Weak effects of owned outdoor cat density on urban bird richness and abundance
Genevieve C. Perkins, Amanda E. Martin, Adam C. Smith and Lenore Fahrig

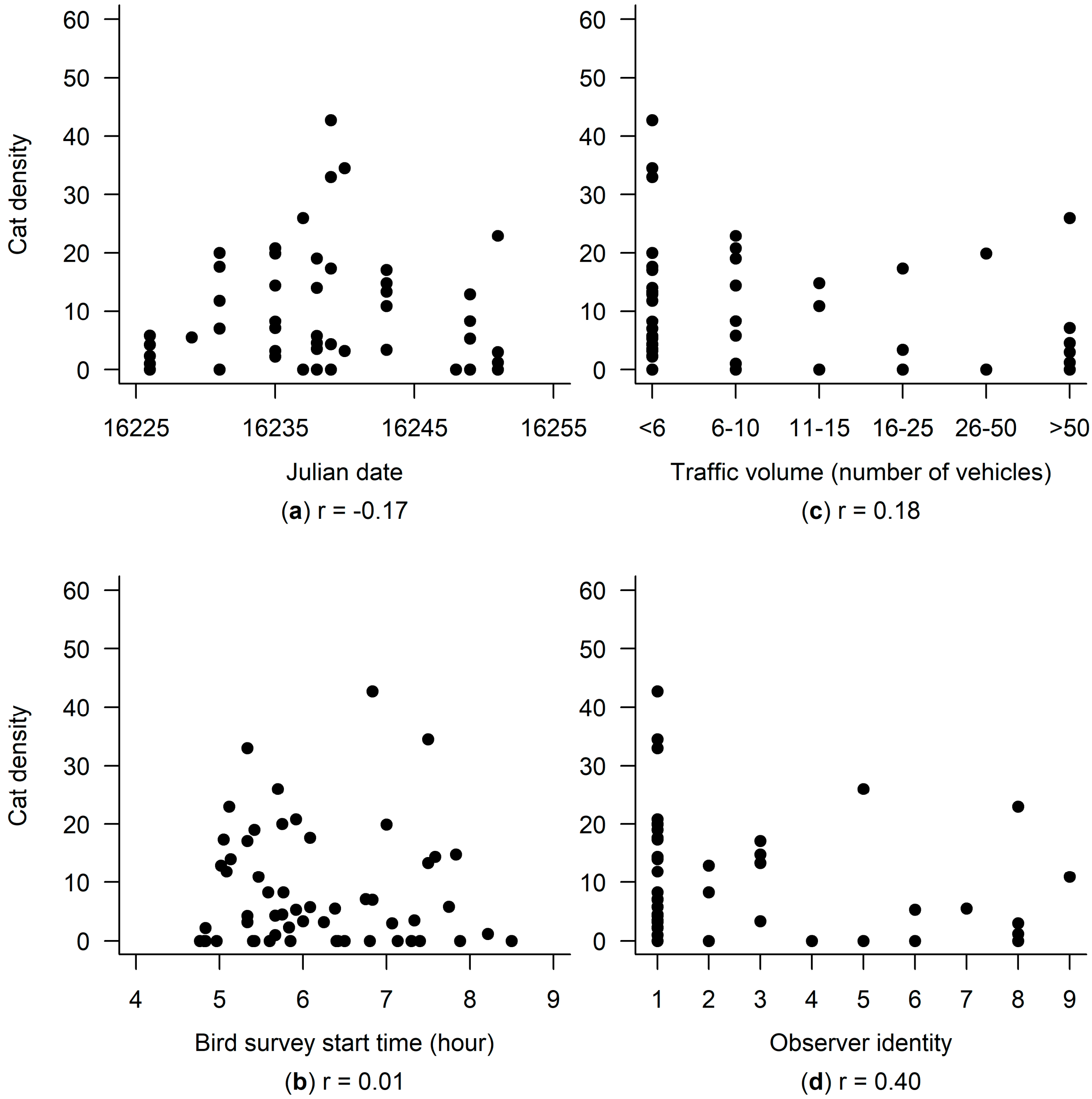


Figure S1. Bivariate plots showing relationships between cat density (number of cats/landscape) and each of four variables that can influence bird detectability at the 58 landscapes: (**a**) bird survey date, (**b**) bird survey start time, (**c**) traffic volume, and (**d**) observer. Each of the nine observers that conducted bird surveys is coded by a unique number. We calculated the Pearson correlation coefficient (r) between cat density and date and start time (**a**, **b**). Relationships between cat density and traffic volume and observer were modeled by one-way ANOVA (**c**, **d**). For ease of comparison, the model r^2 was converted to r ($\sqrt{r^2}$).

