



Habitat preferences of long-tailed bats *Chalinolobus tuberculatus* along forested riparian corridors in the Pikiariki Ecological Area, Pureora Forest Park

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DOC RESEARCH AND DEVELOPMENT SERIES 349

DOC Research & Development Series is a published record of scientific research carried out, or advice given, by Department of Conservation staff or external contractors funded by DOC. It comprises reports and short communications that are peer-reviewed.

This report is available from the departmental website in pdf form. Titles are listed in our catalogue on the website, refer www.doc.govt.nz under *Publications*, then *Series*.

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ISSN 1177-9306 (web PDF)

ISBN 978-1-98-851414-7 (web PDF)

This report was prepared for publication by the Publishing Team; editing and layout by Lynette Clelland. Publication was approved by the Director, Terrestrial Ecosystems Unit, Department of Conservation, Wellington, New Zealand.

Published by Publishing Team, Department of Conservation, PO Box 10420, The Terrace, Wellington 6143, New Zealand.

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Habitat preferences of long-tailed bats *Chalinolobus tuberculatus* along forested riparian corridors in the Pikiariki Ecological Area, Pureora Forest Park

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Abstract

Associations between riparian habitat characteristics and the activity of long-tailed bats, *Chalinolobus tuberculatus* (ranked Nationally Vulnerable under the New Zealand Threat Classification Scheme) were studied in Pikiariki Ecological Area, Pureora Forest Park, North Island, New Zealand. Thirty-two sites were systematically located alongside forest streams within Pikiariki. Bat calls at each site were monitored over consecutive nights in Summer 2014/15 using Automated Bat Monitors (ABMs). In addition, bat activity was also filmed using a thermal imaging camera at two independent sample sites where bats had previously been recorded. Drinking was the dominant behaviour observed ($p < 0.0001$), with foraging and commuting both recorded at significantly lower frequencies. The recorded bat activity was analysed in relation to the habitat characteristics at the monitoring sites. This analysis identified a negative correlation between levels of vegetation clutter and bat activity ($p = 0.009$) and a positive correlation between stream water depth and bat activity ($p < 0.0001$). None of the other habitat characteristics were significantly related to bat activity. In summary, riparian habitats at Pikiariki with less-cluttered forest vegetation and deeper streams supported higher levels of bat activity. Habitats with these characteristics could be targeted to identify potential 'hotspots' for more productive harp-trapping of bats for population assessment and monitoring.

Keywords: long-tailed bat, *Chalinolobus tuberculatus*, temperate rainforest, riparian corridors, habitat preferences, bat conservation, forest management, New Zealand.

1. Introduction

The secretive and nocturnal long-tailed bat *Chalinolobus tuberculatus* is endemic to New Zealand (O'Donnell et al. 2012). It was once common throughout New Zealand but now occupies a more disjunct distribution, occurring patchily throughout much of the North and South Island and on some outlying islands (Wilson 2004). The bat is primarily associated with native temperate forests including kauri (*Agathis australis*) and other podocarps, New Zealand beech, regenerating kānuka (*Kunzea* spp.) and manuka (*Leptospermum scoparium*)-dominated stands, foraging in forest gaps and edges or even in farmland and along linear boundary habitats such as along roads or rivers (Daniel & Williams 1984; O'Donnell 2000). Long-tailed bats typically roost as solitary animals or in communal sites within tree cavities (O'Donnell & Sedgely 1999; O'Donnell et al. 2012). Communal roosts are known to be frequented by reproductive females and their young, whilst solitary roosting bats are mainly males and post-lactating females. Long-tailed bats differ from many other bat species by frequently changing roosts and having low rates of roost re-use (O'Donnell & Sedgely 1999; Sedgely 2003). They also occupy large home ranges of 657–1589 ha (O'Donnell 2001; O'Donnell et al. 2006).



Figure 1. A long-tailed bat, *Chalinolobus tuberculatus*. Photo: J. Mortimer.

The long-tailed bat is the smallest of New Zealand's bat species (Fig. 1), weighing in at an average of just 8–11 g. It is exclusively insectivorous, capturing prey on the wing at night through aerial hawking and echolocating (Daniel & Williams 1984).

