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Anthropogenic Sources of Non-Migratory Avian Mortalities In Singapore

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Abstract

Although urban spaces are increasingly recognised as viable habitats for wildlife, cities remain a major source of anthropogenic mortality for wild birds. While the sources of urban avian mortalities have been well documented in North America, these phenomena remain poorly studied in Southeast Asia, especially for resident species. Here we present the first summary of non-migratory urban bird mortalities for the heavily urbanised island of Singapore. We conducted a citizen science study using print and social media outreach to encourage members of the public to report their observations of dead birds between November 2013 and October 2017, and collected a total of 362 mortality records across 65 resident bird species and five mortality sources. Our results show that a diverse array of bird species is directly impacted by anthropogenic sources of mortality, although mortalities stemming from roadkill and cat predation are likely to be undersampled. We also find that forest-edge frugivores such as the Pink-necked Green Pigeon are likely to be especially vulnerable to building collisions. Our study shows that despite its limitations, opportunistic sampling using citizen science can generate large amounts of ecological data at relatively low cost, and serve as a cost-effective complement to standardised survey methodologies.

Key words : bird mortality, building collisions, urban ecology, cats, human impacts, roadkill, citizen science

Background

Cities present a considerable array of impediments to the movement of wildlife. The proliferation of densely built-up areas with high volumes of vehicular traffic, as well as the introduction of domesticated predators such as cats, all contribute to the anthropogenic mortalities of wildlife in urban areas (Loss et al., 2015).

Birds in particular are especially susceptible to urban mortality resulting from anthropogenic factors. Studies stemming primarily from North America have shown that cat predation (Lepczyk et al., 2004; Loss et al., 2013), building collisions (Klem, 2015, 1989), and roadkill (Kociolek et al., 2011), account for a significant proportion of observed urban avian mortalities (Loss et al., 2015). In the United States, for instance, it is estimated that between 365 and 988 million birds die from collisions with buildings annually, while another 1.31 to 3.99 billion birds die as a result of predation by cats every year (Loss et al., 2014), with similar mortality trends observed in Canada (Calvert et al., 2013) and Australia (Woinarski et al., 2017). With city biodiversity receiving increased focus as part of broader biodiversity conservation strategies (Chan et al., 2014), understanding the sources and impacts of anthropogenic mortality in birds is essential to mitigating and ultimately reducing the deleterious impacts of cities on wild bird populations.

While the anthropogenic sources of avian mortality have been relatively well documented in temperate zones, these phenomena have largely been overlooked in the tropics, especially in Southeast Asia. Aside from a single study from Singapore describing the patterns of migratory mortalities resulting from building collisions

(Low et al., 2017), there exists little other available data in the scientific literature about the sources of urban avian mortalities in Southeast Asia despite the region having one of the fastest growing urban populations in the world (United Nations, Department of Economic and Social Affairs, 2015).

In this study, we summarise the results of a multi-year citizen science survey of avian mortalities across the heavily urbanised island nation of Singapore, with a specific focus on the anthropogenic sources of mortality of resident species. We compare the results of our survey with the migratory mortality data reported in Low *et al.* (2017) as well as with other comparable studies to determine if the pattern of urban avian mortalities in Singapore is congruent with patterns observed in other parts of the world, and highlight the challenges and limitations inherent in assessing the impacts of cities on bird populations.

Materials and Methods

Study Area

We conducted the study in Singapore (1.150°-1.483°N and 103.633°-104.100°E), a 719.2 sq. km island south of Peninsular Malaysia, located within the Sundaland biodiversity hotspot in Southeast Asia. Singapore is one of the most heavily urbanised and densely populated nations in the world, with 100% of its population residing in urban areas (United Nations, Department of Economic and Social Affairs, 2015) comprising approximately 52% of its total landmass (Tan, 2015). Despite this, Singapore continues to maintain substantial patches of urban greenery and forest vegetation, with managed vegetation covering approximately 16% of Singapore's total land area (Tan, 2015), and approximately 0.16% and 20% of Singapore's landmass comprised of primary and secondary forest vegetation respectively (Yee et al., 2011). The combination of high-density urban development and extensive greenery in close proximity to urban areas has resulted in urban Singapore having a relatively high diversity of avian species, both resident and migratory (Lim, 2009).

