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Hamilton City Long-tailed Bat Survey 2016-2017

Table of Contents

ACKNOWLEDGEMENTS

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Executive Summary

Hamilton City is one of the few remaining cities in New Zealand to offer suitable habitat for a resident population of long-tailed bats (*Chalinolobus tuberculata*). Long-tailed bats are a threatened species (Nationally Vulnerable, O'Donnell et al. 2013) and therefore play a special role in Hamilton's urban ecology.

Kessels Ecology was contracted by Project Echo, a multi-agency advocacy group for bats in Hamilton City, to conduct a bioacoustics survey of bats throughout Hamilton. The survey forms part of a wider, long-term research project on bat habitat distribution that, while building on an initial city-wide bat presence/absence survey conducted in 2011/2012, was initiated by Project Echo in 2016 and is funded by the Department of Conservation (DOC), Waikato Regional Council (WRC) and Hamilton City Council (HCC). The aim of the research project is to map bat habitat throughout the city and establish a monitoring programme of changes in habitat utilisation over a five to ten year time frame.

Initial bioacoustics surveys were conducted around Hamilton in 2012 and the results are reported in Le Roux & Le Roux (2012). This report discusses surveys conducted throughout Hamilton in 2017. To increase our understanding of bat habitat use, monitor changes, and inform future bat management plans across the city, an annual monitoring programme has been devised. These surveys formed the first monitoring round of the wider Hamilton City bat research project to initiate the annual monitoring programme that is informed by the findings of a GIS habitat model showing hotspots of bat habitat throughout Hamilton.

For this round of surveying, 18 sites were surveyed over a period of four months, with each location being monitored for around 10-14 nights using 3-4 bioacoustic monitors at each site. As this is a community-driven project with limited funding, a group of volunteers was trained to deploy and retrieve bat monitors in several workshops. The data was then collated and analysed by Kessels Ecology ecologists.

The results of this survey and findings of the bat habitat model have shown that the southern gully systems within Hamilton City are crucial areas for bat roosting, commuting and foraging habitat.

At the same time, these gullies are currently affected (Mangaonua, Mangaone, East-West Link and Mangaharakeke gully), or will be in the near future (Mangakotukutuku gully), by major urban development, with several bridges being built across them and a major subdivision planned for the Mangakotukutuku gully area. While the scale of the effect of these developments on bats is not known, it is almost certain that the cumulative effect of these developments on the main bat habitats will have an adverse effect on the long-tailed bat population present in Hamilton city. These impacts will be significantly exacerbated if no effective strategies are implemented to protect and enhance roosting and foraging habitats, as well as maintain commuting corridors.

Five years on from the conclusions of the first survey, many questions remain regarding bats in the city. More progress will need to be made towards the implementation of adaptive management strategies to ensure that bats can survive in Hamilton City while urban development continues to encroach on their remaining habitat.

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1 Introduction

1.1 Survey Rationale and Context

Hamilton City is one of the few remaining cities in New Zealand to offer suitable habitat for a resident population of long-tailed bats (*Chalinolobus tuberculata*). Long-tailed bats are a threatened species (Nationally Vulnerable, O'Donnell et al. 2013) and therefore play a special role in Hamilton's urban ecology.

Results of a 2011/2012 Hamilton City bat presence/absence and habitat connectivity survey showed the importance of maintaining, restoring and perpetuating these well connected, less developed habitats for long-tailed bats in Hamilton City. A large amount of infrastructure development is currently being constructed or proposed in areas where bats are highly likely to be present. The research project of which this survey forms the first stage is seen as critical to further understand habitat use, and potential changes in bat habitat utilisation, over the coming years. The previous city-wide survey underscored the importance of making the urban landscape (both present and future) more permeable to long-tailed bats as well as protecting and enhancing existing well-connected bat habitats.

Kessels Ecology was contracted by Project Echo, a multi-agency advocacy group for bats in Hamilton City, to conduct a bioacoustics survey of bats throughout Hamilton. The survey forms part of a wider research project on bat habitat distribution that was initiated by Project Echo in 2016 and is funded by the Department of Conservation (DOC), Waikato Regional Council (WRC) and Hamilton City Council (HCC).

The aim of the research project is to map bat habitat throughout the city and establish a monitoring programme of changes in habitat utilisation over a five to ten year time frame. The main project objectives are the following aims:

1. Map bat habitat utilisation throughout Hamilton City based on MaxEnt habitat model and additional monitoring data;
2. Implement monitoring programme to assess changes in bat activity and track habitat usage over the next ten years;
3. Identify key conservation bat habitat areas i.e. bat 'hot spots' requiring concerted conservation efforts; and
4. Offer input for and drive a city-wide bat management plan alongside community involvement and education to establish effective bat conservation and habitat restoration programme in the city.

The research proposal set out a staged research programme with three primary aims. 1) Increase our knowledge of the distribution and habitat use of Hamilton city long-tailed bats; 2) Monitor long-term trends in activity at key monitoring sites; and 3) Use knowledge of bat distribution, habitat use and activity trends to guide the restoration of bat habitat.

To achieve the first two aims, a combination of habitat modelling and bioacoustic site surveys will be used to understand where bats are located throughout the city, how they may move through the landscape, and how this changes over time. Long-term monitoring of bats is an integral part of this research project, with monitoring to take place twice a year for at least five, but ideally ten years. All research conducted is designed to be repeatable in other locations and over time, to inform monitoring of bats both at a regional and national scale.

The third aim of this project is to use knowledge of bat distribution, habitat use and activity trends to guide restoration of habitat, based on an ethos of community involvement in, and education of, Hamilton's urban ecosystems that are utilised by bats. The involvement of the community is an integral part of this research, partnering with tangata whenua and the development and utilisation of trained volunteer community groups as part of the on-going survey rounds.

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The survey presented in this report forms the first round of surveys of this research project. Results from this round were also utilised for the development of a habitat suitability model, which shows likelihood distributions of habitat usage throughout the city and is presented in a separate report (Crewther & Parsons 2017).

1.2 Previous city-wide survey results

A survey conducted on behalf of Project Echo in 2011/2012 (Le Roux & Le Roux 2012) focused on potential bat habitat throughout the city. The survey used bat detectors to conduct presence/absence surveys at 62 ‘green space’ habitats (0.7-92 ha) to better understand bat distribution and habitat use patterns in Hamilton City. Long-tailed bat activity was confirmed at 16 sites (25.8%), all of which were restricted to the most southern urban-rural fringe of the city. Although 14 of these habitats (87.5%) were classified as ‘riparian margins’ or ‘major gullies’ situated 0-100 m from the Waikato River (a major linear landscape feature), significantly higher pass rates were recorded at a rural indigenous forest remnant (Whewell’s Bush). Only six sites (<10%) showed any evidence of foraging activity and nightly activity patterns to suggest possible or likely roosting by bats.

Habitat connectivity or distance to the Waikato River/major gullies emerged as the single most significant explanatory variable the statistical model employed in this initial survey, highlighting the importance between habitat type and distance to the river/gullies for bats. Overall, bat activity significantly increased with: 1) decreasing distances from well-connected habitats and linear landscape features (gullies and river); and 2) increasing distances from the city centre and levels of human activity. Pass rates were consistently highest at habitats where houses, roads and street lights were lowest. Even slight increases in the number of roads and street lights resulted in decreases in pass rates of 86% and 70%, respectively.

