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HAMILTON CITY LONG-TAILED BAT SURVEY

For Project Echo

Annual Monitoring Report 2020

November 2020

REPORT INFORMATION AND QUALITY CONTROL

Prepared for:	Project Echo

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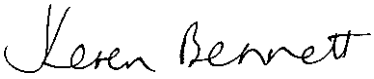
Approved for Release:	Keren Bennett Principal Ecology Consultant	

Document Name	AA6659_Project Echo_Hamilton City Wide Bat Research_Annual Report 2020_v1.2

Version History:	V1.1	20 October 2020
	V1.2	17 November 2020 Revisions of referencing following Waka Kotahi/HCC feedback

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1 ACKNOWLEDGEMENTS

Project Echo would like to thank the Department of Conservation, Waikato Regional Council and Hamilton City Council for funding this project. Thank you to University of Waikato staff and students, in particular Dr Grant Tempero, Titia Schamhart, and Aimee O'Sullivan for extensive assistance with bat monitor deployment and data analysis. The Davidson Watts (2019) report resulted from work commissioned by Hamilton City Council and Waka Kotahi (New Zealand Transport Agency) and is referenced with their permission.

Thank you to Kate Richardson from Waikato Regional Council for peer reviewing this report and adding valuable comments where required.

We would like to thank all involved volunteers for making the survey possible, and thanks to the Waikato Environment Centre/Go Eco for organising and hosting us during monitor deployment, and lending equipment.

2 INTRODUCTION

2.1 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.

Project Echo, a multi-agency advocacy group for Hamilton City bats, commenced this long-term bat research project in 2016. The purpose of this project was to identify, map and track changes in bat habitat use through bio-acoustic surveys. The 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, until at least 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 to 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 bat habitat is present, e.g. the Waikato Expressway that crosses the Mangaonua, Mangaone, and Mangaharakeke gully systems, and the urban development underway in southern Hamilton linked to the Peacocke Structure Plan (Hamilton City Council 2007).

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.

2.2 Report objectives

This report details the findings of the 2020 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 at locations that have been monitored throughout this ongoing survey effort.

This report covers details of the monitoring programme and survey methodology, survey results (such as activity levels and key bat areas), 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, distribution, and activity levels. Comparison to previous survey results also can indicate 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).
- Ongoing monitoring for the 2017/2018 monitoring season (van der Zwan 2018).
- The latest monitoring report for the 2018/2019 season (van der Zwan and Mueller 2019).

2.3 Study area

Hamilton City is New Zealand's fourth most densely populated city in New Zealand with approximately 169,000 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.

Prior to European arrival, Hamilton and its surrounding areas were characterised by low-lying wetlands and swamp areas, with 30 small lakes connected to surrounding peatlands. Hamilton was surrounded by 7 large peat bogs such as Komakorau to the North and Rukuhia and Moanatuatua to the South, as well as many smaller bogs, all of which have now been drained with only small remnants remaining. The total area of peat bog was about 655 km^2.

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 within the urban footprint of 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).

3 METHODOLOGY

3.1 Bioacoustics bat monitoring

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 that have been monitored consistently since the 2017/2018 annual survey, targeting known or likely bat habitat. The recordings were analysed visually using BatSearch3.12 software (developed by DOC 2016) in accordance with protocols described by Lloyd (2017).

3.2 Survey locations

A total of 77 ABMs were deployed in 26 locations between 25 February and 19 March 2020 (Figure 1). The survey locations were chosen based on results from previous monitoring surveys as part of this project (van der Zwan and Mueller 2019, 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.

Bats are known to roost in Hammond Park (Dekrout et al. 2014, Davidson Watts 2019) and Sandford Park using artificial roost boxes (Davidson Watts 2019). During this year's survey, Sandford Park was monitored for the first time since the start of this study. At least one ABM was placed in close vicinity to an artificial roost box known to be utilised on a regular basis by bats. Chelmsford Park was surveyed for the first time as well during this survey.

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.

All echolocation pulses were recorded with a date (day/month/year) and time (hour/minute/second) stamp. By assessing the amount of nightly echolocation activity, an indication of levels of bat activity within each surveyed locality was used as a relative comparison in activity between different survey sites.

3.3 Bat monitor deployment

The 26 survey sites were monitored concurrently over a period of just over three weeks between 25 February and 19 March 2020. One ABM failed to record, while a second ABM was lost during the survey period. An increase in available monitoring equipment to this research means that from this current survey onwards, all sites can be monitored concurrently rather than successively as done in previous monitoring rounds. From this 2020 monitoring round onwards, all sites will be monitored at the same time as well as at the same time of year to improve the comparability of activity recorded between years.

Survey duration of each site ranged from 14 to 22 consecutive nights. The average number of nights surveys across all sites was 21. This amounted to a total of approximately 19,000 hours of monitoring over 1575 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 entire survey period were optimal for bat emergence, as temperatures remained well 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 0.2 mm at dusk. Wind speeds were low to moderate at dusk on all nights with an average windspeed of 6 km/hr across the survey period. A summary of weather conditions is shown in Appendix A: which presents data obtained from NIWA Ruakura EWS weather station, ID 2852.

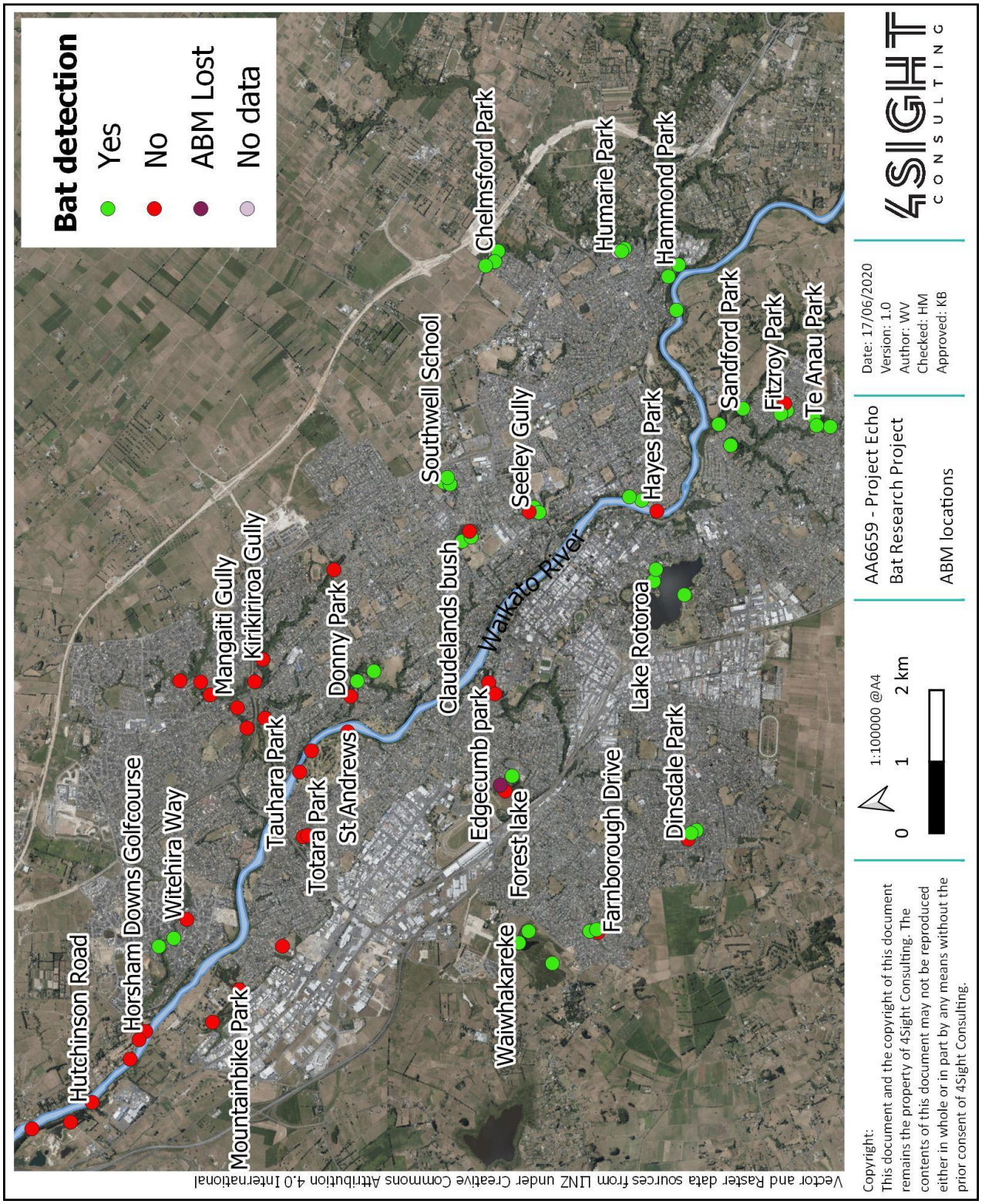


Figure 1. Bat detection shown for the surveyed ABM locations

4 RESULTS

4.1 Bat activity levels

A total of 20245 echolocation passes were recorded from 17 locations (65% of all surveyed locations) comprising 40 of the overall 75 ABMs deployed (Figure 1). One ABM failed to record during the survey period (Humarie Park), while another ABM was lost (Forest Lake).

