HAMILTON CITY LONG-TAILED BAT SURVEY

October 2019

Annual monitoring report, 2018-2019

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CONTENTS

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INTRODUCTION

Project background

Hamilton City is one of at least three urban centres in New Zealand (along with Auckland and Rotorua) with a known population of long-tailed bats (*Chalinolobus tuberculatus*). Long-tailed bats were upgraded to 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 ecosystem restoration as well as in a national species management 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 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 annually, 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 wider project objectives are to:

- Map the spatial configuration and habitat use of bats throughout Hamilton City based on the MaxEnt habitat prediction model (Crewther and Parsons 2017) 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, e.g. the Waikato Expressway that crosses the Mangaonua, Mangaone, and Mangaharakeke gully systems, and the urban development underway in southern Hamilton.

Ongoing monitoring of bat activity and research into their habitat utilisation and distribution is therefore important to further understand spatial distribution of bats and habitat use over the coming years.

[1] Kessels Ecology was purchased by Tonkin + Taylor Limited in May 2018. Following the completion of last year's report by Tonkin + Taylor (van der Zwan 2018), this year's report was completed by Project Echo.

Report objectives

This report details the findings of the 2018/19 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.

This report covers details of the monitoring programme and survey methodology, survey results (such as activity levels and indications of habitat use), and a comparison of the results with previous years of monitoring. Implications of ongoing survey findings for local bat populations and knowledge gaps are also discussed.

The findings of the ongoing research project 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 the following reports:

- 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)
- The 2016/17 monitoring results that were used to inform the choice of study sites in this report (Mueller et al. 2017); and
- The latest monitoring report for the 2017/2018 monitoring season (van der Zwan 2018).

Study area

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 1).

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 (Photo 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.

Photo 1 Gully habitat presenting primarily native vegetation including recent restoration plantings

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 (Photo 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.

Photo 2 Urban Park landscape presenting primarily native vegetation

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 (Photo 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.

Photo 3 A mixture of native and exotic vegetation along the Waikato River at the Mountain bike 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 (Photo

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*)).

Photo 4 Native forest remnant with native regeneration along the margins showing cabbage trees and flax and tall canopy species in the background

METHODOLOGY

Bioacoustics monitoring of bat echolocation calls

To record the presence or absence and activity patterns of bats Hamilton City, omnidirectional Frequency Compression (FC) automatic bat monitors (ABMs; AR4 model, manufactured by Department of Conservation, Wellington) that record bat echolocation calls 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).

Survey locations

A total of 58 ABMs were deployed in 19 locations between 29 January and 12 April 2019 (Figure 1). The survey locations were chosen based on results from previous monitoring surveys as part of this project (van der Zwan 2018, Mueller et al. 2017). 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 (Figure 1). As substantial monitoring has and is taking place in the southern areas of the city, focusing on gully habitats in particular, monitoring in this survey round has targeted areas that offer suitable habitat (including parkland, gully systems and lakes) which have previously been underrepresented in bat monitoring in the city to explore bat distribution in these areas, and assess what activity levels may be present.

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 attempt to distinguish approximate different ways in which bats were using habitats.

Most of the activity in south Hamilton landscape has been shown to be concentrated within small core areas, with relatively 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. It is important to note that areas with low activity levels may still be used for occasional single roosting.

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 ≤ 1 pass/ABM/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, Borkin 2019). 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.

ABM deployment

The 19 survey sites were successively monitored over a period of ten weeks from 29 January to 12 April 2019. 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 23 consecutive nights. The average number of nights surveys across all sites was 13. This amounted to a total of approximately 8,000 hours of monitoring over 675 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 nights of the complete survey period rainfall was absent or minimal below 5 mm at dusk. Wind speeds were low to moderate at dusk on all but two nights of the complete survey period (24, 25 February 2019). A summary of weather conditions is shown in Appendix C which presents data obtained from NIWA CliFlo database, station number 26117 (Ruakura).

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 be 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 lighting roads directly next to the survey locality).

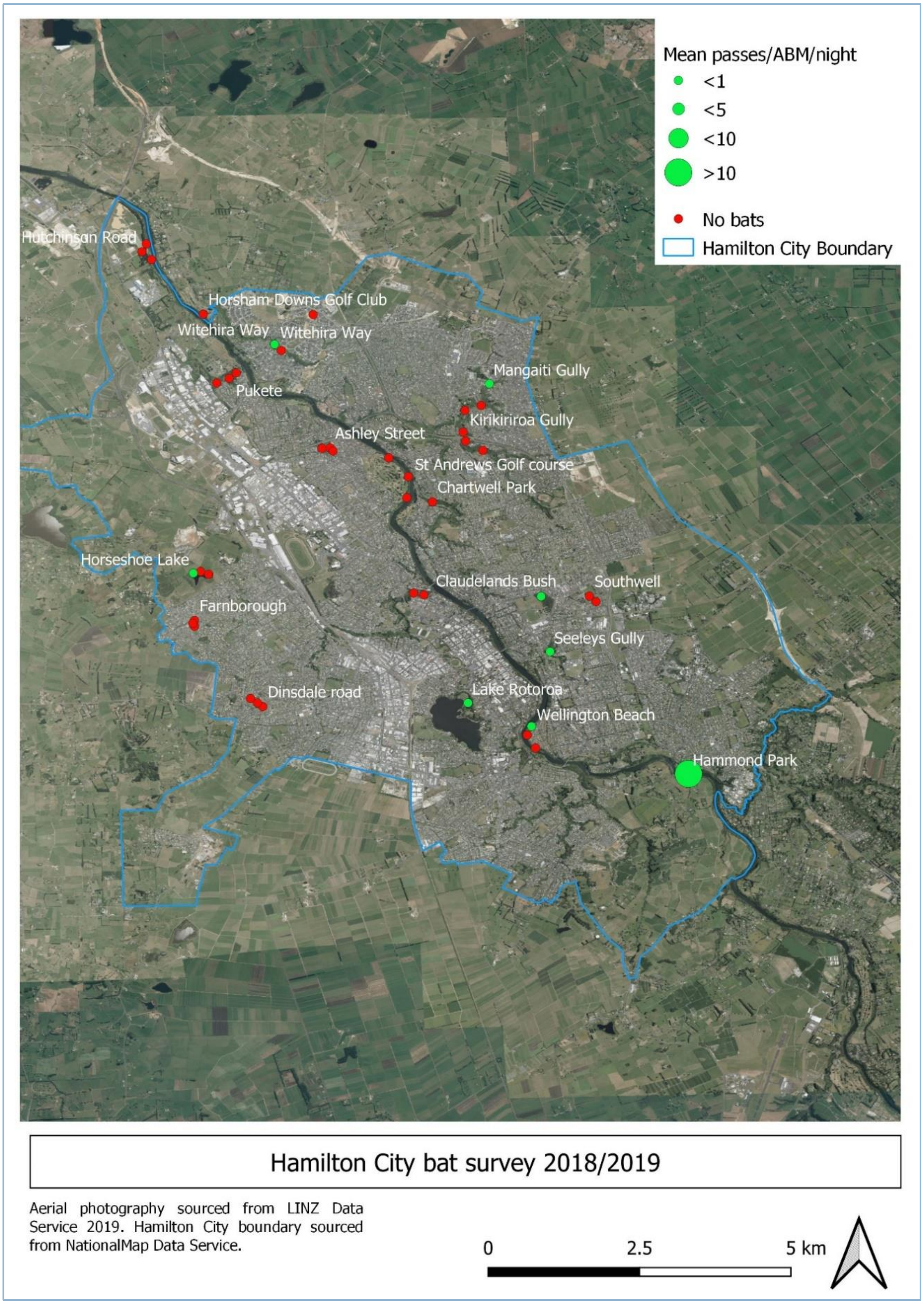

Figure 1 Monitoring sites and results

RESULTS

Bat activity levels

A total of 1242 echolocation passes were recorded from eight locations comprising 15 of the overall 55 ABMs deployed (Figure 1). Of the eight locations with bat activity Hammond Park was characterised by the highest overall mean bat activity with on average, 55 bat passes/detector/night (55.3 ± 45.5 SE) (Table 1), indicating that this location is either important foraging or roosting habitat.