Riparian margins, with dense indigenous and exotic trees and shrubs associated with riverine and gully landscapes, appeared to be critical habitat, as bats depend on access to key resources associated with these environments. In particular, these habitats provide:

1. Mature exotic and indigenous vegetation for roosting purposes;
2. Emergent aquatic insect prey (e.g. mosquitoes) for foraging;
3. Freshwater for drinking; and
4. Linear landscape corridors for movement and navigation.

1.3 Site description

Hamilton City (37°47’S, 175°17’E) is New Zealand’s fourth largest city with a total area of 9,800 ha that supports a population of c.193,000 people. A major landscape feature of the city is the Waikato River, NZ’s largest river, bisecting the city area. Four major gully systems are situated throughout the city. The Mangakotukutuku and Mangaonua gullies situated along the southern urban-rural interface of Hamilton City are the largest of the four gullies and, together with Waikato River, form the single largest and most continuous ecotone in Hamilton. Conversely, the Kirikiriroa and Waitawhiriwhiri gullies are situated within the urban matrix in highly developed areas in the northern part of the city.

DRAFT

2 Methodology

For the bioacoustics surveys, omnidirectional Frequency Compression (FC) automatic bat monitors (ABMs; manufactured by Department of Conservation, Wellington) were deployed to investigate the presence/absence as well as activity patterns of long-tailed bats. The recorders were deployed in suitable sites at the previously identified locations, targeting likely bat habitat. The ABMs were used in accordance with protocols described by Lloyd (2009). The recordings were analysed visually using BatSearch3 software, developed by DOC.

All recorders were pre-set to start monitoring 1 hour before sunset and stopped recording at one hour after sunrise. Wherever possible, the recorders were suspended around 4 m above the ground to reduce noise from terrestrial fauna and target the height of bats flying past or possible areas of bat emergence from roosts.

The FC recorders record any sound that may be a bat call or echolocation. When it is triggered by a potential bat pass, it records one file for each pass. The recordings are in the form of a compressed image of a spectrogram, saved onto the SD card in the form of bitmap format images. The images were viewed using BatSearch3.11, software that was developed to help quickly view the files and create data from them. The frequency spectrum covered ranges from 0 Hz to 88 kHz and images represent 1-6 seconds of recording.

BatSearch3.11 has the option to overlay a ‘frequency guide’ over the spectrogram image that helps visualise the different parts of the spectrum and thus makes it easier to define bat passes from sounds with similar spectrums. Long-tailed bat passes show up as clicks centred at about 40 kHz extending upwards, but may show spikes extending downwards when the clicks are so loud that they overwhelm the sensor and cause an artificial frequency image.

All echolocation pulses were recorded with a date (day/month/year) and time (hour/minute/second) stamp. By assessing the amount, type and temporal peaks in nightly echolocation activity, we were able to distinguish between three different ways in which bats were using habitats. Where data analysis yielded suitable information, habitat usage was defined into the following categories (adapted from Le Roux & Le Roux 2012, Mueller et al. 2016):

- Commuting - sites with no feeding buzzes and ≤ 0.1 pass/detector/night.
- Foraging and possible periodic roosting - sites with feeding buzzes and ≥ 1 pass/detector/night with activity peaks recorded within the first hour after sunset and again before sunrise indicative of roost emergence and return.
- Foraging and likely regular roosting - sites with feeding buzzes and ≥ 10 passes/detector/night with clear bimodal peaks in activity after sunset and before sunrise indicative of roost emergence and return.

Twelve FC-ABMs were available for deployment at any one time, thus not all survey sites could be monitored concurrently, but were surveyed successively over a period of 16 weeks from 16 February to 18 May 2017 and from 23 May to 11 June 2017. The order in which sites were monitored was random and the number of bat detectors deployed at each site depended on the habitat size, hence, ABM numbers per site ranged from three to five. Survey duration of each site ranged from 10 to 28 consecutive nights.

Bats were monitored in a total of 18 locations in the 2017 survey (Figure 1). As set out in the research proposal, sites were chosen based on the previous city-wide bat survey results, to achieve a fair representation of gullies and greenspaces throughout the city, and in consultation with a number of experts on Hamilton’s bat population. This amounted to a total of approximately 880 hours of monitoring over 110 survey nights. The entire survey covered an area of approximately 628.4 ha of the available ‘green spaces’ in and around Hamilton City.

Weather conditions during the first half of the survey period from mid-February until mid-April were optimal for bat emergence (O’Donnell, 2000). Minimum temperatures at dusk for bat emergence are >8 °C, ideally >10 °C. In this context, temperatures remained above 10 °C on all but five nights in the first half of the survey period. Conditions were suboptimal during the second half of the survey period between mid-April and mid-June due to nightly temperatures falling below 8 °C on 33 nights. For all but five nights (5, 6, and 30 April, 4 and 18 May) of the complete survey period, wind speeds were low to moderate, and rainfall exceeding 5 mm/24hrs was observed for 26 nights. A summary of weather conditions is shown in Appendix I.

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Figure 1. Locations of ABMs deployed between 16 February and 11 June 2017. Red circles indicate that no bat passes were detected by that ABM. The size of green circles is indicative of the mean number of bat passes recorded by the ABM each night.

3 Results

3.1 Detection of bat activity

ABMs were deployed in 61 locations at 18 sites. No recordings were obtained from six ABM detectors due to mechanical failure and loss of equipment. Of the 18 sites surveyed, six (33.3% of sites surveyed) had confirmed long-tailed bat activity (Figure 1, Appendix III). In four of these sites, bats had been detected previously in the 2011/2012 survey (see Section 3.3). See the following link for the online distribution map: [Hamilton Bat Distribution 2017.]()

Bat activity recorded throughout the night is shown in detailed graphs presented in Appendix IV. No obvious bimodal patterns (peaks of activity at dusk and dawn) were recorded at any of the sites. Bimodal activity patterns through the night can often indicate bats roosting nearby. However, Hammond Bush and Forest Lake did show peaks of activity immediately after sunset, and Humare Park showed a peak in activity right before sunrise, which may mean that bats could be roosting close to the surveyed sites.

