

Ecography

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Supplementary material

Appendix 1

1) Full description of species assignment to seed-dispersing guilds

To determine how the distribution of vertebrate seed dispersers compares to the plants that they disperse, we first assigned the birds and mammals of North America (north of Mexico) to two seed-dispersing guilds: frugivorous and scatter-hoarding seed dispersers. Animals were considered frugivorous seed dispersers if they consume fruits containing seeds as a significant portion of their diet, and the seeds remain viable after being either regurgitated or passed through the digestive tract. We excluded animals that eat lots of fleshy fruit but that do not disperse seeds, like the northern cardinals (*Cardinalis cardinalis*) and ruffed grouse (*Bonasa umbellus*), which eat fruit, but possess gizzards that destroy seeds by grinding them up. Additionally, animals that disperse seeds but do so infrequently (e.g. most members of the family Vireonidae), were excluded, as they are unlikely to influence plant-disperser coevolution in a significant way. Scatter-hoarding of seeds, which frequently results in a mutualism with plants, is limited to the bird family Corvidae and the mammal order Rodentia in North America (Vander Wall 1990). A species was considered a scatter-hoarder if seeds are a significant portion of its diet, it scatter-wards them in soil, and there is a reasonable expectation that some of those seeds germinate.

Animals were identified to be frugivorous or scatter-hoarders through a combination of personal knowledge and the literature. For species that we suspected of being seed dispersers, we consulted the literature. This included Bird species accounts (American Ornithologist Union), Bent's Life History of Birds series (Bent, 1919-1968), and Mammalian species accounts (American Society of Mammalogists). In some cases we surveyed the primary literature. If no source provided evidence for frugivory or scatter-hoarding of seeds, we excluded the species from the list. The taxonomy of all species is based on current species lists published for birds and

mammals of North America (American Ornithologists' Union 1998; Wilson & Reeder 2005).

Our list of seed-dispersing vertebrates is intended to be comprehensive but the inclusion or exclusion of certain species is debatable. But we maintain that the inclusion or exclusion of a few species is unlikely to change our results in any meaningful way.

2) Raster Creation

All of the rasters were then masked to our geographic range of interest (North America, north of Mexico) using major land areas (largely excluding islands) from CIA World DataBank II (<https://www.evl.uic.edu/pape/data/WDB/>) in R library, *mapdata* (Brownrigg 2016). The master raster has a resolution of 1221×1077 longitude by latitude (573933 terrestrial cells evaluated), and an extent of 164.4167°W – 54.41667°W and 25.06667°N – 73.56667°N . Data were rasterized, overlaid, and projected using Program R (R Core Team 2014) with R libraries, *maptools* (Lewin-Koh *et al.* 2011), *raster* (Hijmans 2014), *sp* (Pebesma & Bivand 2005; Bivand *et al.* 2008), and *rgdal* (Keitt *et al.* 2014). Composite distribution maps were made for all mutualists (frugivores + scatter-hoarders), all frugivorous animals, frugivorous birds, frugivorous mammals, all scatter-hoarding animals, scatter-hoarding birds, and scatter-hoarding mammals.

For initial data analysis, we extracted the animal mutualist richness from the 197 sites used in Vander Wall & Moore (2016). To obtain richness, we used the *extract* function from the R library, *Raster* (Hijmans 2014). This function works by extracting specified data from a raster at given points. The latitude and longitude of the center (mean latitude and longitude) of each site was used as x, y coordinates for data extraction. The center of each site was deemed acceptable because the range maps of the included animals are not detailed enough to show significant differences within a given study site. Furthermore, we reviewed the species list for

both frugivorous and scatter-hoarding animals at each site to eliminate species that were supposedly present according to their range maps but were unlikely actually present due to elevational or ecological limitations.

Table A2: List of frugivorous animals broken up into frugivorous birds (top) and frugivorous mammals (bottom). Species are listed alphabetically by family then genus, order of species does not insinuate a species ability to disperse seeds via frugivory.

Table A3: List of scatter-hoarding animals broken up into scatter-hoarding birds (top) and scatter-hoarding rodents (bottom). For both scatter-hoarding birds and mammals only one family possesses scatter-hoarding behavior (Corvidae and Rodentia respectively), therefore species are listed alphabetically by genus. Order of species does not insinuate a species ability to disperse seeds via scatter-hoar

Table A4: Statistical results of GLS models and Monte Carlo simulations for mutualisms (Z_{diff}) and environmental variables. An asterisk (*) signifies that the effect size is in units per 100 mm/yr AET and a double asterisk (**) signifies that the effect size is in units per 100 m elevation. Arrows signify if the relating ship is negative (downward arrow) or positive (upward arrow).

