Bird diversity indicates ecological value in urban home prices

Michael C. Farmer · Mark C. Wallace · Michael Shiroya

Abstract It is known that public greenspaces contribute positively to urban home prices; yet urban ecologists also have known that not all greenspaces are equally valuable. Also some ecologically valuable space appears on private residences, not only public spaces. This work examines directly whether using a variable derived from bird species richness and relative abundance adds new information regarding ecological value and if high values of that variable significantly improve urban housing prices. We collected information on approximately 368 home sales in Lubbock, TX from 2008 to 2009 from the Multiple Listing Service: Sale Price, Square Footage, Lot Size and Age in 17 neighborhoods identified by the Lubbock Realtor Association. We conducted bird counts in the vicinity of each home sale and recorded both the total numbers of birds and the number of bird species identified in a particular class—less ubiquitous bird species. Finally, we used GIS to record the percentage of tree cover in the immediate area surrounding each sale. We constructed a predictive model for a bird relative abundance and species richness variable (Bird) from AIC$_c$ statistics. Home price for each sale then was regressed against the *predicted* value of 'Bird' from the selected model and regressed against home price along with other attributes from the Multiple Listing Service. The predicted value for Bird finds that the addition of another desirable, less ubiquitous bird species improves mean home price by $32,028, likely due to the human created landscapes on private properties immediately surrounding a home sale. Curiously, the presence of a nearby park neither explained variation in the ecological indicator nor contributed to home price elevation. This deliberately simple and inexpensive indicator helped to direct attention to the composition of local landscapes in specific areas to assess joint ecological and economic gains rather than presume *a priori* that open greenspace jointly satisfies these dual objectives.

Keywords Hedonic price analysis · Greenscape · Urban wildlife

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Introduction

A problem urban ecologists and 'new urbanists' often face is the difficult task of completing ecological-environmental evaluations in a timely and cost effective fashion when land use decisions operate under short timelines and modest budgets. If we add a need by decision-makers for follow-up ecological information with local zoning and planning boards, this places the urban ecologist and ecological economist with a conundrum. Communities slated for new development or redevelopment seek permits and zoning rules in a relatively rapid policy design, decision and development timetable. The time to conduct a full wildlife population assessment or even a landscape inventory is often unavailable.

Currently in these environments certain defaults frequently prevail. For example, it is common to designate any greenspace as ecologically beneficial, environmentally low foot-print and beneficial to economic development. The mantra can be invoked to exculp policy-makers from closer ecological examinations. Perhaps this is because those same defaults have been proven to benefit housing values with little need for nuanced ecological assessment (Cavailhés et al. 2007; Jim and Chen 2006; Wolters 2001). Recently studies are beginning to show that some people pay more to reside near amenities that show more nuanced urban landscapes or greenscapes (Cho, et al. 2008); for example, homes with highly educated owners may prefer quality habitat directly (Bark et al. 2009).

From an ecological perspective, the type and the nature of urban greenspaces yield very different outcomes (Pickett et al. 2001; Mansfield et al. 2005; Sandström et al. 2006). Greenspace can be simple open space such as a greenway, or it can be a rich ecological space populated with urban wildlife and forests (Oleyar, et al. 2008). Nonetheless studies regularly report that undifferentiated open space is an unambiguous public good yielding multiple environmental benefits (Bolund and Hunhammar 1999). So as the urban ecologist aspires to add context to an assertion that all greenspace is necessarily 'green,' we propose to consider methods wherein a little extra field work by the urban ecologist working with economists might identify even stronger gains to housing values, environmental footprint and urban wildlife that might otherwise go unnoticed in a quick-paced development cycle.

This work is motivated by a concern that the form of urban landscapes, of which greenspace is part, needs to be assessed more explicitly. Economic and ecological-environmental effects are more subtle; yet that is often difficult to inject into public discourse in time limited policy settings. One method to motivate rethinking is to design filters—not full ecological evaluations—that can be completed quickly and cheaply but nonetheless compelling to local planners and zoning boards. Filters likely to be especially effective in this policy setting would indicate four things that we consider in this work:

- Does the filter indicate a potential to increase economic value of a development?
- Does the filter indicate a potential to improve ecological and other environmental outcomes?
- Does the filter require few resources and little time to complete?
- Does the filter help to identify locations where follow-up work is likely to be most informative?

