Population assessment of the house crow, Corvus splendens, in Singapore

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Population assessment of the house crow, *Corvus splendens*, in Singapore

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Abstract: The house crow, *Corvus splendens*, is a striking example of an introduced species that has become a pest bird. In Singapore, the introduced house crow population numbered 130,000 birds in 2003 with a density of 1.9 birds/ha despite implementation of population management measures since 1973. A 2003 survey informed and set a model-based target for management. In the present study, we investigate the change in house crow abundance and density on the main island of Singapore since the last population assessment. Applying distance sampling, we conducted 244 point transect surveys and made 21 detections of house crows. Present-day house crow density was estimated to be 0.134 birds/ha, which is close to the target density of 0.1 birds/ha. This translates into approximately 7,295 house crows on the main island of Singapore, a 92% decrease from population estimated in 2003. High-rise and low-rise habitats had the highest house crow density, although all urban habitats shared similar density estimates. This finding corroborates our understanding of the house crow as a human commensal which exploits anthropogenic food sources in the urban environment. Our results show that the population control strategy undertaken on house crows in Singapore since 2003 has achieved its intended targets.

Keywords: Population assessment, house crow, *Corvus splendens*, introduced species, Singapore

INTRODUCTION

World-wide, improved connectivity and global change has seen an increasing prevalence of species introductions (Mack *et al.*, 2000). Introduced species may modify existing ecosystems, threaten the survival of native species, and affect human activities (Vitousek *et al.*, 1997). Increasing research is directed towards the management of introduced species (Pyšek and Richardson, 2010), but is often plagued by a lack of understanding of their natural history and the underlying ecosystem (Simberloff *et al.*, 2005).

In Singapore, a tropical island city-state, the introduction of exotic species has occurred via unintentional introductions, such as the pet trade and hitchhiking, but also intentionally for biological control measures (Yeo and Chia, 2010). A striking example is the house crow (*Corvus splendens*) (Figure 1). Native to South Asia, it was imported into Peninsular Malaysia as a form of biological pest control in plantations, from where it likely dispersed to Singapore (Gibson-Hill, 1949). House crows have long been regarded as a human commensal and are highly adapted to urban environments (Brook *et al.*, 2003; Koul and Sahi, 2013). In Singapore, house crows have been observed to rely on a diet consisting mainly of human refuse and fruits (Lim and Sodhi, 2004).

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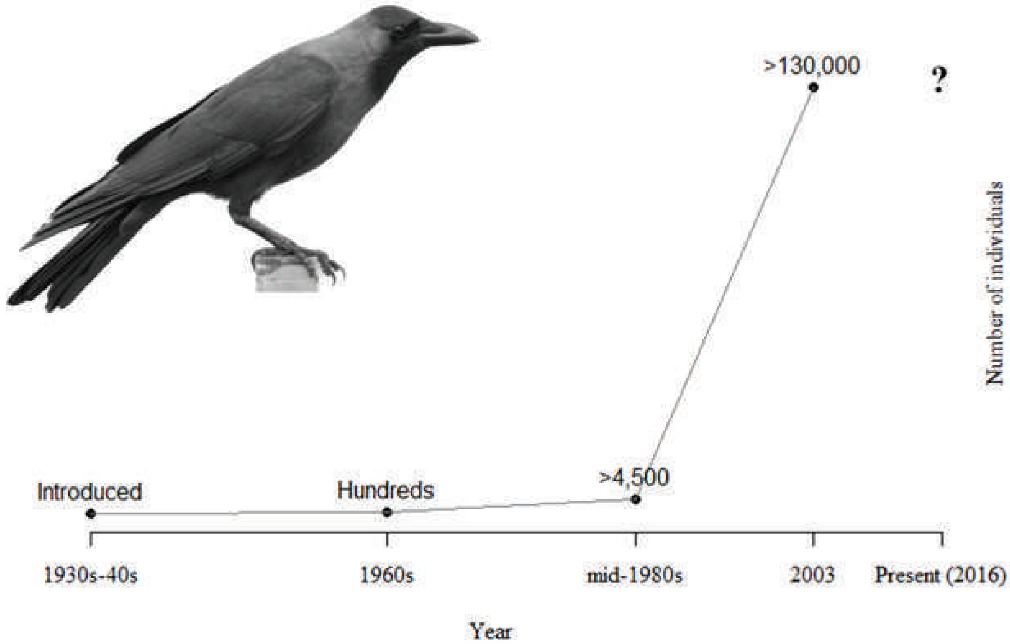

Figure 1. Timeline showing the changes in house crow (*Corvus splendens*) population size in Singapore since the 1930s. By 2003, house crows numbered more than 130,000 individuals and present population size is unknown. From House Crow, Y. C. K. Sin, 2016. Copyright 2016.