Table A2:

Frugivorous Birds of North America			
Genus	Species	Family	Common Name
<i>Bombycilla</i>	<i>cedrorum</i>	Bombycillidae	Cedar Waxwing
<i>Bombycilla</i>	<i>garrulus</i>	Bombycillidae	Bohemian Waxwing
<i>Patagioenas</i>	<i>fasciata</i>	Columbidae	Band-tailed Pigeon
<i>Patagioenas</i>	<i>flavirostris</i>	Columbidae	Red-billed Pigeon
<i>Patagioenas</i>	<i>leucocephala</i>	Columbidae	White-crowned Pigeon
<i>Zenaida</i>	<i>asiatica</i>	Columbidae	White-winged Dove
<i>Aphelocoma</i>	<i>californica</i>	Corvidae	Scrub Jay
<i>Aphelocoma</i>	<i>coerulescens</i>	Corvidae	Florida Scrub Jay
<i>Aphelocoma</i>	<i>insularis</i>	Corvidae	Island Scrub Jay
<i>Corvus</i>	<i>ossifragus</i>	Corvidae	Fish Crow
<i>Corvus</i>	<i>brachyrhynchos</i>	Corvidae	American Crow
<i>Corvus</i>	<i>caurinus</i>	Corvidae	Northwestern Crow
<i>Cyanocitta</i>	<i>cristata</i>	Corvidae	Blue Jay
<i>Cyanocitta</i>	<i>stelleri</i>	Corvidae	Steller's Jay
<i>Gymnorhinus</i>	<i>cyanocephalus</i>	Corvidae	Piñon Jay
<i>Perisoreus</i>	<i>canadensis</i>	Corvidae	Gray Jay
<i>Pica</i>	<i>hudsonia</i>	Corvidae	Black-billed Magpie
<i>Pica</i>	<i>nutalli</i>	Corvidae	Yellow-billed Magpie
<i>Psilorhinus</i>	<i>morio</i>	Corvidae	Brown Jay
<i>Crotophaga</i>	<i>sulcirostris</i>	Cuculidae	Groove-billed Ani
<i>Crotophaga</i>	<i>ani</i>	Cuculidae	Smooth-billed Ani
<i>Icterus</i>	<i>bullockii</i>	Icteridae	Bullock's Oriole
<i>Icterus</i>	<i>cucullatus</i>	Icteridae	Hooded Oriole
<i>Icterus</i>	<i>galbula</i>	Icteridae	Baltimore Oriole
<i>Icterus</i>	<i>gularis</i>	Icteridae	Altamira Oriole
<i>Icterus</i>	<i>parisorum</i>	Icteridae	Scott's Oriole
<i>Icterus</i>	<i>spurius</i>	Icteridae	Orchard Oriole
<i>Quiscalus</i>	<i>major</i>	Icteridae	Boat-tailed Grackle
<i>Quiscalus</i>	<i>mexicanus</i>	Icteridae	Great-tailed Grackle
<i>Quiscalus</i>	<i>quiscula</i>	Icteridae	Common Grackle
<i>Dumetella</i>	<i>carolinensis</i>	Mimidae	Gray Catbird
<i>Mimus</i>	<i>polyglottos</i>	Mimidae	Norther Mockingbird
<i>Oreoscoptes</i>	<i>montanus</i>	Mimidae	Sage Thrasher
<i>Toxostoma</i>	<i>bendirei</i>	Mimidae	Bendire's Thrasher
<i>Toxostoma</i>	<i>crissale</i>	Mimidae	Crissal Thrasher
<i>Toxostoma</i>	<i>curvirostre</i>	Mimidae	Curve-billed Thrasher
<i>Toxostoma</i>	<i>redivivum</i>	Mimidae	California Thrasher
<i>Toxostoma</i>	<i>rufum</i>	Mimidae	Brown Thrasher
<i>Dendroica</i>	<i>coronata</i>	Parulidae	Yellow-rumped Warbler
<i>Icteria</i>	<i>virens</i>	Parulidae	Yellow-breasted Chat
<i>Melanerpes</i>	<i>aurifrons</i>	Picidae	Golden-fronted Woodpecker
<i>Melanerpes</i>	<i>carolinus</i>	Picidae	Red-bellied Woodpecker
<i>Melanerpes</i>	<i>erthrocephalus</i>	Picidae	Red-headed Woodpecker
<i>Melanerpes</i>	<i>lewis</i>	Picidae	Lewis' Woodpecker
<i>Melanerpes</i>	<i>uropygialis</i>	Picidae	Gila Woodpecker
<i>Comuropsis</i>	<i>carolinensis</i>	Psittacidae	Carolina Parakeet
<i>Phainopepla</i>	<i>nitens</i>	Ptiligonatidae	Phainopepla
<i>Piranga</i>	<i>flava</i>	Thraupidae	Hepatic Tanager
<i>Piranga</i>	<i>ludoviciana</i>	Thraupidae	Western Tanager

