REPORT

Tonkin+Taylor

Hamilton City Long-tailed Bat Survey

2017 - 2018

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Executive summary

Hamilton City is one of two cities in New Zealand which supports a resident population of long-tailed bats (*Chalinolobus tuberculatus*). Long-tailed bats are a threatened species listed as Nationally Critical (the highest conservation threat category) and therefore are an important aspect of Hamilton's urban ecosystems.

In 2016, Kessels Ecology[1] was contracted by Project Echo, a multi-agency advocacy group for Hamilton City bats, to undertake a long-term bat research project. The purpose of the project is to identify, map and track changes in bat habitat use by undertaking bioacoustics surveys over a minimum of five years (2017 – 2021).

This report outlines the findings of the 2017/18 bat monitoring survey in Hamilton City. Specific objectives of the survey are to:

- Detail the bat monitoring programme and survey methodology used;
- Present the survey results including bat activity levels and habitat use;
- Compare the 2017/18 results with previous years of monitoring (2011/12 and 2016/17);
- Outline potential implications of the survey findings for the local bat population; and
- Identify knowledge gaps and potential opportunities for future research.

This report follows reports prepared for the initial 2011/12 bat monitoring survey (Le Roux and Le Roux, 2012), a bat habitat modelling report showing the likelihood of habitat usage throughout the city (Crewther and Parsons, 2017), and the 2016/2017 survey results (Mueller *et al.,* 2017) that were used to inform the choice of study sites in this report.

23 locations were surveyed for bats using acoustic bat monitors (ABMs) during a four month period. As this is a community-based project with limited funding, volunteers were trained to deploy and retrieve acoustic bat monitors during several training workshops. The data were then collated and analysed by qualified bat ecologists.

The results of the 2017/2018 survey have shown that the southern gully systems and riparian margins within Hamilton City offer suitable habitat areas for bat roosting, commuting and foraging. Bat activity was sporadically detected at survey locations in the northern, western, and eastern survey sites of the city, indicating commuting and/or or foraging behaviour of bats in these areas. While the surveys conducted to date have not directly studied the impacts of urban development on bats, the results show that bat activity appears to be mostly confined to the southern fringes of the city, where there is less urban development. However, development has now commenced in these areas, including the construction of the Hamilton Section of the Waikato Expressway, and the planned development of subdivisions and roads in close vicinity to the Mangakotukutuku gully system and Waikato River margins.

While the scale of the effect of these developments on bats is unknown, the cumulative effect of these developments on the main bat habitats will likely have an adverse effect on the long-tailed bat population present in Hamilton City. Effective strategies are required to protect and enhance known roosting, commuting corridors and foraging areas.

1 Introduction

1.1 Background

Hamilton City is one of two cities in New Zealand (along with Auckland) with a known population of long-tailed bats (*Chalinolobus tuberculatus*). Long-tailed bats are classified as Threatened – Nationally Critical (O'Donnell *et al*., 2018) and as such, increased knowledge on the Hamilton bat population is an important aspect of Hamilton's urban ecosystems as well as in a national context.

In 2016, Kessels Ecology[1] was contracted by Project Echo, a multi-agency advocacy group for Hamilton City bats, to undertake a long-term bat research project. The purpose of this project was to identify, map and track changes in bat habitat use through bio-acoustic surveys.

This multi-year project[2] has received funding from Department of Conservation (DOC), Waikato Regional Council (WRC) and Hamilton City Council (HCC). Annual monitoring started in 2016 and will continue until at least 2019, and potentially until 2021 if funding is extended.

The aim of the research project is to map bat habitat, based on data collected from bat activity monitoring undertaken throughout the city and establish a programme to monitor changes in habitat use over time. The project objectives are to:

- Map the spatial configuration and habitat use of bats throughout Hamilton City based on the MaxEnt habitat prediction model[3] and additional acoustic monitoring data;
- Implement an acoustic monitoring programme to assess changes in bat activity and to identify habitat usage across the city;
- Identify key conservation bat habitat areas i.e. bat 'hot spots' requiring concerted conservation efforts; and
- Provide information on habitat utilisation, to help inform a city-wide bat management plan for establishing an effective bat conservation programme, which will involve community education and engagement

The project builds on the findings of an earlier city-wide bat survey conducted in 2011/12, which illustrated the importance of maintaining, restoring and perpetuating well connected, less developed habitats for long-tailed bats in Hamilton City (Le Roux and Le Roux, 2012). Since the survey in 2011/2012, a large amount of infrastructure development has occurred, is currently under construction or is proposed in areas where valuable habitats for bats are present, including the Waikato Expressway that crosses the Mangaonua, Mangaone, and Mangaharakeke gully systems. Ongoing research is therefore important to further understand spatial distribution of bats and habitat use over the coming years.

1.2 Objectives

This report details the findings of the 2017/18 acoustic bat monitoring survey in Hamilton City. The purpose of the survey was to monitor bat activity levels across the city, targeting key known and potential habitat areas.

[1] Kessels Ecology was purchased by Tonkin + Taylor Limited in May 2018
[2] Funding has been approved for three years, but ideally the project would continue for another 2 – 7 years after that.
[3] MaxEnt habitat prediction modelling combines species presence data with environmental variables to predict species distribution based on the relationship between where the species occurs and the environments in which it is found.

This report covers the following aspects:

- Details of the monitoring programme and survey methodology;
- Bat survey results including activity levels and likely habitat use;
- A comparison of the 2017/18 results with previous years (2001/12 and 2016/17) of monitoring;
- Implications of survey findings for the local bat population; and
- Knowledge gaps and plans for future research.

The findings of this report can help inform our understanding of bat habitat use, activity levels and types (i.e. feeding, foraging or roosting), along with detecting possible changes in habitat use throughout the monitoring period of the wider research project.

This report sits alongside reports prepared for the initial 2011/12 bat monitoring programme (Le Roux and Le Roux 2012), the bat habitat modelling report showing the likelihood of habitat usage throughout the city (Crewther and Parsons, 2017), and the 2016/17 monitoring results that were used to inform the choice of study sites in this report (Mueller *et al.,* 2017).

1.3 Site description

Hamilton City is New Zealand's fourth most densely populated city in New Zealand with approximately 160,000 people and a total area of 11,080 ha. A major landscape feature of the city is the Waikato River, NZ's longest river that bisects the city area for a length of 16 km.

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 the 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.

A total of 1,000 ha of open space is present in Hamilton City, spread over 145 parks. Some of these parks were identified in the habitat prediction model (Crewther and Parsons, 2017) as potential habitat for long-tailed bats, of which some were surveyed as part this project (Figure 2.1, Appendix A and Appendix H).

Four different habitat types were surveyed for bat activity:

- Gully habitat;
- Urban parklands;
- Riparian margins; and
- Native forest remnants.

A clear distinction of these types can be difficult and some survey sites depict a mixture of habitat types.

Gully habitat

The major gully systems in Hamilton include areas of native vegetation amongst large areas of exotic vegetation (Photograph Appendix A.1). The common factor in gully systems is the connectivity of vegetation over a large area set amongst developed urban environments. Gully systems in the northern parts of the city are often filled in and developed and remain as small remnant sections of a once large connected network of gullies. Gully systems in the southern parts of the city are less developed and extensive areas of connected vegetation remain. They present well vegetated indigenous and/or exotic corridor systems connecting habitats such as forest fragments outside the city with riparian margins within it.

Urban parklands

Urban parkland habitats are 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). They often include large exotic trees standing in pasture (Photograph Appendix A.2). Some parks back up to gully areas, and have areas of indigenous vegetation. Urban parks often have lighting and are in close vicinity to residential areas.

Riparian margins

Riparian margins can be found along water courses such as the Waikato River, which forms an important corridor for bats through the city connecting the north to the south (Photograph Appendix A.3). Riparian margins can also be found along lakes, such as Horseshoe Lake. Vegetation of the surveyed sites included large areas of exotic vegetation immediately flanking (0-50 m) the banks of the Waikato River, but also large areas of restored native vegetation, such as in Hammond Park.

Native forest remnants

The last vegetation type surveyed was native forest remnants. Few such remnants remain in Hamilton City. Vegetation comprises primarily native vegetation which is old and likely to provide habitat for bats (Photograph Appendix A.4). Both urban and rural forest fragments are <12 ha in size and dominated by mature indigenous emergent vegetation (e.g. kahikatea (*Dacrycarpus dacrydioides*) and totara (*Podocarpus totara*)).

2 Methodology

2.1 Acoustic survey methodology

To record the presence or absence and activity patterns of bats Hamilton City, omnidirectional Frequency Compression (FC) automatic bat monitors (ABMs; manufactured by Department of Conservation, Wellington) were used. The ABMs were deployed in suitable sites at the previously identified locations, targeting likely bat habitat. The recordings were analysed visually using BatSearch3.11 software (developed by DOC, 2016) in accordance with protocols described by Lloyd (2017).

2.2 Survey locations

A total of 69 ABMs were deployed in 23 locations (Figure 2.1 and Appendix A). The survey locations were chosen based on results from previous monitoring surveys as part of this project. Five additional survey locations were included compared to the 2016/17 survey (Mueller *et al.,* 2017). These were chosen in areas that were predicted to offer favourable bat habitat conditions based on the habitat model included in the 2017 monitoring, but where limited survey data was available and anecdotal evidence suggested low likelihood of bat presence.

As set out in the research proposal (Kessels Ecology, 2016), monitoring locations were chosen to achieve a fair representation of gullies and greenspaces throughout the city. The entire survey covered an area of approximately 325 ha of the available 'green spaces' in and around Hamilton City (Figure 2.1).

All ABMs were pre-set to start monitoring one hour before sunset and stopped recording at one hour after sunrise. Wherever possible, the ABMs 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.

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, indications of habitat usage were classified into the following categories (adapted from Le Roux and Le Roux, 2012 and Mueller *et al.,* 2016):

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

Bats are known to roost in Hammond Park (Dekrout *et al.,* 2014 and pers. comm. H. Mueller, 2018). Confirming an active roost is in the immediate vicinity at a particular point in time using acoustic data is difficult, as bats can travel at high speeds up to 60 km/hr (Meduna, 2007), and Hamilton bats maintain large home ranges extending out into the rural landscape.

However most of their activity in the south Hamilton landscape has been shown to be concentrated within small core areas, with high roost fidelity (Dekrout, 2009). Therefore we maintain the use of the activity categories used by Le Roux and Le Roux (2012), while acknowledging that such categories are likely to be indicative only, and should not be relied upon as evidence of roosting in the immediate vicinity.

At any one time, 12 ABMs were available for deployment, thus not all survey sites could be monitored concurrently. They were surveyed successively over a period of 19 weeks from 7 January to 17 May 2018. The order in which sites were monitored was random and at each location three ABMs were deployed. Survey duration of each site ranged from seven to 24 consecutive nights. This amounted to a total of approximately 1,000 hours of monitoring over 130 survey nights.

