

# Long-tailed bats' use of a *Pinus radiata* stand in Kinleith Forest: Recommendations for monitoring

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## Abstract

Targeted monitoring of threatened species within plantations is becoming more important due to forest certification programmes' requirement to consider protection of threatened species, and to increase knowledge of the distribution of species. To determine patterns of long-tailed bat (*Chalinolobus tuberculatus*) activity in different habitat structures, with the aim of improving the likelihood of detection by targeting monitoring, we monitored one stand of 26 year-old *Pinus radiata* over seven months between December 2007 and June 2008 in Kinleith Forest, an exotic plantation forest centred around Tokoroa, South Waikato, New Zealand. Activity was determined by acoustic recording equipment, which is able to detect and record bats' echolocation calls. We monitored activity from sunset to sunrise along a road through the stand, along stand edges, and in the interior of the stand. Bats were recorded on 80% of the 35 nights monitored. All activity throughout the monitoring period was detected on the edge of the stand or along the road. No bats were detected within the interior of the stand. Bat activity was highest along the road through the stand (40.4% of all passes), followed by an edge with stream running alongside (35.2%), along the road within a skidsite (19.8%), and along an edge without a stream (4.6%). There was a significant positive relationship between bat pass rate (bat passes h<sup>-1</sup>) and the feeding buzz rate (feeding buzzes h<sup>-1</sup>) indicating that bat activity was associated with feeding and not just commuting. Bat feeding activity was also highest along the road through the stand (59.2% of feeding buzzes), followed by the road within the skidsite (30.6%), and along the stream-side edge (10.2%). No feeding buzzes were recorded in either the interior or along the edge without the stream. Differences in overall feeding activity were significant only between the road and edge and between edges with and without a stream. Bat activity was detected each month and always by the second night of monitoring, and in this stand was highest during April. We recommend targeted monitoring for long-tailed bats be focused on road-side and stand edge habitat, and along streams, and that monitoring take place for at least three nights to maximise probability of detection.

**Keywords:** Long-tailed bat; *Chalinolobus tuberculatus*; plantation; stand-level activity; acoustic monitoring; habitat comparison; *Pinus radiata*; New Zealand

## Introduction

Environmental certification schemes require consideration of protection of imperiled species and communities (Wigley *et al.* 2007). Prior to specific management taking place, it is useful to obtain accurate presence/absence data on species through effective monitoring, thus saving valuable time and resources. However, some native species, such as bats, can be difficult and/or costly to detect and monitor due to their cryptic or nocturnal habits (Miller *et al.* 2003). An understanding of how a species of interest uses the habitat within the area of interest is necessary to enable appropriate techniques and targeting of resources, which may in turn reduce the

effort required to detect species (Greaves *et al.* 2006), and the related costs.

Bats use echolocation to orientate and navigate (Jones & Teeling 2006). Although the calls of most species are ultrasonic, they can be monitored through the use of "bat detectors", small devices that detect the echolocation calls of bats and transform the sound to audible frequencies. One use of bat detectors is estimation of relative habitat use (Hayes 1997). In New Zealand there are only two extant bat species, the long-tailed bat and the lesser short-tailed bat (*Mystacina tuberculata*); both are considered to be acutely threatened (Hitchmough *et al.* 2007). Each of these species has a characteristic frequency to their echolocation calls and so they are easily identifiable using bat detectors (Parsons 2001). This makes the use of ultrasonic detectors particularly useful in New Zealand.

Within New Zealand, bat detectors have been used to show that bats' use of plantation forest is more often associated with certain habitat types within the plantation; older stands and native reserves in the cases of long-tailed and short-tailed bats, respectively (Moore 2001; Oates 2003). In native *Nothofagus* forest bat detectors were used to determine that long-tailed bats used linear landscape features such as forest edges and roads more often than the forest interior (O'Donnell 2000).



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New Zealand's long-tailed bat is an endemic insectivorous vespertilionid, which is generally associated with indigenous forests (O'Donnell 2005). Long-tailed bats were first recorded in plantation forest in New Zealand in 1976, when a *Pinus radiata* containing a long-tailed bat roost was felled in Kinleith Forest, near Tokoroa in the South Waikato, New Zealand (Daniel 1981). They still persist in Kinleith Forest, however little is known of how they use the plantation itself and even whether use of the forest is commonplace. The use of plantations by bats is more widespread than Kinleith Forest with observations of long-tailed bats noted from Waiuku in the north (W. Foran, Crown Forestry, personal communication) to Geraldine in the south (G. Waugh, Blakely Pacific Limited, personal communication), but information on the persistence of long-tailed bats within plantations tends to rely on observations rather than targeted monitoring.

