Searching for New Zealand's Endemic Bats In the Bay of Plenty

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Contents

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Abstract

Bats have evolved to be the only mammals capable of sustained flight and most use echolocation to navigate and hunt. Bats are the only endemic land mammals in New Zealand and form an important part of the ecosystem pollinating plants and performing insect control. They are also under threat from the twin environmental pressures that are loss of habitat and predation from introduced mammals. Monitoring these cryptic animals had been a challenge but the development of Automated Bat Monitoring Systems that record the echolocation calls of bats has allowed larger areas to be surveyed for bats. The two geothermal areas of Te Kopia and Maungakakaramea south of Rotorua and the podocarp hardwood forest of Otanewainuku south of Tauranga had the potential to contain populations of both *Mystacina tuberculata* (lesser short-tailed bat) and *Chalinolobus tuberculatus* (long-tailed bat). The unique ecological and biological characteristics were investigated and made use of when planning to survey these three areas. Knowledge that bats are present in a particular location enables a suitable management strategy to ensure that the population is sustained. *C. tuberculatus* was found at Maungakakaramea and Otanewainuku but no *M. tuberculata* were detected at any of the sites. An analysis of the methods used showed that increasing the length of the study could improve the likelihood of detection, particularly of *M. tuberculata*. It is recommended that further survey work be done in these three study areas to confirm the presence or absence of *M. tuberculata* at Te Kopia and Otanewainuku and *C. tuberculatus* at Te Kopia. Further investigation into the behaviour of *C. tuberculatus* at Maungakakaramea is required to confirm their use of *Pinus radiata* as roosts.

1 Introduction

All bats belong to the class Mammalia and the order Chiroptera (meaning hand-wing). The origins of Chiroptera can be traced back to the mid to late Cretaceous (100-70 million years ago (mya)) using fossil evidence and genetic analysis (Lloyd 2005, Teeling Springer Madsen O'Brien & Murphy 2005). Members of this order are all capable of sustained flight making them unique amongst mammals. They are found throughout the planet with the exception of the Polar Regions and play important ecological roles as pollinators and in insect control (Daniel O'Donnell & Lloyd 2005).

Worldwide, bats are divided into two suborders Microchiroptera, or true bats (834 species) and Megachiroptera, or flying foxes (167 species) (Neuwieler 2000, Daniel et al 2005). Microchiroptera bats are found on all continents with the exception of Antarctica and occupy most habitat types (including modified habitat) and have varied dietary requirements (e.g. insects, fruit and other mammals). Almost half of all species worldwide are classified as threatened or near threatened by the International Union for the Conservation of Nature and Natural Resources (IUCN) (Daniel et al 2005, Hutson Mickleburgh & Racey 2001).

Microchiroptera bats can range in size, from small (5g with a forearm length of 22.5mm) to relatively large (forearm length of 115mm) and they can possess varied morphological features. They have specialised ears and facial skin growths that have evolved as an integral part of the echolocation that they all use for navigating and hunting. There are a number of common features that include the use of echolocation for navigation, the lack of a claw in the second digit, eyes that are usually small and an interfemoral membrane called the uropatagium that is usually well developed (Daniel et al 2005, Hutson et al 2001, Neuweiler 2000).

The three species of bat found in New Zealand all belong to the sub order Microchiroptera. *Mystacina robusta* (greater short tailed bat) and *Mystacina tuberculata* (lesser short tailed bat) belong to the family Mystacinidae while *Chalinolobus tuberculatus* (long tailed bat) belongs to the family Vespertilionidae (Daniel et al 2005). *M. robusta* has not been sighted since 1967 and is believed to be extinct and the other two species are listed as vulnerable in the IUCN Red List (Hutson et al 2001, Molloy 1995). It is believed that the range of *C. tuberculatus* has been reduced in recent years as there have been fewer recorded sightings in areas where they were once common (O'Donnell 2000). However, as *M. tuberculata* does not leave its roost until after it is fully dark there have been fewer confirmed sightings and the reduction in the abundance of *M. tuberculata* is based primarily on the decline of its habitat (Daniel & Williams 1994, Daniel et al 2005, Lloyd 2001).

Both *Chalinolobus tuberculatus* and *Mystacina tuberculata* are known to use exotic plantations of *Pinus radiata*. In 1976 a colony of approximately fifteen *C. tuberculatus* was discovered in the cavity of a newly felled tree near Tokoroa (Clout 1976). Recent studies have shown that *M. tuberculata* are using plantations for roosting but further evidence that *C. tuberculatus* are using plantation forest for roosting has not yet been found (Borkin & Parsons 2010a, Borkin & Parsons 2001b). A recent survey of forestry workers has provided anecdotal evidence of the widespread use of exotic plantations, *Eucalyptus spp.* and *P. radiata*, by *C. tuberculatus* throughout the North and South Islands (Borkin & Parsons 2009).

There is also anecdotal evidence regarding the presence of bats in the geothermal areas south of Rotorua and the Department of Conservation (DOC), Rotorua Lakes office, wished to discover if bats were using older *P. radiata* as roost trees. They were particularly interested to know if the area was used by *Mystacina tuberculata* as they had been discovered in Horohoro forest nearby (B Evans & P Corson pers comm., Borkin & Parsons 2010a).

This report presents the biology and ecology of the two extant species of bat in New Zealand relevant to understanding the methods of monitoring used in the field. Three surveys were conducted in order to establish the presence or absence of the both species of bat in two different habitat types in the Central North Island of New Zealand. Two surveys were conducted south of Rotorua in regenerating forest within geothermal areas where older *Pinus radiata* were present. The aim of these two studies was to provide information regarding the presence of *Mystacina tuberculata* and *Chalinolobus tuberculatus* thereby enabling DOC to plan the management of wilding *Pinus radiata* in these areas. Recommendations are made for further investigations based on the results of these two studies.

The third survey was conducted in relatively unmodified lowland podocarp forest south of Tauranga in the Bay of Plenty for the Otanewainuku Kiwi Trust. The presence of bats in this forest has implications for planning pest control operations using toxins. The importance of considering the welfare of bats was highlighted by the death of several *Mystacina tuberculata* in Pureora Forest after toxin was laid as part of a planned pest control operation (D. Wills DOC Tauranga pers. comm.).