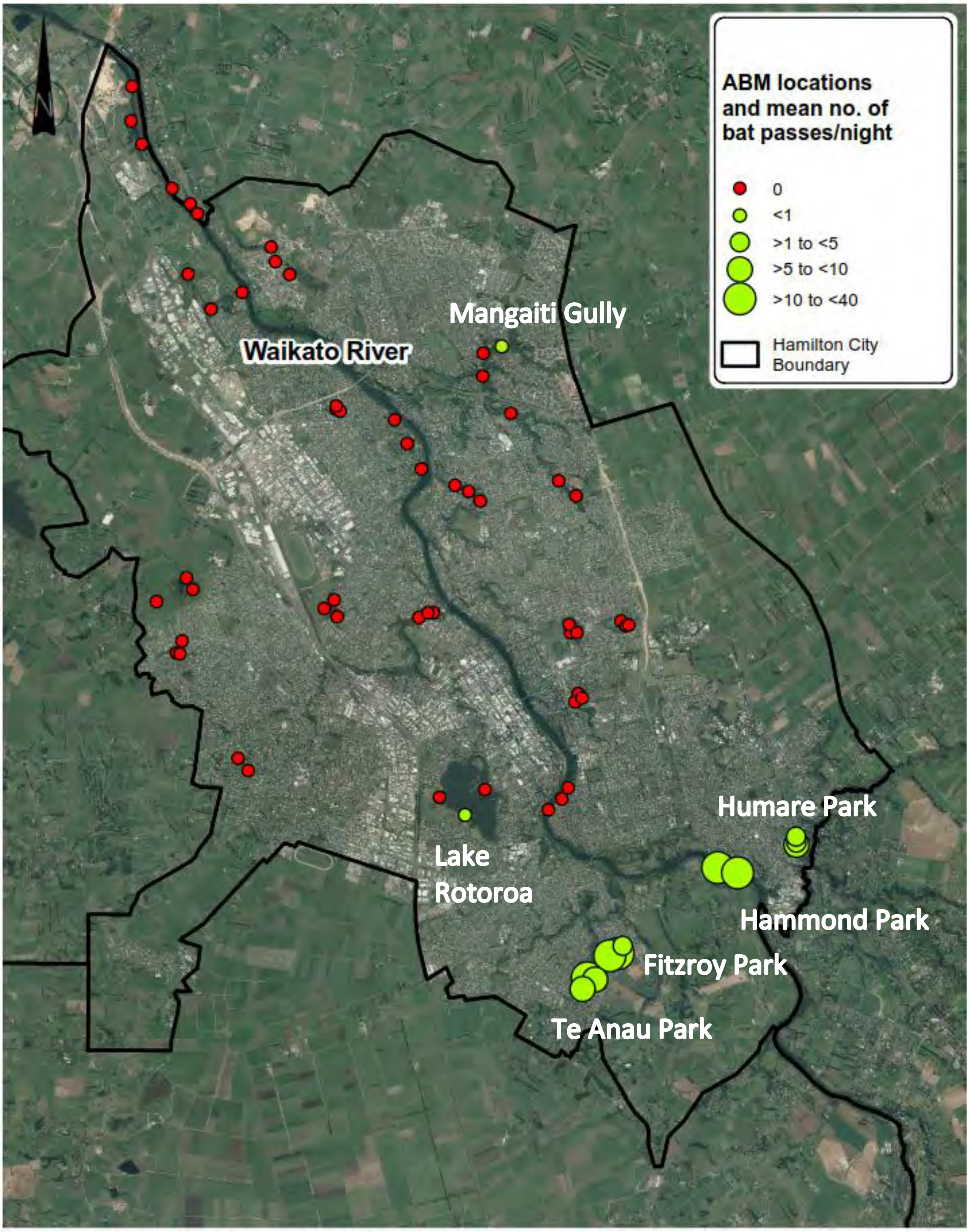
Long-tailed bats consistently emerge from roosts where temperatures at dusk are >8°C, ideally >10°C (O'Donnell, 2000). Weather conditions at dusk during the majority of the survey period were optimal for bat emergence, as temperatures remained above 10°C at dusk on all nights of the survey period. Similarly, for all but one night (1 February) of the complete survey period rainfall was absent or minimal below 5 mm at dusk. Likewise, wind speeds were low to moderate at dusk on all but four nights of the complete survey period (10, 11, 28 April and 7 May). A summary of weather conditions is shown in Appendix B which presents data obtained from NIWA CliFlo database, station number 26117.

While ABMs were deployed notes were taken on sources of noise and light nearby that could have an impact on bat activity at that locality. Distances were estimated and verified using Google Maps, whereas intensity levels were ranked from Level 1 to 3:

Level 1: being very low noise/light disturbance. This disturbance would not likely affecting bats in the area;

Level 2: Normal noise/light, (i.e. houses nearby, but sheltered by surrounding vegetation, roads in the distance); and

Level 3: Loud noise/high light sources nearby. (i.e. street lights, roads directly next to the survey locality).



Aerial photograph sourced from Waikato Regional Council - CC by 4.0 NZ

Figure 2.1: Locations of ABMs deployed between 7 January and 17 May 2018. 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

A total of 2,935 echolocation passes were recorded from six locations comprising 14 of the overall 69 ABMs deployed (Figure 2.1). Of the six locations with bat activity, Fitzroy Park, Hammond Park and Te Anau Park were characterised by the highest overall mean bat activity with on average, more than 10 bat passes/detector/night (15.25 ± 3.33 SD) (Figure 3.1), indicating that these locations may be regularly used roosting habitats. Humare Park was identified as possible periodic roosting habitat with bat activity greater than 1.0 mean bat passes/detector/night (3.95 ± 2.35 SD) (Figure 3.1). In contrast, Lake Rotoroa and Mangaiti Gully were identified as commuting habitats with low nightly activity below 0.1 mean bat passes/detector/night (0.02 ± 0.01 SD) (Figure 3.1). Habitats categorised as both possible periodic roosting and likely regular roosting, however, did not feature strong bimodal nightly bat activities (Appendix E).

Of the 23 locations surveyed, six (26%) recorded long-tailed bat activity and no data was obtained from six ABMs due to mechanical failure and loss of equipment (a general overview of bat activity detected is presented in Appendix C Table 3.1, and in more detail in Appendix C, Appendix D, and Appendix E).

Bat activity recorded at each survey location throughout the night is shown in graphs presented in Appendix E. No obvious bimodal patterns (peaks of activity at dusk and dawn) were recorded at most of the sites, indicating that ABMs were not placed in close proximity of bat roosts. However, activity recorded at Hammond Park and Te Anau Park did show peaks of activity in the first couple of hours after sunset which may mean that bats are likely roosting close to the surveyed sites (Appendix E). Bimodal activity showing peaks of activity (≥ 10 passes/ABM/night) in the first two hours after sunset and just before sunrise may indicate bats roosting nearby (Le Roux and Le Roux, 2012).

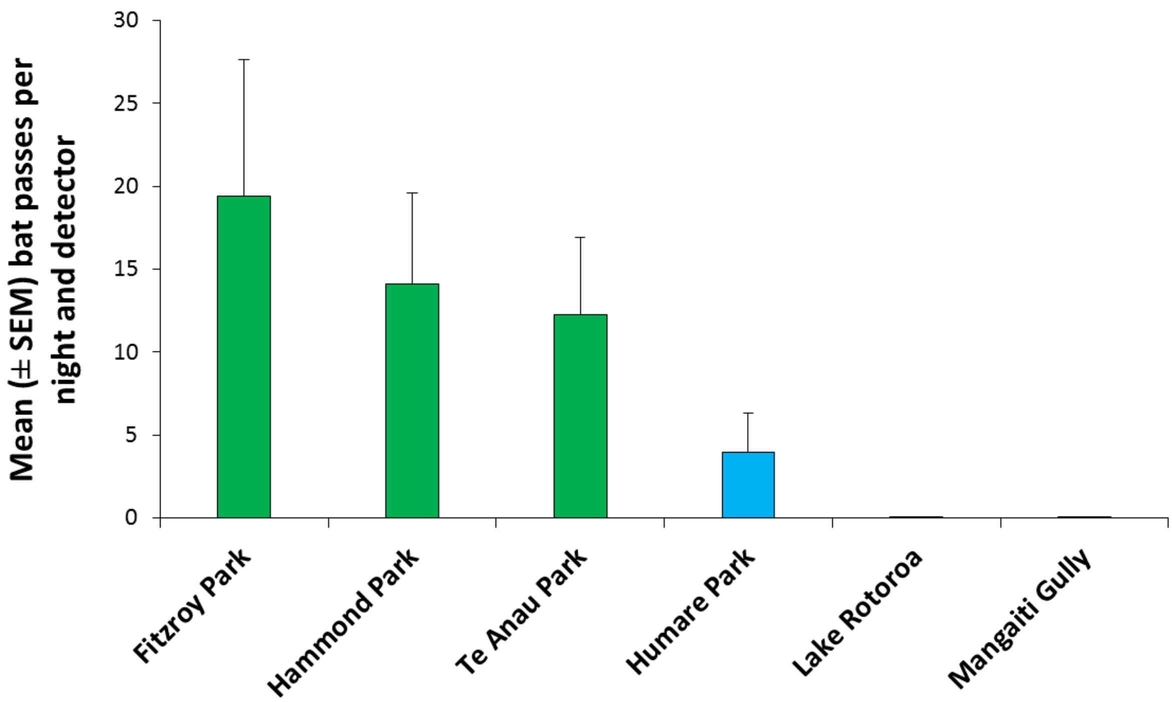


Figure 3.1: Mean (± SEM) nightly number of bat passes per detector for each area where bat activity was recorded. Colour coding indicates type of bat activity, Green: Likely regular roosting; Blue: Possible periodic roosting; No coloration: Commuting (Lake Rotoroa and Mangaiti Gully).

3.2 Habitat use

As described in Section 2.2 above, habitat usage was defined into the following categories (adapted from Le Roux and Le Roux, 2012 and Mueller *et al.,* 2016):

- Commuting;
- Foraging and possibly periodic roosting; and
- Foraging and potentially regular roosting.

Table 3.1 summarises the mean bat activity recorded across the four different habitat types surveyed within Hamilton City: gully habitats, riparian margin, urban parkland and native forest remnants compared to the survey effort across the city (Table 3.1).

Gully habitat

Major gully systems were surveyed over nine different site locations totalling an average of 8.9 bat passes per ABM per night (Figure 2.1, Table 3.1, Appendix C, Appendix D, and Appendix E). Of the nine gully habitats surveyed, bat activity was detected at three sites (Fitzroy Park, Te Anau Park, and Humare Park), of which Fitzroy Park and Te Anau Park may provide regular roosting habitat. Humare Park is also potentially used for periodic roosting (Figure 2.1 and Figure 3.1, Appendix C, Appendix D, and Appendix E).

Urban parklands

In urban parklands bat activity was detected at one location (Lake Rotoroa) with an average of 0.02 bat passes per ABM per night indicating that this locality is used as commuting habitat.

Riparian margins

Most bat activity was recorded in riparian margins (14.1 mean passes/detector/night), (Figure 2.1, Table 3.1). Of the six surveyed sites in riparian margins only one site (Hammond Park) detected bats. High levels of bat activity in Hammond Park and the bimodal pattern in bat activity measured through the night indicates bats may potentially roost in this locality regularly (Figure 3.1, Appendix C, Appendix D, and Appendix E).

Native forest remnants

No activity was recorded in native forest remnants, however, this habitat type is generally under-represented within Hamilton and therefore was not strongly represented in the survey sites (13% of sites).

Table 3.1: Summary of the survey effort allocated to the four major habitat types with their corresponding mean bat passes per detector and night.

Habitat Type	# sites surveyed (% total)	Area (ha) surveyed (% total)*	# detectors allocated (% total)	# ABMs with bat activity (% total)	# sites that recorded bat activity (Location)	Mean (±SEM) passes/ABM/ night
Gully habitat	9 (39%)	173 (53%)	27 (39%)	4 (67%)	3 (Fitzroy Park, Humare Park, and Te Anau Park)	8.9 ± 3.1
Riparian margins	6 (26%)	121 (37%)	18 (26%)	1 (17%)	1 (Hammond Park)	14.1 ± 5.5
Urban parklands	5 (22%)	26 (8%)	15 (22%)	1 (17%)	1 (Lake Rotoroa)	0.02 ± 0.02
Native forest remnants	3 (13%)	7 (2%)	9 (13%)	0 (0%)	0	N/A
Total	**23**	**327**	**69**	**6**		

*Area (ha) were calculated using spatial data. Areas are approximate and may include wider areas to include connected habitat.

4 Discussion

4.1 Summary of survey findings

This survey has detected bat activity at six of 23 locations monitored across Hamilton City. Bat activity was detected at Fitzroy Park, Hammond Park, Te Anau Park, Humare Park, Lake Rotoroa and Mangaiti Gully.

Long-tailed bat activity was confined to a relatively small number of sites with a distribution pattern restricted to the southern most urban-rural fringe (Fitzroy Park, Hammond Park, Te Anau Park, and Humare Park) with occasional bat passes detected further north (Lake Rotoroa and Mangaiti Gully) (Figure 2.1).

The Waikato River was shown to be a major landscape feature connecting habitats. Long-tailed bats are known to use the river system as a corridor to move between different habitats up and downstream (Dekrout, 2009).