Introduced in the late 1930s or early 1940s, the population of house crows in Singapore numbered in the hundreds in the 1960s (Ward, 1968; Figure 1). Excessive noise from communal roosts, fouling of public spaces (Peh and Sodhi, 2002), and reports of aggression toward humans caused house crows to be considered as pests locally (Soh *et al.*, 2002; Loh, 2015). Population management of house crows began in 1973 when the Primary Production Department began culling them (Brook *et al.*, 2003). In 1974, house crows became the only bird species that was not protected from killing or possession under the Wild Animals and Birds Act (Cap 351, 1985 Rev. Ed.) s 4(1). By the mid-1980s, the population of house crows in Singapore had grown to over 4,500 individuals (Brook *et al.*, 2003).

Despite consistent culling efforts, population assessments estimated that there were over 100,000 house crows in Singapore by 2003 (Brook *et al.,* 2003; Lim *et al*., 2003). In order to achieve a stated target of house crow density reduction by 95% (from 1.9 birds/ha to <0.1 birds/ha) within 10 years, Brook *et al.* (2003) recommended culling at least 41,000 house crows each year, based on a discrete-time, density-dependent population model. Since then, transect surveys have indicated a decrease in house crow counts from 1982 birds in 2000-2001 to 258 birds in 2010-2011 (Chong *et al*., 2012). However, a re-assessment of house crows in Singapore to derive absolute abundance estimates has yet to be carried out. To fill this gap in our knowledge of local house crows, this study aims to quantify present-day house crow density and abundance and compare our results with past estimates in order to inform future population control strategies.

MATERIALS AND METHODS

Study area

We surveyed house crows on the main island of Singapore (103° 50′ E, 1° 20′ N), located at the southern tip of Peninsular Malaysia, with a total landmass of 718.3km^2 (Singstat, 2015; Figure 2). Singapore is highly urbanized with less than 95% of its original forest cover remaining (Tan *et al*., 2010). Since house crows favour urban areas strongly, habitat types were considered an important factor for their presence. We defined 10 habitat types with reference to Lim and Sodhi (2004) but categorized housing and commercial buildings by height only and green areas by habitat type instead of extent of management (Table 1). The land area occupied by each habitat was measured using Google Earth and sampling effort in each habitat was matched to these proportions.

Table 1. Habitat description and the proportion of land area occupied by each habitat as of 2016.

Habitat	Description	Proportion of total land area (%)
Agriculture	Plantations and animal farms	1.01
Grassland	Expanse of grass-dominated field, absence of or sparse in trees	6.49
High-rise	> 6 surface storeys, government housing, condominiums, office towers	35.81
Industrial	Heavy industries	16.02
Low-rise	≤ 6 surface storeys, residential buildings, schools or communal buildings, usually with yards	21.35
Mangrove	Intertidal forest characterized by adaptations to biotic conditions (e.g. *Avicennia* trees)	0.46
Park	Manicured green spaces under the charge of National Parks Board	3.94
Secondary Forest	Regenerated forest characterised by *Adinandra belukar* vegetation type	14.56
Primary Forest	Original forest characterised by dipterocarps with distinct forest layers	0.37
Others	Various restricted areas e.g. golf courses, military areas, infrastructure	not measured

Distance sampling

Distance sampling produces density estimates given the perpendicular distance of an organism from the observer. It models the probability of failing to detect objects that are present, in order to derive absolute abundance estimates. Due to the difficulty of placing line transects in urban areas without being confined to existing roads, we used a point transect sampling method. A total of 244 point transects were carried out from January to June 2016. Surveyable zones of 1km in diameter were randomly selected on the main island of Singapore and surveys were conducted at ten randomly selected points within each zone (Figure 2). This approach was chosen for logistical reasons to maximise the number of transects conducted.

For each point transect survey, a buffer time of 2 minutes was observed before starting the survey to allow habituation of birds to observer presence. Each transect was surveyed once for 5 minutes. All key assumptions of distance sampling were met to ensure the validity of estimates (Buckland *et al.*, 1993). Binoculars (Vanguard Venture Plus (10 x 42)) were used to identify house crows and a rangefinder (Nikon LASER 550AS 6 × 21, 6°) was used to measure radial distances to all house crows detected. All objects at the point were detected and all objects were detected at their initial locations. Only perched crows were counted. All transects were completed by the same observer (HZT) to avoid observer bias. Surveys were carried out at similar frequencies throughout the day and only during fair weather.