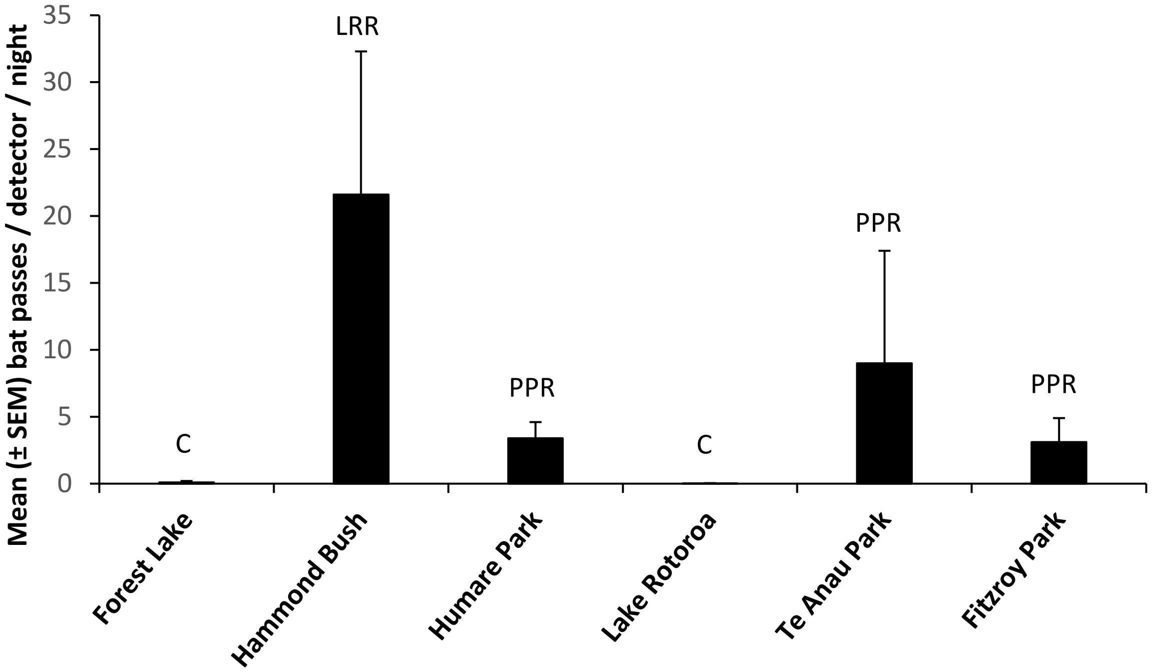

Figure 1 Mean (± SEM) nightly number of bat passes per detector for each bat-positive site. Indices indicate habitat use, C: Commuting; PPR: Possible periodic roosting; LRR: Likely regular roosting.

3.2 Habitat use

A total of 1,431 echolocation passes were recorded from six sites comprising 13 of the overall 61 detectors deployed. Of the six sites with bat activity, Forest Lake and Rotoroa Lake Domain (33.3% of bat-active sites, 11.1% of all sites surveyed) were identified as commuting habitats with low nightly activity below 0.1 mean bat passes/detector/night (0.05 ± 0.03) (graph A in Figure 3). Humare Park, Te Anau Park and Fitzroy Park (50% of bat-active sites, 16.7% of all sites surveyed) were identified as possible periodic roosting habitats with bat activity greater than 1.0 mean bat passes/detector/night (4.64 ± 2.04) (graph B in Figure 3).

In contrast, Hammond Bush (16.7% of bat-active sites, 5.6% of all sites surveyed) was characterised by the highest overall nightly bat activity with more than 10 mean bat passes/detector/night (21.58 ± 10.73) (graph C in Figure 3), strongly indicating this site as a regular roosting habitat (Figure 1). However, for habitats categorized as both, possible periodic roosting and likely regular roosting, no strong bimodal nightly bat activity could be determined (Appendix IV).

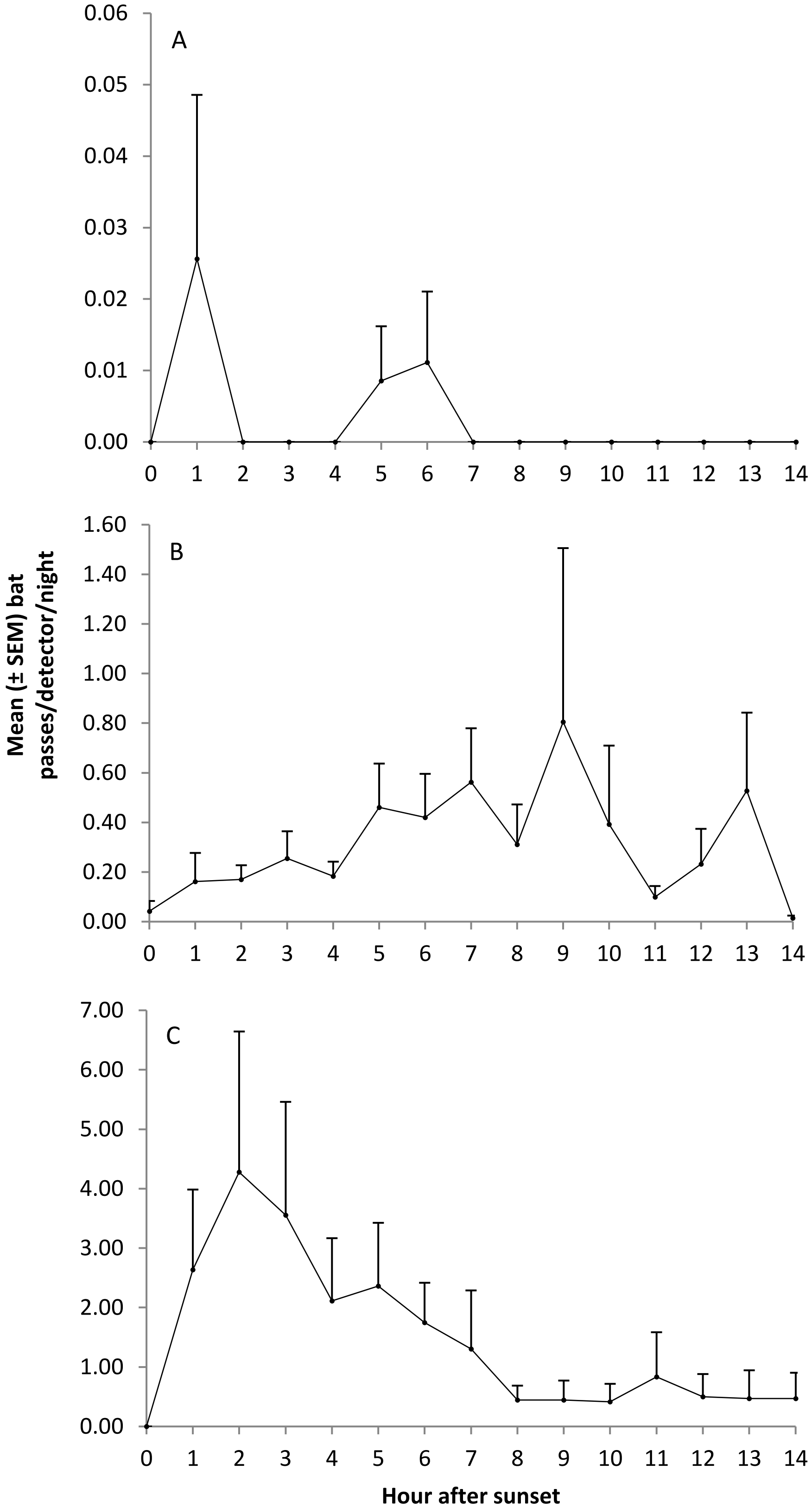

Figure 2 **Nightly bat activity (mean ± SEM bat passes/detector/night) for each hour after sunset for sites categorised as potential commuting habitats (A), possible periodic roosting habitats (B) and likely regular roosting habitats (C; please note: Y-axes scales vary).**

Table 1 summarises the mean activity recorded across gully, riparian margin, urban parkland and indigenous forest remnants compared to the survey effort across the city. Habitat types were categorised as follows:

- Major gullies - well vegetated indigenous and/or exotic corridor systems >50 m from the banks of the Waikato River connecting habitats such as forest fragments with riparian margins;
- Riparian margins - indigenous and/or exotic vegetation immediately flanking (0-50 m) the banks of the Waikato River;
- Urban parklands - designated public recreational areas within the city's boundaries dominated by large open grassy space, mature indigenous and exotic vegetation, and/or artificial or natural waterbodies (e.g. lakes); and
- Indigenous forest remnants - urban and rural forest fragments <12 ha in size dominated by mature indigenous emergent vegetation (e.g. kahikatea (*Dacrycarpus dacryiodes*) and totara (*Podocarpus totara*)).