During this year's survey, no other locations showed activity levels (greater than 1.0 mean bat passes/detector/night) that could indicate communal roosting, though occasional solitary roosts may be present. At the seven other locations where bat activity was recorded, less than 1.0 mean passes/ABM/night mean habitat was likely used for commuting during the time of survey.

Of the 19 locations surveyed, eight (42%) recorded long-tailed bat activity and no data was obtained from three ABMs due to loss of geospatial information for these detectors. A summary of bat activity detected is presented in Appendix A: Summary of survey results and Appendix B: Site specific data.

Bimodal activity showing peaks of activity (≥ 10 passes/ABM/night) in the first two hours after sunset and just before sunrise may also indicate bats roosting nearby (Le Roux and Le Roux 2012). No site indicated such a bimodal pattern during this year's monitoring. However, Hammond Park indicated such a peak of activity at dawn. Mangaiti Gully also indicated an activity peak at dawn, however activity levels were so low (0.02 mean passes/ABM/night) that frequent use for roosting appears to be unlikely at this site (Table 1, Appendix B: Site specific data).

Table 1 Mean and Standard Mean Error for number of bat passes per night and detector for each area where bat activity was recorded

Location	Mean number of passes/ABM/night	Standard Mean Error	Habitat type
Claudelands Bush	0.48	0.26	Forest remnant
Witehira Way	0.10	0.10	Gully habitat
Mangaiti Gully	0.02	0.02	Gully habitat
Seeleys Gully	0.03	0.03	Gully habitat
Hammond Park	55.28	45.55	Riparian margin
Horseshoe Lake	0.02	0.02	Riparian margin
Wellington Beach	0.07		Riparian margin
Lake Rotoroa	0.62	0.23	Urban parkland

Habitat use

Habitat usage was defined into commuting, foraging with possible periodic roosting, and foraging and potential regular roosting (described in the methodology section).

Table 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.

Gully habitat

Major gully systems were surveyed over four different site locations totaling an average of 0.05 bat passes per ABM per night (Table 2). Bat activity was detected at all three out of the four gully habitat sites (Witehira Way, Mangaiti Gully, Seeleys Gully). None of the gully habitat locations indicated regular large communal roosting at the time of survey, but it is likely that generally low numbers of bats in many areas mean collected data are insufficient to provide more certainty around habitat use at this time (Table 1).

Urban parklands

In urban parklands bat activity was detected at one location (Lake Rotoroa) with an average of 0.62 bat passes per ABM per night indicating that this locality is used as commuting habitat (Table 2). Similar to the gully habitats, low numbers of bats present and limited data available mean low levels of certainty around habitat use.

Riparian margins

Most bat activity was recorded in riparian margins (18.46 mean passes/detector/night) (Table 2). Of the five surveyed sites in riparian margins, three sites (Hammond Park, Horseshoe Lake, Wellington Beach) detected bats. Activity levels at Hammond Park (>55 mean passes/detector/night) indicated likely regular, possibly communal roosting, while Horseshoe Lake and Wellington Beach likely indicated commuting activity (Table 1). However, occasional solitary roosting is also possible, and further monitoring would be required to provide more certainty around habitat use.

Native forest remnants

Only one forest remnant site was surveyed (Claudelands Bush), where bat activity was recorded. Activity levels indicate use of the habitat for commuting at the time of survey. However, as for the previous habitat types, low numbers of bats and limited monitoring mean that data recorded here offers limited certainty with regards to habitat use, and occasional solitary roosting may be possible. This habitat type is generally under-represented within Hamilton and was not strongly represented in the survey sites (5% of sites) (Table 2).

Table 2 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)	# ABMs with bat activity (% total)	# sites that recorded bat activity (Location)	Mean (±SEM) passes/ABM/night
Gully habitat	4 (21%)	4 (27%)	3 (Witehira Way, Mangaiti Gully, Seeleys Gully)	0.05 ± 0.02
Riparian margins	5 (26%)	5 (33%)	3 (Hammond Park, Horseshoe Lake, Wellington Beach)	18.46 ± 18.41
Urban parklands	9 (48%)	3 (20%)	1 (Lake Rotoroa)	0.62 ± 0.23
Native forest remnants	1 (5%)	3 (20%)	1 (Claudelands Bush)	0.48 ± 0.26
Total	**19**	**15**		

DISCUSSION

Summary of survey findings

This survey has detected bat activity at eight of 19 locations monitored across Hamilton City. Bat activity was detected at Hammond Park, Witehira Way, Seeleys Gully, Horseshoe Lake, Wellington Beach, Claudelands Bush, Lake Rotoroa and Mangaiti Gully. Most long-tailed bat activity was recorded at Hammond Bush, but occasional bat passes were recorded across the city.

The Waikato River and connected gully systems were shown to be an important 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 (including the Waikato River, gully systems and lakes), 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.

Activity of bats was recorded for the first time at Claudelands Bush, Seeleys Gully, Witehira Way and Horseshoe Lake. While activity levels are very low, the survey findings indicate that these areas are used by bats.

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)[2], 2016/17 (Mueller et al. 2017) and 2017/18 (van der Zwan 2018).

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 D: 2011/2012 Bat habitat locations 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, occasional 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 2018 survey detected bat activity at six of 23 locations monitored across Hamilton City. 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 Humarie Park) with occasional bat passes detected further north (Lake Rotoroa and Mangaiti Gully) (van der Zwan 2018). Survey effort in

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[2] 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)

2017/2018 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 probably indicative of very low bat densities in northern Hamilton.

The acoustic surveys between 2011 and 2019 as well as the habitat distribution model results (Appendix G: Habitat prediction model) 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, which was confirmed by the occasional detection of bat activity in those sites in 2016/17, 2017/18 and 2018/19..

A simple comparison of the results of bat monitoring between years shows that Hammond Park has consistently high levels of bat activity across all survey periods (Table 3).

In 2011/12, directional Heterodyne ABMs were used, whereas in all surveys since, 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. However, activity levels recorded at Hammond Bush have been higher in 2018/19 than they have been in any of the previous surveys (Table 3), although surveys were carried out at different times of year making comparisons difficult.

Activity of bats was recorded for the first time at Claudelands Bush, Seeleys Gully, Witehira Way and Horseshoe Lake. While activity levels are very low, the survey findings indicate that these areas are used by bats. This confirms conclusions of the previous survey reports in 2017 and 2018 that bats are utilising the northern areas of Hamilton City, though at this time likely only for commuting and occasional foraging.

