CHAPTER SIXTEEN

Interactions between People and Birds in Urban Landscapes

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Abstract. A large body of work over the past few decades has revealed the manifestly dramatic impacts of urbanization on species' distributions and ecologies, many of which result from gross changes in land use and configuration. Less well understood are the rather more direct interactions between people and biodiversity in the urban arena. While there is a general concern that urbanization impoverishes human contact with nature, daily interaction with biodiversity in urban greenspaces and the widespread provision of food and nesting resources for wildlife form a part of many city-dwellers' experience. Using data from the UK, we show that supplementary resource provision aimed explicitly at enhancing avian populations can result in high levels of additional foraging and nesting opportunities, particularly in urban areas. However, our data also indicate that levels of such resource provision are strongly positively correlated with human population density at a regional scale, and within a large city. The proportion of households participating in bird feeding depends on social and economic features of the human population, suggesting that strong covariation between human and ecological communities will result. Indeed, we demonstrate that the abundances of some urban-adapted bird species are positively related to the density of feeding stations across the urban landscape, although such relationships were not apparent for other species that commonly use garden feeding stations. It has been suggested that interactions with nature, such as feeding birds, could have beneficial consequences for human health. A better understanding of this potential feedback is required.

Key Words: bird feeding, housing density, private gardens, socioeconomics, urban ecology.

The provision of feeding and nesting resources for birds is a popular activity across much of the world, particularly in industrialized nations. Between one-fifth and one-third of households in Europe, North America, and Australia provide supplementary food for wild birds (Clergeau et al. 1997, Rollinson et al. 2003, Lepczyk et al. 2004), and in the United States alone, 52 million people frequently feed garden birds (U.S. Fish and Wildlife Service

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2001). Surprisingly few studies have considered the role of gardens in supporting biodiversity (but see Savard et al. 2000; Beebee 2001; Thompson et al. 2003; Gaston et al. 2005a, 2005b; Daniels and Kirkpatrick 2006; Smith et al. 2006) or the impact of supplementary resources provisioned within gardens.

SPATIAL PATTERNS IN PROVISION OF RESOURCES FOR BIRDS

Significant sums of money are spent annually on deliberate resource provision for wild birds, and a supply industry has emerged, frequently importing feed from those tropical countries where much of it is grown. CJ WildBird Foods, Europe's largest wild bird food supplier, currently employs more than 150 staff and generated sales worth £20 million (US$39 million) in 2005/06 (http://www.birdfood.co.uk). Total annual expenditure on outdoor feeding of birds in the UK has recently been estimated at £200 million (US$390 million; British Trust for Ornithology 2006), while in the U.S. $3.5 billion is spent annually on bird food and feeding equipment (U.S. Fish and Wildlife Service 2001). International trade supplies a global market in specialty bird seed. For example, niger (*Guizotia abyssinica*) is grown mainly in India [22,609 tons (t) imported to the U.S. for bird food in 2003], Ethiopia (18,290 t), and Myanmar (7,043 t; Lin 2005).

The results of this deliberate resource provision to birds depend on its distribution across the landscape. A recent study in southeastern Michigan, USA, found that while the proportion of landowners providing food for birds did not vary among rural, suburban, and urban landscapes, the density of bird feeders per land parcel was significantly higher in urban than in rural and suburban areas (Lepczyk et al. 2004), presumably driven by the smaller size of plots in urban landscapes. If the density of human settlement predicts the density of bird feeders across the landscape, we might expect resource provision to occur disproportionately in (1) more densely populated regions and (2) more densely populated neighborhoods within cities. However, this will depend on how the popularity of bird feeding varies in relation to human population density and socioeconomic factors. Here, we use data on bird feeding across England at a regional scale, as well as information on small-scale variation in the activity within a large city, to describe spatial variation in the proportion of people engaging in supplementary feeding, and how this variation translates into patterns in the spatial density of resource provision.

DRIVERS OF BIRD-FEEDING ACTIVITY

While providing a significant resource base, the provision of food and nesting sites for birds also represents an opportunity for interaction between people and nature, and it occurs close to where people live and work on a daily basis (Miller and Hobbs 2002). Experiences of nature lead to a variety of measurable benefits, at both individual and societal levels (Vandruff et al. 1995, Mabey 1999, Irvine and Warber 2002, de Vries et al. 2003, Maller et al. 2005). For example, the presence of urban open spaces with trees and grass increased social interaction among neighbors, promoted a sense of community, and reduced crime in inner-city low-income housing areas of Chicago (Kuo et al. 1998, Kuo and Sullivan 2001), and the psychological benefits derived by visitors to urban greenspaces in Sheffield, UK, increased with plant species richness at the sites (Fuller et al. 2007). Given that a large proportion of the human population lives in cities, most of these human-nature interactions will inevitably focus on those species occurring in urban environments. However, surprisingly little is known about the drivers and consequences of these interactions in cities.

Levels of bird feeding and other forms of wildlife gardening vary enormously across the human population (Lepczyk et al. 2002, 2004; Gaston et al. 2007). Landowners participating in bird-feeding activity in southeastern Michigan tended to be older, were more likely to be women, and had achieved higher educational qualifications than those not participating (Lepczyk et al. 2004). Bird feeding was not related to the number of dwelling occupants, their occupation, or dwelling size as measured by floor area. Additional factors that might influence the likelihood of engaging in bird-feeding activity include economic and perceptual considerations, social context and garden size, interest in and knowledge about wildlife, and the amount of time that household members have available. As such, the level of participation in bird feeding is likely to vary consistently among different kinds of human communities, which themselves show complex patterns of spatial organization across urban landscapes (Harris et al. 2005).

Here, we investigate three possible socioeconomic drivers of bird-feeding activity: household income, age of dwelling occupants, and number of people composing the household, at both national and citywide scales.

ARE BIRD DENSITIES ASSOCIATED WITH LEVELS OF BIRD FEEDING?

Supplementary feeding clearly has the potential to improve the condition and increase the probability of survival of individual birds. Black-capped Chickadees (*Parus atricapillus*) with access to supplementary food during the winter months had greater body mass and higher overwinter survival rates than birds without such access (Brittingham and Temple 1988), and supplementary feeding improved nutritional condition as measured by feather growth rates in four North American bark-foraging species (Grubb and Cimprich 1990). Other studies have identified positive associations between urbanization and population density of supplementary feeding species (Jokimäki and Suhonen 1998) and positive effects of supplementary feeding on winter survival (van Balen 1980, Orell 1989).

Despite these specific examples, whether provision of food for birds in gardens can translate into higher population densities in general remains an open question. Given the popularity of bird feeding across much of the developed world, and the fact that bird feeders can reach very high densities in the landscape, one might expect population densities of those species best able to exploit the supplementary food to be positively correlated with levels of resource input at a landscape scale.

