Supporting Information

Ricklefs 10.1073/pnas.1018642108

SI Text S1. Plot and Species Selection

All data were obtained from the Breeding Bird Census (BBC) program in Canada and the United States. The program is described by James D. Lowe on the website http://www.pwrc.usgs.gov/birds/bbc.html. Further information, including the quality and limitations of the BBC data, can be obtained from refs. 1 and 2.

The BBC program should not be confused with the Breeding Bird Survey (BBS) program (http://www.pwrc.usgs.gov/BBS/index.html), which reports species seen or heard along a large number of 25-km, 50-stop survey routes, each of which is driven once each year.

BBC data were kindly made available in digital format by James D. Lowe of the Cornell University (Ithaca, NY) Laboratory of Ornithology. The data cover census years 1991–1996 and included 763 censuses conducted at 278 sites (average 2.7 censuses per site) in which a total of 385 species of bird were recorded. I restricted the sample to census plots and birds typical of eastern forests (deciduous, needle-leafed, and mixed). This region corresponds to the Eastern Temperate Forest Region (Region 8) of the Commission for Environmental Cooperation (3) and the Temperate Broadleaf and Mixed Forest Ecoregion of the World Wildlife Fund (4). Topography is moderate and regional conditions are dominated by a north–south temperature gradient and an east–west precipitation gradient. I excluded raptorial (hawks and owls) and galliform (quail and grouse) species, which occurred in very low densities. Initially, censuses were retained if they included mostly eastern forest habitat; all grasslands, marshes, savannas, and shrublands were excluded, leaving 397 censuses from 146 sites including 119 species. I further deleted 33 species present at <10 sites (retaining golden-crowned kinglet and Nashville warbler, with 8 sites apiece) and also several species present at >10 sites but not typically forest birds (common grackle, eastern kingbird, red-winged blackbird, European starling, American goldfinch, tree swallow, eastern bluebird), leaving 79 species. Next, 4 sites with <12 remaining species among the 79 were deleted, leaving 142 sites (Fig. S1). Basic statistics for plots, and plot and species lists, are provided in Tables S1–S3.

SI Text S2. Plot Ordinations

Stand ordinations were performed in PCORD (http://home.centurytel.net/~mjm/pcordwin.htm). I used a Bray–Curtis ordination with the default parameters (Sorensen distance measure; variance-regression endpoint selection measure; Euclidean axis projection geometry; Euclidean residual distances; number of axes = 9; scores calculated for species by weighted averaging). Nine axes reported by the software extracted 64.2% of the original variance in the data, as shown in Table S4. Distributions of the axis scores over the 142 sites are summarized in Table S5.

The proportions of the variance extracted were compared with a broken-stick model of random subdivision of the total variance, $p_k = \frac{1}{s}\sum_{j=0}^{s-k}\frac{1}{s-j}$, where p is the proportion of the kth smallest of s segments (5). The variance of the ordinated axes exceeds the broken-stick expectation through seven axes. An ordination of row-shuffled species data (densities at a site randomly assigned to each of the 79 species regardless of its presence in the community) placed 2.2–3.0% of the variance on each axis.

The species × site incidence matrix was also subjected to ordination by correspondence (redundancy) analysis (RA, with down-weighted rare species), which returned three axes representing 39% of the distributional variance, and nonmetric multidimensional scaling (NMS), which returned two significant axes. The site scores from the RA and NMS ordinations were compared with those from the Bray–Curtis (BC) ordination by canonical correlation analysis (SAS procedure CANCORR). The RA scores explained 93, 85, and 67% of the variation in the first three BC axes, but only 8–37% of the variation in axes 4–9. The NMS scores explained 88 and 85% of the variation in the first two BC axes, but only 0–34% of the variation in axes 3–9.

As is common in Bray–Curtis ordination, the derived axes were not fully orthogonal. The 36 Pearson product-moment correlations among the scores of the 142 census sites on the nine axes averaged 0.025 ± 0.172 SD, and the P-values averaged 0.255 ± 0.265 SD, with 11 of the 36 having $P < 0.05$. The correlations among the scores of the 79 species on the nine axes averaged −0.034 ± 0.322 SD, and the P values averaged 0.180 ± 0.264 SD, with 17 of the 36 having $P < 0.05$. The nearly twofold greater SD in the correlation coefficients calculated for species compared with those calculated for sites reflects the similar habitat preferences of many species.

Thirty-nine of the species in this analysis also were included in James's (6) classic study of the distribution of forest birds with respect to habitat (vegetation structure) characteristics in Arkansas. The ordination scores for these species on BC axes 1, 3, and 4, calculated across the eastern North American sites, were statistically related ($F_{3,35} = 16.6$, $P < 0.0001$, $R^2 = 0.59$) to a discriminant function that James (6) used to separate the distributions of these species in Arkansas across several habitat principal components. The correspondence between these two approaches emphasizes the close association of several of the BC axes with habitat variables important to birds, including forest canopy height and openness.