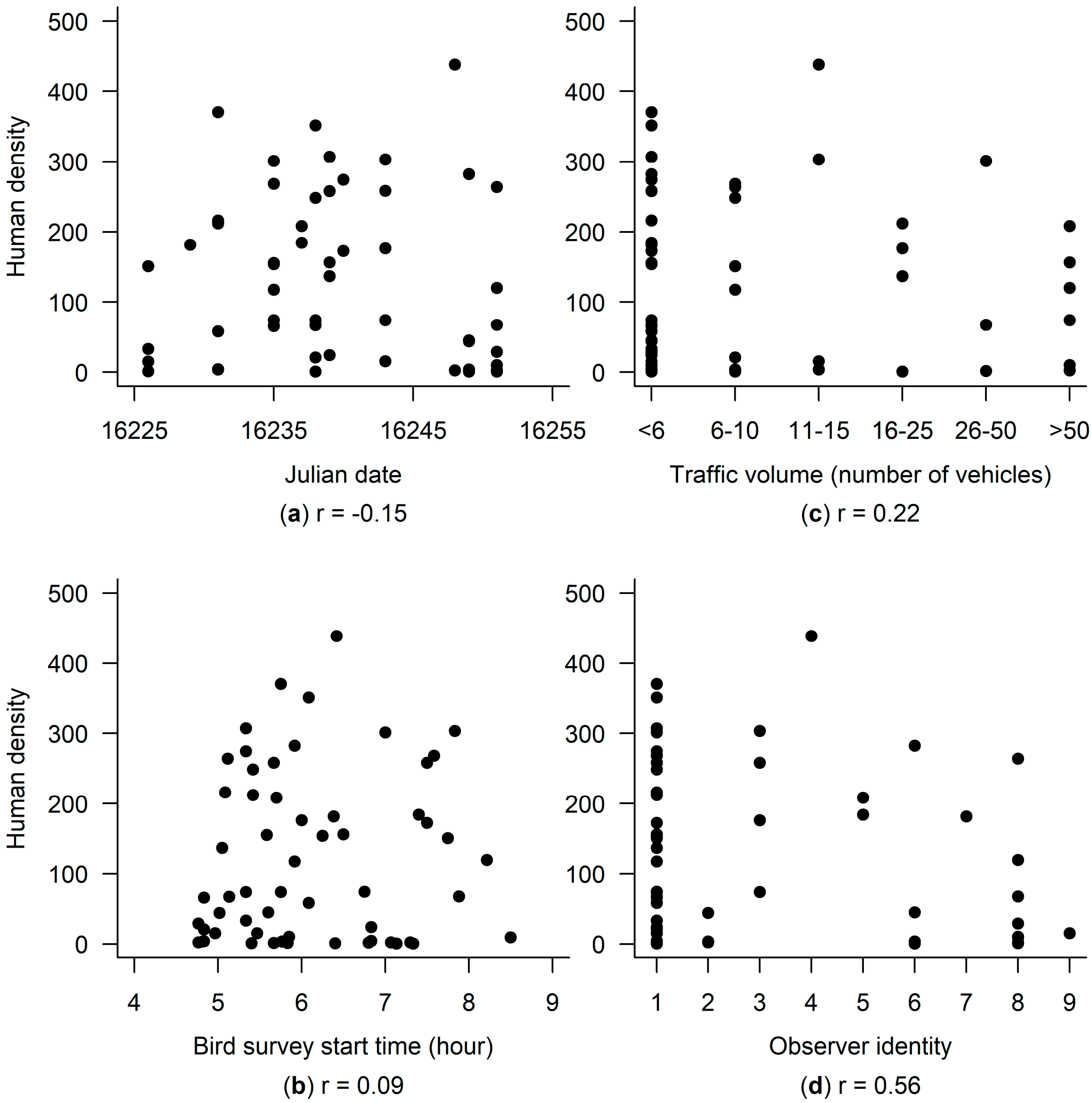


Figure S2. Bivariate plots showing relationships between human density (number of people/landscape) and each of four variables that can influence bird detectability at the 58 landscapes: (**a**) bird survey date, (**b**) bird survey start time, (**c**) traffic volume, and (**d**) observer. Each of the nine observers that conducted bird surveys is coded by a unique number. We calculated the Pearson correlation coefficient (r) between human density and date and start time (**a**, **b**). Relationships between human density and traffic volume and observer were modeled by one-way ANOVA (**c**, **d**). For ease of comparison, the model r^2 was converted to r ($\sqrt{r^2}$).

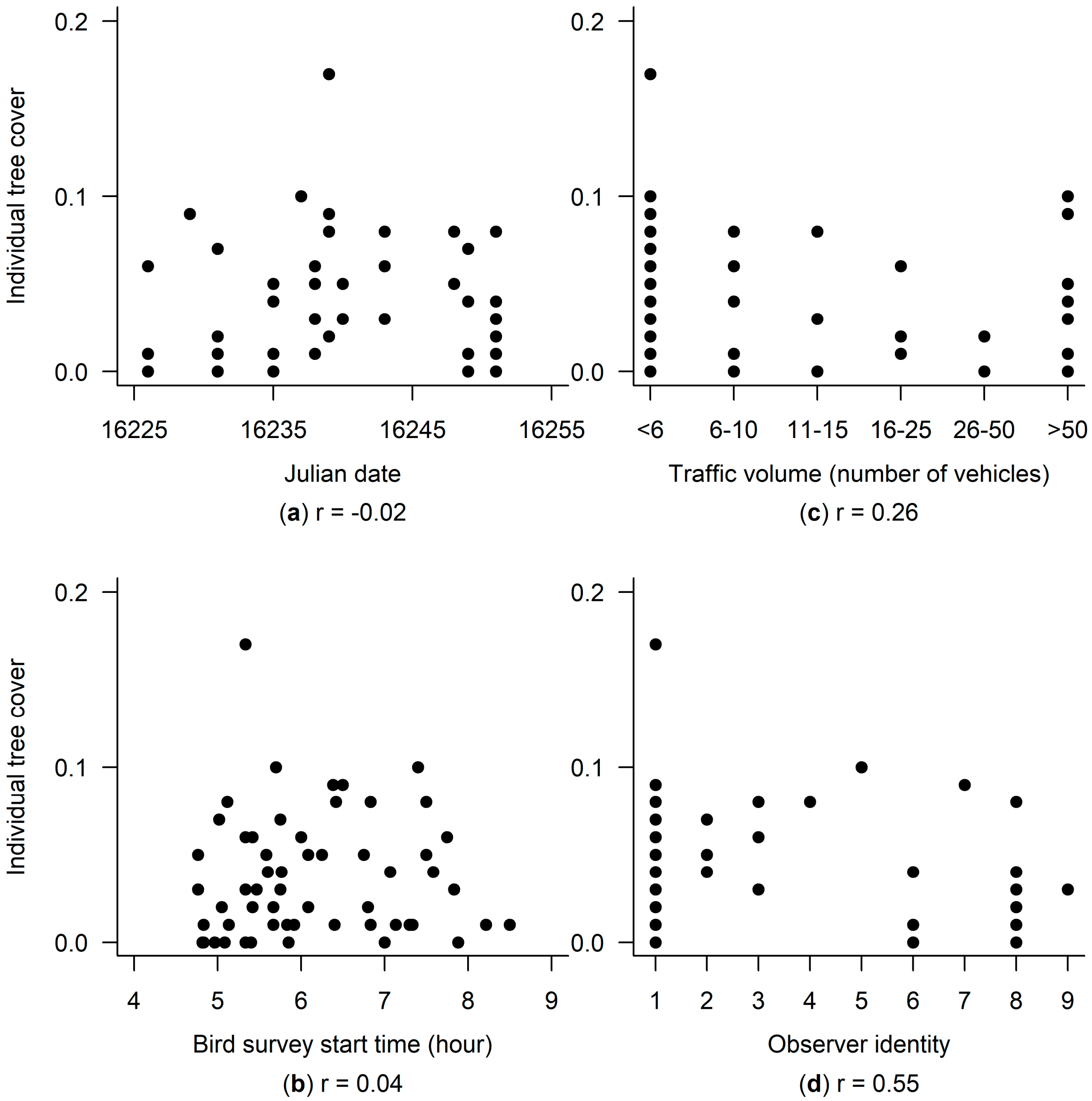


Figure S3. Bivariate plots showing relationships between individual tree cover (proportional cover of individual trees within the landscape) and each of four variables that can influence bird detectability at the 58 landscapes: (**a**) bird survey date, (**b**) bird survey start time, (**c**) traffic volume, and (**d**) observer. Each of the nine observers that conducted bird surveys is coded by a unique number. We calculated the Pearson correlation coefficient (r) between individual tree cover and date and start time (**a**, **b**). Relationships between individual tree cover and traffic volume and observer were modeled by one-way ANOVA (**c**, **d**). For ease of comparison, the model r^2 was converted to r ($\sqrt{r^2}$).