Mortality Documentation

We documented urban avian mortality records from across Singapore between November 2013 and October 2017 via a rudimentary citizen science protocol. Members of the public were encouraged via print media (Feng, 2013) and social media platforms such as FaceBook and Instagram to submit observations of dead or injured birds. All record submissions were verified and identified to species based on photographic documentation or, where possible, collected specimens. Additionally, we collected as much information as possible on the locality, age, and likely cause of death of each record. Birds found at the base of buildings and exhibiting any form of facial injury or head trauma were listed as having died of building collisions, while birds found on or by the sides of roads with injuries indicative of blunt force trauma were identified as roadkill. Identifying instances of cat predation was considerably more challenging, and only specimens that were directly observed being killed by cats and/or self-reported by cat owners were included in our records. All other instances of predation for which the predator was unknown had the likely cause of death listed simply as 'predation'. Specimens for which the cause of death was known but attributable to freak accidents (e.g. falling out of the nest) had their likely cause of death listed as 'misadventure'. Absent better methods for assessing cause of death, all other bird mortality records had their cause of death listed as 'unknown'. We discounted the existence of mortalities resulting from power line, communications tower, or wind farm collisions as such aboveground obstacles are generally absent in Singapore.

For the purposes of this study, we reported records belonging only to resident and naturalised species, and excluded all migratory and escapee species.

Outlier Analysis

To test for potential outlier species that may be overrepresented in the mortality dataset, we conducted a simple linear regression analysis to compare the population densities of the 10 most abundant resident bird species in urban Singapore (per

Tan 2016) with the number of urban mortality records.

Spatial Distribution of Resident and Migratory Building Collision Mortalities

To compare the spatial distribution of resident and migratory building collision mortalities, we filtered our dataset to exclude records without complete GPS coordinates and separately plotted resident and migratory building collision mortality records on a map of Singapore using QGIS v2.18.9 (QGIS Development Team 2016). For both the resident and migratory datasets, we subsequently used the heatmap v0.2 plugin with a radius parameter set at 1,000 m and the QGIS raster calculator to identify hotspots with a pixel value greater than two, and overlaid the resident and migratory collision hotspot polygons on a single map canvas.

Results

Summary of Mortality Records

We documented a total of 362 mortality records from 65 species during the surveyed period, of which 104 mortalities were the result of building collisions, 16 from vehicular collisions, 10 due to predation – of which 7 were attributable to cats – and 7 records resulting from misadventure (Table 1). 225 records had an unknown cause of death, often due to specimens having been moved post-mortem or specimens in advanced stages of decay (Table 1). 21% (n = 76) of the records were identified as juveniles, with 24 building collision cases, 1 roadkill case, 1 instance of cat predation, 4 cases of misadventure, and 46 individuals with an unknown cause of death (Table 1).

Pigeons (family Columbidae) formed the largest proportion (32.6%) of the mortality records, with 73 Pink-necked Green Pigeon (*Treron vernans*) records comprising 61.9% of the total pigeon mortalities. Of the pigeon records with a known cause of death, 88.9% were the result of building collisions, which suggests that pigeons may be especially susceptible to collisions with urban structures.

Starlings and mynas (family Sturnidae) were the second-largest taxon amongst the reported urban mortalities (22.1%), with most of the mortalities in this family comprised of Asian Glossy Starlings (*Aplonis panayensis*) and Javan Mynas (*Acridotheres javanicus*). Interestingly, juveniles formed 81% of the total Asian Glossy Starling building collision records (Fig. 1).

Plotting the distribution of mortalities over time, we find that juvenile mortalities peak during the months of May and June, and again in October and November (Fig. 1). As for overall mortalities, we observe a relative decrease in the number of mortality records between the months of May and September (Fig. 1).

Testing for Outliers

Correlating population densities with number of mortalities for the 10 most abundant species in Singapore, we find a general positive linear correlation between population density and number of mortalities, with the exception of the Pink-necked Green Pigeons and Asian Glossy Starlings, which exhibit far higher mortality rates than would be expected based on their population density (Fig. 2).