To maximize the usefulness of species occurrence data within plantation forest, monitoring needs to be conducted at the stand-level, as this is most relevant to managers. Within stands, monitoring studies must then be designed to maximize the probability of detecting bats. This is best achieved by exploiting habitat preferences shown by the animals. Results of previous monitoring studies in native beech (*Nothofagus* sp) forest, wing morphology (O'Donnell 2005) and echolocation calls (Parsons *et al.* 1997) suggest that long-tailed bats prefer to forage along the edges of forest and in gaps within the forest (O'Donnell 2000). Therefore, we hypothesise that bat activity will be higher along the roads and edges compared with the interior of stands in plantations.

The aim of this research was to determine patterns of activity of long-tailed bats within a single stand of pine within Kinleith Forest. Specifically, this study compared activity patterns between the interior, stand edges, and along a road running through the stand to determine the best place to determine the presence/absence and relative activity levels of long-tailed bats in plantation forest. Based on the results of this study, an estimate of the amount of monitoring required to detect long-tailed bats in plantation forest is also given.

## Method

Long-tailed bat activity was monitored using automatic bat monitoring units (ABMs; O'Donnell & Sedgely 1994) placed within and around a 26 year-old stand of *Pinus radiata* in Kinleith Forest between December 2007 and June 2008. A 26 year-old stand was selected as Moore (2001) found that long-tailed bats were more frequently associated with older stands compared with younger stands. ABMs detect echolocation calls produced by bats as they pass within a distance of approximately 50 m of the unit and calls are automatically recorded on a cassette tape (O'Donnell & Sedgely 1994). ABMs also have an internal clock, which records the passing of each hour with a time stamp. Bat

activity is then quantifiable as the number of echolocation calls (or passes) recorded per hour. A pass is defined as a series of two or more calls separated from other calls by a period of silence lasting at least one second (Thomas 1988). As bats approach a potential prey item the rate at which they call begins to increase, culminating in the production of a rapid series of calls immediately prior to attempted capture (Griffin *et al.* 1960). This is termed a feeding buzz and the number of buzzes detected by the ABMs was used as an index of attempted feeding activity.

## Habitat types

Three habitat types (forest edge, road-side, and forest interior) were identified for one 20.7 ha focal stand. Ten monitoring sites were selected in each habitat type. Half of the forest edge sites bordered a stream and a 2-year old neighbouring stand, while the remainder bordered only a 7-year old stand. Half of the road-side sites were situated around a skid site within the stand (and therefore the road was wider), and half were along a narrower road through the stand. A paired monitoring design was used such that two sites were monitored in each habitat type each night, and each type of forest edge and road-side sites was monitored each night. Sites in each habitat type were at least 50 m apart, and sites in different habitat types were at least 100 m apart. Each site was monitored for one night each month, with the order of monitoring being randomly selected. Eight ABMs were used during the study and were randomly allocated to a habitat type at the start of each monitoring period.

## ABM placement

ABMs were placed on the ground, facing upwards at an angle of approximately 45° to increase the likelihood of detecting bats. ABMs were set to detect calls with a maximum loudness at 40 kHz, the frequency with most energy of long-tailed bats' echolocation calls (Parsons 2001). ABMs were placed with the microphone parallel to an edge if one was present (i.e., forest edge, or road-side). Monitoring took place between official sunset and official dawn based on information from the New Zealand Nautical Almanac (Land Information New Zealand 2006, 2007) for the closest port, Tauranga. Monitoring took place on the first five available fine nights each month. Monitoring did not occur on nights when rain was recorded in the first two hours after sunset. If the weather deteriorated sufficiently to disturb data collection during the night (i.e., ABM audio tape was filled with the sound of rain and therefore monitoring did not continue for the entire night) monitoring was abandoned and repeated on the next fine night. The "Rain Sensitivity" setting of the ABM was turned on. This setting stops recording when sufficient movement is detected on the top surface of the ABM. "Sensitivity" was set to level 6 ("usual sensitivity" to bat passes).