SI Text S3. Climate Correlations

For the latitude–longitude coordinates for each of the census sites, 19 BIOCLIM variables (http://fennerschool.anu.edu.au/publications/software/anuclim/doc/bioclim.html) based on monthly or weekly values of maximum temperature, minimum temperature, and precipitation were downloaded into a data file: P1, annual mean temperature; P2, mean diurnal range (mean(period max-min)); P3, isothermality (P2/P7); P4, temperature seasonality (coefficient of variation); P5, max temperature of warmest period; P6, min temperature of coldest period; P7, temperature annual range (P5–P6); P8, mean temperature of wettest quarter; P9, mean temperature of driest quarter; P10, mean temperature of warmest quarter; P11, mean temperature of coldest quarter; P12, annual precipitation; P13, precipitation of wettest period; P14, precipitation of driest period; P15, precipitation seasonality (coefficient of variation); P16, precipitation of wettest quarter; P17, precipitation of driest quarter; P18, precipitation of warmest quarter; and P19, precipitation of coldest quarter. Variables P4, P13, P15, and P16 were then $\log_{10}$-transformed to make the distributions more nearly normal. Using stepwise regression with backward elimination (SAS procedure STEPWISE), the proportions of the variance in the BC scores accounted for by the BIOCLIM variables were BC1 = 0.81, BC2 = 0.58, BC3 = 0.34, BC4 = 0.46, BC5 = 0.32, BC6 = 0.51, BC7 = 0.52, BC8 = 0.18, and BC9 = 0.33. In a canonical correlation analysis (SAS procedure CANCORR) relating scores on the nine BC ordination axes to the 19 BIOCLIM variables, seven of nine correlations for the canonical axes were $P < 0.001$, and the correlations varied between 0.96 and 0.35. Thus, especially the first BC axis picks up a strong climate gradient (from south to north in eastern North America), whereas the other axes are related to climate to varying degrees, but not particularly strongly in most cases.

SI Text S4. Species Richness and Population Density

Using the SAS STEPWISE procedure with backward elimination of variables, the log-transformed number of species reported from each census site was significantly related ($F_{6,135}$ = 60.2, $P <$ 0.0001, R^2 = 0.73) to the log-transformed number of territories, partly reflecting the size of the census plot (b = 0.342 ± 0.030, F = 133, $P <$ 0.0001) and five of the BC axis scores, but especially BC4 (F = 122, $P <$ 0.0001) and BC6 (F = 57, $P <$ 0.0001). None of the squared terms was significant in a general linear model (SAS GLM procedure) with all nine BC axes included; and neither were the interaction terms between BC4, BC6, and BC9, which controlled most of the variation.

After entering the log-transformed number of territories (b = 0.372 ± 0.037, F = 99.8, $P <$ 0.0001), the BIOCLIM variables P4, P6, P15, P16, and P17 contributed statistically only marginally (P = 0.008–0.068) to variation in the log-transformed density after backward elimination of nonsignificant variables in the SAS STEPWISE procedure ($F_{6,135}$ = 20.9, $P <$ 0.0001, R^2 = 0.493).

The overall density of birds on census plots was also well described by the Bray–Curtis scores ($F_{9,132}$ = 51.5, $P <$ 0.0001, R^2 = 0.78), with significant contributions of the log-transformed number of species (P = 0.002) and all of the ordination axes (P = 0.0001–0.048) except BC2. The relationship was not improved by squared terms or interactions. Overall density was also significantly related ($F_{10,131}$ = 3.6, P = 0.0003, R^2 = 0.22) to BIOCLIM variables P1, P2, P5, P6, P8, P9, P11, P12, P16, and P17.

SI Text S5. Nested Analysis of Variance

I used the taxonomic assignments set forth in the TIF World List, version 4.1 (January 6, 2010), compiled by S. Nawrocki, University of Indianapolis, based on the "Taxonomy in Flux" weblist of birds of the world by J. Boyd (http://jboyd.net/Taxo/List.html). This taxonomy is updated regularly on the basis of recently published molecular phylogenies of birds and provides a nesting of species in a taxonomic hierarchy according to uniform criteria (see the list of species in *SI Text S1*, above). Analyses were carried out with the SAS procedures NESTED and MIXED, the latter using restricted maximum likelihood (REML) estimation and the denominator degrees of freedom estimated by the Satterthwaite method. Proc MIXED was used to check on the statistical significance of variance at higher taxonomic levels. Results of these analyses are presented in Tables S6 (site data), S7 (BC axis score means), S8 (BC axis score standard deviations), S9 (morphological principal components), and S10 (morphological ANOVAs).

SI Text S6. Rank Correlation Statistics

Significant values of Spearman's rank correlation coefficient (r) exceed a value of $t = 2$ (~P = 0.05), where $t = r\sqrt{(n-2)/(1-r^2)}$ (7). For n = 142 census sites and t = 2, the critical value of r = 0.167, which corresponds to about 2 times the SD of the correlation coefficients for randomized data.

SI Text S7. Foraging Group Analysis

The 79 species were divided into 20 taxonomically based, evolutionarily monophyletic foraging groups: warblers (22 species), finches (10 species), woodpeckers (7 species), vireos (5 species), thrushes (5 species), flycatchers (5 species), icterid (4 species), parid (3 species), wren (3 species), corvid (2 species), mimid (2 species), nuthatch (2 species), tanager (2 species), creeper (1 species), cuckoo (1 species), dove (1 species), gnatcatcher (1 species), hummingbird (1 species), kinglet (1 species), and waxwing (1 species). Morphological data were not available for two woodpeckers, a wren, and the hummingbird (n = 75). Eight principal component axes based on eight log-transformed morphological variables (total length, wing length, tail length, tarsus length, midtoe length, and the length, width, and depth of the bill measured at its base) were subjected to a one-way analysis of variance with foraging group as the main effect. The statistical tests for each of the PC axes are presented in Table S7. The density of each species averaged over all 142 census plots (i.e., including zeroes) exhibited a similar positive trend with respect to number of species per group, but the relationship was not significant ($F_{1,17}$ = 3.87, P = 0.066).