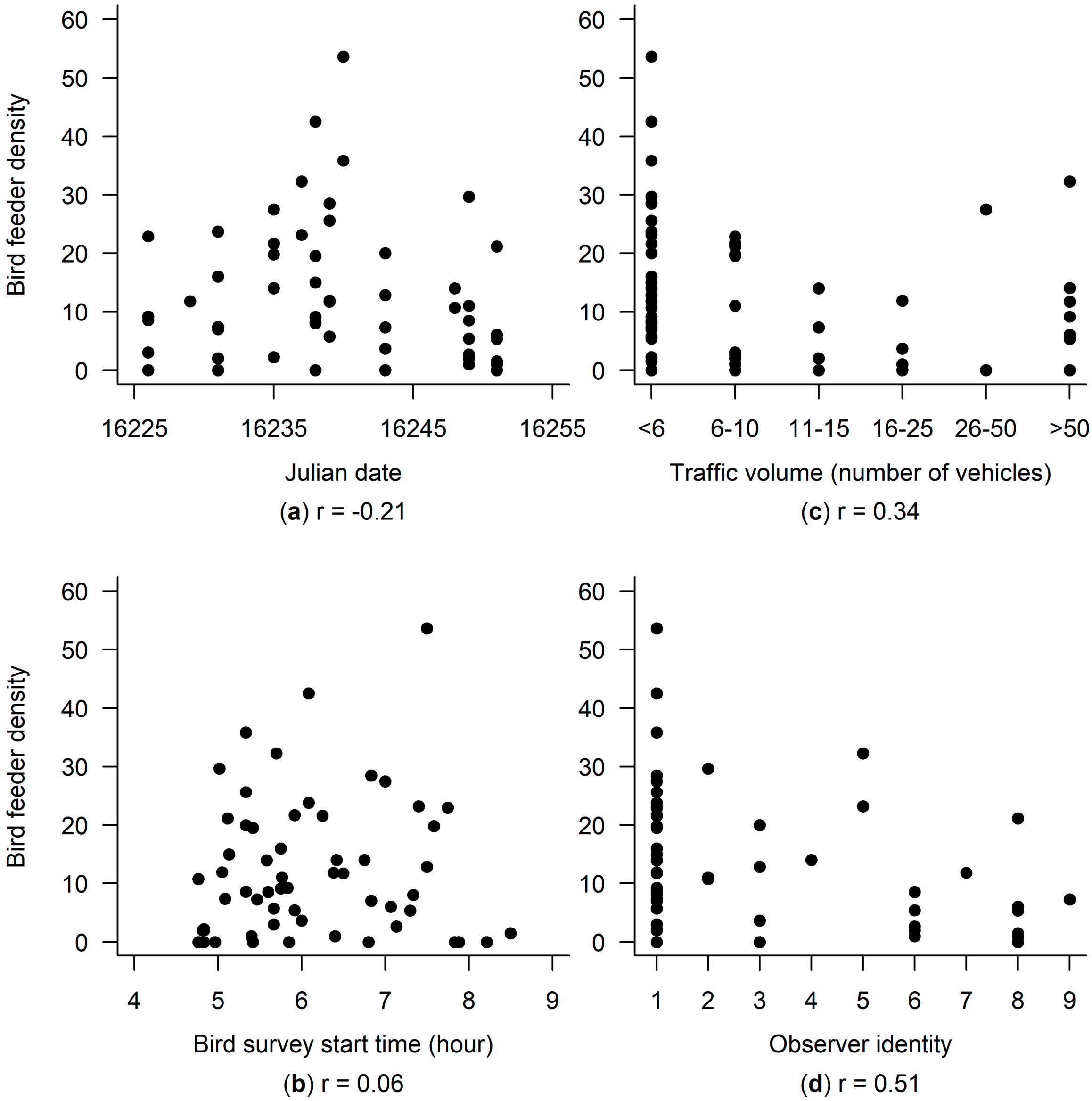


Figure S4. Bivariate plots showing relationships between bird feeder density (number of feeders/landscape) and each of four variables that can influence bird detectability at the 58 landscapes: (**a**) bird survey date, (**b**) bird survey start time, (**c**) traffic volume, and (**d**) observer. Each of the nine observers that conducted bird surveys is coded by a unique number. We calculated the Pearson correlation coefficient (r) between bird feeder density and date and start time (**a**, **b**). Relationships between bird feeder density and traffic volume and observer were modeled by one-way ANOVA (**c**, **d**). For ease of comparison, the model r^2 was converted to r ($\sqrt{r^2}$).

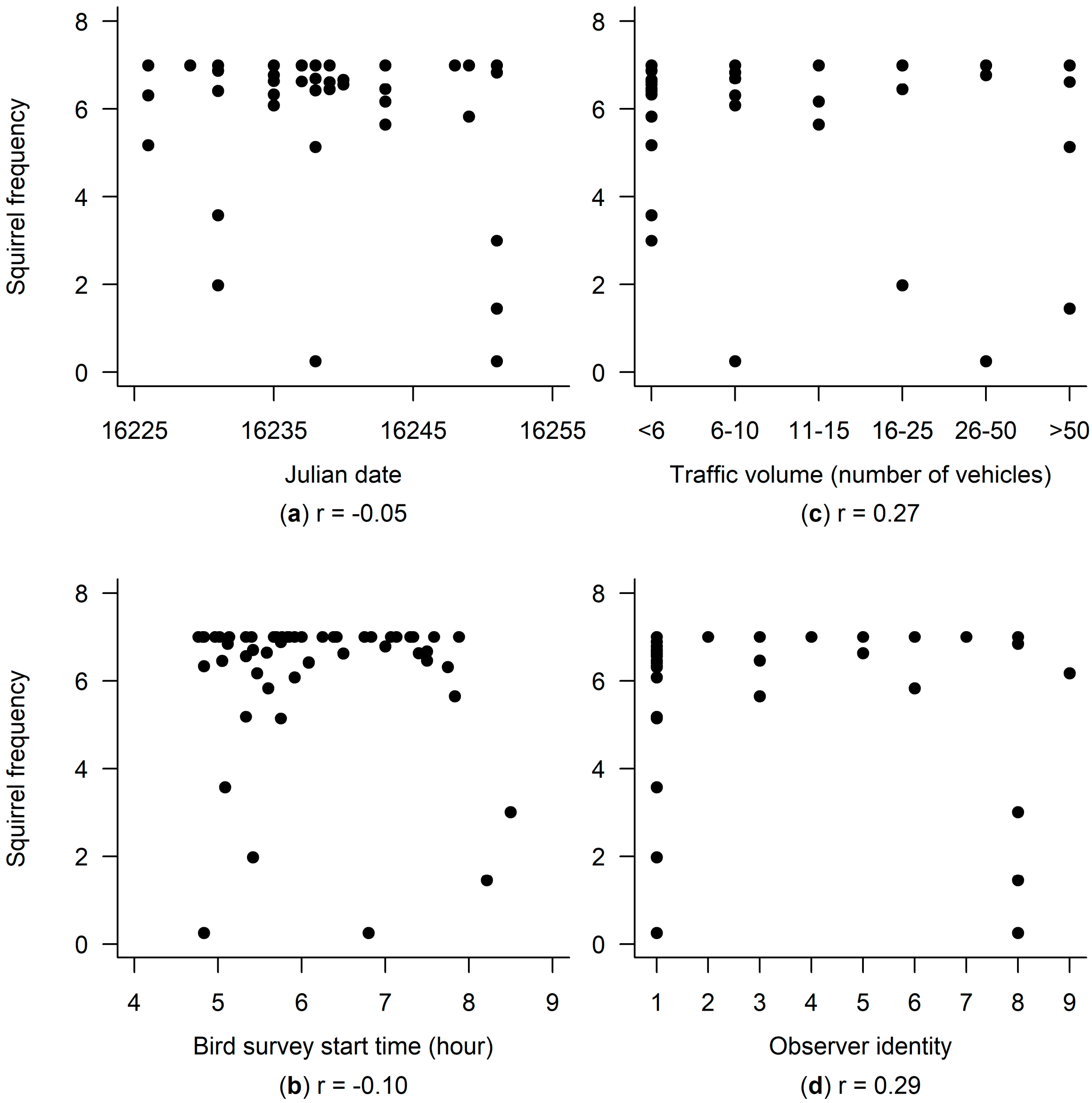


Figure S5. Bivariate plots showing relationships between squirrel frequency (number of days squirrels were observed by homeowners per week, averaged for all surveys within the landscape) and each of four variables that can influence bird detectability at the 58 landscapes: (**a**) bird survey date, (**b**) bird survey start time, (**c**) traffic volume, and (**d**) observer. Each of the nine observers that conducted bird surveys is coded by a unique number. We calculated the Pearson correlation coefficient (r) between squirrel frequency and date and start time (**a**, **b**). Relationships between squirrel frequency and traffic volume and observer were modeled by one-way ANOVA (**c**, **d**). For ease of comparison, the model r^2 was converted to r ($\sqrt{r^2}$).