The Biology and Ecology of New Zealand's Bats

The two extant species of bats are not only morphologically distinct they also have different ecology. Mystacina tuberculata Gray 1843 (lesser short tailed bat) is the larger of the two and is a much more robust bat. It has longer ears, shorter tail that extends beyond the uropatagium or tail wing (Figure 1.1) and is lighter in colour. *M. tuberculata* is one of the few bats to forage terrestrially as well as aerially (Lloyd 2001, Daniel et al 2005, Neuweiler 2000). This is significant for monitoring as it tends not to echolocate while foraging on the ground (Parsons 1998). It is also known to feed on the nectar of several native plants preferring plants with large inflorescences such as *Metrosideros spp.* (e.g. pohutukawa), *Dactylanthus taylorii* (woodrose), *Collospermum hastatum* (perching lily) *and Knightia excelsa* (rewarewa) (Daniel 1976, Lloyd 2001). Targeting areas where these plants are in flower may aid detection. *M. tuberculata* is a deep forest bat spending the majority of its life more that 200m from the forest edge and roosting more than 500m from the forest edge (Christie 2006, O'Donnell et al 2006, Sedgeley 2003). It is only active during the hours of full darkness in the forest (O'Donnell 2001).

In contrast *Chalinolobus tuberculatus Forster 1844 (long tailed bat)* is believed to be exclusively insectivorous foraging aerially at the forest margins (Dwyer 1960, O'Donnell 2001). It is a smaller and less robust bat with a long tail that is fully enclosed by its uropatagium or tail wing (Figure 1.1). It is a dark brown in colour with smaller ears and eyes (Dwyer 1960, O'Donnell 2001, Neuweiler 2000). It is active from dusk in the evening to just after dawn and is the species that is likely to be seen by a casual observer (Daniel & Williams 1984).

Both species use echolocation both for navigation and for detecting and catching prey aerially. M. *tuberculata* uses vision and smell to detect prey on the ground (Lloyd 2001, O'Donnell 2001, Parsons 1998). The echolocation calls of each bat have the largest amplitude at different frequencies enabling the calls to be recorded and identified. *C. tuberculatus* has an echolocation call of maximum amplitude at approximately 40kHz. The maximum amplitude for *M. tuberculata* occurs at approximately 28kHz.

Both species prefer older, unlogged, native forest where there is a plentiful supply of larger trees to find cavities to roost in. Roosts are used periodically, possibly only once or twice in a year and for one or two nights. Maternity roosts tend to be occupied for longer periods (O'Donnell 2001, Lloyd 2001, O'Donnell et al 2006, Sedgeley 2003, Sedgeley 2006). Recent studies have shown that both species can make use of mature exotic plantation forest as well native forests (Daniel 1981, Borkin & Parsons 2009, Borkin & Parsons 2010b).

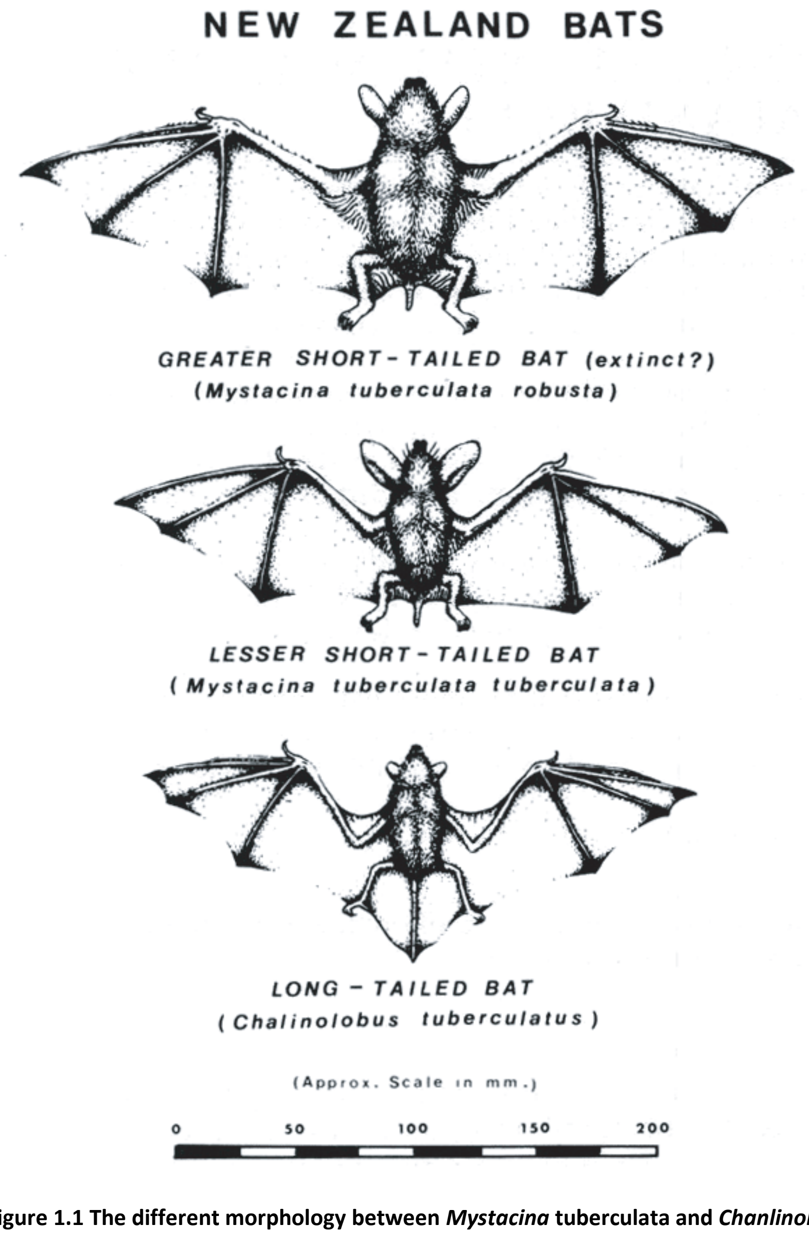

Figure 1.1 The different morphology between *Mystacina* tuberculata and *Chanlinolobus tuberculatus* (Daniel & Williams 1984)

2 Methods

Study Areas

The three study areas are all located in the Bay of Plenty on the North Island of New Zealand. Two are in the geothermal area south of Rotorua and the third, Otanewainuku is to the north of Rotorua and 20km south of Tauranga (Figure 2.1).

