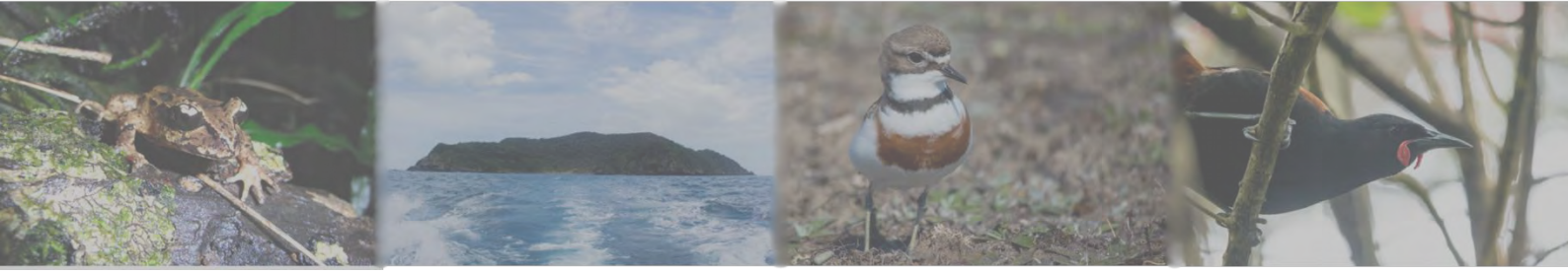

State and trends in the diversity, abundance and distribution of birds in Wellington City

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State and trends in the diversity, abundance and distribution of birds in Wellington City.

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Cover Image: New Zealand pigeon (*Hemiphaga novaeseelandiae*). Photo courtesy of Daniel Burgin.

EXECUTIVE SUMMARY

Five-minute bird counts have been carried out at 100 bird count stations in forest habitat throughout Wellington City's parks and reserves network each year between 2011 and 2018. The aim of these surveys is to monitor trends in the diversity, abundance and distribution of native forest birds throughout Wellington City's reserve network, to provide a measure of local biodiversity management outcomes.

Since 2011 there has been a substantial increase in the proportion of bird species ranked as Nationally Threatened or At Risk in Wellington City. There has also been a significant increase in the average number of native forest bird species encountered per bird count, which has been driven by significant increases in the encounter rates for five endemic bird species: tūī, kākā kākāriki, NI saddleback and kererū.

These results suggest that the presence of large 'source' populations of native forest birds in Zealandia, together with the increasing levels of predator control being carried out in parks, reserves and suburban areas throughout the city are creating improved opportunities for local residents and visitors to encounter a wider range of New Zealand's native forest bird species in the heart of New Zealand's capital city.

These counts have also identified the presence of several 'hotspots' of high native forest species diversity in Wellington City parks and reserves. Forested reserves within 1 km of Zealandia's predator-proof fence support a relatively high diversity of native bird species, likely due to the emigration of birds from Zealandia. The Wellington Botanical Gardens, Otari-Wilton Bush and Khandallah Park all support a similarly high diversity of species, likely due to the presence of stands of original, old-growth native forest, and/or a high diversity of exotic plant species.

Wellington residents are becoming increasingly engaged as citizen scientists, helping to build an ever more detailed picture of changes in bird distribution in the city by contributing to a number of citizen science databases and projects. The New Zealand eBird database and the allied New Zealand Bird Atlas project are the leading repositories of such citizen science data for Wellington City, and we recommend that Wellington City Council takes further steps to encourage local citizen scientists to participate in these two schemes.

We recommend that Wellington City Council continues to carry out these five-minute bird counts on an annual basis, to monitor further improvements in the city's native bird communities as the council continues to work towards its vision of creating a Predator Free Wellington. We also provide a number of additional recommendations aimed at filling gaps in our existing knowledge of the abundance and distribution of native forest birds in Wellington City, and the threats that they face.

Keywords: Bird abundance, citizen science, eBird, encounter rate, five-minute bird count, iNaturalist, New Zealand Bird Atlas, Wellington City, Zealandia

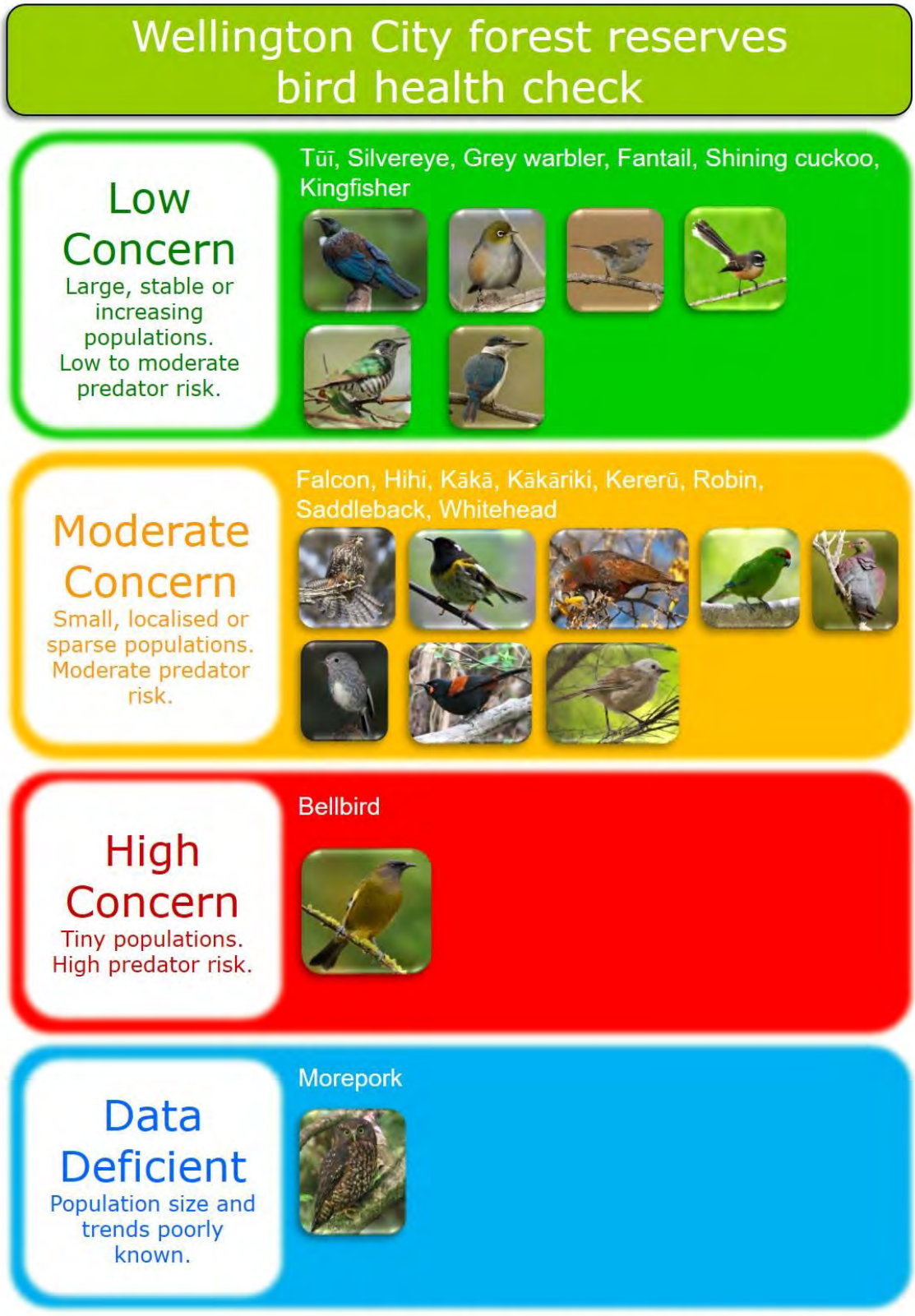

Photo credits: New Zealand Birds Online (http://nzbirdsonline.org.nz/)

Note: This bird health check diagram takes into account the combined status of these species both within predator-free Zealandia and in surrounding Wellington City habitats. A number of these species are secure in Zealandia, but should be considered "High Concern" in surrounding habitats, including hihi, NI robin, NI saddleback and whitehead.

1. INTRODUCTION

Over the past twenty years there has been a conspicuous increase in the diversity, abundance and distribution of native forest bird species in Wellington City (Miskelly et al, 2005). These changes are likely to be a consequence of two improvements in the management of indigenous forest habitats in and around Wellington City. Firstly, a series of species re-introductions to local predator-free sites such as Zealandia, Matiu/Somes Island and Mana Island have successfully established healthy source populations from which previously locally-extinct or near-extinct bird species have been dispersing into nearby forested reserves (Miskelly & Powlesland, 2013). These species include kākā (*Nestor meridionalis*), kākāriki (red-crowned parakeet; *Cyanoramphus novaezelandiae*) whitehead (*Mohoua albicilla*) and bellbird (*Anthornis melanura*) (Miskelly et al, 2005; Froude, 2009; McLaughlin & Harvey, 2013). Secondly, ongoing multi-species predator control being carried out by Wellington City Council, Greater Wellington Regional Council and community conservation groups in many Wellington City parks and reserves has resulted in local increases in resident native bird species such as tūī (*Prosthemadera novaeseelandiae*) (Bell, 2008; Froude, 2009; Brockie & Duncan, 2012) and is creating an opportunity for recently re-introduced species to establish functional populations away from their original re-introduction sites.

Within Zealandia itself, a total of eleven endemic forest birds have been re-introduced to the sanctuary since the eradication of mammalian predators in 2000, and a further two species have recolonised of their own accord (Miskelly & Powlesland, 2013; K. Beaven *personal communication*). This has led to the re-establishment of a diverse and abundant endemic bird forest community within Zealandia's predator-proof fence, which in turn has led to substantial declines in the abundance of three of the four native forest bird species that had been resident in Zealandia prior to the eradication of mammalian predators, namely silvereye (*Zosterops lateralis*), grey warbler (*Gerygone igata*) and fantail (*Rhipidura fuliginosa*) (Miskelly, 2018). At least six introduced bird species have also experienced similar, substantial declines within Zealandia over this time period, including chaffinch (*Fringilla coelebs*), dunnock (*Prunella modularis*) and song thrush (*Turdus philomelos*) (Miskelly, 2018). These changes to Zealandia's bird community over the past two decades may foreshadow the changes we may observe across Wellington City, as efforts to control and/or eradicate mammalian predators continue to escalate.

Mammalian predator control and eradication efforts in Wellington City are continuing to grow in both intensity and coverage. Over 100 community-led conservation groups are now active in Wellington City, and in 2014 these groups contributed a combined total of 34,611 volunteer hours towards local environmental restoration activities (WCC, 2015). Predator Free Wellington, a project co-funded by Wellington City Council, Greater Wellington Regional Council and the NEXT Foundation plans to build on the proliferation of pest-free suburb projects and aims to eradicate rats, mustelids and possums from Wellington City, beginning with a trial eradication project on Miramar Peninsula which is currently underway (Bell & Bell, 2017). If successful, these efforts could result in further dramatic improvements in the distribution and abundance of several native bird species that are currently locally rare or extinct in Wellington City.

Monitoring ongoing changes to native bird populations in the city provides a useful means by which the outcome of the considerable time and effort being spent on improving Wellington City's biodiversity can continue to be measured. For this reason, Wellington City Council has identified a need to monitor local bird populations to provide one measure of the success or otherwise of their recently adopted Biodiversity Strategy & Action Plan (WCC, 2015). Goal 4.2.2a of this Biodiversity Strategy involves setting up a "consistent terrestrial outcome monitoring framework…incorporating existing monitoring work in a collaborative approach with other key organisations" (WCC, 2015).

Five-minute bird count monitoring has been carried out between 2001 and 2009 in nine selected parks and reserves in Wellington City by Pacific Eco-Logic Ltd (Froude, 2009). These counts were successful

in detecting substantial increases in the local abundance of tūī at a key time during which a large expansion in pest control efforts in Wellington City was underway. These counts also provided some of the earliest evidence that bird species re-introduced to Zealandia were dispersing and settling in nearby reserves (Froude, 2009).

In 2011 this bird monitoring programme was replaced with a new survey designed to monitor changes in the distribution and abundance of native forest birds across the entire network of Wellington City parks and reserves, rather than a selected subset of reserves (McArthur et al, 2012). Tūī were chosen as a key focal species for this survey design due to their conspicuousness and popularity with the general public. Based on a power analysis of the pre-2011 Wellington City bird survey data, a sample size of 200 five-minute bird counts carried out at 100 locations across the city's parks and reserves network was chosen to ensure that this new design had sufficient statistical power to detect a 10% or more change in the relative abundance of tūī in Wellington City reserves from one year to the next.

These counts have now been carried out each year since 2011, and have demonstrated the important influence that Zealandia has had on the native forest bird community in the wider Wellington City. Around 33% of the native forest bird species detected in Wellington City parks and reserves each year are species that have been re-introduced to Zealandia and have subsequently expanded their range to include a number of other parks and reserves in the city (McArthur et al, 2012; 2013a; 2015; 2016). Many of these species were found to have very localised distributions beyond Zealandia's predator-proof fence however, indicating that mammalian predators are likely to still be significantly limiting the ability of these species to colonise other native forest habitats in the city's parks and reserves (McArthur et al, 2015).

Another key result from this work is that mean encounter rates for tūī, kākā and kākāriki have increased significantly since 2011, suggesting that these species have increased in abundance and/or conspicuousness in Wellington City parks and reserves over this time (McArthur et al, 2018). This suggests that the improvements in the intensity and spatial coverage of mammalian predator control achieved in the city to date have benefitted these particular bird species.

In November 2017, an additional 77 five-minute bird count stations were established on a 320m x 320m grid overlaid across Miramar Peninsula in order to collect robust baseline measures of bird distribution and abundance on the peninsula prior to the proposed eradication of rats and mustelids (Bell & Bell, 2017; Ray & McArthur, 2017). These counts found that the peninsula supported a lower diversity and lower numbers of native forest birds compared to the rest of Wellington City, and that the local bird community is currently dominated by a relatively small number of introduced bird species (Ray & McArthur, 2017).

The incorporation of bird observations collected by local 'citizen scientists' into the distribution maps created as part of this bird monitoring programme has allowed us to map the distribution of native birds in Wellington City in unprecedented detail. These maps have helped document the range expansion of recently re-introduced species such as kākā and kākāriki in Wellington City virtually in real-time, and have documented a number of local re-colonisation events that have occurred in recent years in several individual parks and reserves (McArthur et al, 2015).

This report provides an update on the emerging trends in the diversity, abundance and distribution of birds throughout Wellington City, by analysing and reporting a seventh year of five-minute bird counts and another year of citizen-science data collected since the publication of the previous bird monitoring report in June 2018.

2. METHODS

2.1 Five-minute bird count data collection

One hundred bird count stations were established at random locations in forest habitat in Wellington City parks and reserves in November 2011 and have been surveyed annually between 2011 and 2018 (Figure 2.1). Bird count stations were established at a minimum distance of 200 metres from one another and each station has been marked with either a blue triangle affixed to a living tree, or with pink flagging tape if situated in plantation forest.

Two five-minute bird counts have been carried out at each station each year, with each count being carried out on a different day. All counts were carried out in November or early December each year and counts were made only on fine, calm days between 1.5 hours after sunrise and 1.5 hours before sunset (approximately 7.30 am to 6.30 pm). At each station, an observer spent five minutes recording the number of individuals of all species seen or heard from the count station (i.e. an unbounded count as per Dawson & Bull, 1975 and Hartley & Greene, 2012). Care was taken not to record the same bird twice during a count. Two experienced observers were employed to conduct the counts each year, with each observer surveying approximately half of the bird count stations.

Bird conspicuousness can vary in response to a number of external variables such as time of year, weather, time of day and change in observer (Bibby et al, 2000). Because of this, every effort was made to standardise or sample the range of variation in each of these factors to ensure that as much as possible any changes in the mean number of birds counted per station from one year to the next would be more likely to reflect changes in bird abundance rather than conspicuousness. Precautions taken include carrying out these counts during the same months each year and in similar weather conditions. Counts were carried out throughout the day, so sampled any variation in bird conspicuousness that occurred during the day.

Observer-related variation can have a substantial impact on five-minute bird count results, and can sometimes either mask or be mistaken for true changes in bird abundance or conspicuous from one survey to the next (McArthur et al, 2013a). For this reason, we've endeavoured to minimise the number of observers used to collect this five-minute bird count data, with only two changes being made so far during the eight year duration of this project. In each case, when one observer has been replaced with another, the second observer has remained the same across both years, thus providing us with some ability to differentiate observer-related variation in bird encounter rates from those caused by true changes in bird conspicuousness or abundance from one year to the next.

Figure 2.1: Locations of five-minute bird count stations established in Wellington City parks and reserves in 2011.

2.2 Five-minute bird count data analysis

The Wellington City five-minute bird count data were entered into a Microsoft Excel spreadsheet and then used to calculate the mean number of birds of each species detected per five-minute bird count each year, in order to examine temporal patterns in bird encounter rates (Dawson & Bull, 1975). For the purposes of this analysis, we defined a "native forest bird" as any native species capable of maintaining a functional population entirely within native forest habitat, and therefore likely to be a resident rather than transitory species in this habitat.

Because these raw data consist of relatively low counts which are naturally truncated at zero, the data is too skewed to conform to a normal distribution, a key assumption for many parametric tests for statistical significance. To deal with this, we first added a value of 1.0 to the number of species and individuals recorded during each count in order to remove zero values from the dataset, then applied an *a priori* square root transformation to the data to ensure that they were approximately normally distributed and with approximately equal sample variances before we proceeded with any further analyses. Once we were satisfied that our transformed data met these assumptions, we used one-way analyses of variance (ANOVA) to test for statistically-significant differences in mean bird encounter rates between years (Fowler & Cohen, 1995). Performing these statistical tests is important because a statistically significant result indicates that any difference between the two or more means being compared is very unlikely to have occurred due to chance sampling error, so instead is assumed to represent a real difference in the abundance and/or conspicuousness of native forest birds between years.

Patterns in the distribution of native birds among Wellington City reserves were examined by mapping the relative frequency at which each native forest bird species was detected at each bird count station using QGIS version 3.0.3. Although this technique does not explicitly take into account relative differences in abundance (less common species present within sight or earshot of a bird count station are less likely to be detected) or variation in detection probabilities between species (less conspicuous species will also be less likely to be detected), it should be sufficient to detect relatively large changes in species' distributions and species recolonization events (Mackenzie et al, 2006).

2.3 Citizen science data analysis

As a result of the increasing popularity of citizen science, there is a rapidly growing pool of bird observation data available online which can be combined with our more systematic five-minute bird count data to help detect changes in bird distribution in Wellington City over time. Since 2011, residents and visitors to the Wellington region have contributed over 230,000 bird observations to online databases and citizen science projects such as the New Zealand eBird database, iNaturalist, the NZ Garden Bird Survey and the Great Kererū Count.

The New Zealand eBird database is the largest source of such citizen science data. The 210,000 bird observation records submitted to the eBird database for the Wellington region since 2011 accounts for around 90% of citizen science bird data available for the region. The New Zealand eBird database (http://ebird.org/content/newzealand/) is run by the Cornell Lab of Ornithology in partnership with Birds New Zealand (formerly the Ornithological Society of New Zealand). It provides a facility for recreational birdwatchers to permanently record their bird observations in a standard format and in one centralised location and makes these observations available to researchers, conservation managers and environmental policy-makers (Scofield et al, 2012). Globally, the eBird database is now the largest and fastest growing biodiversity database in the world, with over 478,000 unique users having so far contributed over 500 million bird records describing the distribution of 98% of the world's bird species (Sullivan et al, 2014; http://ebird.org/content/ebird/news/millions0417/, accessed 31/03/2018).

Within the eBird database, automated data filters and an expert review process ensure that these data are of high quality and accuracy (Sullivan et al, 2014). We used eBird's "download data" tool to access the December 2018 release of the eBird Basic Dataset (EBD) and to build custom datasets containing citizen science records of all native forest bird species recorded in Wellington City between 2011 and 2018. We formatted these datasets using Microsoft Excel, including removing any extraneous data fields and converting latitude/longitude coordinates to NZTM coordinates. We then saved these files as .csv files so that they could be imported into ArcMap and converted into shapefiles. Once in ArcMap, we visually inspected these eBird records to locate and remove any records containing obvious location errors (e.g. records placed offshore, or for which location descriptions didn't match the coordinates provided) before adding these records to the distribution maps created from the five-minute bird count data.

The iNaturalist database is the second-largest online source of citizen science bird data for the Wellington region. iNaturalist is a database that allows citizen scientists to submit, share and store natural history observations online, and unlike eBird it is designed to accept records for almost any taxon of plant or animal rather than just birds. iNaturalist (https://inaturalist.nz/) is run by a charitable trust called the New Zealand Bio-recording Network Trust, and was established using funding from the New Zealand Government's Terrestrial Freshwater Biodiversity Information System Fund. The 10,428 bird observation records submitted to iNaturalist for the Wellington region since 2011 account for around 5% of citizen science bird data available for the region.

Within the iNaturalist database, a community peer-review process is used to validate records, with records tagged as either "research grade" or "casual grade" depending on whether or not the original species identifications have been verified by another iNaturalist user. Because most bird observations submitted to iNaturalist aren't accompanied by photographs, the majority of records are "casual grade" records. We used the search tool on the iNaturalist website to download all bird observations recorded in Wellington City between 2011 and 2018. We formatted this dataset using Microsoft Excel, then saved the resulting file as a .csv file so that it could be imported into ArcMap and converted to a shapefile. We then displayed the data on a map and visually inspected them and removed records with obvious location errors. iNaturalist automatically obscures the locations of taxa that have been given a conservation status of Near Threatened or higher on the IUCN Red List of threatened species (http://naturewatch.org.nz/pages/help#obscured; accessed 30/06/2017). As a result, any records for these taxa are assigned a random set of coordinates that are within a ca. 20x 20 km cell containing the true coordinates. Because the locations of these observations are obscured in such a way, several hundred observations for a number of Nationall Threatened or At Risk bird taxa had to be discarded due to inaccurate location data, as there is no clear guidance on the iNaturalist website regarding how researchers can go about accessing the original, true locations of these records.

Kererū Discovery's Great Kererū Count project is the third-largest source of citizen science bird data available for Wellington. The 176 kererū (*Hemiphaga novaeseelandiae*) bird observations submitted to the Great Kererū Count project accounts for less than 1% of citizen science bird data available for the region. The Great Kererū Count is billed as New Zealand's "largest citizen science project" and is a nationwide kererū survey that takes place over a 10-day period in September each year. Observers from around the country are encouraged to record the presence or absence of kererū at locations of their choosing over a 10-day period. In 2017, a total of 6,946 reports were received nationwide, with a total of 15,459 kererū counted (Hartley, 2017). We made a request for access to the Great Kererū Count data from Kererū Discovery, and received a .csv file containing 176 observations for the city. We imported this .csv file into ArcMap and visually inspected the records to locate and remove any records containing obvious location errors.