This work presents a case study for the first three, pointing to the last. Given prior literature, a measure that emphasizes the number of bird species present in the study area, but that tend to be observed in areas with a variable vegetative height density, is argued to

be an indicator of an array of desirable ecological outcomes. We measure if high values for the indicator map to higher home prices in an immediate area about the size of a city block. In this case, the filter was relatively easy to complete in terms of time to conduct the repeated observations and of cost to conduct the study.

For the last concern, ecologists may use a filter to point to quite specific locations in the urban space that represent specific opportunities to increase economic development values while improving ecological-environmental outcomes. The filter not only may provide breathing space as a precautionary practice during the planning and development approval process, but it may identify where higher resolution follow-up field work is likely to be beneficial, but also cheaper, faster and reasonably robust.

Background

A seminal work by MacArthur and MacArthur (1961) offers one opportunity to construct such a filter that could be useful in numerous regions. This work drew a strong relation between landscape structure and avian wildlife diversity: the more complete the vertical landscape composition of vegetation across heights ranging from low shrubs to higher tree canopy, the richer the avian species diversity. A fuller vertical composition attracts bird species beyond the ubiquitous species. For examples of ubiquitous species in our study area, these included the house sparrow (*Passer domesticus*), European starling (*Sturnus vulgaris*), great-tailed grackle (*Quiscalus mexicanus*), and Eurasian collared dove (*Streptopelia decaocto*). Some members of these species are observed at nearly every site in our study area and often in great numbers, notably the great-tailed grackle.

Subsequent studies validate the MacArthur and MacArthur (1961) assertion that the indicator works both ways: diverse landscape compositions attract diverse avian species; but, also, if the researcher observes more species diversity, or presence of several less ubiquitous species, that is a powerful indicator of a diverse vertical landscape composition (Sandström et al. 2006). That is important. As ecologists have noted that urban ecosystems are quite diverse and scale dependent (Pickett et al. 2001), a common urban ecosystem indicator adopted by ecologists has been tree presence, density and location. DeGraaf and Wentworth (1986) noted that bird diversity varied with, amongst other dimensions, tree density, or tree density predicted bird diversity. Oleyar, et al. (2008) noted the isomorphic relationship: urban forest functionality was an integration of many factors; and bird diversity was a good predictor of tree density. Fernández-Juricic (2000) reached a similar finding. They noted that trees located at the street level had a positive effect on bird diversity and population abundance. Fernández-Juricic (2000) also noted that bird diversity varied with vegetation in urban settings. Crooks et al. (2004) finally equate the presence of bird diversity with urban ecosystem diversity broadly. Temporal variation in canopy and vegetation would be indicated by an observation of neighborhood bird diversity and population. This implies that a more height variable canopy and vegetation, which has known positive environmental externalities, likely supports a richer population of birds.

Some of the associated benefits of a rich greenscape with varied vegetative height range from reduced noise and air pollution, climate regulation, watershed management, rainwater capture, drainage and sewage treatment (Bolund and Hunhammar 1999). Even health (Maas et al. 2006) and physical activity benefits to avert chronic disease (Farmer and Lipscomb 2006) are associated with a rich urban landscape pattern. Other ecological-environmental benefits also flow from simple tree canopy by itself: reductions in air conditioning costs, improvements in air quality, sequestration of carbon, assistance in recharge of water tables and provision of habitat for animals in urban settings (Breuste et al. 1998).

We accept the received literature that bird diversity among less ubiquitous bird species responds to a more progressed and height varied landscape structure; as such, a diverse, progressed vegetation structure delivers a raft of environmental benefits over a high input monoculture lawn (Pickett et al. 1997).

As environmental and ecological studies have shown robust benefits to greenspace generally, economists have identified robust responses to greenspace and open-space, generally, as improving home values (Wolters 2001; Morancho 2003; Bell and Irwin 2002; Lipscomb and Farmer 2005; Mansfield et al. 2005; Cavailhés et al. 2007). Some have gone on to examine gross number of trees to value rental property (Thompson et al. 1999; Luttik 2000). As ecologists began to differentiate among greenspace benefits from studies conducted at higher levels of resolution with respect to the composition of greenspace (DeGraaf et al. 1985; Pickett et al. 2001; Fernández-Juricic 2000; Sandström et al. 2006), data began to permit economists to examine if specific ecological characteristics also benefited home values (Farmer and Lipscomb 2006; Bark et al. 2009; Cho, et al. 2008). This work developed an ecological indicator to facilitate economic study and to improve the precision of ecological-economic linkages while saving study costs and time. Since little has been done in residential areas on the non-public spaces where most developed green landscapes often are located, urban ecology benefits include private greenscapes in the yards of individual homes, alleys and in the collective canopy of, say, a street.

