

Perry, KI, CA Bahlai, TJ Assal, CB Riley, KJ Turo, L Taylor, J Radl, YA Delgado de la flor, FS Sivakoff, and MM Gardiner. Landscape change and alien invasions drive shifts in native lady beetle communities over a century

Appendix 2

Table S2.1. NLCD reclassification crosswalk table. Version NLCD 2016 was used in the analysis (Dewitz 2019).

Map Class	NLCD Classification Description (Class Value)
Agriculture	Hay/Pasture (81) Cultivated Crops (82)
Developed	Developed, Open Space (21) Developed, Low Intensity (22) Developed, Medium Intensity (23) Developed, High Intensity (24)
Forest	Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43) Woody Wetlands (90)
Non-target	Open Water (11) Perennial Snow/Ice (12) Barren Land (31) Shrub/Scrub (52) Herbaceous (71) Emergent Herbaceous Wetlands (95)

Dewitz, J. (2019) National Land Cover Database (NLCD) 2016 Products (ver. 2.0, July 2020): U.S. Geological Survey data release. <https://doi.org/10.5066/P96HHBIE>.

Table S2.2. Historical LULC backcast reclassification crosswalk table for years 1938, 1970, 1992. Version from Sohl et al. (2018) was used in the analysis.

Map Class	Backcast Classification Description (Class Value)
Agriculture	Cultivated Cropland (13) Hay/Pasture (14)
Developed	Urban/Developed (2) Mining (6)
Forest	Deciduous Forest (8) Evergreen Forest (9) Mixed Forest (10) Woody Wetland (16)
Non-target	Open Water (1) Barren (7) Grassland (11) Shrubland (12) Herbaceous Wetland (15)

Sohl, T., Reker, R., Bouchard, M., Sayler, K., Dornbierer, J., Wika, S., Quenzer, R. & Friesz, A. (2018) Modeled historical land use and land cover for the conterminous United States: 1938-1992: U.S. Geological Survey data release. <https://doi.org/10.5066/F7KK99RR>.

Table S2.3. Ohio lady beetle records from institutions across the United States (1900-2018). We compiled historic data records from 25 institutions across the US and identified 4,194 specimens from 28 lady beetle species. Data collection was focused on Coccinellinae specimens and four additional species: *Brachiacantha ursina*, *Chilocorus stigma*, *Hyperaspis undulata*, and *Psyllobora vigintimaculata*.

Lady beetle species	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	Total
<i>Adalia bipunctata</i>	6	8	8	49	18	22	66	15	20	6	0	0	218
<i>Anatis labiculata</i>	1	10	4	26	36	23	27	6	18	19	1	5	176
<i>Anatis mali</i>	0	0	0	5	1	5	4	3	1	0	2	2	23
<i>Anisosticta bitriangularis</i>	0	0	5	0	0	0	0	1	0	0	0	10	16
<i>Brachiacantha ursina</i>	8	19	19	111	20	27	21	6	5	3	12	4	255
<i>Chilocorus stigma</i>	18	10	6	12	5	4	17	2	13	13	7	4	111
<i>Coccinella novemnotata</i>	10	21	28	41	7	28	16	13	5	0	0	0	169
<i>Coccinella septempunctata</i>	0	0	0	0	0	0	0	4	47	6	19	26	102
<i>Coccinella transversoguttata</i>	0	0	5	4	0	4	3	25	10	0	0	0	51
<i>Coccinella trifasciata</i>	0	3	5	4	0	1	5	1	0	0	0	0	19
<i>Coccinella undecimpunctata</i>	0	0	0	0	0	1	0	0	0	0	0	0	1
<i>Coleomegilla maculata</i>	11	14	32	135	11	22	71	55	263	28	9	39	690
<i>Cycloneda munda</i>	10	4	13	28	10	16	46	32	65	10	48	20	302
<i>Harmonia axyridis</i>	0	0	0	0	0	0	0	0	0	35	199	236	470
<i>Hippodamia convergens</i>	6	14	15	131	23	30	66	37	62	1	1	14	400
<i>Hippodamia glacialis</i>	1	4	3	13	4	1	1	5	2	0	3	2	39
<i>Hippodamia parenthesis</i>	20	12	51	102	22	20	30	29	40	0	13	14	353
<i>Hippodamia quindecimmaculata</i>	2	0	0	1	0	0	0	0	0	0	0	0	3
<i>Hippodamia tredecimpunctata</i>	6	5	8	82	6	4	31	5	5	0	0	3	155
<i>Hippodamia variegata</i>	0	0	0	0	0	0	0	0	0	0	4	6	10
<i>Hyperaspis undulata</i>	5	3	6	28	1	3	5	2	3	2	3	0	61
<i>Mulsantina luteodorsa</i>	0	0	0	0	0	0	0	0	0	0	1	0	1
<i>Mulsantina picta</i>	0	0	2	16	12	3	11	3	1	0	2	1	51