Table 3 Comparison of survey results between 2012, 2017, 2018 and 2019.

Site name	Time	Bats	# ABM	ABM with activity	Mean calls / 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
Hammond Bush 2019	February	Y	3	3	55.3
Humarie Park 2011	September	Y	1	1	0.6
Humarie Park 2017	April	Y	2	2	17.5
Humarie 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 Rotoroa 2017	February	Y	5	1	0.02
Lake Rotoroa 2018	January	Y	3	1	0.02
Lake Rotoroa 2019	February	Y	3	3	0.62
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
Mangaiti Gully 2019	February - March	Y	5	2	0.02
Wellington Beach 2011	January	N	3	0	N/A
Wellington Beach 2019	March	Y	1	1	0.07
Horseshoe Lake 2018	January	N	3	0	N/A
Horseshoe Lake 2019	January - February	Y	3	1	0.02

Note that in 2012 directional Heterodyne ABMs were used, whereas in 2017, 2018, and 2019 omni-directional FC ABMs were used which are known to be more sensitive in detecting bat activity. Not all sites were surveyed each survey year. Some data and sites are missing from the 2019 survey results.

Implications for bat management in the city

The results of this survey have showed that bats are distributed throughout Hamilton City, but that most activity is restricted to the southern gully systems and fringes of the city, with low activity levels in the northern areas. 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, to date little is known regarding social groupings of bats in Hamilton, and the linkages of habitat use within the city and the rural fringes, as well as rural areas where bats are present beyond the city fringe. This is particularly the case for the northern and eastern rural fringe areas, and more research is required to explore habitat use alongside population dynamics and social linkages.

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 developments 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(s) that are 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, rats and wasps 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 A: Summary of survey results, Appendix B: Site specific data). This year's survey has confirmed that additionally, bats are also present in the northern areas of the city (including gully systems and lake margins), though lower activity levels indicate that currently habitat utilisation is restricted to commuting and occasional foraging.

Recommendations on future research

The long-tailed bat population within the city is an important ecological feature of Hamilton City, and interactions with Project Echo show that the community is increasingly interested in understanding and protecting Hamilton's bats.

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 bat populations can thrive while urban development continues.

To better understand the effects of development and construction activities on the Hamilton's 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 Hamilton's 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.

If funding can be secured, this annual monitoring should be continued for a minimum of five years (until 2021). The monitoring 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. We suggest that the monitoring sites chosen in this 2018/2019 survey round offer a broad range of sites throughout the city that could be maintained for future survey rounds. Ideally, these sites would be monitored at the same time of year to minimse seasonal variation. Seasonally and spatially consistent monitoring with the same monitoring devices (i.e. AR4 monitors) would ensure more certainty with regards to the tracking of changes in habitat use. 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. As part of the Southern Links development, radio tracking of a small number of bats has led to a better understanding of landscape utilisation and characteristics of trees used for roosting. This research has also proved that artificial roost boxes are used by bats in Hamilton (Borkin 2019).

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. 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 developed by Crewther and Parsons.

REFERENCES

Borkin, K. M. 2019. Statement of Evidence in Chief of Kerry Maree Borkin for the Director-General of Conservation. Submitted in the matter of Application by Weston Lea Limited for land use and subdivision consents for the development of approximately 105 hectares of land at 337 – 461 Peacockes Road, Hamilton, dated 23 April 2019.

Crewther, K and Parsons, S. 2017. Predictive modelling of long-tailed bat distribution in the Hamilton area. Unpublished report prepared for Project Echo by Walkingbats Consultancy, August 2017.

Department of Conservation (DOC) 2016. BatSearch3.11 software. Developed by DOC electronics team

Dekrout, A. 2009. Monitoring New Zealand long-tailed bats (Chalinolobus tuberculatus) in urban habitats: ecology, physiology and genetics. Unpublished PhD thesis, University of Auckland.

Dekrout, A.S., Clarkson, B.D. and Parsons, S. 2014. Temporal and spatial distribution and habitat associations of an urban population of New Zealand long-tailed bats (Chalinolobus tuberculatus). New Zealand Journal of Zoology, 41(4), pp.285-295.

Kessels Ecology. 2016. Hamilton City bat research proposal. Unpublished Letter.

Le Roux, D. and Le Roux, N. 2012. Hamilton City Bat Survey. Unpublished report prepared for Project Echo by Kessels and Associates, Hamilton.

Lloyd, B. 2017. Bat call identification manual for DOC's spectral bat detectors. (Ed. by The Department of Conservation). Wellington, New Zealand.

Meduna, V. 2007. Bats - Bats in New Zealand, Te Ara - the Encyclopedia of New Zealand, http://www.TeAra.govt.nz/en/bats/page-1 (accessed 19 December 2018).

Mueller, H., Livingston, A., and van der Zwan, W. 2016. Tangirau Wetland Ecological Assessment and Restoration Management Plan. Unpublished report prepared by Kessels Ecology for Waikato Regional Council.

Mueller, H., Ulrich, C., Purcell, A. 2017. Hamilton City Long-tailed Bat Survey 2016 – 2017. Client report prepared by Kessels Ecology for Project Echo.

O'Donnell, C.F.J., 2018a. DOC website: https://www.doc.govt.nz/nature/native-animals/bats-pekapeka/how-1080-helps-native-bats/

O'Donnell, C.F.J.; Borkin, K.M.; Christie, J.E.; Lloyd, B.; Parsons, S.; Hitchmough, R.A. 2018: Conservation status of New Zealand bats, 2017. New Zealand Threat Classification Series 21. Department of Conservation, Wellington. 4 p.

O'Donnell, C.F.J., 2000. Influence of season, habitat, temperature, and invertebrate availability on nocturnal activity of the New Zealand long-tailed bat (Chalinolobus tuberculatus). New Zealand Journal of Zoology, 27(3), pp.207-221.

Pryde, M.A., O'Donnell, C.F.J., Barker, R.J. 2005. Factors influencing survival and long-term population viability of New Zealand long-tailed bats (Chalinolobus tuberculatus): Implications for conservation. Biological Conservation, 126, 175-185.

Van der Zwan, W. 2018. Hamilton City Long-tailed Bat Survey, 2017 – 2018. Client report prepared for Project Echo by Tonkin & Taylor Ltd.