This level of resolution facilitates sharper economic evaluations. This work adapted a higher resolution ecological indicator that operates at the scale of a city block; and then estimated if home prices close to bird observation sites responded positively. The reduced cost and time is informative.

We anticipate that a full landscape inventory that evaluates landscape composition according to a consistent and meaningful coding protocol will be difficult and expensive. We sought an indicator easy to measure yet likely to be associated with the array of benefits identified by bird species diversity. The indicator is not a stand alone ecological assessment of bird diversity, but a broad robust indicator of environmental and urban ecological benefits consistent with the literature, that is also easy to collect.

We adapted an indicator to serve as a filter that more quickly highlights potential urban ecological and economic gains to zoning and development practices. The indicator is the simple product of the number of less ubiquitous bird species observed at a site and the number of birds observed. The indicator weights highly repeated observations of less ubiquitous species. If only ubiquitous species were observed, the value for the indicator was zero. This is because our goal was not directly to complete a bird population study but to infer diversity of vegetative cover and broad ecological diversity. To predict values for the indicator variable (Bird), tree canopy cover was observed over an area the size of a city block near a bird observation site. Home sales were observed within the same range. So the indicator, while neither a comprehensive landscape inventory nor a wildlife population study nonetheless was observed at a relatively high spatial scale to indicate higher resolution environmental and ecological benefits. These allow higher resolution economic response estimates of ecological-environmental services. In our study area the less ubiquitous species included the American robin (*Turdus migratorius*), blue jay (*Cyanocitta cristata), mourning dove (Zenaida macroura), northern mockingbird (Mimus polyglottos) and western kingbird (Tyrannus verticalis)*.

In evaluating areas of rich vegetation composition where the built environment was largely private residences, bird diversity and abundance is often easier to capture than direct completion of a comprehensive inventory of vegetative structure and composition. The question is whether this local vegetation diversity supporting more diverse bird life is also

more valuable to home owners, especially in comparison to other forms of public greenspace such as a local park. Rather than construct a continuous or categorical metric of landscape quality, we measured the closely associated urban wildlife variable directly to assess the wildlife variable's effect on housing prices across a 40 sq-mi urban space.

Methods

Study area

We collected a data set of recent house sales, tree canopy density and bird species richness in 17 neighborhoods of interest. The area spans approximately 40 square miles in southwest Lubbock, TX (Fig. 1.). We chose 17 neighborhoods in Lubbock, TX suggested by realtors as diverse for the area and also thought to have a high number of recent sales. Neighborhoods are of similar size and most had comparable numbers of sales. Two neighborhoods (Southhaven and Melonie Park South) had only four or five sales, but were somewhat unique neighborhoods. They were retained in the housing price model; but eliminated in the model to estimate significant effects on the Bird index.
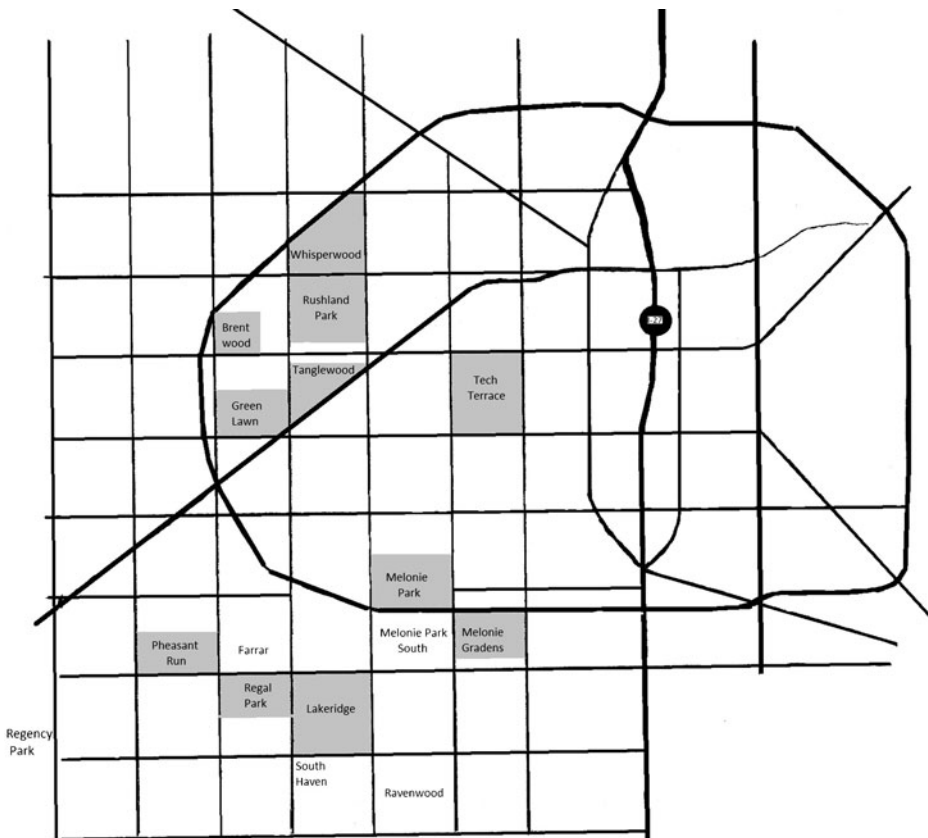