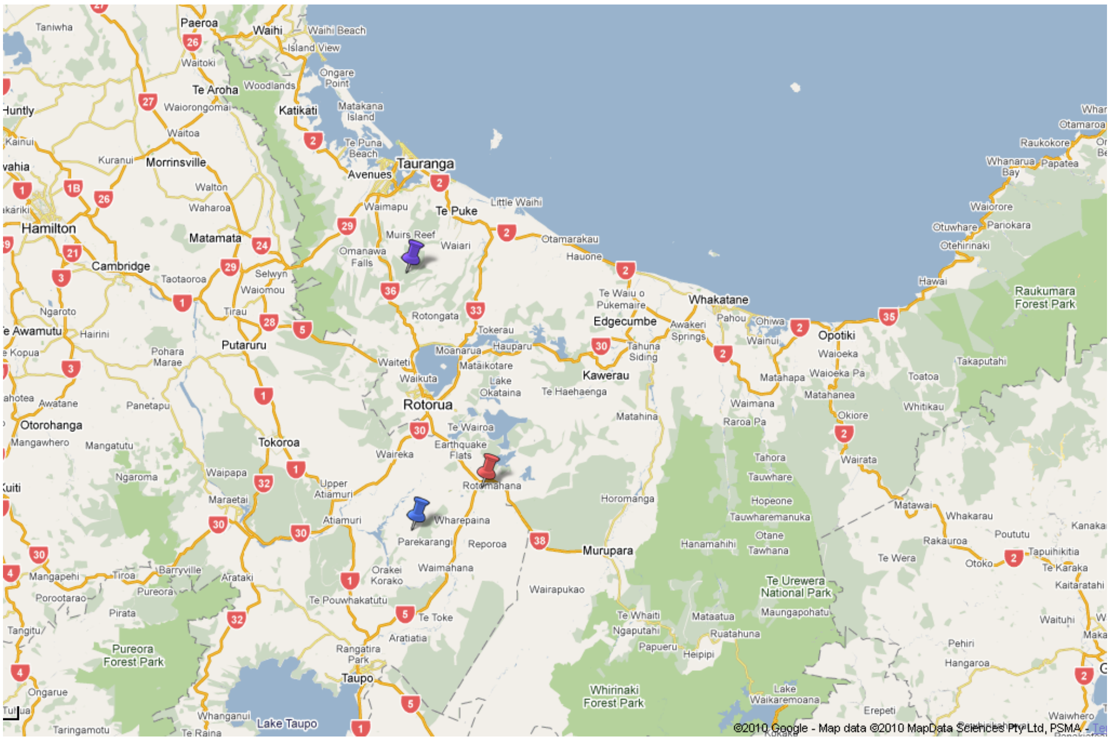

Figure 2.1 The three study areas, Otanewainuku (purple) To the north, Te Kopia (blue) to the South and Maungakakaramea (red) to the East.

Te Kopia

The Te Kopia thermal area that borders and comprises part of the study area is on the Paeroa fault scarp south of Rotorua, New Zealand. The area is characterised by fumeroles, mud pools, warm acid pools and steaming ground. It is geologically linked to the Orakei Korako geothermal area and is thought to regulate high temperature geothermal fluids to that area (Bignall 1963, Soengkono 1999). The area contains one of the few mud geysers on the North Island (P. Corson pers. comm.).

As a result of natural fire damage the vegetation in the study area consists of a mix of secondary growth forest comprising mainly *Weinmannia racemosa* (kamahi) and *Knightia excelsa* (rewarewa) with some larger remnant podocarps, mainly *Dacrydium cupressinum* (rimu). There are also some larger wilding *Pinus radiata* that have been poisoned but are still standing (P. Corson pers. Comm.). The Department of Conservation (DOC) has plans to physically remove the pines and therefore needs to know if they are being used as roost sites by bats (P. Corson pers. Comm.). The current survey is the first step in establishing whether the wilding pines are being used as roost sites by bats.

The area rises from 400m to 600m above sea level (asl) and consists of a ridge that runs from north through east to south west around a partially enclosed a basin. The aim was to survey the ridge to include the area where the *Dactylanthus taylorii* was and the enclosed basin. Sites where there were older *Pinus radiata* or remnant podocarps would also be targeted.

Maungakakaramea (Rainbow Mountain)

Maungakakaramea lies to the south east of the intersection between SH5 and SH38 south of Rotorua between the Wai-o-Tapu and Waimangu geothermal areas. It is the remains of a rhyolite-dacite dome lying on the Ngapouri fault. There are two small crater lakes on Maungakakaramea one is hot and the other is cold. Evidence of thermal activity extends from these lakes near the base (413m asl) almost to the summit (740m asl) on the south side of the mountain (Lloyd 1959, pers. obs.).

The forest on Maungakakaramea has been extensively modified by exotic pine plantation but has recently been allowed to revert to native forest (P. Corson pers. comm.). The mountain is now covered with secondary growth of mainly *Knightia excelsa*, *Melicytis ramiflorus*, *Weinmannia racemosa*, *Hedycarya arborea* with some juvenile *Dacrydium cupressinum* evident. A section of the southern part of Maungakakaramea is covered by slightly older secondary growth forest of the same composition as the rest of the area.

Otanewainuku

The rhyolitic dome Otanewainuku marks the south western boundary of Otanewainuku forest (DOC 2006). The pest controlled area of Otanewainuku forest is just at the lower limit of an area to support a large population of *Mystacina tuberculata* (Daniel et al 2005). However, this area adjoins a Tauranga City Council water catchment area and the southern part of the Otawa forest (DOC 2006). Otanewainuku itself rises to 645m asl but most of the study area ranges between 360m and 420m asl.

This forest is a relatively unmodified lowland podocarp-broadleaf forest consisting of emergent *Dacrydium cupressinum* (rimu) with *Metrosideros robusta* (northern rata) with and understory of mainly *Beilschmiedia tawa* (tawa), *Laurelia novaezelandiae* (pukatea), *Elaeocarpus denatus* (hinau), *Dysoxylum spectabile* (kohehohe) and *Hedycarya arborea* (porokaiwhiri/pigeonwood) (DOC 2006, pers. obs.).

The Otanewainuku Kiwi Trust (OTK) manages the area and was interested in the presence of bats in the forest. This was important to the planning of future toxin operations due to the recent mortalities of *Mystacina tuberculata* that had occurred in Pureora forest after a toxin operation (D Wills DOC Tauranga pers. comm.). OTK had modified the 2009 operations to avoid any potential mortality. The confirmed presence of either *M. Tuberculata* or *Chalinolobus tuberculatus* in the forest would be strongly influence the planning of future toxin operations. In a recent report Wildland (2010) noted that the only bat reported from the forest had been an unidentified specimen found dead on one of the tracks.