SI Text S8. Population Size Distribution

The total population size of a species (summed local densities over the entire region, n = 142 plots) varied widely among species, from 1.3 (brown thrasher) to 84.1 (red-eyed vireo). The distribution of the total population sizes conforms closely to a geometric distribution (Fig. S2) (8), except for the overly abundant populations of the ovenbird (*Seiurus aurocapillus*) and the red-eyed vireo (*Vireo olivaceus*). A geometric distribution can result from a random birth–death process with homogeneous rates. It can also represent the "broken-stick" distribution for n species obtained by randomly breaking a line (representing the summed abundance of all species) at $n - 1$ points (5, 9). Either way, the distribution of species abundances within the regional community cannot be distinguished from the outcome of several types of random processes.

SI Text S9. Sister Species Distributions

The distribution of geographic range sizes within a region depends, in part, on the mechanism of species formation, the resulting sizes of the isolated daughter populations, and the subsequent expansion of the ranges of those populations (10). The geographic distributions of birds included in this analysis, and those of their closest relatives, suggest that species richness within the regional community is driven primarily by species formation occurring broadly within North America and not within the eastern deciduous forest biome. Thus, relative range sizes within the regional community are not directly influenced by species formation and the subdivision of ancestral distributions. For example, in the genus *Dendroica* (including *Parula*) (11, 12), with nine species included in this analysis, plus three species represented in <10 census sites, sister taxa of several of the species occur outside the regional community, either in southwestern North America (*Dendroica chrysoparia* as sister to *Dendroica virens*; *Parula pitiayumi* as sister to *Parula americana*) or in boreal forest to the north [*Dendroica castanea* as sister to *Dendroica fusca*; *Dendroica striata* as sister to *Dendroica pensylvanica*; and possibly *Dendroica palmarum* as sister to *Dendroica pinus*, although the relationships are unclear and *D. pinus* might be more closely related to *Dendroica dominica*, which occurs largely within the study area (but was infrequent in the census sites considered here), or to *Dendroica coronata*, which occurs in the northern part of the study area and in boreal forest].

Little can be said about extinction in this regional community, except that several species of eastern North American birds, including Kirtland's warbler (*Dendroica kirtlandii*) and Bachman's warbler (*Vermivora bachmanii*), currently have small, localized populations and, in the latter case, might be extinct.

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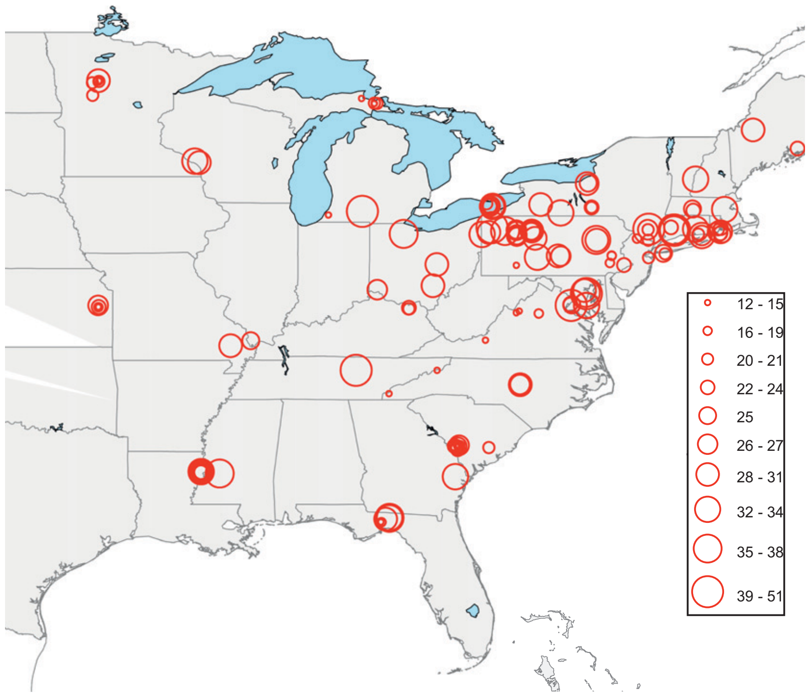

Fig. S1. Distribution of 142 census sites in North America. The concentration of localities in the northeastern United States corresponds to the large number of ornithologists in this area. Closely overlapping symbols generally indicate censuses in different forest types within the same area. Size of symbols indicates number of species recorded in each census site. The map was prepared by W. Jetz.

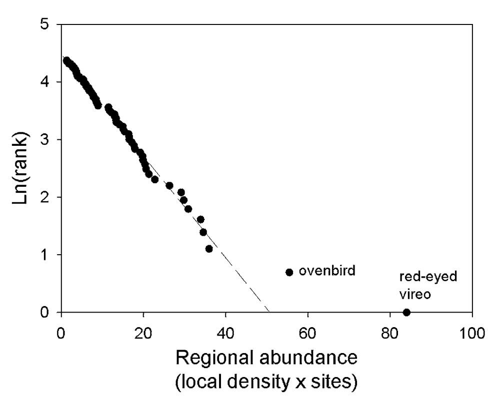

Fig. S2. The relationship of the logarithm of species rank by abundance (n = 79) as a function of the regional abundance. With the exception of the ovenbird (*Seirus aurocapillus*) and red-eyed vireo (*Vireo olivaceus*), the distribution conforms closely to that of geometric and broken-stick distributions, which characterize a number of random processes. The ovenbird and red-eyed vireo are two of the most conspicuous birds of eastern North American forests (1, 2), because of their persistent, distinctive singing, and their abundance might be overestimated as a result.