Comparing Resident and Migratory Building Collisions

Plotting the spatial distribution of building collision victims, we find two broad regions where resident and migratory collision hotspots overlap (Fig. 3), both of which are located in the central region of Singapore (see Low *et al*. (2017) for regional delimitation of Singapore island), with one hotspot occurring around the National University of Singapore campus (Region A, Fig. 3) and the other occurring over the Heritage and Central Business Districts (Region B, Fig. 3). We also observed an absence of collision hotspots for resident species in the western region of Singapore, in contrast to the high number of migratory building collisions in that region (Fig. 3; Low *et al.* 2017).

Discussion

Our study documents for the first time the wide array of non-migratory Southeast Asian bird species affected by anthropogenic sources of mortality, with species representing all but one order (podicipediformes) of resident avians known for Singapore. However, it should be noted that our opportunistic sampling methodology might result in artifacts that may bias the data. Here we discuss the implications of our data and the caveats that need to be taken into account when interpreting our dataset for each anthropogenic mortality source.

Building Collisions

Our results show that while 32 non-migratory species are affected by building collisions (Table 1), some species are likely more susceptible than others. In particular, Pink-necked Green Pigeons and juvenile Asian Glossy Starlings, and to a lesser extent the Asian Emerald Doves (*Chalcophaps indica*), appear to be overrepresented in the building collision dataset (Table 1), and in the case of the Pink-necked Green Pigeon and Asian Glossy Starling, exhibit higher mortality rates than their estimated population densities would suggest (Fig. 2). The fact that all three 'super collider' species are forest-edge frugivores suggests that both feeding guild and local dispersal behaviour may affect a species' susceptibility to collision. Given the patchy distribution of parks and forest fragments in Singapore (Castelletta et al., 2005), it is likely that these nomadic forest edge frugivores pass through urban areas as part of their foraging movements, which increases the likelihood of building collisions occurring. Brisque *et al.* (2017) have also found in Brazil that Columbids appear to be more prone to window collisions, which may explain why all resident pigeon species in Singapore save for the Rock Pigeon (*Columba livia*) and the extremely rare Little Green Pigeon (*Treron olax*) are represented in our building collision dataset (Lim, 2009). In addition, the observation that juveniles form the majority of Asian Glossy Starling building collision mortalities suggests that collision avoidance may be a learnt behaviour in this species (Klem, 2014). It should be noted, however, that sampling bias might also contribute to the relatively high proportion of Pink-necked Green Pigeon, Asian Glossy Starling, and Asian Emerald Dove mortality records. The large size and colourful plumage of both pigeon species, as well as the propensity for entire flocks of Asian Glossy Starlings to collide with buildings at the same time, result in these species being highly conspicuous and detectable to casual observers, and increases their likelihood of being reported relative to other species within an opportunistic sampling framework.

Comparing the number of resident and migratory building collisions, our results show that for the same sampling period and the same sampling methodology, we observe twice as many migratory mortalities (n = 204) as resident mortalities (n = 104; Table 1). This is consistent with findings from both the neotropics and nearctic, which show that migratory species are more vulnerable to building collisions than year-round residents (Agudelo-Álvarez et al., 2010; Arnold and Zink, 2011; Kahle et al., 2016).

As for the spatial distribution of migratory and resident building collision mortalities, while it is tempting to overanalyse the results of the spatial analysis, it should be noted that hotspots are likely to be highly biased by uneven sampling effort. The existence of overlapping migratory and resident hotspots over the National University of Singapore (Region A, Fig. 3), for instance, is likely due to a higher observer density relative to the rest of Singapore. Regardless, the existence of overlapping resident and migratory hotspots in the Heritage and Central Business District (Region B; Fig. 3) as well as non-overlapping resident and migratory hotspots in the central and western regions of Singapore indicate that there are likely both common and unique urban abiotic factors affecting the likelihood of resident and migratory building collision mortalities.

Roadkill and Cat Predation

In contrast to the building collision mortalities, we observed far fewer roadkill and cat predation mortalities in our dataset, with twice as many roadkill mortalities as cat predation mortalities (Table 1). The results of our study appear to be incongruent with the conclusions of Loss *et al.* (2013) and Calvert *et al.* (2013), who find that cats are responsible for the highest number of avian mortalities in the United States and in Canada respectively. This inconsistency suggests that we have likely undersampled the true extent of cat-based mortalities in our study.