Automatic Bat Monitoring System

The Automated bat monitoring System (ABMS) used for this survey was the Digital Bat Recorders (versions D and E) designed and made by DOC and supplied by DOC in Rotorua. The ABMS is enclosed in a waterproof shock resistant case (Pelican 1120). The ABMS are digital heterodyne monitors that process an ultrasound signal heard at one of two frequencies, 28 kHz and 40 kHz, and record an audible sound file to an SD storage card. The two frequencies are those that have the greatest amplitude for the echolocation calls of *Mystacina tuberculata* and *Chalinolobus tuberculatus* respectively (Lloyd 2009).

The ABMS was chosen because it could be left in position over several nights unattended. It is designed to record between two preset times. During this time the ABMS will record to the memory card, a sound file for each of the two frequencies whenever a sound is detected on either frequency. The sound files are named by the time of recording and the frequency and placed into a folder for that night's listening. The sound recorded could by any sound at that frequency and may be the sound of wind, rain, insects or other sounds in the forest as well as the echolocation calls of bats. A noise setting is provided as a filter for excessive. (Lloyd 2009).

Each ABMS was numbered and was paired with an SD card (with the same number) to track where the sound recordings were made. Each ABMS was set up in accordance with Lloyd (2009). The date and time were verified to ensure they were correct. The start time was set to half an hour before sunset and stop time was set to half an hour after sunrise. The noise level was set to low (recommended for good weather conditions). At the low noise setting the unit would stop recording if background noise became excessive. In practice this terminates a long recording (long appears to be approximately 18s). Intense bat activity may also cause the unit to temporarily stop recording.

The Ideal placement for each ABMS was approximately one metre above the ground and away from any vegetation that may brush against it or where it would be vulnerable to wind noise (this may be recorded) (O'Donnell et al 2006). Care was also taken to keep the ABMS out of sight when they were placed near public areas.

Each ABMS would be left in place at each site for three consecutive nights of good bat listening conditions. It has been found that where long tailed bats are present in stands of *Pinus radiata* they will be usually be recorded at a specific location when monitored for at least three nights (Borkin & Parsons 2009). The surveys were timed to take place during summer (November, December) when the weather would be warm, calm with less likelihood of rain. These are ideal conditions for bats to be active overnight (O'Donnell 2000b). Rain and humid weather impairs the bat's ability to echolocate effectively (Neuweiler 2000). Rain and wind noise will also be picked up by the ABMS causing sound clutter that may affect analysis of the recordings (Lloyd 2009). The weather forecast was checked before deploying the ABMS to maximise the chances of there being three consecutive nights of good bat monitoring conditions.

The general listening position for each ABMS was determined in advance using topographical maps, aerial photographs and local knowledge (Corson pers. comm.). Different habitat types would need to be targeted because *Mystacina tuberculata* preferred deep forest (i.e. more than 200m from the edge) whereas *Chalinolobus tuberculatus* spent most time foraging on the forest margins (O'Donnell et al 2006). The listening sites were chosen to cover all the main habitats that bats may be using either for roosting, feeding or navigating to give the best possible coverage.

The precise location of each ABMS was determined in the field at the time of placement. The proximity of larger trees and natural corridors through the forest were considered. The GPS position of each ABMS was recorded when it was positioned and a note made of any salient landmarks so that the ABMS could be easily found and retrieved. Each unit was also clearly marked with the contact details for the DOC office to which it belonged.

Te Kopia

There were known *Dactylanthus taylorii* (woodrose) in the study area and though it was too early in the season for this to be in flower (Warne & Woods 1990) when the survey was carried out an ABMS was placed near that location. The focus for this survey was *Mystacina tuberculata*.

The survey took place from Monday 6th December 2009 to Thursday 10th December 2009 over 3 nights. The weather was calm, warm, clear and dry for all three nights. Ten ABMS boxes were deployed in the area to the north and east of the western geothermal area above the Te Kopia Road (Figure 2.2).

Due to the proximity of the study site to a geothermal area DOC guidelines were followed with regard to additional personal safety practices to those for a normal day working in the bush. This included taking extra equipment (e.g. glad wrap for burns) and informing both the local DOC office and the landowner of the time in an time out of the study area.

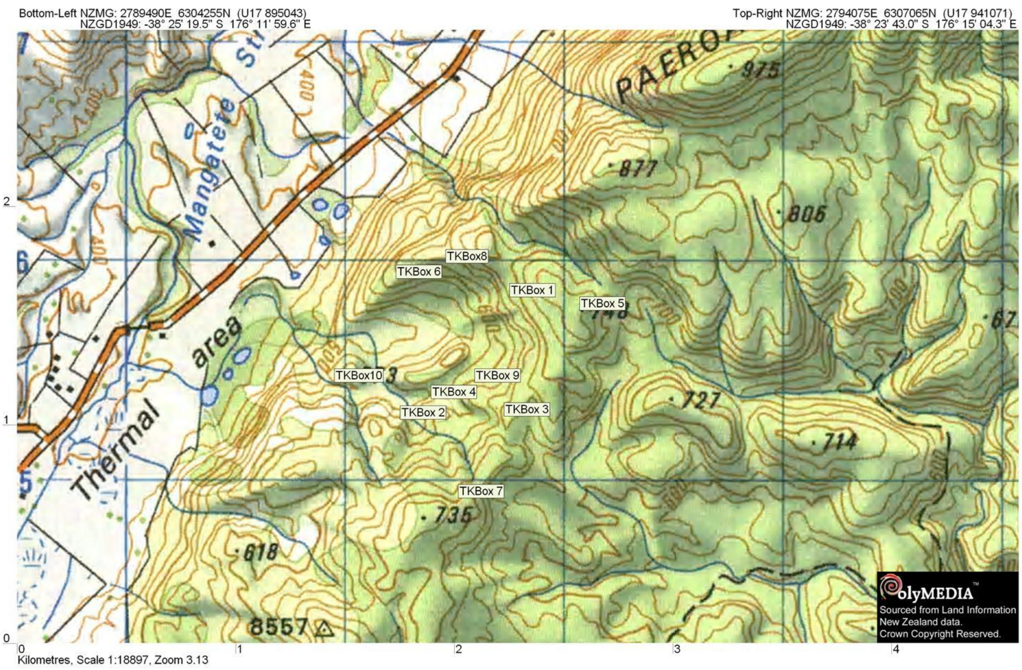

Figure 2.2 Map of the Te Kopia Thermal area showing the locations for the ABMS.

Maungakakaramea

Chalinolobus tuberculatus had previously been detected at this site by the crater lakes and by Ngahewa on the opposite side of SH5. As *Mystacina tuberculata* habitat was sparse the ABMS were positioned with the emphasis on listening *C. tuberculatus*.