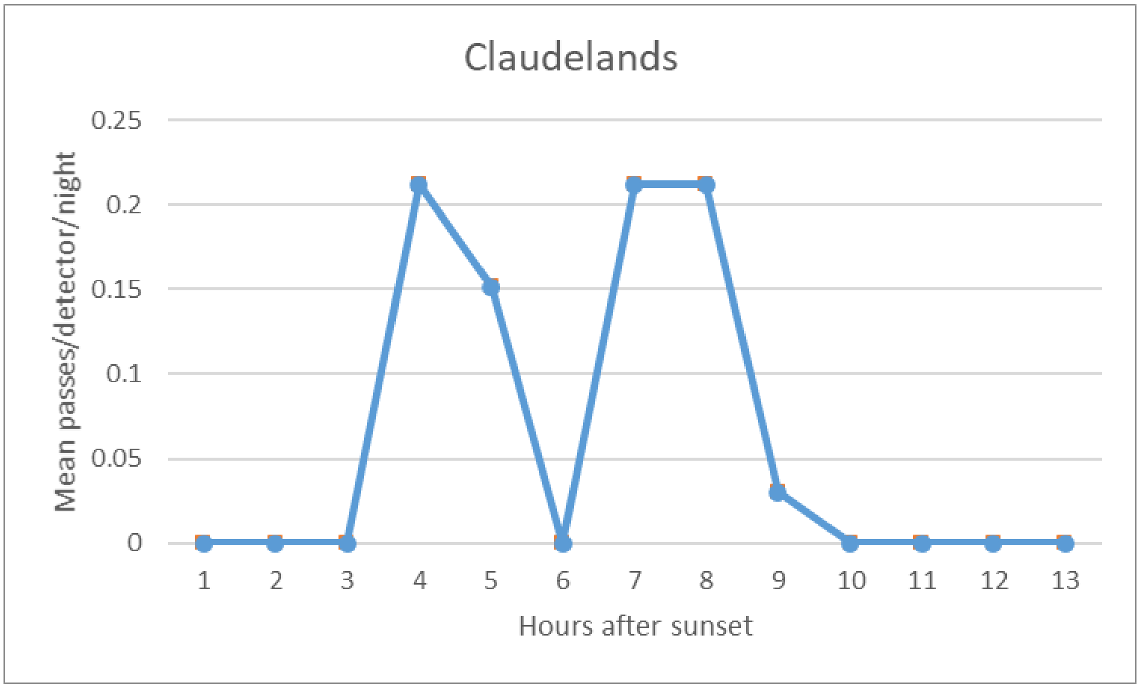
APPENDIX A: SUMMARY OF SURVEY RESULTS

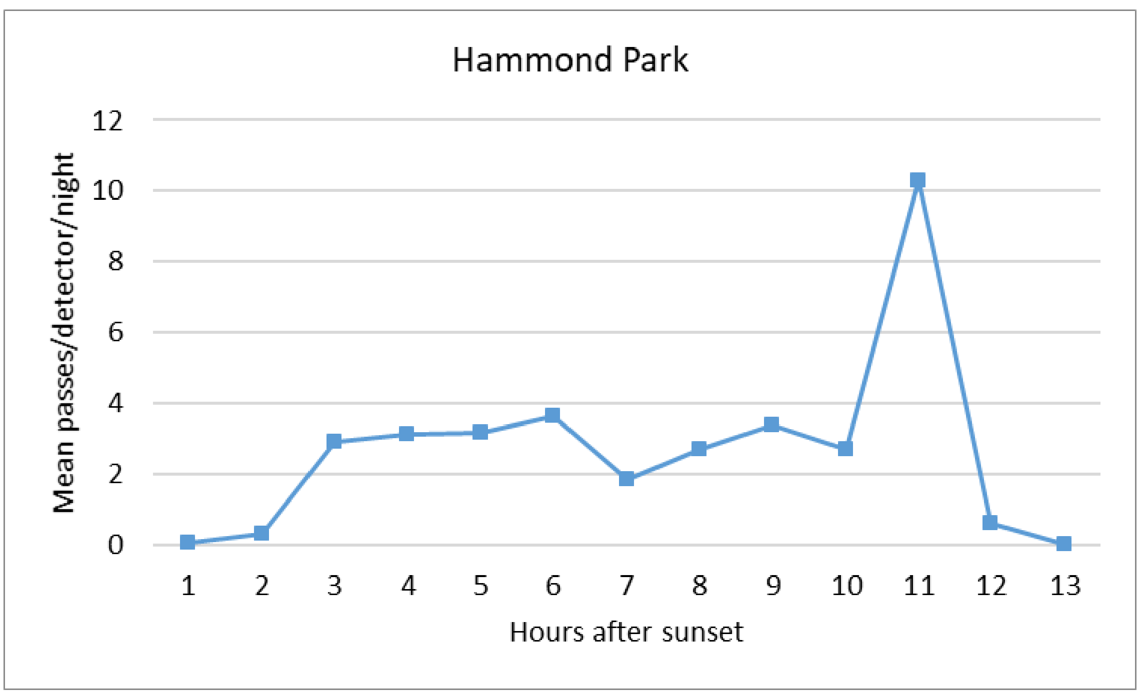
Location	ABM	Latitude (WGS)	Longitude (WGS)	# passes	# surveyed nights	Mean passes/night/ ABM	SEM
Ashley street	Waikato 22	-37.746075	175.25063	0	16	0.00	0.00
	Waikato 32	-37.746417	175.249308	0	16		
	Waikato 33			0	1		
Chartwell Park	Waikato 23	-37.75643	175.269875	0	1	0.00	
Claudelands Bush	Waikato 29	-37.802317	175.244347	4	17	0.48	0.26
	Waikato 30	-37.776612	175.291397	3	15		
	Waikato 39	-37.80229	175.244327	15	15		
Dinsdale road	K4	-37.794907	175.237978	0	15	0.00	0.00
	KS7			0	19		
	TOMII			0	19		
Edgecumbe Park	Waikato 31			0		0.00	0.00
	WEC6			0	28		
	WECA			0	25		
Farnborough	36			0	3	0.00	0.00
	Y			0	1		
	Whaanga 31	-37.779287	175.224845	0	13		
Hammond Park	Whaanga 26	-37.807535	175.317977	278	15	55.28	45.55
	Whaanga 27	-37.809152	175.32487	875	6		
	Whaanga 28	-37.806613	175.320388	19	13		
Horseshoe Lake	Whaanga 30	-37.769692	175.22487	1	17	0.02	0.02
	Whaanga 33	-37.770083	175.227902	0	17		
	Whaanga 39	-37.769535	175.226343	0	17		
Horsham Downs Golf Club	Waikato 21	-37.721168	175.226842	0	3	0.00	0.00
	Waikato 32	-37.718225	175.222577	0	14		
	Waikato 33	-37.71997	175.22517	0	16		
Hutchinson Road	Waikato 20	-37.709437	175.215305	0	2	0.00	0.00
	Waikato 21	-37.708097	175.216107	0	7		
	WEC2			0	14		
Kirikiriroa Gully	Waikato 22	-37.743298	175.275648	0	19	0.00	0.00
	Waikato 32	-37.744803	175.276133	0	16		
	Waikato 33	-37.746592	175.279513	0	2		
Lake Rotoroa	WEC4	-37.795279	175.2769	14	13	0.62	0.23
	Whaanga 35	-37.797498	175.276392	6	13		
	Whaanga 38	-37.796402	175.275985	4	12		
Pukete mountain bike park	Waikato 20	-37.732958	175.23183		20	0.00	0.00