1. Van Horn MA, Donovan TM (1994) Ovenbird (*Seiurus aurocapilla*). *The Birds of North America Online*, ed Poole A (Cornell Lab of Ornithology, Ithaca, NY). Available at http://bna.birds.cornell.edu/bna/species/088.
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Table S1. Basic statistics for the plots (data for species and territories averaged over years)

	Latitude	Longitude	Years	Species	Territories	Plot size, ha	Elevation, m
N	142	142	142	142	142	142	103
Average	39.53	80.45	2.7	25.6	88.7	13.4	291.2
SD	4.25	6.79	1.9	7.8	44.1	5.8	301.5
Minimum	30.28	63.52	1	11.8	16.5	6	1.5
Maximum	47.13	95.35	6	50.5	270.2	42.3	1511

Table S2. List of plots used in the analysis

	Site	State	Latitude	Longitude	Years	Species	Territories	Plot size	Elevation
1	Brewer	FL	30.40	84.15	1	29.0	124.5	15.7	53.5
2	CT1253099	CT	41.22	72.06	5	34.0	93.9	23.1	—
3	CT1265009	CT	41.42	73.13	6	35.8	92.7	8.5	—
4	CT1289097	CT	41.27	72.19	6	20.0	110.8	10.5	122.0
5	CT1291035	CT	41.46	72.30	4	33.3	119.3	21.5	97.0
6	CT2765006	CT	41.42	73.12	6	44.5	102.5	10.1	—
7	CT2765008	CT	41.43	73.12	6	42.8	114.5	10.5	—
8	CT2778262	CT	41.42	73.10	6	43.8	98.4	8.5	—
9	CT2787001	CT	41.53	73.24	2	22.5	75.0	15.8	—
10	Carlile	GA	32.02	81.48	2	33.0	64.3	20.0	38.5
11	DC0461014	DC	38.57	77.03	6	24.2	74.5	26.3	—
12	DC1060009	DC	38.55	77.05	6	41.3	270.2	14.2	—
13	Dawson	SC	33.13	80.20	5	20.6	126.5	8.4	15.0
14	Dowell	MD	38.54	76.46	1	34.0	179.5	14.5	49.0
15	Eddleman	MO	37.21	89.30	1	25.0	68.0	11.3	—
16	Elliott1	LA	32.21	91.20	1	31.0	110.0	13.5	24.0
17	Elliott2	LA	32.20	91.20	1	30.0	123.0	13.5	23.0
18	Elliott3	LA	32.19	91.21	1	28.0	102.0	13.5	22.5
19	Elliott4	LA	32.19	91.20	1	22.0	103.0	13.5	23.0
20	FF	NC	35.53	79.00	6	30.5	97.1	12.6	—
21	FL0393022	FL	30.28	84.30	1	17.0	34.5	12.0	37.0
22	FL0393023	FL	30.29	84.32	4	14.5	33.9	10.5	24.0
23	Fallon	MD	38.55	76.46	1	32.0	140.0	14.5	52.0
24	Fox	MO	37.02	90.07	1	28.0	110.0	10.6	103.5
25	GA0493113	GA	30.45	84.00	2	37.5	110.3	20.0	—
26	GA0493114	GA	30.45	84.00	2	34.0	122.3	20.0	—
27	Gauthey	MD	38.58	77.08	5	23.4	69.5	7.6	16.5
28	Gutsell	ON	42.34	80.17	1	23.0	137.5	12.0	—
29	Hinkle	VA	38.33	79.04	2	13.0	33.8	6.1	—
30	Hochadel	OH	41.26	80.46	3	31.3	64.8	12.1	275.0
31	KS3391021	KS	38.55	95.13	3	27.3	48.8	10.1	251.5
32	Knapp	MI	42.14	85.03	6	47.0	208.5	28.2	285.0
33	Koehler	SC	33.19	81.50	1	20.0	81.0	12.7	36.0
34	MA1291049	MA	42.21	71.19	1	31.0	162.5	28.0	91.5
35	MA1293106	MA	42.23	72.42	2	24.0	59.8	10.1	202.0
36	MA1293107	MA	42.17	72.39	2	21.5	36.3	10.1	43.0
37	MD0490088	MD	39.03	76.49	1	38.0	241.0	42.0	—
38	MD049008a	MD	39.00	76.47	1	43.0	186.0	38.0	36.5
39	MD1071036	MD	39.12	76.54	3	29.7	134.2	11.9	108.5
40	MDF	NC	35.54	79.01	6	26.0	73.3	12.6	—
41	ME27	ME	44.54	68.40	2	22.0	42.5	10.4	—
42	ME2889052	ME	45.25	70.10	6	28.7	67.3	16.0	463.5
43	MI2885037	MI	46.45	85.06	4	12.0	39.1	16.0	—
44	MI2892103	MI	46.27	84.57	2	20.0	87.3	18.6	777.0
45	MI2892104	MI	46.26	84.57	2	14.0	69.5	18.6	875.0
46	MI2892105	MI	46.26	84.47	2	21.0	103.3	18.6	700.0
47	MI2892106	MI	46.25	84.58	2	14.5	73.3	18.6	895.0
48	MN1793105	MN	44.06	91.44	3	31.0	126.2	12.2	213.3
49	MN2090021	MN	47.10	95.10	2	21.0	98.3	10.0	495.3
50	MN2090022	MN	47.13	95.12	2	29.0	132.5	11.5	452.5
51	MN2090023	MN	47.13	95.12	2	17.5	116.8	10.0	483.0
52	MN2091070	MN	47.05	95.35	3	21.3	145.2	13.4	466.5
53	MN2091071	MN	46.57	95.34	2	20.0	78.0	13.4	452.5

Table S2. Cont.