Of the 17 locations with bat activity Sandford Park was characterised by the highest overall mean bat activity with on average, 217.8 bat passes/detector/night (217.8 ± 166.0 SE) (Table 1).

Other locations with high levels of bat activity detected were all concentrated in the southern gully systems. Average bat passes/detector/night in Hammond Park (54.4 ± 31.2 SE), Fitzroy Park (33.3 ± 19.1 SE), and Te Anau Park (12.3 ± 4.4 SE) had the next three highest average levels of bat activity detected during this year's survey. Humarie Park, located northeast of Hammond Park recorded an average bat passes/detector/night of 1.6 ± 1.5 SE) (Table 1).

The remainder of the surveyed locations showed activity levels below 1.0 mean bat passes/detector/night (Table 1).

Nine of the surveyed locations recorded zero bat passes during this year's survey.

Site specific data per site is presented in Appendix B:.

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

Location	Mean No. passes/night/ABM	SEM	Habitat Type
Chelmsford Park	0.92	0.37	Urban gully habitat
Claudelands Bush	0.09	0.05	Urban native forest remnant
Dinsdale Park	0.03	0.02	Urban parkland
Donny Park	0.03	0.02	Urban gully habitat
Farnborough Drive	0.03	0.02	Urban native forest remnant
Fitzroy Park	33.33	19.07	Urban gully habitat
Forest Lake	0.02	0.02	Urban parkland
Hammond Park	54.37	31.16	Urban riparian margin habitat
Hayes Park	0.27	0.18	Urban riparian margin habitat
Humarie Park	1.57	1.48	Urban gully habitat
Lake Rotoroa	0.87	0.37	Urban parkland
Sandford Park	217.76	166.04	Urban gully habitat
Seeley Gully	0.03	0.02	Urban gully habitat
Southwell School	0.10	0.02	Urban parkland
Te Anau Park	12.32	4.43	Urban gully habitat
Waiwhakareke	0.12	0.04	Peri-urban native forest remnant
Witehira Way	0.03	0.02	Urban gully habitat

4.2 Bat detections across Hamilton City

Bats were detected throughout Hamilton City, with highest levels of activity in the southern parts of the city, smaller hotspots of activity in the central and western parts of the city, and occasional bat detections in the northern parts of the city (Figure 2).

Habitats in those different parts of the city include gully habitats, riparian margins along the Waikato River, urban parks, and native forest remnants.

Gully habitats exist throughout the city, largely connected in the southern parts of Hamilton City where the Mangaonua, Mangaone, and Mangaharakeke gully systems are largely still connected (Chelmsford Park, Humarie Park, Sandford Park, Seeley Gully, Fitzroy Park, and Te Anau Park). Gully habitats in the northern parts of the city (Donny Park and Witehira Way) and are set in a more densely populated setting.

Bat activity was detected at riparian margins along the Waikato River in the southern parts of the city (Hammond Park and Hayes Park), while no bat activity was detected further north along the Waikato River margins.

Urban parkland habitats are present in the central parts of the city on either side of the Waikato River at Lake Rotoroa, Forest Lake, Southwell School, and Dinsdale Park to the west.

Native forest remnants are scarce throughout Hamilton City, but bat activity was detected at Farnborough Drive and Waiwhakareke to the west of the city, and at Claudelands Bush in the central part of the city.

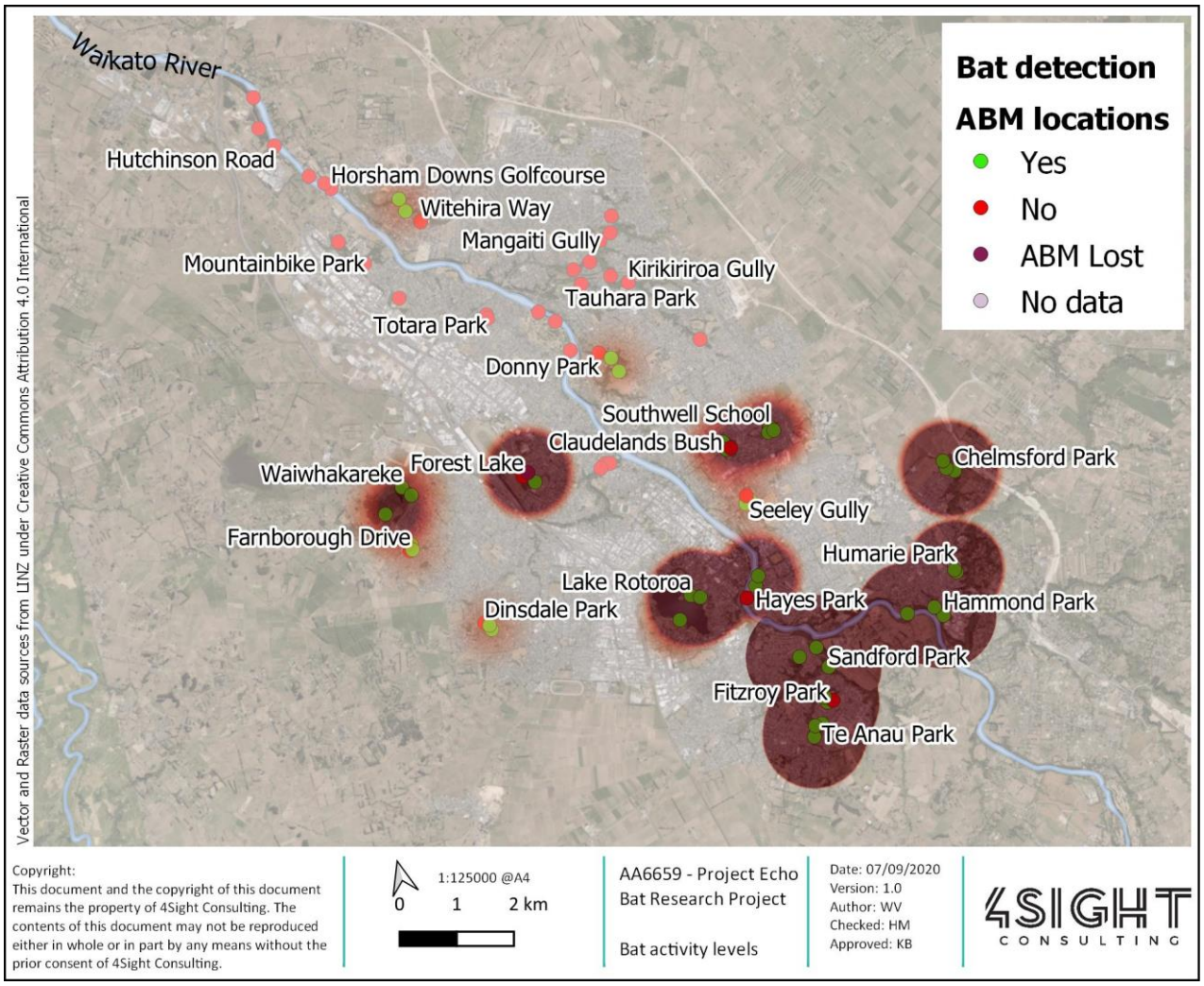


Figure 2. Heatmap showing levels of bat activity throughout Hamilton city

5 DISCUSSION

5.1 Summary of findings

This survey season has detected bat activity at 17 locations across Hamilton City. Bat activity was detected at Chelmsford Park, Claudelands Bush, Dinsdale Park, Donny Park, Farnborough Drive, Fitzroy Park, Forest Lake, Hammond Park, Hayes Park, Humarie Park, Lake Rotoroa, Sandford Park, Seeley Gully, Southwell School, Te Anau Park, Waiwhakareke, and at Witehira Way. Highest levels of bat activity were detected within the southern gully habitats, particularly within Sandford Park. Smaller hotspots of activity were recorded in the central and western parts of the city and occasional bat passes were recorded at the northern survey sites.

Donny Park, Dinsdale Park, Farnborough Park, and Southwell School detected bats for the first time during this seasons survey.

Sandford Park and Chelmsford were surveyed for the first time this survey season, and both locations detected bat activity.

5.2 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), 2016/17 (Mueller et al. 2017), 2017/18 (van der Zwan 2018), and in 2018/19 (van der Zwan and Mueller 2019).

In 2017, the first round of annual surveys of the Project Echo city wide bat survey project were conducted. 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 Forest Lake and Lake Rotoroa). None of the other survey locations further north and east detected bat activity. The results of the 2016/17 survey confirmed findings of the 2011/2012 study (Le Roux and Le Roux 2012) that the southern gully systems and riparian margins within Hamilton are important areas for bats (Appendix C:).

The 2017/18 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 2017/18 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 recorded in the southern fringes of the city, occasional bat passes were also detected at new locations further north and east (Lake Rotoroa and Mangaiti Gully) (Appendix C:).