Most activity was recorded in urban parklands (21.6 mean passes/night), followed by major gully systems (4.6 mean passes/night). No activity was recorded in indigenous forest remnants, however, this habitat type was also under-represented in the survey sites (5.6%) and is generally under-represented in the urban ecosystem space. Appendix III provides details on the habitat type of each survey location.

Table 1 Summary of the survey effort allocated to the four major habitat types along with corresponding mean passes/detector/night

Habitat Type	# sites surveyed (% total)	Area (ha) surveyed (% total)	# detectors allocated (% total)	# sites with bats (% total)	Mean (±SEM) passes/detector/night
Major gullies	8 (44.4%)		27 (44.3%)	3 (50.0%)	4.6 ± 2.0
Riparian margins	5 (27.8%)		17 (27.9%)	1 (16.7%)	0.05 ± 0.03
Urban parklands	4 (22.2%)		14 (23.0%)	2 (33.3%)	21.6 ± 10.7
Indigenous forest remnants	1 (5.6%)		3 (4.9%)	0 (0%)	N/A
Total	**18**		**61**	**6**	

3.3 Comparison to previous survey

In comparison to the initial city-wide bat survey conducted in 2011/2012, less than half of the number of sites were surveyed for this monitoring round due to both variations in research scope and limitations in budget. A total of six sites detected bats in this survey, at four of which bats had been detected previously (Figure 4).

At Hammond Bush, average bat passes per night and detector were lower in the 2017 survey in comparison to the previous 2011/2012 survey. At all other sites with bat activity, average bat passes per night and detector were higher in the 2017 survey in comparison to the previous 2011/2012 survey. However, these differences in bat activity between the 2011/12 and 2017 surveys were not statistically significant (Student t-test assuming unequal variances, $p<0.05$). In Forest Lake and in Lake Rotoroa Domain bats were detected in the 2017 survey, however had not been identified in the previous 2011/2012 survey (Table 2).

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Table 2 Comparing bat activity findings from the 2011/2012 and the 2017 survey.

Site name	Time	Bats	# ABM	# ABM that detected bat presence	Calls / ABM /night
Forest Lake 2012	Jan	N	6	0	N/A
Forest Lake 2017	Mar	Y	4	1	0.1
Hammond Bush 2011	Sept	Y	9	6	29.1
Hammond Bush 2017	May	Y	4	3	21.6
Humare Park 2011	Sept	Y	1	1	0.6
Humare Park 2017	Apr	Y	2	2	17.5
Te Anau Park 2011	Oct	Y	9	2	0.1
Te Anau Park 2017	Apr	Y	3	2	9
Fitzroy Park 2011	Oct	Y	5	1	0.1
Fitzroy Park 2017	May	Y	4	4	3.1
Lake Rotoroa 2011/	Oct	N	10	0	N/A
Lake Rotorua 2017	Feb	Y	5	1	0.02

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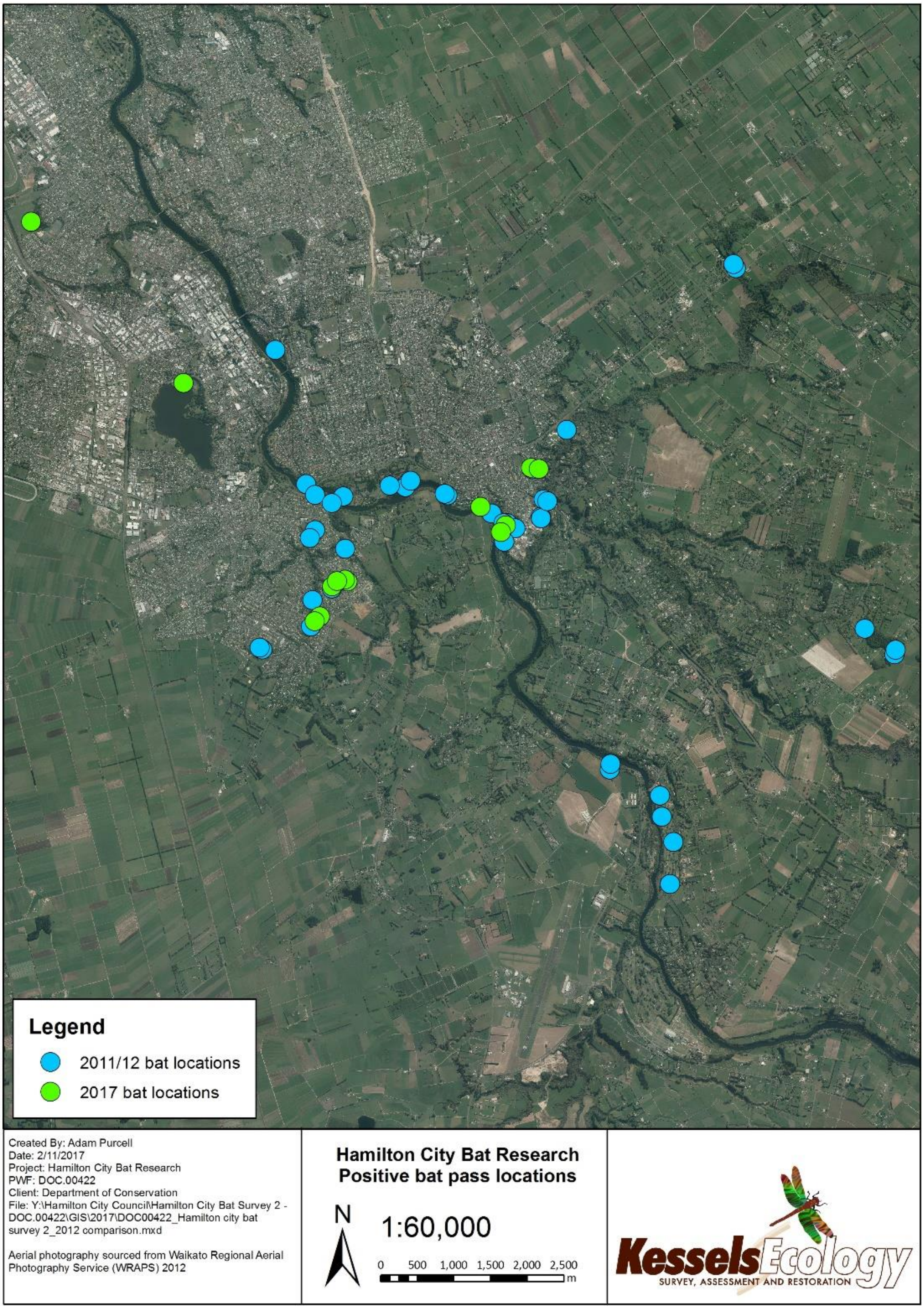

Figure 4. Locations of the positive bat passes recorded in 2011/12 and 2017 surveys.