The survey took place from Thursday 24th December 2009 to Sunday 27th 2009 over 3 nights. The weather was calm, warm, clear and dry for all three nights. Ten ABMS boxes were deployed in the area (Figure 2.3). All the ABMS locations were easily accessible from the main walking track up the mountain or the 4WD service track for the repeater station at the summit so additional precautions was not required.

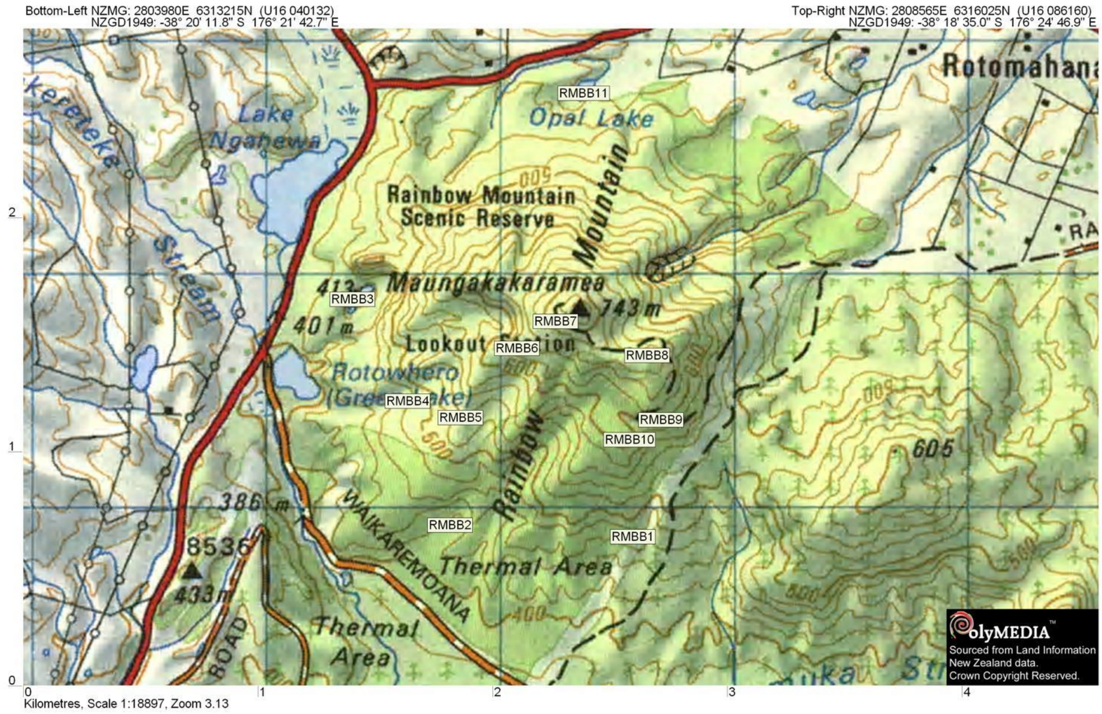

Figure 2.3 Map of Maungakakaramea (Rainbow Mountain) showing the locations for the ABMS

Otanewainuku

As Otanewainuku forest was sufficiently large with enough suitable habitat to support a large population of *Mystacina tuberculata* and *Chalinolobus tuberculatus* the ABMS were positioned so that both species were likely to be recorded, if present. This survey took place from 30th December 2009 to the 3rd January 2010 over four nights. The weather was calm, warm, clear and dry for all three nights. Fifteen sites were monitored (Figure 2.4).

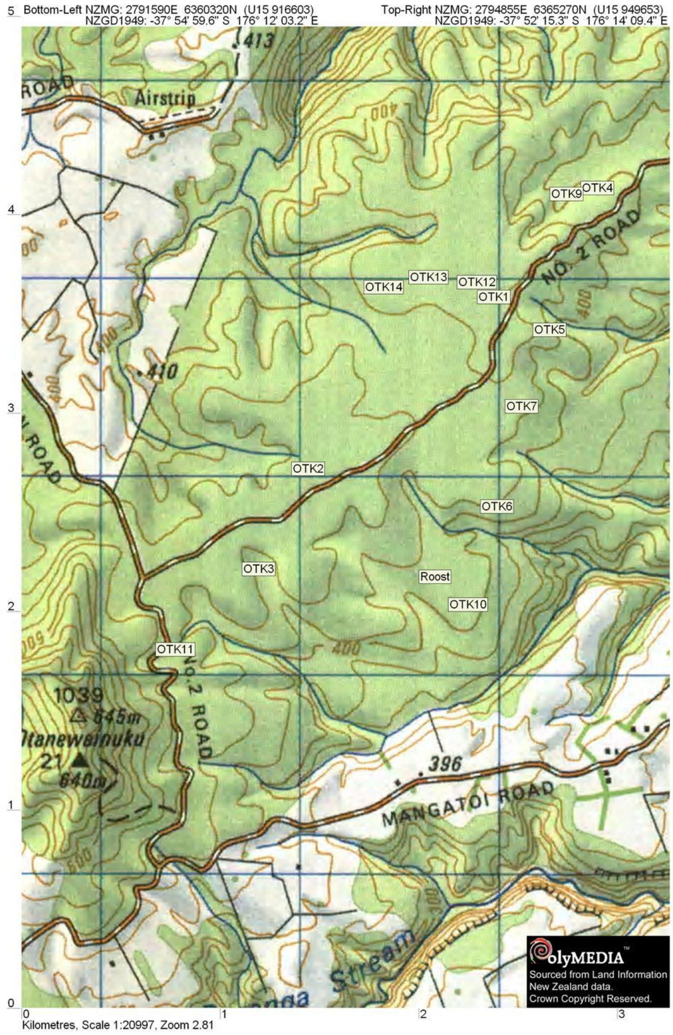

Figure 2.4 Map of Otanewainuku Forest showing the locations of the ABMS.

Data Retrieval and Analysis

On completion of the monitoring, the data from the SD cards were downloaded to a computer. The sound files for each location were kept in a separate folder. The sound files were analysed using the "BatSearch" software supplied by DOC (Lloyd 2009). Bat passes, for each species of bat, were tallied for every complete hour between the start of recording and the end. Passes were defined as two or more echolocation pulses within less than one second of each other. The resultant passes per hour were used as an index of bat activity. This index was used to produce an arithmetic mean for passes per hour over all the listening sites over the period of the survey (O'Donnell et al 2006).