Figure 2. Location of point transects on the main island of Singapore. Map inset shows Singapore's location at the southern tip of Peninsular Malaysia.

Distance sampling analysis

We discarded the earliest 10 transects performed, transects with bad weather (drizzling) and transects whose survey times overlapped with expected roosting times (Peh, 2002). The furthest 5% of observations by distance in high-rise and low-rise habitats were also removed prior to analysis as recommended by Buckland *et al.* (1993). A total of 227 transects were retained in proportion to habitat size and subsequently analysed (Table 2). Results from point transect surveys were analysed using DISTANCE 7.3 to obtain population density estimates globally (main island of Singapore) and per stratum (per habitat) (Thomas et al. 2010). Model selection was based on the Akaike Information Criterion (AIC).

RESULTS

Population assessment

In the final dataset of 227 transects used in analysis, 18 detections of house crows were made over 15 transects at decreasing frequencies with increasing distance (Table 2, Figure 3). Density estimates in all models tested were within the same magnitude (Table 3). The lowest AIC was observed for the hazard rate model, regardless of series expansion type. Due to our small detection sample size, the key function alone (i.e. hazard rate model) was adequate for modelling density. The detection probability function of the hazard rate model presented a shoulder before 15m, then decreasing rapidly beyond the 20m mark, fulfilling the ideal shape criterion (Buckland *et al*., 1993; Figure 4). The function also concurs with our observation in the field that house crow detection probability near transect points is high, but drops rapidly with increasing distance as the observer's field of vision becomes quickly obstructed by buildings and other obstacles (Figure 4). The model estimates an effective strip width of 43.43m and a house crow density of 0.134 birds/ha (13.4/km^2) with a high coefficient of variation of 0.552 due to a small detection sample size (Buckland *et al*., 1993; Tables 2, 3). From the density, we estimate the total population size of house crows on the main island of Singapore to be 7,295 [95% CI: 2,559 – 20,960].

Table 2. Number of transects performed and house crow detections in each surveyed habitat in the final dataset used in analysis.

Habitat	Final number of transects	Number of detections
Agriculture	2	0
Grassland	18	0
High-rise	81	9
Industrial	34	3
Low-rise	47	5
Mangrove	1	0
Park	14	1
Secondary Forest	29	0
Primary Forest	1	0
Total	227	18

In all habitats, one detection was made per transect except in high-rise habitats, where two transects had two and three detections respectively (Table 2). Within the hazard rate model, density estimates were also calculated for each habitat type. High-rise habitats have the highest density estimate of house crows at 0.188 birds/ha, followed by low-rise, industrial and park habitats (Table 4). The coefficient of variation was relatively high for most estimates due to a small detection sample size. No estimates were produced for primary forest, secondary forest, agriculture, grassland and mangrove as there were no detection of house crows (Table 2).

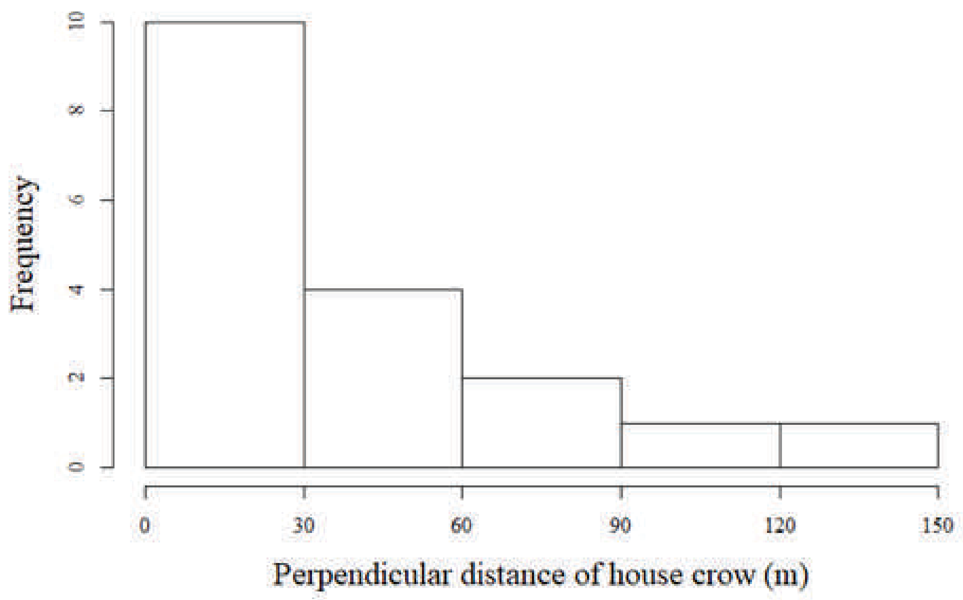

Figure 3. Histogram showing the frequency distribution of perpendicular distances to house crows measured in intervals of 30m.