In 2019, while not all locations were surveyed, eight locations detected bats across Hamilton City, with the highest levels of activity detected in Hammond Park along the Waikato River. Activity of bats was recorded for the first time within Claudelands Bush, Seeley Gully, Witehira Way, and at Waiwhakareke/Horseshoe Lake. While activity levels were very low in the central, northern, and western parts of the city, the survey findings indicate that these areas are used by bats (Appendix C:).

The acoustic surveys between 2011 and 2020 confirmed that highest levels of bat activity are consistently recorded in the southern gully systems and riparian margins of the city, but that bat activity is detected throughout the city. An increased number of bat passes has been recorded over the last few years in the central and northern parts of the city with activity recorded in western parks for the first time in 2020 (Appendix C:).

A direct comparison between different survey years is not easily made, as 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. Additionally, the time of survey and associated weather conditions was not consistent through the different survey years.

5.3 The importance of bat management in the city

The results of this survey and previous years have showed that bats are distributed throughout Hamilton City, but that highest levels of activity are recorded in the southern gully systems and river margins of the city, with low activity levels throughout the rest of the city. While the monitoring conducted so far has not directly studied the impacts of urban development on bats, higher levels of bat activity in the southern fringes of the city may indicate that bat activity is higher where less urban development exists.

To date little is known regarding social groupings of bats in Hamilton as well as rural areas where bats are known to be present beyond the city fringe. Uncertainties exist around the linkages of habitat use within the city and the rural fringes, although it is known from radio-tracking studies that the bats using the southern parts of the city are part of the same social group as bats in the rural fringes of southern Hamilton towards Mystery Creek (Davidson Watts 2019). Less is known about the bats in the northern, western, and eastern rural fringe areas (although a recent student project confirmed bats as present in these rural fringes; Dixon 2020). More research is required to explore habitat use alongside population dynamics and social linkages.

Significant development has commenced in the southern parts of the city, as well as ongoing urbanisation throughout the rest of the city. Some of the larger scale projects in the southern parts of the city include 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 affect 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 cumulative effects on bat populations are currently poorly understood.

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.

While the scale of the effect of ongoing urban developments in the city 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.

5.4 Recommendations and 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.

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. The purpose of this ongoing research project is to contribute to an aspect of the understanding by monitoring activity levels and habitat use throughout the city over the long term.

If funding can be secured, annual monitoring should be continued for a minimum of five years. 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.

An increase in available monitoring equipment to this research means that from this current survey onwards, all sites can be monitored concurrently rather than successively as was done in previous monitoring rounds. Monitoring undertaken at the same time as well as at the same time of year will improve the comparability of activity recorded between years.

Seasonal 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 possible effects associated with ongoing urban development on activity levels and distribution.

The findings of this annual monitoring programme can be used to help 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. Currently, DOC are working on updating the habitat model developed by Crewther and Parsons (2017) for the Waikato Region using the National Database for bats (administered by DOC). Data from the annual surveys and any further data sources are continuously added to this database.

Many questions remain regarding the future of bats persisting in the city, and more progress on the ground is required on 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.

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 further 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 an increased level of understanding of landscape utilisation and characteristics of trees used for roosting within the southern parts of the city and its fringes (Davidson Watts 2019). This research has also shown that artificial roost boxes are used by bats in Hamilton.

In New Zealand, development projects and their associated environmental impact assessments are generally approved at the local government level. Even when decisions are made at the national level, regional and local planning instruments play an important role in decisions on whether to approve projects and the level of mitigation required. This leads to both regulators and development agencies assessing and managing impacts on a case by case basis resulting in a range of outcomes. The development of a nationally accepted framework for studying and developing management strategies would be highly recommended for reducing or mitigating the impact of urban developments on bats.

6 REFERENCES

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.

Davidson-Watts 2019. Long-tailed bat trapping and radio tracking, baseline report 2018 and 2019 Southern Links, Hamilton. Report prepared for AECOM by Davidson-Watts Ecology (Pacific) Ltd.

Department of Conservation (DOC) 2016. BatSearch3.12 software. Developed by DOC electronics team.

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.

Dixon, O. 2020. Spatial distribution survey of long-tailed bats (Chalinolobus tuberculatus) north of Hamilton City. Prepared for Waikato Regional Council. Prepared by School of Sciences, University of Waikato.

Hamilton City Council 2007. Peacocke Structure Plan. Prepared by Hamilton City Council, July 2007. https://www.hamilton.govt.nz/our-council/council-publications/operativedistrictplan/Documents/Variations/Variation%2014/Microsoft_Word_-_Peacocke_Structure_Plan_2007.pdf

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.

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.

Van der Zwan, W. and Mueller, H. 2019. Hamilton City Long-tailed Bat Survey, 2018-2019. Annual Monitoring Report prepared for Project Echo.

Appendix A:

Weather Data

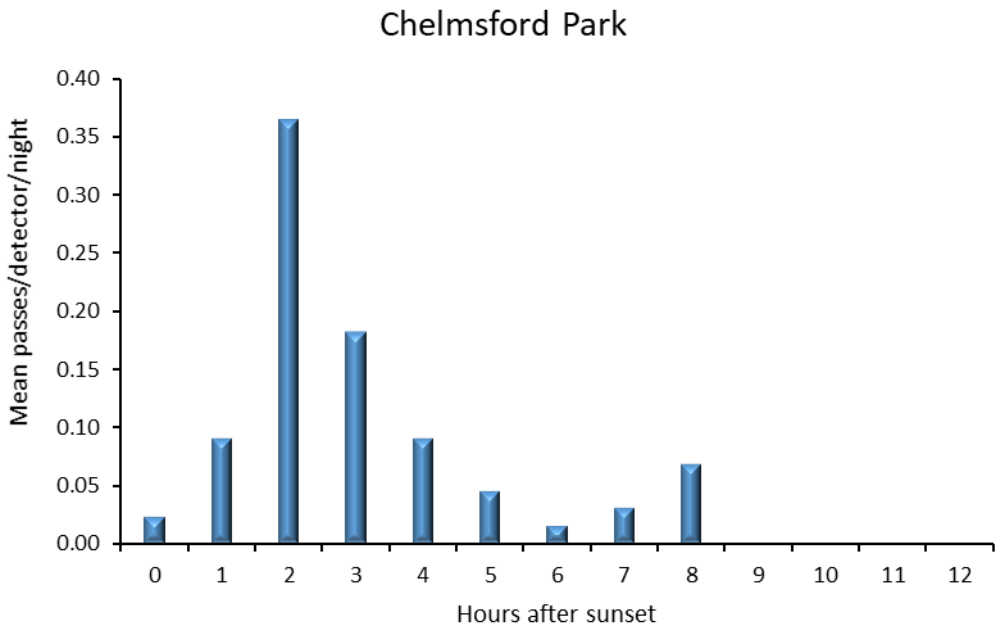
Summary of weather conditions at dusk during the survey period. Data obtained from NIWA weather station: Ruakura EWS, ID 2852.

