

*Type of the Paper (Article)*

# **Title: Urbanization and human population favor species richness of alien birds**

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**Supplementary Material**

MS-1968

MS-2007

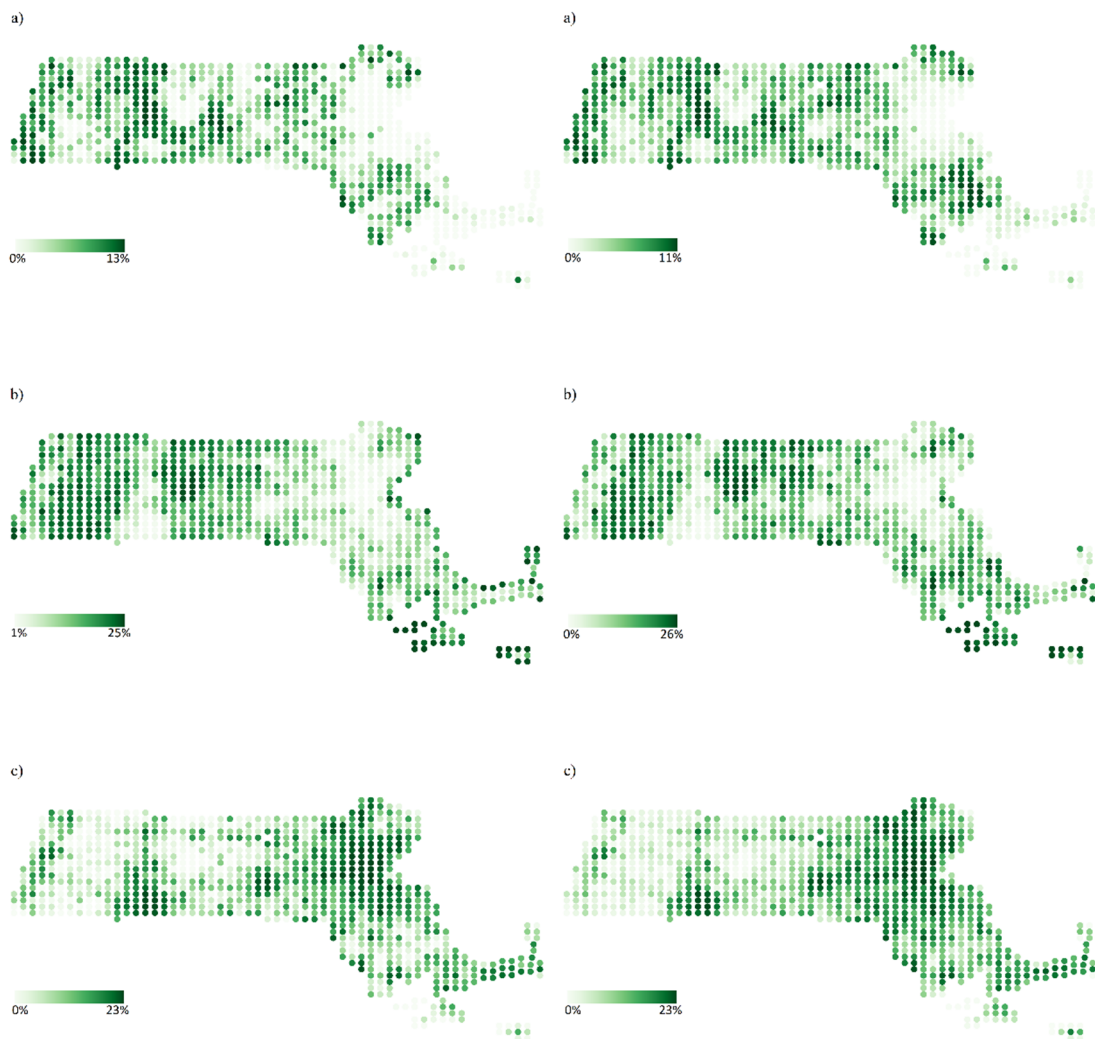


Figure S1. Area of agricultural land-uses (a), natural land-uses (b), and urban land-uses (c) in each atlas cell of the State of Massachusetts for the first time period MS-1968 (left column) and the second time period MS-2007 (right column).

Table S1 The grouping of different land uses obtained by the U.S. Geological Survey Land-Use (Price et al. 2006) for 1970-1980s and by 2006 version National Land Cover Database ( ) (Fry et al. 2011) (NLCD) for the second time period into three broad categories: urban, agricultural, and natural land uses.