	Site	State	Latitude	Longitude	Years	Species	Territories	Plot size	Elevation
54	MN3091044	MN	47.12	95.10	1	15.0	73.5	10.0	466.5
55	Marshall	NY	42.29	76.27	1	20.0	36.0	13.5	—
56	Moore	MS	32.14	90.49	5	36.8	146.6	10.0	—
57	Mullins	MI	42.00	86.33	6	13.8	20.5	8.5	—
58	NJ1064032	NJ	41.04	74.11	5	20.6	37.0	16.2	—
59	NY0989093	NY	40.52	73.47	3	21.3	62.5	10.1	—
60	NY0991069	NY	40.54	73.53	2	25.0	74.5	10.0	39.5
61	NY0995101	NY	40.37	74.10	1	19.0	26.0	16.2	1.5
62	NY1383002	NY	41.46	74.09	2	50.5	150.0	42.3	228.5
63	NY1392063	NY	41.44	74.13	1	26.0	83.0	15.8	335.5
64	NY1395014	NY	41.44	74.12	2	21.0	36.5	12.0	345.0
65	NY1686026	NY	43.20	76.44	6	28.5	76.5	16.2	88.5
66	NY1689013	NY	43.22	76.40	1	25.0	95.0	16.2	87.0
67	NY2474107	NY	42.08	77.45	6	32.2	85.1	16.6	—
68	NY2491013	NY	42.29	76.27	1	23.0	36.5	17.3	—
69	NY2494046	NY	42.40	78.22	3	30.3	62.3	11.0	452.5
70	OH1591043	OH	39.15	84.46	6	25.8	94.9	16.0	215.0
71	OH1593017	OH	38.46	83.26	2	23.0	69.3	10.0	290.0
72	OH1596017	OH	38.42	83.26	1	20.0	70.0	10.0	—
73	OH1689033	OH	41.28	83.46	6	36.5	138.7	18.0	—
74	OH2237200	OH	40.11	82.19	4	29.0	57.3	14.2	297.0
75	OH2291008	OH	39.30	82.34	3	29.0	107.5	10.0	—
76	OHFI	KS	38.48	95.12	1	17.0	37.0	8.1	—
77	OHFII	KS	38.49	95.12	1	13.0	24.5	8.1	—
78	OHFIII	KS	38.49	95.11	1	22.0	42.5	8.1	—
79	PA1091004	PA	40.09	75.03	6	21.8	76.0	10.0	73.0
80	PA1093123	PA	40.17	75.57	3	17.3	41.0	10.9	185.5
81	PA1377204	PA	41.04	76.07	2	30.0	56.5	6.0	—
82	PA1377205	PA	41.05	76.09	2	37.0	98.5	11.1	—
83	PA1382312	PA	40.44	75.50	6	17.3	43.2	19.3	—
84	PA1382313	PA	40.45	75.50	6	18.5	44.3	16.9	—
85	PA1391026	PA	40.44	77.55	6	29.5	97.3	19.2	282.5
86	PA1394005	PA	40.43	77.45	3	26.3	129.0	27.0	432.5
87	PA2493079	PA	41.21	79.13	2	25.5	133.8	15.0	471.5
88	PA2493080	PA	41.20	79.13	2	25.5	152.0	15.0	480.5
89	PA2493081	PA	41.20	79.13	2	24.0	93.3	18.2	409.0
90	PA2493082	PA	41.24	79.13	2	26.5	131.0	15.0	473.5
91	PA2493083	PA	41.39	78.57	2	26.0	153.5	12.0	564.0
92	PA2493084	PA	41.39	78.56	2	29.0	136.8	12.0	553.5
93	PA2494117	PA	41.10	74.54	1	17.0	59.5	12.3	152.5
94	PA2494130	PA	41.39	79.58	1	35.0	77.5	7.5	420.5
95	PA2494131	PA	41.34	80.20	1	29.0	63.5	9.8	386.0
96	PA2494132	PA	40.39	78.34	1	33.0	75.0	10.3	494.0
97	PA2494133	PA	41.11	78.43	1	29.0	87.0	15.0	548.5
98	PA2494134	PA	41.20	79.12	1	25.0	160.5	15.0	451.5
99	PA2494135	PA	41.38	78.57	1	26.0	111.5	12.0	521.5
100	PA2494136	PA	41.38	78.57	1	25.0	130.0	12.0	554.5
101	PA2494137	PA	41.42	79.15	1	24.0	104.0	12.0	556.5
102	PA2494138	PA	41.42	79.15	1	27.0	88.0	10.0	553.0
103	PA2494139	PA	40.08	79.15	3	14.7	36.7	10.0	826.0
104	Palmer	ON	42.33	80.10	1	25.0	69.5	10.0	178.5
105	Payzant	NS	44.55	63.52	1	18.0	49.5	12.3	175.0
106	Prior	ON	42.33	80.17	1	27.0	164.5	12.0	178.5
107	RI1290086	RI	41.30	71.35	4	22.3	76.0	10.1	—
108	RI1290087	RI	41.27	71.29	5	24.0	83.5	10.1	15.0
109	RI1291062	RI	41.36	71.46	5	26.0	87.4	10.2	130.0
110	RI1291065	RI	41.44	71.43	5	21.2	73.3	10.6	155.0
111	RI1294106	RI	41.50	71.33	2	23.5	60.5	10.6	131.0
112	RI1294110	RI	41.36	71.34	1	29.0	91.5	10.3	91.0
113	ROSMF	ON	42.34	80.15	2	25.5	121.3	11.0	181.5
114	SC0492031	SC	33.19	81.38	3	25.3	77.5	12.2	62.5
115	SC0492033	SC	33.07	81.39	2	21.5	59.3	11.0	26.0

Table S2. Cont.