Temporal variation in resident mortalities

While the temporal pattern of juvenile mortalities corresponds generally with known breeding cycles in Singapore, the observed dip in non-juvenile mortalities in the middle of the year, with a slight decline between May and June, and a larger decline between July and September, does not seem consistent with expectations since adult mortality rates should remain relatively stable throughout the year (Fig. 1). The correlation of the non-juvenile mortality peaks with the migratory months (October to April) suggests that the mid-year dip might be due to observational autocorrelation, where observers are less observant when overall mortalities are low and vice versa, although this will need to be ascertained using more structured sampling methods.

Challenges and opportunities of citizen science

The numerous caveats we have raised here highlight the challenges of combining opportunistic sampling with citizen science. The uneven sampling of localities, varying detectabilities of different species, and the impacts of sampling autocorrelation and sampling fatigue result in data that is often inconsistent and incomplete, which confounds efforts at drawing rigorous quantitative insights from the data. Despite this, the results of our study show that citizen science provides a cost-effective means of gathering large amounts of data on a diffuse and stochastic phenomenon, with the added benefit of simultaneously engaging in public outreach and education. Our results therefore show that citizen science can function as a cheap and effective complement to more standardised survey methodologies (Dickinson et al., 2010), especially in intensively developed urban areas such as Singapore.

Tables and Figures

Table 1: Summary of urban avian mortality records for Singapore, with families ordered per Jarvis *et al.* (2014) and names following Eaton *et al.* (2016). Cause of death abbreviations are as follows: BC, building collisions; RK, roadkill; CA, cat predation; PR, predation by unknown predator; MA, misadventure; UK, unknown. Numbers in parentheses are numbers of juvenile and fledgling mortalities.

Family	Species	Cause of Death						Total
		BC	RK	CA	PR	MA	UK	
Anatidae	Lesser Whistling-duck (*Dendrocygna javanica*)	-	-	-	-	-	1	1
Phasianidae	Red Junglefowl (*Gallus gallus*)	1	1	-	-	-	2	4
Columbidae	Asian Emerald Dove (*Chalcophaps indica*)	11	-	-	-	-	5	16
	Rock Pigeon (*Columba livia*)	-	-	-	-	-	7	7
	Pied Imperial Pigeon (*Ducula bicolor*)	2	1	-	-	-	1	4
	Zebra Dove (*Geopelia striata*)	1	-	-	-	-	2 (1)	3
	Spotted Dove (*Spilopelia chinensis*)	1	2	-	-	1	9	13
	Pink-necked Green Pigeon (*Treron vernans*)	32 (4)	-	1	1	-	39 (5)	73