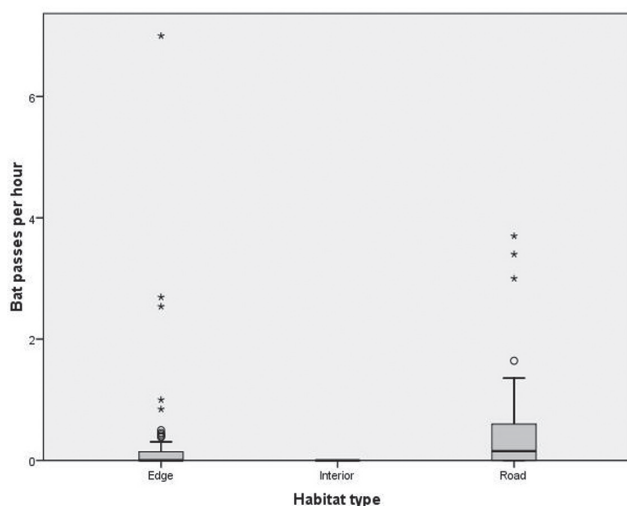


Figure 1. Box-whisker plots showing median ( $\pm$  IQR) bat passes per hour detected in edge, interior, and road habitats over the entire study period. Outliers are shown with \*.

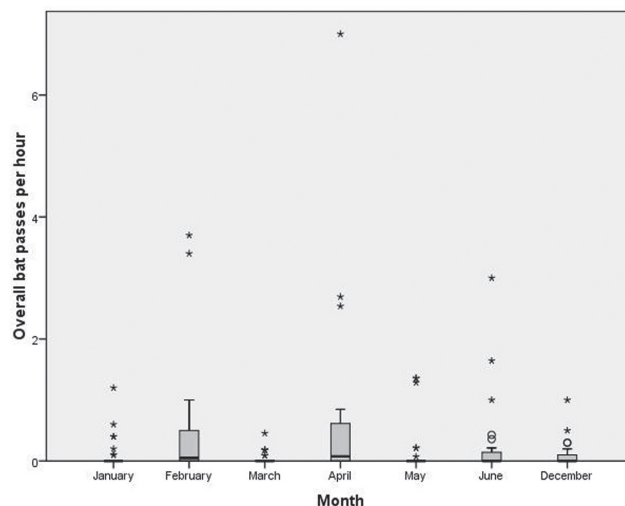


Figure 2. Box-whisker plots showing median ( $\pm$  IQR) bat passes per hour by month for the entire focal stand. Outliers are shown with \*.

### Analyses of data

Kruskal-Wallis tests were used to identify any differences in bat activity and feeding activity between habitat types (edge, road, and interior), month, and ABM. Post-hoc Mann-Whitney U-tests were used to ascertain the source of any detected differences. Continuous data were tested for deviations from normality prior to analyses using the Kolmogorov-Smirnov test. Spearman Rank correlations were used to investigate the relationship between rates of bat passes and feeding buzzes. The likelihood of bat detection was determined for each night of monitoring, i.e., first night of monitoring, second night of monitoring, as the proportion of sites which detected at least one bat pass, or alternatively which detected no bat passes, on that night out of the total seven monitoring sessions (months).

### Results

In total the stand was monitored for 2460 hours over the 7 months of the study. Bats were recorded on 80% of monitored nights (28 out of 35 nights). Bats were always detected by the second night of monitoring within each month. The longest consecutive monitoring period for which bats were not detected was two nights. The likelihood of detection of at least one bat pass on the first night of monitoring was 0.57, and the proportion of monitored nights for which at least one bat pass was detected was 0.80. The proportion of monitored nights on which bats were detected was 0.86; 0.57; and 1.0 for the third, fourth, and fifth nights of monitoring respectively.

In total, 591 bat passes were recorded. Of these, 60.2% (356) were recorded along the road and 39.8% along the edge of the stand (235 passes). No passes were recorded in the interior of the stand. Of the total number of bat passes recorded, 40.4% were along the road through the stand, 35.2% were along the edge with the stream, 19.8% were

along the road through the skid site and 4.6% were along the edge without the stream (239, 208, 117 and 27 passes respectively).