With total bat numbers estimated to be between 5000 and 20 000 after ongoing population declines across the country (estimated at 30–70%, O'Donnell et al. 2012), the species is currently classified

under the New Zealand Threat Classification Scheme (Townsend et al. 2008) as Nationally Vulnerable (O'Donnell et al. 2012). Accordingly, long-tailed bats are considered a high priority for conservation, as they are at risk of becoming extinct over the medium term if nothing is done to reverse their decline. The key objectives proposed for long-tailed bats include developing survey and monitoring techniques, assessing current threats, increasing knowledge of the ecological requirements of the species and undertaking taxonomic studies (Molloy 1995). Although the reasons for the continuing population decline in long-tailed and other bats in New Zealand are not known with absolute certainty (Wilson 2004), predation and competition from a growing population of invasive mammals and the reduction of lowland forest cover remain the assumed causal factors (O'Donnell 2000).

Riparian zones are known to provide important foraging, drinking, commuting and roosting habitats for bats (Lloyd et al. 2006; Vindigni et al. 2009; Jackrel & Matlack 2010) and often there is higher bat activity recorded within riparian zones than in surrounding areas (Grindal et al. 1999). Different species of bat may be selective as to which riparian zones they utilise, depending on the surrounding physical characteristics or the species morphology. For example, vegetation can physically obstruct bats or impede their echolocation reception (Ober & Hayes 2008), so using less-cluttered fly ways (as can often be found along larger streams and rivers) can aid navigation and save energy. Law and Chidel (2002) found significantly higher levels of bat activity along tracks and riparian zones. This suggests that tracks and riparian areas are used preferentially by

bats to move through forest and save energy. In an evaluation of streams surrounded by logged, regrowth and mature forests in Australia, Lloyd et al. (2006) found that streams with dense rainforest cover were negatively associated with bat activity, while structurally de-cluttered areas had greater recorded activity and higher species diversity.

Riparian zones also appear to offer greater foraging opportunities for bats. Russo & Jones (2003) recorded more feeding buzzes in association with lakes and rivers than other habitat types, which suggested that bats were selecting these habitats for foraging purposes. Similarly, higher frequencies of drinking were also suggested to be associated with large bodies of water (Lloyd et al. 2006; Razgour et al. 2010). However, Francl (2008) suggested that the type of bat activity that could be expected around water reflected species' flying habits and body size, with larger, faster-flying bats most abundant above larger waterbodies and smaller, more nimble bats more commonly recorded above smaller waterbodies. Waterbody size may be correlated with the size of surrounding open airspace, which for fast-flying bats, allows safe flight and reduces the chance of collision and injury, while slower, more nimble bats can navigate smaller waterbodies with less risk of injury. This likely provides them with an advantage, as smaller waterbodies (small ponds, streams) are likely to be more accessible in the local landscape.

Law & Anderson (2000) found that riparian zones were important roosting habitats for the eastern forest bat *Vespadelus pumilus* within Australia. Maternity roosts were located an average of 20 m away from riparian zones. Similar roost and riparian associations were found for the evening bat *Nycticeius humeralis*, an American pine forest species. Miles et al. (2006) concluded that evening bats were influenced to select roosts within close proximity of favourable landscape characteristics (including waterbodies), although proximity to waterbodies would be only one of a variety of factors that would influence the species' roost selection preferences.

Whilst several studies have indicated the importance of ecological associations between stream habitats and bat activity in New Zealand (Borkin & Parsons 2009; Borkin & Parsons 2011), little is known about the long-tailed bat's use of riparian habitats in New Zealand's temperate forests. Indeed, previous studies have evaluated the general habitat characteristics which support bat activity for a selection of species along riparian areas (cf. Law & Chidel 2002; Ober & Hayes 2008; Scott et al. 2009; Jackrel & Matlack 2010), yet the implications of local-scale habitat characteristics which may affect long-tailed bat survivorship are not documented. Therefore, the main objective of this empirical study is to investigate riparian zone use by long-tailed bats, which may help identify why they use these areas. Habitats with these characteristics could be targeted to identify potential 'hotspots' for more productive harp-trapping of bats for population assessment and monitoring.

2. Methods

2.1 Field observations

The region selected for study was the Pikiariki Ecological Area, Pureora Forest Park, which include the streams Waimiha (Fig. 2) and Whareana.