<i>Piranga olivacea</i>	Thraupidae	Scarlet Tanager
<i>Piranga rubra</i>	Thraupidae	Summer Tanager
<i>Chamaea fasciata</i>	Timalidae	Wren-tit
<i>Trogon elegans</i>	Trogonidae	Elegant Trogon
<i>Catharus bicknelli</i>	Turdidae	Bicknell's Thrush
<i>Catharus fuscescens</i>	Turdidae	Veery
<i>Catharus guttatus</i>	Turdidae	Hermit Thrush
<i>Catharus minimus</i>	Turdidae	Gray-cheeked Thrush
<i>Catharus ustulatus</i>	Turdidae	Swainson's Thrush
<i>Hylocichla mustelina</i>	Turdidae	Wood Thrush
<i>Ixoreus naevius</i>	Turdidae	Varied Thrush
<i>Myadestes townsendi</i>	Turdidae	Townsend's Solitaire
<i>Sialia currucoides</i>	Turdidae	Mountain Bluebird
<i>Sialia mexicana</i>	Turdidae	Western Bluebird
<i>Sialia sialis</i>	Turdidae	Eastern Bluebird
<i>Turdus migratorius</i>	Turdidae	American Robin
Fruigivorous Mammals of North America		
Genus	Species	Family
		Common Name
<i>Canis</i>	<i>latrans</i>	Canidae
		Coyote
<i>Canis</i>	<i>lupus</i>	Canidae
		Gray Wolf
<i>Urocyon</i>	<i>cinereoargenteus</i>	Canidae
		Gray Fox
<i>Vulpes</i>	<i>macrotis</i>	Canidae
		Kit Fox
<i>Vulpes</i>	<i>velox</i>	Canidae
		Swift Fox
<i>Vulpes</i>	<i>vulpes</i>	Canidae
		Red Fox
<i>Odocoileus</i>	<i>virginianus</i>	Cervidae
		White-tailed Deer
<i>Dasypus</i>	<i>novemcinctus</i>	Dasypodidae
		Armadillo
<i>Didelphis</i>	<i>virginiana</i>	Didelphidae
		Opossum
<i>Conepatus</i>	<i>leuconotus</i>	Mephitidae
		North American Hog-nosed Skunk
<i>Mephitis</i>	<i>macroura</i>	Mephitidae
		Hooded Skunk
<i>Mephitis</i>	<i>mephitis</i>	Mephitidae
		Striped Skunk
<i>Spilogale</i>	<i>gracillis</i>	Mephitidae
		Western Spotted Skunk
<i>Spilogale</i>	<i>putorius</i>	Mephitidae
		Eastern Spotted Skunk
<i>Gulo</i>	<i>gulo</i>	Mustelidae
		Wolverine
<i>Martes</i>	<i>americana</i>	Mustelidae
		American Marten
<i>Martes</i>	<i>pennanti</i>	Mustelidae
		Fisher
<i>Bassariscus</i>	<i>astutus</i>	Procyonidae
		Ringtail
<i>Nasua</i>	<i>narica</i>	Procyonidae
		Coatis
<i>Procyon</i>	<i>lotor</i>	Procyonidae
		Raccoon
<i>Pecari</i>	<i>tajacu</i>	Tayassuidae
		Collared Peccary
<i>Ursus</i>	<i>americanus</i>	Ursidae
		Black Bear
<i>Ursus</i>	<i>arctos</i>	Ursidae
		Brown Bear

Table A3:

