals problematic. Captures from specific trap locations may reflect commuting paths rather than foraging or roosting habitat. However, the maximum distance traveled by banded *K. papuensis* in the Richmond Range, north-eastern NSW was 1,255 m (Schulz 1999). These movements suggest that the commuting distances traveled between roosts and foraging areas is relatively small.

The *K. papuensis* habitat model suggests that a number of structural, topographical and other variables significantly contribute to the probability of the species’ occurrence at a site. The amount of vine drapes and tree layers possibly relate to foraging habitat within the vegetation. *Kerivoula papuensis* primarily feeds on Araneida, with fragments identified to family level all belonging to web builders (Araneidae and Tetragnathidae) (Schulz and Wainer 1997; Schulz 1999). Based on ecomorphological characteristics and observations of light-tagged and Scotchlite-marked individuals, the species probably forages at least in part by gleanung spiders from webs (Rhodes 1995; Schulz and Wainer 1997; Schulz 1999). The importance of an abundance of vine drapes and tree layers may be due to the provision of a large surface area for the attachment of spider webs. Structural complexity of the forest is an important determinant of the structure and abundance of foliage-dwelling spider communities (e.g. Greenstone 1984; Pasquet 1984; Rypstra 1986; Bradley 1993). Physical factors correlated with vegetation structure in foliage-dwelling spiders include availability of web-attachment sites (Enders 1973; Colebourn 1974; Bradley 1993), exposure of the web to wind (Eberhard 1971; Schoener and Toft 1983), exposure to insolation (Biere and Uetz 1981; Hodge 1987), and problems of desiccation (Cherrett 1964; Gillespie 1987). Vine drapes and increased structural layers may increase web-building sites by providing a gradation of gap sizes, which can accommodate webs of many sizes and orientations.

Closely spaced stream channels and high relief, slope and distance to nearest ecotone may be related to structural and vegetation diversity at a landscape level. The combination of closely spaced stream channels, high relief and slope class suggests *K. papuensis* favours a dissected topography. Diversity in landform may result in a diversity of vegetation types over relatively small distances within forest patches, supporting the suggestion by various authors (Parnaby 1992, Gilmore and Parnaby 1994; Woodside 1995) that this species displays a preference for ecotonal habitats. Such vegetation patterns may be favoured by *K. papuensis*, which has only been recorded moving small distances. For
example, the maximum movement recorded by a radio-tagged individual was 1.121 m, and 1.255 m for a banded individual in the Richmond Range (Schulz 1999). Landscape diversity, reflected by vegetation diversity, may further contribute to the abundance and variety of attachment sites and gaps for Araneida to construct webs. Additionally, vegetation diversity may support flexibility in the foraging strategy of *K. papuensis*. Seasonal and nightly changes in habitat use have been recorded in some species of microchiropterans (e.g., de Jong and Ahlén 1991; Vaughan et al. 1997). Shifts in habitat use have been attributed to changes in prey availability (de Jong and Ahlén 1991) or predator avoidance with species moving into open habitats as nocturnal light intensity decreased (Nyholm 1965). Furthermore, vegetation and structural diversity within a forest patch may be reflected by an increase in the number of canopy and subcanopy plants in flower at any one time. Flowers are a critical resource for web-building Araneida foraging for pollinating insects, with a seasonal increase in abundance associated with the onset of flowering demonstrated in some spiders (Chew 1961; Riechert and Tracy 1975). Many bats are opportunistic feeders that exploit local concentrations of prey, such as the emergence flights of some insects (Fenton and Morris 1975; Vaughan 1980). Similarly, *K. papuensis* is likely to exploit patches of abundant prey, with structural and vegetation diversity providing increased opportunities for the presence of abundant prey patches.

The significant relationship between *K. papuensis* and the presence of *S. citreogularis*, as indicated by the regression model, is associated with roost usage in *K. papuensis*. Studies on roost usage in the species showed that 94% (*n* = 53) of non-maternity roosts were located in *S. citreogularis* nests in the Richmond Range, north-eastern NSW and 73% (*n* = 11) of roosts were located in *S. citreogularis* nests in Mt Baldy State Forest, north-eastern Qld (Schulz 2000). In contrast, the absence of a significant relationship with the hanging nest-builder, the brown gerygone *Gerygone mouki*, is supported by the low incidence of roost usage in nests of this bird by *K. papuensis*. For example, only two *G. mouki* nests out of 53 roosts were used in the Richmond Range and none out of 11 roosts in Mt Baldy State Forest (Schulz 2000), even though nests were available.