Pikiariki is dominated by the hardwood species tawa, *Beilschmiedia tawa* and by podocarp conifer species such as rimu, *Dacrydium cupressinum*, mātai, *Prumnopitys taxifolia* and miro, *Prumnopitys ferruginea*. The understory is dense and dominated by soft treefern, *Cyathea smithii*, kāmahi, *Weinmannia racemosa*, whekī, *Dicksonia squarrosa* and māhoe, *Melicytus ramiflorus*. A selection of native treeferns and five-finger, *Pseudopanax arboreus* were dominant in the lower-stature forest on steep slopes and gorges. A total of 32 monitoring sites (20 × 30 m) were systematically selected for monitoring in the Pikiariki Ecological Area (Figs 3 and 4). Surveys were completed between 17 December 2014 and 16 January 2015 during New Zealand's summer months at a time when long-tailed bats were known to be most active (King 1990).



Figure 2. Waimiha stream, Pikiariki Ecological Area. Photo: G. Rockell.

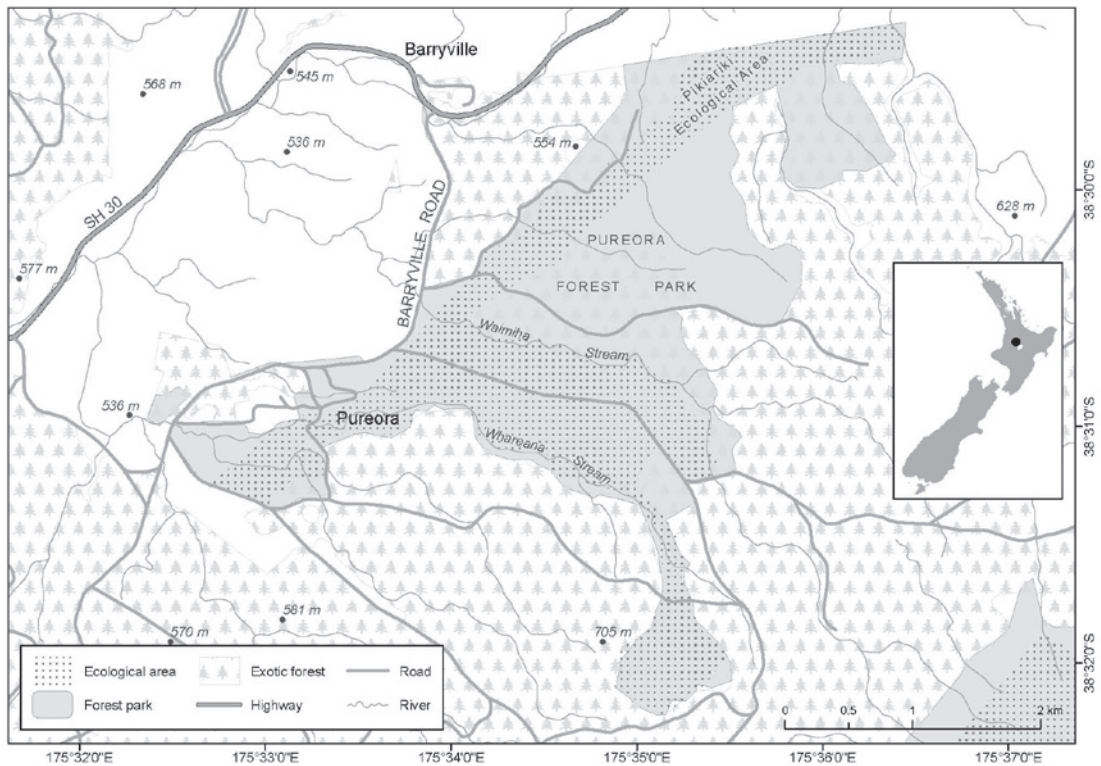


Figure 3. Location of Pikiariki Ecological Area and Waimiha and Whareana streams in Pureora Forest Park. Spot heights (m asl) are also provided.

Following protocols set out by Raven et al. (1998), eight stream habitat characteristics were selected and measured in each site. Variables measured included vegetation clutter (after Law & Chidel 2002 and Specht 1970), flow rate (assessed subjectively by the surveyor) bank-top height (m), bank width (m) (from one bank to the other, measured from the top of the banks), water width (m), water depth (m), riffle cover (%) and pool cover (%). Appraisal of the literature indicated that these variables were considered to be the most influential abiotic factors affecting bat flight and behaviour and, therefore, long-tailed bat activity within each site. A single Automatic Bat Monitor (ABM; developed by The Department of Conservation (DOC) conservation electronics unit) was installed in the centre of each site, attached to an accessible tree trunk, branch or any other suitable physical feature (e.g. log or boulder). The microphone