In this study we test this idea by relating the population density of six urban-adapted species to levels of supplementary bird-feeding activity across a large city. The six species were identified in a recent study as the most highly urbanized of the British avifauna (Cannon 2005), and they vary in their dietary requirements, specifically in the proportion of grains included in the diet. For comparison, we also present data for the Winter Wren (*Troglodytes troglodytes*), an insectivore that does not commonly take supplementary food in urban gardens, yet is found at reasonably high densities within urban environments. There is no *a priori* reason to assume that the density of this species will depend directly on provision of supplementary food.

In sum, the aims of this paper are threefold. First, we describe spatial patterns in bird-feeding activity and how this translates into resource availability on the ground, at both national and citywide scales. Second, we investigate variation in bird-feeding activity and resource availability in relation to housing density and human socioeconomic drivers, also at national and citywide scales. Third, we assess whether densities of selected bird species are associated with levels of supplementary resource provision across the urban landscape.

METHODS

This study was carried out at two spatial scales, first using data at the resolution of counties across the whole of England to characterize regional variation in bird-feeding activity, and second via a grid-based analysis of bird-feeding activity and the distributions of birds across the city of Sheffield, a large inland city in northern England. With a human population of ca. 513,000, Sheffield is the fifth largest municipality in the UK, and the ninth largest urban area (Office for National Statistics 2001, Beer 2005). The urban area of Sheffield was defined as the set of 1 km $\times$ 1 km squares within the administrative boundary of the city in which coverage by urban development exceeded 25% (Gaston et al. 2005b). This resulted in a Sheffield study area of 160 km^2.

Bird Feeding and Socioeconomic Variables

To investigate nationwide variation in bird feeding activity, we used data from the Survey of English Housing (SEH), an annual government-funded survey of ca. 30,000 households across England. The 2001/02 survey (NCSR and DETR 2004) included a small set of questions investigating participation in wildlife gardening. Respondents were asked whether they encourage wildlife in their garden, patio, yard, balcony, or roof terrace by (1) feeding the birds/providing bird feeders, bird tables, or birdbaths and/or (2) putting up nest boxes. Respondents were also asked to give annual gross total household income, age of the household reference person (the person in whose name the house is registered, or with highest income if the house is jointly registered, or the eldest occupant if incomes are equal), and the number of people living in the house.

For reasons of confidentiality, questionnaire data were only available aggregated at the scale of the local authority. Because this resulted in small sample sizes within some local authorities, for the present analysis we used data aggregated at county scale. There were 46 counties recognized in England in 2001, although the Isle of Wight, with only 50 respondents, was excluded from all analyses. We calculated *Proportion Feeding* (the number of households at which birds were fed in each county divided by the number of households in that county included in the survey) and *Feeder Density* (*Proportion Feeding* multiplied by the number of households in the county, derived from the 2001 UK Census; Office for National Statistics 2001). Household density in each county was calculated by dividing the number of households in each county by county area. Household income, household age (age of household reference person), and household size (number of people comprising the household) were expressed as mean values for all responding households in each county.

We sent a postal questionnaire to 2,421 randomly chosen residential addresses in three ca. 1-km^2 study sites in Sheffield, selected to capture a variety of urban forms and neighborhood types: a city center area, a low-density outer suburban area, and a high-density residential area situated between the center and suburbs (see Gaston et al. 2007 for further details). Of the questionnaires sent, 47.3% were returned (32.7%, 49%, and 61% in the inner, middle, and outer study areas, respectively). Respondents were asked to indicate whether they provide (1) food and/or (2) nest boxes for birds in their garden. The questionnaire contained 50 questions relating to a wider project on urban sustainability (Jones 2002) and thus the questions on bird feeding and nest box provision formed only a small part, a structure that minimized bias arising from the level of interest of people in wildlife and/or gardening influencing the likelihood of returning the form.

We used a national commercial classification of neighborhood types (Mosaic UK) developed by Experian's Business Strategies Division (see www.business-strategies.co.uk) to classify each household into one of 61 neighborhood types. This classification is based on a hierarchical cluster analysis across more than 400 social, economic, and demographic variables (Farr and Webber 2001, Harris et al. 2005). The cluster analysis identified 61 distinct neighborhood types, of which 47 occurred within urban Sheffield. Each household within the study area was assigned to one of these of neighborhood types (note that neighborhood types are not explicit spatial units—although the types tend to cluster spatially, adjoining houses can be assigned to different neighborhood types). As part of a national questionnaire sent to over 500,000 households by Experian, respondents were asked to indicate whether they provide food for birds on a regular basis. For each household in Sheffield, we used its neighborhood type to assign a probability that bird feeding was occurring at the household. For each 250 m × 250 m grid cell across the city, *Proportion Feeding* was the average of this probability across all houses in the grid cell, and thus depended on the relative numbers of households of different neighborhood types. *Feeder Density* was calculated for each grid cell by multiplying *Proportion Feeding* by the number of households. Grid cells with no houses ($n = 498$) were excluded from all analyses, apart from figures that report Sheffield-wide *Feeder Density*, because zero values need to be included in that instance.

Data associated with Experian's classification of neighborhood types were similarly used to characterize variation by grid cell in socioeconomic variables. Household income was expressed as the percentage of households where gross income exceeds £50,000 (US$97,000), household age was expressed as the percentage of householders over the age of 55 years, and household size was expressed as the percentage of households in each grid cell comprising more than two people.

Abundance of Selected Bird Species

Each 1-km square in the urban area of Sheffield (the set of 160 such squares within the urban area; Gaston et al. 2005b) was split into four 500 × 500 m cells, and a sampling point was randomly located within each, resulting in 640 points. Between 24 May and 1 July 2005, a point transect (a transect of zero length; Buckland et al. 2001) of 5 min duration was conducted at each survey point, or at the nearest accessible location within the same habitat type. In 318 (49.7%) of the 640 cases, the exact randomly chosen point location was accessible. Where it was not, the observer stood at the nearest accessible point in the same habitat type. The identity and distance from the observer of each detected bird were noted. Birds in flight were excluded from all analyses.

Distances were estimated in the field in 14 bands (0–4.9 m, 5–9.9 m, 10–14.9 m, 15–19.9 m, 20–24.9 m, 25–29.9 m, 30–39.9 m, 40–49.9 m, 50–59.9 m, 60–69.9 m, 70–79.9 m, 80–89.9 m, 90–99.9 m, 100 m+). Because the probability of detecting birds declined with increasing distance from the observer, data were analyzed using the Program Distance software (ver. 5, St. Andrews, Scotland; Thomas et al. 2005). Detection functions were calculated separately by species. Pointwise density estimates were calculated by applying the detection function for each species to the distance data from each survey point. Land cover characteristics within a 100-m buffer around each survey point were determined in a GIS, based on the classification of surface cover polygons by Ordnance Survey within the MasterMap digital cartographic data set at a 1:1,250 scale (Murray and Shiell 2003). Cover by greenspace in each 100-m buffer was determined by summing the area of all polygons classified as natural surface or garden in the MasterMap data.