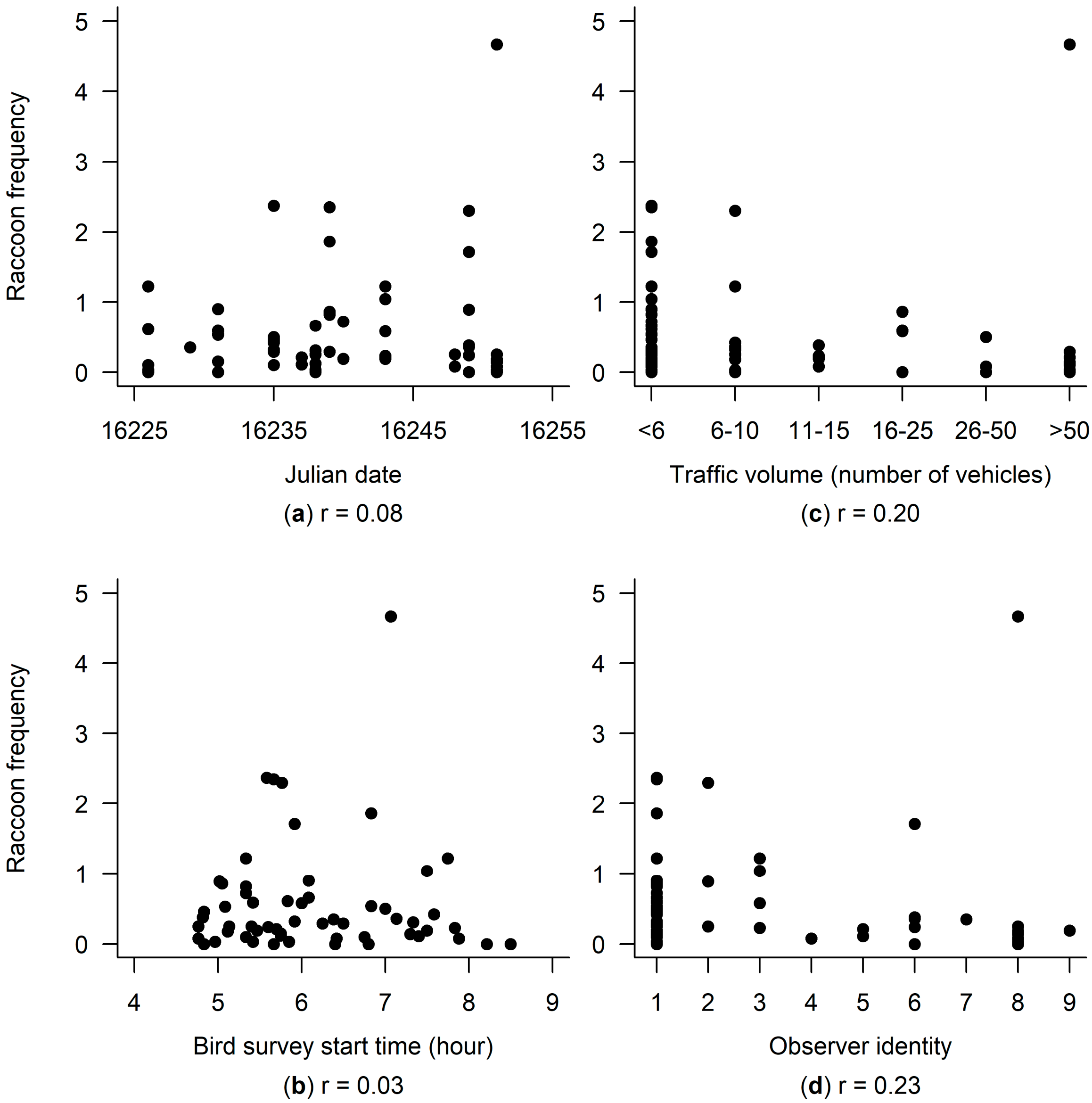


Figure S6. Bivariate plots showing relationships between raccoon frequency (number of days raccoons were observed by homeowners per week, averaged for all surveys within the landscape) and each of four variables that can influence bird detectability at the 58 landscapes: (**a**) bird survey date, (**b**) bird survey start time, (**c**) traffic volume, and (**d**) observer. Each of the nine observers that conducted bird surveys is coded by a unique number. We calculated the Pearson correlation coefficient (r) between raccoon frequency and date and start time (**a**, **b**). Relationships between raccoon frequency and traffic volume and observer were modeled by one-way ANOVA (**c**, **d**). For ease of comparison, the model r^2 was converted to r ($\sqrt{r^2}$).

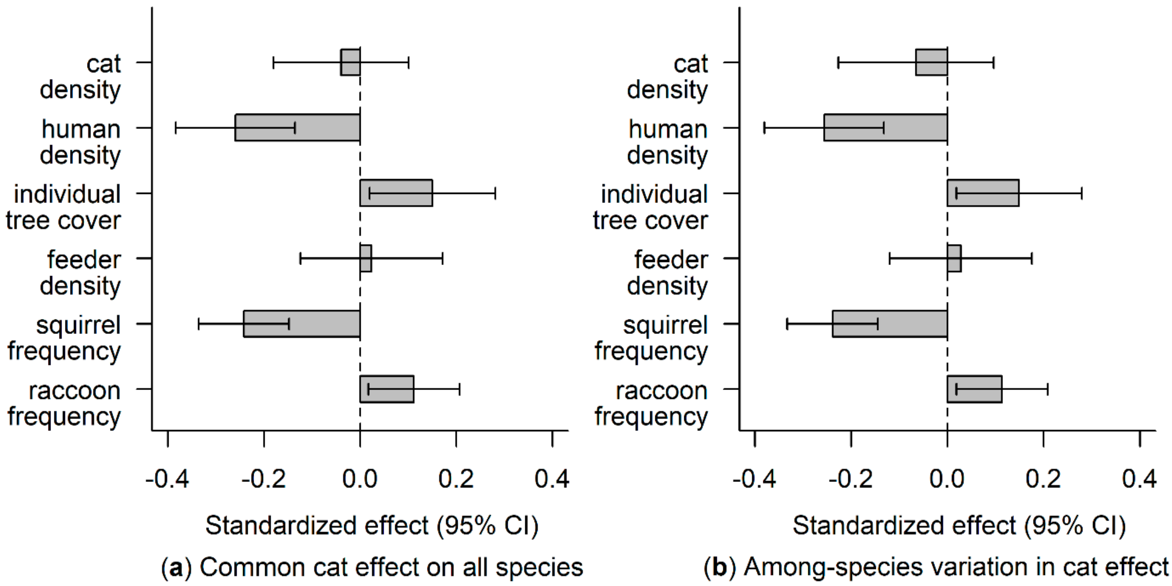


Figure S7. Comparison of the standardized effects of owned outdoor cat density, human population density, individual tree cover, feeder density, squirrel frequency, and raccoon frequency on bird species abundance from (**a**) a model that allowed for variation in overall abundance among bird species and (**b**) a model that allowed for among-species variation in overall abundance and the relationship between abundance and cat density.

Table S1. X^2 tests of association to determine whether a species's risk level for a given trait was independent of its risk level for each of the other four traits. Each bird species was classified as belonging to either the high-risk or low-risk category for each of five species traits. Each trait was modeled as a binary variable, with each species assigned to either the high-risk (1) or low-risk (0) category. A species was classified as high-risk for a given trait if it has a mean adult body size < 150 g; nests < 2 m from the ground; forages < 2 m from the ground; feeds at bird feeders; is migratory. Otherwise, the species was classified as low-risk.