The Landcare Research Garden Bird Survey is the fourth potential source of citizen science bird data for Wellington City. The Garden Bird Survey is an annual, nationwide count of garden birds that has been run in June-July each year since 2007. Observers are encouraged to spend one hour during a specified week in June-July counting all of the birds seen or heard in their gardens, and to submit their

counts via an online form. A small portion of this dataset has been uploaded to iNaturalist, and has therefore been included in the bird distribution maps provided in the report. However, previous attempts by the authors to source more substantial portions of this dataset have been unsuccessful because Landcare Research has not yet developed a data use/management policy for this dataset (Catriona MacLeod, *personal communication*).

A key difference between these citizen science datasets and the five-minute bird count data is that the temporal and spatial distribution of search effort spent by citizen scientists varies unpredictably from year to year, whereas this search effort is standardised during these five-minute bird counts. Nonetheless, accurate bird observations submitted by citizen scientists have the potential to complement distribution data derived from our five-minute bird count dataset by providing information describing the presence of native forest birds at locations and in habitats not sampled by these five-minute bird counts.

3. RESULTS

3.1 Species diversity

Thirty-five bird species were detected during these counts in 2018, the highest number of species recorded in any one year since this monitoring programme began in 2011 (Figure 3.1; Appendix 1). This increase has largely been driven by a slow increase in the number of Nationally Threatened or 'At Risk' species that is detected each year. In 2011, 10% of the species detected were ranked as either Nationally Threatened or 'At Risk' (Robertson et al, 2013); whereas by 2018 this had risen to 28% of the total number of species detected (Robertson et al, 2017; Figure 3.1). Over the same time period, the proportion of native bird species detected each year that are ranked as Not Threatened has dropped from 41% in 2011 to 31% in 2018. Similarly, the proportion of Introduced and Naturalised species detected each year has dropped from 48% in 2011 to 40% in 2018.

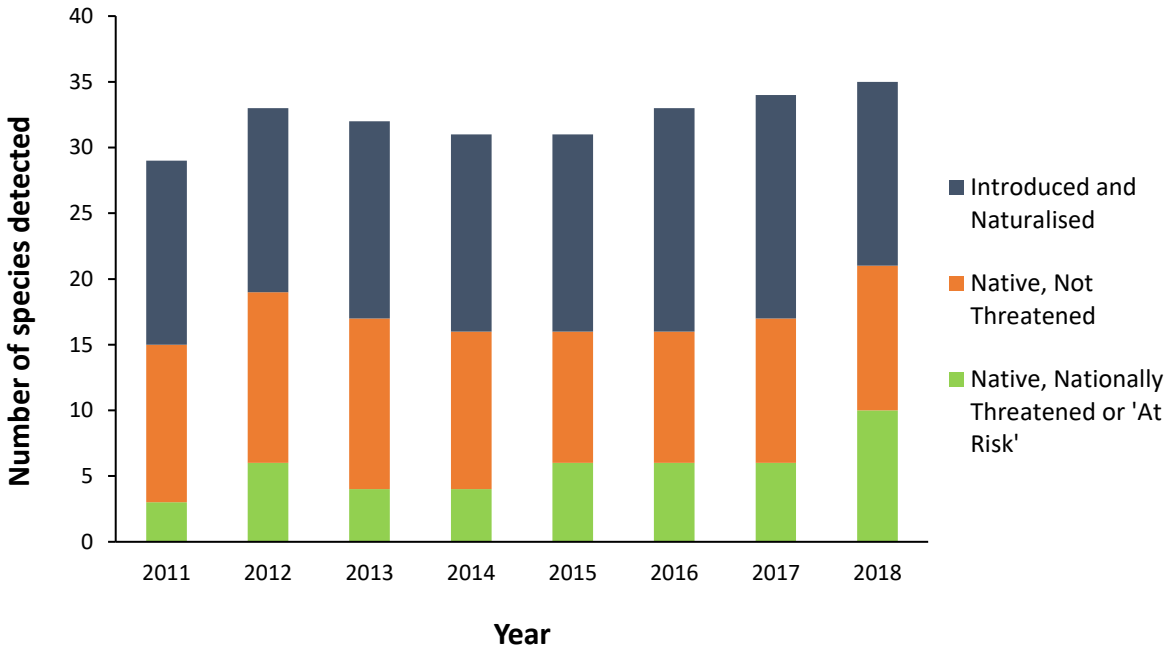

Figure 3.1: Total number of bird species detected during five-minute bird counts carried out in Wellington City parks and reserves, 2011-2018.

Black shags (*Phalacrocorax carbo*) were detected during these counts for the first time in 2018 when three birds were spotted flying overhead above a count station in the Wellington Botanic Gardens. Black shags are sparsely distributed around the Wellington City coastline, and are regular visitors to the lower and upper reservoirs in Zealandia. Several breeding colonies are known in the Wellington region, with small colonies in Zealandia, and at Melling and Lake Kohangatera being the closest colonies to Wellington City (eBird, 2019; Powlesland & Reese, 1999; Powlesland et al, 2007).

Eighteen of the native bird species detected between 2011 and 2018 are species that are typically found in native forest habitat and it is these species for which trends in relative abundance and distribution have been reported below. The remaining 13 native species recorded are either open-country or coastal species such as Australasian harrier (*Circus approximans*), paradise shelduck

(*Tadorna variegata*) or red-billed gull (*Larus novaehollandiae*) and are not included in any further analyses. A full list of all of the bird species detected during these counts can be found in Appendix 1.

Between 2011 and 2018 there has been significant year-to-year variation in the mean number of native forest bird species detected per bird count station in Wellington City reserves ($F_{7,799} = 8.18$, $p = 1.19 \times 10^{-9}$; one-way ANOVA). Over the eight years of bird counts, there has been a gradual upward trend in the mean number of native forest birds detected per station, from a low of 2.5 species detected per station in 2012, to a high of 3.3 species per station in 2018 (Figure 3.2).

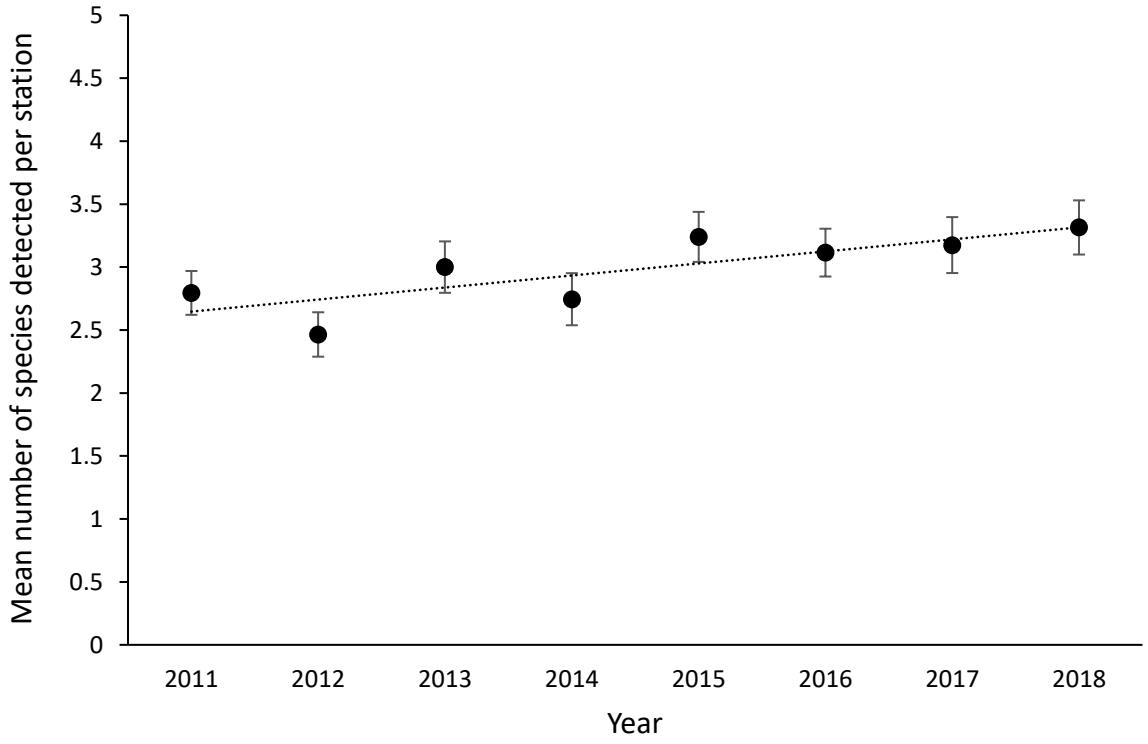

Figure 3.2: Mean number of native forest bird species recorded per five-minute bird count station in Wellington City between 2011 and 2018 (error bars represent 95% confidence limits).

Mean species richness also varied spatially across Wellington City. A substantially greater diversity of native forest bird species tends to be detected at the majority of bird count stations within 1 km of Zealandia's predator-proof fence, in comparison to those count stations situated further from Zealandia (Figure 3.3). This pattern strongly suggests that Zealandia is exerting a 'halo' effect on surrounding forests, likely due to the emigration and dispersal of several forest bird species still largely restricted to the predator-free habitat within Zealandia's fence. In addition to the 'halo' of high species diversity around Zealandia, three other obvious hotspots of high native forest species diversity are evident in the city, in the Wellington Botanical Gardens, Otari-Wilton Bush and in Khandallah Park (Figure 3.3). All three reserves contain remnants of original, old-growth forest, now rare in Wellington City, and the Wellington Botanical Gardens contain a high diversity of both exotic and native plant species that likely provide a convenient year-round food supply for several nectivorous and frugivorous native forest bird species such as kākā, kākāriki, tūī and bellbird.

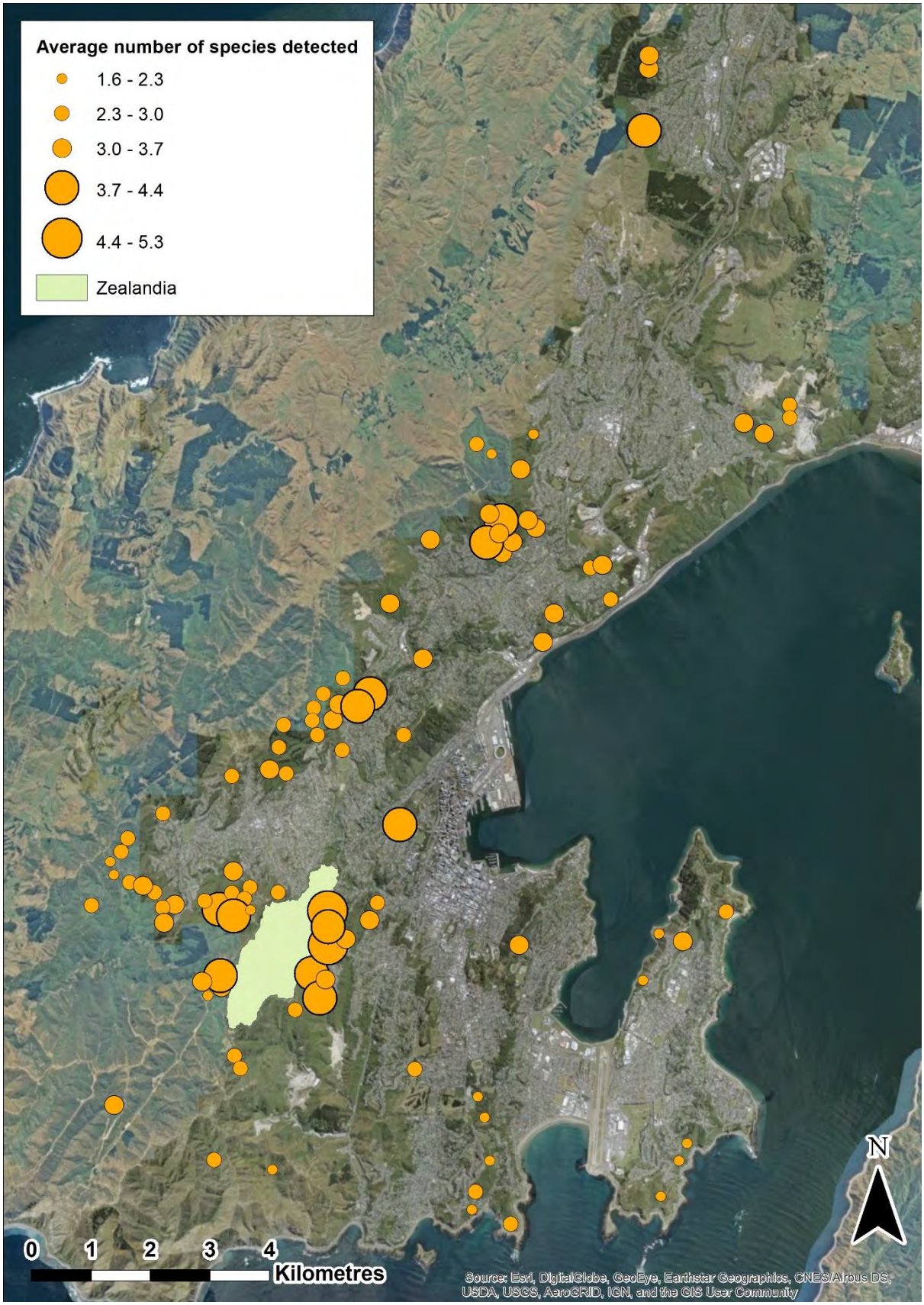

Figure 3.3: Mean number of native forest bird species detected at each five-minute bird count station in Wellington City per year between 2011 and 2018.

3.2 Abundance and distribution of native forest bird species

The following species accounts are listed in approximate order of decreasing abundance in Wellington City. Species that are most frequently encountered during the five-minute bird counts are covered first, and the species that are only seldom encountered, or not encountered at all during these five-minute bird counts are treated last. Every species of native forest bird that has been observed in Wellington City outside of Zealandia since 2011 is included in this section of the report. A separate summary table of native forest bird encounter rates can be found in Appendix 2 of this report.

3.2.1 Tūī (*Prosthemadera novaeseelandiae)*

National conservation status: Not Threatened (Robertson et al, 2017).

Regional conservation status: Not Threatened (GWRC/DoC, unpublished data).

Tūī encounter rates have increased significantly in Wellington City between 2011 and 2018 ($F_{7,1592} = 28.63$, $p = 2.34 \times 10^{-37}$; one-way ANOVA; Figure 3.4). Tūī are common and widespread in Wellington City, and are recorded from the majority of five-minute bird count stations each year. Tūī are also the bird species most frequently reported by local citizen scientists, with 6686 tūī observations reported within Wellington City limits since 2011 (Figure 3.5).

Image courtesy of Tony Whitehead/NZ Birds Online

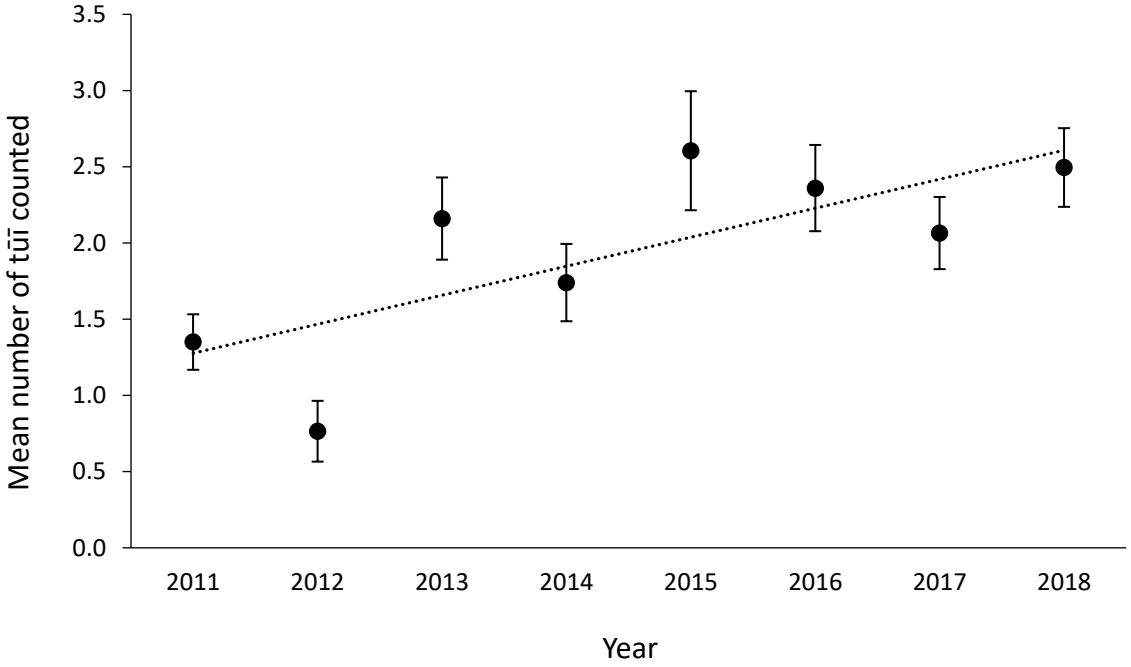

Figure 3.4: Mean number of tūī recorded per five-minute bird count station in Wellington City between 2011 and 2018 (error bars represent 95% confidence limits).

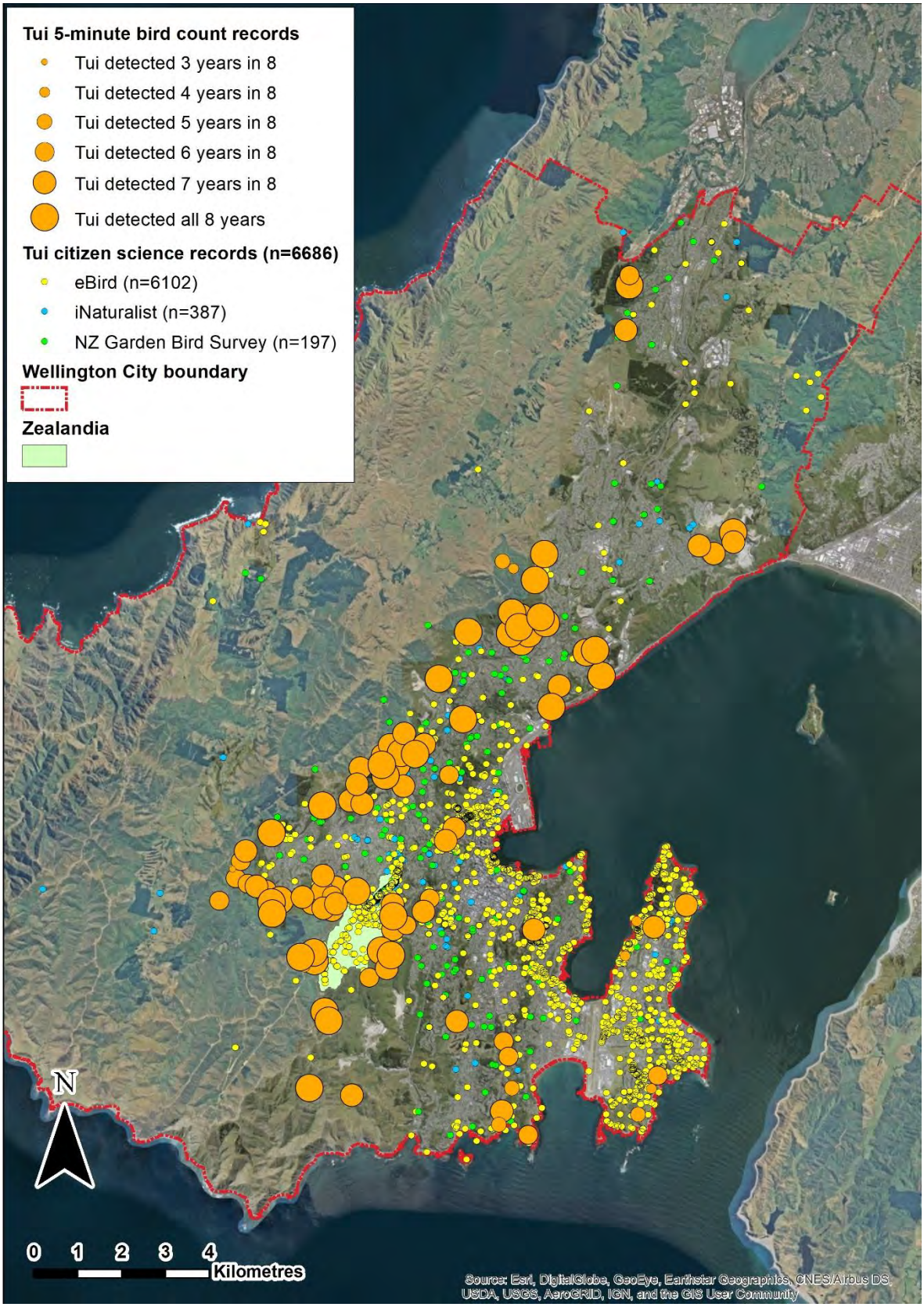

Figure 3.5: Distribution of tūī in Wellington City between 2011 and 2019. Orange circles represent tūī detections at five-minute bird count stations, with the size of the circle corresponding to the relative detection frequency. Smaller coloured circles represent tūī observations reported by local citizen scientists via eBird, iNaturalist or the NZ Garden Bird Survey.

3.2.2 Silvereye (*Zosterops lateralis*)

National conservation status: Not Threatened (Robertson et al, 2017).

Regional conservation status: Not Threatened (GWRC/DoC, unpublished data).

Silvereye encounter rates have not changed significantly in Wellington City between 2011 and 2018, and are relatively consistent from one year to the next ($F_{7,1592} = 1.43$, $p = 0.19$; one-way ANOVA; Figure 3.6). Silvereyes are common and widespread in Wellington City, and are recorded from the majority of five-minute bird count stations each year. Silvereyes are also the second most frequently observed bird species reported by local citizen scientists, with 3075 silvereye observations reported within Wellington City limits since 2011 (Figure 3.7).