Density data were extracted for the six species identified in a recent analysis as having the strongest positive association between distribution and urbanization in the UK (Blackbird, *Turdus merula*; Blue Tit, *Cyanistes caeruleus*; Great Tit, *Parus major*; House Sparrow, *Passer domesticus*; Starling, *Sturnus vulgaris*; and Common Wood-Pigeon, *Columba palumbus*; Cannon 2005). All species except Common Wood-Pigeon regularly take supplementary food from garden feeding stations (Cramp et al. 1977–1994). The Winter Wren was included as a comparator, as it is well adapted to urban conditions but is a strict insectivore, rarely taking artificially provided food. Given that bird-feeding data were available at the level of neighborhood type, relationships between bird feeding and bird abundance were investigated at this level. Bird density was the average from the survey points falling within each of the neighborhood types. Neighborhood types containing fewer than three bird survey points were excluded from analyses, resulting in a set of 35 neighborhood types for assessing relationships between *Feeder Density* and bird density.

Statistical Approach

We constructed mixed models in SAS (ver. 9.1, SAS Institute, Cary, NC). All variables were normally distributed or $\log_{10}$-transformed to achieve normality. No spatial autocorrelation was apparent in the England-wide data set assessed using GeoDA (release 0.95i, Spatial Analysis Laboratory, University of Illinois) with first order queen contiguity-based spatial weights for counties sharing a common boundary. However, there was a strong spatial signal in the Sheffield data set, so analyses at the citywide scale implement spatial correlation models that fit a spatial covariance matrix to the data and use this to adjust test statistics accordingly (Littell et al. 1996). The choice of the exponential over other spatial covariance structures was based on inspection of semi-variograms of independent error model residuals. In all cases, backward stepwise model-building procedures were employed to determine minimum adequate models. In the case of using socioeconomic variables to predict bird feeding, separate models were constructed for each predictor, together with its square term (household income, household age, household size, and density of households). In models predicting bird density, greenspace (the proportion of vegetated surface within 100 m of the bird survey point) and *Feeder Density* were entered initially into the model. Estimates of variance explained (i.e., r^2 values) cannot be derived from spatial models, but are provided for independent error models. The fit of alternative spatial models was compared using Akaike's Information Criterion (AIC). To show the relationships graphically, data points at county scale are presented individually, and grid cell data from Sheffield are split into equal interval groups, based on transformed values where necessary.

RESULTS

Spatial Patterns in Bird Feeding and Nest Box Provision

Household density showed strong spatial variation, both at nationwide (Fig. 16.1a) and citywide (Fig. 16.2a) scales, respectively reflecting the general pattern of urbanization across the country and variation in the intensity of urbanization within the city limits of Sheffield. Across England, 39.1% of respondents reported the presence of bird-feeding equipment and/or provided supplementary food for birds in the outside space associated with their property, and 18.1% provided one or more nest boxes. Questionnaire data from the three study areas in Sheffield indicated that 51.7% of respondents provided food for birds and 16.3% provided at least one nest box.