	Land Use Category	Land Use Type
U.S. Geological Survey Land-Use for 1970-1980s	<b>Urban</b>	Residential, Commercial and services
		Industrial, Transportation, communication, utilities, Industrial and commercial complexes
		Mixed urban or built-up land
		Other urban or built-up land
	<b>Agricultural</b>	Cropland and pasture
		Orchards, groves, vineyards, nurseries, and ornamental horticultural
		Orchards, groves, vineyards, nurseries, and ornamental horticultural
		Confined feeding operations
		Other agricultural land
		Herbaceous rangeland
		Shrub and brush rangeland
	<b>Natural</b>	Deciduous forest land, Evergreen forest land
		Mixed forest land, Streams and canals, Lakes
Reservoirs, Bays and estuaries		
Forested wetland, Nonforested wetland		
Beaches, Sandy areas not beaches		
Strip mines, quarries, gravel pits, Transitional areas		
2006 version National Land Cover Database	<b>Urban</b>	Developed-Open Space
		Developed-Low Intensity
		Developed-Medium Intensity
		Developed-High Intensity
	<b>Agricultural</b>	Cultivated Crops
		Pasture/Hay
	<b>Natural</b>	Open Water
		Barren Land (Rock/Sand/Clay)
		Deciduous Forest
		Evergreen Forest
		Mixed Forest
		Shrub
		Grassland/Herbaceous
Woody Wetlands		
Emergent Herbaceous Wetlands		

Table S2 Results of Generalized Additive Models (GAM; Poisson error distribution and log link function) predicting alien species richness per grid cell ( $\alpha$ -diversity) as function of native species richness per grid cell ( $\alpha$ -diversity), agricultural area, urban area, natural area, and human population (smooth predictors with 3 knots per spline) of breeding birds of Massachusetts for the time period 1968-1972 (MS-1968) and 2007-2011 (MS-2007), after accounting for spatial autocorrelation i.e. inclusion of the grid cell's coordinates (longitude, latitude) as smooth predictors in the GAM models.

<b>MS-1968</b>					
<i>Parametric coefficients</i>					
	Estimate	Std. Error	z value	Pr(> z )	Significance
(Intercept)	2.01	0.01	158.10	<0.00	***
<i>Approximate significance of smooth terms</i>					
	edf	Chi.sq	p-value	Significance	
Native $\alpha$ -diversity	1.99	709.65	<0.00	***	
Natural area	1.00	0.33	0.57		
Agricultural area	1.00	8.36	0.00	**	
Urban area	1.82	26.23	0.00	***	
Human population	1.00	0.59	0.44		
(Longitude, Latitude)	22.46	310.80	<0.00	***	
R-squared (adjusted)=0.70, Deviance Explained = 66.20%, n=913					
<b>MS-2007</b>					
<i>Parametric coefficients</i>					
	Estimate	Std. Error	z value	Pr(> z )	Significance
(Intercept)	2.40	0.01	236.70	<0.00	***
<i>Approximate significance of smooth terms</i>					
	edf	Chi.sq	p-value	Significance	
Native $\alpha$ -diversity	1.92	284.95	<0.00	***	
Natural area	1.90	9.59	0.01	**	
Agricultural area	1.00	0.74	0.39		
Urban area	1.00	0.96	0.33		
Human population	1.00	4.31	0.04	*	
(Longitude, Latitude)	4.55	15.10	0.02	*	
R-squared (adjusted)=0.59, Deviance Explained = 58.10%, n=913					

Significance codes: p<0.05:\*, p<0.01:\*\*, p<0.001:\*\*\*

Table S3 Results of Generalized Additive Models (GAM; Poisson error distribution and log link function) predicting alien species richness per grid cell ( $\alpha$ -diversity) as function of native species richness per grid cell ( $\alpha$ -diversity), agricultural area, urban area, natural area, and human population (smooth predictors with 3 knots per spline) of breeding birds of Massachusetts for the time period 1968-1972 (MS-1968) and 2007-2011 (MS-2007), without using the grid cell's coordinates (longitude, latitude) of the grid cells as predictors in the GAM models.

