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# Accounting for detectability when estimating avian abundance in an urban area

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**Abstract:** Urban areas can support significant bird populations, including species of conservation concern, but urban ecologists have been slow to apply detectability-based counting techniques. We compared abundances and relative abundances of eight urban birds, derived using two commonly applied techniques (fixed-radius point and strip sampling) and distance sampling. We evaluated the influence of habitat and two covariates (observer and whether birds were seen or heard) on detectability. Due to built-up structures in urban areas, point counts are appropriate. Unavoidable and sometimes complex but necessary interactions with multiple property owners may compromise the number of points able to be counted and therefore the precision of estimates. Abundances from strip and fixed-radius point counts were on average only one-third (strip) and less than one-half (fixed-radius point) those obtained using distance sampling, with interspecific variation in the degree to which densities were underestimated. Rankings of relative abundances were mostly similar, although distance sampling ranked silvereye (*Zosterops lateralis*) and grey warbler (*Gerygone igata*) relatively higher in residential habitat. Habitat did not appear to influence detectability for most species, but the two covariates (observer and seen/heard) improved model fit for a number of species, indicating it is useful to record this information. Well-standardised non-detectability-based counts could provide useful information on community structure and relative abundances in urban areas, but distance sampling is necessary to track the population status of species, although it cannot usefully be applied to rare species.

**Keywords**: birds; density; distance sampling

## Introduction

The majority of studies exploring the impacts of urbanisation on birds have focused on comparing species diversity and community composition along a gradient of increasing urbanisation, comparing between different urban habitats, or between urban and non-urban habitats. When abundances have been compared, the methods used to estimate them vary widely, but commonly fail to address the issue of incomplete detectability. Both point-counts (e.g. Crooks et al. 2004; Daniels & Kirkpatrick 2006; Palomino & Carrascal 2006; Sandström et al. 2006; Garaffa et al. 2009; Ortega-Álvarez & MacGregor-Fors 2009; Hedblom & Söderström 2010) and line-transects (DeGraaf & Wentworth 1986; Hostetler & Holling 2000; Lim & Sodhi 2002; Parsons et al. 2003; Crooks et al. 2004; White et al. 2005; Antos et al. 2006) have been used, with lines usually oriented along roads for counts carried out inside residential areas. Point counts used in urban studies vary in duration from 5 to 30 min. Data are interpreted by some as indices of relative abundance (Donnelly & Marzluff 2004; Hedblom & Söderström 2010), and by others as estimates of total abundance (Sewell & Catterall 1998; Sandström et al. 2006; Garaffa et al. 2009; Ortega-Álvarez & MacGregor-Fors 2009). Counts from fixed-radius circular plots have been interpreted as a census (i.e. a total count over a defined area) if the duration of the count was considered sufficiently long to enable detection of all birds within a given radius (e.g. 50 m; Germaine et al. 1998; Daniels & Kirkpatrick 2006; Palomino & Carrascal 2006), but also as abundance indices (Crooks et al. 2004). Incomplete detectability is sometimes acknowledged but discounted as a concern if the analysis looks at within-species comparisons across habitats or gardens (Daniels & Kirkpatrick 2006; Palomino & Carrascal 2006) or if a rigorous sampling design is used to reduce variation in detection probabilities to less than variation in population size (Hedblom & Söderström 2010). Rarely, a correction for detectability is introduced to variable circular plots to calculate a density (Blair 2004).

Transect counts also vary in their application and their interpretation. Some researchers report bird densities from transects centred along streets (DeGraaf & Wentworth 1986; Mills et al. 1989), whereas most studies report abundances (Hostetler & Holling 2000; Lim & Sodhi 2002; White et al. 2005) or relative abundances (Antos et al. 2006). While some studies acknowledge (Daniels & Kirkpatrick 2006) or try to correct for differing detectability (Blair 2004), most urban

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studies have ignored the problem, compromising the reliability of spatial and temporal comparisons of abundance. Exceptions are the studies by Fuller et al. (2009), where densities of a number of species are estimated across the city of Sheffield to obtain a city-wide population estimate, and Van Rensberg et al. (2009) comparing alien species along an urban gradient in South Africa.