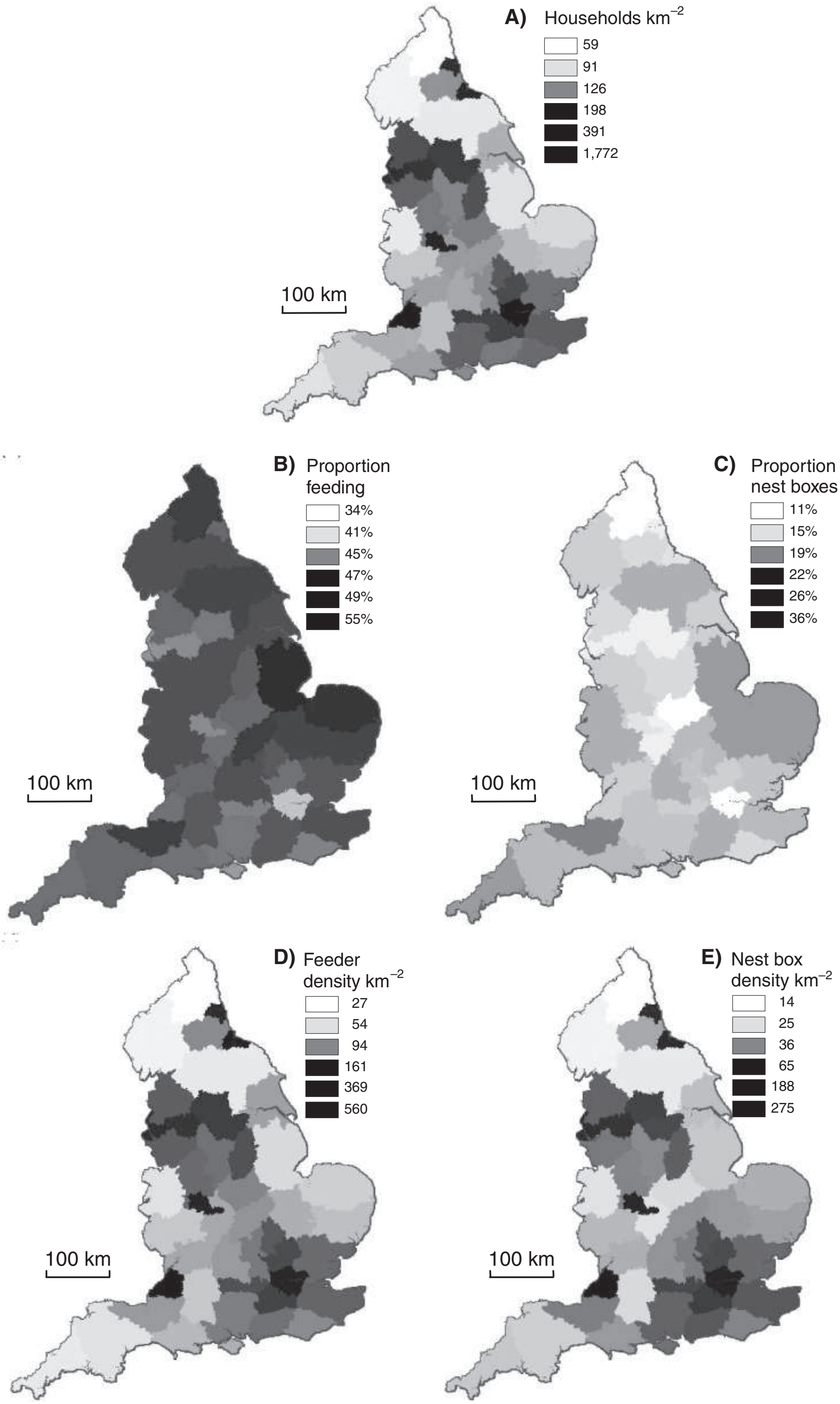

Figure 16.1. Maps of English counties indicating (a) the density of households derived from the 2001 UK census, (b) the proportion of respondents to the Survey of English Housing (SEH) reporting the presence of bird-feeding equipment and/or providing supplementary food for birds in the outside space associated with their property, (c) the proportion of SEH respondents reporting the presence of one or more nest boxes in the outside space associated with their property, and the density of (d) locations at which birds are fed, and (e) locations at which nest boxes are provided. Legends indicate the top of the range of values associated with each of six shades determined using the Jenks natural break classification.

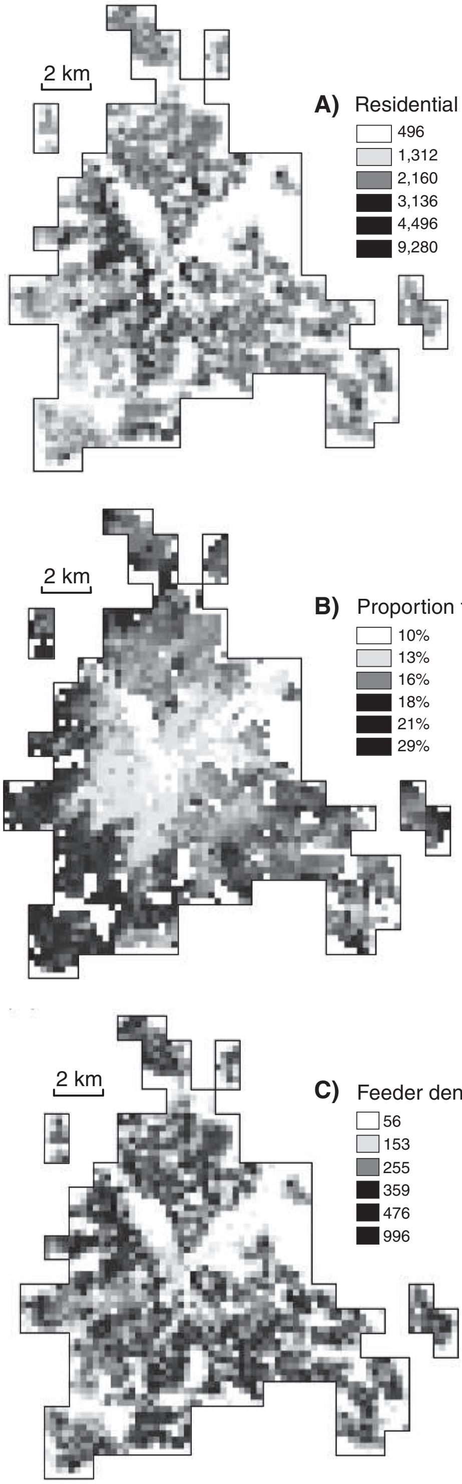

Figure 16.2. Map of urban Sheffield divided into 250 × 250-m grid cells indicating (a) the density of households derived from a count of residential addresses, (b) the estimated proportion of householders who feed birds, based on the numbers of households from different socioeconomic groups and questionnaire data stratified by socioeconomic group, (c) the density of locations at which birds are fed, obtained by multiplying (a) and (b). Legends indicate mid-point of the range of values associated with each of six shades determined using Jenks natural break classification.

The proportions of households providing food and nest boxes for birds showed patterns approximately inverse to that of household density across England as a whole, being higher in less densely populated counties (Fig. 16.1b, c). For bird feeding a similar pattern was evident within the city of Sheffield, where the activity clearly declined in prevalence toward the densely populated inner suburbs and the city center (Fig. 16.2b).

Average feeder density by county across England varied between 14.8 and 559.7 km^{-2} (mean = 107.5), while in the 250 × 250 m grid cells across Sheffield, feeder density varied between zero and 995.9 km^{-2} (mean = 197.7). Average nest box density by county across England varied between 2.6 and 274.8 km^{-2} (mean = 47.3). The spatial patterns of the density of bird-feeding stations depended almost entirely on household density, being more or less independent of *Proportion Feeding*, such that *Feeder Density* tended to be higher in more densely populated areas both at nationwide (Fig. 16.1d) and citywide (Fig. 16.2c) scales. Patterns in *Proportion Feeding* and *Feeder Density* in relation to household density were, therefore, strikingly similar at nationwide and citywide scales. A similar pattern for nest box density was apparent at the nationwide scale (Fig. 16.1e).

Household Density, Socioeconomics, and Bird-feeding Activity

Taking the national data first, household density was by far the strongest predictor of both *Proportion Feeding* and *Feeder Density* (Fig. 16.3a, b; Table 16.1). *Proportion Feeding* declined as household density increased. However, the strong positive relationship between *Feeder Density* and the density of households at the scale of the county, and the absence of a significant squared household density term from this model (Table 16.1), indicate that housing density was much more important in determining the overall density of feeders across the landscape than the popularity of bird feeding. While the relationship between *Feeder Density* and household density is constrained to be at least positive triangular (*Feeder Density* cannot exceed household density; see Fig. 16.3b), the relationship is linear, with no cases of obviously low feeder densities in counties with high household densities, has a slope significantly lower than 1 ($b = 0.88$, 95% CI = 0.85–0.93), and does not decelerate. None of the socioeconomic variables were an important predictor of *Proportion Feeding* or *Feeder Density* (Fig. 16.3c–h; Table 16.1). Household age was negatively related to *Feeder Density* (Fig. 16.3f), and household size was related negatively to *Proportion Feeding* and positively to *Feeder Density* (Fig. 16.3g, h), although the explanatory power of all three relationships was low (Table 16.1).

At the citywide scale across Sheffield, spatial models revealed a hump-shaped relationship between housing density and *Proportion Feeding*, with *Proportion Feeding* declining sharply at high housing densities (Fig. 16.4a; Table 16.1). The model resulted in a strong positive relationship between household density and *Feeder Density* (Fig. 16.4b; Table 16.1). The form of the relationship is notable, with *Feeder Density* initially increasing rapidly with household density (slope of the linear household density term > 1; $b = 1.3$, 95% CI = 1.24–1.35). The squared household density term was negative, indicating a decelerating effect of household density on *Feeder Density*, such that at high household densities little change in *Feeder Density* was apparent (Fig. 16.4b; Table 16.1), presumably due to a combination of a smaller proportion of households having access to a garden and a decline in the popularity of bird feeding at high household densities.