Fig. 1 Map of neighborhoods for study. Shaded neighborhoods were used in final model for *Predicted Bird* (Model 3). Each grid square is approximately one square mile

Data sources and collection

The first set of data collected was housing residential sales data from June 2006 to December 2008 within the neighborhoods of interest by extracting information from the Lubbock area Multiple Listing Service (MLS). We drew from MLS documents physical attributes of each house and the selling price.

Percent tree canopy cover was estimated from Google Earth photos from 2008. Grid size adopted used a 192 point dot-grid overlay on Google Earth images scaled at an elevation of 3,200 ft above the surface, with a resolution of 0.56 by 0.70 miles, and recorded percent of grid dots overlapping trees.

Relative abundance of birds was collected using point count surveys (Bibby et al.; 1992) recording detections <or> 50 m. Birds detected were identified to species and were recorded at $n \geq 8$ sites in each of $n=17$ neighborhoods over ≥ 2 different mornings during summer 2009. We categorized bird species as synanthropic species and suburban species. Species A (synanthropic species) birds were ubiquitous native and invasive species for example, house sparrow (Passer domesticus), European starling (Sturnus vulgaris), great-tailed grackle (Quiscalus mexicanus), Eurasian collared dove (Streptopelia decaocto); and Species B birds (suburban species) were desirable urban birds like: American robin (Turdus migratorius), blue jay (Cyanocitta cristata), mourning dove (Zenaida macroura), northern mockingbird (Mimus polyglottos), western kingbird (Tyrannus verticalis). The bird variable used for analyses was calculated by multiplying the total number of birds at an observation site by the number of Category B bird species, for an indexed variable labeled Bird. All data, such as tree canopy or the measure of the bird variable were referenced to each residential unit sold in the survey; so the bird variable, for example, realized a different value for each housing unit sale that we examined.

Model selection methods for bird richness and abundance

Our approach, based on bird richness and relative abundance, resembles other models that use birds as a barometer of ecosystem complexity (MacArthur and MacArthur 1961), urban ecosystem biodiversity (Crooks et al. 2004) or the quality of greenspace (Sandström et al. 2006; and Fernández-Juricic 2001), or urban forests (Oleyar, et al. 2008). These studies build a theory associating urban avian wildlife abundance as well as diversity with a sizable number of favorable environmental outcomes.

First, we sought to explain variation in the bird variable. Bird is defined as an inter-action variable between the total numbers of birds multiplied by the number of different kinds of Species B birds. We regressed Bird against the percent tree cover, 16 dummy variables to capture variation due to neighborhood effects across the 17 neighborhoods, and a variable 'near park,' defined by the presence (1) or absence (0) of a park fitting two criteria: the park was located within the neighborhood and within a half mile of the residential unit of interest. Model 1 predicts Bird using all 18 independent variables. Using Model 1 results, we eliminated three insignificant variables. The public greenspace, 'near park' was eliminated at this stage. We then regressed Bird against the significant variables to derive Model 2. Following this, we derived Model 3 from the significant variables in Model 2, eliminating two more variables. The process eliminated neighborhoods that had less than 6 sales in 2008 and 2009 to form Model 3. We regressed the remaining 11 neighborhood dummy variables and tree cover on Bird.