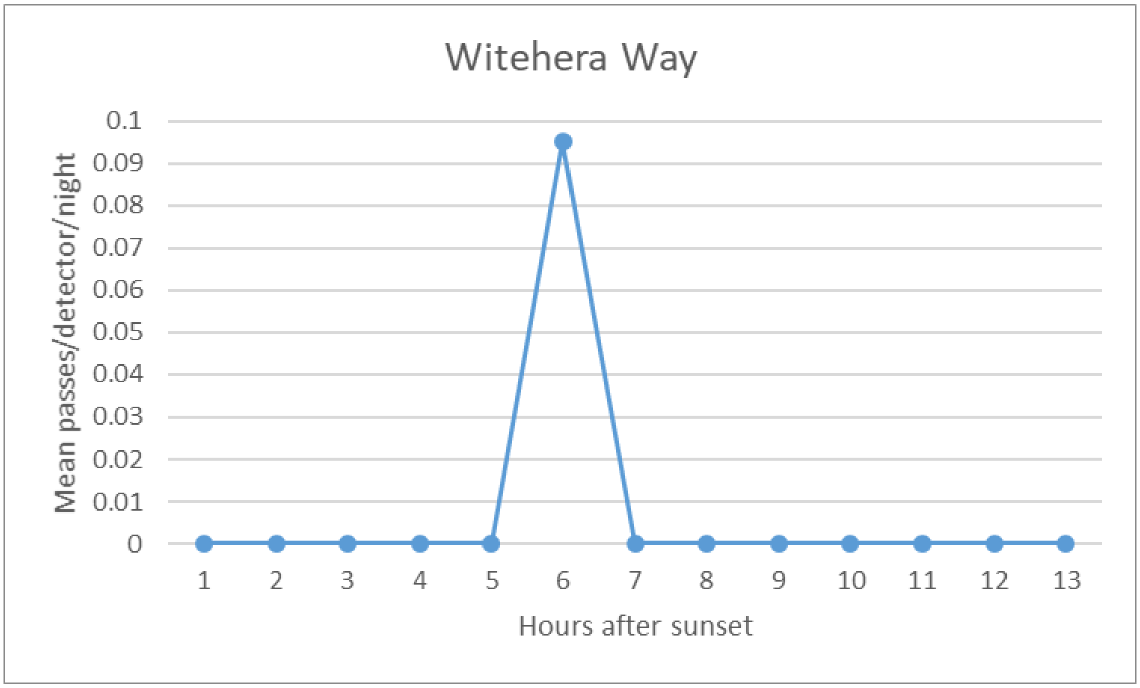
	Waikato 21						
	WEC2				6		
St Andrews Golf course	Waikato 25	-37.751708	175.265345		13	0.00	0.00
	WEC1				3		
	WEC3				1		
Witehira Way	Waikato 20	-37.726742	175.240422		13	0.10	0.10
Witehira Way	Waikato 22	-37.725762	175.239607	4	14		
	WEC2				15		
Mangaiti	WAI25	-37.734237	175.280567	1	14	0.02	0.02
	Waikato 23	-37.739242	175.275997		14		
Mangaiti	Waikato 24	-37.744477	175.265003	1	14		
	Waikato 34	-37.738315	175.279025		14		
	WEC1				15		
	WEC3				15		
Seeleys Gully	WAI23	-37.784578	175.29197	1	15	0.03	0.03
	WEC1				15		
Southwell	WAI24	-37.774137	175.299345		15	0.00	0.00
	WAI34	-37.775197	175.300622		1		
	WEC3				15		
Wellington Beach	Whaanga 28	-37.798632	175.288405	16	23	0.70	0.00

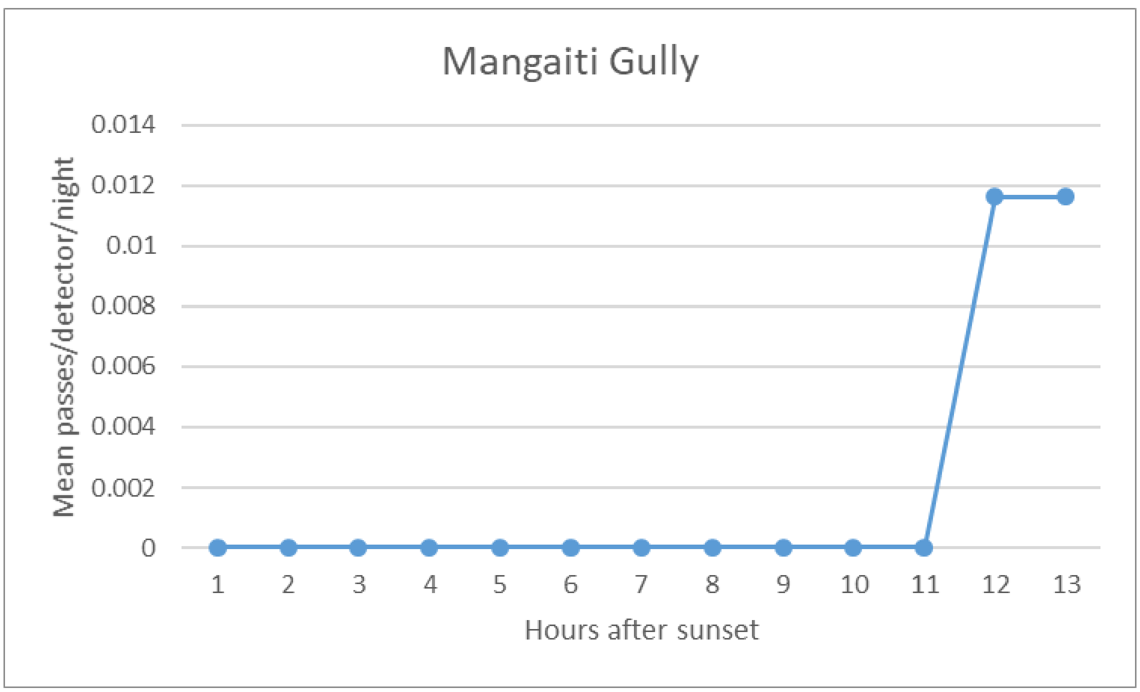
APPENDIX B: SITE SPECIFIC DATA

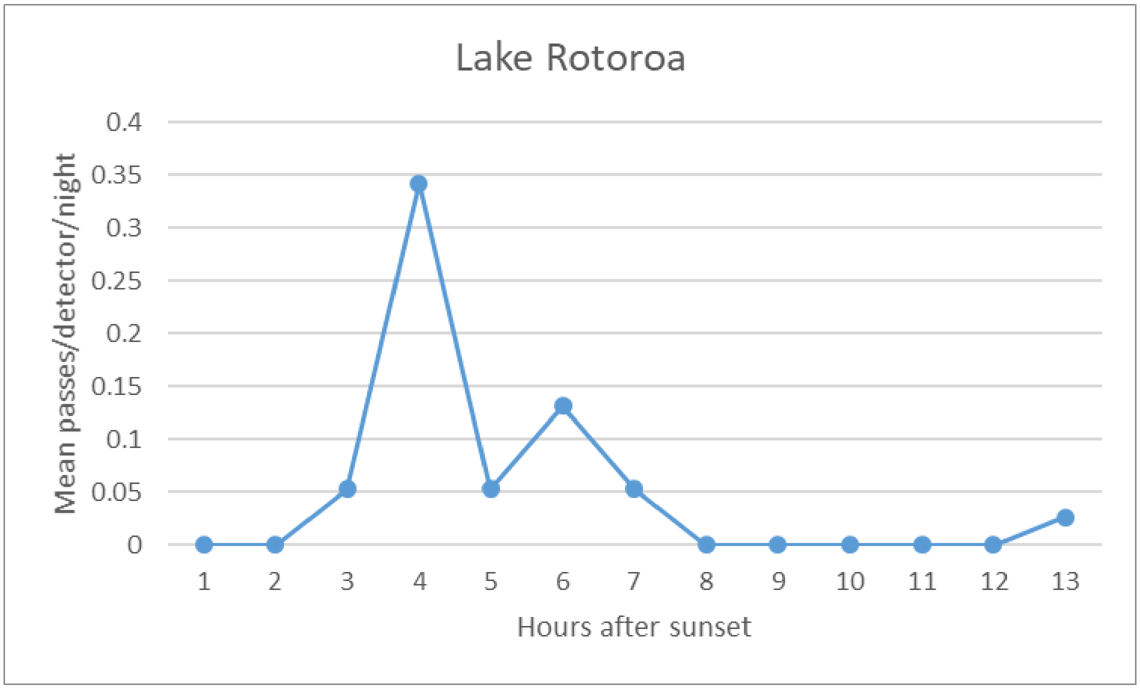
Data based on survey results presented in Appendix A: Summary of survey results, and locations shown in Figure 1.