Detectability of different species may vary substantially, resulting in underestimations of the relative abundance of cryptic species when simple strip transects or point counts are made. Overestimation may also occur for species that are noisy or attracted to people, increasing the chance that they are counted twice. When potential sources of variation in detectability (habitat, observer, season, time of day, weather conditions) mean that detectability cannot be assumed to be complete and constant across time and space (e.g. Meadows et al. 2012; Weller et al. 2012), a technique that explicitly estimates detectability, such as distance sampling, should provide a more reliable estimate of abundance, if underlying assumptions are met (Buckland et al. 2008). However, given the additional technical expertise required to implement distance sampling reliably, and potential uncertainty regarding whether fundamental assumptions are met, some argue that well-standardised counting protocols that reduce the impact of various factors on detectability can provide a more practical solution to obtaining useful information on trends in population size (Rosenstock et al. 2002; Johnson 2008). The urban environment certainly poses particular challenges with respect to study design to ensure assumptions of distance sampling are met. However, we make the case that where the aim is to track population size of a target species it is both necessary and feasible to apply distance-sampling methods in urban areas.

In this paper we (1) explore how distance sampling can appropriately be applied in an urban environment and (2) compare abundance estimates from commonly used techniques (strip and fixed-radius point counts) with distance-generated estimates to evaluate potential discrepancies in estimated population sizes and relative abundance rankings for eight urban bird species. We explore the effects of three variables on detectability: habitat, observer, and whether the bird was seen or heard. We predict that detectability will vary between species and between habitats (primarily between bush fragment and residential habitats, and secondarily between different residential habitats). Finally, we discuss constraints that are typical or unique to urban areas and which need to be considered when designing counts to estimate urban bird abundance.

## Methods

### Study site

Dunedin is a small city in New Zealand with about 120 000 inhabitants, covering a core area of about 65 km$^2$. A GIS-based habitat map of the majority of urban Dunedin (small satellite urban areas located within predominantly rural habitat were not included in the map), developed by Freeman and Buck (2003), that differentiates urban habitats at a fine scale was used to identify habitat types. In this study, counts were made in bush fragments, and in residential areas classified into three categories according to the relative size and vegetative characteristic of gardens: Residential 1 housing (Res1) typically has large mature gardens with a mixture of large trees, shrubs, hedges and lawns; Residential 2 housing (Res2) has similar-sized gardens that were structurally simpler, dominated by lawns; and Residential 3 housing (Res3) has very small gardens comprising mostly lawn and flowerbeds. Dunedin has mostly single- or double-storey detached housing and lacks high-density multi-storey residential areas.

### Estimation of abundance of bird species

(1) *Transects:* Five transects 400 m in length were walked in Bush and Res2 habitat each month during the same four months of the year that the point counts were made (November, December, March, April), during 2004 - 2005. Counts of individual transects were carried out in the mornings and evenings, with care taken to make sure all transects were counted during both mornings and evenings and to obtain even ratios of morning to afternoon counts when summed over all months. Transects were located along roads, and birds were counted to 20 m on either side of the transect line. Density was calculated as the total number of birds of each species counted divided by four and by the total area of the transect.

(2) *Five-minute fixed-radius point counts:* Morning counts (i.e. before 10am) were conducted at 123 points on three separate occasions, in bush fragments ($n$ = 51) and residential habitat ($n$ = 34/56/33 in Res1/Res2/Res3 respectively). Points were determined by generating random locations within each habitat. Within residential areas counts were always carried out in gardens. About half of the counts in each habitat type were made by four observers in November and December of 2007, and the other half by one observer in March and April of 2008; all observers had similar levels of training. All birds seen and heard were recorded, except those flying high above the point. We calculated density estimates by including all observations within a 50-m-radius circle around the observer, and dividing the total counted for each species by three, and then by the area of the circle.

(3) *Five-minute point counts with distance sampling:* During the point counts described above, the distance to birds was recorded for all detections. The position of low-flying birds was noted when they were first seen. A Nikon 440 rangefinder was used to measure the distance between the observer and the bird when it was first seen. Detections for each species were imported into Distance software v5 (Thomas et al. 2006), with 'observer' and 'seen or heard' entered as covariates. Detection functions with and without covariates were modelled: the best model was selected using AICc values. The influence of habitat (bush fragment and the three residential categories) on detectability was explored by determining whether habitat-specific detection models should be used in preference to a global detection model that could be applied across all habitats. Models were run post-stratified on habitat, to ascertain whether a global detection function could be used to estimate densities within each habitat. If the AICc value of the global model was less than the sum of the habitat-specific values for the stratified model, then a global detection function could be used to determine densities for each habitat (Buckland et al. 2001). If this was not the case then individual models were developed for each habitat. Densities were estimated for bush fragment and Residential 2 habitats (Res2 comprises about three-quarters of total residential habitat) and total abundance of each species calculated on the basis of the total areas of each habitat, determined from the Dunedin GIS habitat map.