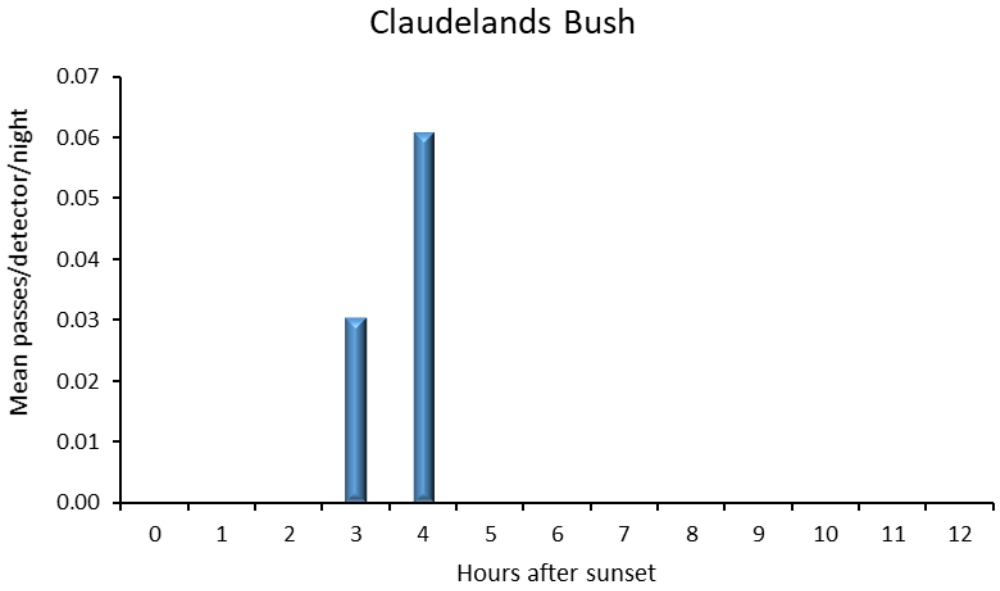
Date	Time	Wind Speed (AVG) (km/hr)	Wind Gust (MAX) (km/hr)	Air Temp. (MAX) (°C)	Air Temp. (MIN) (°C)	Rainfall (TOT) (mm)
25/02/2020	20:00:00	9.36	21.6	22.6	19.4	0
26/02/2020	20:00:00	10.08	19.44	22.3	19.8	0
27/02/2020	20:00:00	7.92	22.32	24.2	21.4	0
28/02/2020	20:00:00	7.92	17.64	24.1	21.4	0
29/02/2020	20:00:00	7.2	21.6	21	18.5	0
1/03/2020	20:00:00	7.92	23.76	23.6	20.2	0
2/03/2020	20:00:00	11.52	14.76	21.1	17.9	0
3/03/2020	20:00:00	5.76	8.64	23.8	20.7	0
4/03/2020	20:00:00	5.04	19.8	22.4	19.8	0
5/03/2020	20:00:00	7.56	18	20.9	17.8	0
6/03/2020	20:00:00	5.76	11.88	20.3	18.1	0
7/03/2020	20:00:00	8.64	13.68	20.6	17.7	0
8/03/2020	20:00:00	1.8	15.12	21.8	19.1	0
9/03/2020	20:00:00	4.32	14.76	19.6	17.3	0.2
10/03/2020	20:00:00	5.76	16.2	18.5	16.2	0
11/03/2020	20:00:00	7.2	18	19.7	17.1	0
12/03/2020	20:00:00	7.2	15.12	18.8	16.2	0
13/03/2020	20:00:00	1.08	9.72	18.2	14.5	0
14/03/2020	20:00:00	1.44	17.64	20.7	17.2	0
15/03/2020	20:00:00	3.96	13.68	20.4	16.8	0
16/03/2020	20:00:00	1.8	6.12	20	17	0
17/03/2020	20:00:00	6.84	27.36	16.8	14.5	0
18/03/2020	20:00:00	7.92	18.72	16.6	13.8	0

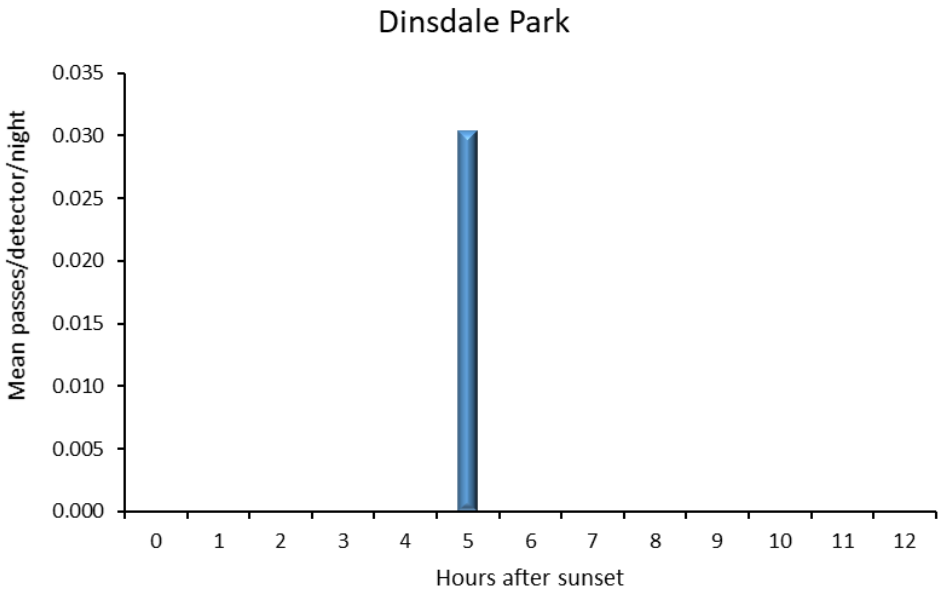
Appendix B:

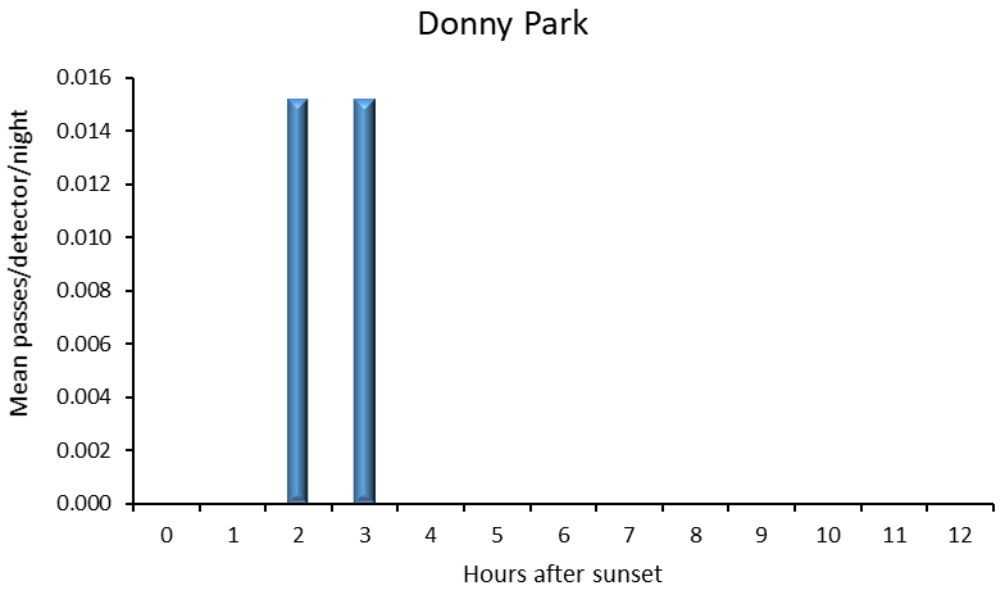
Site specific data

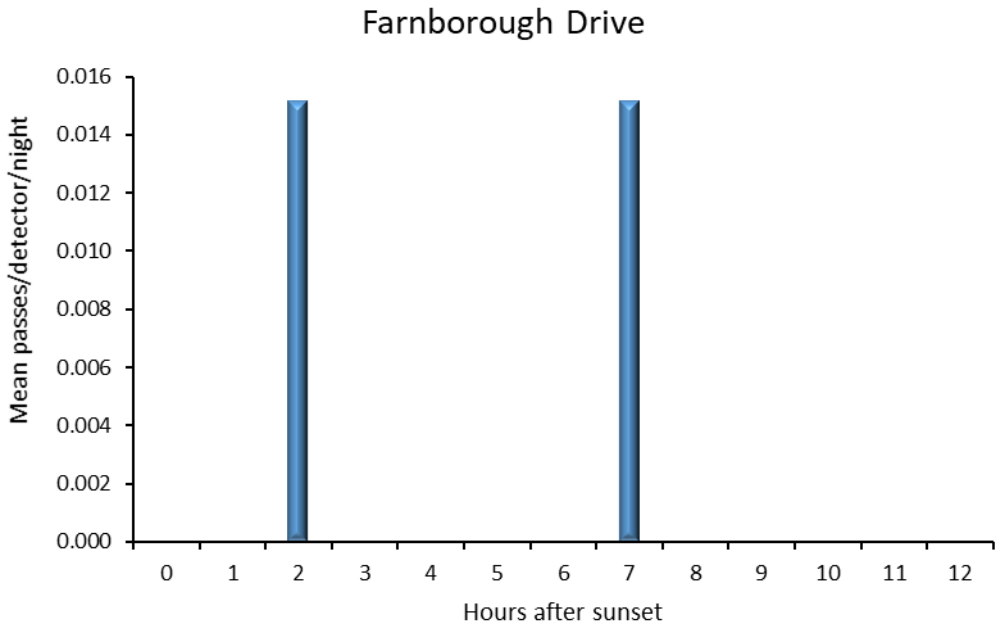
Survey results per surveyed location that recorded bat activity.