<b>MS-1968</b>					
<i>Parametric coefficients</i>					
	Estimate	Std. Error	z value	Pr(> z )	Significance
(Intercept)	2.04	0.01	163.50	<0.00	***
<i>Approximate significance of smooth terms</i>					
	edf	Chi.sq	p-value	Significance	
Native $\alpha$ -diversity	1.95	831.09	<0.00	***	
Natural area	1.65	6.87	0.08		
Agricultural area	1.77	6.03	0.08		
Urban area	1.83	27.05	0.00	***	
Human population	1.73	16.45	0.00	***	
R-squared (adjusted)=0.56, Deviance Explained = 55.90%, n=913					
<b>MS-2007</b>					
<i>Parametric coefficients</i>					
	Estimate	Std. Error	z value	Pr(> z )	Significance
(Intercept)	2.40	0.01	236.80	<0.00	***
<i>Approximate significance of smooth terms</i>					
	edf	Chi.sq	p-value	Significance	
Native $\alpha$ -diversity	1.94	374.77	<0.00	***	
Natural area	1.95	22.04	0.00	***	
Agricultural area	1.00	0.72	0.40		
Urban area	1.00	2.43	0.12		
Human population	1.00	7.10	0.01	*	
R-squared (adjusted)=0.57, Deviance Explained = 56.10%, n=913					

Significance codes: p<0.05:\*, p<0.01:\*\*, p<0.001:\*\*\*

Table S4 Results of Generalized Additive Models (GAM; Poisson error distribution and log link function) predicting native species richness per grid cell ( $\alpha$ -diversity) as function of agricultural area, urban area, natural area, and human population (smooth predictors with 3 knots per spline) of breeding birds of Massachusetts for the time period 1968-1972 (MS-1968) and 2007-2011 (MS-2007), after accounting for spatial autocorrelation i.e. inclusion of the grid cell's coordinates (longitude, latitude) as smooth predictors in the GAM models.

<b>MS-1968</b>					
<i>Parametric coefficients</i>					
	Estimate	Std. Error	z value	Pr(> z )	Significance
(Intercept)	3.63	0.01	664.4	<0.00	***
<i>Approximate significance of smooth terms</i>					
	edf	Chi.sq	p-value	Significance	
Natural area	1.00	37.51	<0.00	***	
Agricultural area	1.87	111.34	<0.00	***	
Urban area	1.00	23.39	<0.00	***	
Human population	1.88	46.89	<0.00	***	
(Longitude, Latitude)	28.65	2060.89	<0.00	***	
R-squared (adjusted)=0.38, Deviance Explained = 35.50%, n=913					
<b>MS-2007</b>					
<i>Parametric coefficients</i>					
	Estimate	Std. Error	z value	Pr(> z )	Significance
(Intercept)	3.85	0.01	787.8	<0.00	***
<i>Approximate significance of smooth terms</i>					
	edf	Chi.sq	p-value	Significance	
Natural area	1.99	11.78	0.00	**	
Agricultural area	1.39	0.46	0.7		
Urban area	1.78	5.06	0.08		
Human population	1.86	33	0.00	***	
(Longitude, Latitude)	26.82	1142.93	0.00	***	
R-squared (adjusted)=0.46, Deviance Explained = 46.50%, n=913					

Significance codes: p<0.05:\*, p<0.01:\*\*, p<0.001:\*\*\*

Table S5 Results of Generalized Additive Models (GAM; Poisson error distribution and log link function) predicting native species richness per grid cell ( $\alpha$ -diversity) as function of agricultural area, urban area, natural area, and human population (smooth predictors with 3 knots per spline) of breeding birds of Massachusetts for the time period 1968-1972 (MS-1968) and 2007-2011 (MS-2007), without using the grid cell's coordinates (longitude, latitude) of the grid cells as predictors in the GAM models.

<b>MS-1968</b>					
<i>Parametric coefficients</i>					
	Estimate	Std. Error	z value	Pr(> z )	Significance
(Intercept)	3.66	0.01	688.10	<0.00	***
<i>Approximate significance of smooth terms</i>					
	edf	Chi.sq	p-value	Significance	
Natural area	1.83	6.76	0.03	*	
Agricultural area	1.94	96.02	<0.00	***	
Urban area	2.00	25.83	<0.00	***	
Human population	1.00	92.78	<0.00	***	
R-sq.(adj)=0.06, Deviance Explained = 7.00%, n=913					
<b>MS-2007</b>					
<i>Parametric coefficients</i>					
	Estimate	Std. Error	z value	Pr(> z )	Significance
(Intercept)	3.86	0.01	802.10	<0.00	***
<i>Approximate significance of smooth terms</i>					
	edf	Chi.sq	p-value	Significance	
Natural area	1.74	99.97	<0.00	***	
Agricultural area	1.91	80.27	<0.00	***	
Urban area	2.00	113.37	<0.00	***	
Human population	1.87	41.34	<0.00	***	
R-sq.(adj)=0.15, Deviance Explained = 13.30%, n=913					

Significance codes: p<0.05:\*, p<0.01:\*\*, p<0.001:\*\*\*