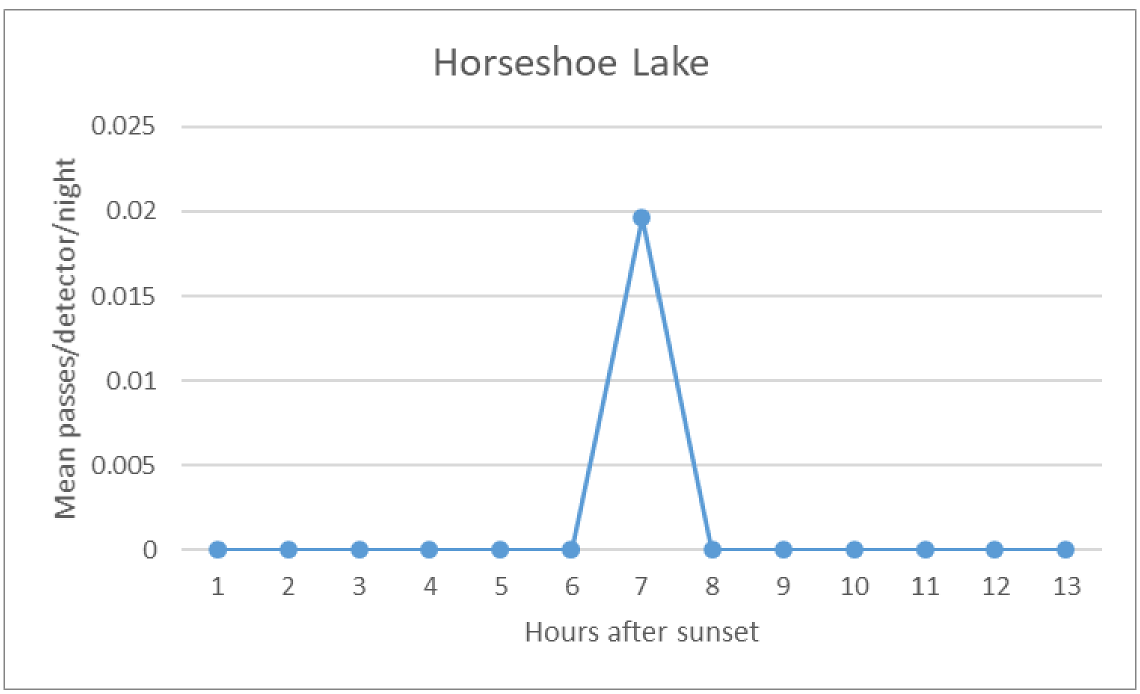


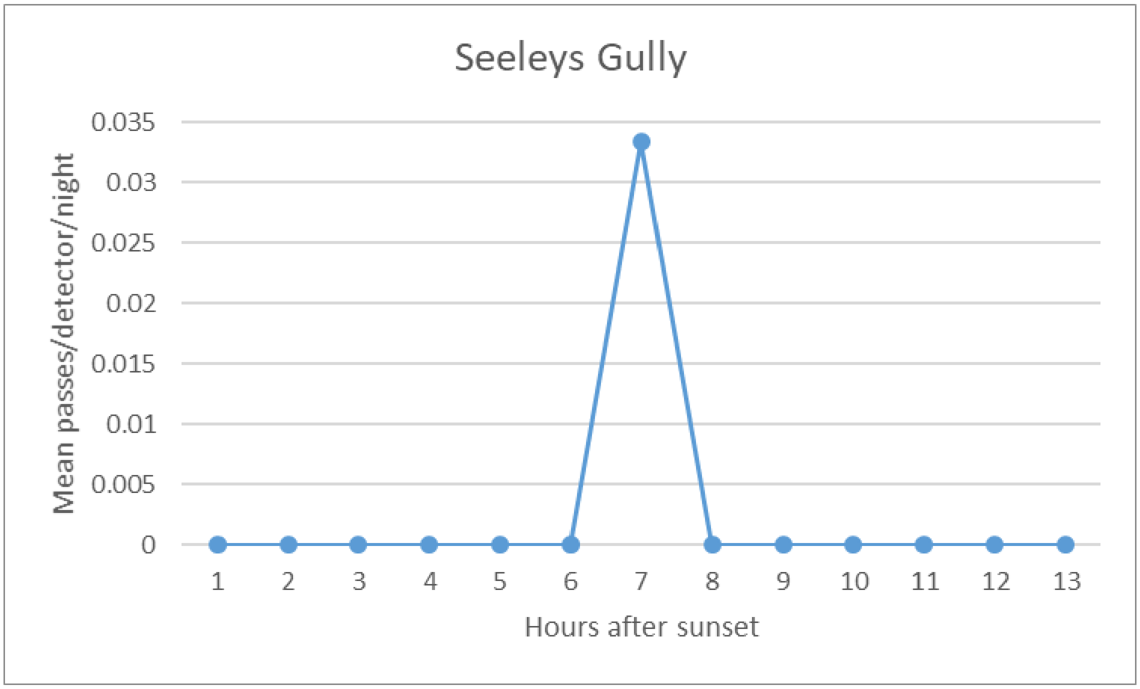


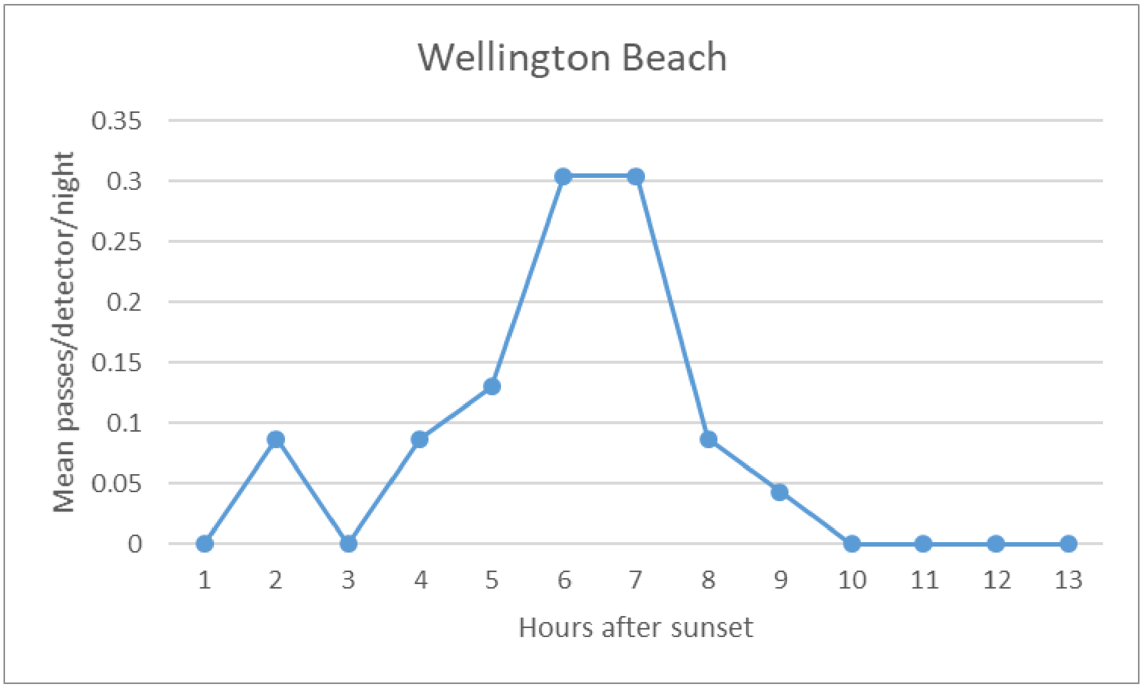

Witehera Way
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Mean passes/detector/night
1
2
3
4
5
6
7
8
9
10
11
12
13
Hours after sunset


Mangaiti Gully
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Mean passes/detector/night
1
2
3
4
5
6
7
8
9
10
11
12
13
Hours after sunset


Lake Rotoroa
Mean passes/detector/night
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Hours after sunset


Horseshoe Lake
Mean passes/detector/night
0.025
0.02
0.015
0.01
0.005
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Hours after sunset


Seeleys Gully
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Mean passes/detector/night
1
2
3
4
5
6
7
8
9
10
11
12
13
Hours after sunset



Wellington Beach
Mean passes/detector/night
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Hours after sunset

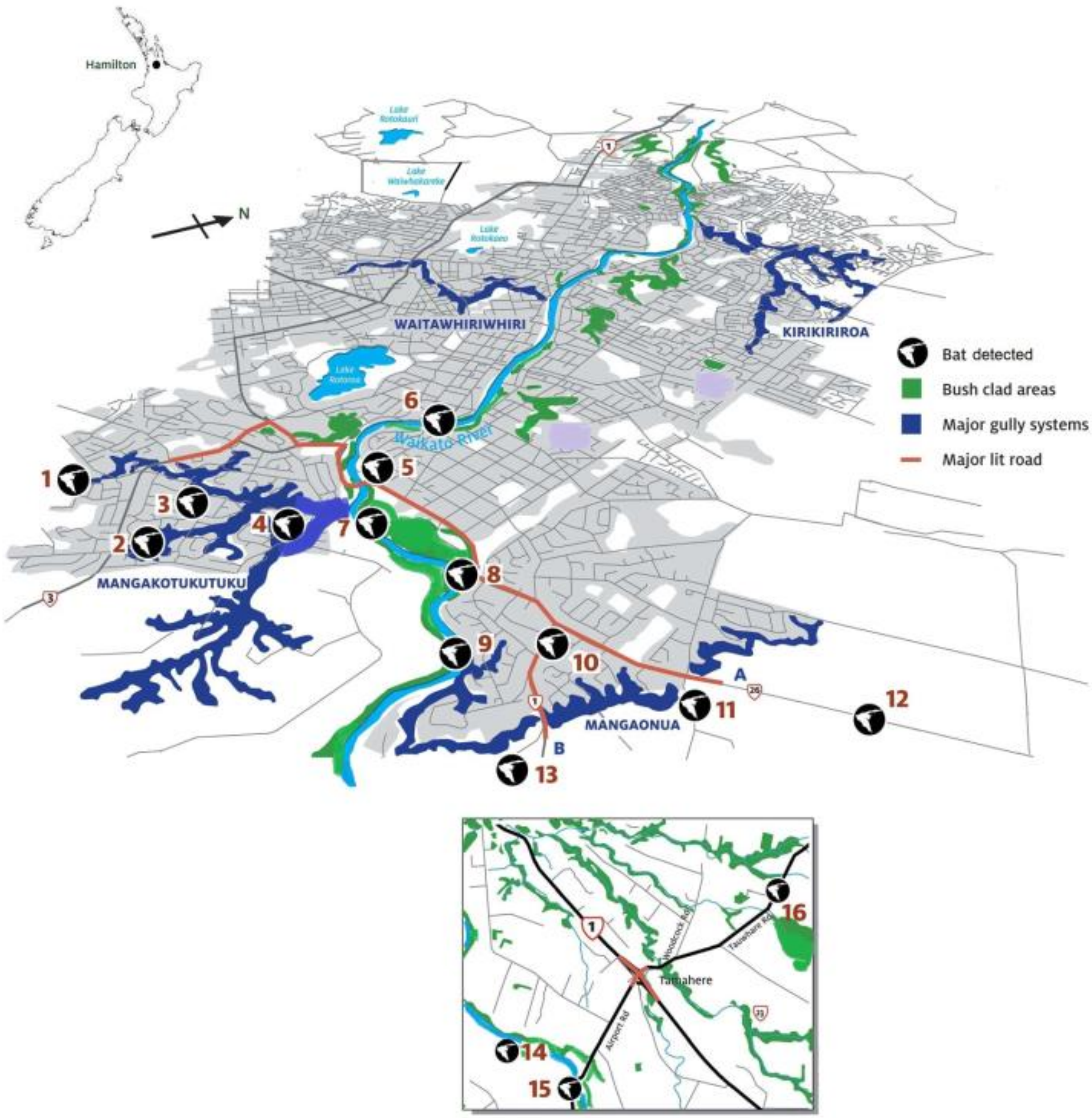
APPENDIX C: WEATHER DATA

Summary of weather conditions after dusk 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 (Ruakura).

Date	Time	Max. temperature	Min. temperature	Precipitation	Max. windspeed