4 Discussion

4.1 Survey findings

This survey, and the wider project on Hamilton city bat habitat was conducted for, and has studied presence/absence of bats across the city at 18 different sites. Building on the understanding gained of bat distribution during the 2011/2012 Project Echo city-wide survey (Le Roux & Le Roux 2012), this study complemented the findings of the initial survey by adding new sites and surveying each location for a longer period of time, therefore increasing the likelihood of bat detections.

The initial 2011/2012 survey at the time was the most comprehensive bioacoustic bat survey undertaken to date in any New Zealand city. Presence/absence survey results revealed that long-tailed bats, the more widespread of the two indigenous bat species found in New Zealand, were confirmed at 16 of the 62 sites surveyed. Short-tailed bats inhabit large indigenous forest areas, and have not been found in urban or peri-urban spaces. Long-tailed bat activity was shown to be confined to a relatively small number of sites with a distribution pattern restricted to the southern most urban-rural fringe of the city. The Waikato River was shown to be a major habitat connecting landscape feature which long-tailed bats are known to use as a corridor to move between habitats (Dekrout 2009).

4.2 Bat distribution

In this 2017 study, bats were found to be present predominantly throughout the southern fringes of the city (repeating the findings of the 2011/2012 study). While there was a bias in the sampling effort favouring data collected in the southern parts of the city (see Figure 1), this survey again has shown that bats are mostly present throughout the southern gully systems of the city. A couple of bat passes were also detected at new locations further north, but these were infrequent and habitat use seems to be restricted to commuting or perhaps foraging.

The 2012 study concluded that bats in Hamilton might be impacted by urban development, including noise, lighting and traffic (Le Roux & Le Roux 2012). While the research conducted here so far has not directly studied the impacts of urban development on bats, similar results show once more that bats appear to be mostly confined to the southern fringes of the city, where less urban development has impacted important habitats including the Waikato river and associated gully systems. However, development has now commenced in these spaces, including the construction start of the Hamilton Section of the Waikato Expressway. These and further projects of infrastructure and housing development are expected to have an impact on resident bats in these areas.

4.3 Implications of findings for bat management in the city

Given that long-tailed bat populations are likely under pressure due to predation (Pryde et al. 2005) and competition by introduced species for roost sites (O'Donnell 2000), further restriction of access to core habitats and disturbance/destruction of roosts through urban expansion is likely to exacerbate population declines. The 2012 survey results, results of this survey and findings of the bat habitat model have shown that the southern gully systems within Hamilton city are crucial areas for bat roosting, commuting and foraging habitat (Figure 5). At the same time, these gullies are currently (Mangaonua, Mangaone, East-West Link and Mangaharakeke gully) or in the near future (Mangakotukutuku gully) affected by major urban development, with several bridges being built across them and a major subdivision planned for the Mangakotukutuku gully area.

While the scale of the effect of these developments on bats is not known, it is almost certain that the cumulative effect of these developments on the main bat habitats will have an adverse effect on the long-tailed bat population present in Hamilton city. These impacts will be significantly exacerbated if no effective strategies are implemented to protect and enhance roosting and foraging habitats, as well as maintain commuting corridors.

From the community perspective, the long-tailed bat population within the city is considered to be a special ecological feature of Hamilton City. The prospect of losing this threatened species in Hamilton's urban ecosystems needs to be considered in current and future management of urban development. Five years on from the conclusions of the first survey, many questions remain regarding bats in the city, and more progress will need to be made towards the implementation of adaptive management strategies to ensure that bats can survive in Hamilton City while urban development continues to encroach on their remaining habitat.

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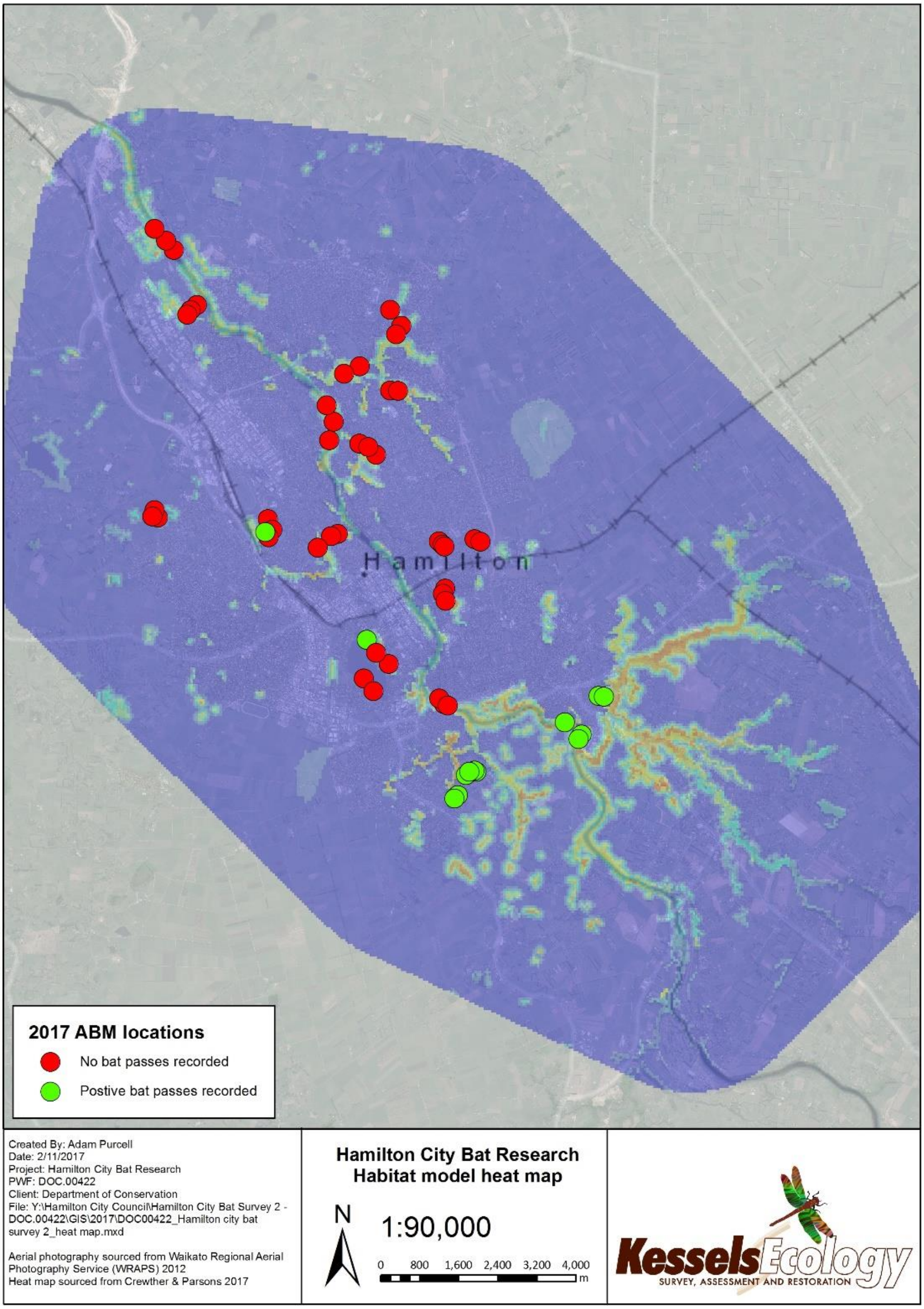

Figure 5. Heat map of Hamilton City bat habitat produced using the habitat model of Crewther & Parsons (2017).