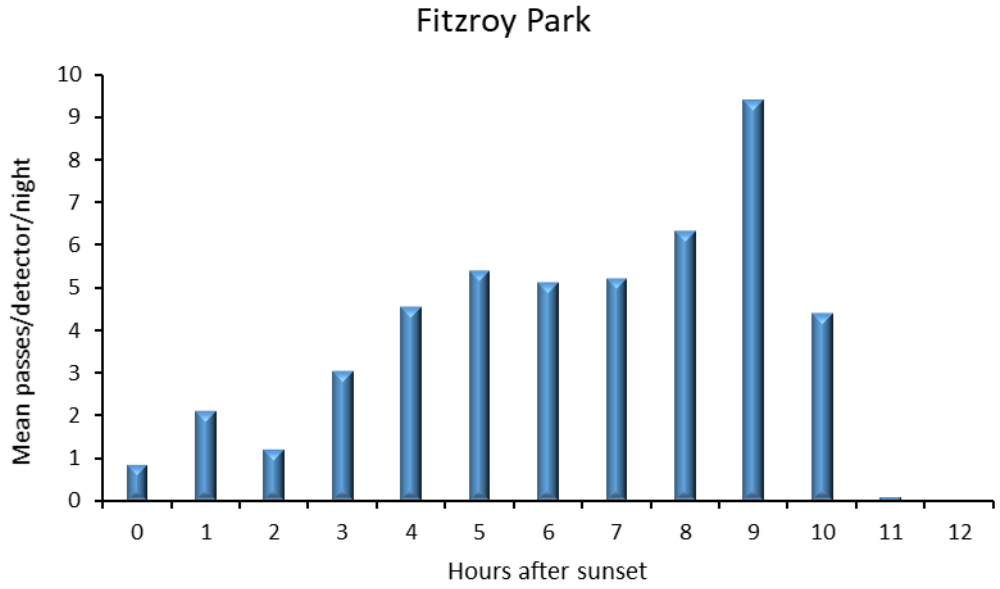

Chelmsford Park
Mean passes/detector/night
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours after sunset

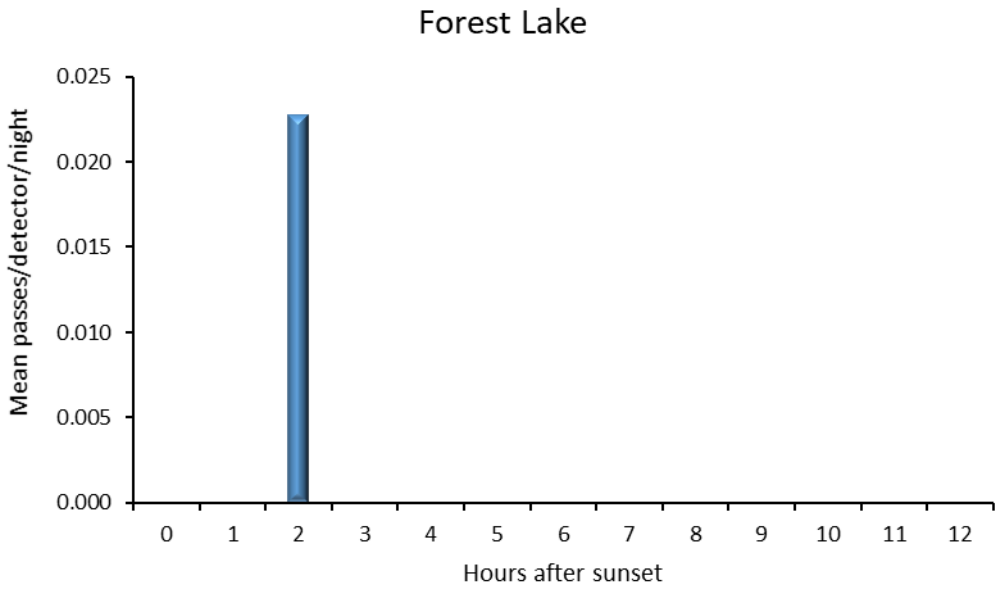

Claudelands Bush
Mean passes/detector/night
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours after sunset

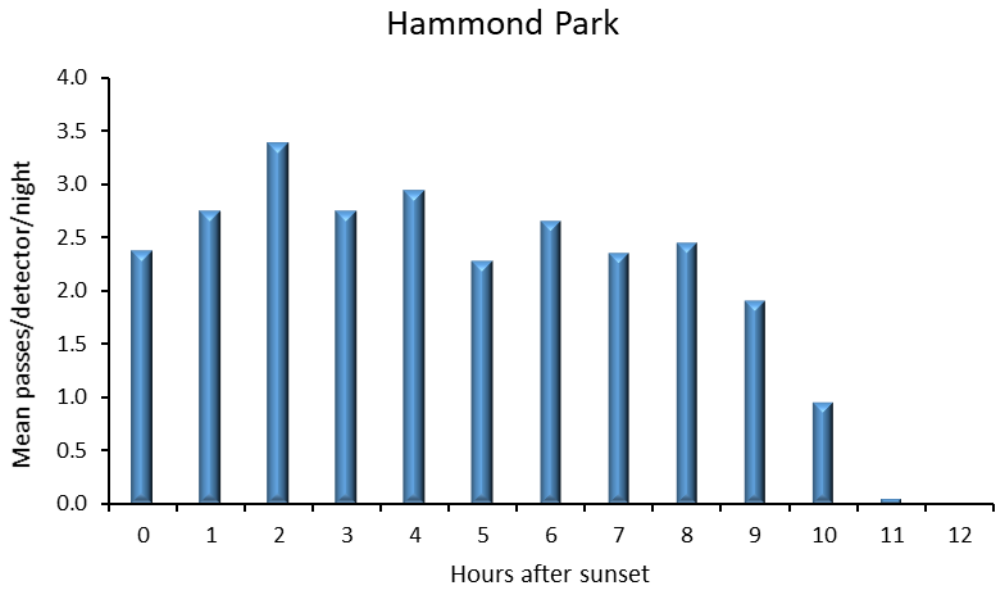

Dinsdale Park
Mean passes/detector/night
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours after sunset

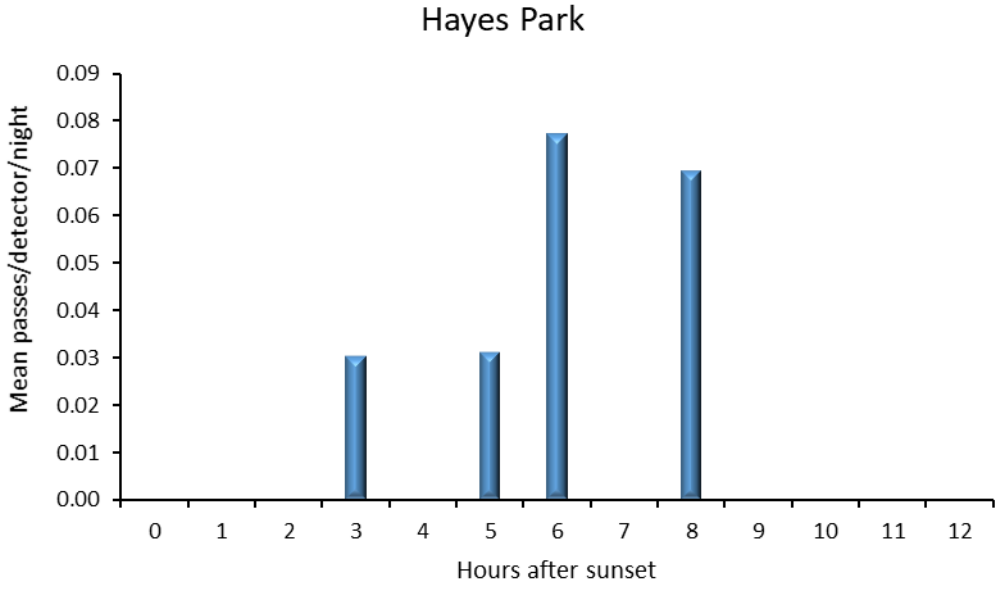

Donny Park
Mean passes/detector/night
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours after sunset

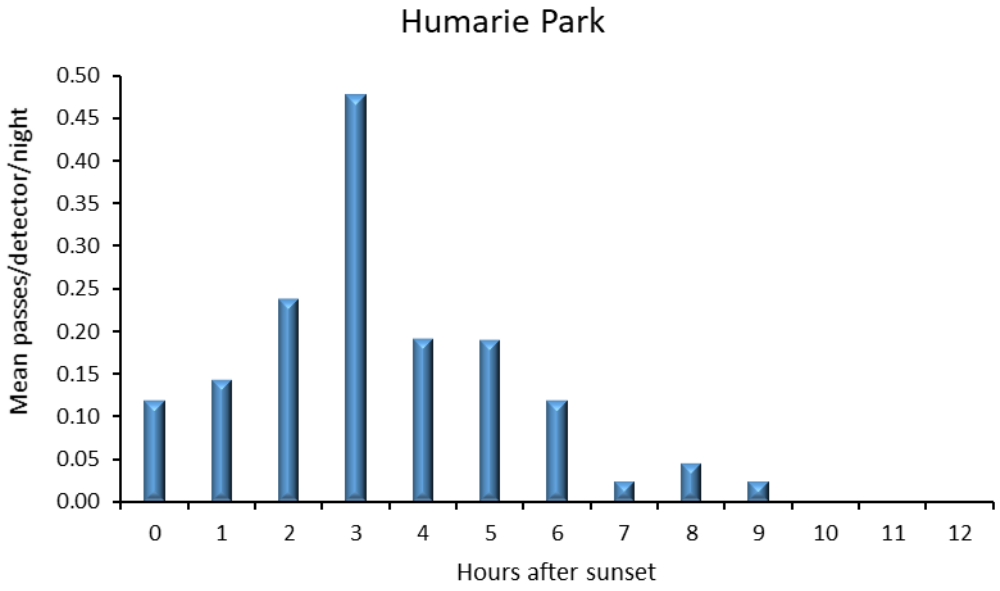

Farnborough Drive
Mean passes/detector/night
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours after sunset