	Thick-billed Green Pigeon (*Treron curvirostra*)	1	-	-	-	-	1	2
Cuculidae	Banded Bay Cuckoo (*Cacomantis sonneratii*)	1	-	-	-	-	-	1
	Little Bronze Cuckoo (*Chrysococcyx minutillus*)	1	-	-	-	-	2	3
	Asian Koel (*Eudynamys scolopaceus*)	3	1 (1)	-	-	-	7 (1)	11
Caprimulgidae	Savanna Nightjar (*Caprimulgus affinis*)	-	-	-	-	-	1	1
	Large-tailed Nightjar (*Caprimulgus macrurus*)	-	-	-	-	-	4	4
Apodidae	Edible-nest Swiftlet (*Aerodramus fuciphagus*)	1	-	-	-	-	3	4
	Plume-toed Swiftlet (*Colocalia affinis*)	-	-	-	-	-	1	1
Hemiprocnidae	Grey-rumped Treeswift (*Hemiprocne longipennis*)	-	-	-	-	-	1	1
Rallidae	White-breasted Waterhen (*Amaurornis phoenicurus*)	-	4	1	-	-	3	8
	Red-legged Crake (*Rallina fasciata*)	-	1	-	-	-	3	4
	Slaty-breasted Rail (*Lewinia striata*)	-	-	-	-	-	3	3
Charadriidae	Lapwing (*Vanellus* sp.)	-	-	-	-	-	1 (1)	1
Ardeidae	Purple Heron (*Ardea purpurea*)	-	-	-	-	1 (1)	-	1
	Cattle Egret (*Ardea ibis*)	-	-	-	-	-	1	1
	Striated Heron (*Butorides striata*)	-	-	-	-	-	3	3
Accipitridae	Crested Goshawk (*Lophospiza trivirgata*)	2 (1)	-	-	-	-	2 (1)	4
	White-bellied Fish-eagle (*Ichthyophaga leucogaster*)	1	-	-	-	-	-	1
	Brahminy Kite (*Haliastur indus*)	-	-	-	-	-	1	1
	Changeable Hawk-Eagle (*Nisaetus limnaeetus*)	2 (1)	-	-	-	-	-	2
	Crested Serpent Eagle (*Spilornis cheela*)	1	-	-	-	-	-	1
Strigidae	Collared Scops Owl (*Otus lempiji*)	-	1	-	-	-	1	2
	Spotted Wood Owl (*Strix seloputo*)	-	-	-	-	-	1	1
	Barn Owl (*Tyto alba*)	1	-	-	-	-	3	4
Bucerotidae	Oriental Pied Hornbill (*Anthracoceros albirostris*)	-	-	-	-	-	1 (1)	1
Megalaimidae	Coppersmith Barbet (*Psilopogon haemacephalus*)	1	-	-	-	-	3	4
	Lineated Barbet (*Psilopogon lineatus*)	1	-	-	-	-	-	1
Picidae	Sunda Pygmy-woodpecker (*Picoides moluccensis*)	-	-	-	-	-	1	1

	Common Flameback (*Dinopium javanense*)	-	-	-	-	1 (1)	-	1
Alcedinidae	White-breasted Kingfisher (*Halcyon smyrnensis*)	1	-	-	-	-	3 (1)	4
	Collared Kingfisher (*Todiramphus chloris*)	1	-	-	-	-	2	3
Coraciidae	Common Dollarbird (*Eurystomus orientalis*)	-	-	-	-	-	1 (1)	1
Psittacidae	Blue-crowned Hanging Parrot (*Loriculus galgulus*)	1	-	-	-	-	1	2
	Red-breasted Parakeet (*Psittacula alexandri*)	1	-	-	-	-	1	2
	Long-tailed Parakeet (*Psittacula longicauda*)	1	-	-	-	-	1 (1)	2
Aegithinidae	Common Iora (*Aegithina tiphia*)	-	-	-	-	-	2	2
Cisticolidae	Ashy Tailorbird (*Orthotomus ruficeps*)	-	-	-	-	-	1	1
	Common Tailorbird (*Orthotomus sutorius*)	-	-	-	-	1 (1)	-	1
Dicaedae	Scarlet-backed Flowerpecker (*Dicaeum cruentatum*)	3 (1)	-	-	-	-	2	5
Dicruridae	Greater Racket-tailed Drongo (*Dicrurus paradiseus*)	-	-	-	1	-	1	2
Estrildidae	White-headed Munia (*Lonchura maja*)	1	-	-	-	-	-	1
	Scaly-breasted Munia (*Lonchura punctulata*)	2	-	-	-	-	5	7
	Javan Munia (*Lonchura leucogastroides*)	-	-	-	-	-	1	1
Irenidae	Asian Fairy Bluebird (*Irena puella*)	-	-	-	-	-	1	1
Muscicapidae	Oriental Magpie-robin (*Copsychus saularis*)	1	-	1	-	-	3 (2)	5
Nectariniidae	Brown-throated Sunbird (*Anthreptes malacensis*)	-	-	-	-	-	1 (1)	1
	Ornate Sunbird (*Cinnyris ornatus*)	-	-	1 (1)	-	-	3 (1)	4
	Little Spiderhunter (*Arachnothera longirostra*)	-	-	-	-	-	1	1
Oriolidae	Black-naped Oriole (*Oriolus chinensis*)	-	2	1	-	1 (1)	6 (4)	10
Passeridae	Eurasian Tree Sparrow (*Passer montanus*)	2	-	1	-	-	2 (1)	5
Pycnonotidae	Sunda Yellow-vented Bulbul (*Pycnonotus analis*)	-	-	-	-	-	16 (5)	16
	Olive-winged Bulbul (*Pyccnonotus plumosus*)	2	-	-	-	-	1	3
Sturnidae	Javan Myna (*Actidotheres javanicus*)	2	3	-	1	2	22	30