	Site	State	Latitude	Longitude	Years	Species	Territories	Plot size	Elevation
116	SC0492034	SC	33.22	81.34	3	25.7	57.0	12.2	80.5
117	SC0492035	SC	33.15	81.44	1	19.0	44.0	12.2	56.5
118	SC0492036	SC	33.17	81.47	3	23.0	87.8	12.2	40.5
119	SC0493100	SC	33.11	81.34	2	17.0	30.3	12.2	77.5
120	SC0493102	SC	33.22	81.30	2	16.5	25.3	12.2	100.5
121	SC0493133	SC	33.19	81.51	3	23.0	81.3	12.3	39.0
122	SC0495040	SC	33.19	81.52	1	17.0	102.0	11.4	32.5
123	SC0495051	SC	33.18	81.43	1	13.0	16.5	12.2	66.5
124	Snyder	PA	41.52	80.08	1	44.0	80.5	8.1	—
125	Swanson	WI	44.00	91.27	1	28.0	85.0	12.6	265.0
126	TFAT	CT	41.22	72.06	5	25.6	25.3	6.5	—
127	TN1491015	TN	36.08	85.27	6	42.3	51.3	10.2	309.0
128	TN2392093	TN	36.08	82.18	5	11.8	37.6	9.9	1511.0
129	TN2392102	TN	35.19	84.02	5	14.2	80.2	10.2	1457.0
130	TS	ON	42.33	80.05	2	29.5	121.8	8.8	178.5
131	TWCS	ON	42.33	80.05	1	33.0	101.0	8.8	178.5
132	TwedtBHF1	LA	32.21	91.20	1	29.0	106.0	13.5	24.0
133	TwedtBHF2	LA	32.20	91.20	1	26.0	128.0	13.5	23.0
134	TwedtBHF3	LA	32.19	91.21	1	22.0	114.5	13.5	22.5
135	TwedtBHF4	LA	32.19	91.20	1	25.0	135.5	13.5	23.5
136	VA1083031	VA	38.24	78.29	6	17.8	56.1	6.1	907.0
137	VA1087013	VA	38.24	78.29	6	16.3	55.0	6.1	843.0
138	VA1391037	VA	38.27	79.15	3	14.3	36.2	6.1	—
139	VA1392010	VA	37.23	80.33	1	15.0	31.0	10.0	1168.0
140	VT2791010	VT	43.37	72.30	4	31.3	54.6	12.3	326.5
141	Wallace	ON	42.43	80.28	1	19.0	44.5	11.5	219.5
142	Wojnowski	ON	42.34	80.17	1	25.0	152.5	12.0	178.5

Plot size is in hectares; elevation is in meters.

Table S3. Species in descending order of number of sites occupied, including the taxonomic groups (superfamily, family, genus) used in the nested analysis of variance