<i>Myzia pullata</i>	0	0	0	12	5	6	1	1	1	0	3	1	30
<i>Neoharmonia venusta</i>	2	0	0	63	32	13	3	1	2	1	1	1	119
<i>Olla v-nigrum</i>	0	0	0	5	0	14	0	0	1	0	1	0	21
<i>Propylea quatuordecimpunctata</i>	0	0	0	0	0	0	0	0	0	0	6	21	27
<i>Psyllobora vigintimaculata</i>	2	5	8	95	11	11	9	3	51	60	61	5	321
Total Collections	108	132	218	963	224	258	433	249	615	184	396	414	4194
Total Collections of Natives	108	132	218	963	224	257	433	245	568	143	168	125	3584
Total Species	15	14	17	21	17	21	19	21	20	12	20	19	28
Total Native Species	15	14	17	21	17	20	19	20	19	10	16	15	23

Table S2.4. Results for permutational multivariate analysis of variance (PERMANOVA) and analysis of multivariate homogeneity of group dispersions (BETADISPER) for taxonomic community similarity of all lady beetle species and aphidophagous lady beetle species across decades in Ohio, USA. PERMANOVA tests whether the centroid of communities differs among groups in multivariate space, while BETADISPER tests whether groups differ in the amount of dispersion from its spatial median among communities within a group. Beta-diversity indices were incidence-based pairwise Sorensen dissimilarity (β_{sor}) which was partitioned into turnover (β_{sim} ; reflects species replacement) and nestedness (β_{sne} ; reflects species loss or gain) components. Significant differences ($\alpha < 0.05$) in lady beetle community similarity are indicated in bold.

Decades	Test		All Lady Beetle Species			Aphidophagous Species		
			(β_{sim})	(β_{sne})	(β_{sor})	(β_{sim})	(β_{sne})	(β_{sor})
1900s-1910s	PERMANOVA	<i>F</i>	4.56	-1.04	2.35	4.35	-1.08	2.23
		<i>P</i>	0.111	0.923	0.066	0.155	0.963	0.102
	BETADISPER	<i>F</i>	5.10	2.78	0.09	6.23	1.12	0.06
		<i>P</i>	0.043	0.121	0.760	0.028	0.310	0.810
1910s-1920s	PERMANOVA	<i>F</i>	0.53	24.92	1.01	0.08	49.49	0.60
		<i>P</i>	0.571	0.011	0.466	0.657	0.003	0.633
	BETADISPER	<i>F</i>	4.75	1.99	0.99	2.27	0.06	2.37
		<i>P</i>	0.049	0.183	0.337	0.157	0.805	0.149
1920s-1930s	PERMANOVA	<i>F</i>	2.19	5.51	3.88	2.57	3.38	2.99
		<i>P</i>	0.301	0.060	0.014	0.241	0.120	0.025
	BETADISPER	<i>F</i>	0.93	0.49	1.45	1.26	0.32	2.29
		<i>P</i>	0.352	0.495	0.250	0.282	0.580	0.155
1930s-1940s	PERMANOVA	<i>F</i>	-1.73	5.86	3.12	-68.35	5.68	2.96
		<i>P</i>	0.866	0.073	0.003	0.997	0.056	0.008
	BETADISPER	<i>F</i>	4.75	1.16	5.80	3.91	1.85	5.45
		<i>P</i>	0.046	0.299	0.030	0.067	0.194	0.034
1940s-1950s	PERMANOVA	<i>F</i>	0.33	2.08	1.06	-3.44	2.70	1.19
		<i>P</i>	0.614	0.230	0.376	0.967	0.159	0.381
	BETADISPER	<i>F</i>	0.56	0.28	0.33	0.25	1.19	0.24
		<i>P</i>	0.465	0.604	0.572	0.619	0.292	0.626
1950s-1960s	PERMANOVA	<i>F</i>	2.23	6.65	1.10	1.73	13.04	0.91
		<i>P</i>						