In contrast to the England-wide data, all three socioeconomic variables were strong predictors of *Proportion Feeding* and *Feeder Density* across Sheffield. Household income had a positive accelerating relationship with *Proportion Feeding* (Fig. 16.4c; Table 16.1), but a negative accelerating relationship with *Feeder Density* (Fig. 16.4d; Table 16.1), presumably reflecting the tendency for higher income groups to live in lower-density neighborhoods. The age of householders and household size showed hump-shaped relationships with *Proportion Feeding* and *Feeder Density*, with both the popularity of bird feeding and the spatial density of the resource peaking at intermediate levels of household age and size (Fig. 16.4e–h, Table 16.1).

Bird Feeding and the Abundance of Selected Bird Species

Densities of three of the seven urban-adapted bird species in each of the 35 neighborhood types across urban Sheffield were positively related to the density of feeders (Fig. 16.5). These relationships remained significant when greenspace

TABLE 16.1

Results of single-predictor regression models using housing density and three socioeconomic variables to predict the proportion of households at which food for birds is provided and the spatial density of feeding sites (a) across 45 English counties and (b) across 250 × 250 m grid cells comprising urbanized Sheffield (using spatial models).

	Density of households			Household income			Household age			Household size		
	Linear	Square	r^2	Linear	Square	r^2	Linear	Square	r^2	Linear	Square	r^2
England												
Prop. feeding	33.2^{---}		0.44							6.5^{-}		0.13
Feeder density	$2,043^{+++}$		0.98				7.4^{--}		0.15	5.58^{+}		0.12
Sheffield												
Prop. feeding	96.36^{+++}	122.3^{---}		89.31^{+++}	31.33^{+++}		607^{+++}	273.1^{---}		277.8^{+++}	220^{---}	
Feeder density	$2,236.4^{+++}$	130.7^{---}		56.3^{---}	58.56^{---}		38.91^{+++}	22.74^{---}		172.6^{+++}	186^{---}	

NOTE: Each model includes the linear and square term for the predictor. Backward stepwise selection was used to remove nonsignificant terms from each model, and only terms significant in the final model are shown. r^2 values are provided for each final model for the national data, but cannot be computed for spatial models. Superscript symbols after F values indicate effect direction and significance level ($P < 0.05$, $P < 0.01$, $P < 0.001$ for one, two, and three symbols, respectively).

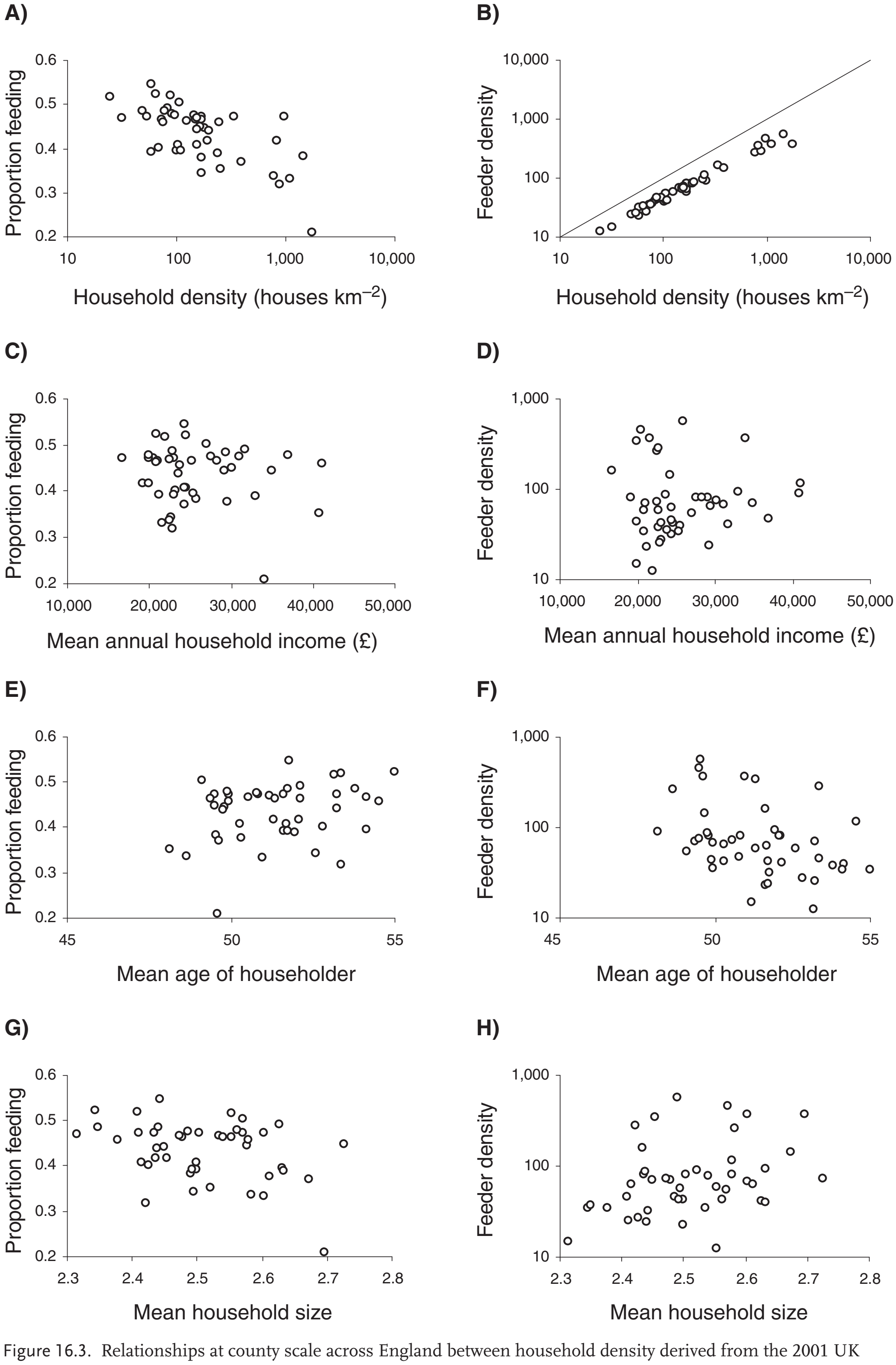

Figure 16.3. Relationships at county scale across England between household density derived from the 2001 UK census and (a) the proportion of respondents to the Survey of English Housing (SEH) reporting the presence of bird-feeding equipment and/or providing supplementary food for birds in the outside space associated with their property (*Proportion Feeding*), and (b) the density of such locations at which birds are fed (*Feeder Density*). Solid line indicates $y = x$. Also, the relationships between three socioeconomic variables derived from SEH responses and *Proportion Feeding* and *Feeder Density*—(c, d) mean gross annual household income, (e, f) mean age of the household reference person, and (g, h) household size, expressed as the mean number of occupants per household. Note that *Feeder Density* and household density are plotted on a log scale.