5 Future Research

As this survey is part of an ongoing research project, the survey will be repeated in the 2017/2018 monitoring season. Ideally, this annual monitoring will be continued for a minimum of five years, if funding can be found beyond 2019.

The survey will be conducted in the same format as the monitoring described in this report. However, 5 additional sites (total of 23 sites including the sites monitoring for this survey) will be added to the survey as informed by the outcomes of the habitat model (Crewther & Parsons 2017). Sites will be chosen to monitor areas throughout the northern parts of Hamilton city that the model has identified to be of high suitability for bat presence.

The methodology shall be kept the same wherever possible to allow for the results to be comparable throughout the years of monitoring. Future research should aim to address the bias towards southern sample sites described here, by focusing on surveying and data collection from northern parts of the city.

It is envisaged that additional data from the annual surveys as well as any further data sources that may become available should be used as future inputs for repeated runs of the habitat model in order to refine the model and increase certainty of the understanding of bat habitat utilisation and bat presence distribution in Hamilton City.

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Appendix I

Summary of weather conditions during the survey period. Temperatures in °C, wind speed in km/h and precipitation in mm/24hrs. Data obtained from NIWA CliFlo database, station number 26117 and 2112 (23. and 24. May 2017)

Date	Max. temperature	Min. temperature	Precipation	Max. wind speed
16/02/2017	24.6	14.9	1	24.1
17/02/2017	19.4	15.3	39.8	27.8
18/02/2017	23.2	17.8	28.2	31.5
19/02/2017	24.6	19.3	14.2	33.4
20/02/2017	25.4	17.1	7.4	33.4
21/02/2017	25.2	15	0	20.4
22/02/2017	25.4	13.4	0	33.4
23/02/2017	25.7	12.2	0	20.4
24/02/2017	27.8	16.1	0	27.8
25/02/2017	26.7	13.3	0	31.5
26/02/2017	25.4	10.8	0	31.5
27/02/2017	25.1	12	0	33.4
28/02/2017	26	15.9	0.6	18.5
1/03/2017	24.8	17.7	0.4	29.7
2/03/2017	25.4	11.3	0	31.5
3/03/2017	23.5	7.5	0	31.5
4/03/2017	22.8	13	0	44.5
5/03/2017	23.7	12.4	0	35.2
6/03/2017	22.1	16.6	0	42.6
7/03/2017	23.2	12.4	0	27.8
8/03/2017	22.8	12.5	63.8	37.1
9/03/2017	17.3	12.8	10.4	35.2
10/03/2017	23.2	17.3	0	48.2
11/03/2017	24.7	19.2	77.4	33.4
12/03/2017	25.2	18.8	5.6	44.5
13/03/2017	24.6	18	11	42.6
14/03/2017	22.8	13	0	38.9
15/03/2017	21.8	10.2	0	27.8
16/03/2017	22.9	8.9	0	22.2
17/03/2017	24	10.2	0	22.2
18/03/2017	24.7	12.5	0	37.1
19/03/2017	23	11.7	0	31.5
20/03/2017	24.3	8.8	0	38.9
21/03/2017	21.5	12.9	0	38.9
22/03/2017	23.4	13.1	0	33.4
23/03/2017	23.3	17.8	0	33.4
24/03/2017	24	11.3	0	27.8
25/03/2017	22.8	14.1	0	16.7
26/03/2017	22.2	16.2	1.2	37.1
27/03/2017	23.8	17.2	21.6	29.7
28/03/2017	24.7	15.7	0.2	22.2

29/03/2017	25.5	17.3	37.2	31.5
30/03/2017	20.3	17.5	9	29.7
31/03/2017	23	12.4	0.4	18.5
1/04/2017	23.1	12.4	0	22.2
2/04/2017	24	13	0	14.8
3/04/2017	24.2	15.7	0.2	22.2
4/04/2017	24.4	18.4	17.8	33.4
5/04/2017	18.5	13.9	80.8	51.9
6/04/2017	22.5	14.2	9.8	53.7
7/04/2017	20.2	11.8	0.4	31.5
8/04/2017	21.4	8.7	0	20.4
9/04/2017	21.6	8.1	0	16.7
10/04/2017	20.6	10.4	0	24.1
11/04/2017	22.1	13.2	0	35.2
12/04/2017	24	17.6	0	31.5
13/04/2017	21.6	17.2	68	33.4
14/04/2017	18.3	14.2	24.6	40.8
15/04/2017	21.5	13.6	2	42.6
16/04/2017	19.3	12	8.2	31.5
17/04/2017	21.1	11.4	8.2	29.7
18/04/2017	19.1	7.6	6.4	22.2
19/04/2017	21.3	6.8	0	33.4
20/04/2017	19.5	8.8	0	24.1
21/04/2017	19.7	7	0	18.5
22/04/2017	18.6	7.9	0	16.7
23/04/2017	21.3	8.4	0	18.5
24/04/2017	19.8	12.5	0	25.9
25/04/2017	21.6	6.6	0	20.4
26/04/2017	21.7	5.6	0	24.1
27/04/2017	20.9	6.3	0	16.7
28/04/2017	21.2	7.7	0	22.2
29/04/2017	21.4	11.3	0.2	25.9
30/04/2017	17.7	16.3	24.2	50
1/05/2017	18.2	8.6	2.8	37.1
2/05/2017	15.7	1.5	0	20.4
3/05/2017	16.6	4.4	0	33.4
4/05/2017	17.8	9.2	4.6	50
5/05/2017	16.5	10.7	0.2	31.5
6/05/2017	17.9	2.7	0	18.5
7/05/2017	19	5.4	0	13
8/05/2017	16.7	8.9	0	18.5
9/05/2017	18.3	6.2	0	9.3
10/05/2017	19.8	9.9	0	29.7
11/05/2017	20.3	12	0	31.5
12/05/2017	17.8	13	33.8	44.5
13/05/2017	14.1	8	27	33.4
14/05/2017	15.4	0.9	0	25.9
15/05/2017	15.9	3.8	0	16.7

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16/05/2017	17.6	4.3	0	18.5
17/05/2017	16.2	7.9	4.4	44.5
18/05/2017	17.9	14.2	18.2	63
23/05/2017	14.5	-2.7	0	11.1
24/05/2017	11.3	2.5	0.8	24.1
25/05/2017	17.9	4.6	2.4	11.1
26/05/2017	11.2	5.1	0	29.7
27/05/2017	18.4	6.7	13.6	13
28/05/2017	19.3	11	0.4	16.7
29/05/2017	18.2	8.8	0	20.4
30/05/2017	19.9	7.4	0	18.5
31/05/2017	18.2	8.4	0.2	16.7
1/06/2017	18.8	4.4	0	11.1
2/06/2017	18.1	6.5	9.8	27.8
3/06/2017	17.8	8.4	0	31.5
4/06/2017	17.9	2.4	0	18.5
5/06/2017	15.9	5.2	0.6	13
6/06/2017	12.9	2.3	4.6	11.1
7/06/2017	15	0.1	0	29.7
8/06/2017	15.9	0.7	0	24.1
9/06/2017	14.8	-1.4	0	16.7
10/06/2017	15.2	3.6	0	40.8
11/06/2017	16.3	1.3	0.2	22.2

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Appendix II

Table 1 Summary of 2017 bat survey findings.