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

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

Survey effort focused on areas where bat presence was more likely to be found, following the outcomes of the habitat distribution model (Crewther and Parsons, 2017). Although the majority of bat activity was found in the southern fringes of the city, a couple of bat passes were also detected at new locations further north and east (Lake Rotoroa and Mangaiti Gully), but these were infrequent and habitat use seems to be restricted to commuting or perhaps foraging.

4.2 Comparison to previous surveys

This survey builds on information gained regarding bat presence and activity during previous surveys conducted in 2011/2012 (Le Roux and Le Roux, 2012)[4] and 2016/17 (Mueller *et al.,* 2017). This survey complemented the findings of these two surveys by monitoring at additional sites and surveying each location for a longer period of time.

In 2017, the first round of surveys of the Project Echo city wide bat survey project were conducted. The results of the survey confirmed findings of the 2011/2012 study (Le Roux and Le Roux, 2012) (Appendix E) that the southern gully systems and riparian margins within Hamilton are important areas for bat roosting, commuting and foraging habitat (Mueller *et al.,* 2017) The highest number of bat passes detected were in the southern areas of Hamilton City, sporadic commuting bat passes were detected further north in the city (e.g. single bat passes were detected at Horseshoe Lake and Lake Rotoroa). None of the other survey locations further north and east detected bat activity.

The acoustic surveys as well as the habitat distribution model results (Appendix H) confirmed that bats primarily use the southern gully systems and riparian margins of the city, but that potential bat habitat (in particular gullies and riparian margins) is present throughout the city (as shown in the habitat distribution map, Appendix H), which is confirmed by the occasional detection of bat activity in those sites. The 2017/18 survey confirmed the findings in the 2011/12 and 2016/17 surveys, as well as detection of a new location (Mangaiti gully) with bat activity (Figure 2.1).

A simple comparison of the results of bat monitoring between years shows that Hammond Park has consistently high levels of bat activity across the three survey periods (Table 4.1). Bat activity was recorded in Hammond Park, Humare Park, Te Anau Park and Fitzroy Park in all survey years. Both Te Anau Park and Fitzroy Park show an increase in bat activity with each survey season.

In 2011/12, directional Heterodyne ABMs were used, whereas in 2016/17 and 2017/18 omni-directional FC ABMs were used which are known to be more sensitive in detecting bat activity. The increase in recorded bat activity between 2011/12 survey and 2016/17 and 2017/18 surveys may have been influenced by this change in ABMs.

Bat activity was recorded for the first time in Mangaiti gully in the 2017/18 survey. No bat activity was recorded at Lake Rotoroa in 2017/18, despite activity occurring in the previous two surveys.

[4] The distribution map can be found online: Habitat Bat Distribution 2018.
(https://www.google.com/maps/d/u/0/edit?mid=1bRmnRnrF2asOSEWimxqc0iALHwgandll=-37.810502350670724%2C175.2555173276022andz=12)

Table 4.1: Comparison of survey results between 2012, 2017 and 2018. Note that in 2012 directional Heterodyne ABMs were used, whereas in 2017 and 2018 omni-directional FC ABMs were used which are known to be more sensitive in detecting bat activity.

Site name	Time	Bat activity	# of ABMs	# of ABMs with bat activity	Mean bat passes / ABM /night
Forest Lake 2012	January	N	6	0	N/A
Forest Lake 2017	March	Y	4	1	0.1
Forest Lake 2018	April	N	3	0	N/A
Hammond Bush 2011	September	Y	9	6	29.1
Hammond Bush 2017	May	Y	4	3	21.6
Hammond Bush 2018	March	Y	3	3	14.1
Humare Park 2011	September	Y	1	1	0.6
Humare Park 2017	April	Y	2	2	17.5
Humare Park 2018	February - March	Y	3	3	4.0
Te Anau Park 2011	October	Y	9	2	0.1
Te Anau Park 2017	April	Y	3	2	9.0
Te Anau Park 2018	April - March	Y	3	3	12.2
Fitzroy Park 2011	October	Y	5	1	0.1
Fitzroy Park 2017	May	Y	4	4	3.1
Fitzroy Park 2018	March - April	Y	3	3	19.4
Lake Rotoroa 2011/2012	October	N	10	0	N/A
Lake Rotorua 2017	February	Y	5	1	0.02
Lake Rotorua 2018	January	Y	3	1	0.02
Mangaiti Gully 2011	December	N	8	0	N/A
Mangaiti Gully 2017	March - April	N	3	0	N/A
Mangaiti Gully 2018	March - April	Y	3	1	0.02

4.3 Implications of findings for bat management in the city

The 2011/12 study concluded that bats in Hamilton might be impacted by urban development, including noise, lighting and traffic (Le Roux and Le Roux, 2012). While the monitoring conducted here so far has not directly studied the impacts of urban development on bats, we have found further evidence of bat activity focused in the southern fringes of the city, where there is less urban development.

However, significant development has now commenced in these spaces, including the construction of the Hamilton Section of the Waikato Expressway and the planned development of subdivisions and roads in close vicinity to the Mangakotukutuku gully system and Waikato River margins.

Infrastructure and housing development are expected to have an effect on resident bats in these areas through vegetation clearance reducing connectivity between different habitat areas, altering commuting corridors and removing roosting and foraging habitat. However, the effects on bats are currently poorly understood. While the scale of the effect of these developments on bats is not known, the cumulative effect of urban developments on key areas of bat habitat will likely have an adverse effect on the long-tailed bat population present in Hamilton City. These impacts may be exacerbated if strategies to protect and enhance roosting and foraging habitats, as well as maintaining and creating commuting corridors are not put in place.

Predators such as possums, stoats, cats, but particularly rats also pose a significant risk to the survival of bats. Given that long-tailed bat populations are also under pressure due to predation (O'Donnell, 2018a; 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 2011/12, 2016/17 and 2017/18 survey results, as well as outputs from the habitat prediction model (Crewther and Parsons, 2017), have shown that the southern gully systems and riparian margins within Hamilton City are important areas for bat roosting, commuting and foraging activity (Appendix C, Appendix D, and Appendix E).

5 Future research

From a community perspective, the long-tailed bat population within the city is considered to be a special ecological feature of Hamilton City. Many questions remain regarding the prospect of bats persisting in the city, and more progress is required towards the implementation of adaptive management strategies (for example creating vegetation corridors or retaining potential roost trees in new infrastructure developments) to ensure that bats can survive in while urban development continues.

In order to better understand the effects of development and construction activities on the Hamilton bat population, it is important to identify key aspects of what enables bats to persist in the landscape. The impact of habitat fragmentation, pressure from pest animals, the role of lighting and noise in Hamilton City and its surroundings need to be properly understood. Additionally, more information on social structures within and between Hamiltonian bat populations is needed to inform future management of bats in Hamilton and its wider landscape.

Due to the cryptic nature of bats and the limited amount of research done in this area, it is challenging to quantify the effects of all these impacts. This purpose of this ongoing research project is to contribute to an aspect of this understanding by monitoring activity levels and habitat use throughout the city over the long term.

The survey presented in this report will be repeated in the 2018/19 monitoring season. Ideally, this annual monitoring should be continued for a minimum of five years, subject to funding.

The methodology should be kept the same wherever possible to allow for the results to be comparable throughout the years of monitoring. The survey should be conducted in the same format as the monitoring described in this report. If long-term funding can be secured, these repeat surveys will provide valuable information on bat distribution and effects associated with ongoing urban development on activity levels and distribution.

In areas of bat habitat where numbers of bats are likely to be low, data gathered using acoustic monitoring has high levels of uncertainty when inferring likelihood of the presence of roosts. In Hamilton, the relationship between bat activity levels and roosting in the immediate vicinity is difficult to establish. Therefore, more research (such as radio tracking and observational monitoring of potential roost sites) will be needed to establish detailed knowledge of critical roosting areas across the city.

Additional data from the annual surveys as well as any further data sources that may become available will be used as future inputs for refinement of the habitat model.

Besides the bat surveys undertaken as part of this project, bats are (or will be) studied intensively as part of other projects, particularly in relation to the Peacocke Structure Plan change and associated infrastructure development. Radio-tracking studies in particular, and ideally the identification of population social structures through genetic research, will help better understand population dynamics in the city. This further research can also be used to better quantify the effects of ongoing development on Hamilton's bat population.

The findings of this annual monitoring programme can be used to inform future research aiming to quantify aspects such as the impacts on development on habitat use. Data collected here may therefore contribute to the understanding of bats within the city, as well as the potential cumulative effects of development on the future of the urban bat population.

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7 Applicability

This report has been prepared for the exclusive use of our client Project Echo, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

Report prepared by:

....

Wiea van der Zwan

Terrestrial Ecologist

Authorised for Tonkin & Taylor Ltd by:

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Peter Cochrane

Project Director

WVDZ
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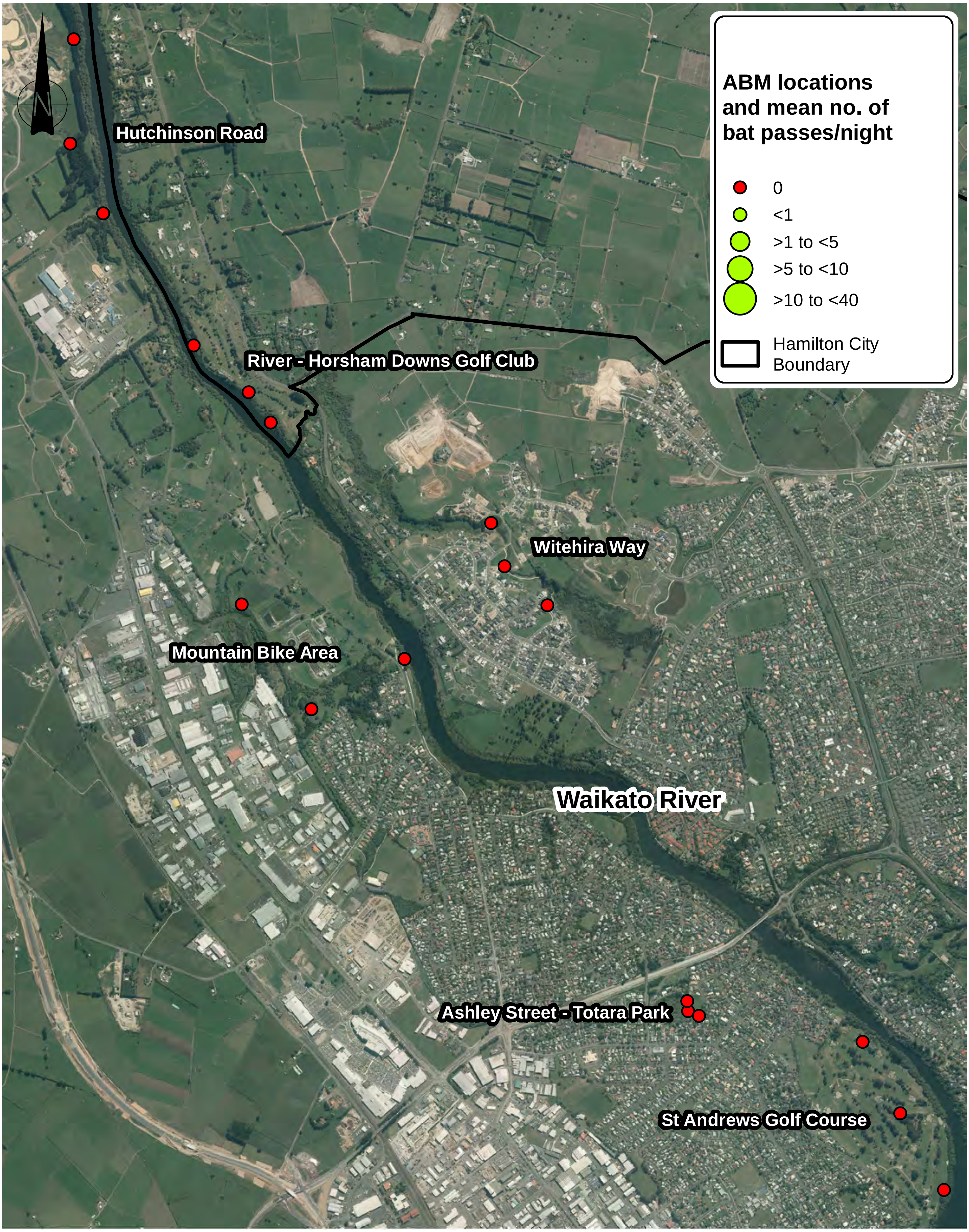
Appendix A: Report photographs and figures

Photograph Appendix A.1: Gully habitat presenting primarily native vegetation including recent restoration plantings.