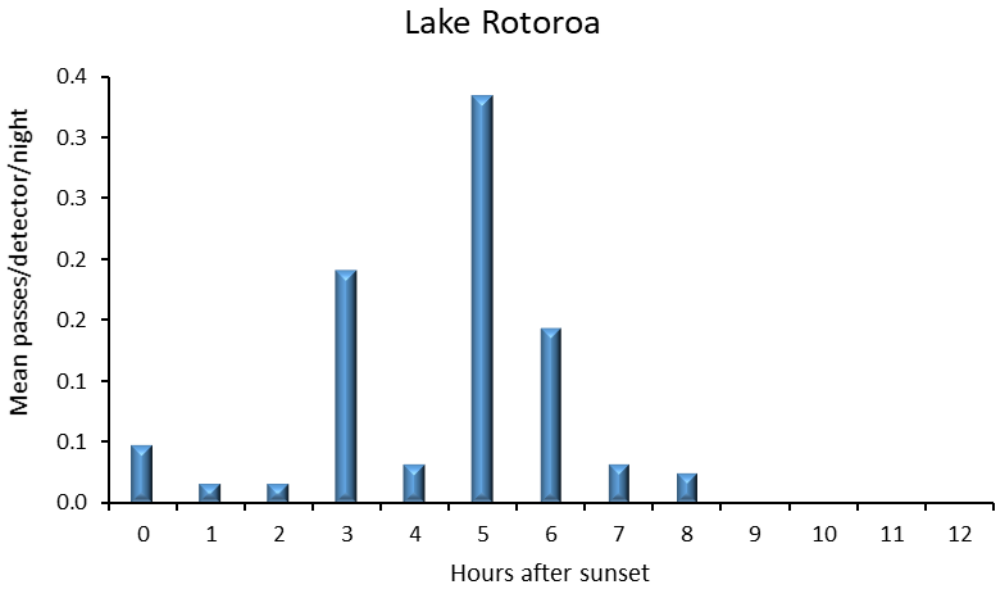

Fitzroy Park
Mean passes/detector/night
10
9
8
7
6
5
4
3
2
1
0
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours after sunset

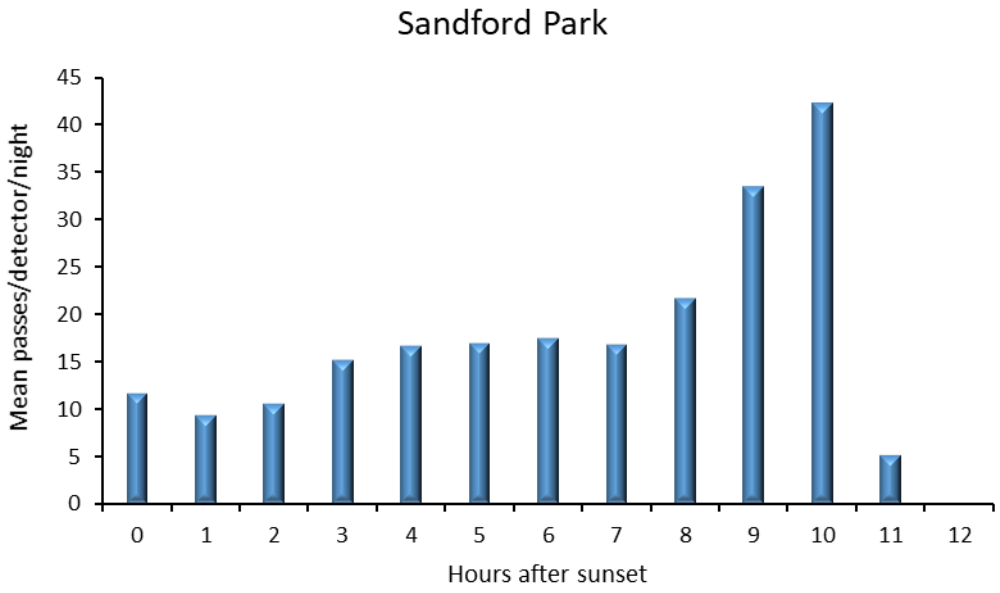

Forest Lake
Mean passes/detector/night
0.025
0.020
0.015
0.010
0.005
0.000
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours after sunset

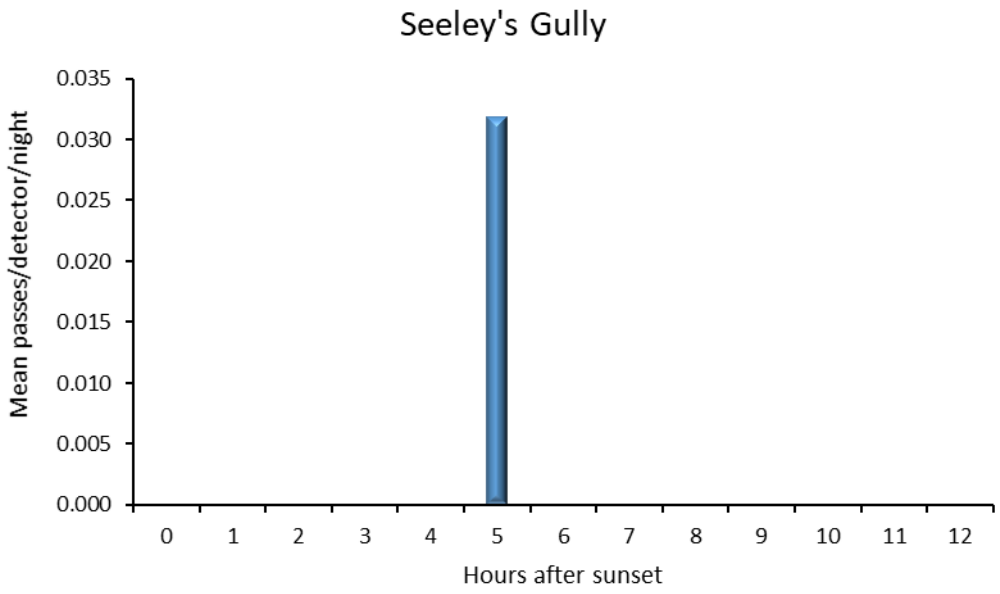

Hammond Park
Mean passes/detector/night
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours after sunset


Hayes Park
Mean passes/detector/night
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours after sunset

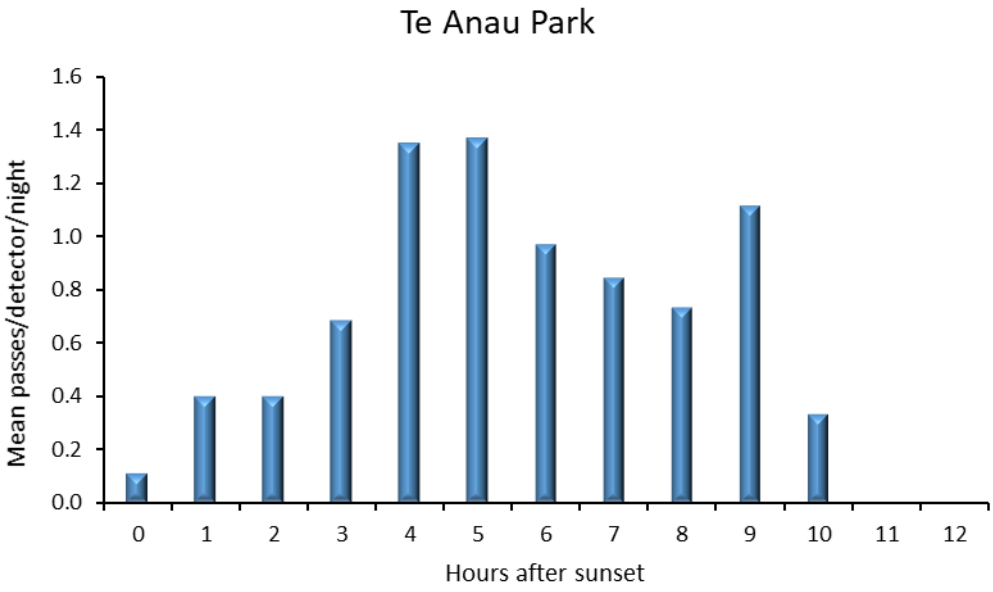

Humarie Park
Mean passes/detector/night
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours after sunset