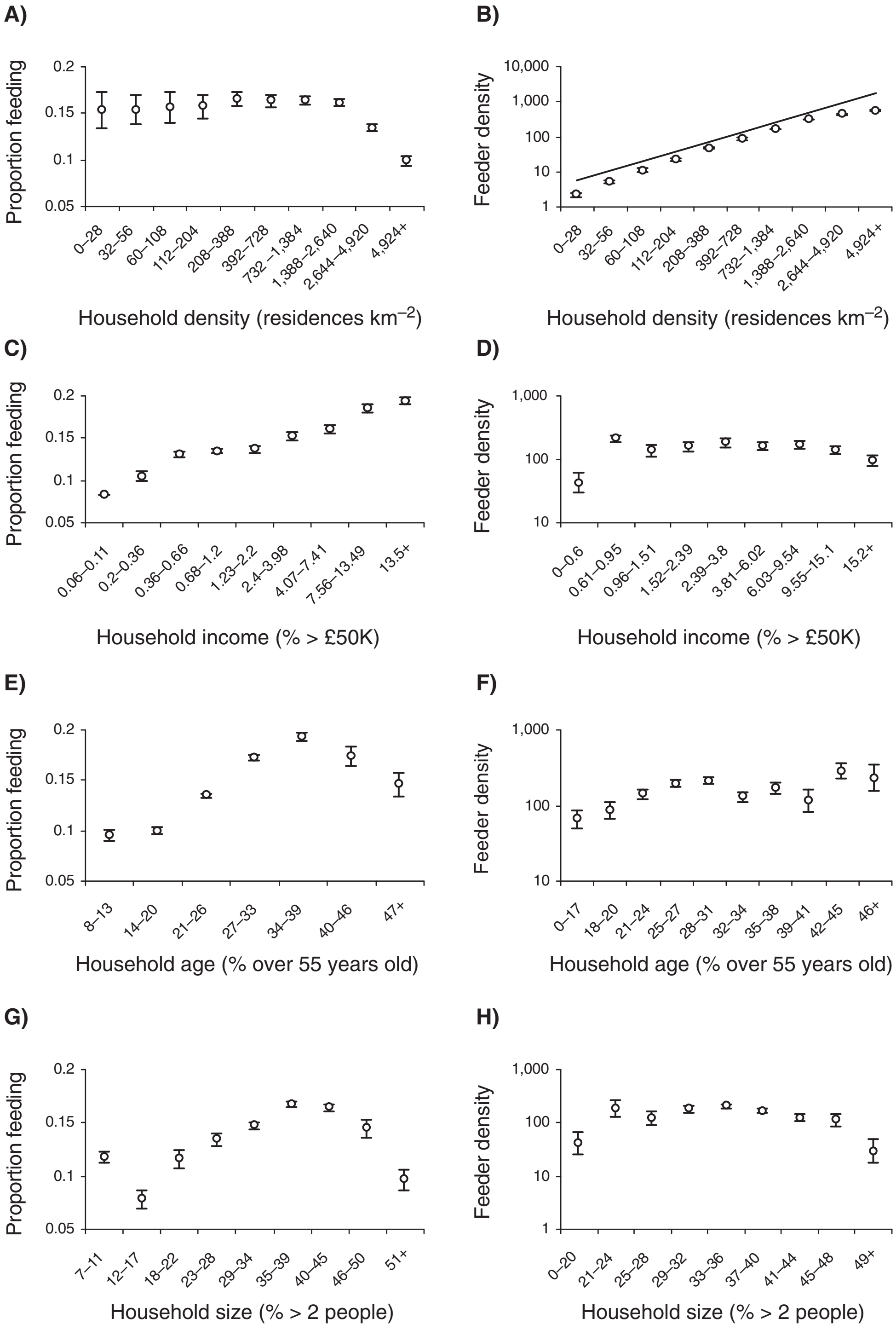

Figure 16.4. Relationships within Sheffield city at 250 × 250-m grid cell resolution between household density derived from counts of residential addresses and (a) the proportion of households in each grid cell providing supplementary food for birds in the outside space associated with their property (*Proportion Feeding*), and (b) the density of such locations at which birds are fed (*Feeder Density*). Solid line indicates $y = x$. Also, the relationships between three socioeconomic variables calculated using statistics by neighborhood type in the MOSAIC classification (see text) and *Proportion Feeding* and *Feeder Density*—(c, d) household income expressed as the percentage of households where gross income exceeds £50,000, (e, f) household age expressed as the percentage of householders over the age of 55 years, and (g, h) household size expressed as the percentage of households comprising more than two people. Note that *Feeder Density* and household density are plotted on a log scale.