Photograph Appendix A.2: Urban Park landscape presenting primarily native vegetation.

Photograph Appendix A.3: A mixture of native and exotic vegetation along the Waikato River at the Mountain bike Park.

Photograph Appendix A.4: Native forest remnant with native regeneration along the margins showing cabbage trees and flax and tall canopy species in the background.



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Notes: Aerial photograph sourced from Waikato Regional Council - CC by 4.0 NZ

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DRAWN	WVDZ	Dec.18
CHECKED	DWM	Dec.18
APPROVED	PRC	Dec.18

ARCFILE
Bat research survey sites_2.mxd

SCALE (AT A4 SIZE)
1:25,000

PROJECT No.
1006949

PROJECT ECHO
HAMILTON CITY WIDE BAT RESEARCH
2018 SURVEY LOCATIONS

Site plan

FIGURE No. Figure A

Rev. 0

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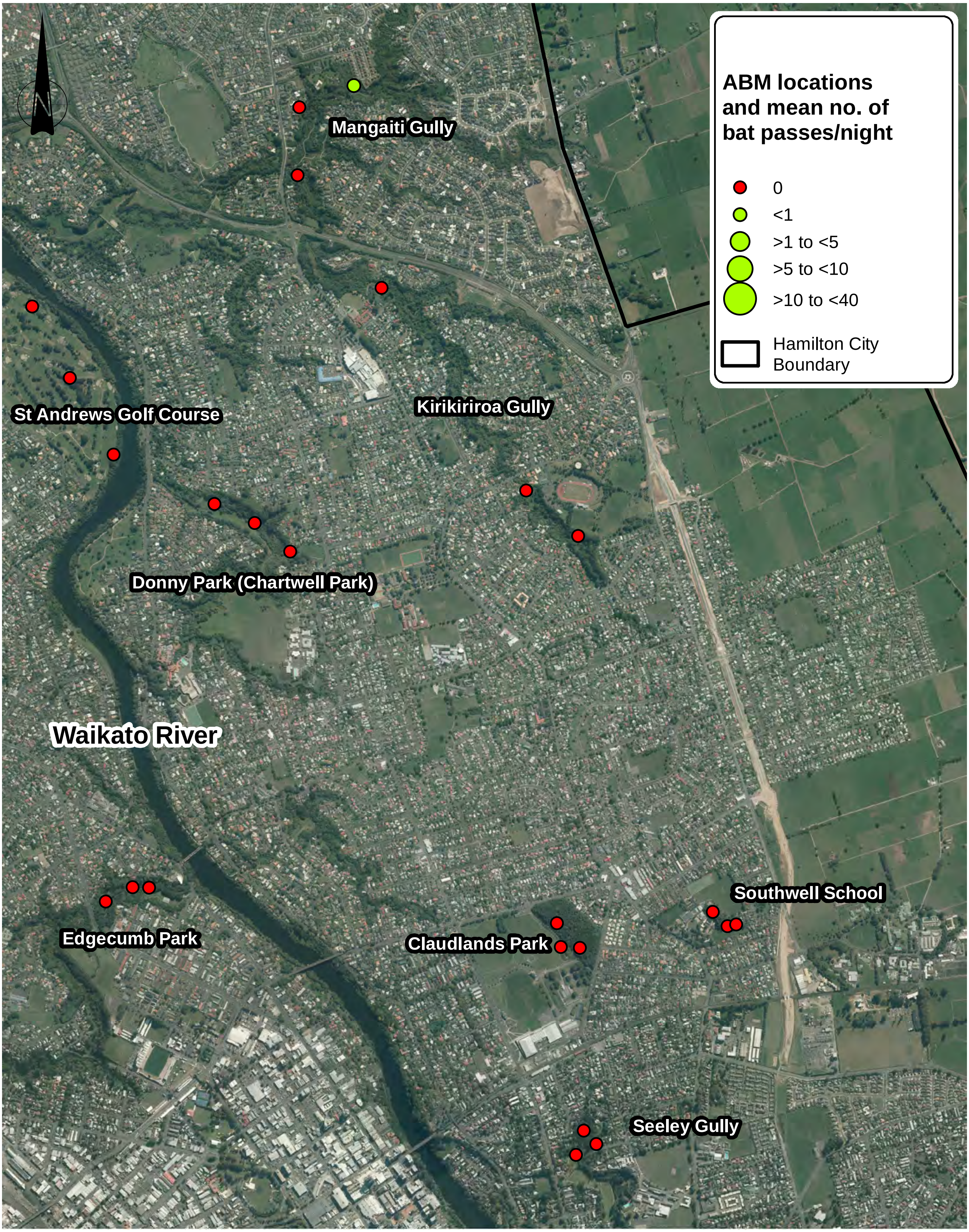

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Notes: Aerial photograph sourced from Waikato Regional Council - CC by 4.0 NZ

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APPROVED	PRC	Dec.18

ARCFILE
Bat research survey sites_3.mxd

SCALE (AT A4 SIZE)
1:25,000

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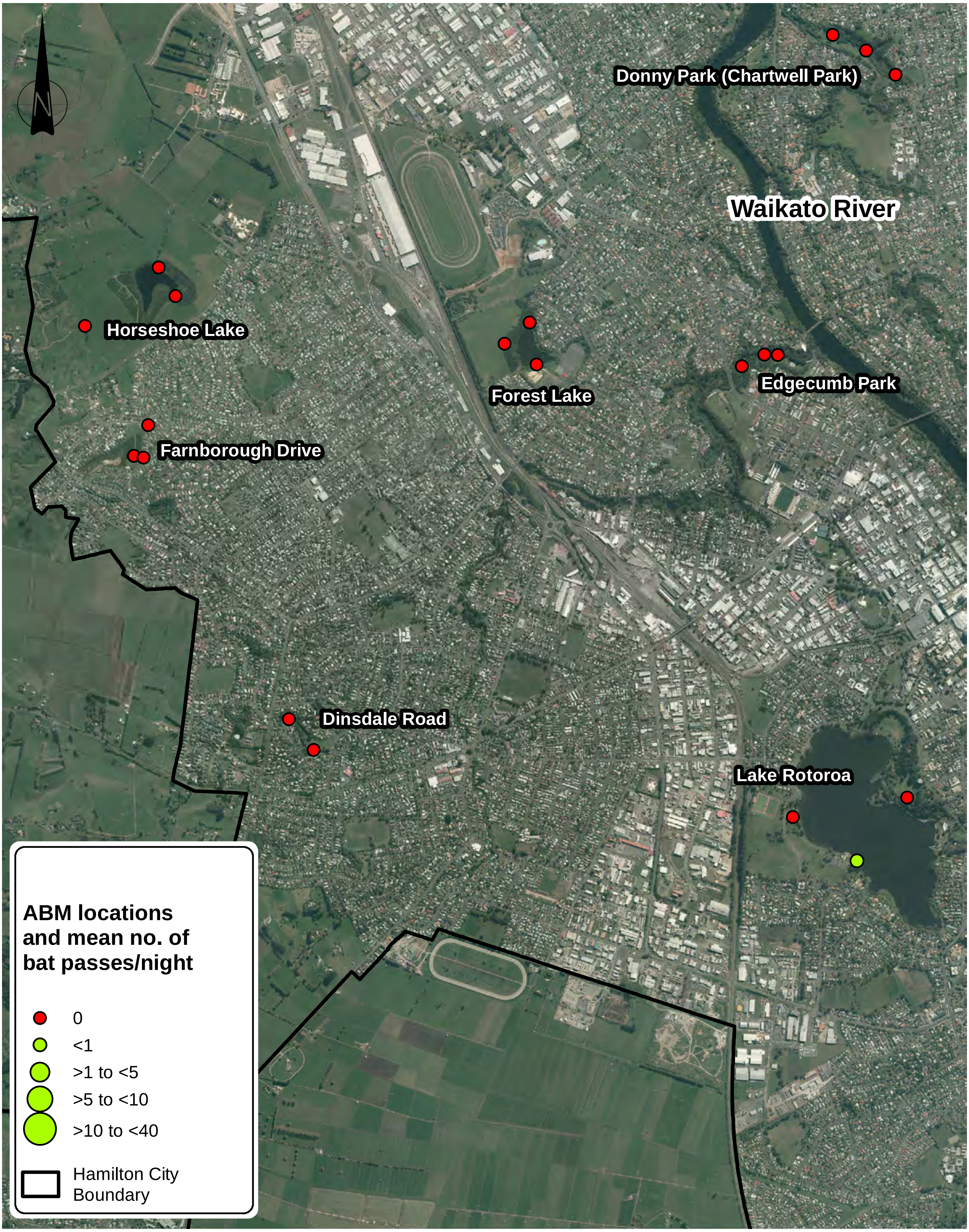
HAMILTON CITY WIDE BAT RESEARCH
2018 SURVEY LOCATIONS
Site plan

FIGURE No. Figure B

Rev. 0



A4 SCALE 1:30,000

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Notes: Aerial photograph sourced from Waikato Regional Council - CC by 4.0 NZ

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APPROVED	PRC	Dec.18

ARCFILE
Bat research survey sites_4.mxd

SCALE (AT A4 SIZE)
1:30,000

PROJECT No.
1006949

PROJECT ECHO
HAMILTON CITY WIDE BAT RESEARCH
2018 SURVEY LOCATIONS

Site plan

FIGURE No. Figure C

Rev. 0

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Notes: Aerial photograph sourced from Waikato Regional Council - CC by 4.0 NZ

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DRAWN	WVDZ	Dec.18
CHECKED	DWM	Dec.18
APPROVED	PRC	Dec.18

ARCFILE
Bat research survey sites_5.mxd

SCALE (AT A4 SIZE)
1:24,801

PROJECT No.
1006949

PROJECT ECHO
HAMILTON CITY WIDE BAT RESEARCH
2018 SURVEY LOCATIONS
Site plan

FIGURE No. Figure D

Rev. 0

Path: P:\1006949\WorkingMaterial\GIS\Bat research survey sites_5.mxd Date: 18/12/2018 Time: 5:22:00 PM

Appendix B: Summary of weather conditions

Summary of weather conditions at dusk (between 21:00 and 18:00 in the course of the survey) during the survey period. Temperatures in °C, wind speed in km/h and precipitation in mm. Data obtained from NIWA CliFlo database, station number 26117.