## Results

### Density and population estimates

There were sufficient detections (60-80; Buckland et al., 2006) to model detectability for four exotic (house sparrow *Passer domesticus*, n = 320 detections, blackbird *Turdus merula*, n = 438 detections, starling *Sturnus vulgaris*, n = 325 detections, song thrush *Turdus philomelos*, n = 108 detections) and three native species (silvereye *Zosterops lateralis*, n = 542 detections, bellbird *Anthornis melanura*, n = 342 detections, and grey warbler *Gerygone igata,* n = 119 detections) We also modelled detectability for fantail *Rhipidura fuliginosa*, n = 54 detections, as the number of detections fell just under the recommended practical minimum. Density values and population sizes calculated for strip counts, fixed-radius point counts and point counts with distance sampling can be compared in Tables 1 and 2. In most cases (11/16), density calculated using a 50-m radius around a point yielded a higher value than density calculated along a strip.

There was considerable interspecific variation in the degree to which densities varied between counting methods. In residential areas silvereye counts generated densities only 16% (D strip) and 23% (D point) of distance-based estimates, whereas starling counts were 49% and 70% the distance-based estimate, respectively. For all values except for bellbirds in residential areas, density values obtained using distance

**Table 1.** Density (individuals ha$^{-1}$) estimates of birds in bush fragments derived from strip transects (D strip), point counts assuming a radius of 50 m (D point) and distance sampling at point counts (D point distance). The total population size across that habitat category in Dunedin City is given in brackets following the density value; 95% confidence intervals of the density estimate and the % coefficient of variation are given underneath.

| Bird species in bush habitat | D strip | D point | D point distance |
|---|---|---|---|
| House sparrow | 0.3 (267)<br>(0–0.6; 229%) | 0.8 (712)<br>(0.4–1.1;164%) | 2.5 (2225)<br>(1.7–3.8; 20.2%) |
| Blackbird | 2.2 (1958)<br>(1.4–3.0;76%) | 1.7 (1513)<br>(1.4–2.0;63%) | 5.4 (4806)<br>(4.7–6.4; 7.9%) |
| Song thrush | 0.2 (178)<br>(0.03–0.4;173%) | 0.4 (356)<br>(0.2–0.6;155%) | 1.1 (979)<br>(0.6–1.4; 22.7%) |
| Starling | 0.5 (445)<br>(0.1–0.8;165%) | 0.6 (534)<br>(0.2–1.0;230%) | 1.2 (1068)<br>(0.6–2.3; 34.1%) |
| Silvereye | 5.4 (4806)<br>(3.9–6.9;57%) | 3.7 (3293)<br>(2.8–4.5;87%) | 19.1 (17 000)<br>(15.0–24.2; 12.0%) |
| Fantail | 0.6 (267)<br>(0.4–0.9;68%) | 0.3 (267)<br>(0.2–0.4;162%) | 0.7 (623)<br>(0.4–1.3; 31.6%) |
| Bellbird | 1.5 (1335)<br>(1.2–1.9;47%) | 1.3 (1157)<br>(0.9–1.7;93%) | 3.1(2759)<br>(2.4–4.1; 14.3%) |
| Grey warbler | 0.8 (712)<br>(0.6–1.1;60%) | 0.8 (712)<br>(0.5–1.1;134%) | 1.7 (1602)<br>(1.1–2.3; 19.3%) |

**Table 2.** Density (individuals ha$^{-1}$) estimates of birds in residential habitat (Res2) derived from strip transects (D strip), point counts assuming a radius of 50 m (D point) and distance sampling at point counts (D point distance). The total population size across that habitat category in Dunedin City is given in brackets following the density value; 95% confidence intervals of the density estimate and the % coefficient of variation are given underneath.