3 Results

Te Kopia

All the ABMS were retrieved and the data for each listening night was recovered from the SD cards. On inspection of the sound files it was found that no bat passes had been recorded.

Maungakakaramea (Rainbow Mountain)

On returning to collect the boxes it was found that the data collection was compromised in two of the ABMS. In the ABMS at location RMBB1 the batteries had come loose so no data had been recorded for any of the three nights. The ABMS at RMBB3 was no longer at its location and could not be found nearby. The ABMS was later retrieved from a member of the public who had found it and picked it up. The ABMS was removed after the second night so no data had been recorded for the third night.

There were no confirmed passes for *Mystacina tuberculata* on any of the nights where data was recorded. The activity for *Chalinolobus tuberculatus* (Figure 3.1) shows a maximum of 1.1bph (mean bat passes per hour) during the second hour after sunset. This is followed by a lull of 0.1bph and then a slight increase to 0.4bph during the middle part of the night with activity decreasing again towards dawn.

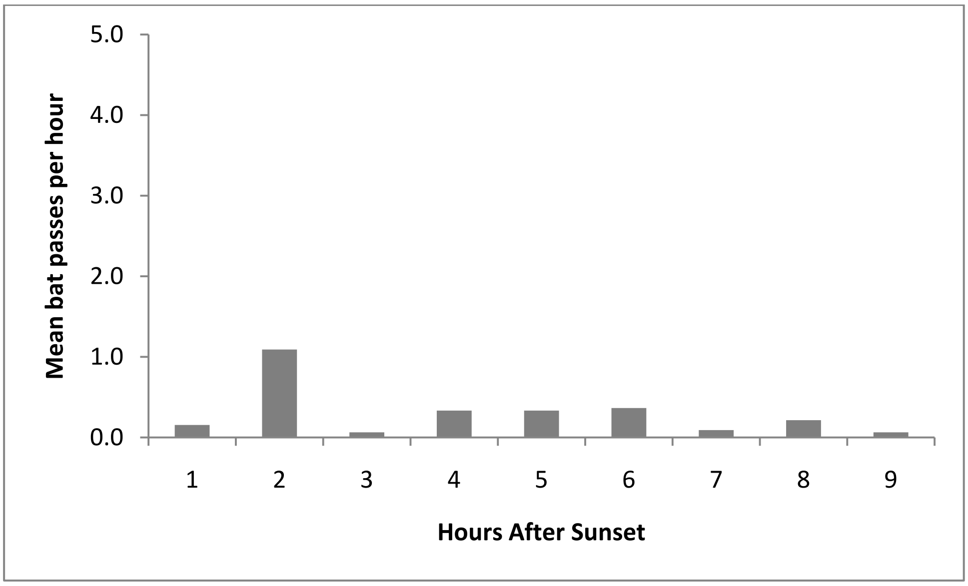

Figure 3.1 The mean number of bat passes per hour of *Chalinolobus Tuberculatus* for Maungakakaramea.

There were a total of 89 identified passes by *Chalinolobus Tuberculatus* over the study period between the ten sites where data was recovered. Of these, 44 were recorded at RMBB3 (crater lake lookout, only two nights data) and 32 at RMBB4. The majority of the passes took place over the first two listening nights and included four feeding buzzes, three at RMBB3 and one at RMBB4, that may be interpreted as an indication of foraging.

Otanewainuku

The ABMS were deployed for four nights at this site. There were no confirmed passes for *Mystacina tuberculata* during the survey. The activity for *Chalinolobus tuberculatus* (Figure 3.2) shows a peak of 4.2bph during the second hour after sunset followed by a period of decreasing activity to 0.4bph during hour four. Activity then increased to a second smaller peak of 2.3 during hour eight, just before dawn.

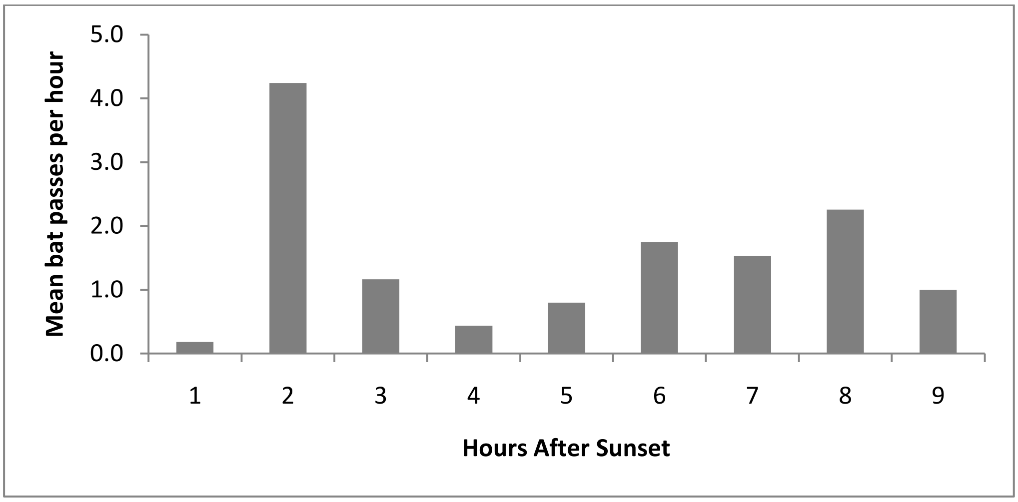

Figure 3.2 The mean number of bat passes per hour for *Chalinolobus tuberculatus* Otanewainuku.

Of the total 401 passes, 183 were detected at OTK4 and 160 at OTK9 (Table 3, Figure 2.4). Feeding buzzes were also detected exclusively at the two sites by an area of open water besides the water supply dams towards the east of the study area. There were a total of 12 feeding buzzes detected, 8 at OTK4, 4 at OTK9 giving an indication that these areas are being used for foraging.

No bat passes were detected at any of the deep forest sites that targeted *M. tuberculata.*

4 Discussion

The activity profile for *Chalinolobus tuberculatus* at both Maungakakaramea and Otanewainuku followed a similar pattern to that found in during other studies of this species(Griffiths 2007, O'Donnell et al 2006). A peak of activity occurred just after dark followed by an hour or two of reduced or minimal activity. Activity then varied throughout the remainder of the night with a second peak of activity just before dawn.