Traits		**X^2**	**p**
body size	bird feeder use	1.19	0.39
body size	ground feeding	5.80	0.02
body size	ground nesting	0.51	0.65
body size	migration status	3.54	0.15
bird feeder use	feeding location	4.60	0.06
bird feeder use	nesting location	2.23	0.16
bird feeder use	migration status	24.51	<0.001
feeding location	nesting location	9.01	0.01
feeding location	migration status	3.47	0.08
nesting location	migration status	0.00	1.00

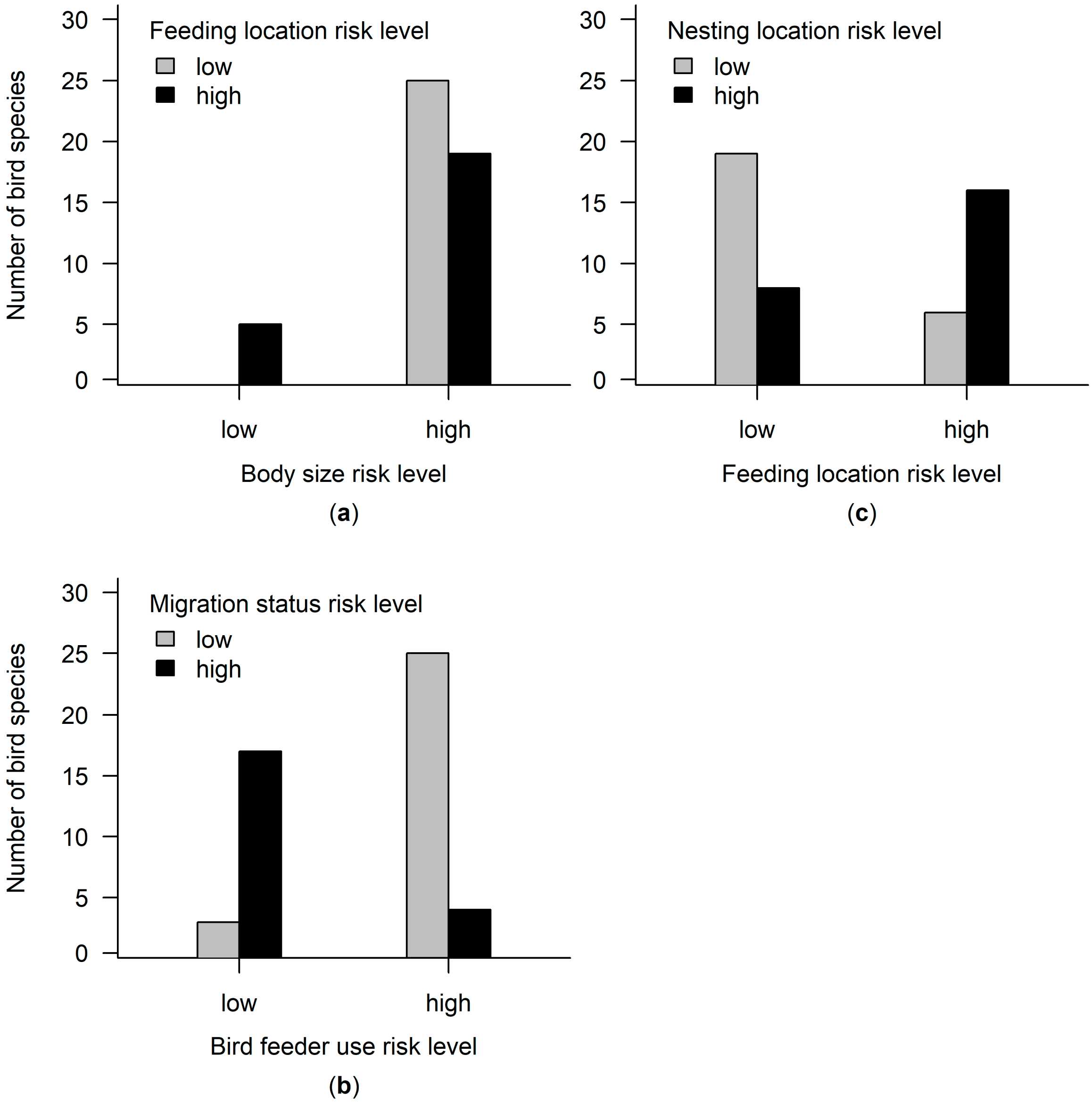


Figure S8. Proportion of bird species classified as high-risk versus low-risk, for each pair of traits where a species' risk level for a given trait was not independent of its risk level for another trait (based on a X^2 test of association; see Table S1).

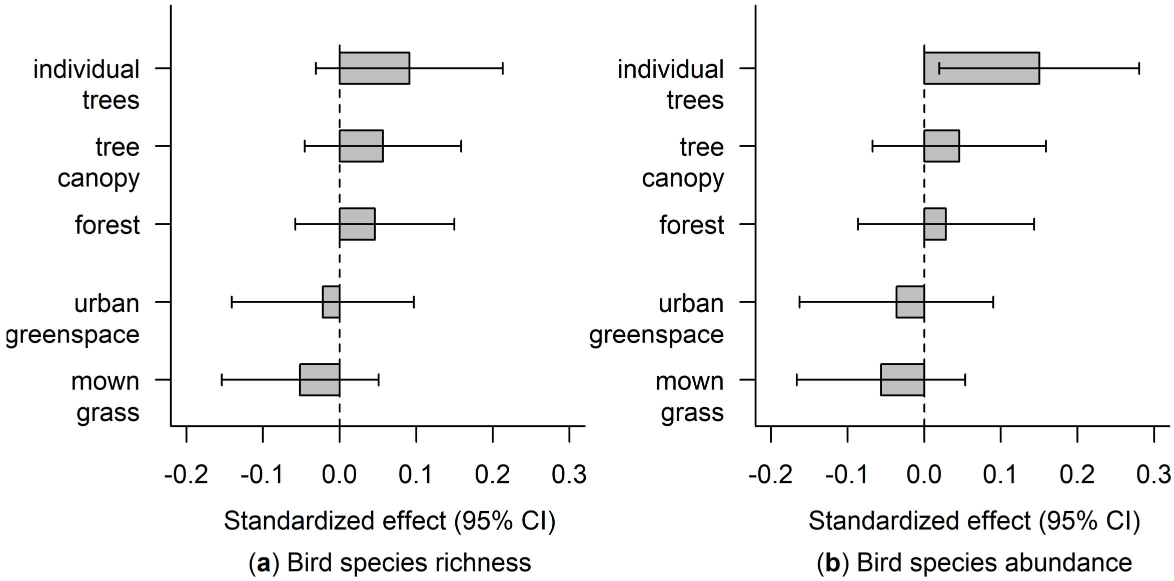


Figure S9. Standardized effects of five alternative measures of bird habitat availability on (**a**) bird species richness and (**b**) bird abundance. We used a generalized linear model with a Poisson distribution and log link to model the relationship between bird species richness and each measure of habitat availability, and a generalized linear mixed effects model with a negative binomial distribution, log link, and random effect of bird species identity to model the relationship between bird abundance and each measure of habitat availability. We included owned outdoor cat density, human population density, bird feeder density, squirrel frequency, and raccoon frequency in each model. We retained the measure of habitat availability with the strongest positive relationship with bird species richness/abundance, based on the size of the model coefficient. Effects are ordered from most positive (top) to most negative (bottom).

Table S2. Pairwise relationships among predictor variables: cat density (number of cats/landscape), cat activity (number of outdoor cat hours/day per landscape), human density (number of people/landscape), individual tree cover (proportional cover of trees within the landscape), bird feeder density (number of feeders/landscape), squirrel frequency (number of days squirrels were observed by homeowners per week, averaged for all surveys within the landscape), and raccoon frequency (number of days raccoons were observed by homeowners per week, averaged for all surveys within the landscape), across the 58 landscapes. We calculated the Spearman rank correlation (ρ) for each pairwise comparison.