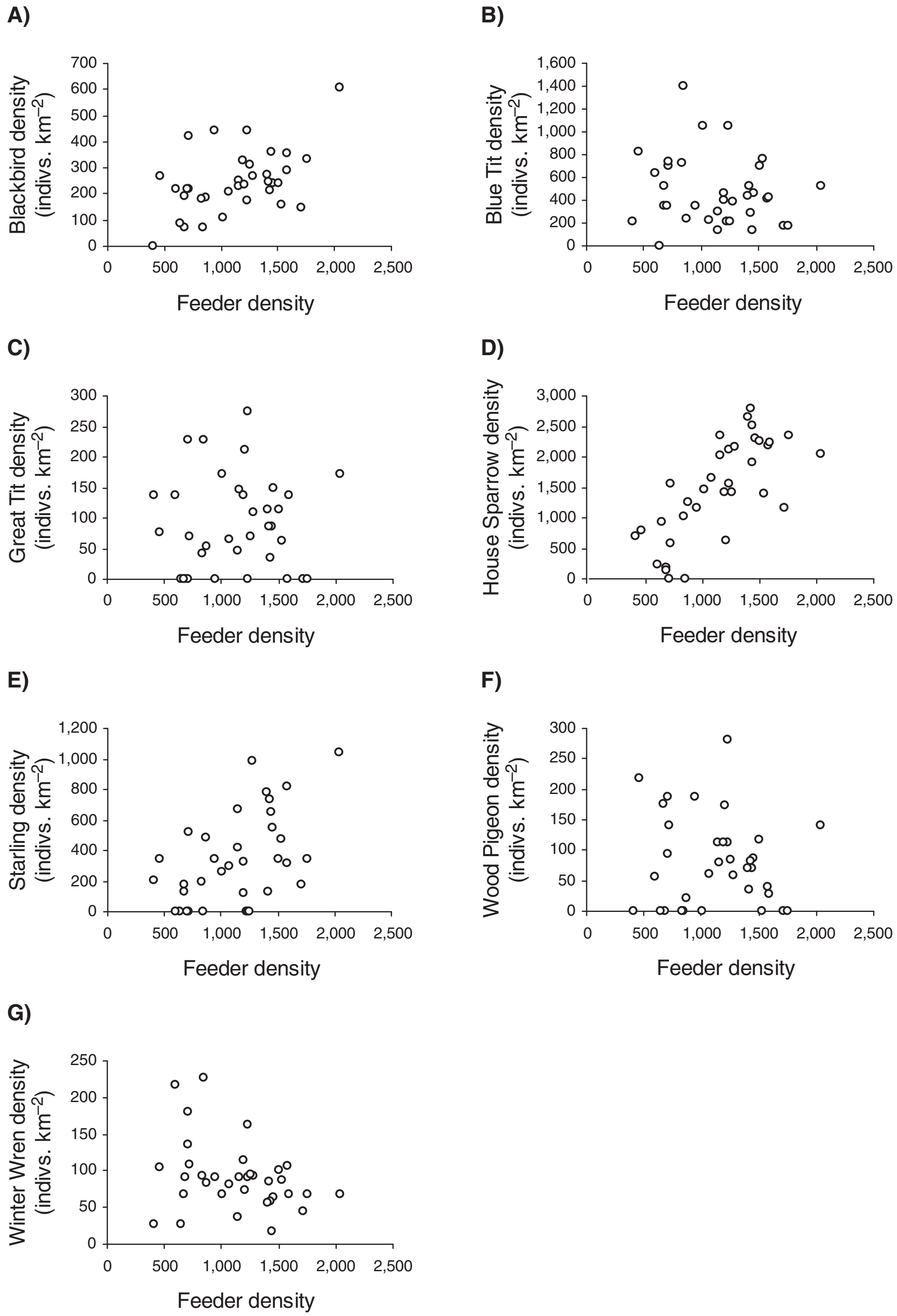

Figure 16.5. Relationship between *Feeder Density* (feeding stations km^{-2}) and species abundance in each of 35 neighborhood types across Sheffield. Species are (a) Blackbird, (b) Blue Tit, (c) Great Tit, (d) House Sparrow, (e) Starling, (f) Wood-Pigeon, and (g) a habitat-generalist insectivore, the Winter Wren. The relationships for Blackbird and Starling remain significant upon removal of the right-hand data point.

TABLE 16.2

Results of regression models using greenspace coverage and the density of feeding stations in 35 neighborhood types to predict the density of seven highly urbanized species within the city of Sheffield.

	Greenspace			Feeder density		
	β	F	r^2	β	F	r^2
Blackbird	0.14	10.07^{**}	0.23			
Blue Tit						
Great Tit						
House Sparrow	1,916.23	7.52^{*}	0.19	1.43	42.34^{***}	0.57
Starling				0.37	11.45^{**}	0.26
Common Wood Pigeon						
Winter Wren						

NOTE: Backward stepwise selection was used to remove nonsignificant terms from the full model, and only terms significant in the final model are shown. r^2 values are for the whole final model where there is only one predictor, and partial r^2 statistics where both predictors were retained in the final model. Superscript symbols after F values indicate significance level ($P < 0.05$, $P < 0.01$, $P < 0.001$ for one, two, and three symbols, respectively). β = model slope.

coverage was included in the model to account for variation in gross urban form (Table 16.2). The House Sparrow showed the strongest pattern, with a positive relationship with *Feeder Density*, explaining 57% of the variation in its abundance (Fig. 16.5d; Table 16.2). The abundances of Blackbird and Starling were also positively related to *Feeder Density*, which explained 23% and 26% of the variation in their numbers, respectively (Fig. 16.5a, e; Table 16.2). Densities of the remaining four species (Blue Tit, Great Tit, Common Wood-Pigeon, and Winter Wren) showed no significant relationship with greenspace or feeder density at the scale of the neighborhood (Fig. 16.5b, c, f, g; Table 16.2).

DISCUSSION

Extent of the Resource and Spatial Patterns of Bird Feeding

Our results confirm that the provision of food for birds is popular in the UK, with 39% of households across England engaging in the activity. We estimate an average feeder density across England of about 100 km^{-2}, and within Sheffield of about 200 km^{-2}. We are aware of no published estimates of the average amount of food for wild birds put out in individual gardens, and in particular how stocking scales up to a standing crop, so estimating the size of the resource base that this provision generates is not straightforward. Clearly, however, these densities of bird-feeding stations represent a large potential resource for birds, and one that is concentrated in more densely populated areas.

The resource base of supplementary food is unlikely to be static over time. Lepczyk et al. (2004) showed that the highest proportion of landowners feeding birds in southeastern Michigan occurred between December and March, with a decline through summer to autumn. Historically in the UK, feeding was mainly carried out in winter, in the belief that typical supplementary food types are unsuitable for fledglings and that adults could find all the natural food they needed during summer (Moss and Cottridge 1998). More recently, advice from the British Trust for Ornithology recommends that feeding be carried out year-round, with the additional provision of live food suggested during the summer months (Toms 2003), and a carryover effect has been demonstrated whereby winter-fed birds show increased productivity in the following breeding season (Robb et al. 2008). Much more work is required to document variation in the amount and types of food put out for wild birds in gardens, and how this varies temporally, both in the short term and over seasons (Jones and Reynolds 2008). A significant proportion of people feeding birds only do so on an infrequent basis (Gaston et al. 2007), so care is needed when interpreting data on bird feeding in terms of the amount of the resource available.

The provision of supplementary food and nesting sites for birds showed distinct spatial patterning, both at a regional scale across England and within Sheffield. The proportion of people providing resources for wild birds was generally negatively related to population density, both at the county and neighborhood scale, although in Sheffield the proportion feeding only declined noticeably at high household densities (Figs. 16.3a, 16.4a). However, because of marked variation in household density, the density of feeding stations depended much more closely on the density of human settlement than on the proportion of people engaged in supplementary resource provision. In practice, the link means that supplementary resources are being provided disproportionately in (1) more densely populated regions of the country and (2) more densely populated neighborhoods within cities. The pattern has obvious implications for the kinds of avian assemblages that will receive resource inputs and the kinds of environments in which these human-nature interactions are taking place.