	Species code	Group	Superfamily	Family	Genus	Species
1	REEVIR	Vireo	Corvoidea	Vireonidae	*Vireo*	*olivaceus*
2	EAWPEW	Flycatcher	Tyrannoidea	Tyrannidae	*Contopus*	*virens*
3	DOWWOO	Woodpecker	Piciformes	Picidae	*Dryobates*	*pubescens*
4	GRCFLY	Flycatcher	Tyrannoidea	Tyrannidae	*Myiarchus*	*crinitus*
5	BLUJAY	Corvid	Corvoidea	Corvidae	*Cyanocitta*	*cristata*
6	BNHCOW	Icterid	Passeroidea	Icteridae	*Molothrus*	*ater*
7	HAIWOO	Woodpecker	Piciformes	Picidae	*Leuconotopicus*	*villosus*
8	TUFTIT	Parid	Sylvioidea	Paridae	*Baeolophus*	*bicolor*
9	WHBNUT	Nuthatch	Certhioidea	Sittidae	*Sitta*	*carolinensis*
10	NORCAR	Finch	Passeroidea	Cardinalidae	*Cardinalis*	*cardinalis*
11	SCATAN	Tanager	Passeroidea	Cardinalidae	*Piranga*	*olivacea*
12	WOOTHR	Thrush	Muscicapoidea	Turdidae	*Hylocichla*	*mustelina*
13	PILWOO	Woodpecker	Piciformes	Picidae	*Dryocopus*	*pileatus*
14	BKCCHI	Parid	Sylvioidea	Paridae	*Poecile*	*atricapillus*
15	OVENBI	Warbler	Passeroidea	Parulidae	*Seiurus*	*aurocapilla*
16	REBWOO	Woodpecker	Piciformes	Picidae	*Melanerpes*	*carolinus*
17	AMEROB	Thrush	Muscicapoidea	Turdidae	*Turdus*	*migratorius*
18	NORFLI	Woodpecker	Piciformes	Picidae	*Colaptes*	*auratus*
19	COMYEL	Warbler	Passeroidea	Parulidae	*Geothlypis*	*trichas*
20	BUGGNA	Gnatcatcher	Certhioidea	Polioptilidae	*Polioptila*	*caerulea*
21	CARWRE	Wren	Certhioidea	Troglodytidae	*Thryothorus*	*ludovicianus*
22	ACAFLY	Flycatcher	Tyrannoidea	Tyrannidae	*Empidonax*	*virescens*
23	AMERED	Warbler	Passeroidea	Parulidae	*Setophaga*	*ruticilla*
24	VEERY	Thrush	Muscicapoidea	Turdidae	*Catharus*	*fuscescens*
25	INDBUN	Finch	Passeroidea	Cardinalidae	*Passerina*	*cyanea*
26	MOUDOV	Dove	Columbiformes	Columbidae	*Zenaida*	*macroura*
27	YEBCUC	Cuckoo	Cuculiformes	Cuculidae	*Coccyzus*	*americanus*
28	YETVIR	Vireo	Corvoidea	Vireonidae	*Vireo*	*flavifrons*
29	ROBGRO	Finch	Passeroidea	Cardinalidae	*Pheucticus*	*ludovicianus*
30	RUSTOW	Finch	Passeroidea	Passerellidae	*Pipilo*	*maculatus*
31	AMECRO	Corvid	Corvoidea	Corvidae	*Corvus*	*brachyrhynchus*
32	BTNWAR	Warbler	Passeroidea	Parulidae	*Dendroica*	*virens*
33	RTHHUM	Hummingbird	Apodiformes	Trochilidae	*Archilochus*	*colubris*
34	BRNCRE	Creeper	Certhioidea	Certhiidae	*Certhia*	*americana*
35	GRYCAT	Mimid	Muscicapoidea	Mimidae	*Dumetella*	*carolinensis*
36	HERTHR	Thrush	Muscicapoidea	Turdidae	*Catharus*	*guttatus*
37	BAWWAR	Warbler	Passeroidea	Parulidae	*Mniotilta*	*varia*
38	PINWAR	Warbler	Passeroidea	Parulidae	*Dendroica*	*pinus*
39	CARCHI	Parid	Sylvioidea	Paridae	*Poecile*	*carolinensis*
40	HOOWAR	Warbler	Passeroidea	Parulidae	*Wilsonia*	*citrina*
41	SOLVIR	Vireo	Corvoidea	Vireonidae	*Vireo*	*solitarius*
42	EASTOW	Finch	Passeroidea	Passerellidae	*Pipilo*	*erythrophthalmus*
43	SONSPA	Finch	Passeroidea	Passerellidae	*Melospiza*	*melodia*
44	SUMTAN	Tanager	Passeroidea	Cardinalidae	*Piranga*	*rubra*
45	CHISPA	Finch	Passeroidea	Passerellidae	*Spizella*	*passerina*
46	NORORI	Icterid	Passeroidea	Icteridae	*Icterus*	*bullocki*
47	HOUWRE	Wren	Certhioidea	Troglodytidae	*Troglodytes*	*aedon*
48	CEDWAX	Waxwing	Bombycilloidea	Bombycillidae	*Bombycilla*	*cedrorum*
49	NORPAR	Warbler	Passeroidea	Parulidae	*Parula*	*americana*
50	WHEVIR	Vireo	Corvoidea	Vireonidae	*Vireo*	*griseus*
51	BKBWAR	Warbler	Passeroidea	Parulidae	*Dendroica*	*fusca*
52	DAEJUN	Finch	Passeroidea	Passerellidae	*Junco*	*hyemalis*
53	EASPHO	Flycatcher	Tyrannoidea	Tyrannidae	*Sayornis*	*phoebe*
54	BTBWAR	Warbler	Passeroidea	Parulidae	*Dendroica*	*caerulescens*
55	KENWAR	Warbler	Passeroidea	Parulidae	*Geothlypis*	*formosus*
56	REBNUT	Nuthatch	Certhioidea	Sittidae	*Sitta*	*canadensis*
57	LOUWAT	Warbler	Passeroidea	Parulidae	*Parkesia*	*motacilla*
58	CHSWAR	Warbler	Passeroidea	Parulidae	*Dendroica*	*pensylvanica*
59	WINWRE	Wren	Certhioidea	Troglodytidae	*Nannus*	*hyemalis*
60	YEBSAP	Woodpecker	Piciformes	Picidae	*Sphyrapicus*	*varius*
61	MAGWAR	Warbler	Passeroidea	Parulidae	*Dendroica*	*magnolia*
62	WOEWAR	Warbler	Passeroidea	Parulidae	*Helmitheros*	*vermivorum*

Table S3. Cont.

	Species code	Group	Superfamily	Family	Genus	Species
63	YELWAR	Warbler	Passeroidea	Parulidae	*Dendroica*	*petechia*
64	LEAFLY	Flycatcher	Tyrannoidea	Tyrannidae	*Empidonax*	*minimus*
65	PURFIN	Finch	Passeroidea	Fringillidae	*Burrica*	*purpurea*
66	REHWOO	Woodpecker	Piciformes	Picidae	*Melanerpes*	*erythrocephalus*
67	YERWAR	Warbler	Passeroidea	Parulidae	*Dendroica*	*coronata*
68	BALORI	Icterid	Passeroidea	Icteridae	*Icterus*	*galbula*
69	CANWAR	Warbler	Passeroidea	Parulidae	*Wilsonia*	*canadensis*
70	SWATHR	Thrush	Muscicapoidea	Turdidae	*Catharus*	*ustulatus*
71	PROWAR	Warbler	Passeroidea	Parulidae	*Protonotaria*	*citrea*
72	WARVIR	Vireo	Corvoidea	Vireonidae	*Vireo*	*gilvus*
73	BUWWAR	Warbler	Passeroidea	Parulidae	*Vermivora*	*pinus*
74	BRNTHR	Mimid	Muscicapoidea	Mimidae	*Toxostoma*	*rufum*
75	GOCKIN	Kinglet	Reguloidea	Regulidae	*Regulus*	*satrapa*
76	NASWAR	Warbler	Passeroidea	Parulidae	*Leiothlypis*	*ruficapilla*
77	SWASPA	Finch	Passeroidea	Passerellidae	*Melospiza*	*georgiana*
78	CERWAR	Warbler	Passeroidea	Parulidae	*Dendroica*	*cerulea*
79	ORCORI	Icterid	Passeroidea	Icteridae	*Icterus*	*spurius*