Scatter-hoarding Corvids		
Genus	Species	Common Name
<i>Aphelocoma</i>	<i>californica</i>	Western Scrub Jay
<i>Aphelocoma</i>	<i>coerulescens</i>	Florida Scrub Jay
<i>Aphelocoma</i>	<i>insularis</i>	Island Scrub Jay
<i>Aphelocoma</i>	<i>wollweberi</i>	Mexican Jay
<i>Cyanocitta</i>	<i>cristata</i>	Blue Jay
<i>Cyanocitta</i>	<i>stelleri</i>	Steller's Jay
<i>Cyanocorax</i>	<i>yncas</i>	Green Jay
<i>Gymnorhinus</i>	<i>cynocephalus</i>	Pinon Jay
<i>Nucifraga</i>	<i>columbiana</i>	Clark's Nutcracker
<i>Psilorhinus</i>	<i>morio</i>	Brown Jay
Scatter-hoarding Rodents		
Genus	Species	Common name
<i>Ammospermophilus</i>	<i>harrisii</i>	Harris' Antelope Squirrel
<i>Ammospermophilus</i>	<i>interpres</i>	Texas Antelope Squirrel
<i>Ammospermophilus</i>	<i>leucurus</i>	White-Tailed Antelope Squirrel
<i>Ammospermophilus</i>	<i>nelsoni</i>	Nelson's Antelope Squirrel
<i>Chaetodipus</i>	<i>baileyi</i>	Bailey's Pocket Mouse
<i>Chaetodipus</i>	<i>californicus</i>	California Pocket Mouse
<i>Chaetodipus</i>	<i>eremicus</i>	Chihuahuan Pocket Mouse
<i>Chaetodipus</i>	<i>fallax</i>	San Diego Pockety Mouse
<i>Chaetodipus</i>	<i>formosus</i>	Long-Tailed Pocket Mouse
<i>Chaetodipus</i>	<i>hispidus</i>	Hispid Pocket Mouse
<i>Chaetodipus</i>	<i>intermedius</i>	Rock Pocket Mouse
<i>Chaetodipus</i>	<i>nelsoni</i>	Nelson's Pocket Mouse
<i>Chaetodipus</i>	<i>penicillatus</i>	Desert Pocket Mouse
<i>Chaetodipus</i>	<i>rudinoris</i>	Baja Pocket Mouse
<i>Chaetodipus</i>	<i>spinatus</i>	Spiny Pocket Mouse
<i>Dipodomys</i>	<i>agilis</i>	Agile Kangaroo Rat
<i>Dipodomys</i>	<i>Californicus</i>	California Kangaroo Rat
<i>Dipodomys</i>	<i>compactus</i>	Gulf Coast Kangaroo Rat
<i>Dipodomys</i>	<i>deserti</i>	Desert Kangaroo Rat
<i>Dipodomys</i>	<i>elator</i>	Texas Kangaroo Rat
<i>Dipodomys</i>	<i>heermanni</i>	Heermanns' Kangaroo Rat
<i>Dipodomys</i>	<i>ingens</i>	Giant Kangaroo Rat
<i>Dipodomys</i>	<i>merriami</i>	Merriam's Kangaroo Rat
<i>Dipodomys</i>	<i>microps</i>	Chisel-Toothed Kangaroo Rat
<i>Dipodomys</i>	<i>nitratoides</i>	San Joaquin Kangaroo Rat
<i>Dipodomys</i>	<i>ordii</i>	Ord's Kangaroo Rat
<i>Dipodomys</i>	<i>panamintinus</i>	Panamint Kangaroo Rat
<i>Dipodomys</i>	<i>simulans</i>	Dulzura Kangaroo Rat
<i>Dipodomys</i>	<i>spectabilis</i>	Banner-Tailed Kangaroo Rat
<i>Dipodomys</i>	<i>stephensi</i>	Stephens' Kangaroo Rat
<i>Dipodomys</i>	<i>venustus</i>	Narrow-Faced Kangaroo Rat
<i>Liomys</i>	<i>irroratus</i>	Mexican Spiny Pocket Mouse