We compared the three Models for Bird using AIC_c values for the three regressions. Having chosen the Model with the lowest AIC_c score (results below) and the highest weight

to predict Bird, we extracted the predicted value of Bird from that model, which we labeled Predicted Bird.

We then tested regressed each observed home sale price against household structural variables and Predicted Bird to examine how well this urban wildlife measure correlated with home prices.

Two models of home price compared

We estimated several factors expected to affect housing price. The housing characteristics used were Square Footage, Age of House, Garage (0/1) and Lot Size. We compared two housing price models to predict home price for sales in 2008 and 2009. The first housing price model did not include Predicted Bird (Generic Model); the other model included Predicted Bird (Modified Model). The two models are:

Generic Housing Price Hedonic Model:

$$\text{House value} = \beta_0 + \beta_1 * \text{Square Footage} + \beta_3 * \text{AgeofHouse} + \beta_4 * \text{Garage}$$
$$+ \beta_4 * \text{Lot Size}$$

Modified Housing Price Hedonic Model:

$$\text{House value} = \beta_0 + \beta_1 * \text{Square Footage} + \beta_2 * \text{AgeofHouse} + \beta_3 * \text{Garage}$$
$$+ \beta_4 * \text{Lot Size} + \beta_5 * \text{Predicted Bird}$$

Results

Model selection for bird We conducted 296 point counts and used total number of birds and total number of species B detected on 2 point counts (randomly selected if there were >2 conducted) for each neighborhood to attach a Bird value to each sale. The results of model comparisons for Bird are presented in Table 1.

Model 3, in which Bird was regressed against tree cover and remaining significant neighborhood dummy variables was the best model from our tests. Model 3 showed the lowest overall AIC$_c$ value; was assigned the entirety of the explanatory weight; and generated the highest R_{adj}^2 (=0.4965) value. Therefore we used Model 3 to generate '*Predicted Bird*,' which was then used as an independent variable to explain home sale prices for which we had MLS data in 2008–2009 across 17 neighborhoods.

Model selection method for home price We collected MLS data for 368 home sales in Lubbock, TX from 2008 to 2009. Three hundred twenty-three had no missing data and were used for analyses.

Table 2 reports our hedonic price model for the Modified Housing Price Model. Home Price was regressed against physical house characteristic variables (house square footage, garage, lot size, and age) and one ecological variable (Predicted Bird). Predicted Bird, square footage, age and lot size of each house were all significant ($P<0.001$). R_{adj}^2 also improved for Modified Model that included Predicted Bird over the Generic Model, increasing R_{ad}^2 from 0.7348 to 0.7792 using *Predicted Bird*.

Table 1 Akaiki (AIC$_c$) comparison of regression models to derive *Predicted Bird* variable

Statistics for model comparison

Model	SSE	−2log(L)	K	n	AIC$_c$	w
1	242279	−4299.63	17	319	−4263.60	0
2	247221	−4292.51	12	319	−4267.49	0
3	288441	−4386.90	11	319	−4364.04	1

Where:

Model 1 Bird regressed against near park, tree cover and neighborhood dummy variables

Model 2 Bird regressed against tree cover and significant neighborhood dummy variables from Instrument 1

Model 3 Bird regressed against tree cover, significant neighborhood dummy variables with >6 sales from Instrument 2

Variables: bird, was derived using total birds times number of suburban bird species; near park, was distance to nearest open space/city park; and, neighborhood dummy variables. Data are from summer 2009 in Lubbock, TX

Not shown are several alternatives to the Generic Housing Price Model and Modified Housing Price Model. 'Near park' was added to both models; and in a third case, 'near park' directly replaced Predicted Bird in the Modified Model. In all three cases, 'near park' added virtually no explanatory value (t-stat <0.18 in all cases) and, in each case, overall model performances fell (see below).

Table 3 summarizes key information. Table 3 records neighborhood name (referenced on Fig. 1) and reports the mean values for Bird, Tree Cover, and Home Price. Implications are discussed below.