Table S4. Statistics of the Bray–Curtis (BC) ordination axes

BC axis	Variance, %	Cumulative	Broken stick, p_k	Cumulative	Row shuffled	Cumulative
1	16.74	16.74	6.27	6.27	2.97	2.97
2	11.91	28.64	5.00	11.27	2.64	5.61
3	7.47	36.11	4.37	15.64	2.58	8.19
4	7.65	43.76	3.95	19.59	2.49	10.68
5	6.06	49.82	3.63	23.23	2.22	12.90
6	4.16	53.98	3.38	26.60	2.44	15.34
7	3.90	57.88	3.17	29.77	2.34	17.68
8	2.94	60.81	2.99	32.76	2.78	20.46
9	3.36	64.18	2.83	35.59	2.62	23.08

Table S5. Statistics for the Bray–Curtis scores over the 142 census sites

	BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
N	142	142	142	142	142	142	142	142	142
Average	0.422	0.382	0.359	0.443	0.272	0.163	0.334	0.158	0.144
SD	0.220	0.185	0.147	0.148	0.132	0.109	0.106	0.092	0.098
Skewness	−0.076	0.384	−0.026	−0.718	0.924	1.933	0.632	1.604	0.598
Kurtosis	−0.584	0.387	−0.258	0.759	1.757	6.292	1.741	4.349	1.444
Minimum	0.000	−0.004	0.000	0.000	0.000	−0.015	0.000	−0.015	−0.071
Maximum	0.966	0.913	0.782	0.834	0.800	0.749	0.771	0.594	0.552

Table S6. Distribution of variance (%) among taxonomic levels for a number of sites occupied per species, average density of each species in occupied sites, and total density (sites × local density) of each species

Taxonomic level	df	Sites	Average density	Total density
Superfamily	11	9.7	0.0	0.6
Family	9	0.0	8.3	0.0
Genus	33	8.2	0.0	0.0
Error	25	82.1	91.7	99.4

None of the variance components above the level of species within genera is significant. df, degrees of freedom.

Table S7. Distribution of variance (%) among taxonomic levels for average score on the Bray–Curtis ordination axes

Taxonomic level	df	BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
Superfamily	11	0.0	0.0	0.0	0.0	5.7	0.0	14.5	0.0	0.0
Family	9	12.7	24.4	14.4	10.2	0.0	0.0	0.0	0.0	0.0
Genus	33	0.0	0.0	0.0	14.1	0.0	0.0	0.0	0.0	0.0
Error	25	87.3	75.6	85.6	75.7	94.3	100.0	85.5	100.0	100.0

None of the variance components above the level of species within genera is significant.

Table S8. Distribution of variance (%) among taxonomic levels for SD of the distribution on the Bray–Curtis ordination axes

Taxonomic level	df	SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8	SD9
Superfamily	11	10.2	0.0	0.0	5.2	3.8	0.0	2.3	0.0	4.5
Family	9	0.0	26.3	5.8	0.0	0.0	0.0	0.0	0.0	9.1
Genus	33	0.0	3.5	0.0	0.0	0.0	7.9	0.0	0.0	0.0
Error	25	89.8	70.2	94.2	94.8	96.2	92.1	97.7	100.0	86.4

None of the variance components above the level of species within genera is significant.

Table S9. Distribution of variance (%) among taxonomic levels for scores on morphological principal components

Taxonomic level	df	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Superfamily	10	0.8	28.4	33.7	55.4	0.0	0.0	30.0	5.1
Family	9	68.6	34.1	40.8	16.7	27.9	55.8	30.2	9.5
Genus	31	24.1	0.0	20.5	18.5	34.1	22.8	8.0	57.0
Error	24	6.5	37.5	5.0	9.3	38.0	21.4	31.8	28.4

Most of the variance components above the level of species within genera are significant. Principal components analysis was performed on the covariance matrix of $\log_{10}$-transformed measurements of eight external variables (total length, wing length, tail length, tarsus length, midtoe length, and the length, breadth, and depth of the bill) (1).

1. Ricklefs RE, Travis L (1980) A morphological approach to the study of avian community organization. *Auk* 97:321–338.

Table S10. Analysis of variance of species scores (n = 75) on axes 1–8 of a principal components analysis based on eight morphological measurements, with 19 foraging groups as the main effect

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
F (df = 18, 56)	11.9	6.8	14.9	12.2	2.2	5.3	5.6	2.4
P	<0.0001	<0.0001	<0.0001	<0.0001	0.0122	<0.0001	<0.0001	0.0071
R^2	0.793	0.687	0.827	0.797	0.416	0.628	0.644	0.433