Image courtesy of Ormond Torr/NZ Birds Online

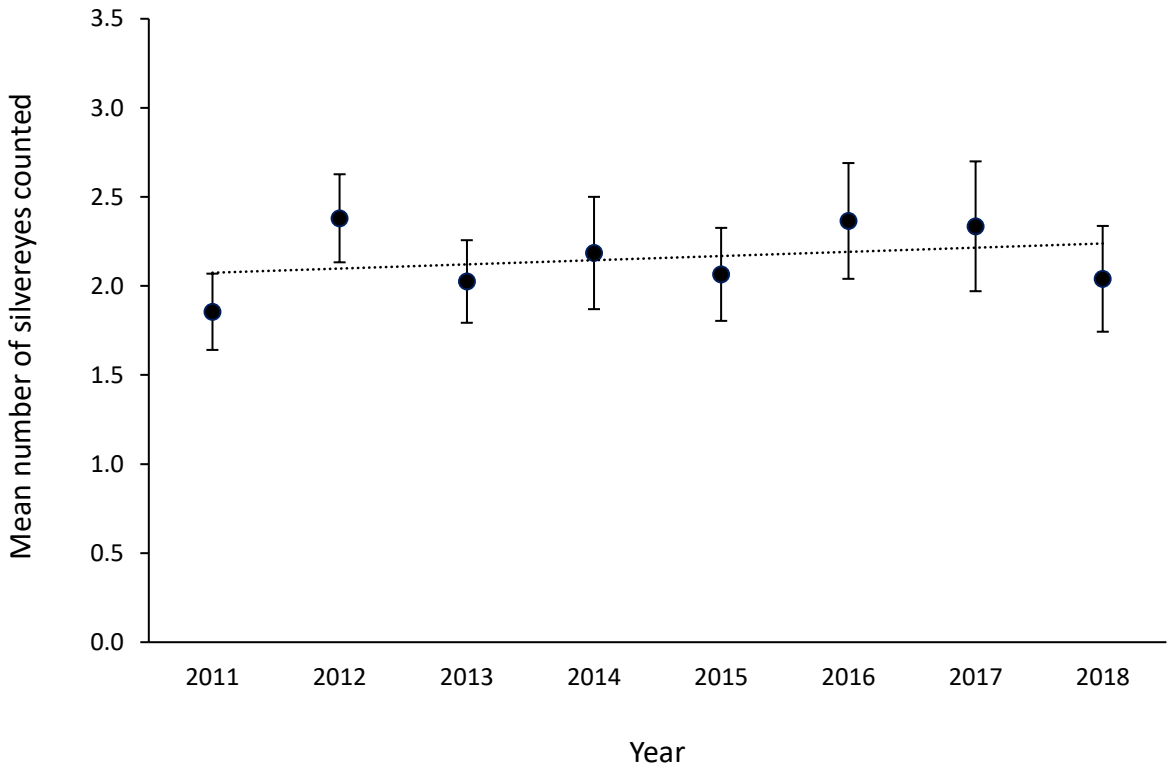

Figure 3.6: Mean number of silvereyes recorded per five-minute bird count station in Wellington City between 2011 and 2018 (error bars represent 95% confidence limits).

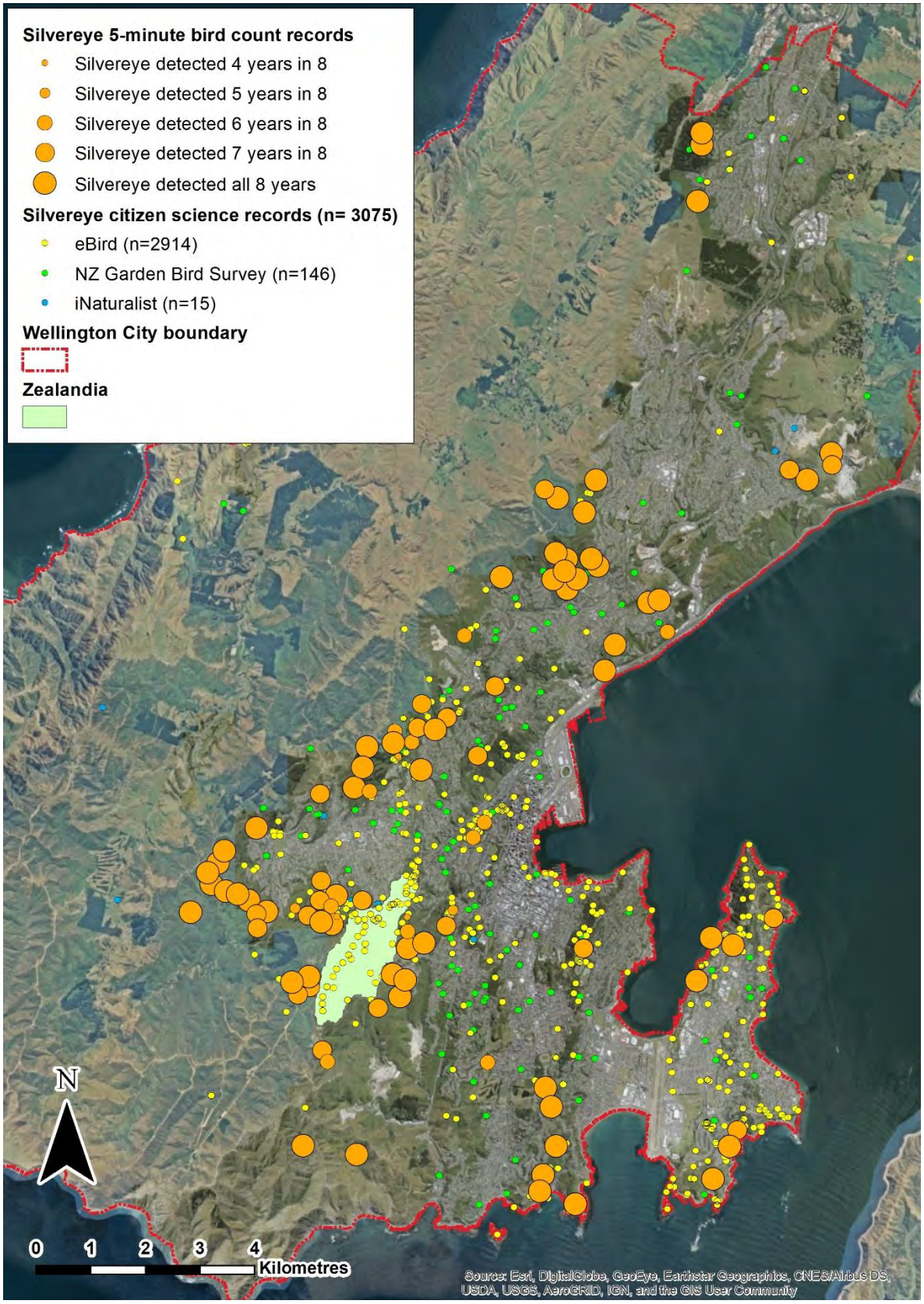

Figure 3.7: Distribution of silvereye in Wellington City between 2011 and 2019. Orange circles represent silvereye detections at five-minute bird count stations, with the size of the circle corresponding to the relative detection frequency. Smaller coloured circles represent silvereye observations reported by local citizen scientists via eBird, iNaturalist or the NZ Garden Bird Survey.

3.2.3 Grey Warbler (*Gerygone igata*)

Image courtesy of Bartek Wypych/NZ Birds Online

National conservation status: Not Threatened (Robertson et al, 2017).

Regional conservation status: Not Threatened (GWRC/DoC, unpublished data).

There has been no overall trend in grey warbler encounter rates in Wellington City between 2011 and 2018, despite some statistically-significant year to year fluctuations ($F_{7,1592}$ = 6.85, p = 4.79 x 10^{-8}; one-way ANOVA; Figure 3.8). Grey warblers are common and widespread in Wellington City, and are recorded from the majority of five-minute bird count stations each year. Grey warblers are also the fourth most frequently observed bird species reported by local citizen scientists, with 2769 grey warbler observations reported within Wellington City limits since 2011 (Figure 3.9).

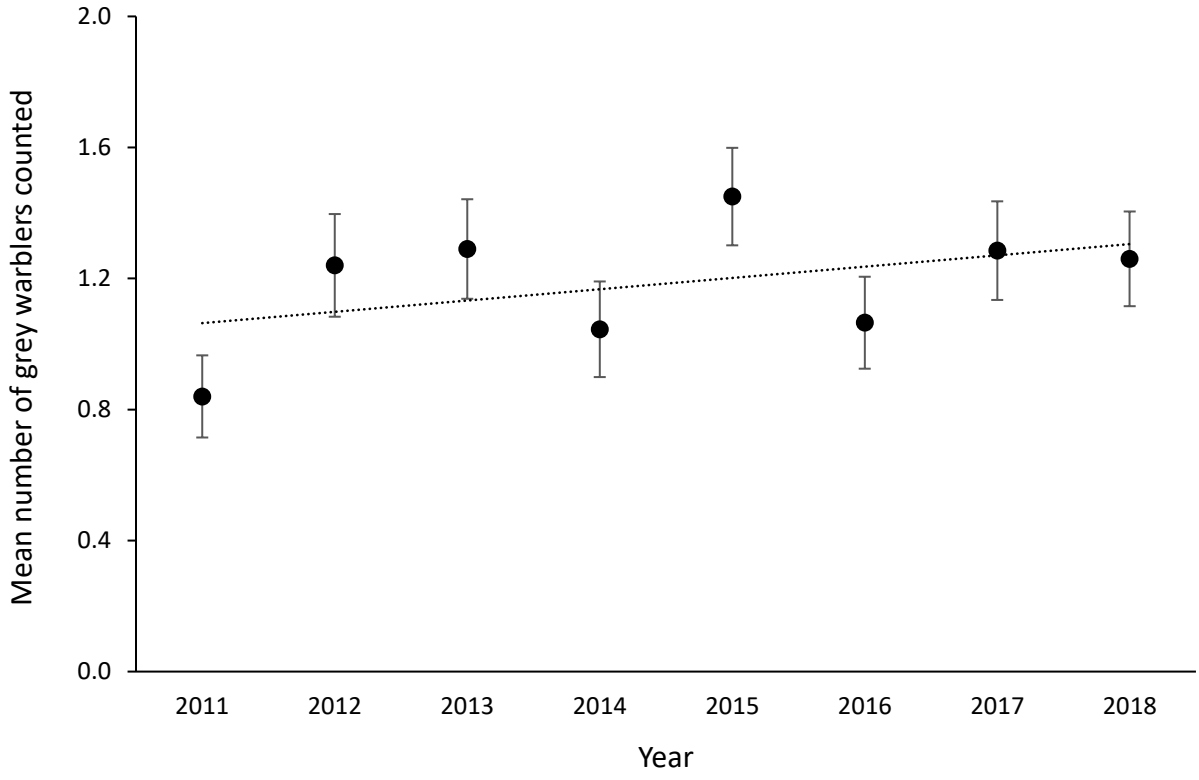

Figure 3.8: Mean number of grey warblers recorded per five-minute bird count station in Wellington City between 2011 and 2018 (error bars represent 95% confidence limits).

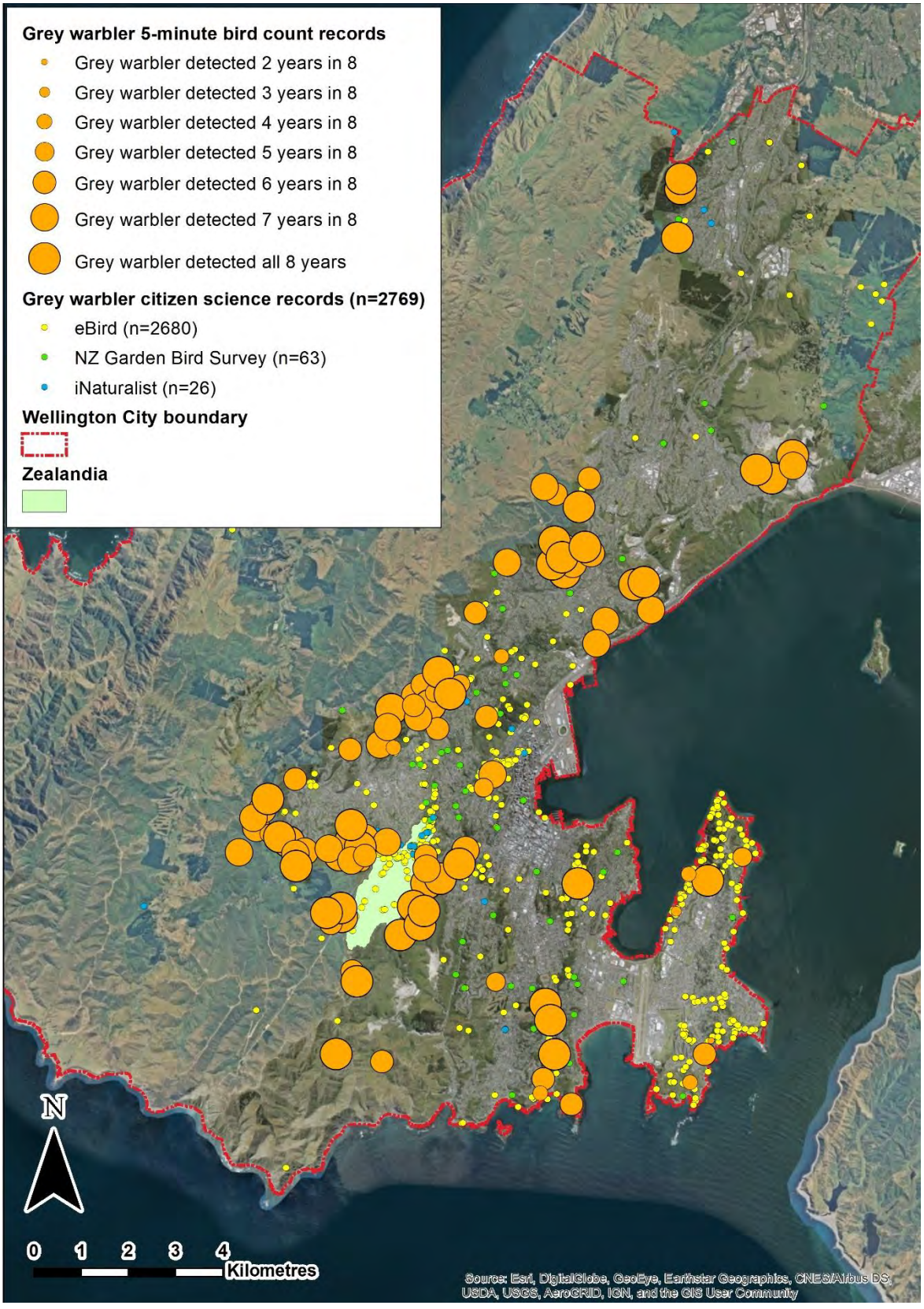

Figure 3.9: Distribution of grey warbler in Wellington City between 2011 and 2019. Orange circles represent grey warbler detections at five-minute bird count stations, with the size of the circle corresponding to the relative detection frequency. Smaller coloured circles represent grey warbler observations reported by local citizen scientists via eBird, iNaturalist or the NZ Garden Bird Survey.

3.2.4 Fantail (*Rhipidura fuliginosa*)

Image courtesy of Cheryl Marriner/NZ Birds Online

National conservation status: Not Threatened (Robertson et al, 2017).

Regional conservation status: Not Threatened (GWRC/DoC, unpublished data).

Fantail encounter rates have not changed significantly in Wellington City between 2011 and 2018 ($F_{7,1592}$ = 1.99, p = 0.053; one-way ANOVA; Figure 3.10). Fantails are common and widespread in Wellington City, though are less frequently encountered at five-minute bird count stations in the southern parts of the city. Fantails are also the sixth most frequently observed bird species reported by local citizen scientists, with 1902 fantail observations reported within Wellington City limits since 2011 (Figure 3.11).

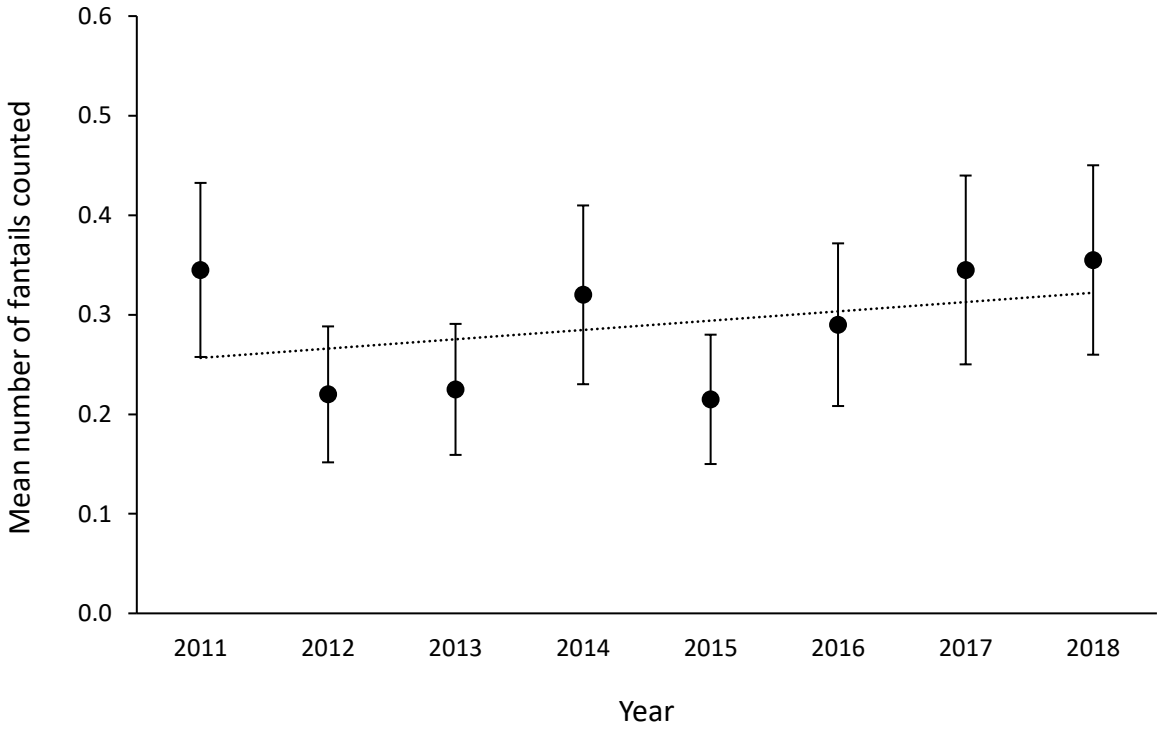

Figure 3.10: Mean number of fantails recorded per five-minute bird count station in Wellington City between 2011 and 2018 (error bars represent 95% confidence limits).

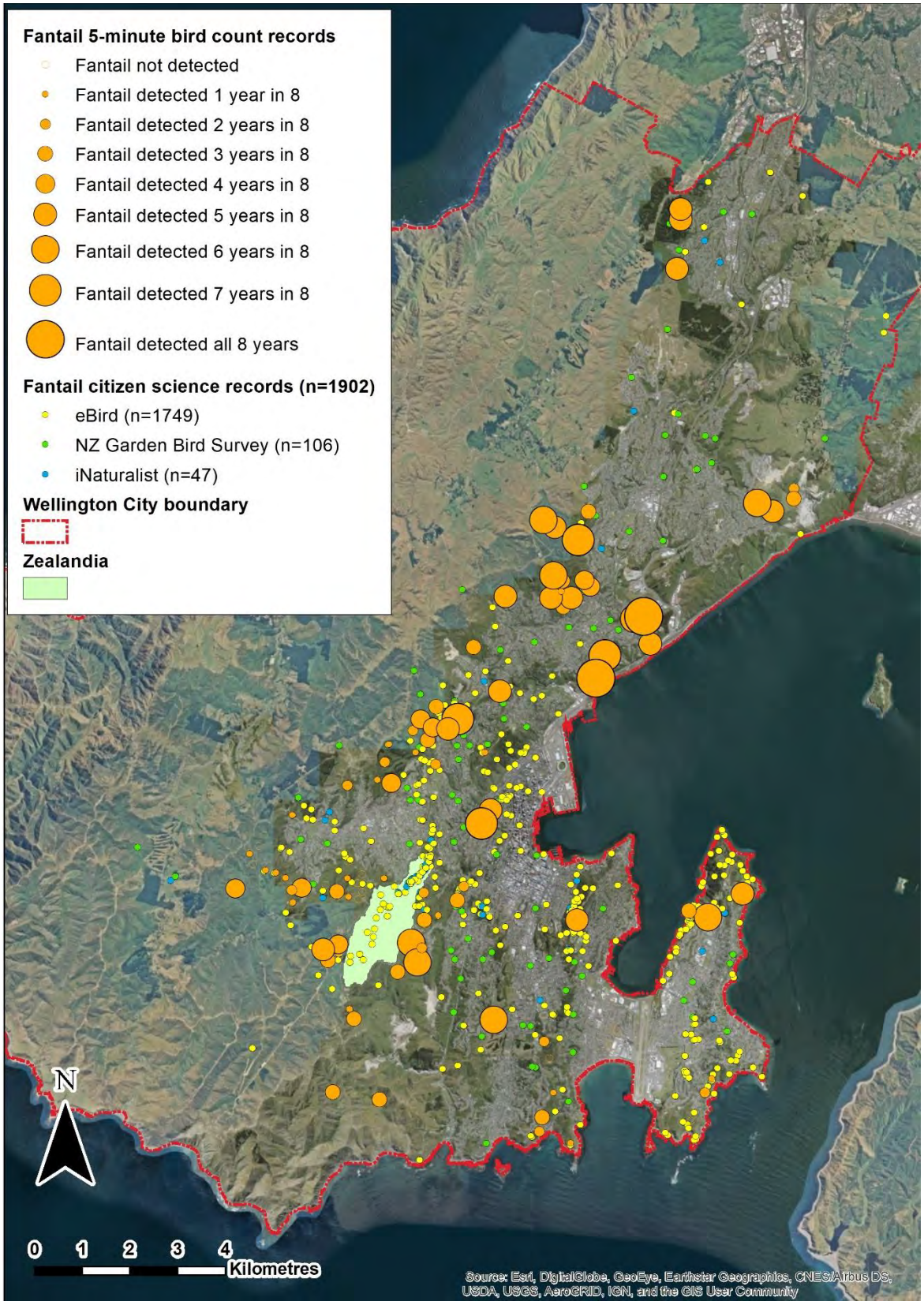

Figure 3.11: Distribution of fantail in Wellington City between 2011 and 2019. Orange circles represent fantail detections at five-minute bird count stations, with the size of the circle corresponding to the relative detection frequency. Smaller coloured circles represent fantail observations reported by local citizen scientists via eBird, iNaturalist or the NZ Garden Bird Survey.

3.2.5 Shining cuckoo (*Chrysococcyx lucidus*)

Image courtesy of Rob Lynch/NZ Birds Online

National conservation status: Not Threatened (Robertson et al, 2017).

Regional conservation status: Not Threatened (GWRC/DoC, unpublished data).

Shining cuckoo encounter rates have not changed significantly in Wellington City between 2011 and 2018 ($F_{7,1592}$ = 0.63, p = 0.73; one-way ANOVA; Figure 3.12). Shining cuckoos are sparsely distributed throughout Wellington City, though encounter rates appear to be highest in forest habitat within 1km of Zealandia, in Khandallah Park and in Tawa. Shining cuckoos are also the twelfth most frequently observed bird species reported by local citizen scientists, with 553 shining cuckoo observations reported within Wellington City limits since 2011 (Figure 3.13).