Site name	Habitat	R/U	Area	Time	Bats	Use	# ABM	Active ABM	Mean Passes/ABM/night
Southwell School	I	U		Feb-Mar	N	N/A	2	0	N/A
Lake Rotoroa	P	U	92.0	Feb-Mar	Y	C	5	1	0.02
Forest Lake	P	U	40.0	Mar	Y	C	4	1	0.1
Horsham Downs Golf Course	R	R	25.0	Mar	N	N/A	3	0	N/A
Claudelands Park	I	U	5.1	Mar	N	N/A	3	0	N/A
Mangaiti Gully	G	U	10.0	Mar-Apr	N	N/A	3	0	N/A
Humare Park	G	U	0.6	Apr-May	Y	PPR	2	2	3.4
Te Anau Park	G	U	5.8	Apr-May	Y	PPR	3	2	9.0
Hammond Bush	R	U	11.0	May	Y	LRR	4	3	21.6
Edgecumbe Park	G	U	3.8	May	N	N/A	5	0	N/A
Fitzroy Park	G	U	5.4	May-June	Y	PPR	4	4	3.1

Indices

Habitat type: G = Gully; P = Parkland; R = Riparian; I = Indigenous

R/U: R = Rural; U = Urban

Potential habitat use: C = Commuting; PPR = Possible periodic roosting; LRR = Likely regular roosting

Area: Indicated in hectare

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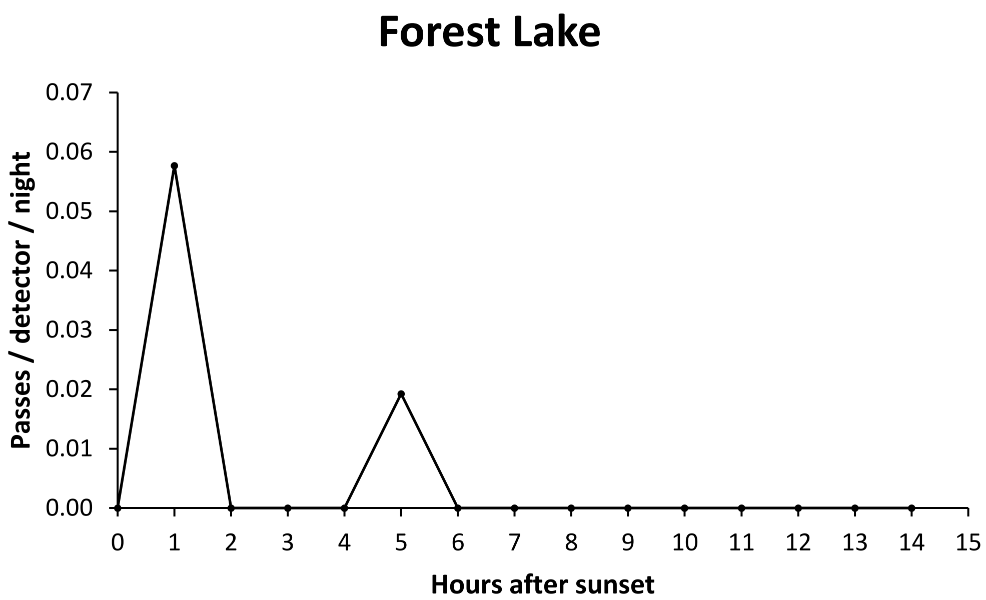
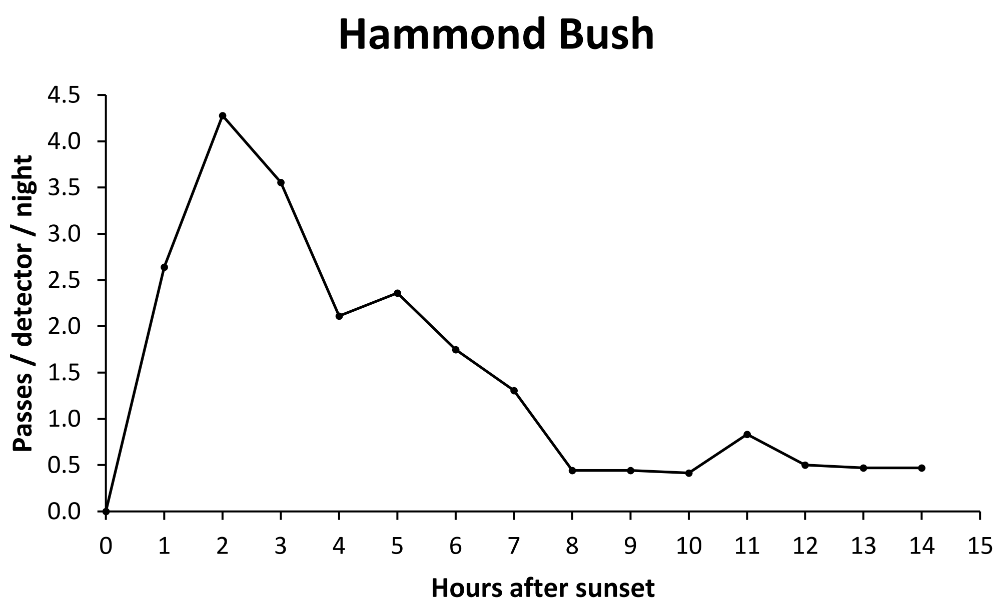
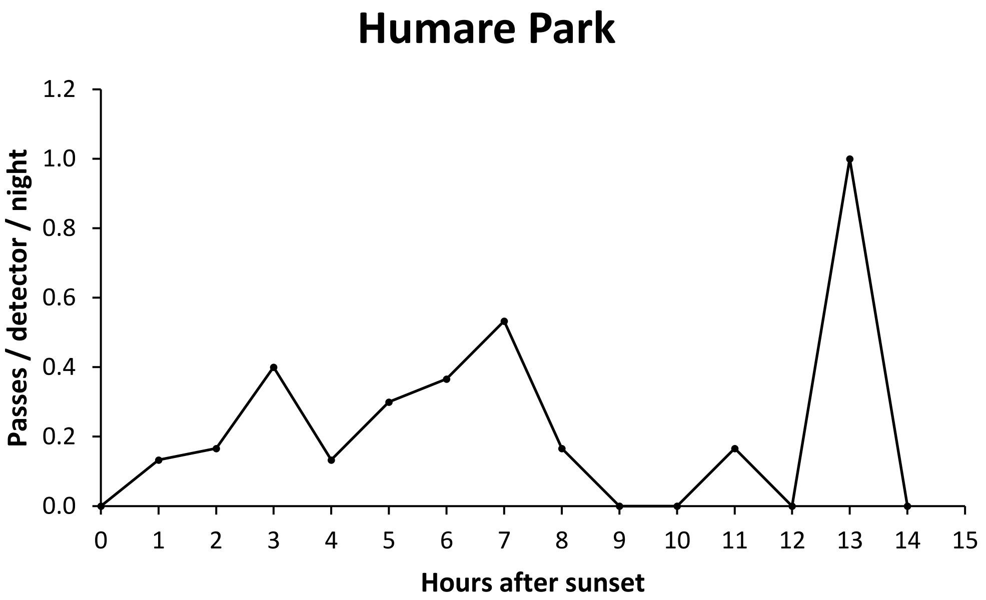
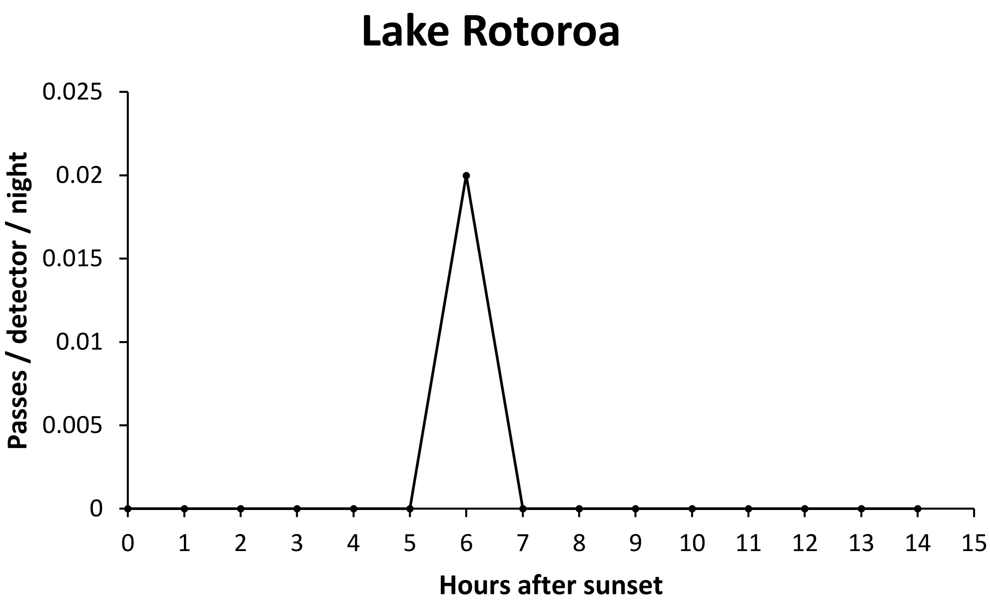
Appendix III