<i>Microdipidops</i>	<i>megacephalus</i>	Dark Kangaroo Mouse
<i>Microdipidops</i>	<i>pallidus</i>	Pale Kangaroo Mouse
<i>Perognathus</i>	<i>alticolus</i>	White-Eared Pocket Mouse
<i>Perognathus</i>	<i>amplus</i>	Arizona Pocket Mouse
<i>Perognathus</i>	<i>fasciatus</i>	Olive-Backed Pocket Mouse
<i>Perognathus</i>	<i>flavescens</i>	Plains Pocket Mouse
<i>Perognathus</i>	<i>flavus</i>	Silky Pocket Mouse
<i>Perognathus</i>	<i>inornatus</i>	San Joaquin Pocket Mouse
<i>Perognathus</i>	<i>longimembris</i>	Little Pocket Mouse
<i>Perognathus</i>	<i>merriami</i>	Merriam's Pocket Mouse
<i>Perognathus</i>	<i>mollipilosus</i>	Great Basin Pocket Mouse
<i>Perognathus</i>	<i>parvus</i>	Columbia Plateau Pocket Mouse
<i>Peromyscus</i>	<i>attwateri</i>	Texas Mouse
<i>Peromyscus</i>	<i>boyllii</i>	Brush Mouse
<i>Peromyscus</i>	<i>californicus</i>	California Mouse
<i>Peromyscus</i>	<i>crinitus</i>	Canyon Mouse
<i>Peromyscus</i>	<i>eremiscus</i>	Cactus Mouse
<i>Peromyscus</i>	<i>fraterculus</i>	Northern Baja Mouse
<i>Peromyscus</i>	<i>gossypinus</i>	Cotton Mouse
<i>Peromyscus</i>	<i>gratus</i>	Osgood's Mouse
<i>Peromyscus</i>	<i>keeni</i>	Keen's Mouse
<i>Peromyscus</i>	<i>leucopus</i>	White-Footed Mouse
<i>Peromyscus</i>	<i>melanotis</i>	Black-eared Mouse
<i>Peromyscus</i>	<i>maniculatus</i>	American Deer Mouse
<i>Peromyscus</i>	<i>merriami</i>	Mesquite Mouse
<i>Peromyscus</i>	<i>nasutus</i>	Norther Rock Mouse
<i>Peromyscus</i>	<i>pectoralis</i>	White-Ankled Mouse
<i>Peromyscus</i>	<i>polionotus</i>	Oldfield Mouse
<i>Peromyscus</i>	<i>truei</i>	Pinon Mouse
<i>Sciurus</i>	<i>aberti</i>	Tassel-Eared Squirrel
<i>Sciurus</i>	<i>arizonensis</i>	Arizona Gray Squirrel
<i>Sciurus</i>	<i>carolinensis</i>	Eastern Gray Squirrel
<i>Sciurus</i>	<i>griseus</i>	Western Gray Squirrel
<i>Sciurus</i>	<i>nayaritensis</i>	Mexican Fox Squirrel
<i>Sciurus</i>	<i>niger</i>	Eastern Fox Squirrel
<i>Spermophilus</i>	<i>lateralis</i>	Golden-mantled Ground Squirrel
<i>Spermophilus</i>	<i>saturatus</i>	Cascade Golden-mantled Ground Squirrel
<i>Spermophilus</i>	<i>spilosoma</i>	Spotted Ground Squirrel
<i>Spermophilus</i>	<i>tridecemlineatus</i>	Thirteen-lined Ground Squirrel
<i>Tamias</i>	<i>alpinus</i>	Alpine Chipmunk
<i>Tamias</i>	<i>amoenus</i>	Yellow-Pine Chipmunk
<i>Tamias</i>	<i>canipes</i>	Gray-Footed Chipmunk
<i>Tamias</i>	<i>cinereicollis</i>	Gray-Collared Chipmunk
<i>Tamias</i>	<i>dorsalis</i>	Cliff Chipmunk
<i>Tamias</i>	<i>merriami</i>	Merriam's Chipmunk
<i>Tamias</i>	<i>minimus</i>	Least Chipmunk
<i>Tamias</i>	<i>obscurus</i>	California Chipmunk
<i>Tamias</i>	<i>ochrogenys</i>	Yellow-Cheeked Chipmunk