		<i>P</i>	0.215	0.037	0.387	0.313	0.004	0.483
	BETADISPER	<i>F</i>	0.002	0.58	0.39	0.01	2.55	1.31
		<i>P</i>	0.963	0.456	0.539	0.917	0.132	0.270
1960s-1970s	PERMANOVA	<i>F</i>	0.05	1.63	0.46	1.38	0.45	0.92
		<i>P</i>	0.857	0.277	0.805	0.348	0.533	0.442
	BETADISPER	<i>F</i>	3.25	5.69	0.92	1.10	0.30	2.06
		<i>P</i>	0.092	0.031	0.352	0.311	0.591	0.172
1970s-1980s	PERMANOVA	<i>F</i>	0.03	-0.14	0.33	0.60	0.55	0.43
		<i>P</i>	0.717	0.735	0.947	0.636	0.483	0.812
	BETADISPER	<i>F</i>	1.12	2.26	0.01	1.57	0.58	1.06
		<i>P</i>	0.305	0.154	0.943	0.231	0.459	0.320
1980s-1990s	PERMANOVA	<i>F</i>	4.32	0.50	2.94	1.73	32.80	4.73
		<i>P</i>	0.091	0.570	0.021	0.260	0.004	0.012
	BETADISPER	<i>F</i>	0.42	0.32	0.18	1.62	0.39	1.89
		<i>P</i>	0.527	0.577	0.672	0.226	0.540	0.194
1990s-2000s	PERMANOVA	<i>F</i>	4.98	0.22	3.36	3.32	2.80	4.00
		<i>P</i>	0.061	0.670	0.009	0.151	0.171	0.010
	BETADISPER	<i>F</i>	2.73	0.47	0.53	3.52	0.99	0.33
		<i>P</i>	0.122	0.504	0.479	0.083	0.335	0.570
2000s-2010s	PERMANOVA	<i>F</i>	2.24	0.08	1.58	0.24	2.49	0.75
		<i>P</i>	0.190	0.960	0.187	0.709	0.108	0.605
	BETADISPER	<i>F</i>	0.04	0.47	0.25	0.001	0.40	0.56
		<i>P</i>	0.832	0.501	0.624	0.994	0.536	0.465

Figure S2.2. Number of collections of native aphidophagous lady beetle species in Ohio by decade from 1900 to 2018.