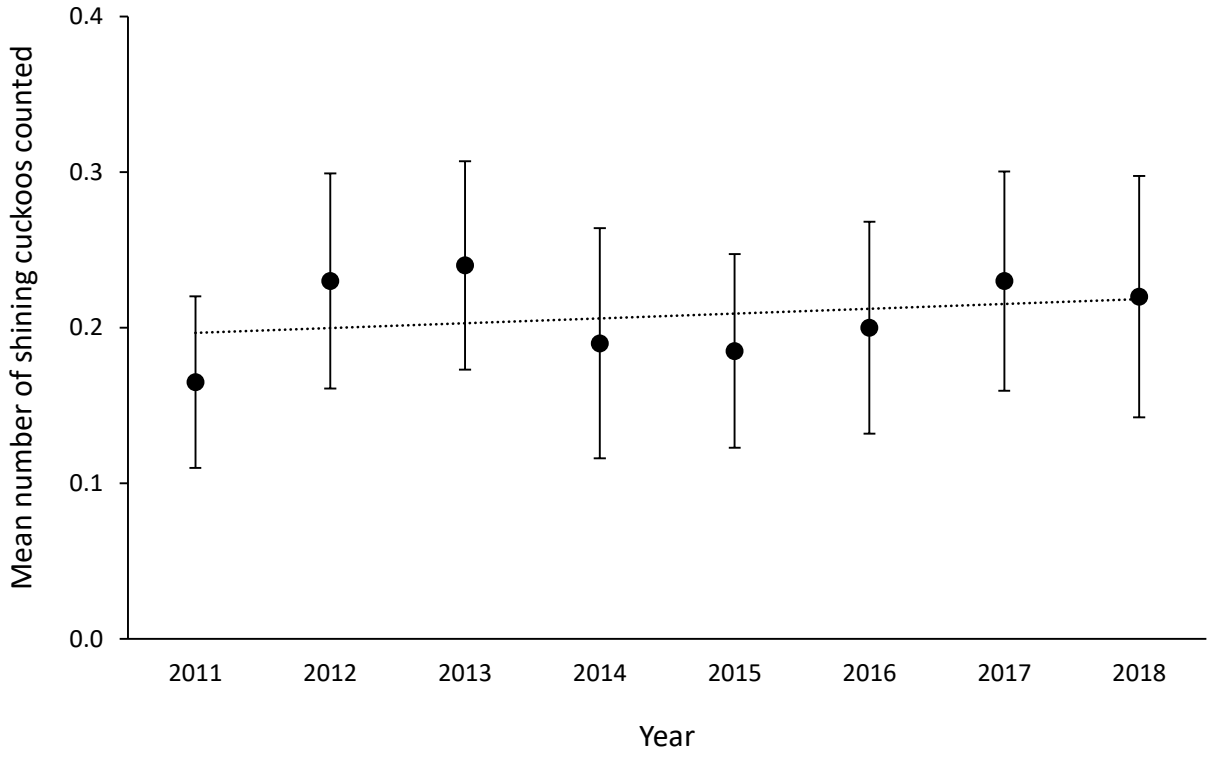

Figure 3.12: Mean number of shining cuckoos recorded per five-minute bird count station in Wellington City between 2011 and 2018 (error bars represent 95% confidence limits).

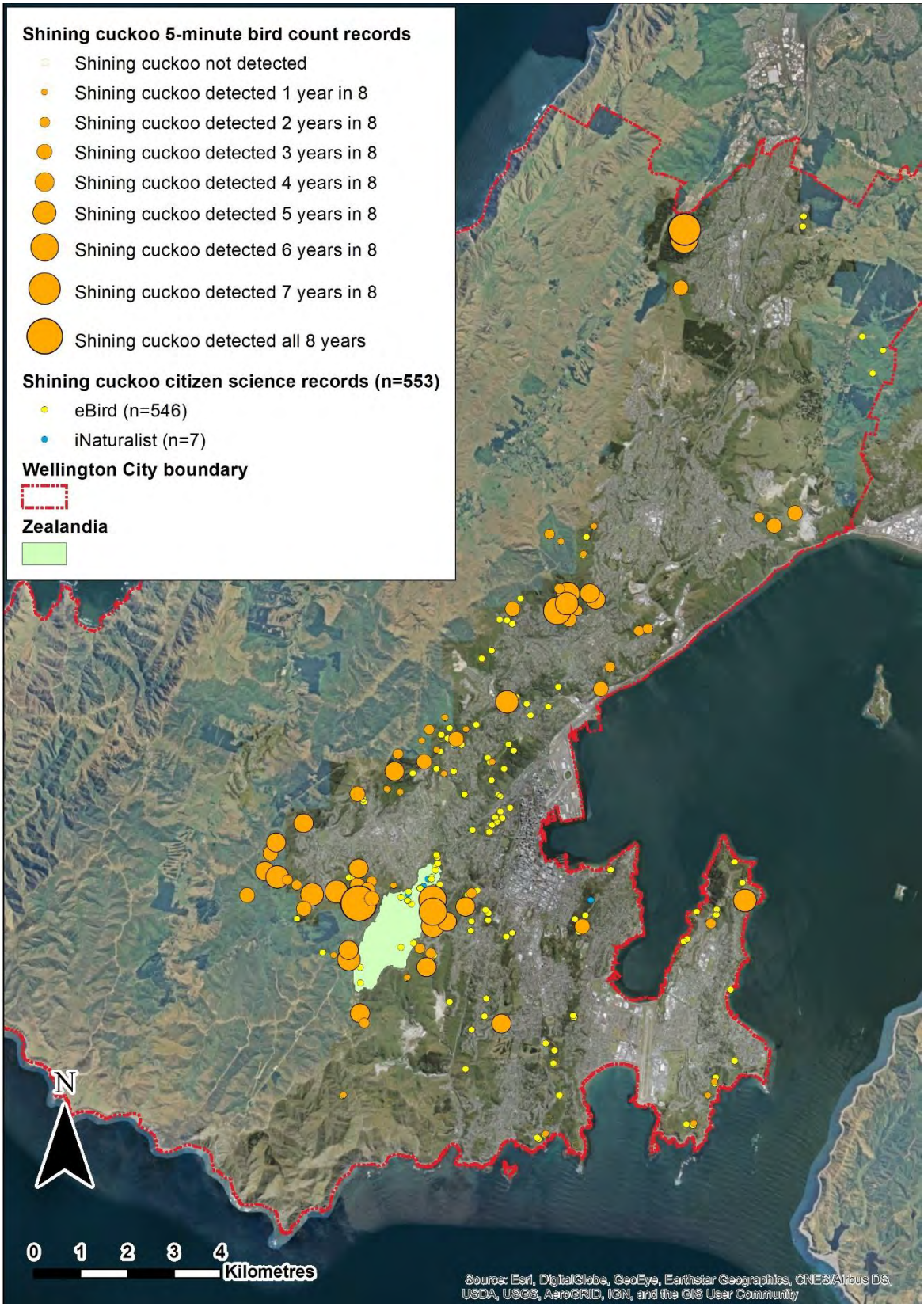

Figure 3.13: Distribution of shining cuckoo in Wellington City between 2011 and 2019. Orange circles represent shining cuckoo detections at five-minute bird count stations, with the size of the circle corresponding to the relative detection frequency. Smaller coloured circles represent shining cuckoo observations reported by local citizen scientists via eBird or iNaturalist.

3.2.6 kākā (*Nestor meridionalis*)

Image courtesy of Jean-Claude Stahl/NZ Birds Online

National conservation status: At Risk, Recovering (Robertson et al, 2017).

Regional conservation status: Regionally Vulnerable (GWRC/DoC, unpublished data).

Kākā encounter rates have increased significantly in Wellington City between 2011 and 2018 ($F_{7,1592}$ = 3.88, p = 0.0003; one-way ANOVA; Figure 3.14). Kākā are now commonly encountered in central Wellington, particularly in the suburbs of Karori, Wadestown, Ngaio, Kelburn, Te Aro and Brooklyn. They are also continuing to extend their range into more northern suburbs such as Johnsonville, and more eastern suburbs such as Miramar. Kākā are also the fifth most frequently observed bird species reported by local citizen scientists, with 2616 kākā observations reported within Wellington City limits since 2011 (Figure 3.15).

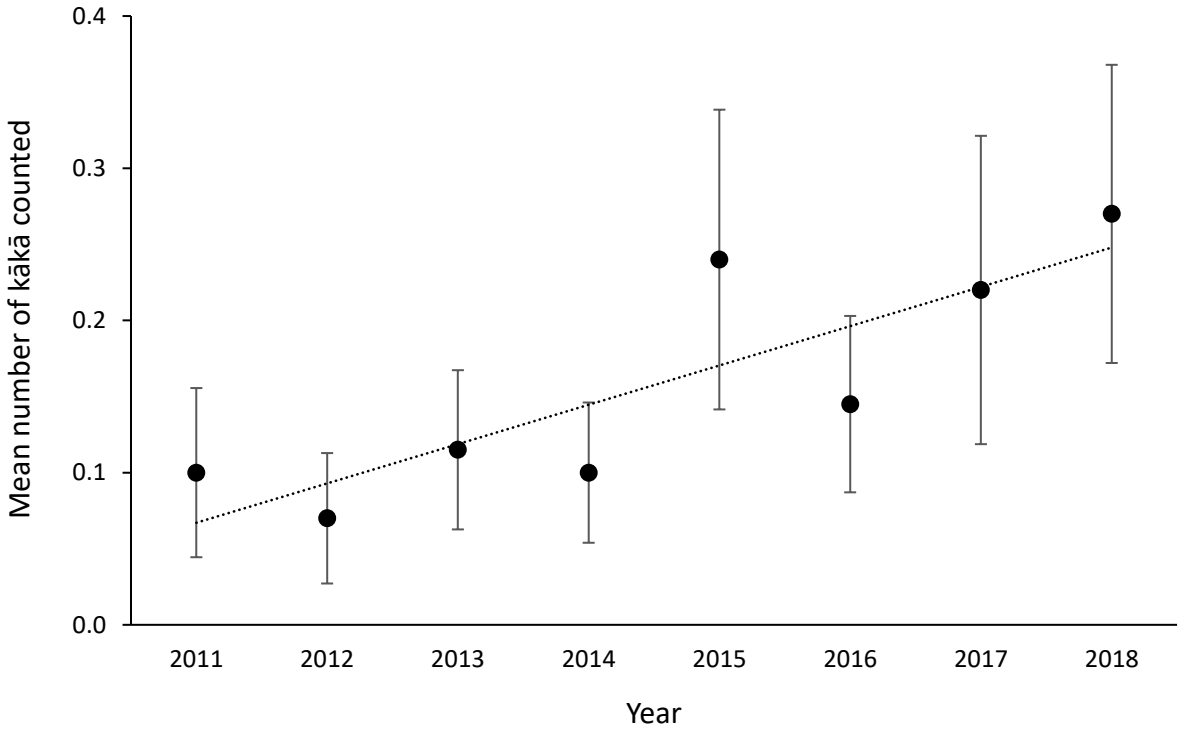

Figure 3.14: Mean number of kākā recorded per five-minute bird count station in Wellington City between 2011 and 2018 (error bars represent 95% confidence limits).

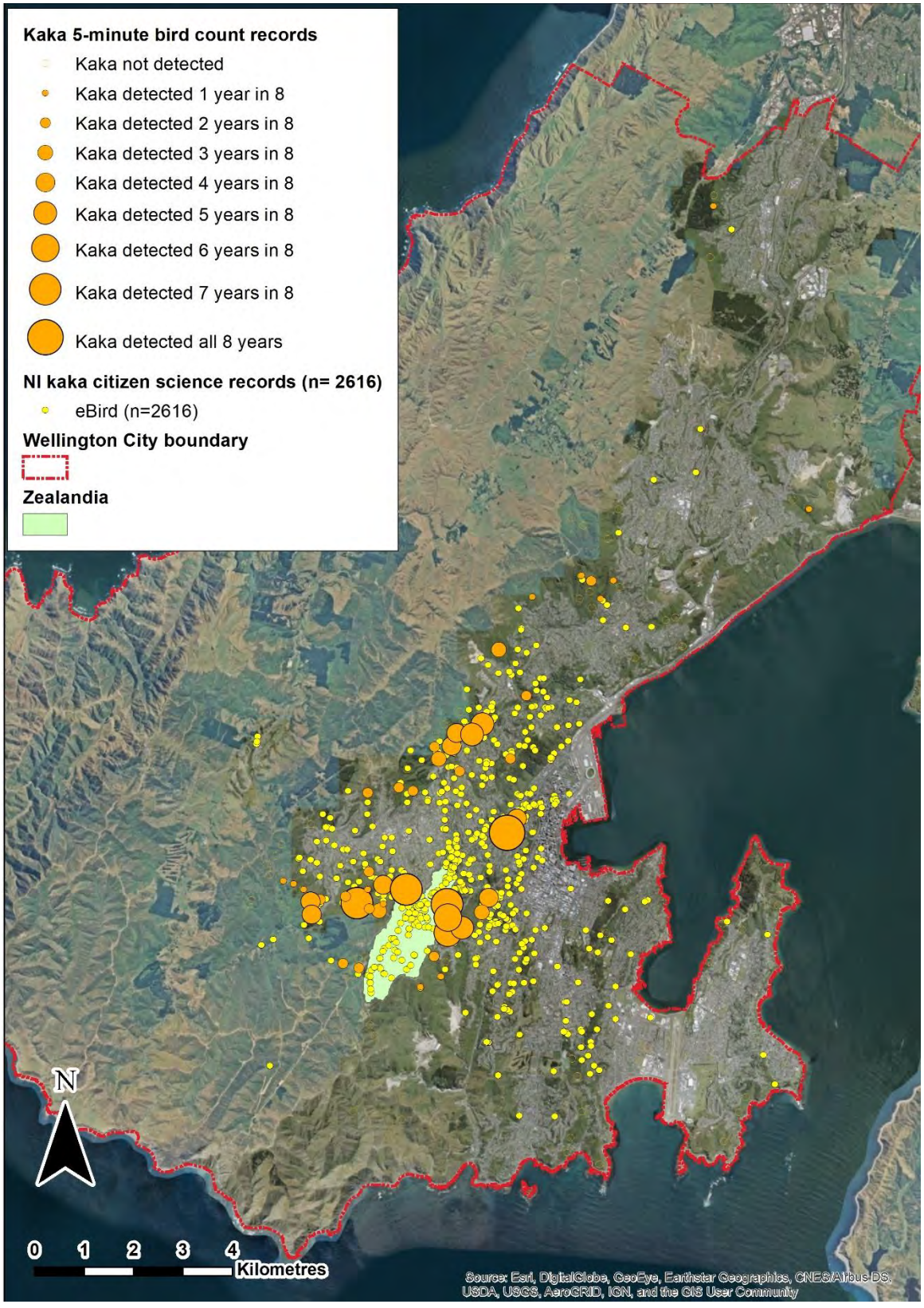

Figure 3.15: Distribution of kākā in Wellington City between 2011 and 2019. Orange circles represent kākā detections at five-minute bird count stations, with the size of the circle corresponding to the relative detection frequency. Smaller coloured circles represent kākā observations reported by local citizen scientists via eBird.

3.2.7 Kererū (*Hemiphaga novaeseelandiae*)

National conservation status: Not threatened (Robertson et al, 2017).

Regional conservation status: Not threatened (GWRC/DoC, unpublished data).

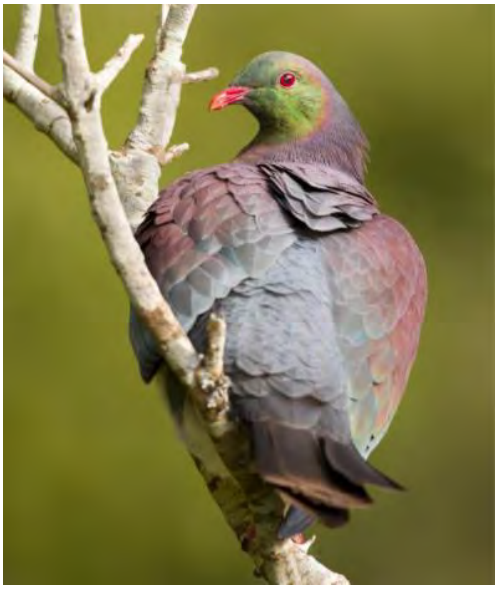

Image courtesy of Arindam Bhattacharya/NZ Birds Online

Kererū encounter rates have increased significantly in Wellington City between 2011 and 2018 ($F_{7,1592}$ = 3.06, p = 0.003; one-way ANOVA; Figure 3.16). Much of this increase has been between 2015 and 2018 however, so further monitoring will be required to determine whether this increase is part of a long-term trend, or simply inter-annual variation in encounter rates caused by a change in distribution or habitat use. Kererū encounter rates are highest in reserves containing original native forest habitat, such as Otari-Wilton Bush and Khandallah Park, but they are also frequently observed in adjacent suburban areas. Kererū are the third most frequently observed bird species reported by local citizen scientists, with 2978 kererū observations reported within Wellington City limits since 2011 (Figure 3.17).

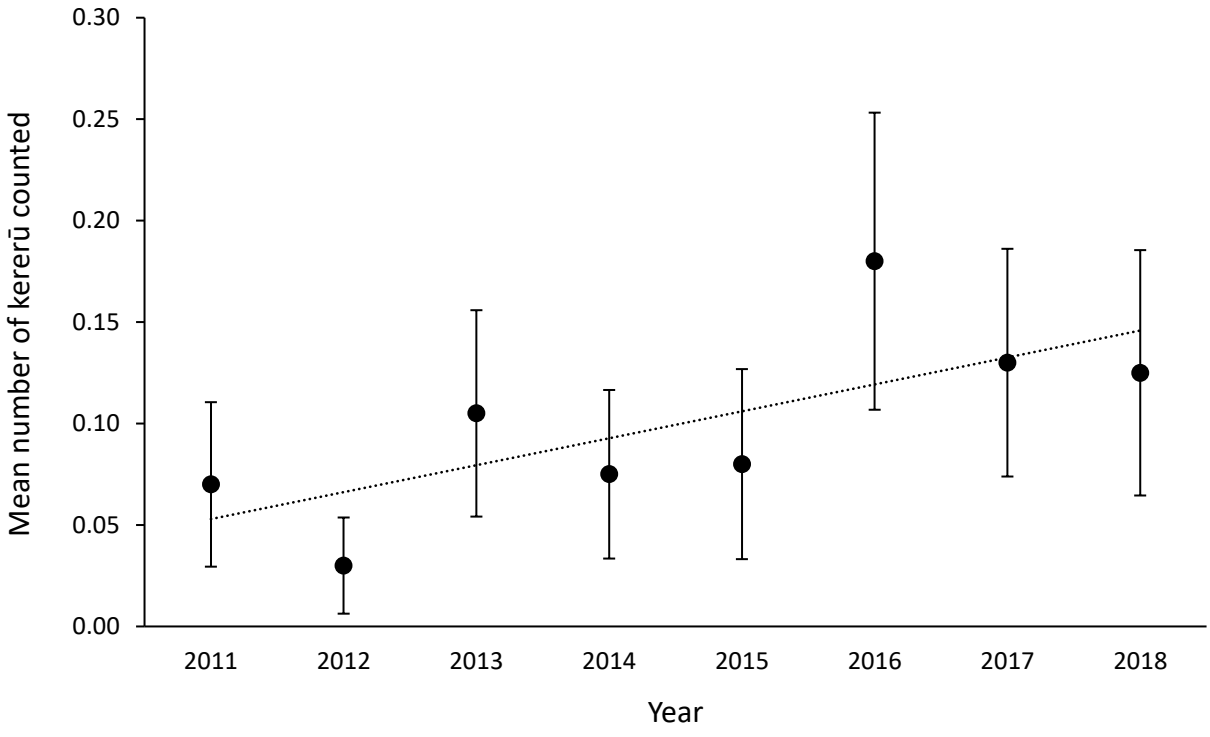

Figure 3.16: Mean number of kererū recorded per five-minute bird count station in Wellington City between 2011 and 2018 (error bars represent 95% confidence limits).

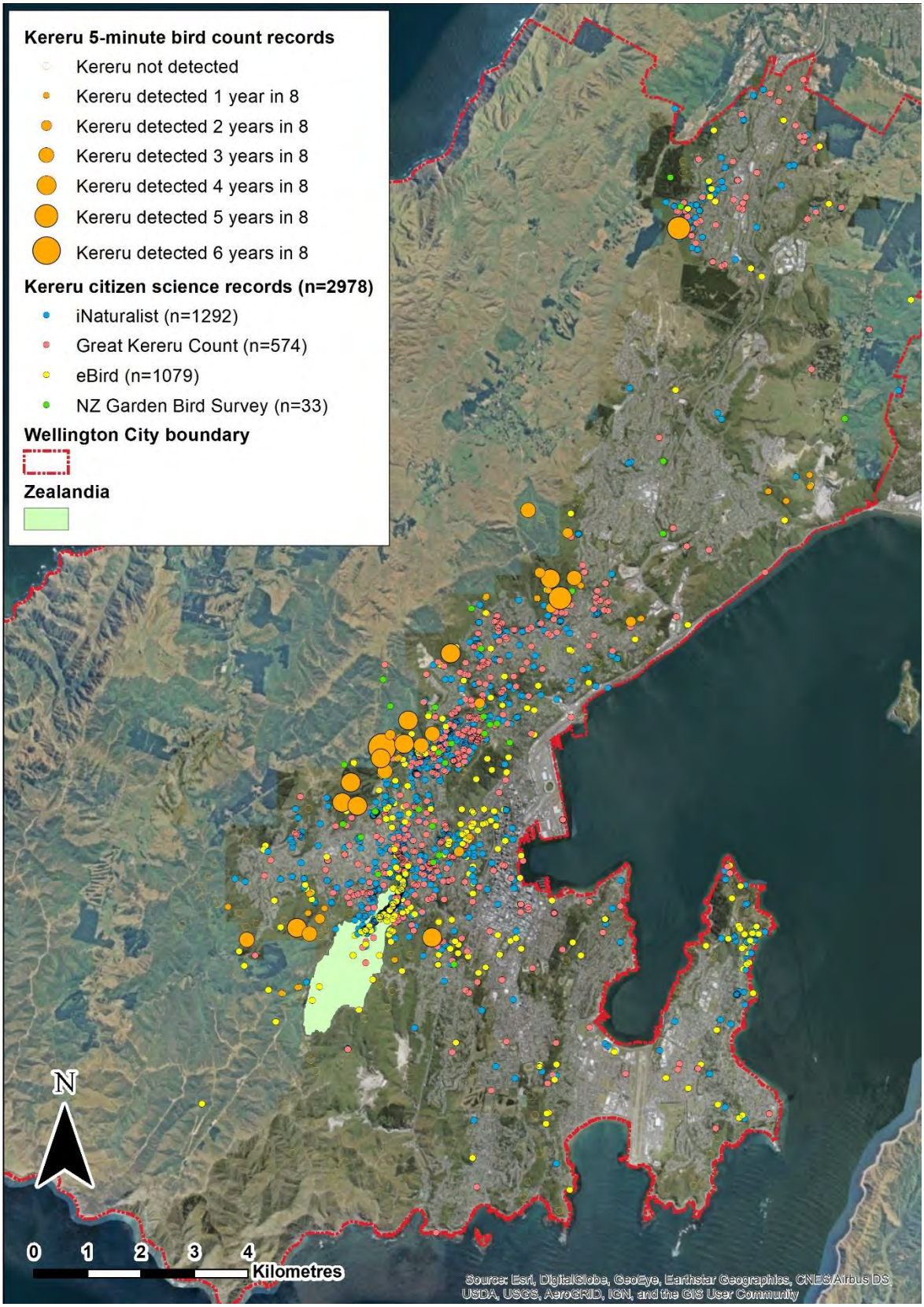

Figure 3.17: Distribution of kererū in Wellington City between 2011 and 2019. Orange circles represent kererū detections at five-minute bird count stations, with the size of the circle corresponding to the relative detection frequency. Smaller coloured circles represent kererū observations reported by local citizen scientists via eBird, iNaturalist, the Great Kereru Count or the NZ Garden Bird Survey.