<i>Tamias</i>	<i>palmeri</i>	Palmer's Chipmunk
<i>Tamias</i>	<i>panamintinus</i>	Panamin Chipmunk
<i>Tamias</i>	<i>quadrimaculatus</i>	Long-Eared Chipmunk
<i>Tamias</i>	<i>quadrivittatus</i>	Colorado Chipmunk
<i>Tamias</i>	<i>ruficaudus</i>	Red-Tailed Chipmunk
<i>Tamias</i>	<i>rufus</i>	Hopi Chipmunk
<i>Tamias</i>	<i>senex</i>	Allen's Chipmunk
<i>Tamias</i>	<i>siskiyou</i>	Siskiyou Chipmunk
<i>Tamias</i>	<i>sonomae</i>	Sonoma Chipmunk
<i>Tamias</i>	<i>speciosus</i>	Lodgepole Chipmunk
<i>Tamias</i>	<i>townsendii</i>	Townsend's Chipmunk
<i>Tamias</i>	<i>umbrinus</i>	Uinta Chipmunk

Table A4:

Independent Variable	Dependent Variable (Z _{diff})	Regression Models						Monte Carlo Simulations			
		Spatially correlated?	Fit	F-statistic	p-value	Effect size	R ²	Spatially correlated?	p-value (estimated)	rho	
Precipitation	Frugivory										
	Birds and plants	Yes	Gaussian	1.14	0.29	0.12	0.01	Yes	0.14	0.21	
	Mammals and plants	Yes	Gaussian	0.81	0.37	0.12	0.04	Yes	0.25	0.17	
	Scatter-Hoarding										
	Birds and plants	Yes	Gaussian	41.52	0.00	0.60	↑	0.05	Yes	0.10	0.22
AET	Frugivory										
	Birds and plants	Yes	Gaussian	1.61	0.21	0.08*	-0.08	Yes	0.21	0.21	
	Mammals and plants	Yes	Gaussian	2.48	0.12	0.11*	0.13	Yes	0.07	0.37	
	Scatter-Hoarding										
	Birds and plants	Yes	Gaussian	130.67	0.00	0.29*	↑	0.23	Yes	0.00	0.58
Elevation	Frugivory										
	Birds and plants	Yes	Gaussian	0.97	0.33	0.1**	-0.54	Yes	0.00	-0.45	↓
	Mammals and plants	Yes	Gaussian	0.08	0.78	0.003**	0.01	Yes	0.07	0.37	
	Scatter-Hoarding										
	Birds and plants	Yes	Gaussian	3.03	0.08	0.11**	0.09	Yes	0.00	-0.50	↓
latitude	Frugivory										
	Birds and plants	Yes	Gaussian	23.37	0.00	0.06	↑	0.31	Yes	0.15	0.30
	Mammals and plants	Yes	Gaussian	0.94	0.33	-0.16	-0.26	Yes	0.35	-0.14	
	Scatter-Hoarding										
	Birds and plants	Yes	Gaussian	3.54	0.06	0.02	0.00	Yes	0.15	-0.23	
	Rodents and plants	Yes	Gaussian	1.15	0.22	0.01	-0.01	Yes	0.29	-0.15	

Figure A5: Richness of seed-dispersal mutualism with birds. The left panels are the distribution of plants involved in each category of seed dispersal mutualism with birds after Vander Wall et al. (2017). The middle panel is the richness distribution of birds involved in each category of seed dispersal mutualisms, and the right panel is the difference between plant and bird richness (Z_{diff}) involved in each category of mutualisms. In the left and middle panels, the legend represents the number of plants or birds at any given locations. While in the right panel the legend represents the relative difference in richness between plants and birds.