Table 3. Results of DISTANCE analysis showing Akaike Information Criterion (AIC), effective strip width (ESW), estimated population density and abundance with 95% confidence interval (95% CI), as well as coefficient of variation (CV) for each model. The hazard rate model (denoted with *) has the lowest AIC of 156.78 regardless of series expansion. For other models, only results of the series expansion that presented the lowest AIC are shown.

Main Function	AIC	ESW	Density [95% CI]	Abundance [95% CI]	CV
Uniform + cosine	167.08	43.22	0.135 [0.068 – 0.270]	7,350 [3,702 – 14,699]	0.358
Half-normal + cosine	167.56	39.45	0.162 [0.077 – 0.342]	8,819 [4,192 – 18,619]	0.386
Hazard rate*	165.28	43.43	0.134 [0.047 – 0.385]	7,295 [2,559 – 20,960]	0.552
Negative Exponential	165.91	31.93	0.248 [0.106 – 0.579]	13,501 [5,771 – 31,521]	0.440

DISCUSSION

Population assessment of house crows in Singapore

The 2003 population assessment of house crows (Brook *et al.*, 2003) recommended a reduction of house crow density from 1.9 birds/ha to <0.1 birds/ha by 2011 via culling. Our population estimate of 0.134 birds/ha reveals a decrease in density of more than 92%, which is very close to the recommended target. Considered together with the decrease in house crow observations (Chong *et al.*, 2012), we can ascertain that Singapore's house crow population has decreased significantly over the course of a decade.

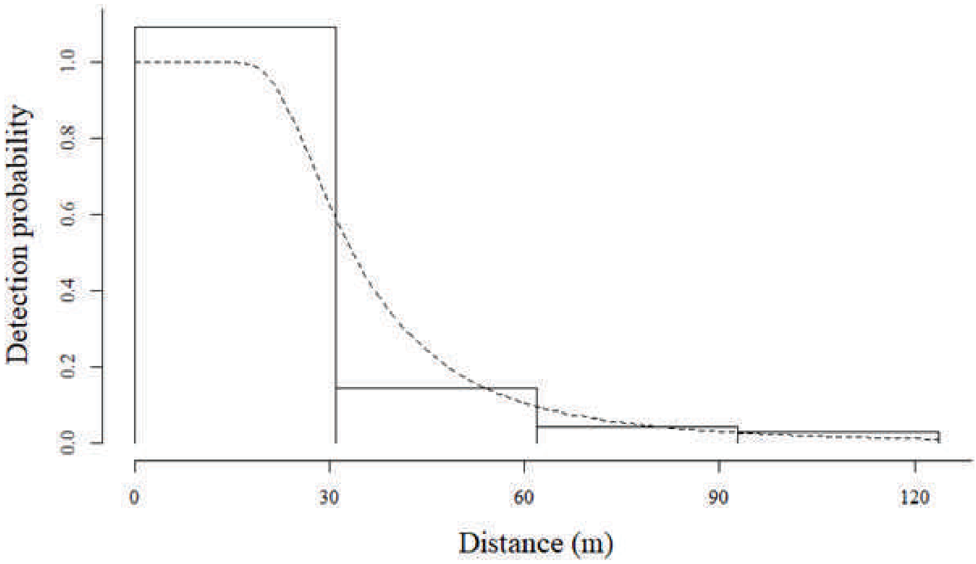

Figure 4. Probability density function estimated using the hazard rate model. A shoulder is present from 0m to 15m which then quickly decreases.

Table 4. Density estimates under the hazard rate model for each habitat type with house crow detections.