3.2.8 North Island saddleback (*Philesturnus rufusater*)

Image courtesy of Rob Lynch/NZ Birds Online

National conservation status: At Risk, Recovering (Robertson et al, 2017).

Regional conservation status: Regionally Endangered (GWRC/DoC, unpublished data).

There has been a significant increase in North Island saddleback encounter rates between 2011 and 2018 ($F_{7,1592} = 2.81$, $p = 0.007$; one-way ANOVA; Figure 3.18). NI saddleback are largely restricted to Zealandia and to forested reserves less than 1-2 km from Zealandia's pest-proof boundary fence, so this increase in encounter rates is likely to be a result of ongoing improvements in the mammalian predator control being carried out in forested reserves adjacent to Zealandia. NI saddleback are the eighth most frequently observed bird species reported by local citizen scientists, with 718 NI saddleback observations reported within Wellington City limits since 2011 (Figure 3.19).

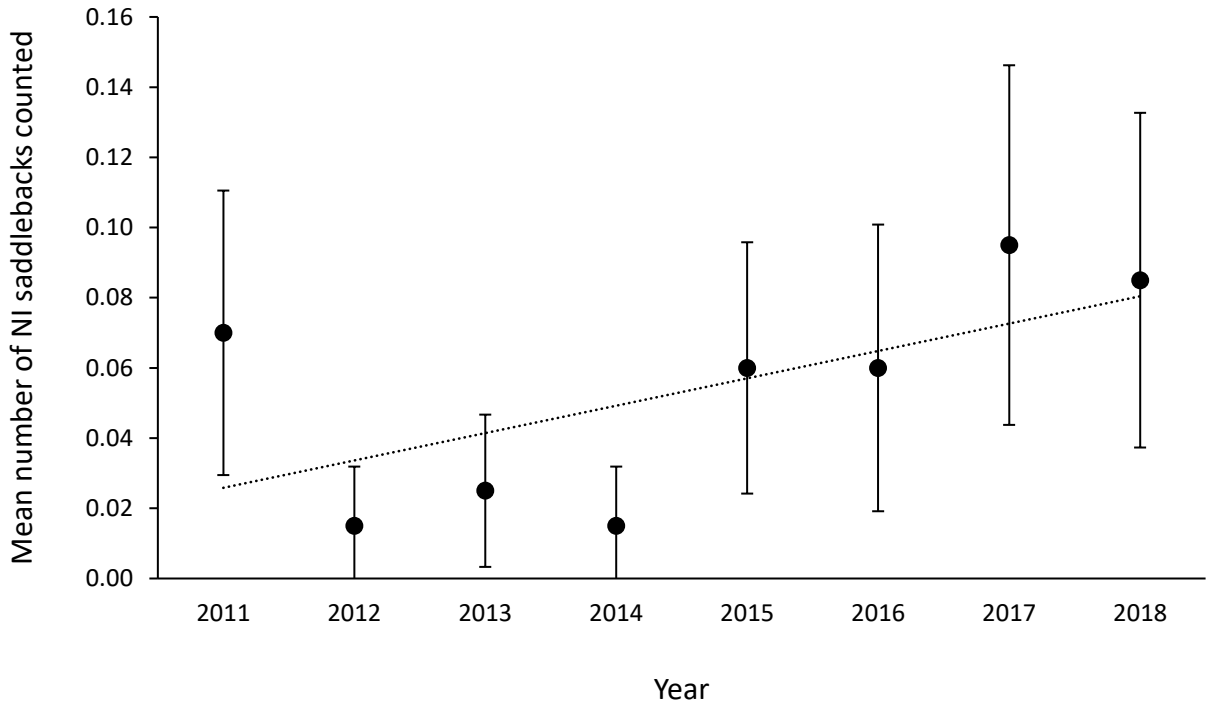

Figure 3.18: Mean number of NI saddlebacks recorded per five-minute bird count station in Wellington City between 2011 and 2018 (error bars represent 95% confidence limits).

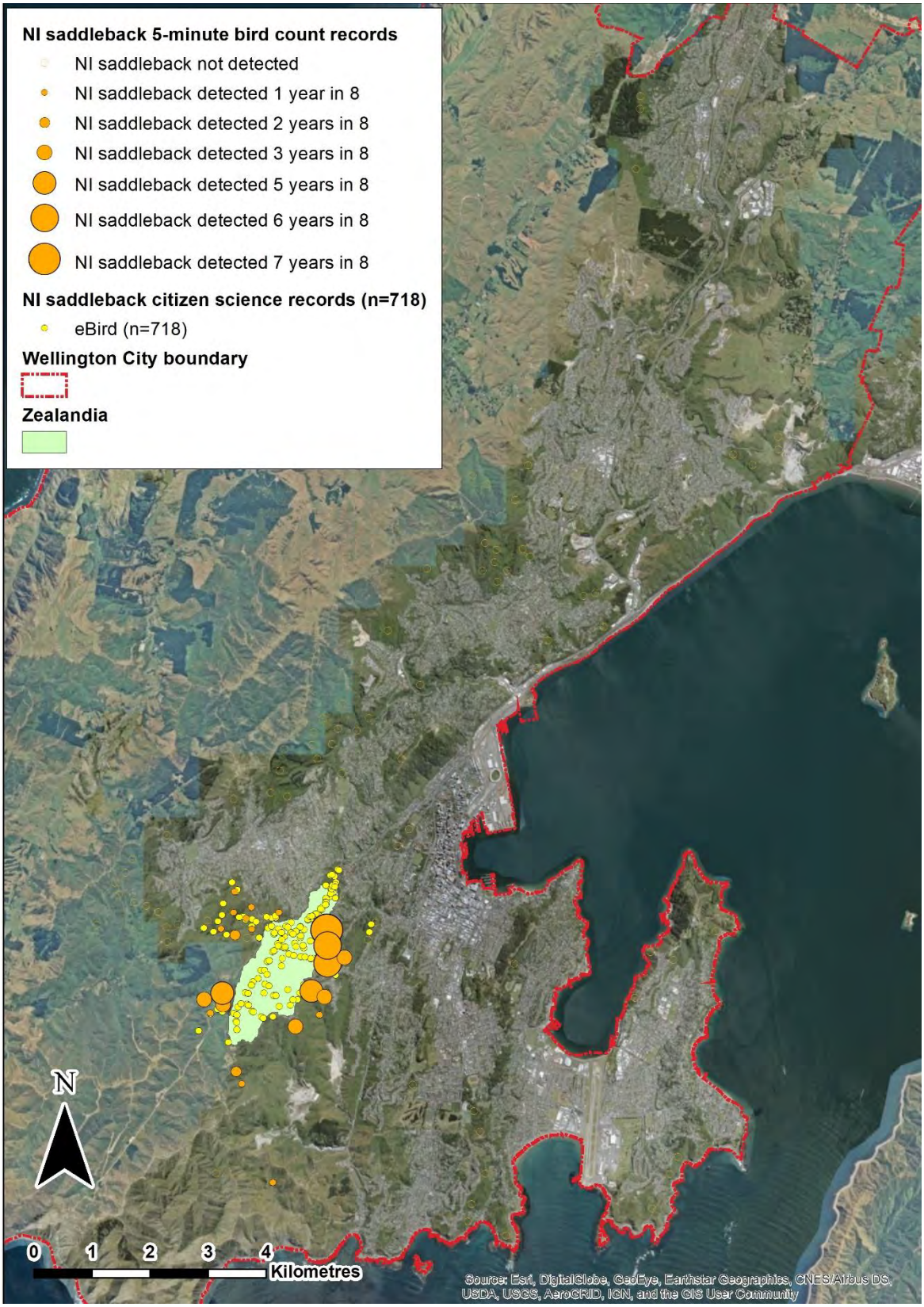

Figure 3.19: Distribution of NI saddleback in Wellington City between 2011 and 2019. Orange circles represent NI saddleback detections at five-minute bird count stations, with the size of the circle corresponding to the relative detection frequency. Smaller coloured circles represent NI saddleback observations reported by local citizen scientists via eBird.

3.2.9 Whitehead (*Mohoua albicilla*)

Image courtesy of Tony Whitehead/NZ Birds Online

National conservation status: At Risk, Declining (Robertson et al, 2017).

Regional conservation status: Not Threatened (GWRC/DoC, unpublished data).

Whitehead encounter rates have not changed significantly in Wellington City between 2011 and 2018 ($F_{7,1592}$ = 0.38, p = 0.92; one-way ANOVA; Figure 3.20). Whiteheads are largely restricted to Zealandia and to forest reserves within 1-2 km of Zealandia's boundary fence, however they have now also been recorded as far afield as Trelissick Park, Tinakori Hill, Makara Peak and Prince of Wales Park. Whiteheads are the ninth most frequently observed bird species reported by local citizen scientists, with 717 whitehead observations reported within Wellington City limits since 2011 (Figure 3.21).

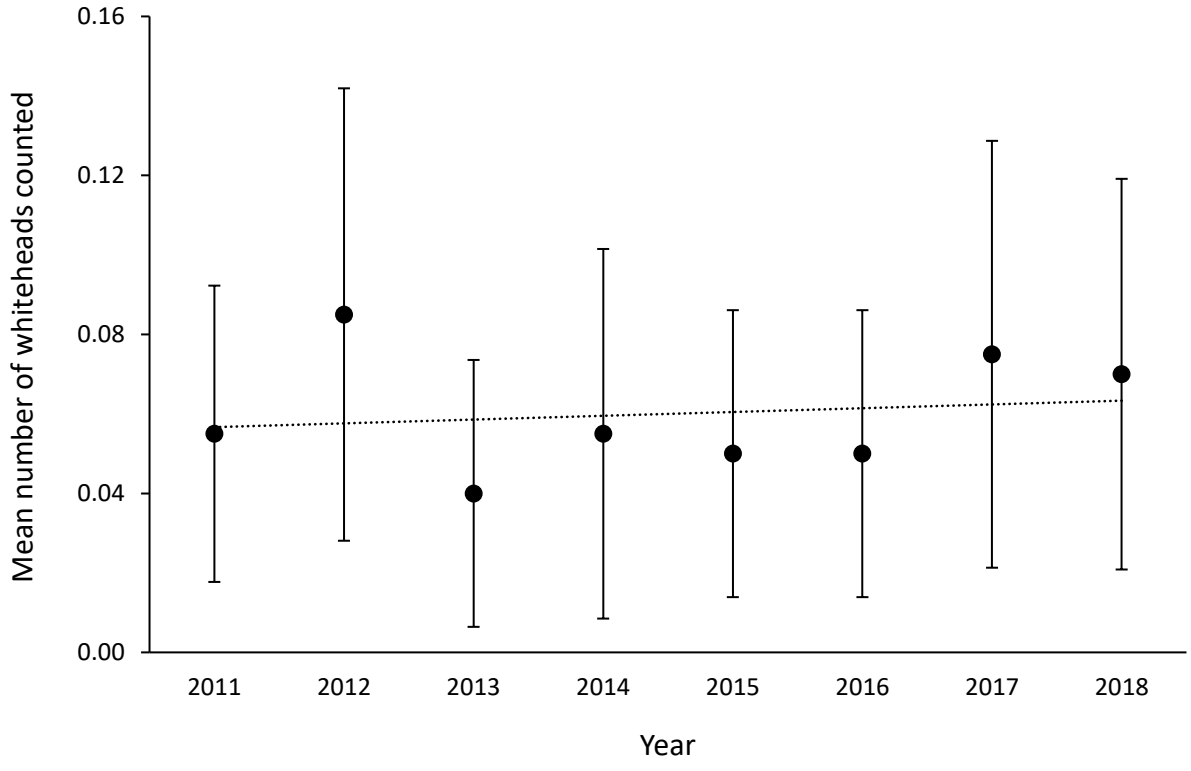

Figure 3.20: Mean number of whiteheads recorded per five-minute bird count station in Wellington City between 2011 and 2018 (error bars represent 95% confidence limits).

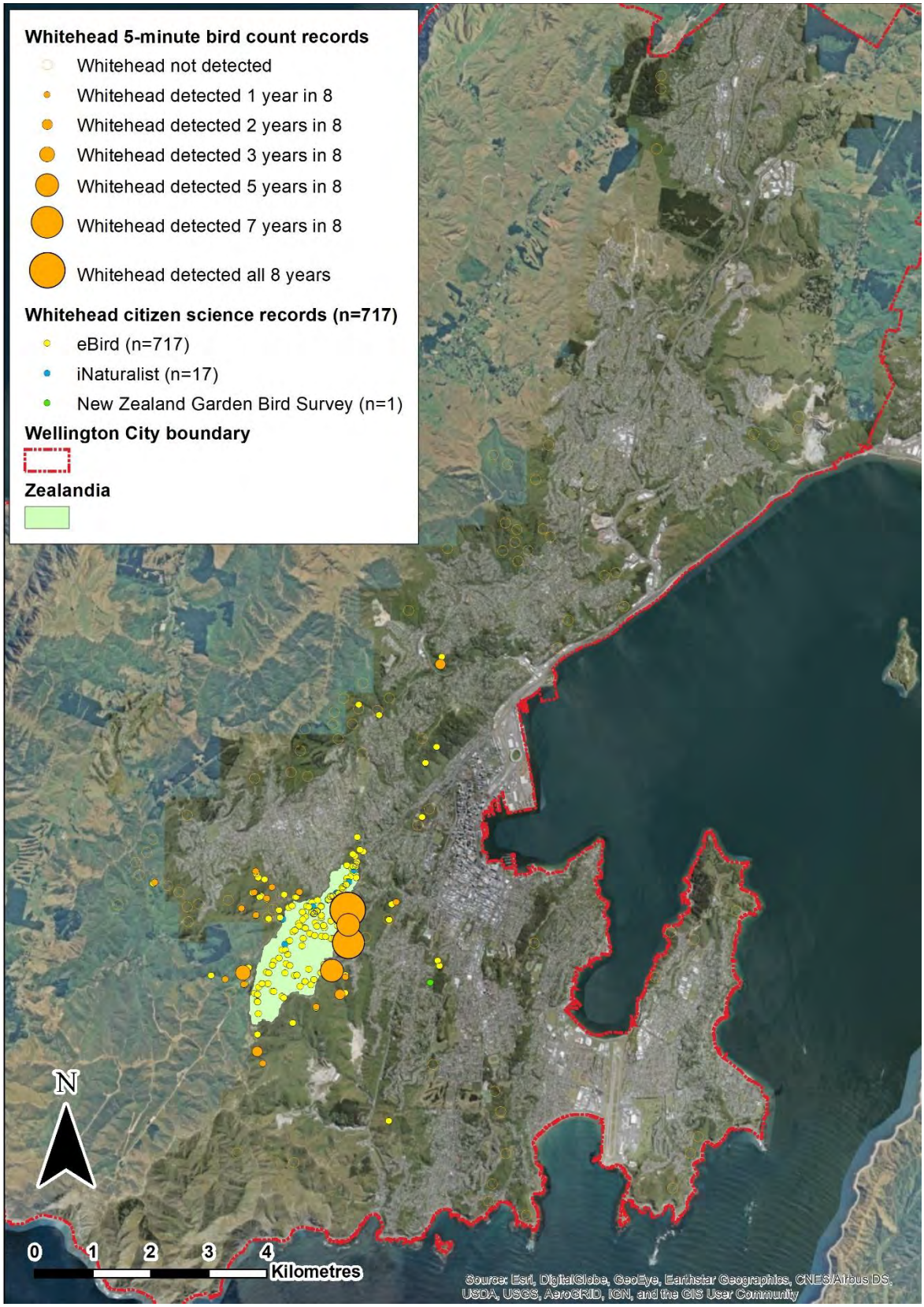

Figure 3.21: Distribution of whitehead in Wellington City between 2011 and 2019. Orange circles represent whitehead detections at five-minute bird count stations, with the size of the circle corresponding to the relative detection frequency. Smaller coloured circles represent whitehead observations reported by local citizen scientists via eBird, iNaturalist or the NZ Garden Bird Survey.

3.2.10 New Zealand kingfisher (*Todiramphus sanctus*)

Image courtesy of Bartek Wypych/NZ Birds Online

National conservation status: Not Threatened (Robertson et al, 2017).

Regional conservation status: Not Threatened (GWRC/DoC, unpublished data).

New Zealand kingfisher encounter rates have not changed significantly in Wellington City between 2011 and 2018 ($F_{7,1592}$ = 0.60, p = 0.76; one-way ANOVA; Figure 3.22). NZ kingfisher encounter rates are higher in reserves with original, old-growth native forest cover, namely Otari-Wilton Bush, Wellington Botanical Gardens and Khandallah Park. However, NZ kingfishers are sparsely distributed throughout the city, including in suburban habitats. NZ kingfishers are the tenth most frequently observed bird species reported by local citizen scientists, with 611 kingfisher observations reported within Wellington City limits since 2011 (Figure 3.23).

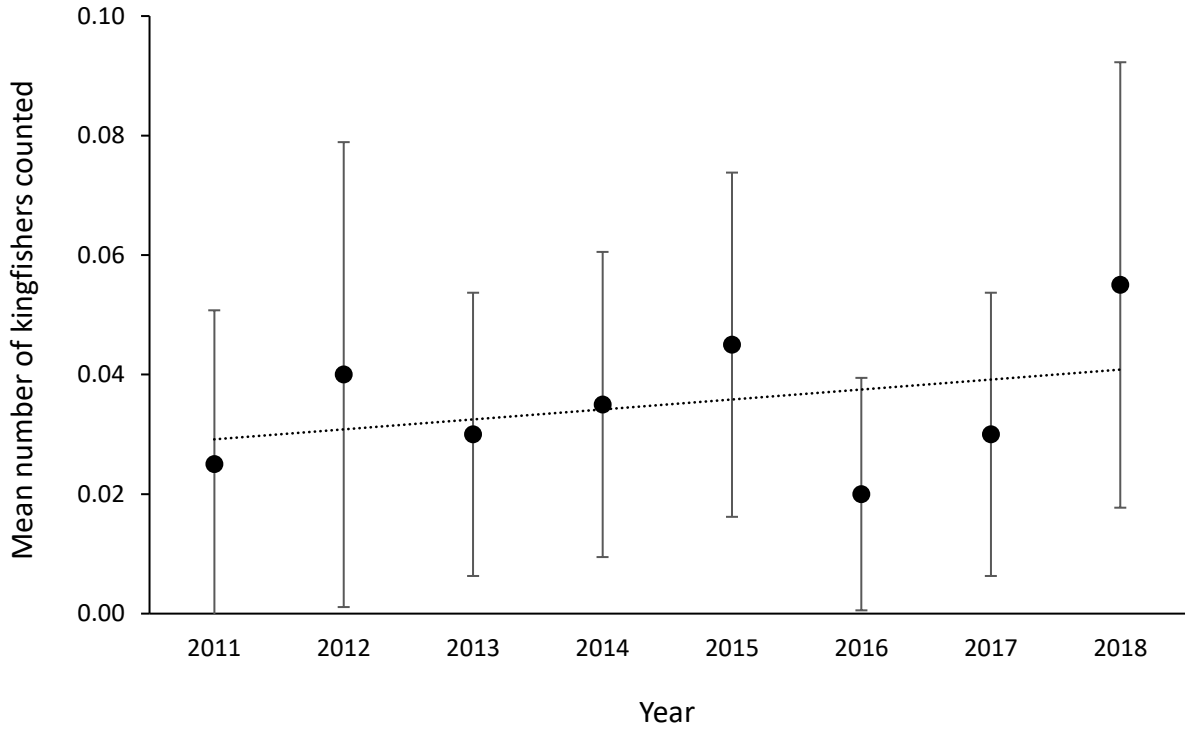

Figure 3.22: Mean number of NZ kingfishers recorded per five-minute bird count station in Wellington City between 2011 and 2018 (error bars represent 95% confidence limits).

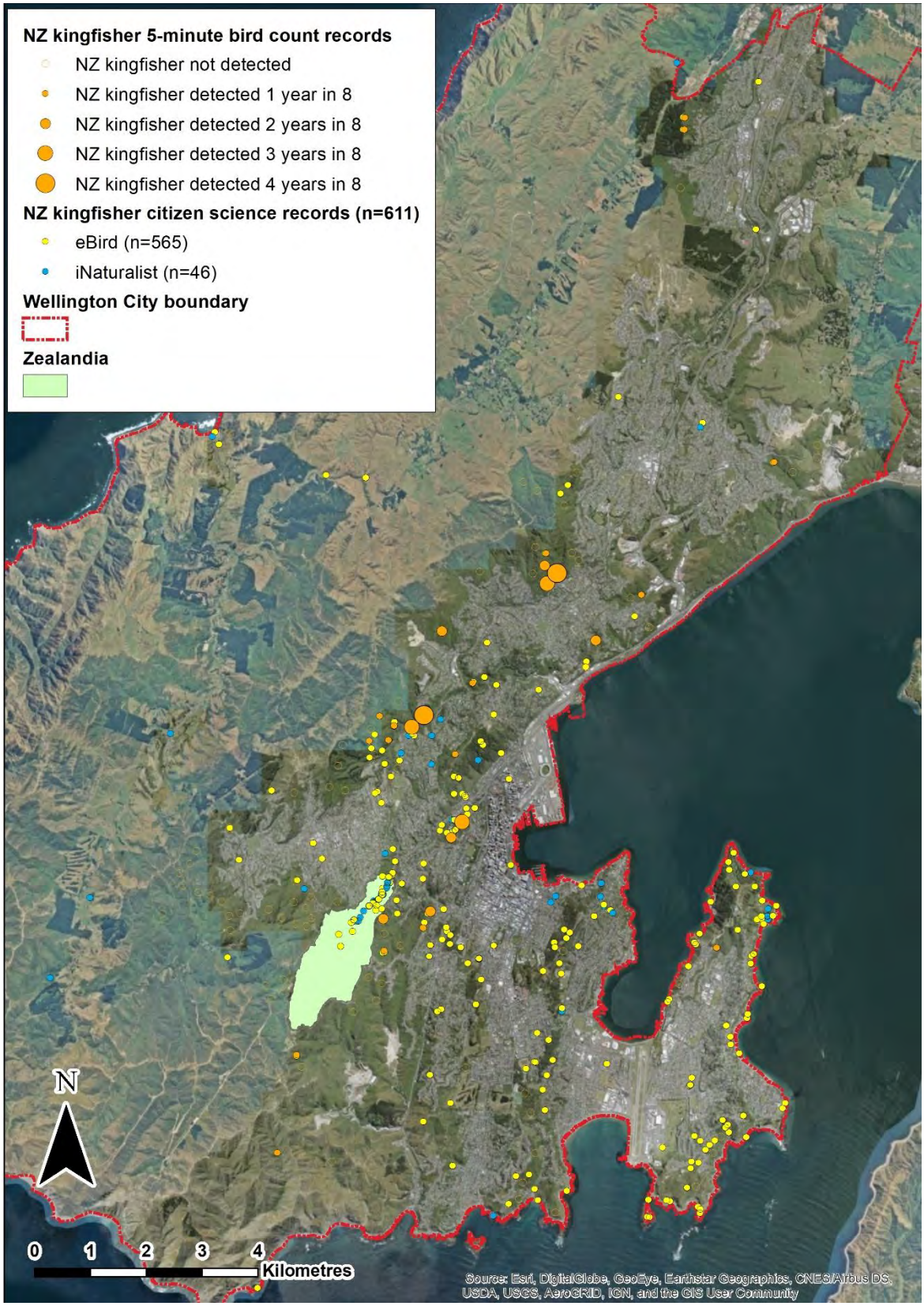

Figure 3.23: Distribution of NZ kingfisher in Wellington City between 2011 and 2019. Orange circles represent NZ kingfisher detections at five-minute bird count stations, with the size of the circle corresponding to the relative detection frequency. Smaller coloured circles represent NZ kingfisher observations reported by local citizen scientists via eBird or iNaturalist.