| Bird species in Res2 habitat | D strip | D point | D point distance |
|---|---|---|---|
| House sparrow | 4.6 (8823)<br>(2.1–7.1;48%) | 6.3 (12 083)<br>(4.7–7.8;58%) | 13.6 (26 084)<br>(11.4–16.2; 8.9%) |
| Blackbird | 1.4 (2685)<br>(0.1–2.8;80%) | 1.74 (3337)<br>(1.4–2.1;21%) | 3.8 (7288)<br>(3.1–4.5; 9.0%) |
| Song thrush | 0.19 (364)<br>(0.1–0.3;200%) | 0.23 (441)<br>(0.1–0.4;149%) | 0.47 (901)<br>(0.3–0.6; 22.6%) |
| Starling | 2.1 (4028)<br>(1.6–2.7;52%) | 3.0 (5754)<br>(2.1–3.9;75%) | 4.3 (8247)<br>(3.1–5.9; 12.2%) |
| Silvereye | 2.4 (4603)<br>(1.4–2.4;50%) | 3.5 (6713)<br>(1.8–5.2;121%) | 15.3 (29 345)<br>(11.9–19.7; 12.7%) |
| Fantail | 0.08 (153)<br>(0–0.2;105%) | 0.2 (384)<br>(0–0.4;21%) | 0.4 (767)<br>(0.2–0.8; 37.8%) |
| Bellbird | 0.1 (192)<br>(0–0.3;133%) | 1.1 (2110)<br>(0.6–1.5;21%) | 0.9 (1726)<br>(0.6–1.4; 23.0%) |
| Grey warbler | 0.03 (58)<br>(0–0.1;211%) | 0.1 (192)<br>(0–0.3;377%) | 0.2 (384)<br>(0.1–0.4; 37.5%) |

sampling at a point yielded higher values with confidence intervals that overlapped hardly or not at all with those of the other estimates.

Coefficients of variation of distance-based estimates were above 30% for starlings and fantails in bush habitat, and fantails in residential habitat, and above 20% for house sparrows, song thrushes and grey warblers in bush habitat, and song thrushes and bellbirds in residential habitat (Tables 1 & 2). However, coefficients of variation for the distance-based estimates were much lower than those for estimates based on strip counts or fixed-radius point counts (Tables 1 & 2).

### Relative abundances of birds

Ranked abundances of birds according to values from the three methods for obtaining densities are shown in Table 3. In bush fragment habitat, the top three most abundant species (silvereye, blackbird, bellbird) are ranked consistently across the three calculation methods. Fantails were ranked more highly for strip counts, but there were no notable differences for the remaining species. In residential habitat, distance-sampling techniques switched the ranks of silvereyes and house sparrows obtained by the other two methods, and ranked grey warblers higher. Several other discrepancies in ranks between density calculation methods occur but none involve large differences.

### Variables influencing detectability

Global detection functions could be used for seven out of 8 species (except starling and silvereye) indicating that differences in habitat between residential areas and bush fragments did not influence detectability to the extent that habitat-specific detection functions were required. For silvereyes, a global function could be applied across residential habitats, but bush habitat had to be modelled separately. The covariate 'seen/heard' improved the fit of the detectability function for seven species (except starling, silvereye in the bush and fantail), while the covariate 'observer' improved fit for six species (except house sparrow, song thrush and fantail).

## Discussion

### Distance sampling in urban areas

Urban areas pose a number of challenges for those attempting to account for detectability when estimating avian abundances using distance sampling. Urban landscapes are densely built up, with visual barriers such as fences and buildings, and in some places high levels of background noise, which can reduce detection probabilities for species detected aurally (Pacifici et al. 2008). Much of the land is parcelled up into small privately owned areas. Although line-transects are the most widely used form of distance sampling (Thomas et al. 2009), generating more detections and yielding estimates with lower bias and greater precision (Buckland et al. 2008), they cannot be realistically employed in built-up urban areas as it is not possible to navigate randomly across the obstacles that fill urban landscapes. Transects placed along roads are unlikely to be representative of the entire survey region and different species may respond to roads in different ways.

Point transects are therefore most appropriate. Five-minute counts are recommended in temperate regions to reduce the likelihood of double counting (Bibby et al. 2000). Some urban researchers have used extended counts (20 min) on the assumption that if the count duration was sufficiently long then the count could be considered a census (Germaine et al. 1998; Daniels & Kirkpatrick 2006; Palomino & Carrascal 2006), or at least a more reliable index of abundance (Crooks et al. 2004). However, total detectability of all species is unlikely. Point-transect methods also may not work well for species that are insufficiently noisy or visible to allow adequate numbers of detections: Buckland et al. 2006 recommend a practical minimum of between 60 and 80.