	Cat activity	**Human density**	**Individual tree cover**	**Feeder density**	**Squirrel frequency**	**Raccoon frequency**
Cat density	0.91	0.49	0.40	0.69	-0.05	0.44
Cat activity		0.39	0.37	0.60	0.03	0.49
Human density			0.49	0.48	-0.24	0.23
Individual tree cover				0.61	0.05	0.27
Feeder density					0.05	0.43
Squirrel frequency						0.14

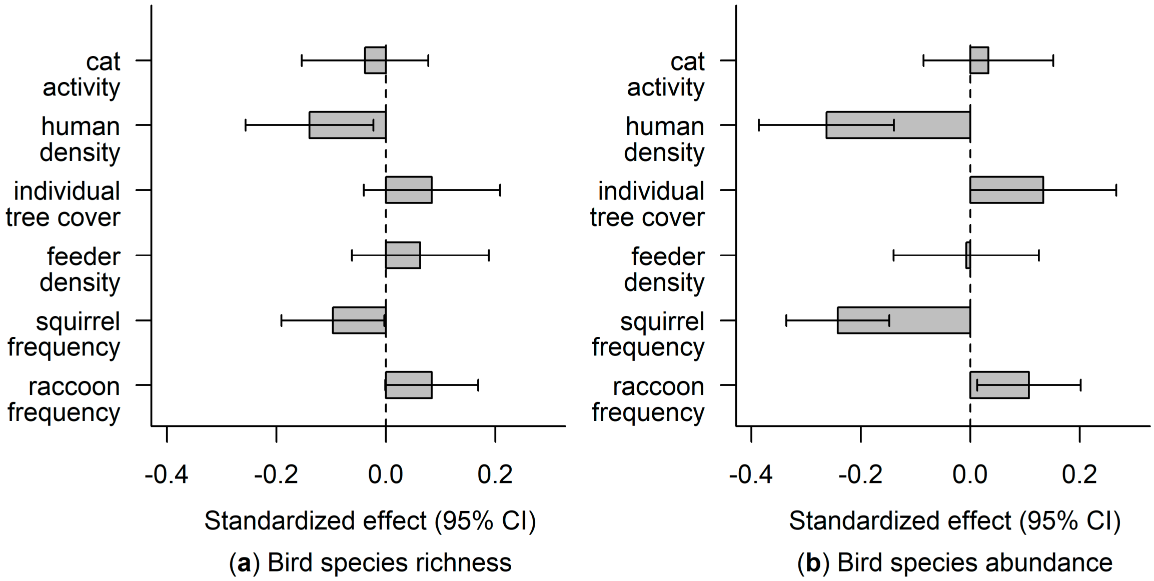
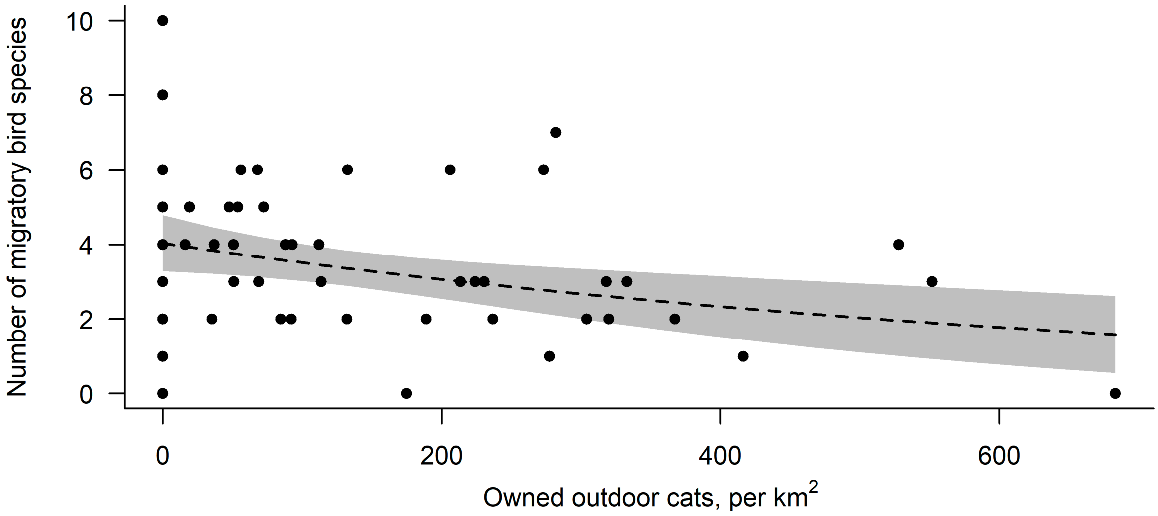
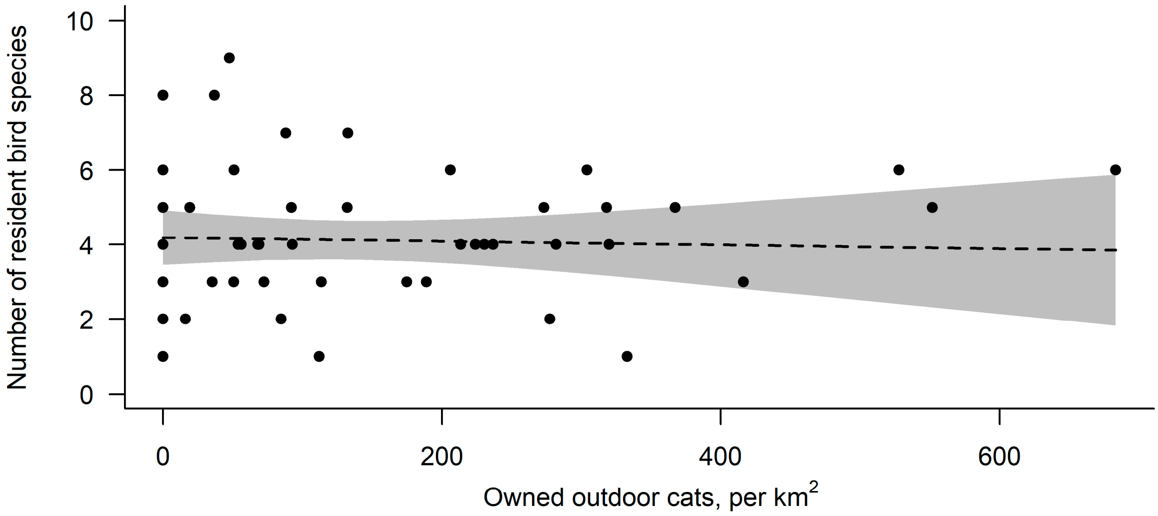


Figure S10. Standardized effects of owned outdoor cat activity, human population density, individual tree cover, feeder density, squirrel frequency, and raccoon frequency on bird species (**a**) richness and (**b**) abundance. Bird richness and abundance decreased with human population density and squirrel frequency. Birds were more abundant in landscapes with more individual trees and more raccoons. Bird responses to cat activity were weak. Relationships between bird species richness and the six standardized predictors were estimated from a generalized linear model with a Poisson distribution and a log link. Relationships between bird species abundance and the six standardized predictors were estimated from a generalized linear mixed effects model with a negative binomial distribution, log link, and random effect of species identity.