3.2.11 Red-crowned parakeet (*Cyanoramphus novaezealandiae*)

Image courtesy of Laurie Ross/NZ Birds Online

National conservation status: At Risk, Relict (Robertson et al, 2017).

Regional conservation status: At Risk, Recovering (GWRC/DoC, unpublished data).

Red-crowned parakeet encounter rates have increased significantly in Wellington City between 2011 and 2018 ($F_{7,1592}$ = 4.39, p = 7.73 x 10^{-5}; one-way ANOVA; Figure 3.24). Beyond Zealandia, red-crowned parakeets are now established in Wright's Hill reserve, Otari-Wilton Bush and Khandallah Park, Huntleigh Park and possibly also the Wellington Botanic Gardens. Red-crowned parakeets are sparsely distributed throughout Wellington City, in both native forest and suburban habitats and are the eleventh most frequently observed bird species reported by local citizen scientists, with 575 observations reported within Wellington City limits since 2011 (Figure 3.25).

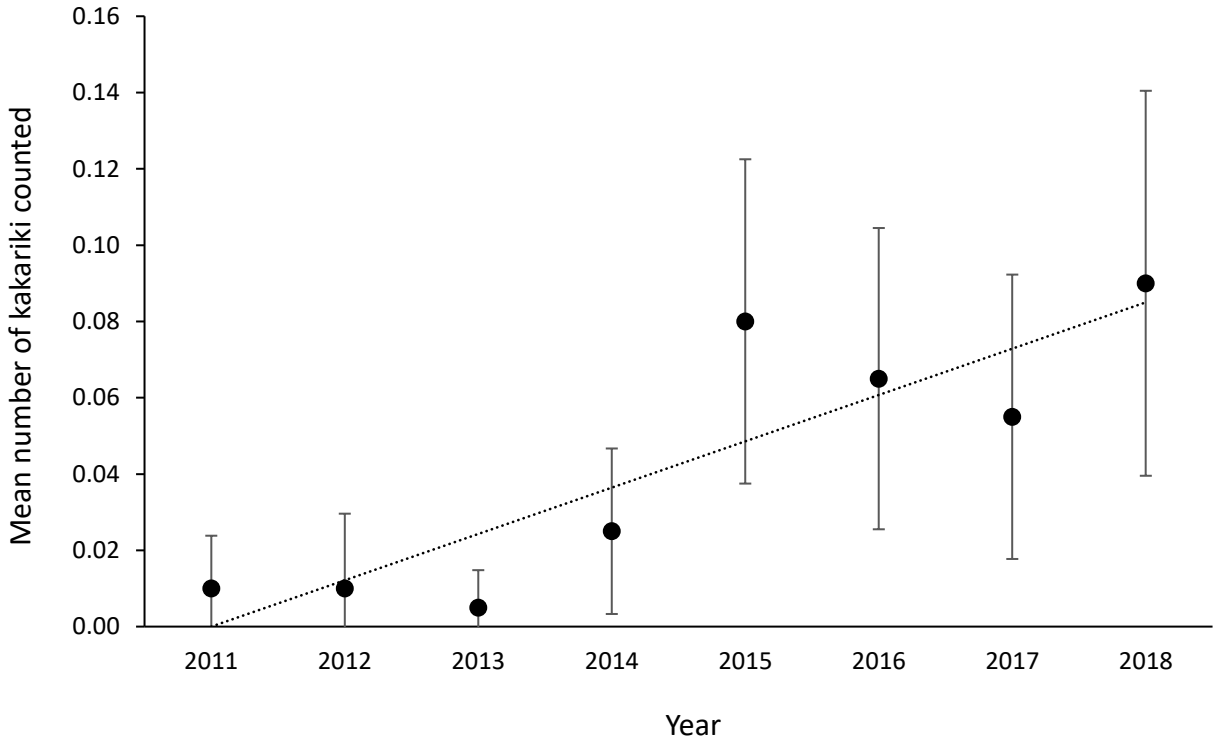

Figure 3.24: Mean number of red-crowned parakeets recorded per five-minute bird count station in Wellington City between 2011 and 2018 (error bars represent 95% confidence limits).

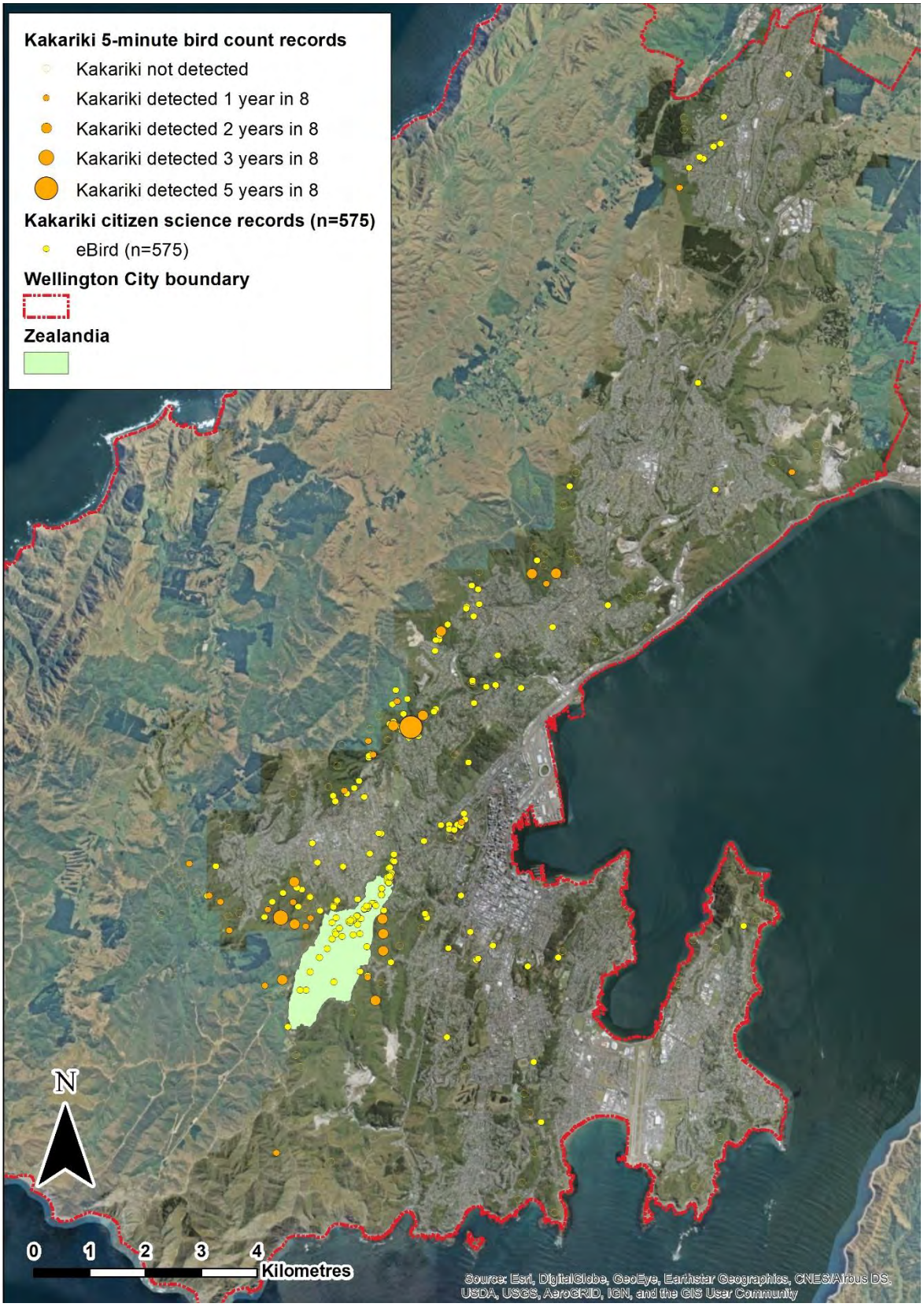

Figure 3.25: Distribution of red-crowned parakeet in Wellington City between 2011 and 2019. Orange circles represent red-crowned parakeet detections at five-minute bird count stations, with the size of the circle corresponding to the relative detection frequency. Smaller coloured circles represent red-crowned parakeet observations reported by local citizen scientists via eBird.

3.2.12 North Island robin (*Petroica longipes*)

National conservation status: At Risk, Declining (Robertson et al, 2017).

Regional conservation status: Not Threatened (GWRC/DoC, unpublished data).

North Island robin encounter rates are exceedingly low in Wellington City parks and reserves, and have not changed significantly in Wellington City between 2011 and 2018 ($F_{7,1592} = 0.48$, $p = 0.852$; one-way ANOVA; Figure 3.26). NI robins are largely restricted to Zealandia and to native forest habitats within 1-2 km of Zealandia's pest-proof boundary fence. NI robins are the seventh most frequently observed bird species reported by local citizen scientists, with 771 robin observations reported within Wellington City limits since 2011 (Figure 3.27).

Image courtesy of Neil Fitzgerald/NZ Birds Online

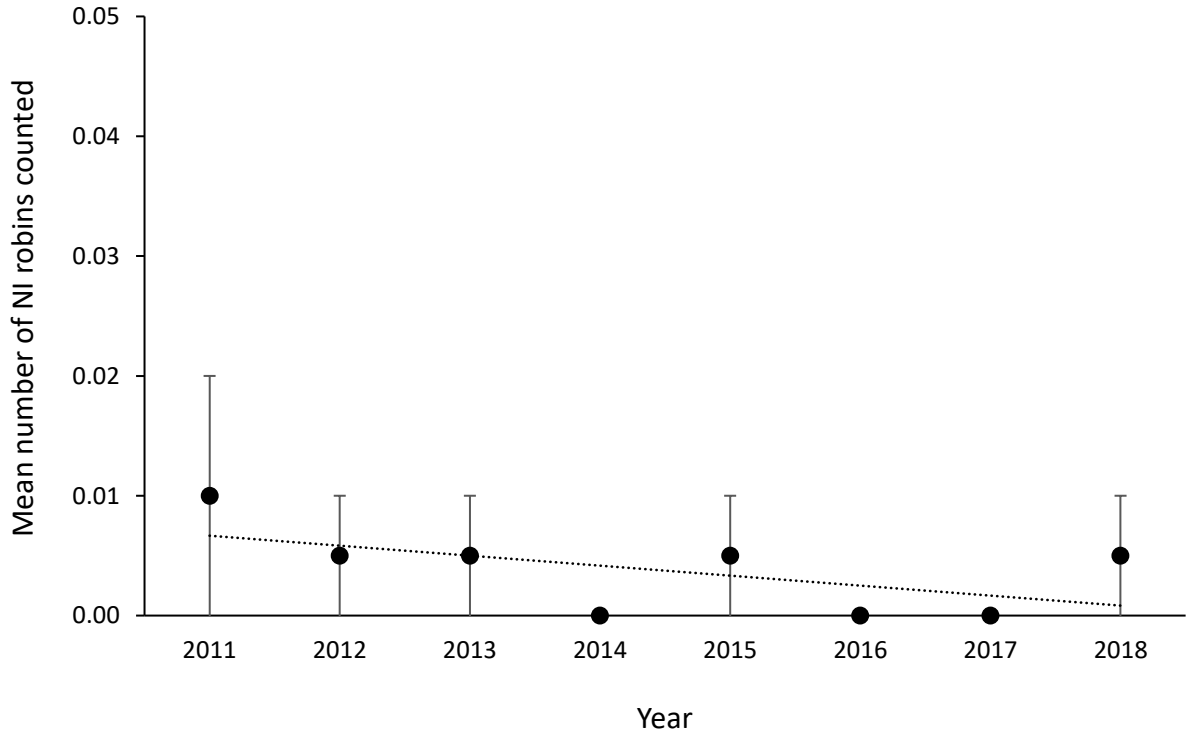

Figure 3.26: Mean number of NI robins recorded per five-minute bird count station in Wellington City between 2011 and 2018 (error bars represent 95% confidence limits).

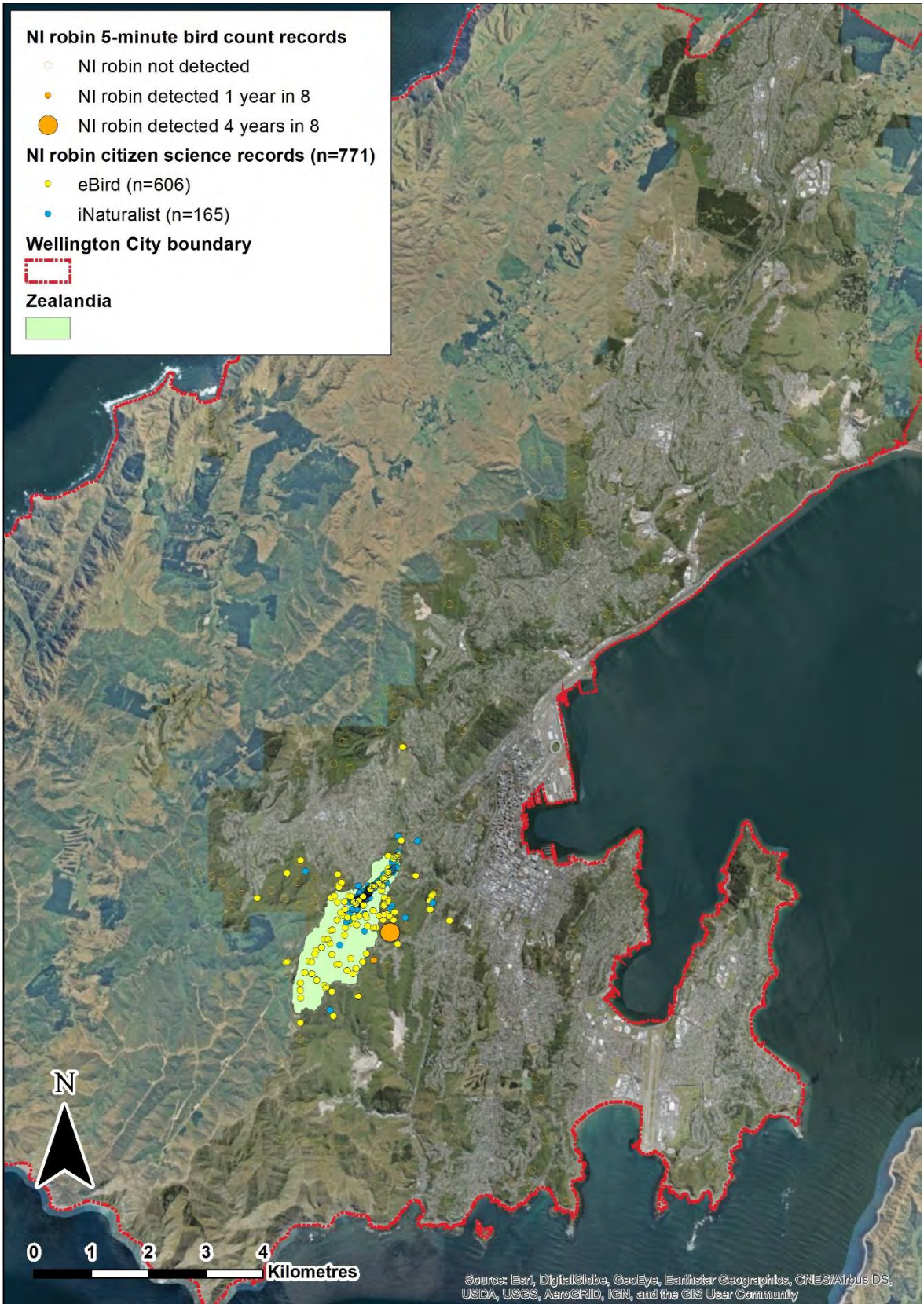

Figure 3.27: Distribution of NI robin in Wellington City between 2011 and 2019. Orange circles represent NI robin detections at five-minute bird count stations, with the size of the circle corresponding to the relative detection frequency. Smaller coloured circles represent NI robin observations reported by local citizen scientists via eBird and iNaturalist.

3.2.13 Bellbird (*Anthornis melanura*)

Image courtesy of Craig McKenzie/NZ Birds Online

National conservation status: Not Threatened (Robertson et al, 2017).

Regional conservation status: Not Threatened (GWRC/DoC, unpublished data).

Bellbird encounter rates have varied significantly from year to year in Wellington City between 2011 and 2018 ($F_{7,1592} = 2.09$, $p = 0.041$; one-way ANOVA; Figure 3.28). However these changes appear to be a result of inter-annual fluctuations in abundance and/or distribution, rather than forming part of a longer-term trend in abundance. Bellbirds are very sparsely distributed across Wellington City, with a small breeding population established in Zealandia, and possibly also in the Wellington Botanic Gardens and Khandallah Park. Bellbirds are the thirteenth most frequently observed bird species reported by local citizen scientists, with 543 bellbird observations reported within Wellington City limits since 2011 (Figure 3.27).

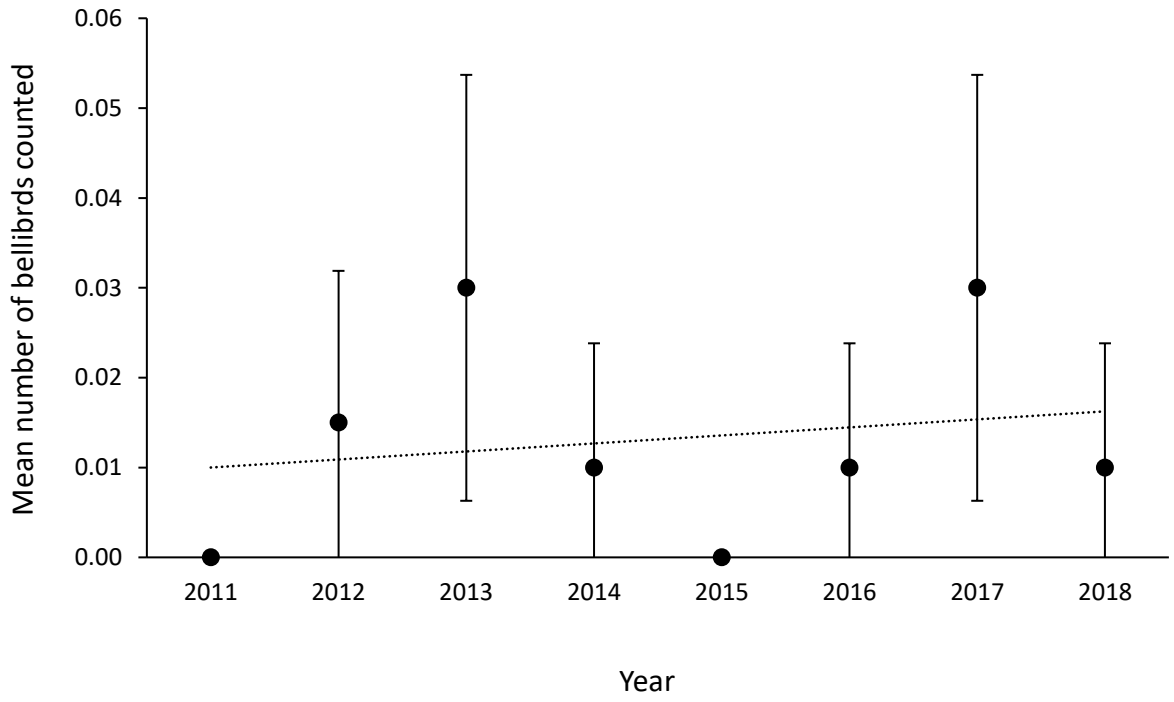

Figure 3.28: Mean number of bellbirds recorded per five-minute bird count station in Wellington City between 2011 and 2018 (error bars represent 95% confidence limits).

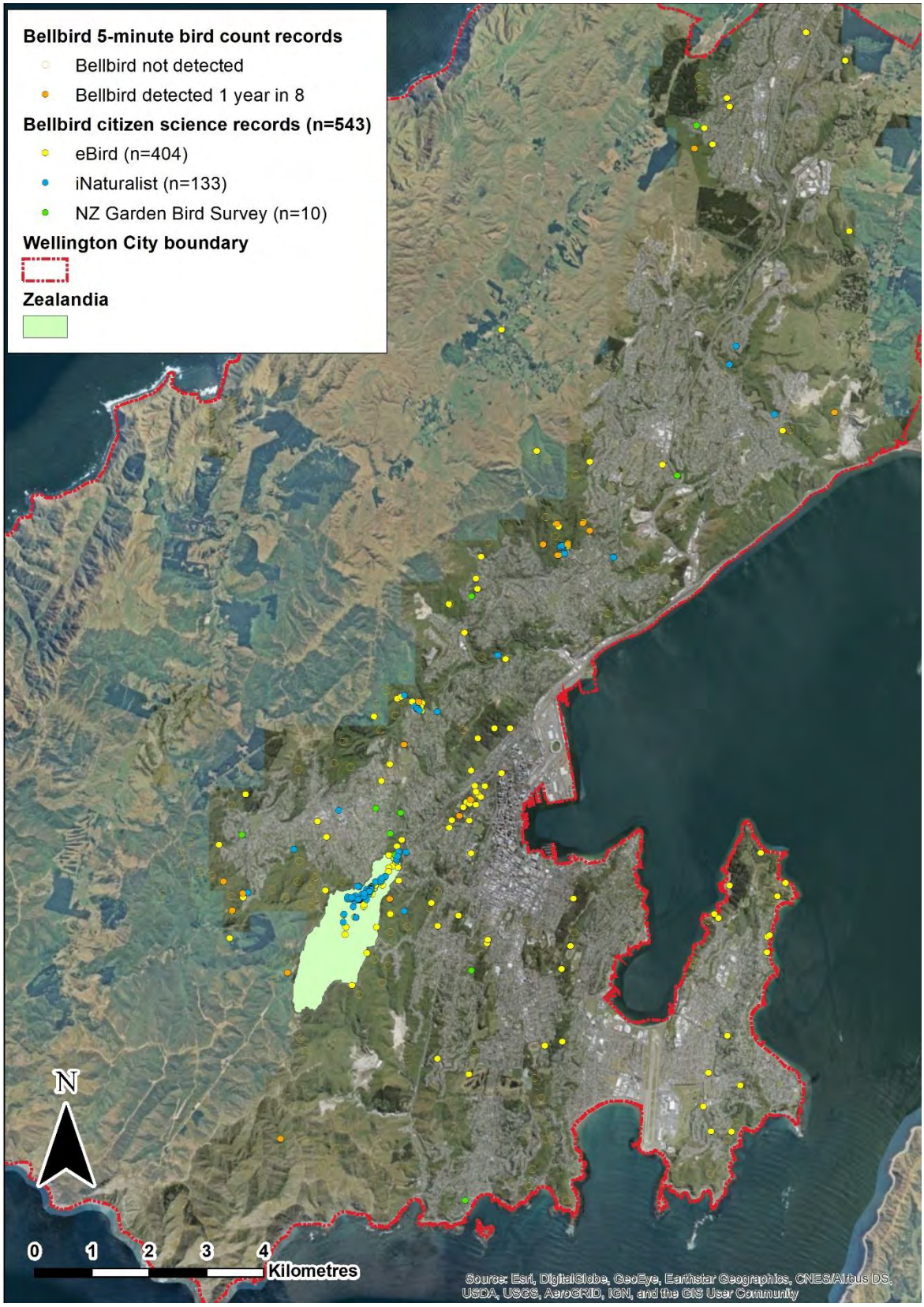

Figure 3.29: Distribution of bellbird in Wellington City between 2011 and 2019. Orange circles represent bellbird detections at five-minute bird count stations, with the size of the circle corresponding to the relative detection frequency. Smaller coloured circles represent bellbird observations reported by local citizen scientists via eBird, iNaturalist or the NZ Garden Bird Survey.