Overall, bat activity data were not normally distributed (for all habitat types:  $D(210) = 0.372$ ,  $p < 0.001$ ; For habitat types separately: Edge:  $D(20) = 0.464$ ,  $p < 0.001$ ; Road:  $D(20) = 0.304$ ,  $p < 0.001$ ), and so Kruskal-Wallis tests were used for further analyses.

There was a significant difference in the overall bat pass rate (bat passes  $h^{-1}$ ) between habitat types ( $H(2) = 56.5$ ,  $p < 0.0001$ ). Post-hoc Mann-Whitney tests showed that there were significantly higher bat pass rates along the road than along the edge of the stand ( $U = 1805.50$ ,  $p = 0.004$ ,  $r = -0.24$ ; Figure 1). In addition, there were significantly higher bat pass rates along the edge which had a stream than the non-stream edge ( $H(1) = 9.145$ ,  $p = 0.002$ ). No significant difference in bat pass rates was found between road types (through the skid site or stand,  $H(1) = 0.647$ ,  $p = 0.421$ ).

In total, 49 feeding buzzes were recorded. Of these, 89.8% (44) were recorded along the road, 59.2% (26) along the road through the stand, 30.6% (18) along the road through the skid site, and 10.2% (5) along the edge of the stand bordering the stream. No feeding buzzes were recorded in the interior of the stand or along the edge of the stand which was not bordering the stream. Overall, feeding buzzes were also not normally distributed ( $D(210) = 0.503$ ,  $p < 0.001$ ) and so Kruskal-Wallis tests were also used for further analyses.

There was a significant difference in the overall rate of feeding buzzes between habitat types ( $H(2) = 26.93$ ,  $p < 0.0001$ ). Mann-Whitney tests detected a significantly higher rate of feeding buzzes along the road than along the edge of the stand bordering the stream ( $U = 1963.50$ ,  $p = 0.001$ ,  $r = -0.28$ ). There was no significant effect of road type (through



stand or skidsite) on the number of feeding buzzes recorded ( $U = 550.50$ ,  $p = 0.33$ ,  $r = -0.12$ ). There was a significant positive relationship ( $r = 0.58$ ,  $p$  (one-tailed)  $< 0.0001$ ) between the bat pass rate (bat passes  $h^{-1}$ ) and the rate at which feeding buzzes were detected (feeding buzzes  $h^{-1}$ ).

There was a significant difference in overall bat activity between months ( $H(6) = 16.30$ ,  $p = 0.012$ ). The overall bat pass rate was highest in April and lowest in March, although differences were small (April median overall bat activity rate  $= 0.08 \pm 0.62$  I.Q.R. compared with a March median overall bat activity rate  $= 0.00 \pm 0.00$  I.Q.R.; Figure 2).

There were no significant differences in overall bat activity recorded on different ABM units ( $H(6) = 9.93$ ,  $p = 0.128$ ).

## Discussion

Our data supports the stated hypothesis that long-tailed bats are more likely to be detected along the road and edges of our focal stand compared to the stand interior. In fact, all bat activity was located along either the road or edge of the stand. In addition, there was significantly more activity along roads than along forest edges. There was also significantly more activity along the edge bordering a stream than along the non-stream edge. As the bat pass rate increased so did the rate of feeding buzzes. Activity differed significantly between months with April having the highest number of passes. This was unexpected as April falls within the southern hemisphere's autumn period, a time when levels of bat activity and foraging bout lengths are starting to decrease (Griffiths 2007). Bats were detected on 80% of monitored nights, and were always detected by the second night of monitoring each month. The longest consecutive monitoring period for which bats were not detected was two nights. As this study took place in only one stand with Kinleith Forest results should be applied to other areas with caution, however we believe it is likely to be indicative of the use of *P. radiata* stands elsewhere.