Date	Time	Max. temperature	Min. temperature	Precipitation	Max. wind speed
7/01/2018	21:00	18.2	15.9	0	28.1
8/01/2018	21:00	20.5	17.4	0	19.8
9/01/2018	21:00	20.6	18.4	0	23.8
10/01/2018	21:00	21.1	18.8	0	18.7
11/01/2018	21:00	21.9	19.2	0	20.5
12/01/2018	21:00	22.3	19.4	0	15.5
13/01/2018	21:00	20.8	17.8	0	10.1
14/01/2018	21:00	21.8	18.8	0	16.2
15/01/2018	21:00	20.4	17.4	0	13
16/01/2018	21:00	19.7	18.2	0	23
17/01/2018	21:00	20.8	17.8	3.9	26.6
18/01/2018	21:00	20.2	17	3.3	25.2
19/01/2018	21:00	22	20.1	0	16.2
20/01/2018	21:00	25	22.5	0	15.1
21/01/2018	21:00	24.8	22.3	0	14.4
22/01/2018	21:00	22.9	20.6	0.6	8.6
23/01/2018	21:00	22.3	20.2	0	12.6
24/01/2018	21:00	22.1	19.5	0	20.9
25/01/2018	21:00	22.8	20.9	0	17.6
26/01/2018	21:00	20.7	18.5	0.1	12.2
27/01/2018	21:00	24.8	21.5	0	16.6
28/01/2018	21:00	22.7	20.2	0	15.1
29/01/2018	21:00	23.3	20.8	0	12.6
30/01/2018	21:00	21.1	17.6	0	13
31/01/2018	21:00	21.5	19.3	0	26.6
1/02/2018	21:00	21.9	19.8	16.2	29.2
2/02/2018	21:00	18.7	16	0	21.6
3/02/2018	21:00	18.6	16.3	0	22.3
4/02/2018	21:00	20.4	17.8	0	12.2
5/02/2018	21:00	20	17.6	0	20.9
6/02/2018	21:00	19.3	16.8	0	24.1
7/02/2018	21:00	19.6	17.1	0	21.6
8/02/2018	21:00	19	16.8	0	8.3

Date	Time	Max. temperature	Min. temperature	Precipitation	Max. wind speed
9/02/2018	21:00	20.3	18.1	0	8.6
10/02/2018	21:00	22.6	20.4	0	15.1
11/02/2018	21:00	23.3	21.3	3.9	17.3
12/02/2018	21:00	25.1	22.8	0	16.9
13/02/2018	21:00	23.1	20.4	0	5.8
14/02/2018	21:00	21.6	19.3	0.1	12.2
15/02/2018	21:00	20.4	17.8	0	19.8
16/02/2018	21:00	22.5	18.9	0	7.9
17/02/2018	21:00	22.9	20.6	0	7.6
18/02/2018	21:00	24.4	21.6	0	12.2
19/02/2018	21:00	22.8	20.3	0	21.6
20/02/2018	21:00	23.5	21	0	27
21/02/2018	21:00	17.6	14.8	0	8.6
22/02/2018	21:00	18.7	16.4	0	10.8
23/02/2018	21:00	19.5	16.6	0	18.4
24/02/2018	21:00	19.6	16.7	0	14.4
25/02/2018	21:00	18.4	15.3	0	8.3
26/02/2018	21:00	20.8	17.5	0.3	18.7
27/02/2018	20:00	19.6	17.1	0	16.9
28/02/2018	20:00	20.4	17.7	0	9.4
1/03/2018	20:00	20.5	18.4	0	21.6
2/03/2018	20:00	21.6	19.2	0	19.4
3/03/2018	20:00	20.8	18.2	0	16.2
4/03/2018	20:00	21.9	18.7	0	10.1
5/03/2018	20:00	23.3	20.4	0	19.4
6/03/2018	20:00	23.8	21.4	0	10.4
7/03/2018	20:00	20.1	17.4	1.4	12.2
8/03/2018	20:00	20.1	16.9	0	15.5
9/03/2018	20:00	20.3	17	0	25.9
10/03/2018	20:00	20.4	17.3	0	10.1
11/03/2018	20:00	18.9	15.5	0	5
12/03/2018	20:00	16.8	14.6	2	27.4
13/03/2018	20:00	19.7	17.6	0	18
14/03/2018	20:00	18.2	15.7	0	19.8
15/03/2018	20:00	18.6	16.2	0	10.8
16/03/2018	20:00	20.1	17.9	0	16.9
17/03/2018	20:00	19.8	17.6	0	14.8
18/03/2018	20:00	19.3	16	0	12.2
19/03/2018	20:00	18.2	15.1	0	9.4

Date	Time	Max. temperature	Min. temperature	Precipitation	Max. wind speed
20/03/2018	20:00	19.5	16.7	0	10.1
21/03/2018	20:00	18.8	16.5	0.4	9.7
22/03/2018	20:00	19.3	17.2	0	10.1
23/03/2018	20:00	18.4	16.2	0	18.7
24/03/2018	20:00	18.8	16.4	1.4	7.9
25/03/2018	20:00	18.9	15.9	0	12.6
26/03/2018	20:00	22.4	19.4	0	11.2
27/03/2018	20:00	20.4	18.2	0	18.7
28/03/2018	20:00	19.4	17.4	0	7.2
29/03/2018	20:00	20.4	18.1	0	9
30/03/2018	20:00	19.8	16.6	0	18
31/03/2018	20:00	20.1	17.8	0	24.8
1/04/2018	19:00	21.3	17.7	0	26.3
2/04/2018	19:00	21	17	0	24.8
3/04/2018	19:00	21.2	18.5	0	20.9
4/04/2018	19:00	21	18.1	0	22.3
5/04/2018	19:00	24.2	19.8	0	14.4
6/04/2018	19:00	20.9	18.2	0	20.5
7/04/2018	19:00	20.8	17.5	0	36
8/04/2018	18:00	21.4	18.6	0	29.9
9/04/2018	18:00	20.9	18.6	0	23
10/04/2018	18:00	18.4	15	0.6	44.6
11/04/2018	18:00	14.4	11.8	0	40.7
12/04/2018	18:00	15.3	12.6	0	31.7
13/04/2018	18:00	17.9	15.1	0	36.4
14/04/2018	18:00	20.4	17.6	0	8.3
15/04/2018	18:00	17.8	15.7	0	15.8
16/04/2018	18:00	21.2	18.9	0	37.8
17/04/2018	18:00	22	19.5	0	29.5
18/04/2018	18:00	16.9	14.1	0	38.2
19/04/2018	18:00	17.7	15.3	0	27
20/04/2018	18:00	19.3	16.5	0	33.1
21/04/2018	18:00	19.8	17.4	0	36.4
22/04/2018	18:00	18.5	15.8	0	31.7
23/04/2018	18:00	17	14.9	0	12.2
24/04/2018	18:00	17.5	14.9	0	20.2
25/04/2018	18:00	20	16.8	0	28.1
26/04/2018	18:00	20.4	17.2	0	25.9
27/04/2018	18:00	18.9	16.3	0	25.9

Date	Time	Max. temperature	Min. temperature	Precipitation	Max. wind speed
28/04/2018	18:00	18.4	16	0.4	40.3
29/04/2018	18:00	19.5	17.8	0	23
30/04/2018	18:00	22.9	19.7	0	16.6
1/05/2018	18:00	22.4	20.3	0	13.3
2/05/2018	18:00	20.1	16.6	0	26.6
3/05/2018	18:00	18.5	14.9	0	7.6
4/05/2018	18:00	18	15.4	0	10.8
5/05/2018	18:00	17.5	14.8	0	10.4
6/05/2018	18:00	19.1	15.8	0	27.4
7/05/2018	18:00	18.3	15.2	0	43.2
8/05/2018	18:00	18.2	15.9	0	30.2
9/05/2018	18:00	19.8	17.2	0	28.1
10/05/2018	18:00	19.1	16.5	0	9
11/05/2018	18:00	19	16.6	0	14.4
12/05/2018	18:00	18.1	16.2	0.1	15.1
13/05/2018	18:00	22.7	19.9	0	9
14/05/2018	18:00	20.4	17.8	0	8.6
15/05/2018	18:00	21	18.4	0	20.9
16/05/2018	18:00	17.4	15.2	0.9	22.7

Appendix C: ABM survey results

Appendix C Table 1: ABM survey results for the 23 survey locations

Site name	ABM	Latitude (WGS)	Longitude (WGS)	Total passes	# nights surveyed	Mean # of bat passes/night
Ashley Street - Totara Park	KB 1	-37.7469	175.2508	0	15	0
Ashley Street - Totara Park	KB 2	-37.7471	175.2514	0	15	0
Ashley Street - Totara Park	KB 14	-37.7465	175.2507	0	15	0
Claudelands Park	WEC7	-37.7757	175.2906	0	15	0
Claudelands Park	WEC5	-37.7746	175.2904	0	17	0
Claudelands Park	WECA	-37.7757	175.2917	0	15	0
Dinsdale Road	WEC 5	-37.7941	17523683	0	17	0
Dinsdale Road	WEC 7	-37.7934	175.2358	0	17	0
Dinsdale Road	WEC A	-37.795	175.2375	0	17	0
Donny Park (Chartwell Park)	WEC 2	-37.7566	175.2708	0	11	0
Donny Park (Chartwell Park)	WEC 3	-37.7573	175.2731	0	11	0
Donny Park (Chartwell Park)	WEC 4	-37.7586	175.2751	0	11	0
Edgecumbe Park	WEC7	-37.7735	175.2677	0	15	0
Edgecumbe Park	WECA	-37.7742	175.2653	0	15	0
Edgecumbe Park	WEC5	-37.7735	175.2668	0	10	0
Farnborough Drive	WEC 5	-37.7796	175.225	0	17	0
Farnborough Drive	WEC 7	-37.778	175.226	0	17	0
Farnborough Drive	WEC A	-37.7797	175.2257	0	17	0
Fitzroy Park	WEC 1	-37.818	175.2999	674	21	32
Fitzroy Park	WEC 6	-37.8183	175.2985	465	21	22
Fitzroy Park	WEC 8	-37.817	175.006	84	21	4
Forest Lake	WEC 5	-37.7743	175.2517	0	11	0
Forest Lake	WEC 7	-37.7721	175.2512	0	11	0
Forest Lake	WEC A	-37.7733	175.2495	0	11	0
Hammond Park	WEC 1	-37.8063	175.3162	438	20	22
Hammond Park	WEC 6	137.5087	175.3176	71	20	4
Hammond Park	WEC 8	-37.8069	175.3195	338	20	17
Jellicoe Drive - Hayes Common	WEC 1	-37.7962	175.2909	0	15	0
Jellicoe Drive - Hayes Common	WEC 6	-37.7977	175.2899	0	15	0
Jellicoe Drive - Hayes Common	WEC 8	-37.7992	175.2877	0	15	0
Horseshoe Lake	WEC 5	-37.7712	175.2276	0	17	0
Horseshoe Lake	WEC 7	-37.7697	175.2264	0	17	0
Horseshoe Lake	WEC A	-37.7729	175.2216	0	17	0

Site name	ABM	Latitude (WGS)	Longitude (WGS)	Total passes	# nights surveyed	Mean # of bat passes/night
Humare Park	WEC 1	-37.803	175.3292	121	14	9
Humare Park	WEC 6	-37.8019	175.3291	20	14	1
Humare Park	WEC 8	-37.8027	175.3292	25	14	2
Hutchinson Road	KB 9	-37.7048	175.2154	0	14	0
Hutchinson Road	KB 14	-37.7094	175.2154	0	14	0
Hutchinson Road	KB 39	-37.7124	175.2173	0	14	0
Kirikiriroa Gully	KB 1	-37.7556	175.2881	0	24	0
Kirikiriroa Gully	KB 2	-37.7576	175.291	0	24	0
Kirikiriroa Gully	KB 14	-37.7469	175.2798	0	24	0
Lake Rotoroa	WEC 1	-37.7967	175.277	0	16	0
Lake Rotoroa	WEC 6	-37.7573	175.2793	0	16	0
Lake Rotoroa	WEC 8	-37.8001	175.2738	1	15	0
Mangaiti Gully	WEC 3	-37.739	175.275	0	16	0
Mangaiti Gully	WEC 4	-37.738	175.278	1	16	0
Mangaiti Gully	WEC 2	-37.742	175.275	0	16	0
Mountain Bike Park	KB 1	-37.7317	175.2346	0	16	0
Mountain Bike Park	KB 2	-37.7295	175.2255	0	16	0
Mountain Bike Park	KB 14	-37.734	175.2295	0	16	0
River (Horsham Downs Golf Club)	KB 9	-37.7201	175.2256			
River (Horsham Downs Golf Club)	KB 14	-37.7214	175.2269	0	17	0
River (Horsham Downs Golf Club)	KB 39	-37.7181	175.2225	0	17	0
Seeley Gully	WEC 4	-37.7837	175.2922	0	7	0
Seeley Gully	WEC 3	-37.7848	175.2917		7	0
Seeley Gully	WEC 2	-37.7843	175.2929	0	7	0
Southwell School	WEC 4	-37.774	175.299	0	13	0
Southwell School	WEC 2	-37.7746	175.2998	0	13	0
Southwell School	WEC 3	-37.7745	175.3003	0	13	0
St Andrews Golf Course	WEC 2	-37.7545	175.2652	0	14	0
St Andrews Golf Course	WEC 3	-37.7481	175.2605	0	14	0
St Andrews Golf Course	WEC 4	-37.7512	175.2626	0	14	0
Te Anau Park	WEC 8	-37.8213	175.2949	404	19	21
Te Anau Park	WEC 6	-37.8215	175.2962	185	19	10
Te Anau Park	WEC 1	-37.8228	175.2941	108	19	6
Witehira Way	KB 14	-37.7275	175.24	0	16	0
Witehira Way	KB 39	-37.7292	175.2424	0	16	0
Witehira Way	WEC 7	-37.7256	175.2392	0	15	0

Appendix D: Summary of 2018 bat survey results and habitat findings

Appendix D Table 1: Summary of 2018 bat survey results and habitat findings for each of the 23 survey locations, combining the results collected from the individual ABMs at those survey locations.