Two variables, broad structural vegetation type and emergent type, were not identified as significant habitat variables, indicating that *K. papuensis* occurs in a variety of mesic forest types. The significant relationship between the species and low numbers of large tree epiphytes may be a reflection of the diversity of vegetation types inhabited by *K. papuensis*. Tropical and subtropical rainforest is typified by an abundance of large tree epiphytes due to high humidity (Floyd 1989). While in dry rainforest (e.g. at the western range limit of *K. papuensis*) and cool temperate rainforest (e.g., high elevation areas of north-eastern NSW) large tree epiphytes are less common due to lower humidity or cooler conditions in these respective forest types.

The importance of a westerly aspect is not clear and may represent an artifact of the *K. papuensis* trapping localities sampled. In contrast to the importance of a westerly aspect in capture sites, roosts located in the Richmond Range were predominantly situated on slopes with a southerly aspect, in particular south-east facing (Schulz 2000). The apparent preference for a southerly aspect in this site was suggested to have been a function of the topography, with both Culmaran and Tryney Creek valleys having a southerly aspect.

Predicted distribution based on bioclimatic modelling suggested *K. papuensis* preferred equable thermal environments and that temperature was the most significant bioclimatic attribute governing the species' distribution (Walton et al. 1992). Therefore, the significant relationship between *K. papuensis* and higher altitudes is not clear but may represent an artifact of the *K. papuensis* localities sampled. Much of the coastal lowland rainforest and associated habitats in eastern Australia have been lost through large-scale habitat clearance for agricultural, pastoral and urban purposes resulting in only fragmented remnants remaining. It has been suggested that the species may be susceptible to such large-scale habitat alteration, due to a preference for forest interiors away from cleared areas (NSW National Parks and Wildlife Service 1994). The species has only been recorded from larger remnant forest tracts (> 10 000 ha in area) close to sea level in a number of localities, including on the ecotone of littoral rainforest and tidal mudflats at Cape Hillsborough (Schulz 1999). However, many small, isolated remnants (e.g. < 500 ha) of lowland rainforest have not been sampled and it is not known whether the species persists in these small remaining forest patches. Owing to the loss of large tracts of lowland forest, recent fauna surveys in north-eastern NSW and south-eastern Qld (accounting for 61% *K. papuensis* sites sampled) were primarily restricted to mid- and high-elevation forests under crown tenure, particularly state forests and national parks located in the foothills and ranges (e.g., Baverstock and Chambers 1992; Barker et al. 1994; NSW NPWS 1994; Schulz 1994; CSIRO Division of Wildlife and Ecology 1996; Forest Assessment Unit 1998; Schulz and Spark 1998).

The four outlier *K. papuensis* sites that were excluded from the analyses were located either in tall
open forest with a sclerophyllous substorey (n = 2) or in *Melaleuca bracteata* dominated riparian forest (n = 2) backed by partially cleared farmland. Based on the current knowledge of the roosting and foraging ecology of *K. papuensis*, the presence of this species in tall open forest greater than 500 m from the closest rainforest cannot be explained (e.g. Schulz 1999, 2000). In the latter situation it is probable that foraging or commuting individuals were restricted to the narrow band of riparian vegetation rather than flying over treeless terrain, and therefore were likely to travel a greater linear distance from core habitat areas than in a normal forested landscape.

Habitat selection involves a wide range of factors, not just structural and topographical attributes of trapping sites, as recorded in this study. Factors such as food supplies, competitors, predators and parasites all play a part in habitat selection. Critical components of habitat selection have not yet been determined in the species. For example, the only maternity colony documented in Australia was located in a tree cavity (Schulz 2000), while extralimitally on Biak Island a roost including lactating females and dependent young was located in a cave (Flannery 1995). The sensitivity of *K. papuensis* to forest harvesting, in particular logging intensity is not known. Further studies concentrating specifically on the biology of *K. papuensis*, including maternity site selection and identification of foraging areas using radio-tagged bats are needed, and may reveal other habitat variables that characterise the habitat of the species.