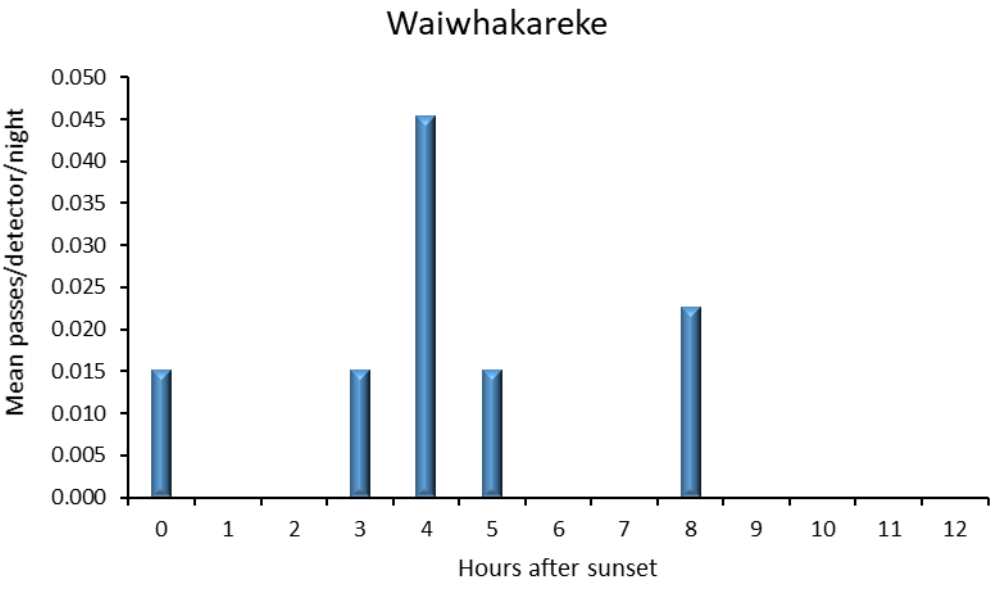

Lake Rotoroa
Mean passes/detector/night
0.4
0.3
0.3
0.2
0.2
0.1
0.1
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours after sunset

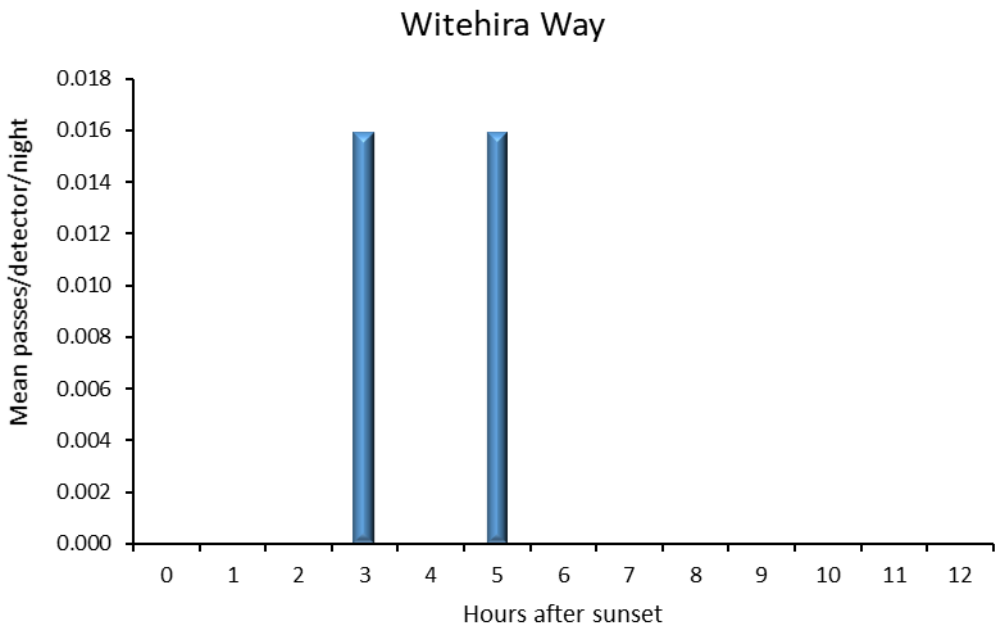

Sandford Park
Mean passes/detector/night
45
40
35
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours after sunset


Seeley's Gully
Mean passes/detector/night
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours after sunset


Southwell School
Mean passes/detector/night
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours after sunset


Te Anau Park
Mean passes/detector/night
1.6
1.4
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


Waiwhakareke
Mean passes/detector/night
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0 1 2 3 4 5 6 7 8 9 10 11 12
Hours after sunset


Witehira Way
Mean passes/detector/night
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0
1
2
3
4
5
6
7
8
9
10
11
12
Hours after sunset

Appendix C:

Comparison of survey results to previous monitoring

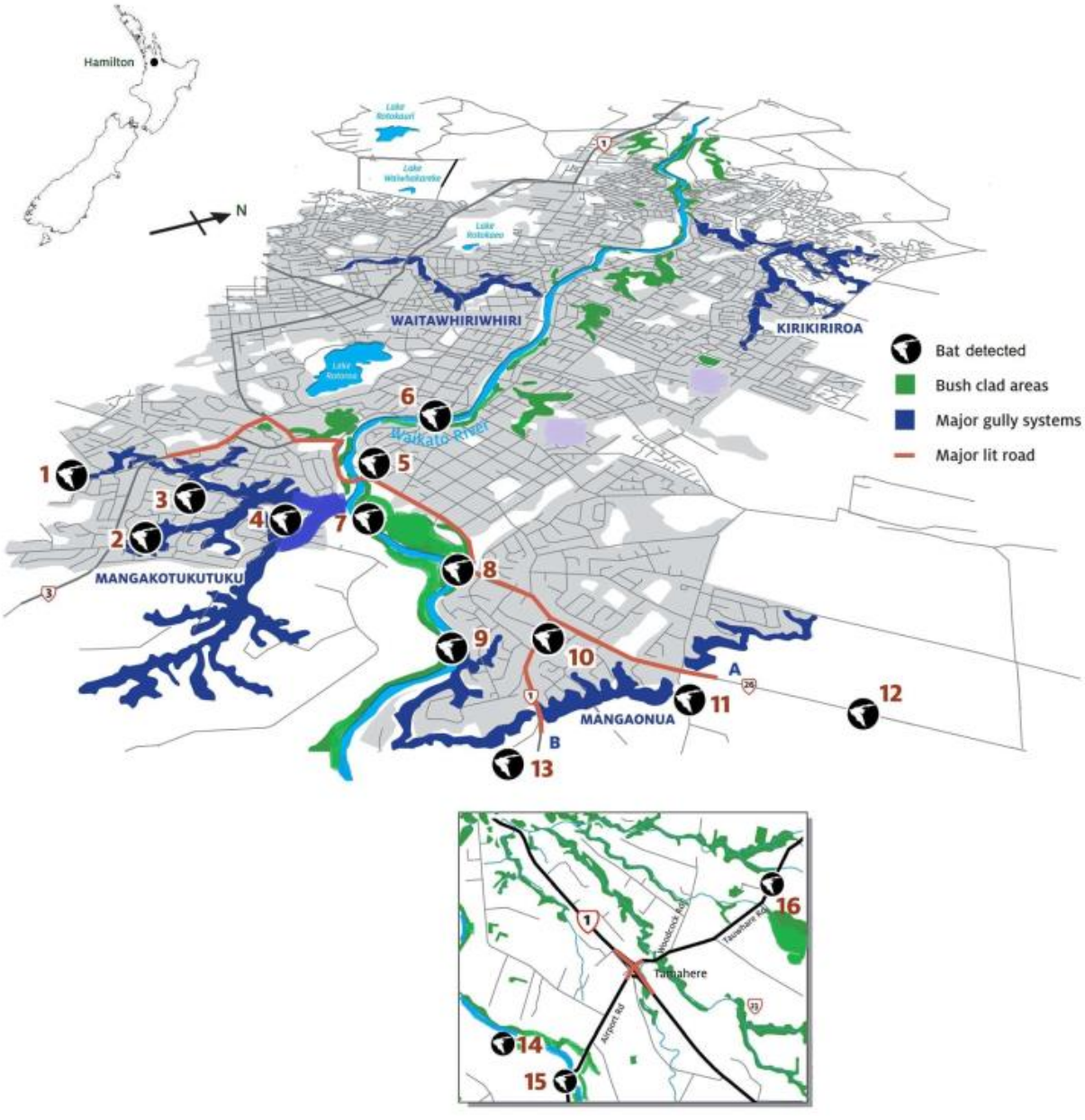
Site name	Time	Bats	# ABM	ABM with activity	Mean calls / ABM /night
Chelmsford Park 2020	February - March	Y	3	3	0.92
Claudelands Bush 2019		Y	3	3	0.48
Claudelands Bush 2020	February - March	Y	3	2	0.09
Dinsdale Park 2019		N	3	0	N/A
Dinsdale Park 2020	February - March	Y	3	2	0.03
Donny Park/Chartwell Park 2017		N	3	0	N/A
Donny Park/Chartwell Park 2020	February - March	Y	3	2	0.03
Farnborough Park 2019		N	3	0	N/A
Farnborough Park 2020	February - March	Y	3	2	0.03
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
Fitzroy Park 2020	February - March	Y	3	2	33.3
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
Forest Lake 2020	February - March	Y	2	1	0.02
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
Hammond Bush 2020	February - March	Y	3	3	54.37
Waiwhakareke/Horseshoe Lake 2018	January	N	3	0	N/A
Waiwhakareke/Horseshoe Lake 2019	January - February	Y	3	1	0.02
Waiwhakareke/Horseshoe Lake 2020	February - March	Y	3	3	0.12
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
Humarie Park 2020	February - March	Y	2	2	1.57
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
Lake Rotoroa 2020	February – March	Y	3	3	0.87
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
Sandford Park 2020	February - March	Y	3	3	217.76
Seeley Gully 2019		Y	2	1	0.03
Seeley Gully 2020	February - March	Y	3	2	0.03
Southwell School 2019		N	3	0	N/A
Southwell School 2020	February - March	Y	3	3	0.10
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
Te Anau Park 2020	February - March	Y	3	3	12.32
Wellington Beach 2011	January	N	3	0	N/A
Wellington Beach/Hayes Park 2017		N	3	0	N/A
Wellington Beach/Hayes Park 2019	March	Y	1	1	0.70
Wellington Beach/Hayes Park 2020	February - March	Y	3	2	0.27
Witehira Way 2019		Y	3	1	0.10
Witehira Way 2020	February - March	y	3	2	0.03

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.