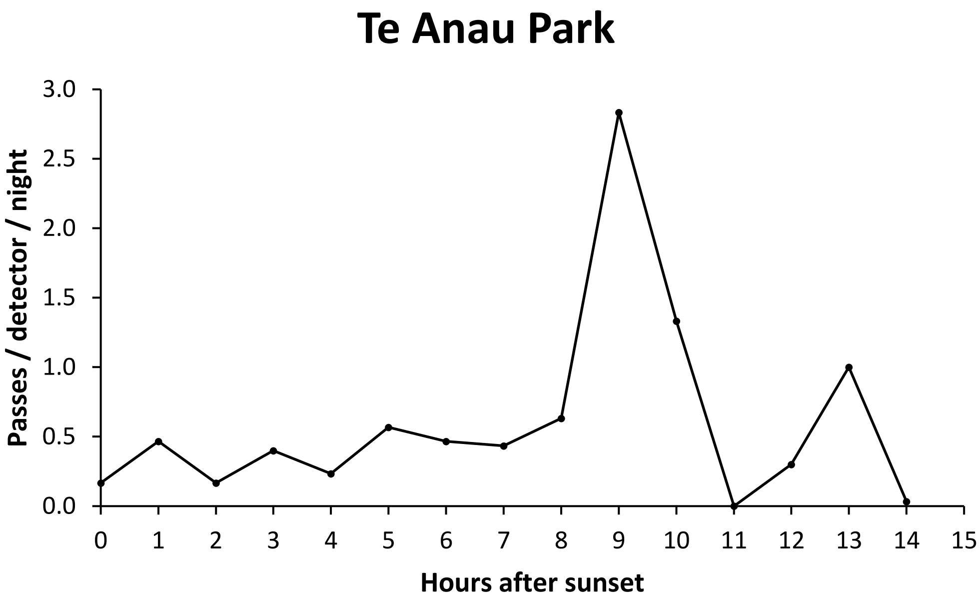
Site-specific bat passes per detector and night for each hour after sunset

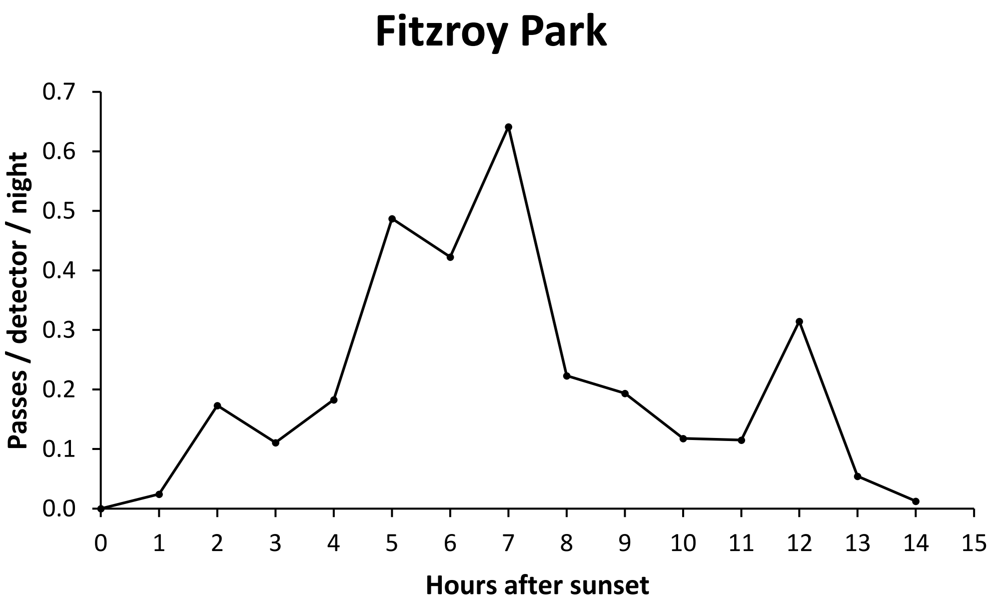





Humare Park
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Passes / detector / night
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Hours after sunset


Lake Rotoroa
0.025
0.02
0.015
0.01
0.005
0
Passes / detector / night
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Hours after sunset


Te Anau Park
Passes / detector / night
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Hours after sunset


Fitzroy Park
Passes / detector / night
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Hours after sunset