Appendix 2. Details of multivariate analysis. Methods and Results.

Methods

Because both habitat loss and fragmentation are known to also drive patterns of bird species richness, we tested for the influence of these factors in the patterns of species richness we observed. We used the National Land Cover Dataset (NLCD) 1992 and 2001 Land Cover Change Retrofit Product (Fry et al 2009) to calculate within each 19.7 km radius buffer surrounding a BBS route, the area of agriculture cover (a proxy for habitat loss) and the area of forest cover. We then conducted morphological pattern analysis (Vogt et al, 2007) to determine the area of core forest. Finally, we calculated the percent of each BBS buffer composed of core forest.

We created bivariate scatterplots of all these potential drivers of species richness (SI Appendix 4). We then computed the Spearman rank correlation between the potential drivers. Core forest area was $\log_{10}$ transformed to improve linearity with bird richness. (SI Appendix 5).

Finally, we modeled species richness in multiple linear regression models. Because the area of core forest and percent core forest were highly correlated we elected not to include them both in these models, and omitted percent core forest from consideration. We related species richness of our various guilds to $\log_{10}$ housing density, $\log_{10}$ area of forest core, and area of agriculture as independent variables (SI Appendix 5). For each of these regression models, we applied hierarchical partitioning analysis to determine the independent contribution of each of these three predictors when the other two were held constant (Chevan and Sutherland 1991).

Results

Initial inspection of scatterplots of these factors highlighted the fact that the relationship between housing density and any of the other potential factors is weak in the vast majority of cases (SI Appendix 4). Spearman rank correlation revealed that in 77 of the 80 correlations (9 ecoregions plus the forested extent as a whole [total of 10 geographic units] times two time points, times four variables to correlate with housing), the correlation coefficient rho was less than 0.7 (max of 0.76), and in 64 of the 80 combinations, it was less than 0.5 Thus, in 80% of the models that we analyzed, housing density was not strongly correlated with either fragmentation or habitat loss. Therefore we suggest that the observed patterns that we report for the relationships between housing and avian species richness are not solely due to correlation with habitat loss or fragmentation.

The ecoregion where we found the strongest correlations of housing with any other variable was the Adirondack-New England Mixed ecoregion, where correlation with the area of agriculture reached 0.76. For this ecoregion, the relationships between housing and birds that we report are generally weak (Figure 5), with the exception of cavity nesters (positive), ground nesting species (negative), and synanthropes (positive). Among these three guilds, the independent contribution of housing for ground nesting species is about 80% in both 1990 and 2000, indicating that housing is indeed the key factor. Similarly, for synanthropes, the independent contribution of housing is 60% in both 1990 and 2000, thus representing in the majority of the variation that is explained. The same is true for cavity nesting species in 2000, but not in 1990. However, we report only a weak relationship between housing and cavity nesting birds for 1990, and core forest area has the highest independent contribution, not agriculture, with which housing is correlated.

The ecoregion with the second-highest levels of collinearity was the Eastern Broadleaf (Oceanic) ecoregion where housing was correlated with the area of forest and log core forest area. In this ecoregion, we found negative relationships between housing and birds for the forest and woodland guild, cavity nesting species, Neotropical migrants, ground nesting species, and forest interior species. For all five guilds, the independent contribution of core forest area was higher than the contribution of housing (Appendix 7), and this means that core forest area may have been more strongly related to avian richness than was housing.

The ecoregion with the third-highest levels of collinearity was the Central Appalachian ecoregion, where housing was also correlated with forest area. In this ecoregion, we found clear negative relationships between housing and birds for Neotropical migrants, ground nesting species, and forest interior species, and a positive relationship with synanthropes. Again, for all four guilds, the independent contribution of core forest area was higher than for housing, and this means that core forest area may have been more strongly related to avian richness than was housing.

The last ecoregion where we found collinearity was the Laurentian Mixed Forest ecoregion, where housing was correlated with the area of agriculture. For this ecoregion, we reported negative relationships between housing and avian richness for forest and woodland species, short-distance migrants, Neotropical migrants, ground-nesting species, and forest interior species, and a positive relationship for synanthropes. For these guilds agricultural area had a stronger independent contribution than housing density, and this means that area of agriculture may have been more strongly related to avian richness than was housing.

In summary, in 82.5% out of the 160 combination of housing density and avian species richness (2 dates, 10 ecoregions, 8 guilds), it is unlikely that the reported relationship with housing was attributable to correlations between housing and other factors. However, in the remaining 17.5% of these cases, we cannot rule out that collinearity affected our results. These cases are concentrated in two ecoregions, i.e., the Eastern Broadleaf (Oceanic), and the Central Appalachian ecoregion were the places where core forest area was important, and one ecoregion, i.e., the Laurentian Mixed Forest ecoregion, where the area of agriculture was important.

Our conclusion from the analyses of potential factors other than housing was that they strengthen our findings about the relationships between housing and birds, because they assess the role of housing versus other factors. This assessment shows that while other factors certainly matter for bird richness patterns, housing density has a clear independent contribution to patterns of bird species richness.

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