The peak in activity of 4.2bph found at Otanewainuku and the 1.1bph found at Maungakakaramea during this study were generally lower than those from other surveys. When the deep forest listening sites at Otanewainuku were removed from the study the level of activity increased to 9.3bph. This was still lower than that found at Hanging Rock in Canterbury where c. 12bph was recorded (Griffiths 2007) and the Eglinton Valley, Fjordland National Park where 100bph was recorded at the forest edge (O'Donnell et al 2006). The adjusted peak activity of 9.3bph is greater than that found in exotic plantations where activity levels of less than 5bph have been recorded (Borkin & Parsons 2009). While none of the comparison studies were carried out either in podocarp/hardwood forest or in geothermal areas they show a smaller population than those at Hanging Rock or the Eglinton Valley.

The habitual use of linear landscape features such as forest edges, streams and roads through the forest by *Chalinolobus tuberculatus* simplifies the selection of sites for ABMS placement. It also increases the likelihood of detection where there is a population. It has been suggested that where *C. tuberculatus* are present, three listening nights is usually sufficient to detect them (O'Donnell et al 2006, Borkin & Parsons 2009). Where *C. tuberculatus* was found at Otanewainuku and Maungakakaramea it was either by open water or in open areas. As the study only ran for three or four nights there is insufficient data to predict the length of study that would routinely detect *C. tuberculatus*.

The more cryptic *Mystacina tuberculata* prefers to forage only after full dark and then in the forest interior further than 200m from the forest edges (Sedgeley 2003, O'Donnell et al 2006). Recently published literature has suggested that more than three listening nights would be necessary in order to successfully detect *M. tuberculata*. Many of the discoveries of large populations have been as a result of long term work or, in the case of Eglinton Valley, of chance encounters (Borkin & Parsons 2010b). This would suggest that non detection in these short studies should not rule out their absence of from any of the three sites, particularly Te Kopia and Otanewainuku where potential roost sites were observed amongst areas of forest large enough to support a large population.

The majority of the passes for Maungakakaramea were at the two sites closest to the crater lakes (RMBB3/4 (Figure 2.3)). The feeding buzzes indicate that these areas were being used for foraging probably due to a good supply of insects over these bodies of water. It was unfortunate that the ABMS next to the stand of older *P. radiata* failed and that no listening was done at that site. However, the 4WD track that leads to the summit is only a few hundred metres away from this stand and the ABMS located at sites on this track recorded bat passes. The low numbers of bats recorded at these sites may indicate that the area was being used for commuting. More monitoring would be needed to confirm this.

Most of the activity detected in Otanewainuku was over the two water supply dams near the eastern end of the pest controlled block. Feeding buzzes were detected here indicating that the area was a foraging location for *C. tuberculatus*. Other locations recorded fewer passes per hour, with no feeding buzzes indicating that they may be used for commuting.

General Comments on Methodology

The published maximum distances for detecting echolocation calls (20m for *Mystacina tuberculata* and 50m for *Chalinolobus tuberculatus*) are for calls coming from in front of the microphone. Calls from behind or to the side of the microphone would be detected at a shorter distance (O'Donnell & Sedgeley 1994, O'Donnell et al 2006). During an evening listening for *C. tuberculatus* at Maungakakaramea (around the same time as this survey) it was shown that a Batbox III hand held bat detector would detect echolocation calls that the ABMS failed to record. Therefore, it would seem that there is a possibility that the ABMS are under detecting bat activity. There would appear to be no data to compare these results to at present.

It has been shown that the echolocation calls of *M. tuberculata* have lower amplitude that those of *C. tuberculatus* and that *M. tuberculata* do not use echolocation while foraging terrestrially (Parsons 1998). A study on Little Barrier Island (cited by Parsons 1998) found that up to 50% of their diet was terrestrial insects in summer. If a significant portion of the time is spent foraging terrestrially and therefore not echolocating, the detection rates for *M. tuberculata* using ABMS could be lower than those for *C. tuberculatus* for the same population density. The current survey was designed to listen for bat activity over three suitable listening nights at each location. While this has been shown to be sufficient to detect *C. tuberculatus* (Borkin & Parsons 2009) it would not be sufficient to have a reasonable chance of detecting *M. tuberculata* (Borking & Parsons 2010b). The timing of the surveys, the behaviour patterns of *M. tuberculata* and a less powerful echolocation call combined with a short sampling period could explain the lack of detection of these bats at Te Kopia and Otanewainuku. It is also possible that they are not present in those areas.

The passes per hour index that was used to represent the bat passes detected in this study can only be used to indicate relative abundance and portray the temporal spread of activity during the night. This method has been used in other similar studies and would usually followed up by, or used in conjunction with, the capture and radio tracking of bats to obtain a more detailed understanding of their ecology within a particular area (Griffiths 2007, O'Donnell et al 2006, Borkin & Parsons 2009).

The differences in the behaviour of the two species of bat and their use of different habitat would suggest that surveys should be designed for one species of bat. Targeting either *C.* tuberculatus or *M. tuberculata* would maximise the chances of detection. However when time and funding is limited the ability of the ABMS to detect both species can be a useful feature. For example, the ABMS were laid out to detect either species of bat in Otanewainuku where it may have been more productive to target each species separately as two distinct studies. Seven of the sites were in deep forest where it would not be expected to detect *C. tuberculatus* and their inclusion in the analysis for this bat may have affected the results.

The loss of recordings from one ABMS due to dislodged batteries was disappointing and could be avoided in the future by ensuring the unit is in working order and set up correctly when deploying each ABMS. The clear labelling of equipment with contact details proved to be extremely useful and led to the recovery of an ABMS that may otherwise have been lost. Consideration should also be given to any animals that may be capable of dislodging an ABMS. It may be necessary to secure the unit to a solid object. For example there are known to be pigs in Otanewainuku so the units were placed out of their reach or secured to trees (or roots).

Fresh batteries have been shown to last a month during trials at Otanewainuku and that the SD card use is not significant during this time. Leaving the ABMS deployed in the field for one to three weeks is a viable proposition.

Recommendations for Te Kopia

Given the size of forest and the availability of older trees in which to roost this area is capable of hosting a population of both species of bat. A population of *Mystacina tuberculata* has also been confirmed nearby, at Horohoro (Borking & Parsons 2010b), and *Chalinolobus tuberculatus* were confirmed at Maungakakaramea less than 10km away. The area surveyed was a small portion of the native forest and only three nights listening were done so the presence of *M. tuberculata* cannot be ruled out. The positioning of the ABMS at this site was biased towards *M. tuberculata* further reducing the likelihood of detecting *Chalinolobus tuberculatus*. Further study should be planned and if possible a larger area should be included. Each ABMS needs to be left in place for at least five good listening nights before being moved on to the next location (Paddy Stewart, Red Admiral Ecology, pers. comm.). The flowering of *Dactylanthus taylorii,* between February and April (Warne &Woods 1990), should also be taken into consideration so that an ABMS is near their location during that period to capitalise on any *Mystacina tuberculata* feeding on the nectar of these plants (Eckroyd 1994).