(**a**) Migratory bird species richness



(**b**) Resident bird species richness

Figure S11. Estimated relationships between owned outdoor cat density, measured as the number of cats/km^2, and the number of (**a**) migratory and (**b**) resident bird species. Relationships between bird species richness and cat density were predicted from a generalized linear model with a Poisson distribution and a log link, holding human population density, individual tree cover, feeder density, squirrel frequency, and raccoon frequency at their mean values. The model predicts (a) 0.7 additional migratory species and (b) 0.07 additional resident bird species if policies/programs reduced owned outdoor cat densities to zero in an average landscape, i.e. one with the mean cat density of 130.2 cats/km^2.

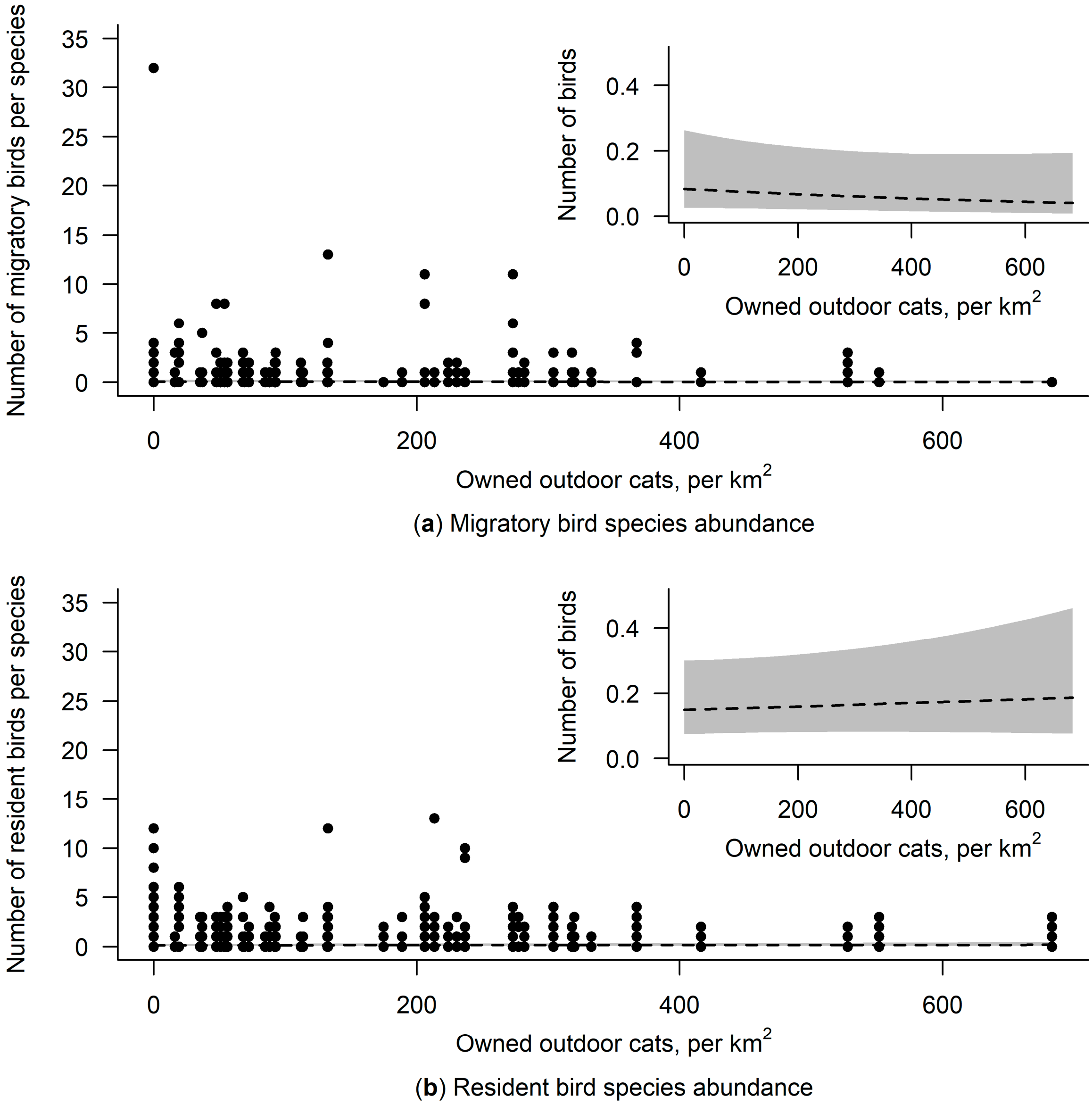


Figure S12. Estimated relationships between owned outdoor cat density, measured as the number of cats/km^2, and the number of (**a**) migratory and (**b**) resident birds per species. Relationships between bird species abundance and cat density were predicted from a generalized linear mixed effects model with a negative binomial distribution, log link, and random effect of species identity, holding human population density, individual tree cover, feeder density, squirrel frequency, and raccoon frequency at their mean values. The model predicts (a) 0.01 more individuals for a migratory species, and 0.006 fewer individuals for a resident species.

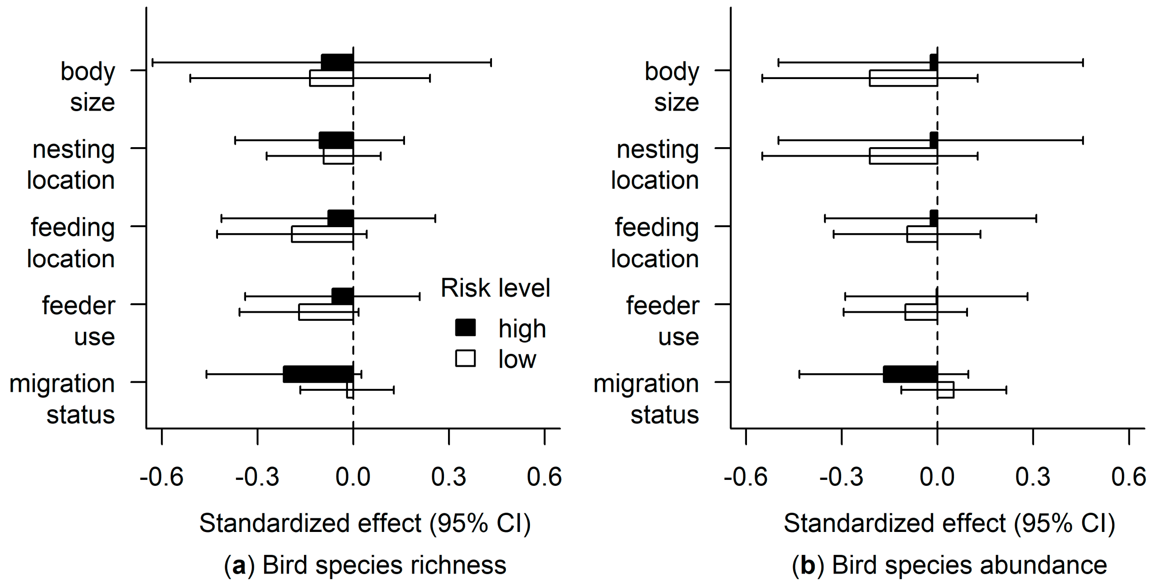


Figure S13. Marginal effects of owned cat density on birds with high-risk relative to low-risk species traits. We compared relationships between the standardized density of owned outdoor cats (number of cats / landscape) and (**a**) bird species richness and (**b**) pooled bird abundance for the high-risk relative to the low-risk species group for each of five bird species traits. Assumed high-risk traits were: low body mass, a tendency to nest or feed near the ground, a tendency to use bird feeders, and migratory behavior. For species richness, we used a generalized linear model with a Poisson distribution and log link, and modeled the interacting effects of cat density and each species trait, when controlling for the human population density, individual tree cover, bird feeder density, squirrel frequency, and raccoon frequency. We modeled bird abundance as above, with the exception that we used a generalized linear mixed effects model with a negative binomial distribution, log link, and random effect of species identity. All interactions were non-significant ($p > 0.26$), except for the interacting effect of cat density × migration status on bird species richness ($z = -2.00$, $p = 0.05$) and abundance ($z = -2.07$, $p = 0.04$). Confidence intervals for the marginal effects were calculated as in Brambor et al. [1].