### Long-tailed bats are more likely to be detected on roads and other edges

We found that long-tailed bats were more likely to be detected along roads and other edges than in the interior of forest stands. Our results, therefore, are consistent with those found elsewhere for long-tailed bats outside of plantation forest (O'Donnell 2000; Griffiths 2007). Griffiths (2007), in a study of agricultural landscape in South Canterbury, found that habitat use by long-tailed bats was not equally distributed across habitat types, with significantly higher activity in willow and riparian areas than in limestone or shrubland. Further, O'Donnell (2000) found that in native beech forest in the South Island most long-tailed bat activity was along roads within the forest (46.3% of all echolocation calls) or along forest edges (42.7%). O'Donnell (2000) did record some activity within forest but this was low (2.9%

of all echolocation calls). A similar pattern occurs within Kinleith Forest. Previous research on long-tailed bat activity in Kinleith Forest also appears to support this pattern. Moore (2001) consistently found that more long-tailed bat echolocation calls were detected along roads than in forest interior sites for both native and exotic areas in Kinleith Forest. Moore (2001) also found a far higher proportion of echolocation calls (24.1 - 25.9% of all detected passes) in the *P. radiata* forest interior than found in this study and any other studied forest interiors in other habitat types (only 2.9% of echolocation calls were detected within *Nothofagus* forest, O'Donnell 2000).

The simplest explanation for why some bat species preferentially use linear habitat features is that bats are more frequently detected in areas that contain more of their prey. Within New Zealand's *P. radiata* forests the relative abundance of exotic beetles is highest 5 m from the edge of recently clear-felled areas (Pawson *et al.* 2008). Higher densities of individuals and species diversity of invertebrates have also been found at edges compared with interior forest sites in Australia (Major *et al.* 2003). All bat activity recorded during this study was along edges, formed either by roads or stand edges. This indicates that long-tailed bat activity may also be directly related to the relative abundance of their invertebrate prey in each habitat type.

Temperatures may be higher and more stable, and wind speed lower, along roads surrounded by stands than along the exterior edge of stands due to the buffering effect of the stands themselves (Chen *et al.* 1995). With higher more stable road-side temperatures, there may be longer periods of high abundances of flying insects (Alma 1975), and consequently more foraging by bats. In addition, lower wind speeds found along roads within forests are also likely to reduce the energetic cost of flying for both invertebrates and bats (Bowlin & Wikelski 2008 studying small passerines), and so be favoured by both prey and predator.

### Long-tailed bats are more active along edges of stands with streams than non-stream edges

As bats are known to forage over and navigate along bodies of water (Verboom *et al.* 1999; Lloyd *et al.* 2006), it was not surprising that we found higher levels of overall bat activity along the edge of the stand that had a stream running alongside. We also found that bats were feeding along the stream edge, but not the non-stream edge. Long-tailed bats are frequently observed foraging along water bodies (Dwyer 1962; Griffiths 2007), apparently to exploit the high numbers of emerging insects present; and this likely explains our greater detection rates here.

Long-tailed bats may also select edges due to their uncluttered nature which enables fast flying, as the bats have limited maneuverability within dense cluttered vegetation (O'Donnell 2005). This lack of maneuverability will in turn

reduce the amount of prey they are able to capture. Further, they may use edges as landmarks for navigation (Verboom *et al.* 1999). The reason long-tailed bats use linear habitat features more often than other habitat types is likely be a combination of all, or some, of these factors, but is most likely related to prey abundance.

## Activity differences occur between months

Differences in bat activity between months were found during this study, although these do not match those found elsewhere (K. Borkin, unpublished data, O'Donnell 2000). Activity in this study was highest in April, yet O'Donnell (2000) found lower activity in winter compared with other seasons using similar methods to this study.

Bat pass rates were very variable in this study. Variability in the bat pass rate may occur at the stand-level due to, for example: a change in habitat utilization, use of roosts which are either nearby or distant to the focal stand, the destruction or other disturbance of foraging and roosting areas by harvesting operations, an increase in home range size of reproductive female bats in the period post-lactation (O'Donnell 2001), unseasonably warm or cold weather, and/or social aggregations of bats.

Care must also be taken when comparing monitoring results and bat activity levels from different regions due to potentially varying temperatures at which bats may be active, and reproductive stages occurring at slightly differing times of year (Gillingham 1996; O'Donnell 2002). However, we note that O'Donnell's (2000) pass rates recorded in indigenous *Nothofagus* forest are far higher than those found in this study; 31.7 times higher in January, and 15.3 times higher in March. Whilst bat detector-based studies cannot determine the number of bats in the sampling area (Parsons 2001), we presume that such large differences in pass rates reflects differences in population size.