28/01/2019	2100	22.3	20	0	23
29/01/2019	2100	27.6	22.1	0	25.2
30/01/2019	2100	23.8	21.4	0	9.4
31/01/2019	2100	24.3	19.6	0	23
1/02/2019	2100	22.3	19.6	0	19.8
2/02/2019	2100	23.4	21.1	0	11.5
3/02/2019	2100	21.9	19.7	0	19.4
4/02/2019	2100	23.2	20.7	0	20.9
5/02/2019	2100	22.3	19.4	0	20.9
6/02/2019	2100	22.9	20.9	0	23.4
7/02/2019	2100	19.8	17.6	0	12.2
8/02/2019	2100	19.5	16.8	0	12.2
9/02/2019	2100	19.9	17.2	0	13.7
10/02/2019	2100	23.1	20.2	0	10.8
11/02/2019	2100	22	19.1	0	18
12/02/2019	2100	21.9	19.2	0	19.1
13/02/2019	2100	22.1	19.3	0	17.3
14/02/2019	2100	22.9	20	0	18
15/02/2019	2100	20	17.5	0	21.2
16/02/2019	2100	20.8	17.6	0	11.9
17/02/2019	2100	22	19.8	0	10.4
18/02/2019	2100	18.9	16.7	0	19.1
19/02/2019	2100	20.5	17.7	0	10.1
20/02/2019	2100	23.2	20.9	0	13.3
21/02/2019	2100	23.2	20.2	0	11.5
22/02/2019	2100	20.3	18.2	1	13
23/02/2019	2100	18.1	15.7	0	10.4
24/02/2019	2100	17.7	14.4	0	33.1
25/02/2019	2100	16.6	15.5	0	30.6
26/02/2019	2100	17.3	14	0	10.1
27/02/2019	2100	18	17.4	0	14.8
28/02/2019	2100	17.7	16.2	0	11.5
1/03/2019	2100	18	16.9	0	17.3
2/03/2019	2100	18.8	15.2	0	7.9
3/03/2019	2100	20	18.4	0	16.6