Habitat	Density Estimate [95% confidence interval]	Standard Error	% Coefficient of Variation
High-rise	0.188 [0.565E^{-1}, 0. 623]	0.123	65.43
Industrial	0.149 [0.397E^{-1}. 0.559]	0.110	73.57
Low-rise	0.180 [0.550E^{-1}, 0.586]	0.115	64.09
Park	0.121 [0.185E^{-1}, 0.786]	0.134	110.82

The success of population control strategies by local authorities was likely, in part, a result of characteristics intrinsic to house crows which lead to high detectability: house crows are conspicuous, vocal (Ranjan and Kushwaha, 2013) and reside in highly accessible urban environments (Puttoo and Archer, 2003). With a reduced population density, house crows may now be more vulnerable to brood parasitism by Asian koels (*Eudynamys scolopaceus*), which serves to reduce their numbers further (Begum *et al.*, 2011; Chong *et al.*, 2012). However, despite their present low density in Singapore, it is also important to note that the house crow population in Singapore is not a closed one. Current numbers may be supplemented by individuals from Peninsular Malaysia as house crows have been observed to traverse the Johor Strait.

In our study, areas such as airports, golf courses and military areas in Singapore were not surveyed due to restricted access. However, we expect that these habitats will only harbor small numbers of house crows and should not affect our overall density estimates significantly. Reasons for this include measures in place at airports that continually deter bird presence to prevent collisions with aircraft (Cleary and Dolbeer, 2005), as well as the minimal urbanisation of military areas which are mostly heavily forested.

House crow detections and densities across different habitats

Our study detected house crows in urban environments, but not in natural environments like forests (Table 2). House crows were present at similar densities in high-rise, low-rise, industrial and park habitats, which have been shown to be positive predictors of their abundance (Lim *et al.*, 2003; Lim and Sodhi, 2009; Table 4). High-rise and low-rise habitats, encompassing both residential (public and private) and commercial buildings, have the highest number of detections and density estimates amongst all habitats.

A human commensal (Yeo and Chia, 2010), the feeding, roosting and reproductive behaviours of house crows are well-adapted to urban environments and accounts for their strong presence. For example, house crows benefit from improper food refuse handling and the resulting high availability of anthropogenic food (Peh and Sodhi, 2002; Soh *et al.,* 2002; Lim *et al*., 2003; Nyári *et al*., 2006; Lim and Sodhi, 2009). House crows prefer roost sites close to large buildings and food sources for protection against wind and rain and to reduce flight costs in foraging respectively (Peh and Sodhi, 2002). Finally, they have a strong preference to nest in urbanised areas and are able to utilise man-made structures, such as electricity poles, for nesting if trees are not available (Soh *et al.*, 2002).

Given the human commensal status of house crows, the lack of detections in primary and secondary forest patches of Singapore is expected. Furthermore, the native large-billed crow (*Corvus macrorhynchos*) is present in the latter habitats and house crows may therefore avoid forests due to potential aggression and competition (Shanbhag *et al.*, 2012). The lack of house crows in grasslands may be explained by the lack of trees or other tall structures, which house crows use for nesting (Soh *et al.*, 2002). In agricultural areas, low human activity and the protection of crops with nets reduces foraging potential for house crows.

House crow presence in mangroves was expected but not detected during surveys carried out in the habitat. We were limited in our study of house crows in mangroves due to the difficulty of placing random transects in mangroves, but other sources have cited the presence of house crows in mangroves locally (Sodhi *et al.*, 1997; Ng and Sivasothi, 1999; Arnold, 2000) and across the Malay Peninsula (Nisbet, 1967). While conducting our surveys, we also made opportunistic records of their presence in the vicinity of mangroves. Despite this, we do not expect our lack of detections in mangroves to change our overall abundance estimate of house crows in Singapore, because mangroves only occupy only a small proportion of the total land area of Singapore's main island (0.46%, Table 1).

CONCLUSION AND FUTURE WORK

This study focuses on a population assessment of house crows in Singapore, 12 years after the last study. We found that population control has reduced house crow density in Singapore by 92%, nearly meeting the recommendation of <0.1 birds/ha as put forth by

Brook *et al.* (2003). Population management efforts have therefore achieved its intended targets. At present, the house crow population on the main island of Singapore numbers around 7,295. Future studies could investigate house crow presence throughout restricted areas in Singapore as well as offshore islands. Studies on the roost and nest site preferences of house crows could also be conducted and compared to previous surveys to evaluate if preferences have changed over time and in response to culling. Transborder movements of house crows could be characterized to predict the likelihood of recolonization by individuals from Peninsular Malaysia at various culling efforts locally. The effects of brood parasitism by Asian koels should also be accounted for in future population modelling.

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