Discussion

Model for predicted bird Overall, Model 3 in displayed the lowest overall AIC$_c$ value in predicting Bird variation; was assigned the entire explanatory weight (100%); and showed the highest R_{adj}^2. Because Model 3 was the most efficient estimate of bird species richness and relative abundance, this model was used to predict Bird (i.e. Predicted Bird). Predicted Bird from this model then was used in the modified hedonic regression (Modified Model) to predict of house value. The final model of Bird (Model3) showed a strong positive relationship between bird species richness and relative abundance with tree cover. Tree cover producing a t stat=4.13. Yet paradoxically, proximity to a park was not a significant predictor of bird richness and relative abundance. In fact, the 'near park' variable produced a t stat=0.15 in Model 1. When we added 'near park' to Model 3 as a test, 'near park' again realized a virtually identical t stat (0.148); and when we replaced 'near park' for Predicted Bird the t-stat was low (0.185).

This seemingly counterintuitive result for parks is explained by the composition of tree cover in most Parks in Lubbock, TX, which is not particularly dense, nor a multi-layered canopy. Tree cover is composed of punctuated trees heavily pruned below 8′ to 10′. Also many city parks are converted (filled) playa lakes, managed partly to serve as flood control drainage as well as public space. So parks on average were not valuable in predicting higher Bird outcomes. A development model premised on clearing space for a park but not

Table 2 Modified hedonic price model

Hedonic Price Model With Predicted Bird

Dependent Variable: Price

Number of Observations Read		368
Number of Observations Used		323
Number of Observations with Missing Values		45

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	3.746561E12	7.493121E11	228.27	<.0001
Error	317	1.040565E12	3282540056		
Corrected Total	322	4.787126E12			

Root MSE	57293	R-Square	0.7826
Dependent Mean	234809	Adj R-Sq	0.7792
Coeff Var	24.40002		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	Intercept	1	−45434	16924	−2.68	0.0076
Square Footage		1	94.25576	3.95636	23.82	<.0001
Age of House		1	−2926.60790	286.06107	−10.23	<.0001
Garage		1	8655.86801	6582.18243	1.32	0.1894
Lot Size		1	1.55797	0.34163	4.56	<0001
Predicted Bird		1	1243.93485	172.42051	7.21	<.0001

Mean total number of bird=24.14. Mean value of B Species=2.08; for $32,028 gain in expected mean home value from a gain of one more Type B species observed

Regressing MLS characteristics (house square footage, garage, lot size, and age) and ecological variables (Predicted Bird) to prices of most recent home sale in Lubbock, TX. 2008–2009

Table 3 Mean values for key variables by neighborhood

	Mean bird	Mean home price	Mean tree cover
Tech terrace	91	178,285	0.33824
Whisperwood	51	167,881	0.37414
Rushland	65	386,933	0.37905
Brentwood	56	145,500	0.3
Tanglewood	123	470,838	0.385
Greenlawn	37	98,124	0.28
Melonie Park South	67	174,806	0.29
Melonie Park	53	177,742	0.24167
Melonie Gard	27	318,358	0.11739
Ravenwood	10	280,960	0.05
Southhaven	30	307,437	0.29426
Lakeridge	26	148,243	0.28556
Farrar	10	222,712	0.04107
Regal Park	34	155,861	0.05071
Pleasant Run	46	340,056	0.23444
Regency Park	9	162,448	0.05

For Neighborhoods Used in Bird Model, See Fig. 1

improving zoning and building requirements for an improved landscape on residential property would remove an ecological benefit and substitute for it an expensive public commitment to upkeep that cleared area. The same decision also would lower home values.

Home price effects of predicted bird

The Modified hedonic housing price regression included Predicted Bird; again the expected value of Bird associated with each home sale from Model 3 discussed above. The regressors for the Generic housing price model are identical, except they do not include Predicted Bird.

Predicted Bird had a significant effect on housing prices. First, the significance level of Predicted Bird is well above 99%, with a t-stat=7.21. This stands in contrast to results for 'near park.' When entered into either the Generic Home Price Model or the new Modified Home Price Model, 'near park' had an insignificant effect on home price. The Modified Model, for example, generated a t stat=0.49 for near park. Further, in both models, the addition of 'near park' as a regressor resulted in a decline in adjusted R^2. So greenspace alone was not significantly related to improvements in either the urban wildlife variable, Bird, nor in average home prices.

In contrast, the inclusion of Predicted Bird increased the value of the *adjusted* R^2 from 72.6% to 77.9%, meaning the variable added to real explanatory power for the regression adjusting for the decline in the degrees of freedom. Again, *Adjusted* R^2 fell when 'near park' was added. The inclusion of Predicted Bird into the regression model for home price was not only significant, but passed several internal consistency checks when the Modified Model was compared to the Generic Model.