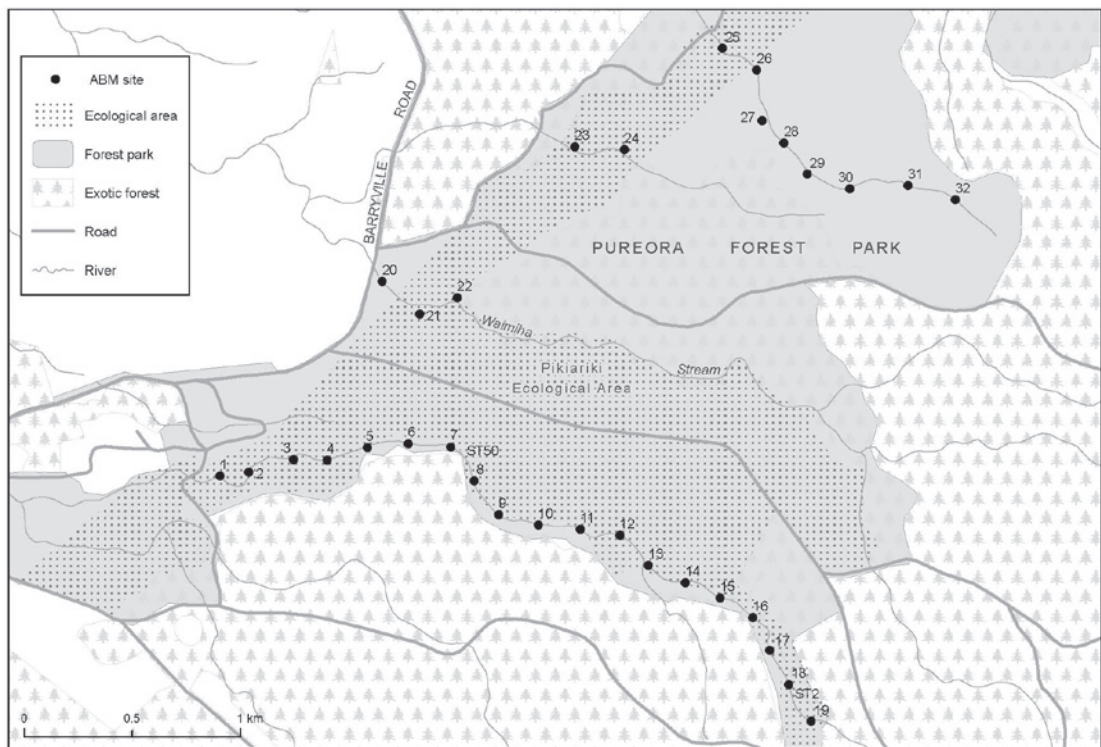


Figure 4. The location of monitoring sites including ST50 and ST2 in Pikiariki Ecological Area, Pureora Forest Park (ABM = Automatic Bat Monitor).

was angled at approximately 45° towards the height above the ground at which bats would be expected to fly (2–3 m; King 1990). Each site was monitored for three consecutive, rain-free nights over an 11-day period (Lloyd et al. 2006). Recording started 30 minutes before sunset and continued throughout the night until 30 minutes after sunrise. Recordings were then uploaded into DOC’s bat call analysis software (BatSearch 3.05) and were tallied together to give a total bat call number for each night in each site.

Sites within Pikiariki Ecological Area known to contain a historical population of long-tailed bats were preferentially selected for monitoring. Moreover, DOC had found two sites (Stream 2 (ST2) 1825377, 5732593 and Stream 50 (ST50) 1823872, 5733705) that consistently had high bat activity levels and were used for trapping bats, and these were included in this study (Fig. 4). A handheld thermal imagery camera (FLIR hand-held thermal imager, HM-Series, Model number: 432-0004-02-OOS) was also used to monitor long-tailed bats at night at these extra two sites. Prior to the surveys starting, a heterodyne bat detector (Batbox Duet) was used to identify the bat species present at the two sites and to determine whether bats were using terminal phase buzz calls. This enabled the surveyor to recognise if the bat was commuting (no buzz call) or drinking/foraging (buzz call present). Bat flight patterns were monitored using the thermal imagery camera. Drinking was distinguished after bats were observed flying down to the stream’s surface whilst emitting a terminal buzz call. Foraging was identified after bats were recorded using terminal buzz calls whilst flying above the water surface. The use of the thermal imagery camera was considered to be an effective method of determining whether bats were drinking or foraging, as bats are known to emit terminal phase buzz calls to identify both water-bodies and prey (Griffiths 2013).