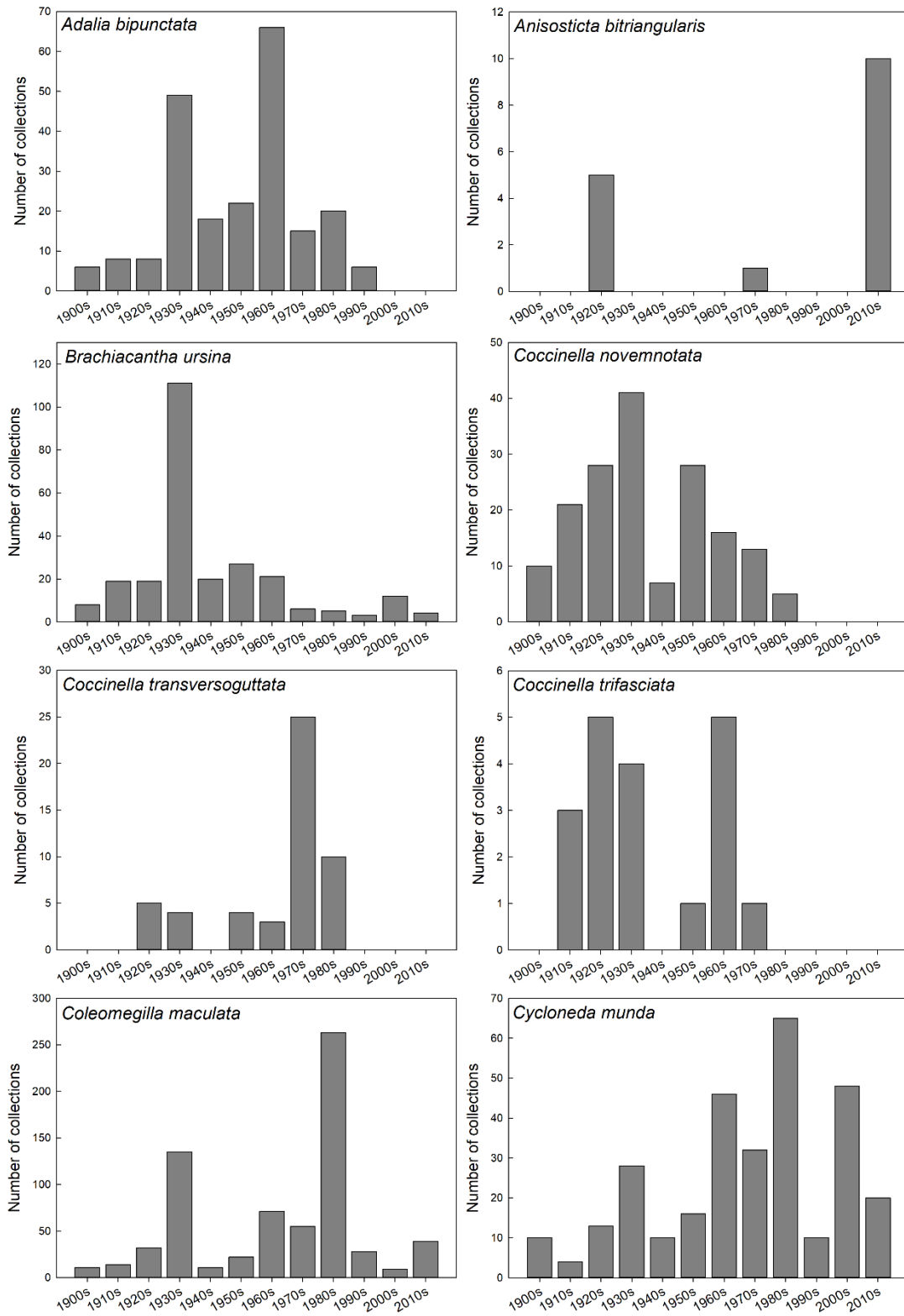


Figure S2.3. Number of collections of native aphidophagous lady beetle species (continued) in Ohio by decade from 1900 to 2018.