Site name	Habitat *	R/U	Area (ha)**	Survey period	Bat activity (Y/N)	#of ABM	# of ABMs with bat activity	Distance to lighting (m)	Lighting intensity level (1-3)	Distance to source of noise (m)	Noise intensity level (1-3)	Distance to City Centre (km)	Mean passes/ ABM/night
Ashley Street - Totara Park	N	U	1.9	April	N	3	0	20 - 30	1 - 3	20 - 30	1 - 2	4.0	N/A
Claudelands Park	N	U	5.5	May	N	3	0	50 - 100+	1 - 2	100 - 200	2	1.2	N/A
Dinsdale Road	P	U	1.3	March - April	N	3	0	30 - 50	2 - 3	30 - 50	2 - 3	1.9	N/A
Donny Park (Chartwell Park)	G	U	16.5	January	N	3	0	50	1	50	1	2.3	N/A
Edgecumbe Park	G	U	20.1	April	N	3	0	50 - 150	1 - 2	50 - 150	1 - 2	0.7	N/A
Farnborough Drive	N	U	1.4	February	N	3	0	30 - 50	3	30 - 50	2	2.5	N/A
Fitzroy Park	G	U	27.9	March - April	Y	3	3	50	1	50	2	3.0	19.41
Forest Lake	P	U	3.1	April	N	3	0	15 - 200	2 - 3	15 - 200	2 - 3	1.8	N/A
Hammond Park	R	U	26.2	March	Y	3	3	100	1	100	1	3.2	14.12
Jellicoe Drive - Hayes Common	R	U	7.3	February	N	3	0	5 - 50	1 - 2	5 - 200	1 - 2	1.0	N/A
Horseshoe Lake	R	R	11.1	January	N	3	0	75 - 200	1 - 2	75 - 200	1 - 2	3.3	N/A
Humare Park	G	U	32.6	February - March	Y	3	3	30 - 200+	1 - 2	30 - 200+	1 - 2	4.2	3.95
Hutchinson Road	R	U	14.8	January	N	3	0	100 - 550	1 - 2	300 - 400	1	9.2	N/A

Site name	Habitat *	R/U	Area (ha)**	Survey period	Bat activity (Y/N)	#of ABM	# of ABMs with bat activity	Distance to lighting (m)	Lighting intensity level (1-3)	Distance to source of noise (m)	Noise intensity level (1-3)	Distance to City Centre (km)	Mean passes/ ABM/night
Kirikiriroa Gully	G	U	26.0	April - May	N	3	0	30 - 75	1 - 2	30 - 75	1 - 2	2.8	N/A
Lake Rotoroa	P	U	7.8	January	Y	3	1	50 - 200+	1	50 - 200+	1	0.6	0.02
Mangaiti Gully	G	U	25.6	March - April	Y	3	1	50	1	50 - 100	1 - 2	4.0	0.02
Mountain Bike Park Area	P	U	12.5	March	N	3	0	50 - 150	1 - 2	50 - 200	1 - 3	6.5	N/A
River (Horsham Downs Golf Club)	R	R	17.4	February	N	3	0	80 - 100	1	80 - 100	1	7.9	N/A
Seeley Gully	G	U	6.5	March	N	3	0	20 - 60	1 - 2	20 - 60	1	0.9	N/A
Southwell School	P	U	1.1	February - March	N	3	0	20	1	20	1	1.9	N/A
St Andrews Golf Course	R	U	43.8	January - February	N	3	0	200 - 500	1 - 2	50 - 500	1 - 2	3.1	N/A
Te Anau Park	G	U	5.2	April - May	Y	3	3	100 - 200	1	50 - 150	1	3.3	12.23
Witehira Way	G	U	12.3	February - March	N	3	0	15 - 30	1 - 2	50	1 - 2	6.3	N/A

* Legend see below

**Area (ha) were calculated using spatial data. Areas are approximate and may include wider areas to include connected habitat.