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**APPENDIX 1**

### SAMPLED SITES

**Kerivoula papuensis present sites**

**Queensland**

Barretts Lagoon, north of Cooktown (15°25', 145°09'); Cape Tribulation area (16°04', 145°27' ; 16°05', 145°27'; 16°06', 145°27'), Mt Lewis State Forest (16°27', 145°12'), Kuranda State Forest (16°49', 145°39'; 16°50', 145°41'; 16°50', 145°40'); Danbulla State Forest (17°08', 145°35'), Mt Baldy State Forest (17°17', 145°25'), Koombooloomba State Forest (17°51', 145°35'; 17°56', 145°33'); Waterview Creek downstream of Jourama Falls National Park (18°51', 146°07'), Jourama Falls National Park (18°51', 146°07'), Cape Hillsborough National Park (20°55', 149°02'), Koombit Tops State Forest (24°20', 150°56'; 24°22', 150°56'; 24°24', 151°02'), Bullburin State Forest (24°30', 151°22'; 24°34', 151°27'; 24°36', 151°32'), Cooloola National Park (26°01', 153°05'), Brooyar State Forest (26°09', 152°33'), Oakview State Forest (26°09', 152°20'; 26°09', 152°19'), Wartens State Forest (26°17', 152°19'), Kenilworth State Forest (26°38', 152°39'; 26°41', 152°36'), Jimna State Forest (26°42', 152°32'), Squirrel Creek State Forest (two sites: 26°42', 152°20'), Tarong State Forest (26°47', 151°55'; 26°49', 151°55'), Mt Mee State Forest (27°08', 152°42'), D'Aguilar State Forest (27°19', 152°44'), Mt Mistake area (27°50', 152°21'; 27°51', 152°21').

**New South Wales**


### SAMPLED SITES

- Kerivoula papuensis present sites
  - **Queensland**
    - Barretts Lagoon, north of Cooktown (15°25', 145°09'); Cape Tribulation area (16°04', 145°27'; 16°05', 145°27'; 16°06', 145°27'), Mt Lewis State Forest (16°27', 145°12'), Kuranda State Forest (16°49', 145°39'; 16°50', 145°41'; 16°50', 145°40'); Danbulla State Forest (17°08', 145°35'), Mt Baldy State Forest (17°17', 145°25'), Koombooloomba State Forest (17°51', 145°35'; 17°56', 145°33'); Waterview Creek downstream of Jourama Falls National Park (18°51', 146°07'), Jourama Falls National Park (18°51', 146°07'), Cape Hillsborough National Park (20°55', 149°02'), Koombit Tops State Forest (24°20', 150°56'; 24°22', 150°56'; 24°24', 151°02'), Bullburin State Forest (24°30', 151°22'; 24°34', 151°27'; 24°36', 151°32'), Cooloola National Park (26°01', 153°05'), Brooyar State Forest (26°09', 152°33'), Oakview State Forest (26°09', 152°20'; 26°09', 152°19'), Wartens State Forest (26°17', 152°19'), Kenilworth State Forest (26°38', 152°39'; 26°41', 152°36'), Jimna State Forest (26°42', 152°32'), Squirrel Creek State Forest (two sites: 26°42', 152°20'), Tarong State Forest (26°47', 151°55'; 26°49', 151°55'), Mt Mee State Forest (27°08', 152°42'), D’Aguilar State Forest (27°19', 152°44'), Mt Mistake area (27°50', 152°21'; 27°51', 152°21').
  - **New South Wales**
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152°26'), Demon Nature Reserve area (29°05', 152°15'; 29°06', 152°15'), Forest Land State Forest (29°09', 152°06'), Washpool State Forest (29°16', 152°25'; 29°17', 152°26'; 29°17', 152°23'), Spirabo State Forest (29°18', 152°10'; 29°20', 152°08'), Chaelundi State Forest (29°53', 152°19'), Wooloolga Creek Flora Reserve (30°07', 153°08'), Irishman State Forest (30°32', 152°43'), Tinebank Flora Reserve (31°12', 152°31'), Ballengarra State Forest (31°15', 152°48'), Lorre State Forest (31°36', 152°38'), Kerewong State Forest (31°36', 152°35'; 31°38', 152°32'), Marsh State Forest (31°39', 152°22'), Woko National Park (32°14', 151°46'),

* Sites not used in the logistic regression analysis.

Kerivoula papuensis absent sites

Queensland


New South Wales