3.2.14 New Zealand falcon (*Falco novaeseelandiae*)

Image courtesy of Steve Attwood/NZ Birds Online

National conservation status: At Risk, Recovering (Robertson et al, 2017).

Regional conservation status: Regionally Critical (GWRC/DoC, unpublished data).

New Zealand falcon encounter rates have not changed significantly in Wellington City between 2011 and 2018 ($F_{7,1592}$ = 0.62, p = 0.74; one-way ANOVA; Figure 3.30). NZ falcons are sparsely distributed across Wellington city, in both native forest and suburban habitats. There is likely to be only a handful of pairs of birds present, at sites such as Zealandia and Otari-Wilton Bush. NZ falcons are the fifteenth most frequently observed bird species reported by local citizen scientists, with 413 falcon observations reported within Wellington City limits since 2011 (Figure 3.31).

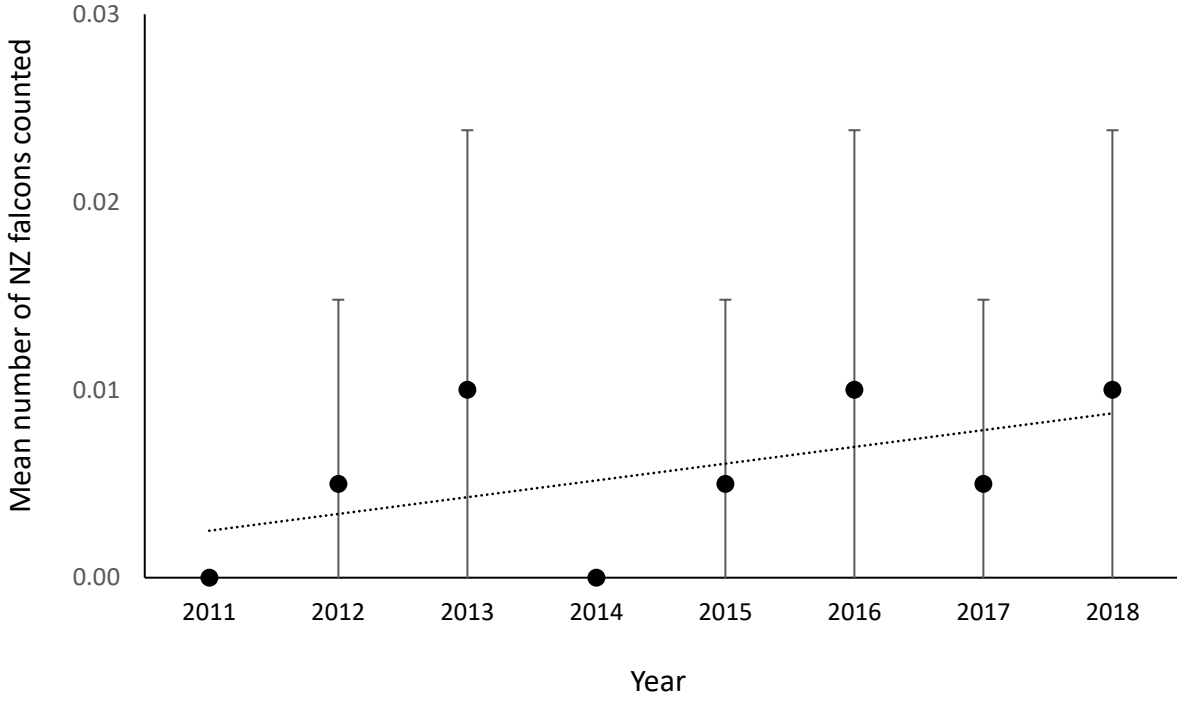

Figure 3.30: Mean number of NZ falcons recorded per five-minute bird count station in Wellington City between 2011 and 2018 (error bars represent 95% confidence limits).

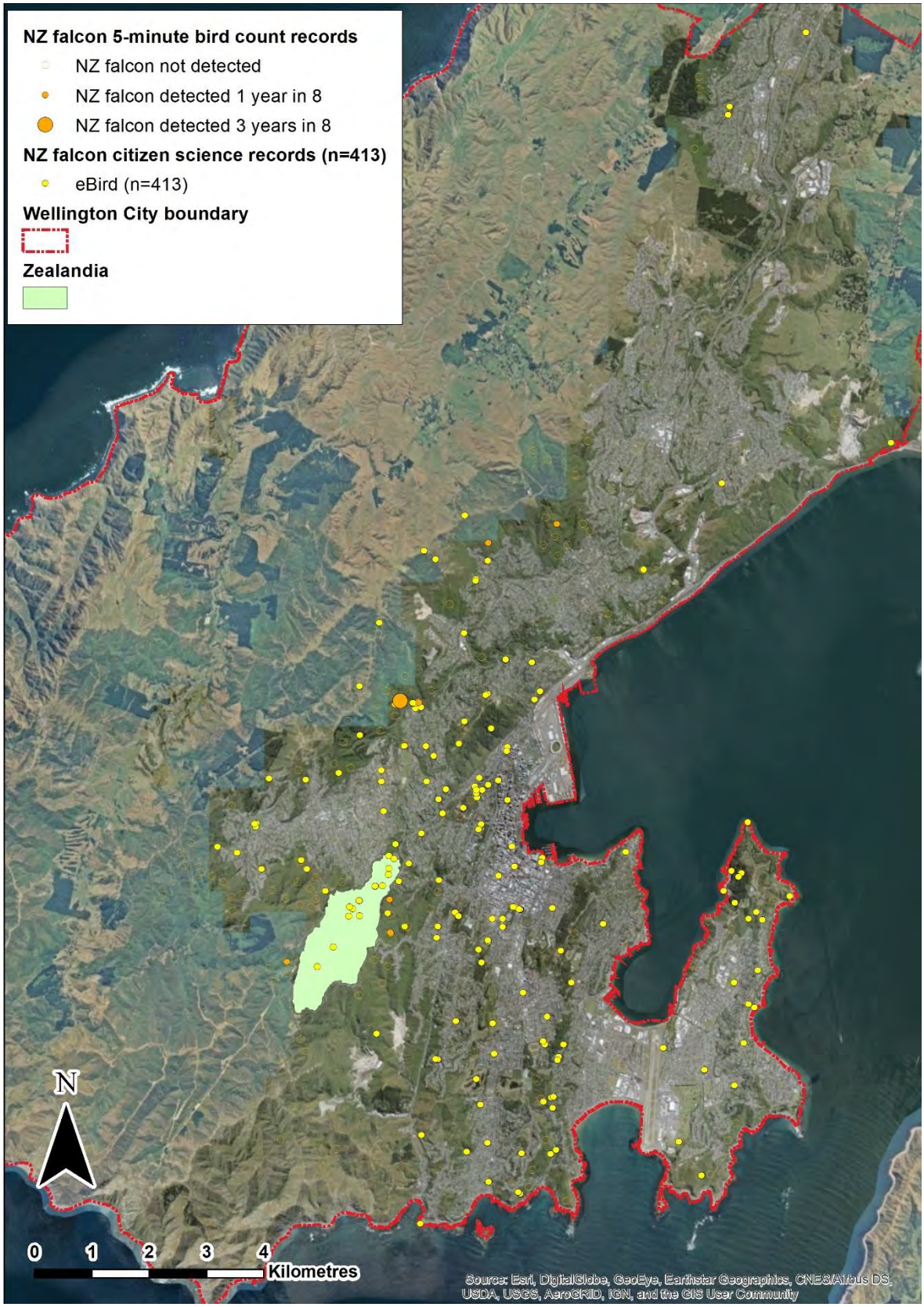

Figure 3.31: Distribution of NZ falcon in Wellington City between 2011 and 2019. Orange circles represent NZ falcon detections at five-minute bird count stations, with the size of the circle corresponding to the relative detection frequency. Smaller coloured circles represent NZ falcon observations reported by local citizen scientists via eBird.

3.2.15 Tomtit (*Petroica macrocephala*)

Image courtesy of Paul Shaw/NZ Birds Online

National conservation status: Not Threatened (Robertson et al, 2017).

Regional conservation status: Not Threatened (GWRC/DoC, unpublished data).

Tomtits are a vagrant (irregular visitor) to Wellington City at the present time, with no local self-sustaining population known to exist within Wellington City boundaries. A single tomtit was recorded for the first time during this five-minute bird count project in 2016, at a count station in Khandallah Park. Prior to this, the only other known tomtit record since 2011 was a single bird observed by Peter Hodge on Tinakori Hill in 2015 (Figure 3.32; Hodge, 2015). Over the past 12 months however, tomtits have been recorded in the city on two further occasions, another record on Tinakori Hill, and one in Otari-Wilton Bush. Tomtit populations did occur in Wellington City historically, R.H.D. Stidolph noted their presence in both Otari-Wilton Bush and Khandallah Park in the mid-1920s (Stidolph, 1924; 1925). Tomtits were also reintroduced to Zealandia between 2001 and 2014, however these re-introduction attempts did not result in the establishment of a self-sustaining population (Empson and Fastier, 2013).

3.2.16 Morepork (*Ninox novaeseelandiae*)

Image courtesy of Adam Clarke/NZ Birds Online

National conservation status: Not Threatened (Robertson et al, 2017).

Regional conservation status: Not Threatened (GWRC/DoC, unpublished data).

Moreporks have not yet been detected during these five-minute bird counts, due to the fact that moreporks are largely nocturnal, and these counts are carried out during daylight hours. Nonetheless, moreporks are the sixteenth most frequently observed bird species reported by local citizen scientists, with 332 morepork observations reported within Wellington City limits since 2011 (Figure 3.33). The distribution of these records suggest that morepork are likely to be widespread in Wellington City, and are found in both native forest and suburban habitats.

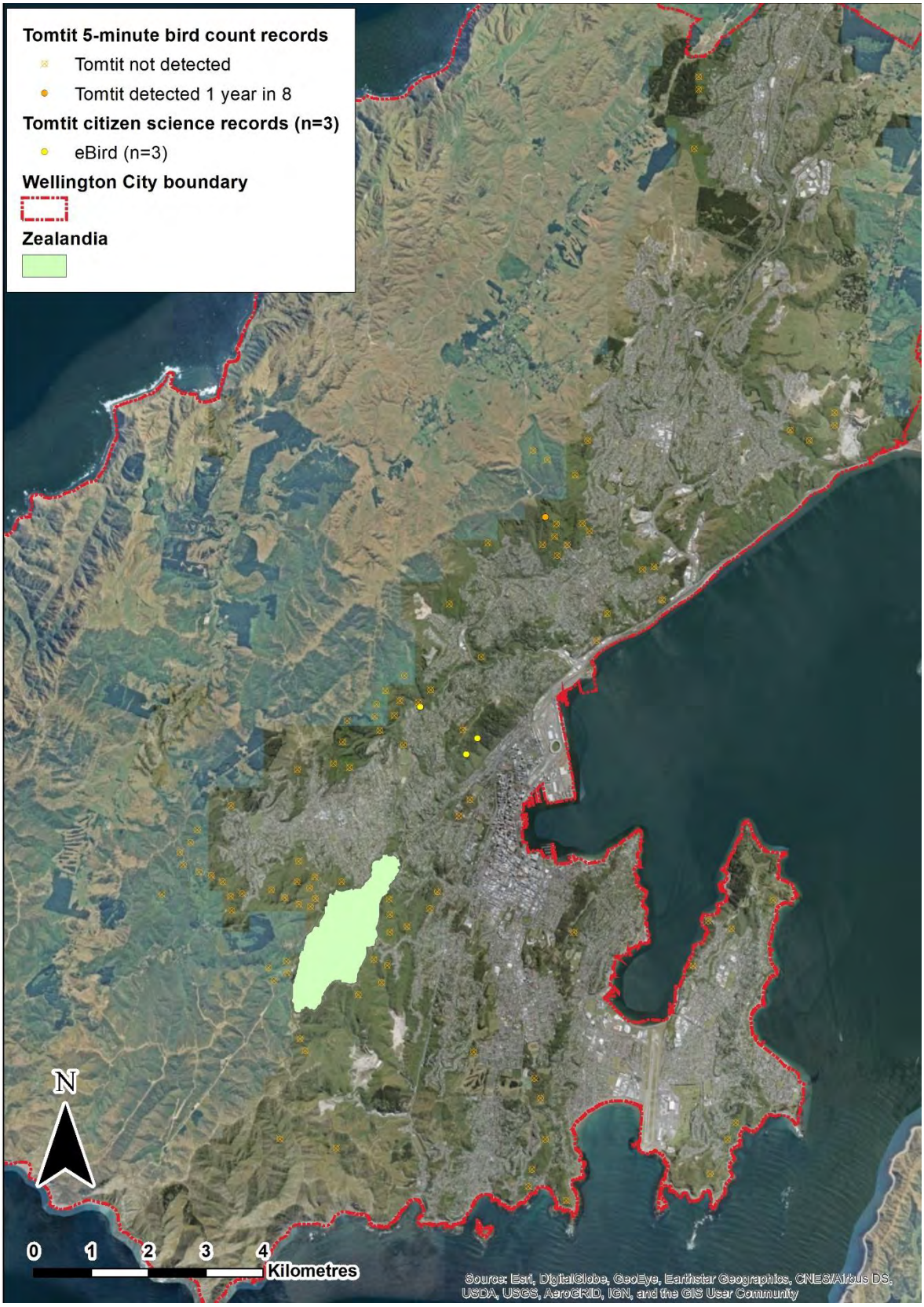

Figure 3.32: Distribution of tomtit in Wellington City between 2011 and 2019. Orange circles represent tomtit detections at five-minute bird count stations, with the size of the circle corresponding to the relative detection frequency. Smaller coloured circles represent tomtit observations reported by local citizen scientists via eBird.

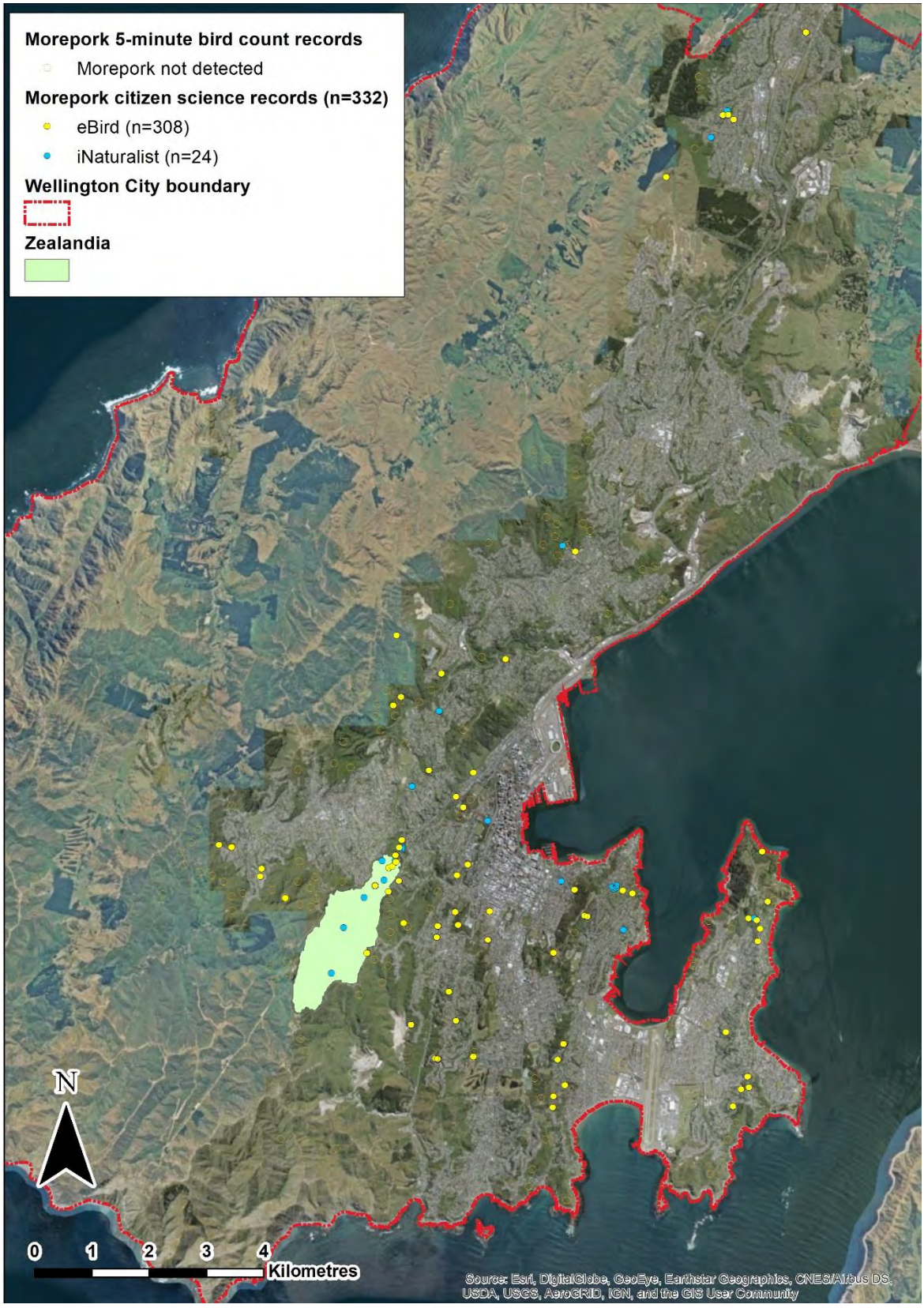

Figure 3.33: Distribution of morepork in Wellington City between 2011 and 2019. Orange circles represent morepork detections at five-minute bird count stations, with the size of the circle corresponding to the relative detection frequency. Smaller coloured circles represent morepork observations reported by local citizen scientists via eBird or iNaturalist.

3.2.17 Hihi (*Notiomystis cincta*)

Image courtesy of Paul Le Roy/NZ Birds Online

National conservation status: Nationally Vulnerable (Robertson et al, 2017).

Regional conservation status: Regionally Critical (GWRC/DoC, unpublished data).

Hihi have not yet been detected during these five-minute bird counts, despite the fact that a small resident population is now established in Zealandia. Nonetheless, hihi are the fourteenth most frequently observed bird species reported by local citizen scientists, with 421 hihi observations reported within Wellington City limits since 2011 (Figure 3.34). The majority of these observations are from within Zealandia or within a few hundred metres of Zealandia's pest proof fence. This suggests that hihi either don't usually stray far from Zealandia, or if they do, that they don't persist for long in adjacent reserves.

3.2.18 Long-tailed cuckoo (*Eudynamys taitensis*)

Image courtesy of Adam Clarke/NZ Birds Online

National conservation status: At Risk, Naturally Uncommon (Robertson et al, 2017).

Regional conservation status: At Risk, Naturally Uncommon (GWRC/DoC, unpublished data).

Long-tailed cuckoos are a vagrant (irregular visitor) to Wellington City at the present time, which means that Wellington City's whitehead population is likely to be largely free of brood-parasitism by long-tailed cuckoos. Long-tailed cuckoos have not yet been recorded during five-minute bird counts carried out as part of this project, and have only been recorded by citizen scientists on three occasions since 2011 (Figure 3.35).

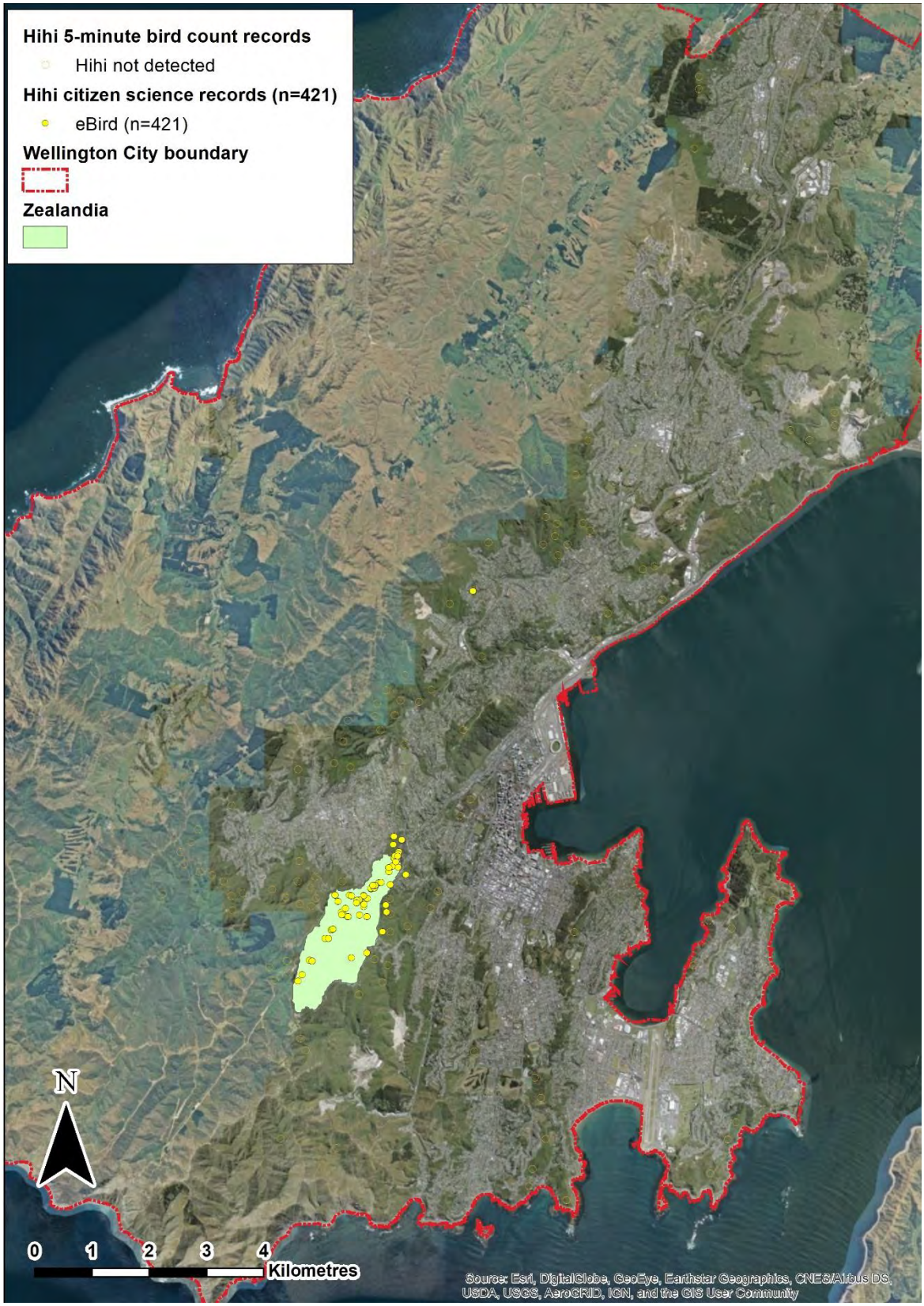

Figure 3.34: Distribution of hihi in Wellington City between 2011 and 2019. Orange circles represent hihi detections at five-minute bird count stations, with the size of the circle corresponding to the relative detection frequency. Smaller coloured circles represent hihi observations reported by local citizen scientists via eBird.