The relationship between household density and the intensity of resource provision for birds indicates that the majority of these interactions between people and nature are occurring in highly urbanized areas. Urban sites are precisely the environments where enhanced contact with nature through gardens is likely to result in significant psychological, physical, and social benefits to the human population. The garden has long been considered an integral part of health and well-being (Gerlach-Spriggs et al. 1998). Access to a garden has been shown to reduce self-reported sensitivity to stress (Stigsdotter and Grahn 2004), while lack of access is associated with increased self-reported levels of depression and anxiety (Macintyre et al. 2003). While we are not aware of any studies that directly explore the contribution of wildlife to quality of life, a few studies do include insight into this question (Vandruff et al. 1995, Clergeau et al. 2001). The presence of wildlife has been cited as a part of planting and water gardening that make them enjoyable activities (Catanzaro and Ekanem 2004), and observing and feeding wildlife were found to predict neighborhood satisfaction (Frey 1981). However, any benefits to human well-being associated specifically with feeding wild birds remain unknown.

Socioeconomic Correlates of Bird Feeding

Three socioeconomic variables (household income, age of householders, and number of people comprising the household) were poor predictors of both the prevalence of bird-feeding activity across the human population and the resulting spatial density of bird-feeding stations at the national scale. Conversely, within Sheffield, the three variables were strongly related to both the prevalence of bird feeding and the spatial density of bird-feeding stations (Table 16.1; Fig. 16.3). The proportion of households feeding birds increased with household income, and showed hump-shaped relationships with both age of householders and number of people comprising the household. The density of bird-feeding stations across the urban landscape was negatively related to household income, but the hump-shaped relationships with household age and household size were retained (Table 16.1; Fig. 16.4). The differences in these relationships at the two scales suggest that local variation in socioeconomic status is much more important than regional differences in, for example, household income in determining the likelihood that a given household provides food for birds. By aggregating data at a county scale, important socioeconomic effects were averaged away. This contrast is important because it demonstrates the utility of fine-scale studies such as this one. Data at county scale are relatively easy to obtain, but they may be uninformative, as demonstrated here. However, it is important to note that such socioeconomic patterns might not be universal; our findings contrast with those of Lepczyk et al. (2004), who detected no influence of household size or wealth on levels of bird feeding in Michigan.

A positive local relationship between the proportion of households feeding birds and household income makes intuitive sense, yet it suggests that human socioeconomic deprivation is directly related to the quality of the experience that people have of nature. Although bird feeding can exclusively comprise throwing out kitchen scraps, a large proportion of people provide specialist feeds grown and purchased specifically for provision to wild birds and use specific equipment such as bird feeders and bird tables (Cowie and Hinsley

1988a, Moss and Cottridge 1998). In Cardiff, UK, 56% of questionnaire respondents fed birds daily or several times per week (Cowie and Hinsley 1988a). Such frequent replenishment of bird food carries a significant financial commitment, given that a standard birdseed mix currently retails at between approximately £1.00 (US$1.95) kg^{-1} and £1.50 (US$2.93) kg^{-1} depending on the quantity purchased (www.birdfood.co.uk).

The relationships between the prevalence of bird feeding and household age and size reveal additional variation across human society in the popularity of the activity. Given that public policy, at least in the UK, explicitly encourages wildlife-friendly garden management practices (DEFRA 2002), significant potential exists for directed interventions via public campaigns. The resultant levels of resource provision across the landscape imply that the status of avian populations, at least in urban areas, might be managed via such programs (Ilyichev et al. 1990, Fuller et al. 2008). Clergeau et al. (2001) showed that avian diversity was positively perceived by city dwellers in Rennes, France, and suggested that successful conservation of urban avifaunas will enhance human quality of life. Further work could profitably focus on how such socioeconomic variation relates to opportunity and motivation for, as well as the benefits of, bird feeding.

Bird Feeding and Bird Abundance across the Urban Landscape

We found significant relationships, all of which were positive, between the density of feeding stations and bird abundance in urban environments for Blackbird, House Sparrow, and Starling. All three species regularly take supplementary food in gardens (Cramp et al. 1977–1994). The relationship was strongest for the House Sparrow, a species native in the UK and in severe decline across the country (Robinson et al. 2005). Steep declines in urban House Sparrows in the past have been associated with declines in winter food supply, when the replacement of horse-drawn vehicles with motor vehicles led to a sharp drop in grain availability (Bergtold 1921). More recently, building on brownfield sites leading to loss of sites supporting ruderal plants has been proposed as a factor reducing food availability (Crick et al. 2002). All this suggests that urban House Sparrow populations may be food limited, and the positive relationship with the density of bird-feeding stations raises the intriguing possibility that the population may be responding to the availability of supplementary food at the neighborhood scale within Sheffield.

The Winter Wren is insectivorous (Cramp et al. 1977–1994) and, as such, there is no *a priori* expectation that it will respond directly to bird feeding. The absence of a relationship between Winter Wren density and feeder density suggests that the relationships for Blackbird, House Sparrow, and Starling were not being driven simply by variation in some other component of the urban landscape. Somewhat surprisingly, though, feeder density did not predict the abundance of Blue Tit and Great Tit, both species that feed commonly on garden bird feeders, including during the breeding season (Cowie and Hinsley 1988b). However, populations of both of these hole-nesting species are relatively stable in urban environments (Cannon et al. 2005), and there is no reason to suppose that their populations are especially food limited within UK cities. Large-scale experiments that can generate meaningful variation in supplementary food availability within urban areas are needed to isolate the effects of garden bird feeding on avian abundance.

Only 10 of 76 nest boxes provided for Great Tits and Blue Tits in a recent study in Sheffield were occupied, suggesting that nest sites were unlikely to be a limiting resource for those species (Cannon 2005). Conversely, for House Sparrows in the UK, older houses appear to be important for nesting sites, suggesting some nest site availability limitation and that newer developments may be less suitable (Wotton et al. 2002, Mason 2006). Individual species will doubtless respond to food and nest site availability in different ways, and detailed studies will be required to understand how these factors interact to determine population densities.

CONCLUSION

Our data indicate that garden bird feeding is a popular activity in England and within a typical large city. The level of resource provision across the landscape is strongly influenced by human population density, being higher in more densely populated areas. Garden bird feeding has strong socioeconomic predictors that are scale dependent, and is positively associated with the densities of some urban-adapted bird species. Garden bird feeding therefore represents a large resource input that, coupled with other forms of management, might be used as a conservation option in urban environments. Promoting interaction with garden birds might also lead to increased human engagement with nature and potential for a positive effect on quality of life, particularly within urban environments, where arguably such engagement is most needed.

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