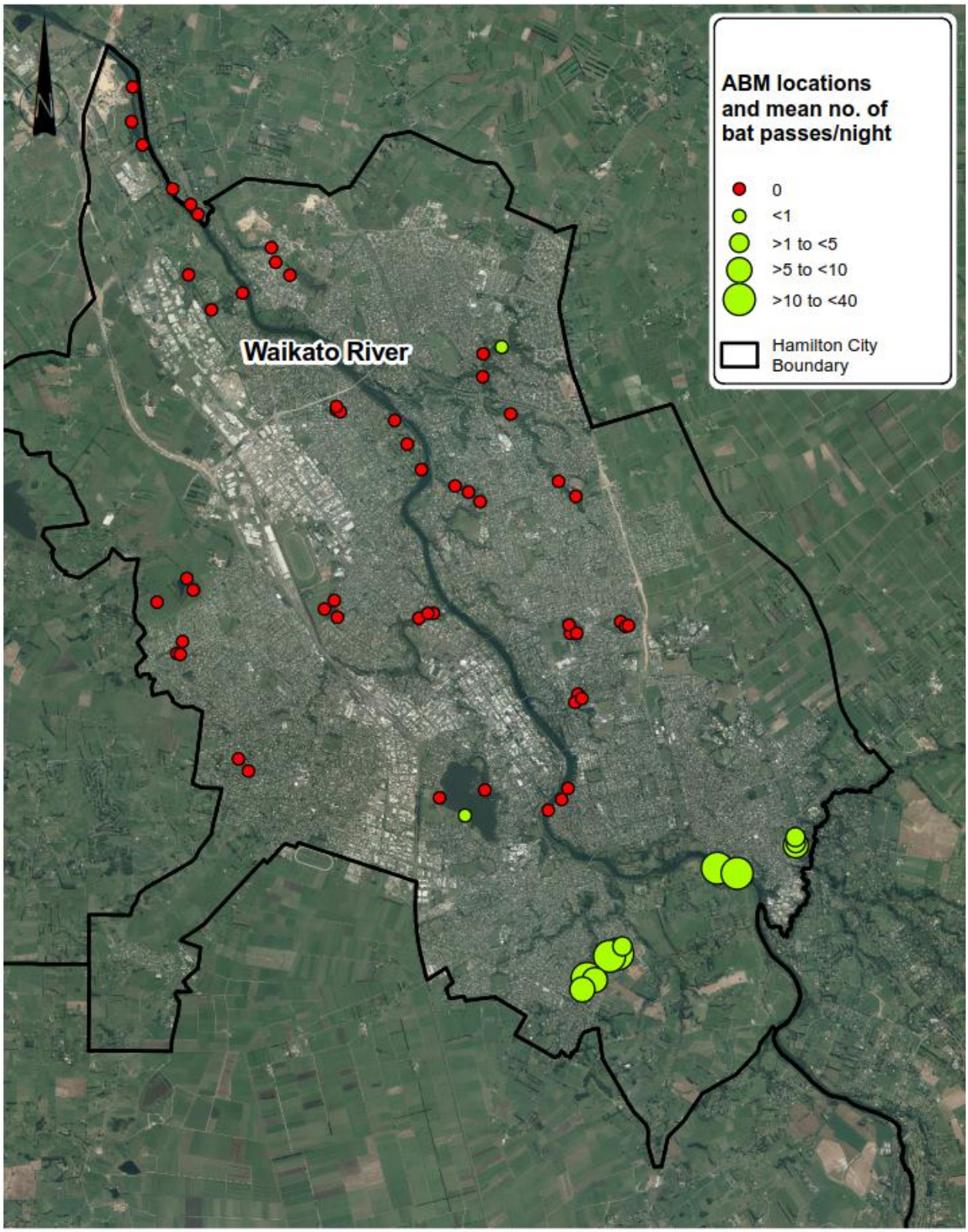
Appendix D:

Survey results from previous years



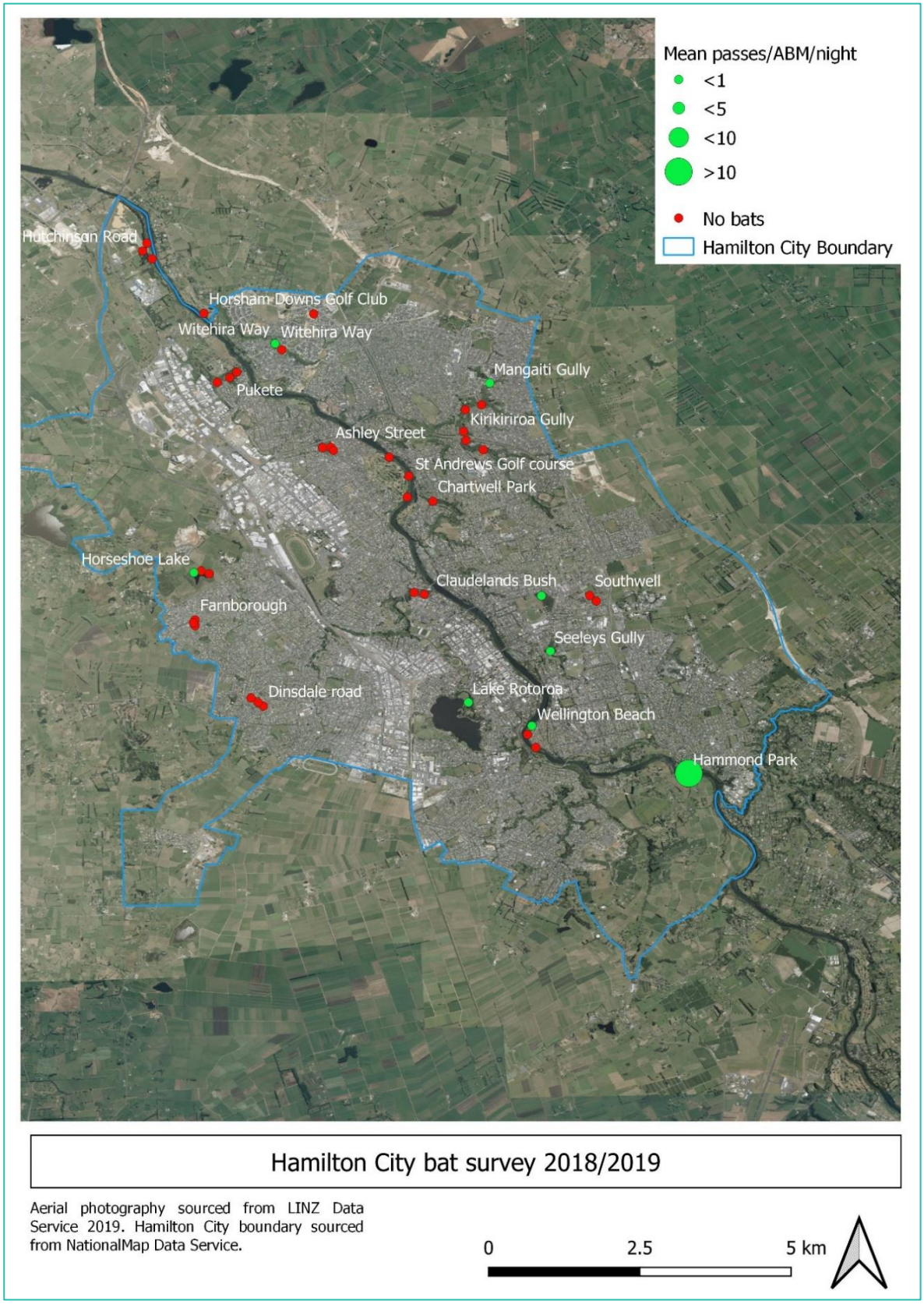
Le Roux and Le Roux, 2012

Mueller et al. 2017



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

Van der Zwan 2018



Van der Zwan and Mueller 2019