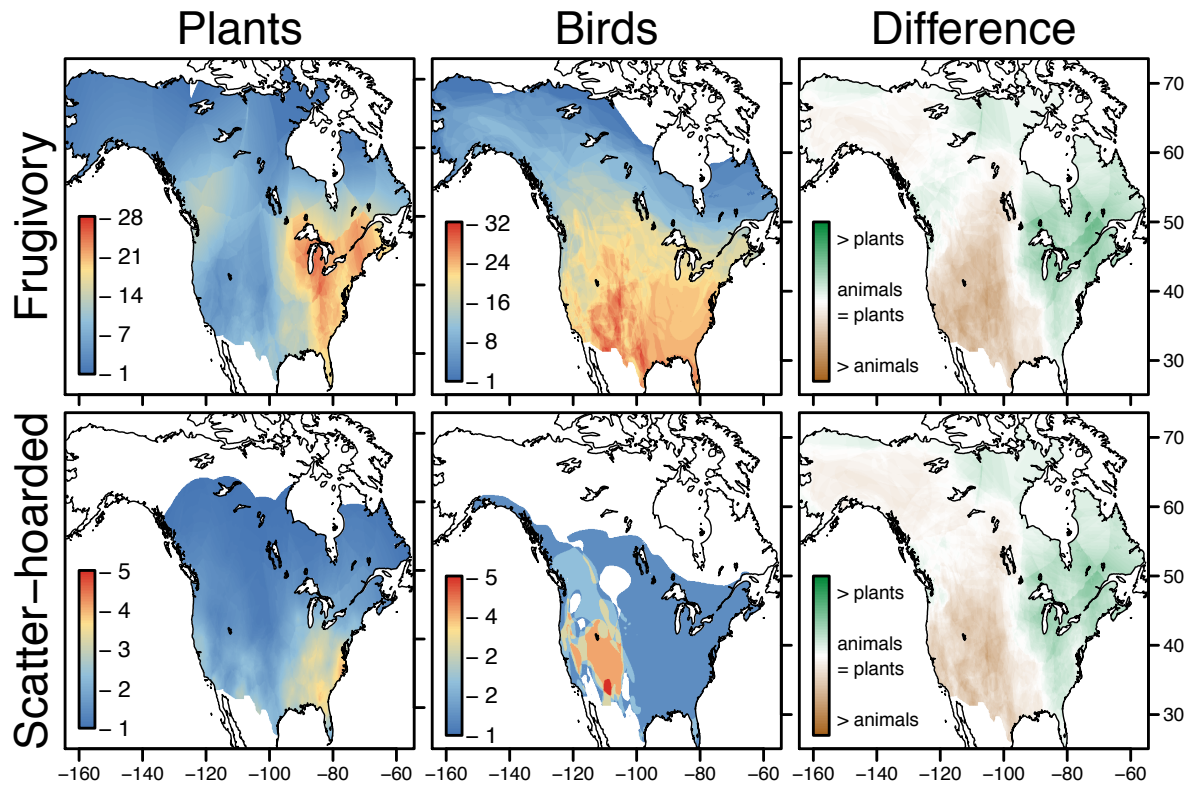
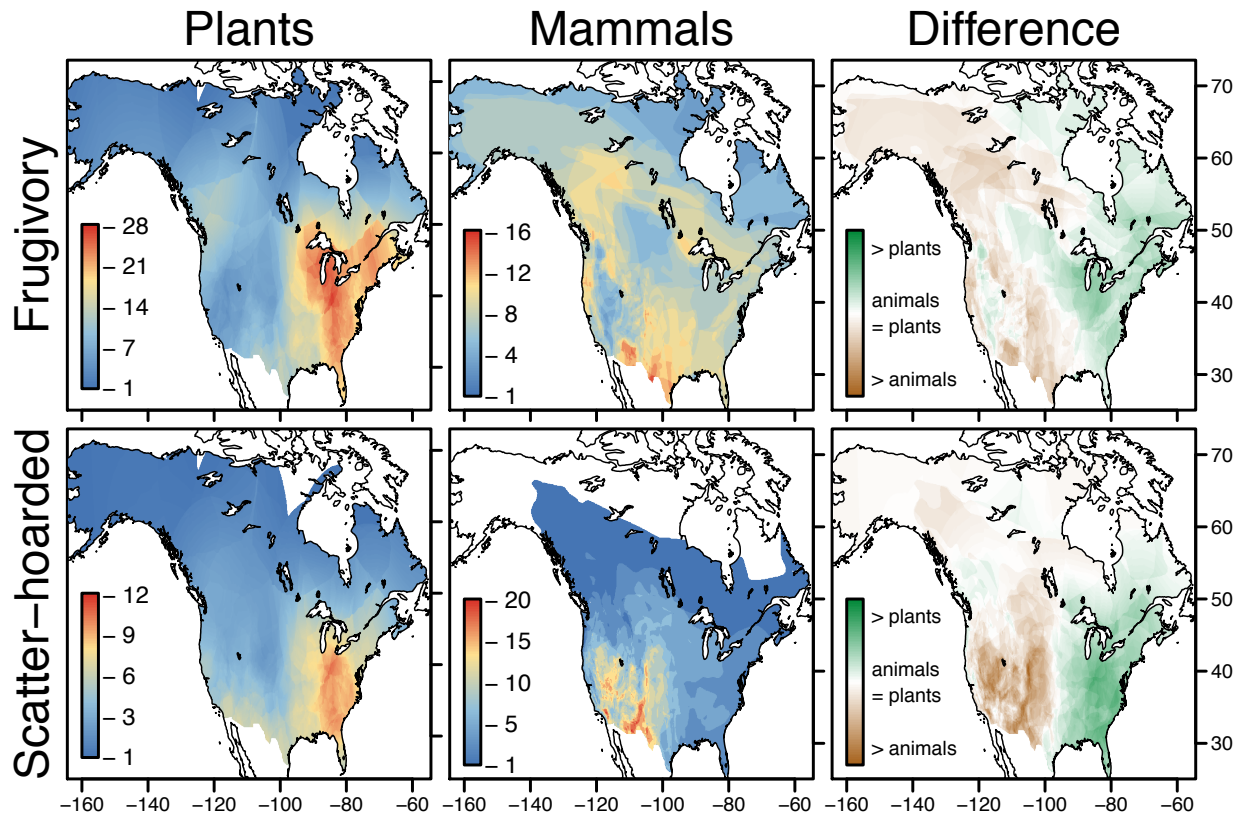