Recommendations for Maungakakaramea

The area of older secondary growth to the South of the mountain including the stand of *P. radiata* should be more intensively surveyed. Sufficient activity in this area could indicate the presence of roost sites. The activity levels could also be used to indicate suitable capture sites where bats may be fitted with radio transmitters. Monitoring the behaviour of individual bats would then allow their roost sites to be identified.

Recommendations for Otanewainuku

Given that the forest contains many old growth podocarp and hardwood trees and that the wider area is in excess of 1000ha, it would indicate that this would be good habitat for *Mystacina tuberculata* (Daniel et al 2005, John Heaphy pers. comm.). The length of this survey (four days) was probably too short for a good chance of detecting *M. tuberculata* and a longer study, leaving the ABMS at each location for at least five days (P. Stewart pers. comm.), would be required before their absence could be stated with more certainty. Meanwhile toxin operations should be planned with the consideration that *Mystacina tuberculata* may be present in the forest.

5 Conclusions

Using the characteristics of each of the two species of bats in New Zealand it is possible to target likely habitat when designing a survey. It is important to understand the type of habitat each species uses so that the ABMS may be deployed with maximum chance of detection within the time available. *Chalinolobus tuberculatus* make use of the forest margins and natural corridors for navigation and for foraging while *Mystacina tuberculata* spends the majority of its time deep within a forest (O'Donnell et al 2006, Borkin & Parsons 2009). Both species require older trees for roosting, particularly for maternity roosts (Sedgeley 2003, Sedgeley 2006).

Initial surveys using ABMS are a useful for discovering if a forest is used by a population of bats. The information they record can indicate general patterns of use of a particular habitat by a population of bats. In order to more fully understand their habits particularly with regard to roosting, foraging and social behaviour further in depth study of individual bats is required (O'Donnell & Sedgeley 1994). This may be done by fitting individual bats with radio transmitters and then tracking their movements.

Successful detection of *C. tuberculatus* was achieved at Maungakakaramea and at Otanewainuku but *M. tuberculata* was not detected any of the three sites despite good habitat at Te Kopia and Otanewainuku. The positive detection of *Chalinolobus tuberculatus* in the geothermal areas around Maungakakaramea enables further action to be taken to determine whether the bats are using the older *Pinus radiata* as roost trees through further monitoring work followed by radio tracking individual bats. The positive detection at Otanewainuku enables *C. tuberculatus* to be considered when planning pest control operations using toxins.

It was noted that due to their cryptic nature and the methods employed in the survey the non detection of *Mystacina tuberculata* at any of the sites should not be taken as an indication that these bats are not present. The brevity of the study would suggest that such a conclusion would be premature. Further survey work would be required before their lack of presence could be stated with any confidence.

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7 Appendices

7.1 ABMS Locations

Table 1 The GPS locations of the ABMS Te Kopia Thermal area

ABMS Location	Easting	Northing	Description of the Location
TKBOX 1	2791858	6305945	On the edge of the ridge, down from B8.
TKBOX 2	2791357	6305382	At the top of the next clearing up from the stream
TKBOX 3	2791835	6305397	In the col up the gulley above B9 on ridge (marked with pink triangles)
TKBOX 4	2791497	6305478	To the left side of the gulley along from B2
TKBOX 5	2792179	6305882	Along the ridge (triangles) down slope past ridge marked by tape to two large rimu.
TKBOX 6	2791339	6306030	On the ridge marked with pink flag tape. By large rimu to the right of the track going down.
TKBOX 7	2991624	6305029	On top of ridge (marked with pink triangles) To South of B3
TKBOX 8	2791606	6304964	Further down the track from B6 on top of some rocks to left of track
TKBOX 9	2791701	6305554	By 2 large rimu to left of large bowl (dip). One is a tall stump
TKBOX 10	2791063	6305553	On edge of path 50m up from the stream

Table 2 The GPS locations of the ABMS for Maungakakaramea (Rainbow Mountain)

ABMS Location	Easting	Northing	Description of the Location
RMBB1	2806590	6313924	Up the power lines track from the hot springs at the gate end of Waikeremoana Road
RMBB7	2805811	6313975	Follow 4wd to top then go to top left of clearing beyond flax/toetoe at base of a mahoe
RMBB8	2805392	6314937	Crater lakes, lookout. Off to the left about 5m into the bush behind the seat.
RMBB10	2805630	6314505	On up from Crater lakes, a shallow valley to the right with geothermal activity, near path
RMBB2	2805853	6314433	Up 400m from B10. In secondary growth forest.
RMBB6	2806092	6314782	Up from B2 where the track opens up on left overlooking a steep drop off
RMBB3	2806259	6314842	The far end of the 'car park' where track meets 4wd track near the top.
RMBB5	2806649	6314698	Down the 4wd track approx 400m. Rocks to right on a right hand corner
RMBB9	2806710	6314422	Another 250-300m down 4wd on the left side of the road.
RMBB4	2806573	6314340	Just past the hairpin on 4wd track going down, on right had side of the track.
RMBB11	2806378	6315821	On the north east edge of Opal Lake. To left of the beach.

Table 3 The GPS locations of the ABMS for Otanewainuku

ABMS Location	Easting	Northing	Description of the Location
OTK1	2793978	6361026	N17 BS3 Off the track to the west at the ruru nest tree
OTK2	2793044	6363165	N8 Straight on to clearing past BS3 15m off track (track goes left)
OTK3	2792792	6362658	S20 BS2 on Right behind windfall
OTK4	2794498	6364581	Lower Dam behind pump
OTK5	2794258	6363862	S8 BS3, off to left by 4m stump 10m off track
OTK6	2793993	6362974	Rat line C meets S13, top of clearing S. down S13 a bit
OTK7	2794117	6363477	Rat line C meets S10, by C1
OTK9	2794342	6364548	Upper Dam on left side of dam
OTK10	2793849	6362478	Rat line C meets S16, on tunnel C20
OTK11	2792372	6362253	S24 BS3 in top of wheki
OTK12	2793892	6364103	On north side of where N17 meets the Totara Track.
OTK13	2793640	6364129	Where N16 meets the Totara Track in clearing
OTK14	2793426	6364081	Windfall Just past where the Totara track meets line N15