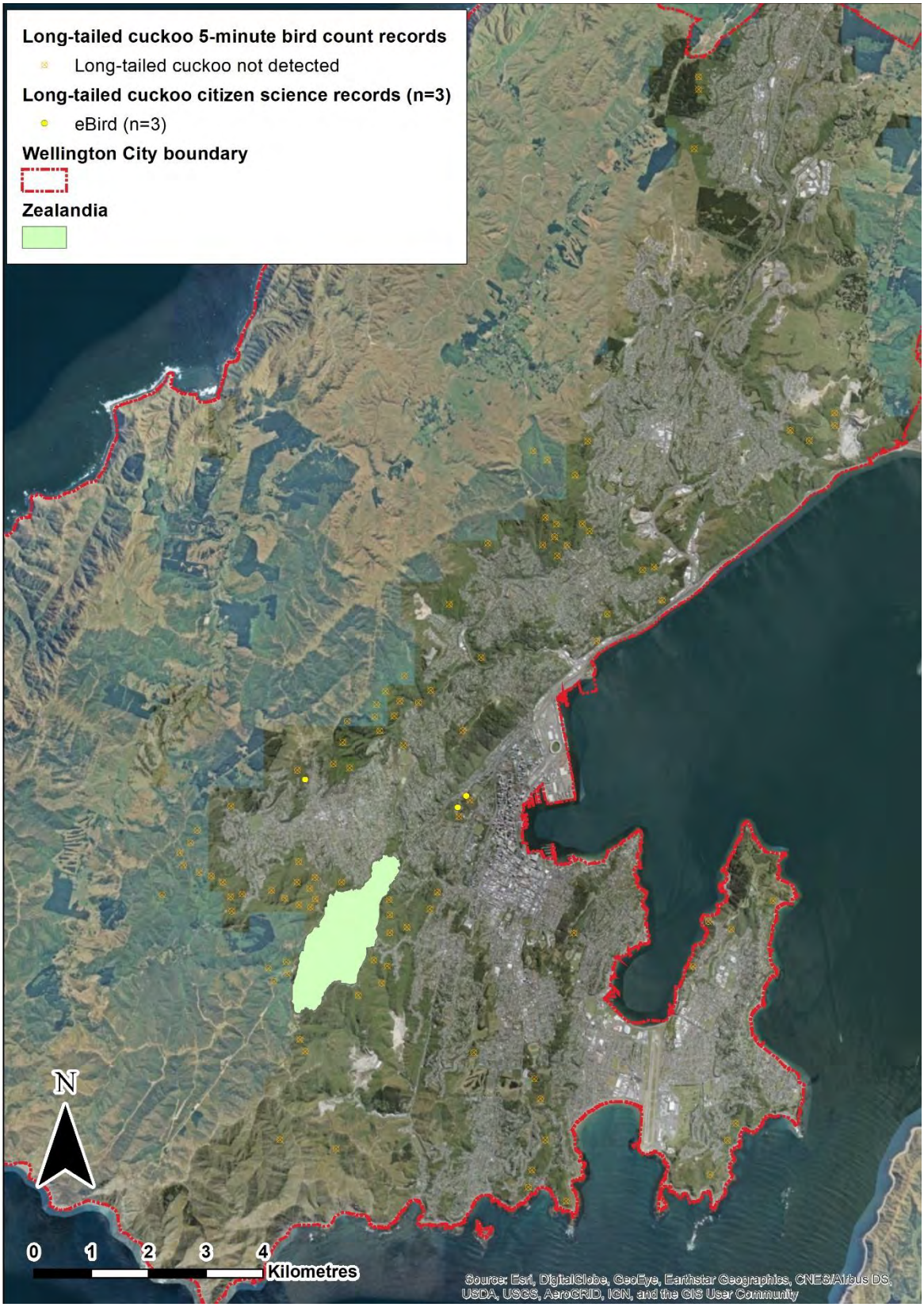

Figure 3.35: Distribution of long-tailed cuckoo in Wellington City between 2011 and 2019. Orange circles represent long-tailed cuckoo detections at five-minute bird count stations, with the size of the circle corresponding to the relative detection frequency. Smaller coloured circles represent long-tailed cuckoo observations reported by local citizen scientists via eBird.

4. DISCUSSION

4.1 Bird diversity, abundance and distribution

One trend that is emerging from these counts is that the average number of native forest bird species being encountered per five-minute bird count is slowly increasing over time. Because only one new native forest bird species (tomtit) has been detected since 2011, much of this increase in average species richness is likely a result of ongoing range expansions of bird species already present in Wellington City. In particular, the ongoing dispersal of species that have been re-introduced to Zealandia, and their establishment in other forested reserves in the city, is driving these improvements in local species richness in some parks and reserves. Given how vulnerable some of these species are to depredation by mammalian predators, it's unlikely that these improvements would be occurring were it not for the presence of Zealandia, and for the widespread implementation of mammalian predator control throughout Wellington City's parks, reserves and suburban areas. The results of these five-minute bird counts therefore demonstrate that these initiatives are leading to a gradual improvement in bird species richness in parts of Wellington City, and are creating more opportunities for local residents and visitors to encounter a wider range of New Zealand's native forest bird species in the heart of New Zealand's capital city.

Of the eighteen native forest bird species currently present in Wellington City outside of Zealandia's predator-proof fence, encounter rates for five species, namely tūī, kākā, kākāriki, NI saddleback and kererū have increased significantly since 2011. Given that these five-minute bird counts are carried out at the same time each year, in the same weather conditions and usually by the same observers, these trends are providing ever-strengthening evidence that the abundance of these five species has increased in Wellington City since 2011. All five species are vulnerable to depredation by mammalian predators, so the presence of Zealandia, and the widespread mammalian predator control now in place throughout Wellington City are almost certainly contributing to the ongoing increase in encounter rates being observed for these five species.

One further key result from these counts is that no long-term declines in encounter rates for any native forest bird species have been detected between 2011 and 2018. This means that as well as leading to the improvements in encounter rates for species such as tūī, kākā and kākāriki, the establishment of Zealandia, coupled with the instigation of city-wide predator control has successfully prevented any decrease in the abundance and/or conspicuousness of native forest birds in Wellington City since 2011. That said, recent results from bird monitoring that has been carried out within Zealandia suggest that future declines in several native forest bird species, and introduced bird species, should be expected in Wellington City, as the diversity and abundance of endemic forest bird species continue to increase (Miskelly, 2018). In particular, it is possible that we will see declines in species such as silvereye and grey warbler at some time in the future, as they are gradually outcompeted by more dominant endemic bird species that re-establish in Wellington City reserves.

Against the backdrop of these successes, there are several vulnerable species that have been reintroduced to Zealandia, but have not expanded their distribution very far beyond Zealandia's predator-proof fence. For example, NI robins have been well established in Zealandia for at least 15 years (McGavin, 2009; Empson & Fastier, 2013), yet have only been detected at two five-minute bird count stations between 2011 and 2018, and are seldom reported by citizen scientists at distances greater than around 1 km from Zealandia (Figure 3.27). NI robins are known to have relatively strong dispersal capabilities through habitats dominated by woody vegetation, with juvenile birds capable of dispersing up to 11 km from their natal territories in forested habitat (Oppel & Beaven 2004; Richard 2007), so habitat connectivity is unlikely to be the factor limiting the expansion of this species in Wellington City. Mark-resighting and nest monitoring of NI robins in reserves adjacent to Zealandia over the past two breeding seasons have confirmed that poor adult and juvenile survival rates are

limiting the ability of these species to colonise forest habitat outside of Zealandia. Of 37 adult robins banded in forested reserves adjacent to Zealandia in the winter of 2017, only eleven birds were still present on their territories by the beginning of the following breeding season, and only four were still present in the winter of 2018. During the 2017-18 breeding season, a total of ten nesting attempts were monitored. Eight of these successfully fledged young, with 11 young subsequently reaching independence. However, only three of these 11 offspring were detected subsequently, and only one appeared to survive long enough to attempt to breed (unsuccessfully) the following season. Of the two nests that failed, one was depredated by a cat, and the other by a stoat (Shaw and Harvey, 2018). Adult survival rates were similarly low during the 2018-19 breeding season. Of 16 adult birds known to be present on breeding territories in September 2018, only one was still present by March 2019. Breeding success during this second season was substantially worse than the previous year. Of seven nests monitored during the 2018-19 season, only one successfully fledged young (MacKinlay, unpublished data).

Given this evidence, by far the most likely factor limiting the establishment of NI robins (as well as other species including NI saddleback and whitehead) beyond the boundaries of Zealandia is depredation of both adult and juvenile robins by mammalian predators, particularly both domestic and wild cats (*Felis catus*) and mustelids (*Mustela* spp.). Although considerable effort is being invested in reducing populations of a number of mammalian predators in Wellington City including rats, possums and mustelids, cats are currently not targeted. Camera-trapping work carried out by researchers at Victoria University of Wellington has shown that cats accounted for a relatively large proportion of the approximately 22,000 animal 'detections' collected from several Wellington City reserves over a five-month period in 2014 (http://identifyanimals.co.nz/; accessed 24/09/2015; Anton et al, 2018), suggesting that they occur at relatively high densities in the parks and reserves that were sampled. Further camera trapping work carried out in 2016 confirmed that cats were likely to be present across most of the total area of Polhill Reserve (one of the forested reserves adjoining predator-free Zealandia), and that the majority of these cats appeared to be domestic pets (Woolley & Hartley, 2019).

This being the case, we agree with the conclusion drawn by Shaw & Harvey (2018), that if Wellington City Council and Predator Free Wellington wish to create "a natural city that flourishes with native wildlife and a dawn chorus that will be the envy of other cities" (https://www.pfw.org.nz/; accessed 25/06/2019), then progress will need to be made to manage the risk to wildlife posed by feral, stray and free-roaming domestic cats. Until this occurs, creating healthy, productive populations of endemic forest birds such as NI robin, NI saddleback and whitehead outside of Zealandia's predator-proof fence is unlikely to be attainable, irrespective of the degree to which other mammalian predators such as rats, possums, mustelids and hedgehogs are controlled or eradicated.

4.2 The role of citizen scientists in monitoring Wellington City's bird fauna

Citizen scientists are playing an increasingly important role in providing bird observation data that complement this Wellington City five-minute bird count dataset, enabling us to map the distribution of birds in Wellington City to a level of detail never done before. A total of 25,708 verified observations of native forest birds have been contributed by citizen scientists in Wellington City between 2011 and 2018, and are included on the distribution maps in this report. 87%, or 22,419 observations, have been contributed via the New Zealand eBird database, making eBird by far the most preferred, and most popular database used by Wellington-based citizen scientists that have an interest in birds. A further 8% (2159 observations) were submitted via the iNaturalist NZ database, making this the second-most preferred database used by Wellington-based citizen scientists[1]. An additional 4% of

[1] Note: This number is likely to underestimate iNaturalist usage among Wellington-based citizen scientists, for two reasons. Firstly, a much larger proportion of iNaturalist observations was discarded during data analysis due to location and/or species identification errors, compared to the eBird database. This suggests that either the data validation process used by iNaturalist is not as effective at picking up errors in comparison to eBird's data

records (556 and 574 observations) were sourced from the New Zealand Garden Bird Survey and Great Kererū Count respectively.

On the first of June 2019, Birds New Zealand (the Ornithological Society of New Zealand) launched a new, five-year, national-scale citizen science project called the New Zealand Bird Atlas. The NZ Bird Atlas aims to map spatial patterns in the occupancy and abundance of all of New Zealand's bird species across the country over the next five years. Furthermore, the data from this Atlas project will be combined with data collected during two earlier Atlas projects run between 1969-1979 and 1999-2004 respectively, to create a 45-year time series describing changes in bird distribution throughout the country. To carry out the Atlas project, volunteers from Birds New Zealand and other stakeholder organisations will be systematically surveying over 3,200 10 x 10 km grid squares throughout New Zealand, and collecting complete bird checklists from all habitat types within each grid square. These complete checklists will be submitted to the New Zealand eBird database via a portal custom-built for the NZ Bird Atlas project, from which the resulting dataset will be made freely-accessible to be used to inform conservation policy or decision-making. Since the launch of the Atlas in early June 2019, data submission rates to eBird have almost doubled, and in Wellington City alone, a total of 418 complete checklists have been submitted, describing the distribution of 72 bird species detected within Wellington City limits. Over the next five years therefore, the New Zealand Bird Atlas will become a major source of citizen science bird data for Wellington City, which can be used to complement the systematic bird monitoring data collected by the city council. Both the quantity and quality of the data being collected as part of this ground-breaking project can be further improved by Wellington City Council playing an active role at promoting the New Zealand Bird Atlas in Wellington City, and encouraging local citizen scientists to participate.

Although our knowledge of the distribution of diurnal, or day-active bird species in Wellington City has improved substantially over the past eight years, the distribution of our one relatively widespread nocturnal species is very poorly understood. Morepork may well be relatively common in Wellington City, and trends in morepork encounter rates or distribution over time could provide an additional measure of the outcomes of local pest control efforts. An opportunity exists therefore, to fill this knowledge gap by running a citizen-science project specifically aimed at mapping the distribution of morepork in Wellington City and quantifying encounter rates as an indirect measure of abundance. While the New Zealand Bird Atlas project will partly fill this knowledge gap, the 10 x 10 km grid square spatial sampling resolution of this project, together with the added challenge of carrying out nocturnal bird surveys, will probably limit the number of nocturnal checklists submitted through this scheme over the next five years. To ensure that this knowledge gap is filled, we suggest that Wellington City council could run a citizen-science project aimed at carrying out nocturnal counts across the city, with the data to be submitted to the New Zealand Bird Atlas. Such a project could be modelled on the 2011 Hamilton City morepork survey, whereby volunteers were assigned to a pre-defined set of survey locations over a period of five consecutive nights (Morgan & Styche, 2012). This project would also serve a secondary purpose of providing Wellington City residents with an additional opportunity to engage with their surrounding natural environment, learn more about the birds around them and improve their skills as citizen scientists.

validation processes, or that there is a difference in skill level between the average iNaturalist and eBird user. Secondly, location data for any iNaturalist records of species classified as Threatened or Near Threatened on the IUCN Red List is withheld from users, meaning that their locations could not be mapped accurately. These erroneous and 'obscured' records (ca. 200-300 records in total) were all discarded from our analysis and are not included in the numbers of observations reported here.

5. Recommendations

Based on the results described in this report, we suggest that Wellington City Council considers adopting the following recommendations:

- That Wellington City Council continues to undertake this five-minute bird count monitoring programme on an ongoing, annual basis, to provide a consistent, repeatable measure of the state and trends in the diversity, distribution and abundance of birds in Wellington City parks and reserves, in order to contribute towards objective 4.2.2a of WCC's Biodiversity Strategy and Action Plan (WCC, 2015).

- That Wellington City Council takes steps to encourage local citizen scientists to submit their bird observations in the form of complete bird checklists to the New Zealand Bird Atlas portal of the New Zealand eBird database (objective 4.3.3a of WCC's Biodiversity Strategy and Action Plan) (WCC, 2015). By doing so, local citizen scientists will not only be contributing to an exciting new national-scale citizen science project aimed at mapping bird distribution across the entire country, but will be submitting their data to the largest and fastest growing database of citizen science bird observations in New Zealand.

- That Wellington City Council works with communities to explore cat management options for bird protection.

- That Wellington City Council considers designing and carrying out a citizen science project aimed at mapping the distribution of morepork in Wellington City in 2019 (objective 3.3.4b of WCC's Biodiversity Strategy and Action Plan (WCC, 2015). Such a project could involve public requests for morepork sightings during a particular month of the year (e.g. November, 2019), much like the Great Kererū Count, coupled with recruiting a pool of local volunteers to carry out night-time surveys of a pre-determined network of locations throughout the city to determine morepork distribution in local parks and reserves.

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8. APPENDICES

8.1 Appendix One

This table contains a list of all of the bird species encountered in Wellington City parks and reserves during five-minute bird counts carried out between 2011 and 2018 (P = species present). Species names and taxonomic order are those listed in Gill, et al. (2010). Threat classification rankings are those listed in Robertson, et al. (2017): DE = At Risk, Declining; RC = At Risk, Recovering; RE = At Risk, Relict; NU = At Risk, Naturally Uncommon; NT = Not threatened; I = Introduced and Naturalised; N/A = Not applicable.

Scientific Name	Common Name	Threat Ranking	2011	2012	2013	2014	2015	2016	2017	2018
Eudyptula minor	little penguin	DE							P	
Callipepla californica	California quail	I	P	P	P	P	P	P	P	P
Gallus gallus	feral chicken	N/A[2]	P	P	P	P	P	P	P	
Tadorna variegata	paradise shelduck	NT		P	P				P	P
Anas platyrhynchos	mallard	I					P	P		
Phalacrocorax carbo	black shag	NU								P
P. varius	pied shag	RC					P			
Stictocarbo punctatus	spotted shag	NT							P	
Egretta novaehollandiae	white-faced heron	NT			P					
Circus approximans	swamp harrier	NT	P	P		P				
Falco novaeseelandiae	New Zealand falcon	RC		P	P		P	P	P	P
Haematopus unicolor	variable oystercatcher	RC		P		P	P	P		P
Vanellus miles	spur-winged plover	NT				P				P
Larus dominicanus	southern black-backed gull	NT	P	P	P	P	P	P	P	P

[2] Feral chicken is not recognised as a naturalised species in New Zealand (Gill et al, 2010) and therefore does not have a New Zealand Threat Classification System ranking (Robertson et al, 2017).

Scientific Name	Common Name	Threat Ranking	2011	2012	2013	2014	2015	2016	2017	2018
L. novaehollandiae	red-billed gull	DE		P	P					P
Sterna striata	White-fronted tern	DE								P
Columba livia	rock pigeon	I						P	P	
Hemiphaga novaeseelandiae	New Zealand pigeon (kererū)	NT	P	P	P	P	P	P	P	P
Nestor meridionalis	kākā	RC	P	P	P	P	P	P	P	P
Platycercus eximius	eastern rosella	I	P	P	P	P	P	P	P	P
Cyanoramphus novaezelandiae	red-crowned parakeet	RE	P	P		P	P	P	P	P
Chrysococcyx lucidus	shining cuckoo	NT	P	P	P	P	P	P	P	P
Todiramphus sanctus	New Zealand kingfisher	NT	P	P	P	P	P	P	P	P
Philesturnus rufusater	North Island saddleback	RC	P	P	P	P	P	P	P	P
Gerygone igata	grey warbler	NT	P	P	P	P	P	P	P	P
Anthornis melanura	bellbird	NT		P	P	P		P	P	P
Prosthemadera novaeseelandiae	tūī	NT	P	P	P	P	P	P	P	P
Mohoua albicilla	whitehead	DE	P	P	P	P	P	P	P	P
Gymnorhina tibicen	Australian magpie	I	P		P	P	P	P	P	P
Rhipidura fuliginosa	New Zealand fantail	NT	P	P	P	P	P	P	P	P
Petroica macrocephala	tomtit	NT						P		
P. longipes	North Island robin	DE	P	P	P		P			P
Alauda arvensis	skylark	I	P	P	P	P	P		P	P
Zosterops lateralis	silvereye	NT	P	P	P	P	P	P	P	P
Hirundo neoxena	welcome swallow	NT	P					P	P	

Scientific Name	Common Name	Threat Ranking	2011	2012	2013	2014	2015	2016	2017	2018
Turdus merula	Eurasian blackbird	I	P	P	P	P	P	P	P	P
T. philomelos	song thrush	I	P	P	P	P	P	P	P	P
Sturnus vulgaris	common starling	I	P	P	P	P	P	P	P	P
Passer domesticus	house sparrow	I	P	P	P	P	P	P	P	P
Prunella modularis	dunnock	I	P	P	P	P	P	P	P	P
Fringilla coelebs	chaffinch	I	P	P	P	P	P	P	P	P
Carduelis chloris	greenfinch	I	P	P	P	P	P	P	P	P
C. carduelis	goldfinch	I	P	P	P	P	P	P	P	P
C. flammea	common redpoll	I		P	P	P	P	P	P	P
Emberiza citrinella	yellowhammer	I	P	P	P	P	P	P	P	P

8.2 Appendix Two

This table provides a summary of the mean number of birds observed per bird count station for each native forest bird species that has been recorded in Wellington City since 2011. Orange rows represent those species with stable trends over time, whereas green rows denote species for which mean encounter rates have increased significantly since 2011. Section 3.2 of this report provides a more detailed picture of the temporal trends in encounter rates for each individual species on this list.

Species	Average number of birds observed at each station							
	2011	2012	2013	2014	2015	2016	2017	2018
Silvereye	1.86	2.38	2.03	2.19	2.07	2.34	2.34	2.04
Tūī	1.35	0.77	2.16	1.74	2.61	2.37	2.07	2.50
Grey warbler	0.84	1.24	1.29	1.05	1.45	1.07	1.29	1.26
Fantail	0.35	0.22	0.23	0.32	0.22	0.29	0.35	0.36
Shining cuckoo	0.17	0.23	0.24	0.19	0.19	0.20	0.23	0.22
Kākā	0.10	0.07	0.12	0.10	0.24	0.15	0.22	0.27
Kererū	0.07	0.03	0.11	0.08	0.08	0.18	0.13	0.13
NI saddleback	0.07	0.02	0.03	0.02	0.06	0.06	0.10	0.09
Whitehead	0.06	0.09	0.04	0.06	0.05	0.05	0.08	0.07
NZ kingfisher	0.03	0.04	0.03	0.04	0.05	0.02	0.03	0.06
Kākāriki	0.02	0.01	0.01	0.03	0.09	0.07	0.06	0.08
NI Robin	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.01
Bellbird	0.00	0.02	0.03	0.01	0.00	0.01	0.03	0.01
NZ falcon	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01
Tomtit	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Morepork	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hihi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long-tailed cuckoo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00