Model consistency checks

Compare hedonic regressions with and without Predicted Bird (the Generic and the Modified Model above). Theory suggests some estimated parameters that explain home prices should change when Predicted Bird is added to the Modified Model. Theory also suggests others should not change.

Square footage is one example. The parameter value for square footage, an interior home attribute, should not shift between the Generic and the Modified models. Adding Predicted Bird into the Modified Model is an exterior attribute, which we expect to be independent from values of interior home attributes. Comparing the Generic to the Modified model, the parameter estimate for square footage shifted only from $94.25 to $94.48 per square foot—almost no change. Both results were well in line with the average $92 to $98 per square foot value provided to us by local realtors (Linda Gaither, Westmark Realty, personal communication).

Lot Size and AgeofHouse parameter estimates, however, are predicted by theory to change between the Generic Model and the Modified Model, which includes Predicted Bird as a regressor.

The regression parameter for *Lot Size* (in square yards) fell when Predicted Bird was entered into the Modified regression. Some lots will be improved with added tree cover and others will not. So we expect that when Predicted Bird is added to the regression, the value of lot size should fall. By entering Predicted Bird into the Modified Home Price Model, the model ought to differentiate better between the values for lot size on unimproved space versus private lots improved by mature trees. Indeed, the value for lot size fell from $1.97 per square yard in the Generic Model to $1.56 per square yard in the Modified Model. What is noteworthy is that the ecological indicator helped to tease out a qualitative difference among lots with and without mature trees in the economic model.

We expect a similar type of outcome for the coefficient values for house *AGE*. Older houses are less valuable on average. Yet older homes can accommodate older, more mature trees. That feature should increase home values. Again, some older houses have mature trees and some do not. So with the addition of Predicted Bird into the Modified Model, house age by itself should exert a more powerful *negative* effect. In the Generic Model, it was estimated that age diminished home price by an expected $1516.84 per year old (e.g. a 10 year old home would fall by $15,168). Adding Predicted Bird to the Modified Model increased the predicted negative impact of home age, reducing housing price by $2926.61 per year. Differentiating between older homes with mature trees and older home without mature trees, the stronger depreciating value of home age was more properly identified.

These shifts in parameter values from the Generic Housing Price Model and the Modified Housing Price Model appeared as expected. Further, no shifts in parameters arose between where they were not expected, such as square footage. This internal consistency would explain the improvement in adjusted R^2 from 0.7348 to 0.7792 by adding Predicted Bird.

Estimated mean home price premium for bird richness and abundance

There is a strong average premium for features that attract more desirable bird species, Bird. For the mean home sale in this market, a premium of $32,028 was correlated with the presence of just one more Type B, or suburban, species observed near the home site. The number, while high, makes sense when we note the average number of type B species

observed was only 2.08. So the value on average from, say, 2 to 3 of such species may suggest a strong improvement in the aesthetics, neighborhood walkability and the wildlife diversity that collectively helps to form a 'streetscape.'

The average number of Type B bird species observed for all positions was 2.08. The mean number of total birds observed was 24.14. On Table 2, as the total value of Predicted Bird increased by one unit, home price, on average, improved by $1243.93. That regression coefficient is equivalent to observing another bird at a site where at least one type B species was observed. The critical contribution to home value, however, arose likely from a landscape that on average improved the number of Type B species by one. Such a change, on more observed type B species, realized a gain of $32,028.47 in home price; or average home price changed by 24.14(mean of total birds observed)*$1243.93 (expected home price change as Predicted Bird value increases by one unit).

Not to be taken too literally, the result does divide the observations into those with landscapes nearby that favor a vegetative cover that would improve diversity in Bird species in terms of including non-ubiquitous bird species from those that do not. The home price contribution of the suite of services correlated with a higher Bird value is not only significant, but it is a substantive contribution to overall home price. Whatever are the component details of the landscape differential or, perhaps, ecological function, the sharp impact on home prices broadly across this study area is one that we submit would draw attention from planners and developers.

Efficient targeting of subsequent field work

Our final comment is that our empirical results direct attention to higher resolution studies at specific locations. This is item four regarding the benefits of a good filter in the Introduction. A way to target locations for further study is to examine those sites that have high recorded Bird values yet were predicted to have much lower Bird values. We hypothesize that unobserved landscape characteristics, such as vertical height cover, would be responsible for higher observed than expected Bird values. This would isolate quite specific spots for closer inspection. Landscape architects or forest ecologists would need to conduct site studies, but some features stand out to suggest those studies would be constructive. We start with cross neighborhood comparisons and then drill down to specific blocks.