## Need to monitor stands for more than one night

During this study, no bat activity was recorded on 20% of monitored nights, even though we know bats are frequently present at this stand. This highlights the need for more than one night of monitoring within an area to determine the presence of long-tailed bats. Bats were always detected by the second night of monitoring each month. However, the longest consecutive monitoring period without any bat activity detected was two nights, so we recommend that monitoring take place for at least three nights at each stand to increase the likelihood of detection.

## Limitations of acoustic sampling

There are several limitations to the monitoring of bat activity using acoustic sampling. ABMs can only detect bats which pass within approximately 50 m of any unit

(O'Donnell & Sedgely 1994), and so their ability to detect bats is limited. In addition, acoustic sampling cannot be used to determine habitat preferences and selection, and should only be used to ascertain general habitat associations and levels of relative activity between and within habitat types (Miller *et al.* 2003).

## Recommendations for monitoring by forest managers

Long-tailed bats are currently considered "data poor" by the Department of Conservation (Hitchmough *et al.* 2007), and this has contributed to their classification as "nationally vulnerable to extinction". A better understanding of how long-tailed bats use habitat that results in more targeted monitoring is likely to increase detection rates (Greaves *et al.* 2006). Targeted monitoring for long-tailed bats within plantations, and the reporting of their presence to the Department of Conservation who maintain a database of bat distribution, will help provide a better understanding of long-tailed bat distribution throughout New Zealand.

We therefore recommend that when forest managers wish to monitor their forests for the presence of long-tailed bats they place monitoring equipment along roads within stands or along the edges of stands to maximise the likelihood of detection of long-tailed bats. If placing monitoring equipment along edges, and there is the option of placing it along an edge with or without a stream, we recommend monitoring the edge with the stream. We suggest monitoring for bat activity for a minimum of three nights to maximise the likelihood of detection of long-tailed bats in similar stands of plantation forest. We also recommend reporting bat activity to the Department of Conservation to assist those interested in bats in gaining a better understanding of the distribution of long-tailed bats throughout New Zealand.

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## Reference

Alma PJ 1975. A study of captures of Noctuidae and Geometridae in a light-trap at the Forest Research Institute, Rotorua. *Forest Entomology Report*. Rotorua, Production Forestry Division, Forest Research Institute, New Zealand Forest Service. Pp. 34.