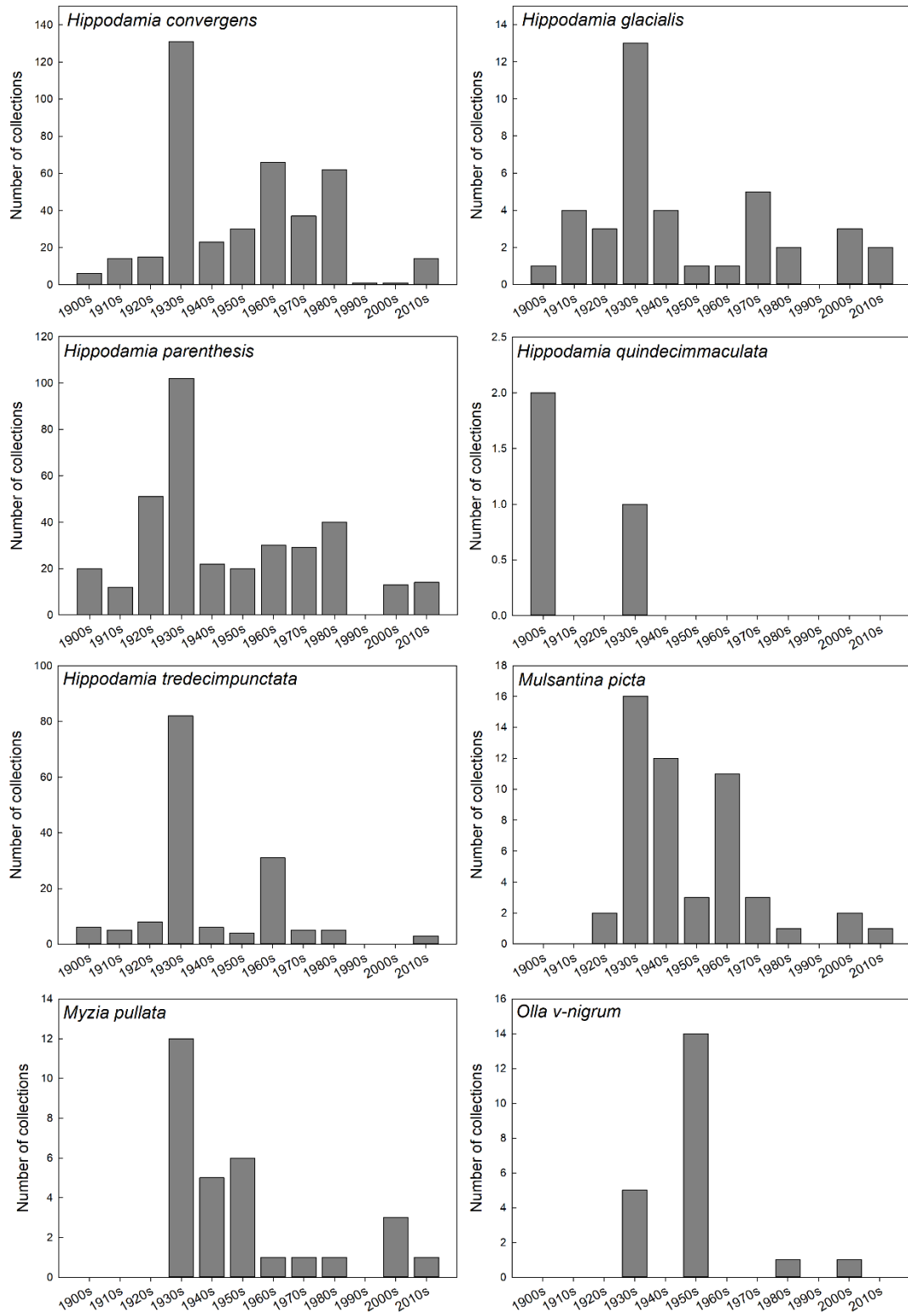


Figure S2.4. Number of collections of native coccidophagous and fungivorous lady beetle species in Ohio by decade from 1900 to 2018.