Over 10 nights between 5 and 16 January 2015, bat surveys were completed at the two sites by one person (G. Rockell). Surveys were reliant on suitable weather conditions and five surveys each were carried out at ST2 and ST50. Each bat survey commenced 15 minutes before sunset and continued for 2 hours (20:45–22:45; Adams & Simmons 2002; Russo & Jones 2003). Water pH was recorded using a pH stick prior to the start of each survey. Ambient wind speed and temperature were recorded using a digital anemometer and thermometer every 30 minutes during the 2-hour survey periods. The surveyor was positioned a minimum of 2 m from the

stream, not obstructing any obvious commuting routes and with a clear line of sight along the stream. Bat behaviour was divided into three main categories: drinking, foraging and commuting. These behavioural traits were recorded every time an individual entered the monitored site. Bat behaviour was recorded in four 30-minute time intervals (20:45–21:15, 21:15–21:45, 21:45–22:15, 22:15–22:45).

2.2 Data handling

Data was analysed using Minitab (v. 16) software. Associations between mean bat calls and each of the independent variables were investigated using Spearman Rank correlations. Stepwise and multiple regression modelling was undertaken on the data and, where required, dependent variables were data transformed to meet assumptions for normality. Frequency data were handled using chi-square and Kruskal-Wallis tests.

3. Results

Only two of the independent variables investigated—vegetation clutter and water depth—were identified using a stepwise regression approach as having significant influences on the level of long-tailed bat activity along the riparian habitats (Fig. 5). There was a highly significant negative correlation ($p = 0.007$, $r_s = -0.469$) between mean bat calls and the vegetation clutter index score. In contrast, there was a significant positive correlation ($p = 0.010$, $r_s = +0.449$) between mean bat calls and water depth. The remaining variables were not found to significantly affect the level of bat activity, but there were some interesting trends noted (water depth: $p = 0.129$, $r_s = +0.274$; coarse woody debris: $p = 0.190$, $r_s = -0.238$; fallen trees: $p = 0.131$, $r_s = -0.272$; overhanging boughs: $p = 0.105$, $r_s = -0.292$).

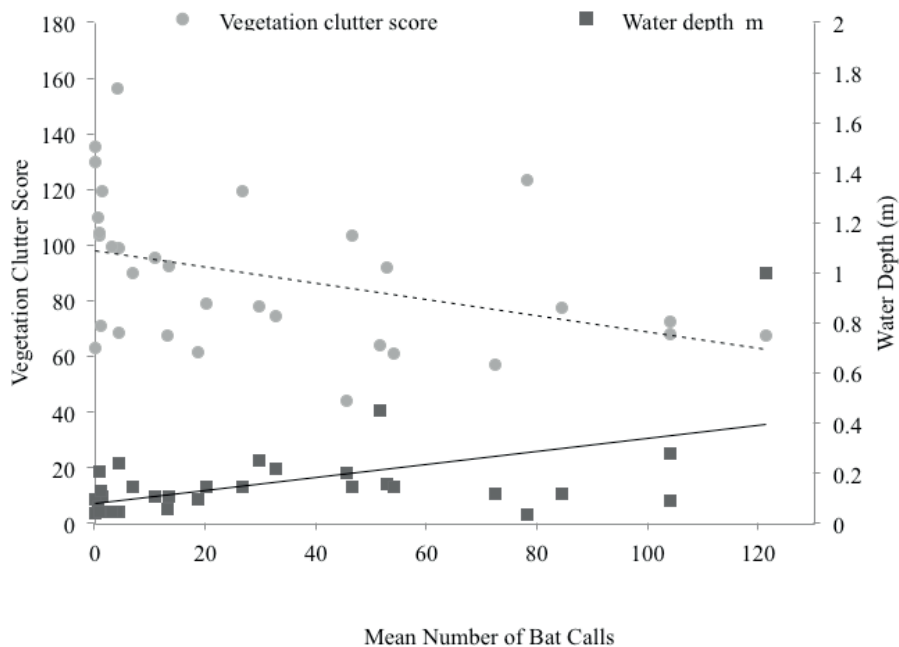


Figure 5. Associations of long-tailed bat activity with vegetation clutter (light grey circles) and water depth (dark grey squares) at Pikiariki Ecological Area, Pureora Forest Park.