- Berndt LA, Brockerhoff EG, Jactel H 2008. Relevance of exotic pine plantations as a surrogate habitat for ground beetles (Carabidae) where native forest is rare. *Biodiversity Conservation* 17(1171 - 1185): 1171.
- Bowlin MS, Wikelski M 2008. Pointed wings, low wingloading and calm air reduce migratory flight costs in songbirds. *PLoS ONE* 3(5): 1 - 8.
- Brockerhoff EG, Burns B, Shaw W, Deconchat M, Hock B 2006. Forest biodiversity: identifying the issues and opportunities for management. NZIF Conference 2006: Absolutely Positively Forests.
- Chen J, Franklin JF, Spies TA 1995. Growing-Season Microclimatic Gradients from Clearcut Edges into Old-Growth Douglas-Fir Forests. *Ecological Applications* 5(1): 74 - 86.
- Daniel MJ 1981. First record of a colony of long-tailed bats in a Pinus radiata forest. *New Zealand Journal of Forestry* 26: 108 - 111.
- Dwyer PD 1962. Studies on the Two New Zealand Bats. Zoology Publications Victoria University Wellington 28: 7 - 28.
- Gillingham NJ 1996. The behaviour and ecology of long-tailed bats (*Chalinolobus tuberculatus* Gray) in the central North Island. Unpublished MSc thesis, Massey University, Palmerston North. 115 p.
- Greaves GJ, Mathieu R, Seddon PJ 2006. Predictive modelling and ground validation of the spatial distribution of New Zealand long-tailed bat (*Chalinolobus tuberculatus*). *Biological Conservation* 132: 211 - 221.
- Griffiths RW 2007. Activity patterns of long-tailed bats (*Chalinolobus tuberculatus*) in a rural landscape, South Canterbury, New Zealand. *New Zealand Journal of Zoology* 34: 247 - 258.
- Hayes JP 1997. Temporal variation in activity of bats and the design of echolocation-monitoring studies. *Journal of Mammalogy* 78(2): 514 - 524.
- Hitchmough R, Bull L, Cromarty P 2007. *New Zealand Threat Classification System Lists 2005*. Stand - alone publication 236. 194 p.
- Jones G, Teeling E 2006. The evolution of echolocation in bats. *Trends in Ecology and Evolution* 21(3): 149 - 156.
- Land Information New Zealand 2006. *New Zealand Nautical Almanac 2006/07 Edition* (NZ204). Land Information New Zealand.
- Land Information New Zealand 2007. *New Zealand Nautical Almanac 2007/08 Edition* (NZ204). Land Information New Zealand.
- Lloyd A, Law B, Goldingay R 2006. Bat activity on riparian zones and upper slopes in Australian timber production forests and the effectiveness of riparian buffers. *Biological Conservation* 129: 207 - 220.
- Major RE, Christie FJ, Gowing G, Cassis G, Reid CAM 2003. The effect of habitat configuration on arboreal insects in fragmented woodlands of south-eastern Australia. *Biological Conservation* 113: 35 - 48.
- Maunder C, Shaw W, Pierce R 2005. Indigenous biodiversity and land use - what do exotic plantation forests contribute? *New Zealand Journal of Forestry* 49(4): 20-26.
- Miller DA, Arnett EB, Lacki MJ 2003. Habitat management for forest-roosting bats of North America: a critical review of habitat studies. *Wildlife Society Bulletin* 31(1): 30 - 44.
- Moore GE 2001. Use of Kinleith Forest by native New Zealand bats and effects of forestry. Unpublished thesis, Massey University, Palmerston North. 255 p.
- O'Donnell CFJ 2000. Influence of season, habitat, temperature, and invertebrate availability on nocturnal activity on the New Zealand long-tailed bat (*Chalinolobus tuberculatus*). *New Zealand Journal of Zoology* 27: 207 - 221.
- O'Donnell CFJ 2001. Home range and use of space by *Chalinolobus tuberculatus*, a temperate rainforest bat from New Zealand. *Journal of Zoology* (London) 253: 253 - 264.
- O'Donnell CFJ 2002. Timing of breeding, productivity and survival of long-tailed bats *Chalinolobus tuberculatus* (Chiroptera: Vespertilionidae) in cold-temperate rainforest in New Zealand. *Journal of Zoology* (London) 257: 311 - 323.
- O'Donnell CFJ 2005. New Zealand long-tailed bat. In: King CM ed. *The Handbook of New Zealand Mammals*. 2 ed. Melbourne, Oxford University Press. Pp. 98-109.
- O'Donnell CFJ, Sedgeley JA 1994. An automatic monitoring system for recording bat activity. Department of Conservation Technical Series 1172 - 6873.
- Oates KE 2003. Part 5: Bats. Rotoaira Forest Specific Fauna Surveys: Report # 10038.
- Parsons S 2001. Identification of New Zealand bats (*Chalinolobus tuberculatus* and *Mystacina tuberculata*) in flight from analysis of echolocation calls by artificial neural networks. *Journal of Zoology* (London) 253: 447 - 456.
- Parsons S, Thorpe W, Dawson SM 1997. Echolocation calls of the long-tailed bat: A quantitative analysis of types of calls. *Journal of Mammalogy* 78(3): 964 - 976.
- Pawson SM, Brockerhoff EG, Meenken ED, Didham RK 2008. Non-native plantation forests as alternative habitat for native forest beetles in a heavily modified landscape. *Biodiversity Conservation* 17: 1127 - 1148.
- Seaton R 2007. The ecological requirements of the New Zealand Falcon in plantation forestry. Unpublished thesis, Massey University, Palmerston North. 126 p.
- Thomas DW 1988. The distribution of bats in different ages of Douglas-Fir forests. *Journal of Wildlife Management* 52(4): 619 - 626.
- Verboom B, Boonman AM, Limpens HJGA 1999. Acoustic perception of landscape elements by the pond bat (*Myotis dasycneme*). *Journal of Zoology* (London) 248: 59 - 66.
- Wigley TB, Miller DA, Yarrow GK 2007. Planning for bats on forest industry lands in North America. In: Lacki MJ, Hayes JP, Kurta A ed. *Bats in Forests: Conservation and Management*. Baltimore, The John Hopkins University Press. Pp. 293 - 318.