							(5)	
	Common Myna (*Acridotheres tristis*)	-	-	-	-	-	1	1
	Asian Glossy Starling (*Aplonis panayensis*)	21 (17)	-	-	-	-	26 (13)	47
	Common Hill Myna (*Gracula religiosa*)	-	-	-	-	-	2	2
Zosteropidae	Sunda White-eye (*Zosterops melanurus*)	1	-	1	-	-	6 (1)	8
	Total	104	16	7	3	7	225	362

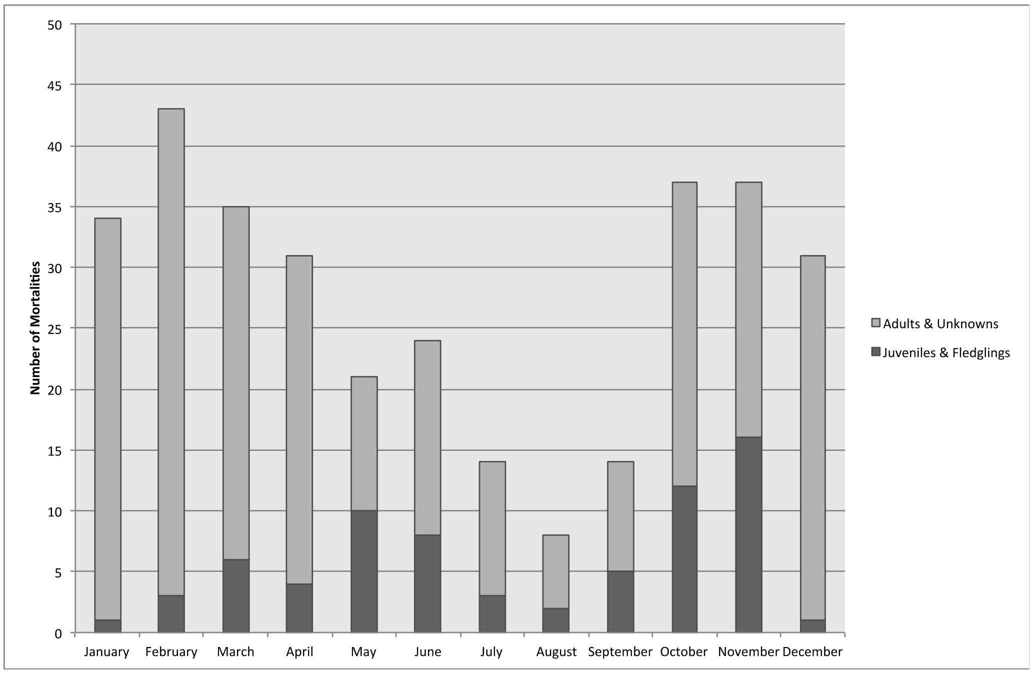

Figure 1: Reported resident mortalities by month, stratified by age category. The two peaks in juvenile and fledgling mortalities in May and November likely correspond with primary and secondary breeding periods (Lim, 2009). It is unclear why there exists a dip in mortality records during the months of July to September.