Legend

R/U: Rural / Urban

N: Native forest remnants

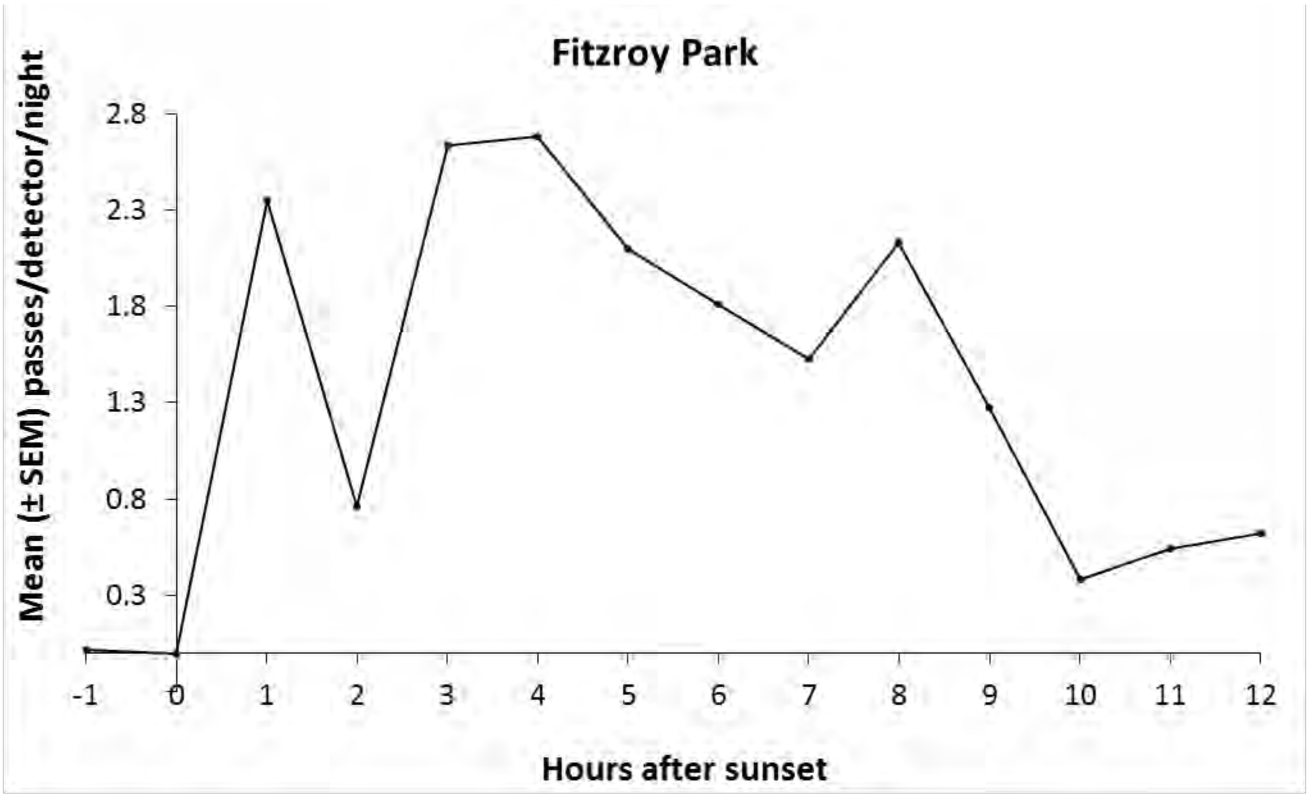
R: Riparian margins

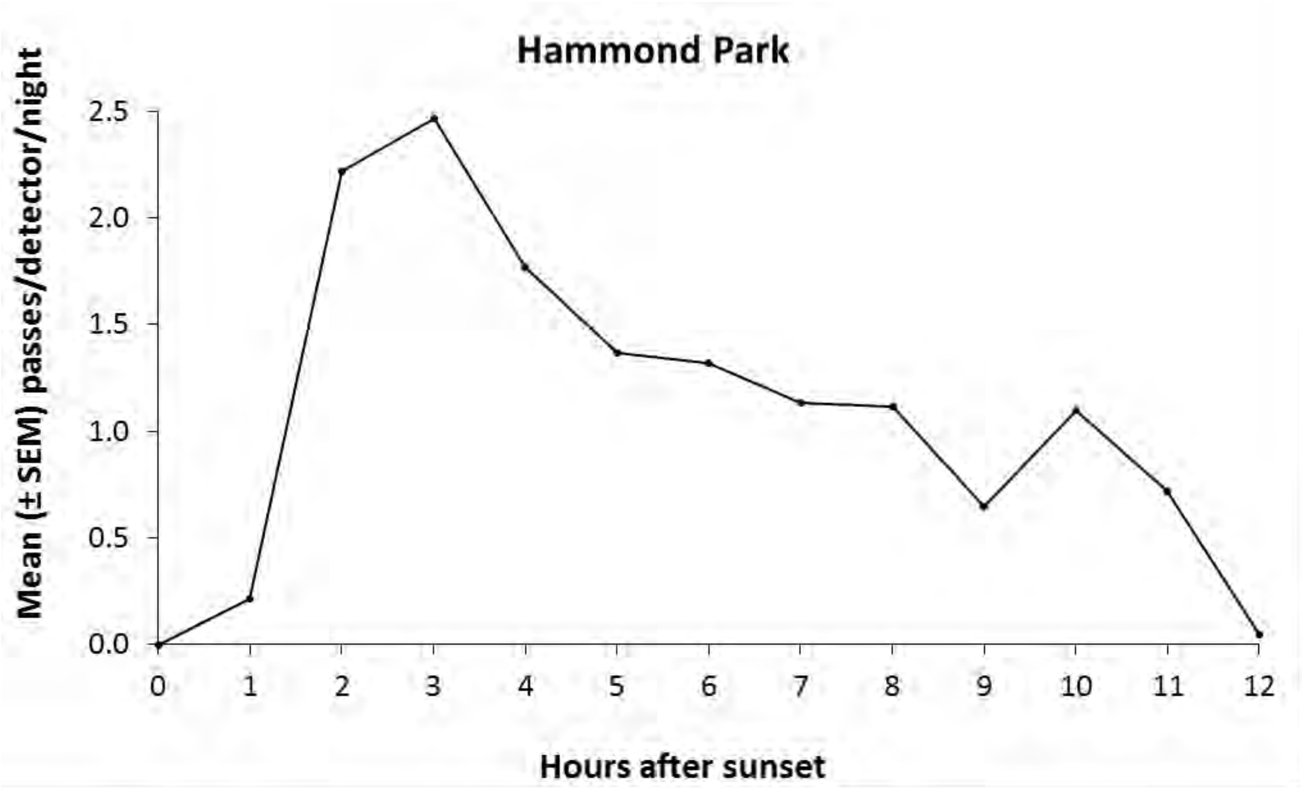
G: Major gullies

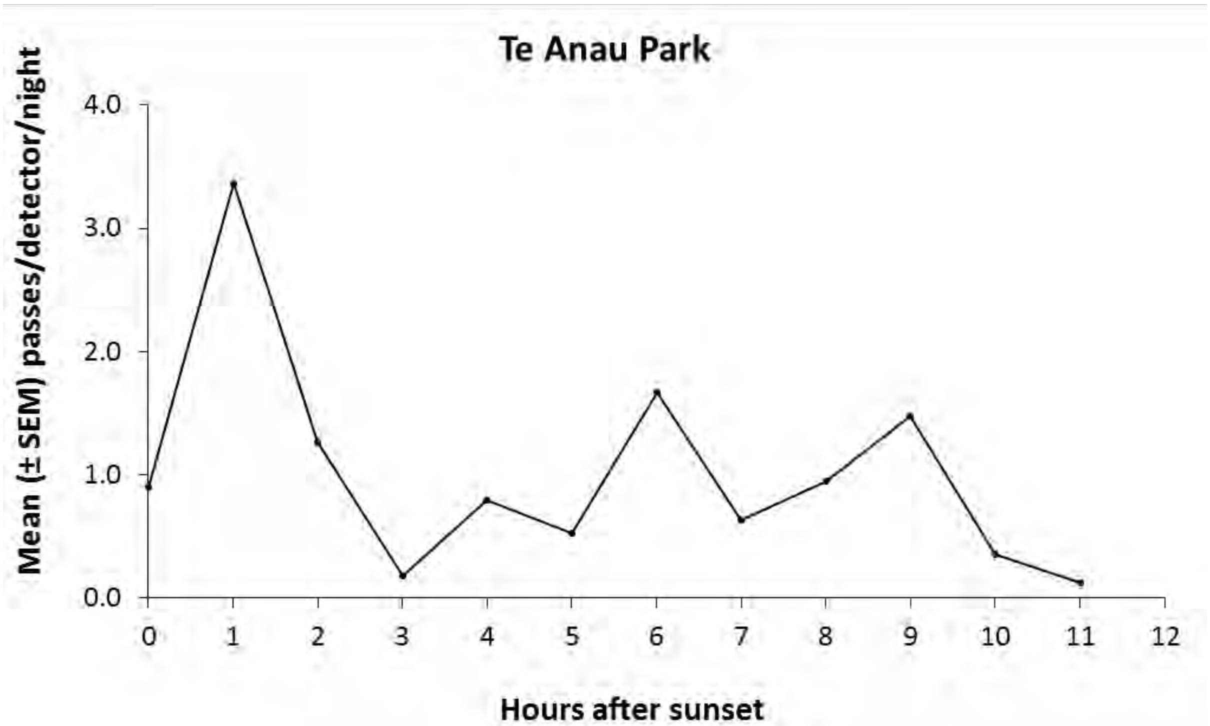
P: Urban parklands

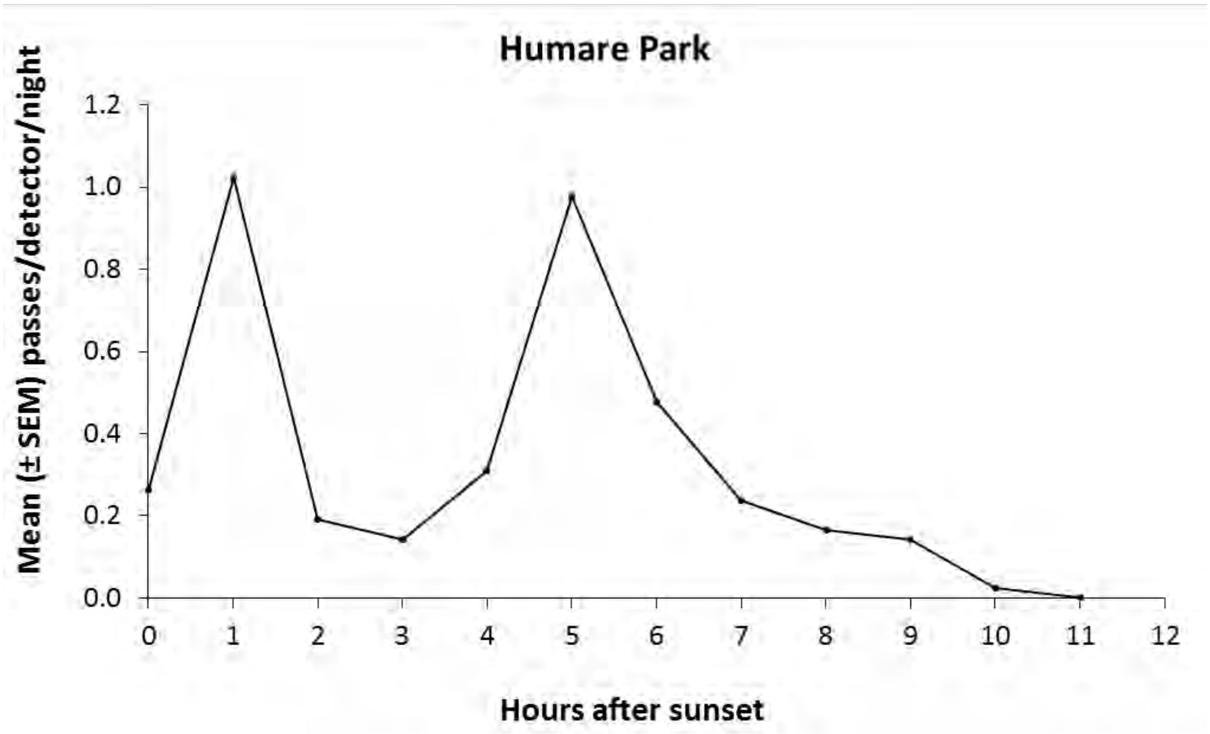
Appendix E: Site specific bat passes per detector and night for each hour after sunset

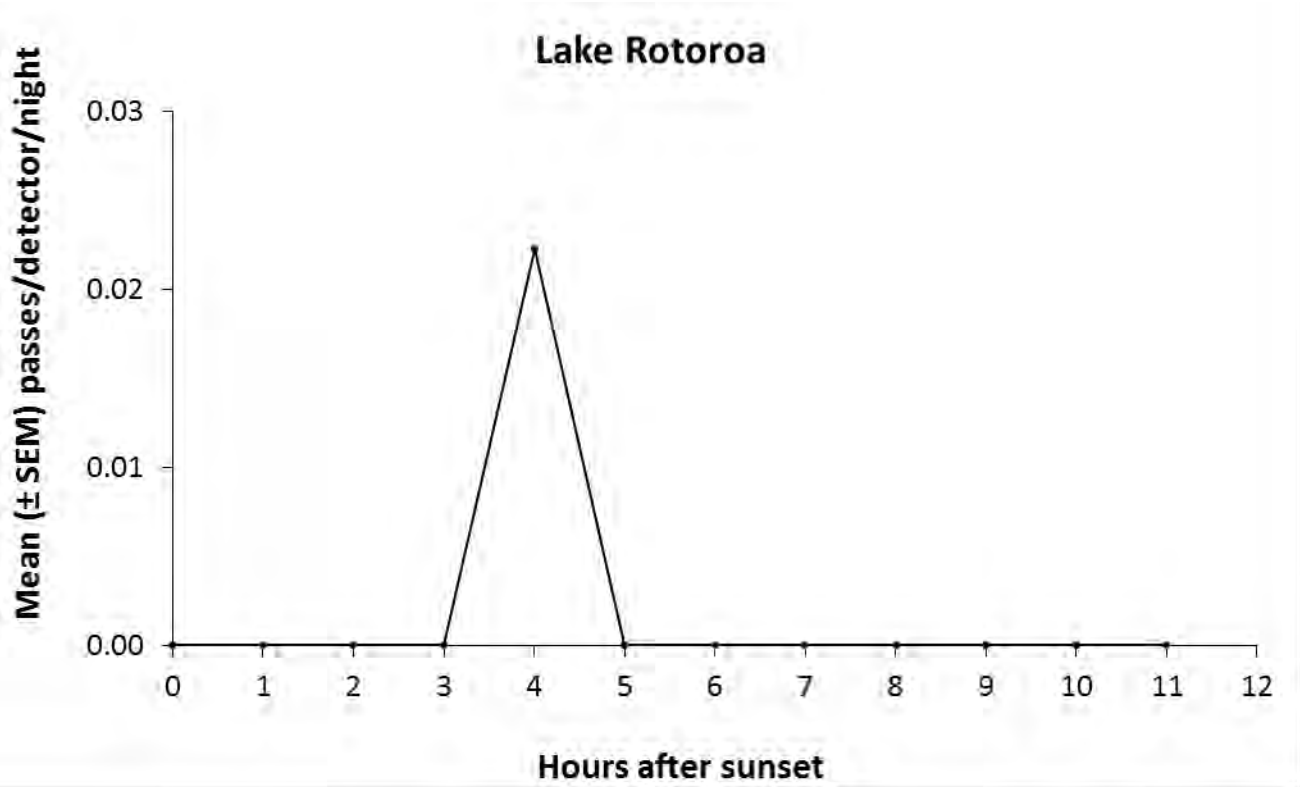
Data based on ABM survey results as presented in Appendix C. Survey locations are shown in Figure 2.1 and Appendix A.

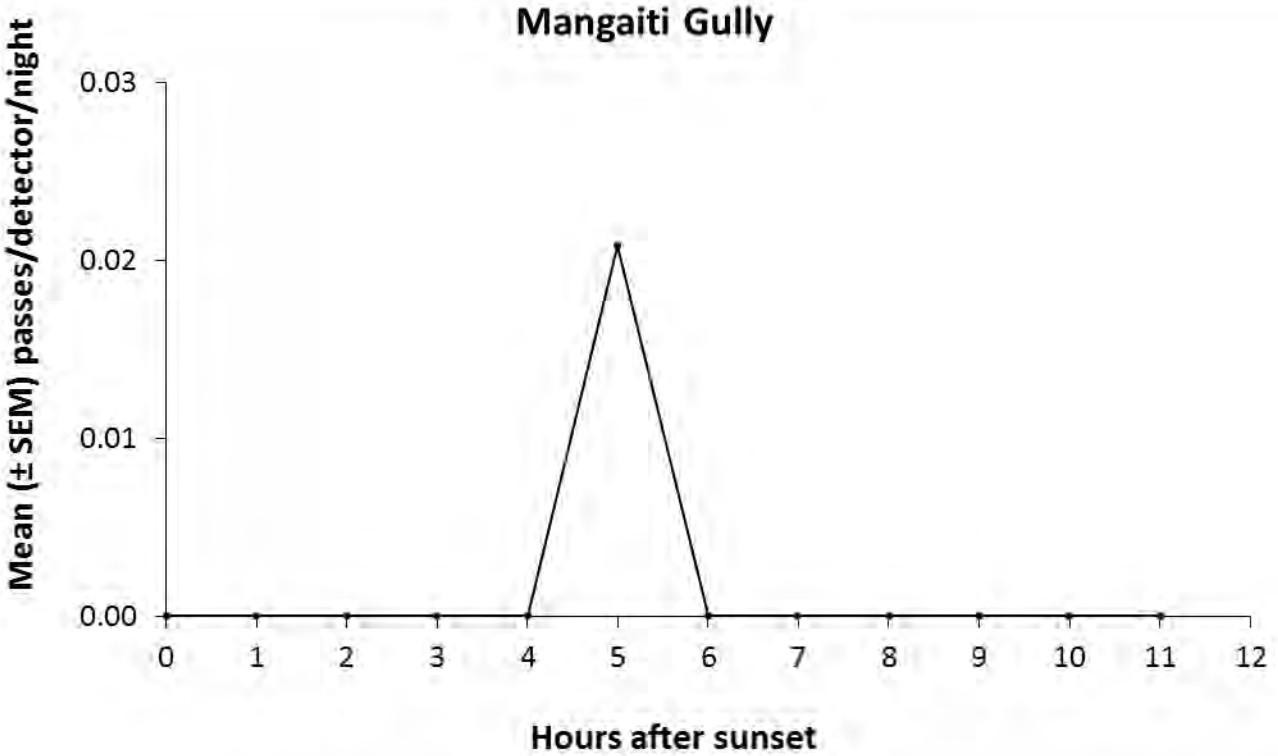



Hammond Park
Mean (± SEM) passes/detector/night
2.5
2.0
1.5
1.0
0.5
0.0
0
1
2
3
4
5
6
7
8
9
10
11
12
Hours after sunset


Te Anau Park
Mean (± SEM) passes/detector/night
4.0
3.0
2.0
1.0
0.0
0
1
2
3
4
5
6
7
8
9
10
11
12
Hours after sunset


Humare Park
Mean (± SEM) passes/detector/night
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
10
11
12
Hours after sunset


Lake Rotoroa
Mean (± SEM) passes/detector/night
0.03
0.02
0.01
0.00
0
1
2
3
4
5
6
7
8
9
10
11
12
Hours after sunset



Mangaiti Gully
Mean (± SEM) passes/detector/night
0.03
0.02
0.01
0.00
0
1
2
3
4
5
6
7
8
9
10
11
12
Hours after sunset