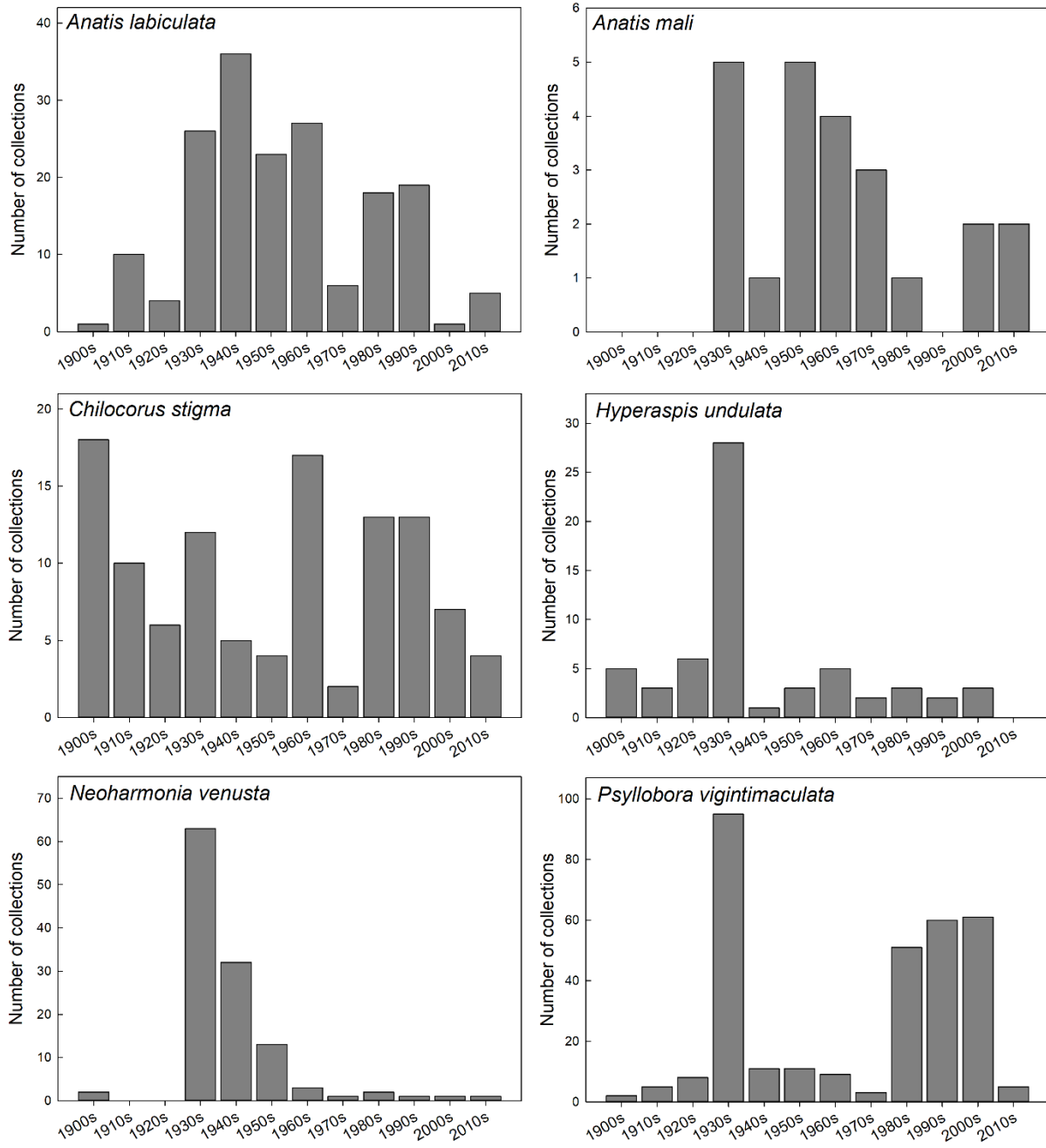


Figure S2.5. Non-metric multidimensional scaling (NMDS) ordination depicting incidence-based pairwise Sorensen dissimilarity (β_{sor}) for lady beetle museum records across decades in Ohio, USA. Results for permutational multivariate analysis of variance (PERMANOVA) are provided in Appendix 1: Table 2 and significant comparisons between (A) the 1920s and 1930s; (B) the 1930s and 1940s; (C) the 1980s and 1990s; and (D) the 1990s and 2000s are depicted here.