Because point-transect estimates tend to be biased relatively more than line-transects if distances are over- or under-estimated (Buckland et al. 2001) it is important to obtain accurate distance measurements. Observers should be aware of the tendency to overestimate short distances and underestimate long distances (Simons et al. 2005), and practise and recalibrate themselves regularly (Moffat & Minot 1994). Ideally, distances are measured rather than estimated. In urban areas rangefinders should be used to measure distances to birds observed in private property. The simple vegetation structure typical of most urban habitats allows accurate distance measurements even for aural detections, because it is usually possible to identify the hedge, bush or tree concealing a calling bird. When using equipment such as binoculars and rangefinders in residential areas, the observer should wear some kind of identifying clothing, to alleviate suspicions of residents.

Another fundamental assumption behind distance sampling is that birds are detected at their initial location. Buckland (2006) recommends using a snapshot approach; however, Fuller et al. (2009) found urban species were well

**Table 3.** Ranked densities of eight urban bird species calculated in three ways: strip transects, point counts with a 50-m radius, and point counts using distance sampling. Where two species had the same rank the average value is given for both.

| | Bush fragment habitat | | | Residential2 habitat | | |
|---|---|---|---|---|---|---|
| | D strip | D point | D point distance | D strip | D point | D point distance |
| House sparrow | 7 | 4.5 | 4 | 1 | 1 | 2 |
| Blackbird | 2 | 2 | 2 | 4 | 4 | 4 |
| Song thrush | 8 | 7 | 7 | 5 | 6 | 6 |
| Starling | 6 | 6 | 6 | 3 | 3 | 3 |
| Silvereye | 1 | 1 | 1 | 2 | 2 | 1 |
| Fantail | 5 | 8 | 8 | 7 | 7 | 7 |
| Bellbird | 3 | 3 | 3 | 6 | 5 | 5 |
| Grey warbler | 4 | 4.5 | 5 | 8 | 8 | 8 |

habituated to human presence and moved little in response to observers.

### Influence of counting technique on abundance estimates of birds in Dunedin

Precise estimates of population size are necessary in order to track changes due to management actions or in response to over-harvest, loss of habitat and other threats (Sutherland 1996). Population size is used in models that evaluate the viability of populations (Morris & Doak 2002; van Heezik et al. 2010) and change in population size is an important criterion in the IUCN Red List classification scheme (IUCN 2001; Buckland et al. 2008). Population estimates in Sheffield, UK, identified some species of wider conservation concern existing at high densities within the city (Fuller et al. 2009). In this study, densities obtained using strip transects and point counts with a fixed radius were seldom greater than half of the density estimated using distance sampling.

Relatively high coefficients of variation (>20%) for some species in one or both habitats reflect low numbers of detections and indicate more sampling effort is necessary to obtain counts with greater precision for each habitat type. We also probably introduced variation into the estimates by pooling counts carried out at the end of spring and beginning of summer, and in autumn. Nevertheless the precision of the distance-based estimates was always considerably better than those of the estimates based on the two other methods.

### Influence of counting techniques on relative abundances of bird species

The ability of index counts to produce reliable information has been debated for some time (Rosenstock et al. 2002; Bart et al. 2004; Moore & Kendall 2004; Johnson 2008). While standardised sampling protocols reduce the influence of factors that affect detectability, such as environmental variables, observer performance, topography, vegetation characteristics and the physical and behavioural attributes of the birds, the assumption of constant detectability cannot usually be met (reviewed in Rosenstock et al. 2002). However, index counts can still be useful monitoring tools as long as variations in detectability are substantially less than the variation in population size one wishes to detect (Johnson 2008). While the counts in this study were standardised only to a certain extent, abundance rankings of the top eight species in bush fragments did not vary much according to the counting method used (Table 3), with identical rankings for the top three species (silvereye, blackbird, bellbird). Fantails ranked as relatively more abundant using strip as opposed to point counts, possibly because they are more likely to be attracted to an observer who is moving through vegetation and creating foraging opportunities. Strip counts of fantails in bush habitat are therefore likely to result in overestimates of abundance. Conversely, detectability of house sparrows was lower during strip counts, resulting in an underestimate. Strip counts were carried out in a different year to the point counts, and these differences could also reflect inter-annual trends in population density of these species.

In residential habitat differences in rankings were small, suggesting that unless abundances are required, it may not be necessary to model detectability to obtain reasonably reliable representations of relative abundances in suburban habitat. Differences in rankings of silvereyes and house sparrows (Table 3) probably reflected behavioural differences. House sparrows are very tolerant of human disturbance and are closely associated with buildings, whereas silvereyes are abundant but are associated primarily with vegetation and are less tolerant of human presence.