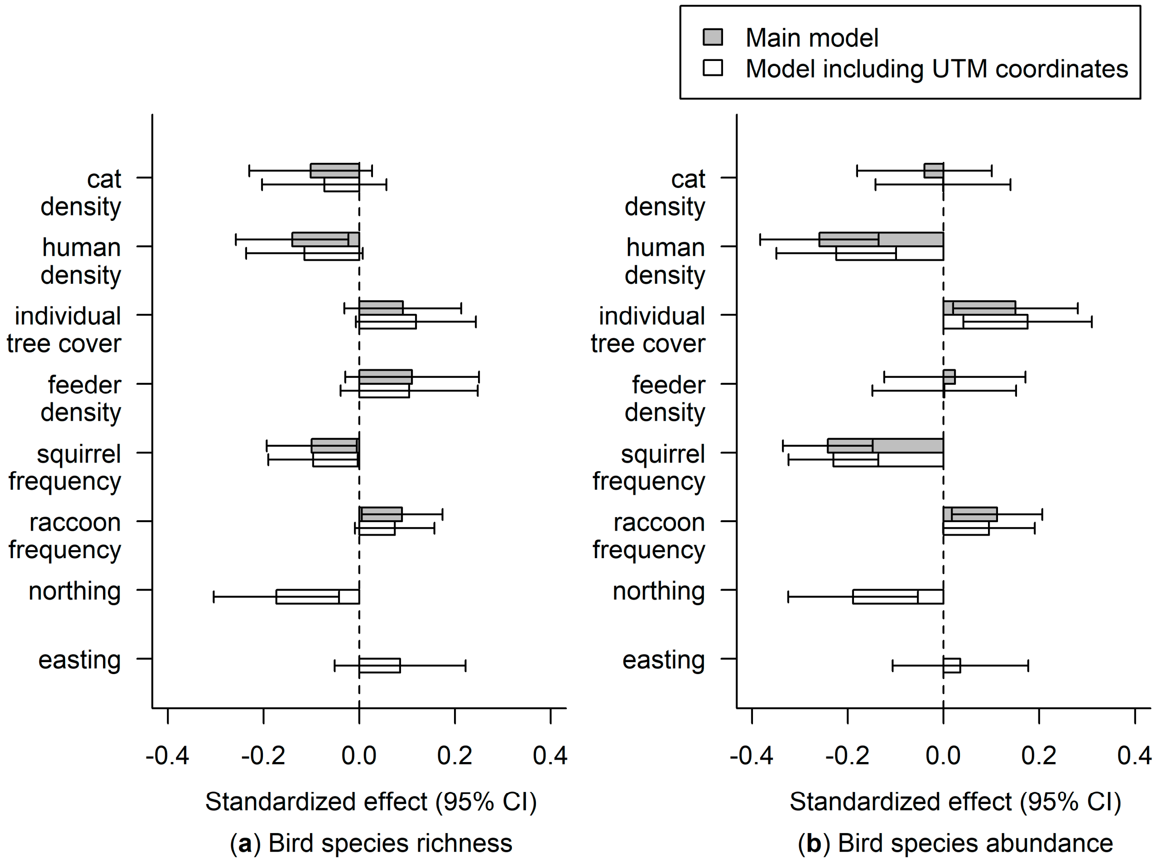


Figure S14. Comparison of the standardized effects of owned outdoor cat density, human population density, individual tree cover, feeder density, squirrel frequency, and raccoon frequency on bird species (**a**) richness and (**b**) abundance between our main model (see main text and Figure 3) versus a model that also included UTM coordinates of the sampling locations. Although there were fewer bird species, and fewer birds per species, at higher latitudes than at lower latitudes, the conclusions from these models was similar. In both cases we found weak and negative effects of cat density on birds. Relationships between bird species richness and the standardized predictors were estimated from a generalized linear model with a Poisson distribution and a log link. Relationships between bird species abundance and the standardized predictors were estimated from a generalized linear mixed effects model with a negative binomial distribution, log link, and random effect of species identity.

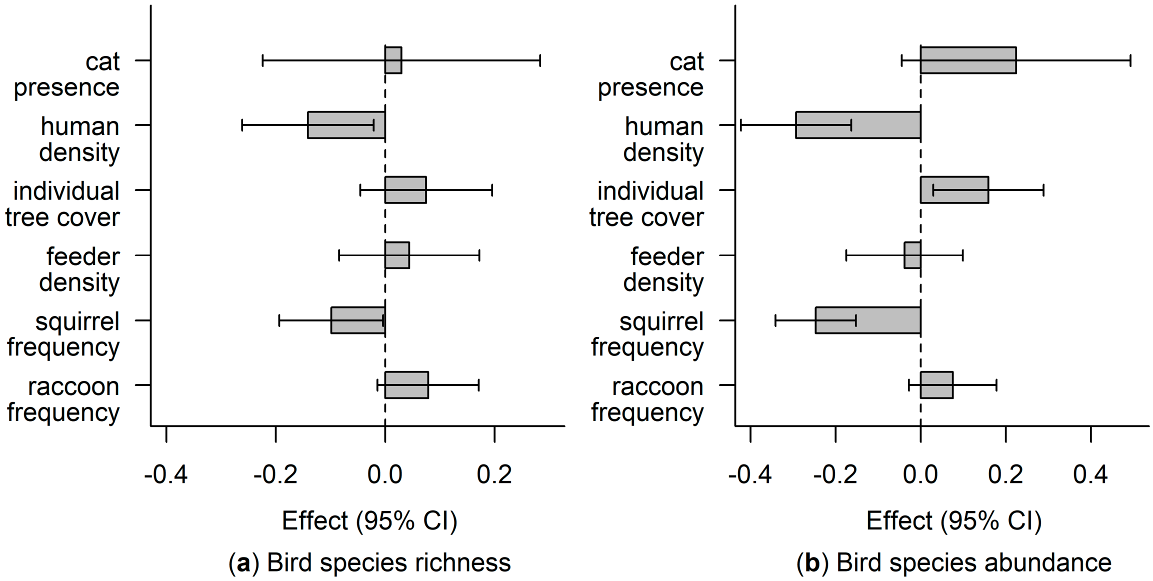


Figure S15. Effects of the presence-absence of owned outdoor cats, human population density, individual tree cover, feeder density, squirrel frequency, and raccoon frequency on bird species (**a**) richness and (**b**) abundance. Owned outdoor cats were classified as "present" at a site if the estimated cat density was > 0 (39 sites); otherwise, cats were classified as "absent" from the site (19 sites). Bird responses to the presence of owned outdoor cats were weak, with 95% confidence intervals (CI) that crossed zero. Relationships between bird species richness and the six predictors were estimated from a generalized linear model with a Poisson distribution and a log link. Relationships between bird species abundance and the six predictors were estimated from a generalized linear mixed effects model with a negative binomial distribution, log link, and random effect of species identity. Continuous predictors were standardized prior to analysis.

References

1. Brambor, T.; Clark, W.R.; Golder, M. Understanding interaction models: improving empirical analyses. *Polit. Anal.* **2006**, *14*, 63–82, doi:10.1093/pan/mpi014.