Appendix F: Confirmed bat habitat locations from 2011/2012

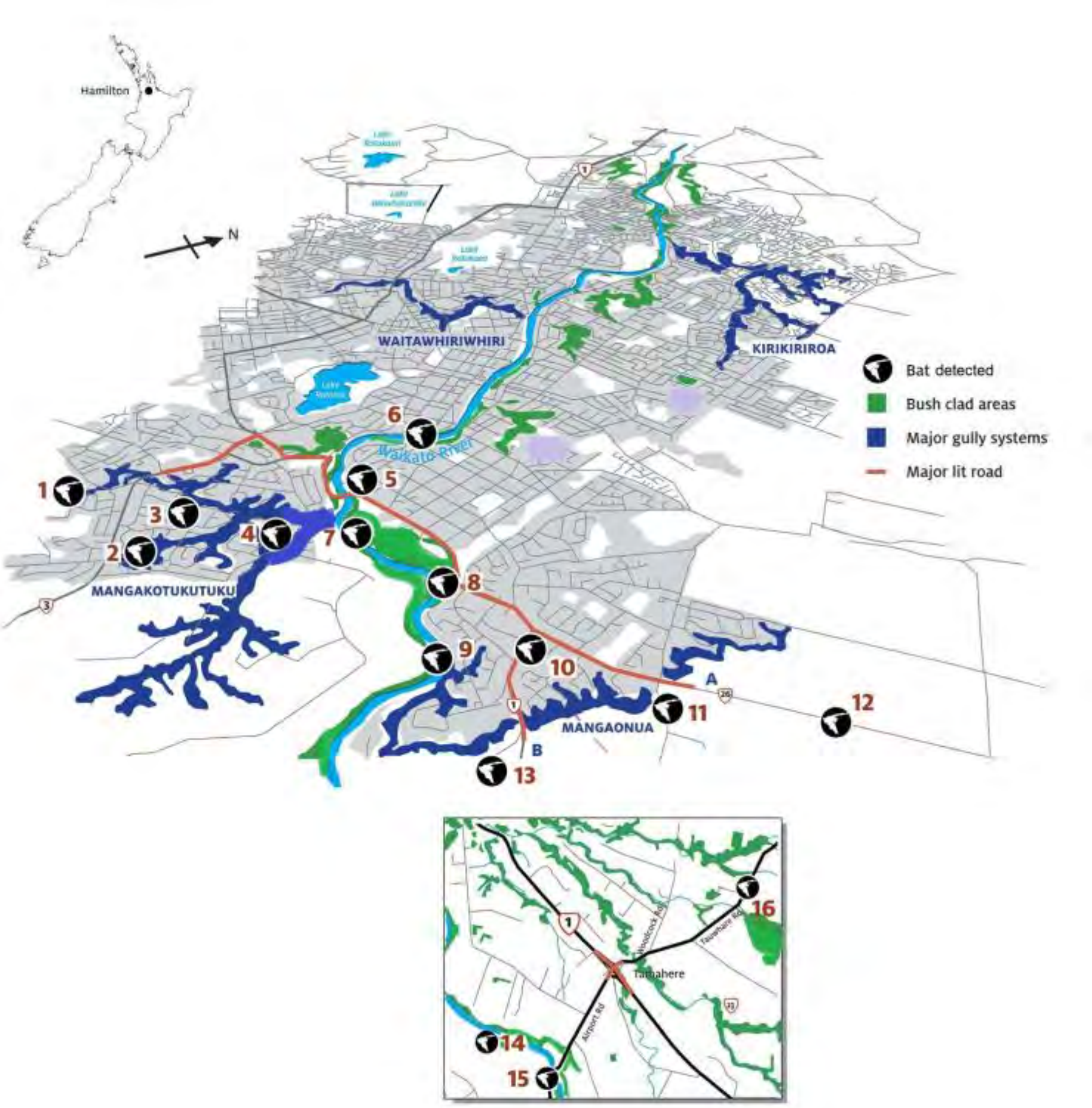


Figure Appendix F.1: Survey results of the 2011/2012 bat survey by Le Roux and Le Roux (2012).

Appendix G: Survey locations and results of 2017

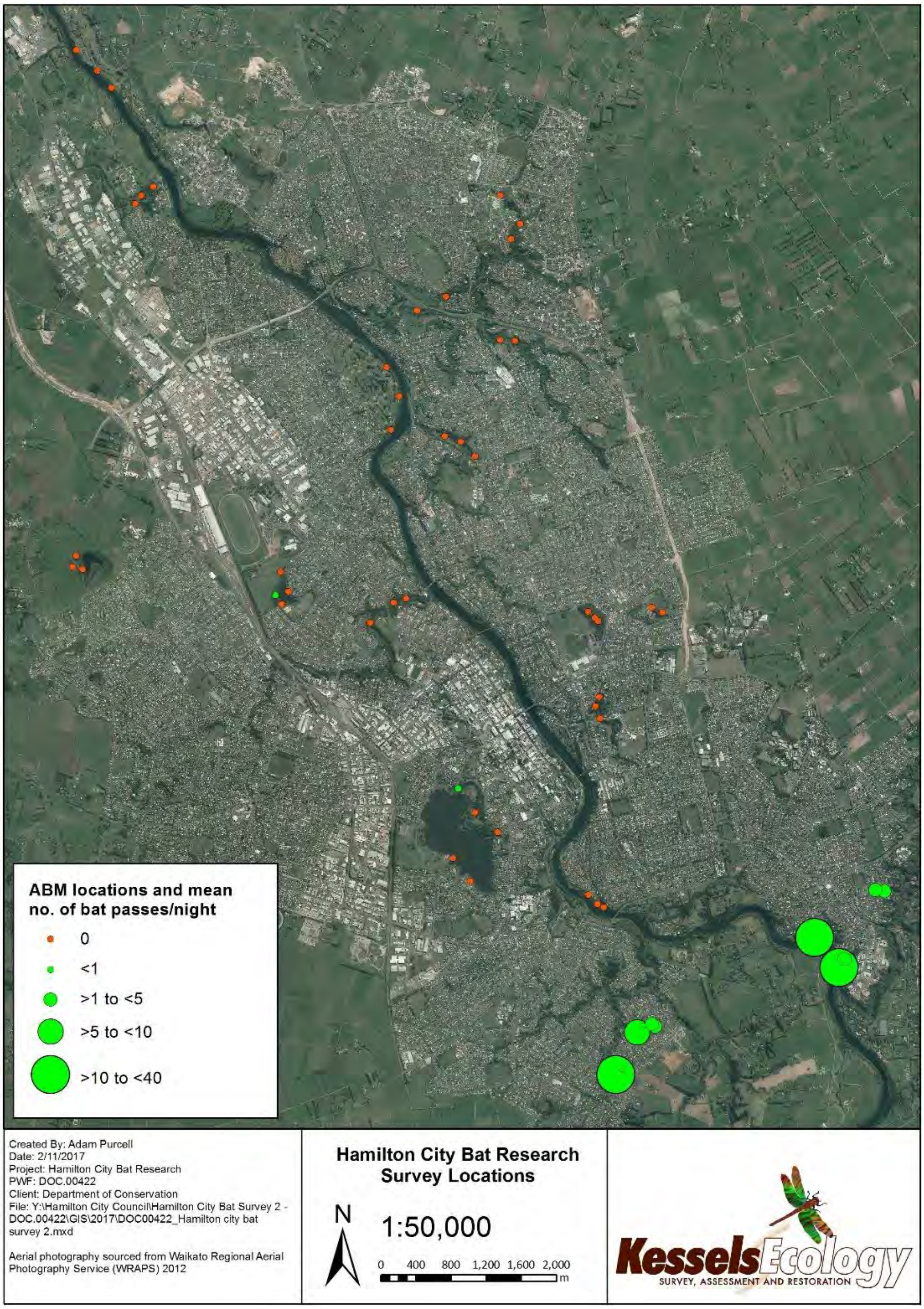


Figure Appendix G.1: Locations of ABMs deployed between 16 February and 11 June 2017. Red circles indicate that no bat passes were detected by that ABM. The size of green circles is indicative of the mean number of bat passes recorded by the ABM each night.

Appendix H: Habitat prediction model

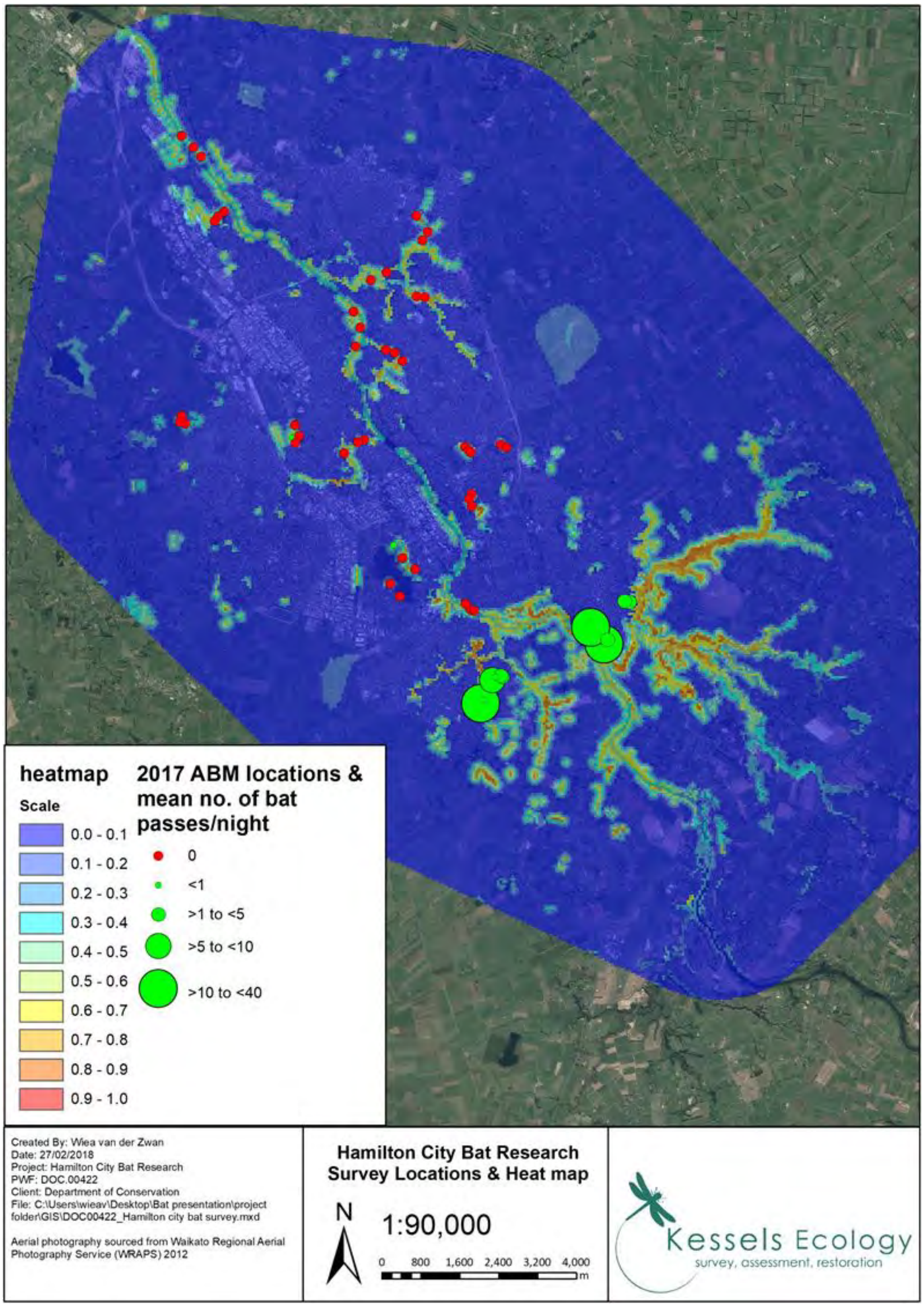


Figure Appendix H.1: Heat map of Hamilton City bat habitat, using the habitat prediction model of Crewther and Parsons (2017) overlaid by the survey results of the acoustic monitoring done by Mueller et al., (2017).