Starting with *neighborhood by neighborhood comparisons*, when we look a little closer at the neighborhoods in the Bird prediction model (Model 3) that explain very high Bird values that are statistically significant and compare them to neighborhoods with insignificant or negative effects on mean Bird values, the vegetative canopy has a visibly more complete vertical composition. On Table 3, consider two neighborhood comparisons. Comparing Tanglewood to Rushland, they neighborhoods have similar tree canopy percentages (0.385 versus 0.379) and other home characteristics, such as size, were similar. Tangelwood realized much higher values for Bird (123 versus 65) and for home value ($471 K versus $387 K). As the neighborhoods are adjacent (Fig. 1), it is clear that older trees with high canopies with lawns below dominate the landscape in Rushland compared to a more height varied and denser tree composition for the same overall canopy coverage. Three other neighborhoods with reasonably similar characteristics, Tech Terrace, Wisperwood, and Brentwood, have similar values for tree cover (0.38, 0.37, 0.30, respectively); yet Tech Terrace realizes higher home prices ($178 K, $167 K, $146 K, respectively) and Bird values (91, 51, 56), and by casual inspection has more landscape diversity.

The is good reason to suspect the area 'beneath the canopy' explains much of the variance and serves as a guide to a higher resolution enunciation of ecological services.

Oleyar, et al. (2008), evaluate urban forest functionality, especially in light of the connection between avian assembleges in a fragmented urban landscape and vegetative structures (Crooks, et al. 2004).

Drilling down just a little further to *street block by street block*, there is variation in vertical composition of the vegetative landscape at this resolution. We compare six bird sites in Wisperwood and three in Tech Terrace with identical tree cover percentages, evidence we believe useful to policy.

In Wisperwood areas with equivalent low tree canopy sites, those that predicted Bird accurately were largely not vegetated, marked by younger ornamental fruit trees and impervious surfaces. This contrasts with sites yielding higher than expected Bird values, which had, in one case, clearly more undergrowth (still modest) and another site near an alley that possessed both more overgrowth and more vegetative layers than dominant lawn landscapes. In Tech terrace we identified local blocks with higher than, lower than and expected bird values for canopy cover values that all realized the identical cover percentage measure. The highest Bird valued site had a dense tree cover, as Oleyar, et al. (2008) found elsewhere, a high canopy cover, yet a filled understory, including some fruit and nut bearing plants. The site that predicted Bird higher than actually observed was not a layered landscape and the site was adjacent to park open space inhabited by ubiquitous birds (grackles) with no barrier. The site that predicted well also had open space nearby; but it was more protected. Also a strong canopy existed with limited undergrowth and somewhat larger lawns. These all conform to the developed theory.

These results, using a very accessible ecological indicator for the region as a filter, focus attention for comparison to a very few select neighborhoods and even fewer selected blocks for quite close, high resolution inspection and study. The higher resolution results will not surprise ecologists who have found repeatedly that a progressed or layered vegetative structure tends to encourage diversity of avian and other urban wildlife (Sandström, et al. 2006; Fernández-Juricic 2000), as well as many other environmental benefits (Crooks, et al. 2004); yet there was some corroboration in this exercise. What is perhaps valuable is the speed and relative ease to obtain these comparisons from this one indicator that served as a filter to identify particular sites to conduct more close study. Fortunately, those more nuanced assessments correlated with direct economic benefits. Persons appear to be willing to pay for some elements of the suite of services delivered, demonstrable by filtered illustration to a few points.

These clearly casual inspections of neighborhoods or blocks with similar tree canopy but higher Bird measures corresponded to landscapes with intermediate zone vegetation at the one meter and two meter levels. So, a planner may wish to know what shapes contribute to ecological value per se; and, then, with even greater specification from very local fieldwork filtered through our ecological indicator coupled with an economic assessment, a planner may be able to isolate which improvements lead to economic improvements and at what point ecological enhancement starts to improve at the expense of further economic outcomes. If the ecologist, economist and planner seek ecological economic outcomes, the analysis here points to subsequent fieldwork where landscape design contributes to ecological outcomes and to economic development. The sort of analysis conducted here opens the pathway for defining where to sharpen field work to study specific ecological and social conditions that affect ecological and economic outcomes, separately and together.

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