4/03/2019	2100	17.1	16.4	0	22
5/03/2019	2100	18.2	17.2	0	19.4
6/03/2019	2100	19.3	17.5	0	9.4
7/03/2019	2100	21.1	20.5	0	9.4
8/03/2019	2100	15.3	15	0.4	15.1
9/03/2019	2100	14	12.6	0	3.2
10/03/2019	2100	20	18.5	0	11.5
11/03/2019	2100	18.6	17.8	0	11.5
12/03/2019	2100	19.1	16.2	0	7.9
13/03/2019	2100	20.9	20.2	0	10.8
14/03/2019	2100	20.8	19.6	0	10.8
15/03/2019	2100	19.9	19.3	0	16.2
16/03/2019	2100	20.9	19	0	9
17/03/2019	2100	22	21.4	0	11.2
18/03/2019	2100	20.3	19.5	0	6.5
19/03/2019	2100	19.4	19	0	18.7
20/03/2019	2100	18.9	17	0	6.8
21/03/2019	2100	19.7	18.4	0	4.7
22/03/2019	2100	19.3	16.8	0	7.2
23/03/2019	2100	17	15.8	0	10.1
24/03/2019	2100	18.8	17.9	0	13.7
25/03/2019	2100	18.4	16.8	0	11.9
26/03/2019	2100	17.8	16.6	0	14.4
27/03/2019	2100	18.9	18.4	0	7.9
28/03/2019	2100	17.3	17.1	0	20.9
29/03/2019	2100	19.5	19.3	0	3.6
30/03/2019	2100	18.1	17	0	15.5
31/03/2019	2100	19	18.3	0	10.8
1/04/2019	2100	19.1	18.4	0	11.2
2/04/2019	2100	15.4	14.8	0	7.2
3/04/2019	2100	16.1	15.7	0	8.3
4/04/2019	2100	15.2	13.3	0	5
5/04/2019	2100	15	14.6	0	13
6/04/2019	2100	14.6	13	0	8.3
7/04/2019	2100	11.6	10.2	0	19.8
8/04/2019	2100	15.5	14.4	0	5.4
9/04/2019	2100	12.6	11	0	13
10/04/2019	2100	17.6	16.6	0	25.2
11/04/2019	2100	12.1	11.7	3.2	13.7
12/04/2019	2100	15.4	14.6	0	9.4

APPENDIX D: 2011/2012 BAT HABITAT LOCATIONS

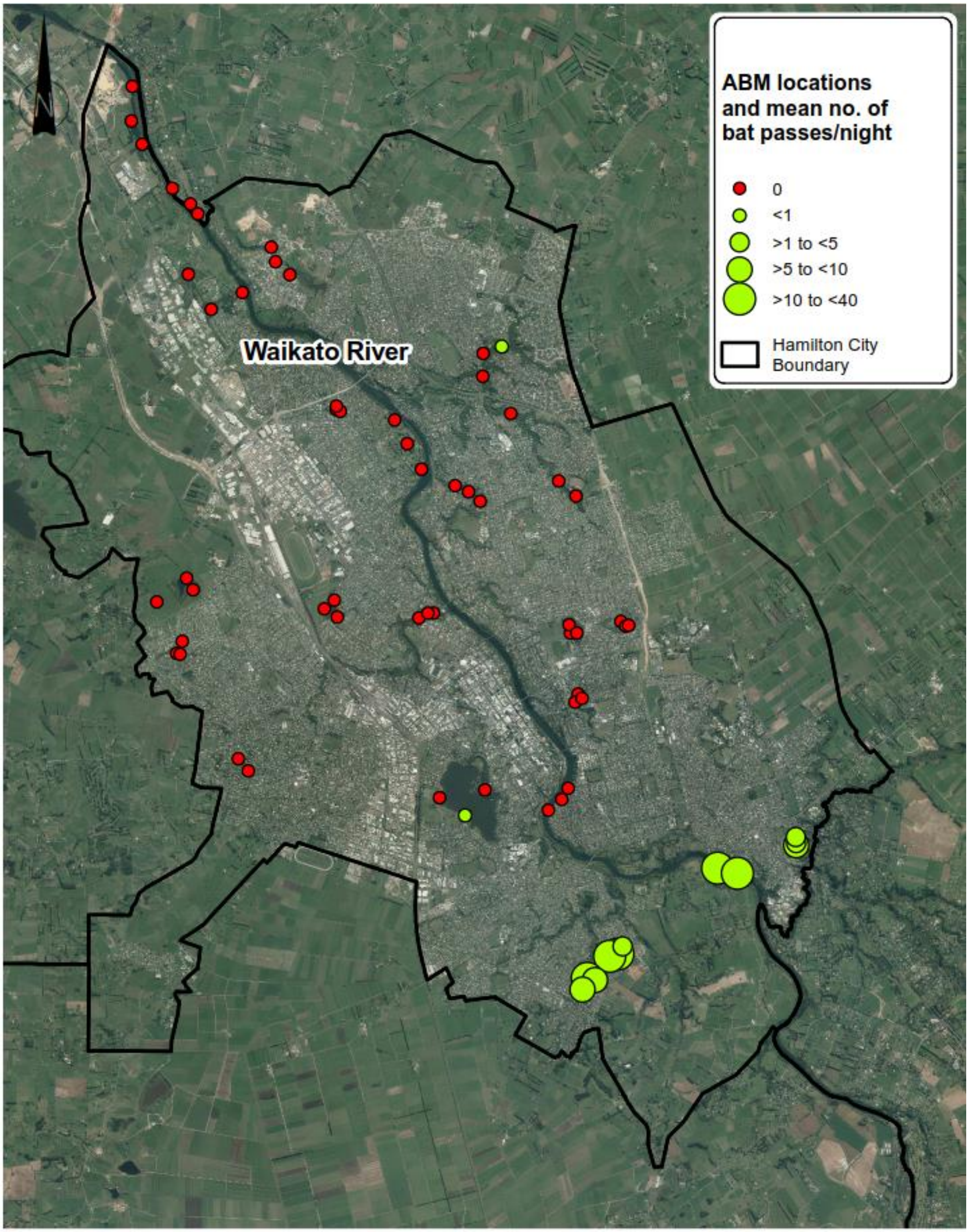


Le Roux and Le Roux, 2012

APPENDIX E: SURVEY LOCATIONS AND RESULTS, 2017

Mueller et al. 2017

APPENDIX F: SURVEY LOCATIONS AND RESULTS, 2018



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

Van der Zwan 2018

APPENDIX G: HABITAT PREDICTION MODEL

Mueller et al. 2017, Crewther and Parsons 2017