Both independent variables were included in a significant multiple regression model to enable the prediction of bat activity, specifically: mean bat calls (Johnson transformation function) = $0.614 - (0.0126 \times \text{vegetation clutter index score}) + (3.06 \times \text{water depth})$.

Drinking was identified as the most dominant activity recorded (70% of observations), followed by commuting (20% of observations) and finally foraging (10% of observations). However, the frequency of observed bat activity between the two sites ST2 and ST50 was found to be significantly different ($X^2 = 6.9741, p = 0.031$), and the proportion of activity type (drinking, foraging or commuting) differed between sites (Table 1).

Table 1. Number of times particular bat activities were recorded at sites ST2 and ST50 in Pikiariki Ecological Area, Pureora Forest Park, as well as proportion of each activity type over the survey period.

	DRINKING (%)	FORAGING (%)	COMMUTING (%)	TOTAL %	G-TEST
Stream 2 (ST2)	37 (57.8)	8 (12.5)	19 (29.7)	64	G = 115.84 $p < 0.0001$
Stream 50 (ST50)	114 (75.5)	13 (8.6)	24 (15.9)	151	G = 20.86 $p < 0.0001$

Behaviour across the four time periods differed significantly ($H = 10.46, p = 0.005$). The frequency of drinking and foraging recorded across the four time periods differed over both of the sites. Foraging at site ST2 and commuting at both this and site ST50 did not differ across the four time periods (Table 2).

Table 2. Bat activity recorded at ST2 and ST50, Pikiariki Ecological Area, Pureora Forest Park, over the survey period. Overall bat activity was higher in ST50 than ST2, by virtue of bats drinking more frequently ($H = 10.46, p = 0.005$), in particular between the hours of 21:15 and 22:15.

	SURVEY NUMBER	DRINKING				FORAGING				COMMUTING			
		2045-2115	2115-2145	2145-2215	2215-2245	2045-2115	2115-2145	2145-2215	2215-2245	2045-2115	2115-2145	2145-2215	2215-2245
STREAM 2	1	3	2	0	0	0	0	0	0	0	0	0	0
	2	0	4	3	2	0	0	0	0	0	7	3	0
	3	0	3	3	2	0	1	2	1	0	0	1	3
	4	0	6	0	1	1	0	0	0	0	1	2	1
	5	0	2	4	2	2	1	0	0	1	0	0	0
	Total*	3	17	10	7	3	2	2	1	1	8	6	4
STREAM 50	1	2	17	12	4	0	1	1	0	2	0	9	0
	2	2	23	15	7	0	2	1	0	5	4	2	1
	3	0	2	5	0	0	1	2	0	2	0	3	0
	4	0	4	2	3	0	1	1	0	1	0	0	0
	5	1	3	9	3	1	1	1	0	0	1	1	2
	Total*	5	49	43	17	1	6	6	0	10	5	6	3

Both drinking and commuting behaviour were recorded in higher frequencies within the second and third time periods (21:15 – 22:15) in both locations. The frequency of foraging activity was also slightly higher between the same time periods in ST50, yet foraging activity across the four time periods in ST2 did not vary dramatically.

4. Discussion

4.1 Vegetation clutter and forest stratification

Long-tailed bats at Pikiariki appeared to prefer riparian corridors with less-dense vegetation than areas with high vegetative clutter. This is consistent with observations made elsewhere for long-tailed bats (O'Donnell 2000; O'Donnell et al. 2006; Griffiths 2007; Dekrout et al. 2014) and other bat species (Lloyd et al. 2006; Vindigni et al. 2009; and Jackrel & Matlack 2010). This is most likely because many species of bats are known to preferentially forage in less-cluttered, more open areas, such as edge and linear habitats. Dense forest vegetation not only impedes echolocation reception, but also physically impedes bat species that tend to fly at high speed (Ober & Hayes 2008; Dwyer 1960). This may offer an explanation as to why the frequency of foraging activity was limited along the generally cluttered riparian environment at Pikiariki. Further studies into invertebrate abundances along riparian habitats within Pikiariki may also help to discover whether the level of available prey is too limited for optimal foraging.