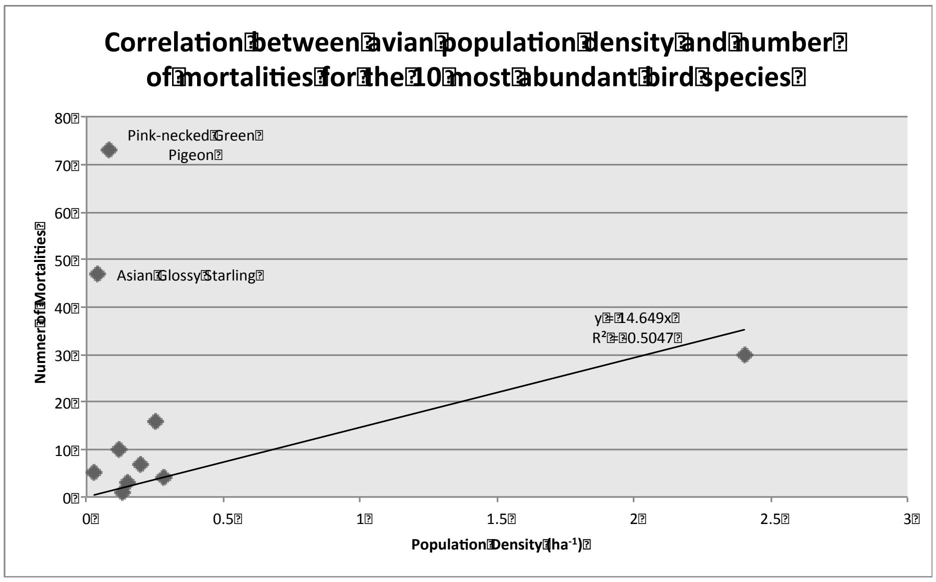

Figure 2: Correlation between avian population density (derived from Tan (2016)) and number of mortalities for the 10 most abundant species in Singapore. The scatterplot shows a general positive linear correlation between population density and number of recorded mortalities, with

the notable exception of the Pink-necked Green Pigeon and the Asian Glossy Starling, which suggests that these two species may either be more susceptible to urban mortalities or subject to positive sampling bias.

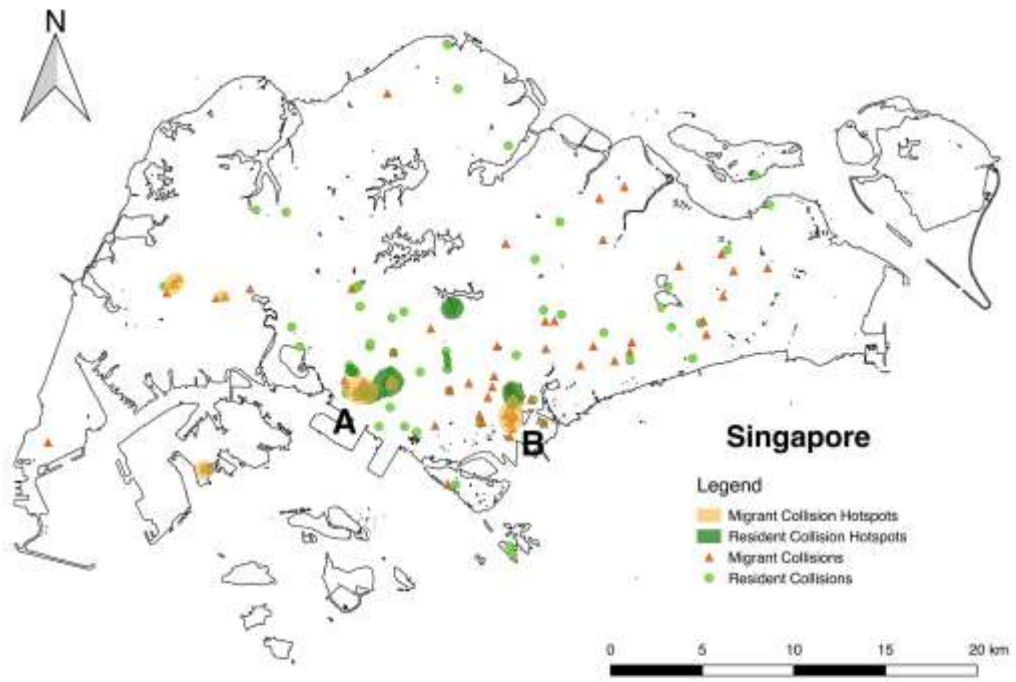

Figure 3: Spatial distribution of resident and migratory building collisions in Singapore, with shaded regions highlighting likely collision hotspots. Overlaying the inferred collision hotspots of both resident and migratory species shows two regions of overlap, with one region centering around the National University of Singapore campus (region A) and the other around the Heritage and Central Business Districts (region B)

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