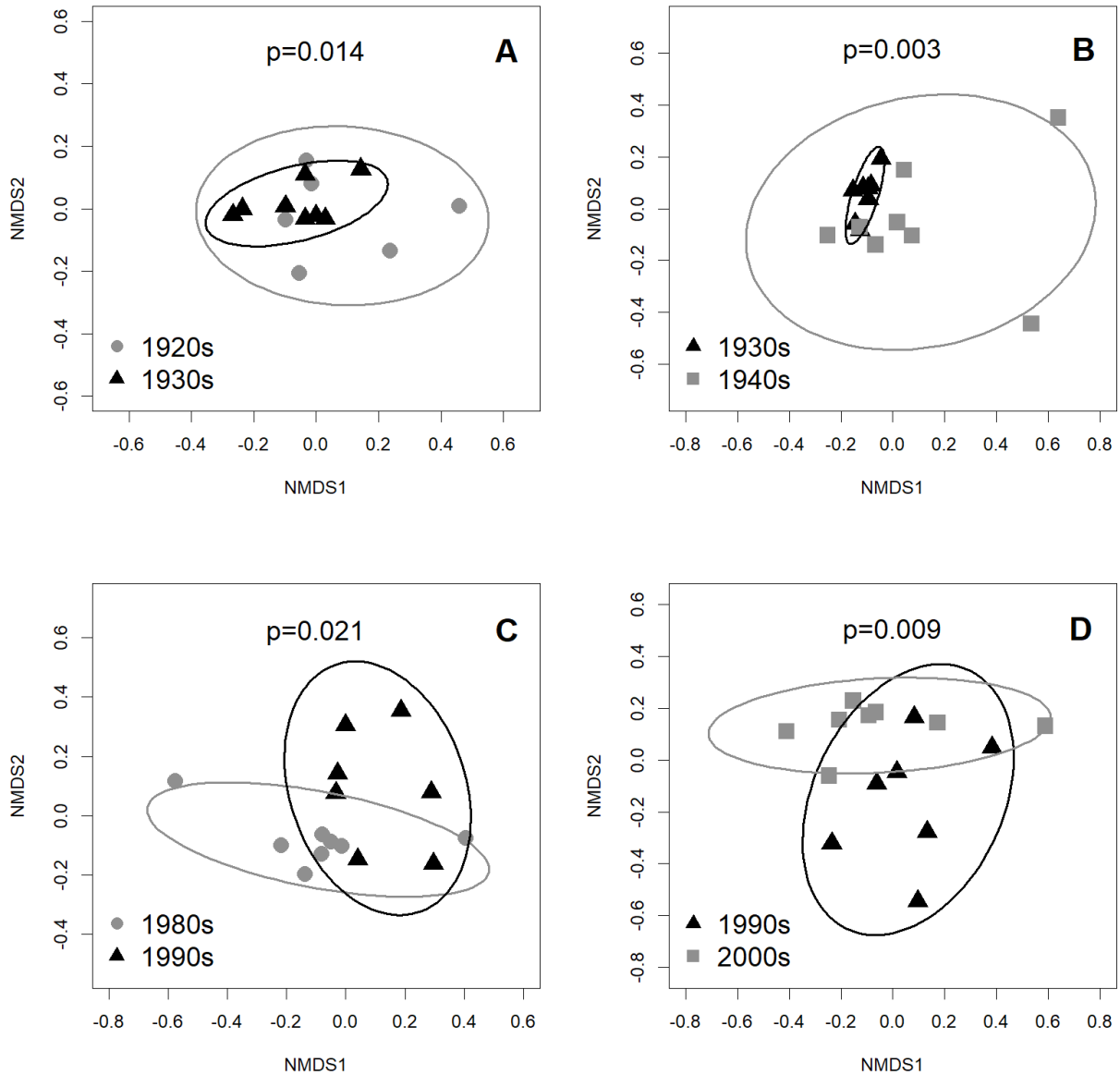


Figure S2.6. The variability in Ohio land cover area by county. Horizontal black lines represent the median. Boxes extend to the 25th and 75th percentile. Whiskers extend to the most extreme data point, which is no more than 1.5 times the interquartile range from the box. Data beyond the end of the whiskers are outlying points and are plotted individually.