### Factors influencing detectability in an urban landscape

The Dunedin urban counts did not reveal habitat-related differences in detectability for the majority of modelled species (except starling), and since rankings of relative abundance were not hugely different to those derived from distance estimation, well-standardised index counts may reliably reflect changes in absolute abundance for most species. Habitat-related differences may emerge in larger cities where residential areas vary more in terms of the density of housing and amount of vegetation, although Fuller et al. (2009) found little variation in detectability with the degree of urbanisation in Sheffield, UK (a much larger city), and used global detection functions across habitats and seasons.

The inclusion of covariates when modelling detection can reduce the variance of the density estimate (Thomas et al. 2009) as well as identify factors influencing detectability. The covariates 'observer' and 'seen/heard' improved the precision of estimates for five species. Given that observers had similar skills, the significance of this covariate could reflect idiosyncrasies between observers (training does not always remove observer effects; Alldredge et al. 2008), but may also reflect temporal variation in the data since three observers counted in November and December and only one in March and April. Starling observations were almost exclusively visual (only 6% observations were aural), so this covariate was unlikely to affect detectability in this species.

## Conclusions

The most striking difference between the counting methods was estimated population size. Given that knowledge of population size is important in population modelling and when evaluating conservation status, distance sampling is a valuable tool in urban areas that can be achieved by trained observers without a large increase in time and effort.

One of the criticisms levelled against distance sampling is that it does not apply well to extensive multi-species surveys (Johnson 2008), because density estimates can only be calculated for the most abundant species. Van Rensberg et al. (2009) could model detectability for only 16 of the 92 species recorded on their surveys, Fuller et al. (2009) only 13 out of 68, and in Dunedin only 8 out of 34, although more points would result in more detections. Species of most conservation interest may often be the rarer ones. The use of surrogate species of similar size and with apparently comparable detection characteristics has been advocated by Buckland et al. (2001) for species with too few detections. Fuller et al. (2009) applied this to a large proportion (45/55) of the species for which they calculated population estimates in Sheffield. However, this approach should be applied with caution; in this study the detection functions for the two species one might expect to be most similar in detection characteristics (blackbird and song thrush) were truncated at different values, and while the blackbird function was improved by both covariates, the song thrush function was improved only by one covariate (seen/heard).

The human element should not be underestimated when conducting urban bird counts. Permission for access must be obtained for all points that fall within private property, and given that a large portion of urban space in Dunedin (36%; Mathieu et al. 2007) and in larger cities (21.8–26.8% in Belfast, Edinburgh, Sheffield, Leicester, Oxford and Cardiff; Gaston et al. 2004; Loram et al. 2007) is comprised of private gardens, this involves a lot of door-knocking. The efficiency with which repeat counts can be carried out will depend on agreed arrangements for access to properties on multiple occasions without having to seek permission each time. Granting access to private property can be interpreted by some property owners as a contract to participate in the research, and by others as an invitation to socialise. Time spent interacting with people can significantly reduce the number of points counted, reducing the number of detections and the precision of any estimates. In addition, the personality and demeanour of the observer making contact with property owners will influence their willingness to grant access.

Urban areas are the obvious prime locations for the application of citizen science; engaging the public in data collection can encourage a connection with nature, and also provide opportunities for data collection over a much larger scale and longer time frame than can be achieved through funded research (Cooper et al. 2007; Silvertown 2009). If citizen-science-based counts can be sufficiently standardised, then they may produce data that will detect large-scale trends. However, standardisation can be difficult, and ideally such counts should be supplemented by distance-based counts to reveal population trends of common species, which can be useful indicators of changes in characteristics of urban landscapes (Shaw et al. 2008).

A feasible alternative using the general public and yielding useful information on trends in geographic distributions of even rare species across different urban habitats over time could be estimating occupancy, or the proportion of area occupied by a species (MacKenzie & Nichols 2004; MacLeod et al. 2012). Issues of detectability in occupancy modelling may be more easily addressed than for abundance modelling, and occupancy methods allow for unequal sampling effort and can incorporate covariate information (MacKenzie & Nicholls 2004). However, occupancy data would not provide the abundance data necessary for population modelling. We believe that the logistic and analytical demands of techniques that account for variable detectability when estimating abundance should not be seen as a barrier to their application when robust estimates of population size are needed to track the status of birds in urban areas.

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