4.2 Local-scale physical parameters of forest streams

Long-tailed bats tend to drink whilst in flight, and less-turbulent and deeper water has been shown to provide optimal drinking conditions by virtue of elevated bat activity recorded above deeper water. Deeper water may reduce the probability of collisions and possible injury associated with bats flying into features (such as rocks) protruding from the water surface, making drinking from it a safer option (Mackey & Barclay 1989). The sound of turbulent water has also been shown to deter activity of bats when played over calm water, suggesting that the noise may interfere with echolocation and prey detection (Mackey & Barclay 1989). This association with deeper water has not previously been reported for long-tailed bats. Although no association between size of water body and bat activity was determined within this study, site-specific intra-correlation comparisons have indicated that when there are low levels of clutter and deeper bodies of water, forest streams are generally wider. Flow rate, riffles and pools were not found to be associated with bat activity in Pikiariki.

4.3 Drinking behaviour in riparian habitats

Direct observations at sites ST2 and ST50 in Pikiariki showed that long-tailed bats spent two-thirds of their time drinking at suitable sites, significantly more time than they spent foraging and commuting. Similar species of hawking (catching insects in mid-air) bat have also been shown to use riparian habitats primarily for drinking rather than for foraging (Lloyd et al. 2006). This type of habitat use may be expected of hawking specialists in comparison to trawling (catching insects or fish out of the water) bats, which are known to use riparian habitats more for foraging (Kruger et al. 2014).

Within the 2-hour periods surveyed, drinking activity was observed to be clustered at certain time intervals, which is a typical behaviour of hawking bat species. The highest frequency of drinking occurred shortly after sunset, so it appears that ready access to drinking resources

post-emergence from roosts is important for long-tailed bats, as they are known to emerge approximately 30 minutes after sunset (Griffiths 2007). Other species of bat are known to fly to water sources shortly after emerging from their roosts in order to drink (Krutzhsh 1954; Hayes 1997), and Borkin & Parsons (2011) found that females appeared to select roosts close to water sources, whereas males were less selective. Close proximity to drinking sites enables bats to optimise their drinking requirements before travelling on to foraging sites and also prevents disruption to foraging activity; as having to stop feeding to drink comes at a cost to energy allowances (Hayes 1997). It is likely that long-tailed bats will drink from suitable sites within riparian habitats several times during each night, as the bats' physiological features demand a regular consumption of water. Their bodies have a large surface area when their wings are extended for flight and this means that they can lose significant amounts of water through evaporation (Morris et al. 1994).

5. Conclusion

This empirical study demonstrated that riparian areas within forests that contained low amounts of vegetation clutter and areas of deeper water along streams showed higher activity levels for long-tailed bats compared with other more densely-vegetated or shallower-water areas along the stream. In addition, bat activity at two sites known to have high numbers of bats was found to be dominated by drinking rather than foraging and commuting.

At present, the model developed for predicting mean bat calls based on vegetation clutter scores and water depths can only be utilised with data collected from Pikiariki, but it could contribute to developing a site-specific Habitat Suitability Index (HSI) for long-tailed bats. Vegetation management along deeper stretches of streams in Pikiariki Ecological Area could provide long-tailed bats with more drinking locations. Such vegetation management could be targeted to areas in close proximity to known bat roosts and on direct routes to foraging locations. Deploying harp-traps in places known to be favourable to bats (along riparian corridors, especially near deeper water and more open vegetation) may result in higher numbers of long-tailed bats being caught, and assist future bat monitoring programmes.

Although this study is limited to only one study site, it provides an evidence base for documenting long-tailed bat activity in riparian habitats. Extending the monitoring period over various time scales, capturing data over multiple years and distinguishing activity patterns of individual bats would enhance the integrity of future work. Moreover, this study could be replicated in forests in other locations where long-tailed bats are known to be present. This may improve overall understanding of the bats' interactions with riparian habitats in forested landscapes across New Zealand.

6. Acknowledgements

A travel bursary was awarded to the primary author and was kindly provided by the Vice-Chancellor's Fund at the University of Northampton, UK. The primary author would also like to give a special thank you to the Department of Conservation for providing the opportunity to research the long-tailed bat. The author would also like to thank Tertia Thurley and all other staff working at Pikiariki Ecological Area, Pureora Forest Park. Thanks also to Zenon Czenze and Amy and Greg Crestanello, who provided accommodation and equipment. Thank you to Geraldine Moore for the support with creating the GIS maps, and to the people who reviewed the draft and provided comments to significantly improve the paper.

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