Figure A6: Richness of seed-dispersal mutualisms with mammals. The left panels are the distribution of plants involved in each category of seed dispersal mutualism with mammals after Vander Wall et al. (2017). The middle panel is the richness distribution of mammals involved in each category of seed dispersal mutualisms, and the right panel is the difference between plant and mammal richness (Z_{diff}) involved in each category of mutualisms. In the left and middle panels, the legend represents the number of plants or mammals at any given locations. While in the right panel the legend represents the relative difference in richness between plants and mammals. Note: For seed-dispersal mutualisms, the only mammals that form this mutualism are from the family Rodentia.



SUPPLEMENTARY INFORMATION—SPATIAL RANDOMIZATIONS

Included in this document are the results from the complete (A7–10) and structured (A11–14) spatial randomizations. The methods are described in *Materials and Methods, §Data Analysis* of the paper, and the code to recreate the analysis and figures can be found at <https://github.com/dispersing/SpatialRandomizations>.

Figure A6 shows an example of an observed pattern (column 1) and 10 complete randomizations (rows 1 and 2) and 10 structured randomizations (rows 3 and 4). Figures A7–10 show the results for the complete randomizations of the correlations between animal and environmental variables (A6), the animal and plant variables (A8), the difference in richness and environmental variables (A9), and the plant and environmental variables (A10). Figures A11–14 show the results for the structured randomizations of the correlations between animal and environmental variables (A11), the animal and plant variables (A12), the difference in richness and environmental variables (A13), and the plant and environmental variables (A14).

Variables names translate:

- I. Environmental variables
 - a. aet: actual evapotranspiration
 - b. dem: elevation
 - c. ppt: precipitation
 - d. lat: latitude
- II. Animal variables
 - a. a.mut: all mutualist animals
 - b. a.hoard: hoarding animal guild
 - c. a.frug: frugivorous animal guild
 - d. a.hoard.rod: hoarding rodent subguild
 - e. a.hoard.bird: hoarding bird subguild
 - f. a.frug.mamm: frugivorous mammal subguild
 - g. a.frug.bird: frugivorous bird subguild
- III. Plant variables
 - a. p.mut: all mutualist plants
 - b. p.hoard: hoarded plant guild
 - c. p.frug: frugivory plant guild
 - d. p.hoard.rod: rodent-hoarded plant subguild
 - e. p.hoard.bird: bird-hoarded plant subguild
 - f. p.frug.mamm: mammal frugivory plant subguild
 - g. p.frug.bird: bird frugivory plant subguild
- IV. Richness difference
 - a. d.mut: difference in richness of all mutualists
 - b. d.hoard: difference in richness of the hoarding guild
 - c. d.frug: difference in richness of the frugivory guild
 - d. d.hoard.rod: difference in richness of the rodent hoarding subguild
 - e. d.hoard.bird: difference in richness of the bird hoarding subguild
 - f. d.frug.mamm: difference in richness of the mammal frugivory subguild
 - g. d.frug.bird: difference in richness of the bird frugivory subguild

Figure A6. An example of an observed pattern (column 1, "Original data") and 10 complete randomizations (rows 1 and 2) and 10 structured randomizations (rows 3 and 4). This example is to visually demonstrate to the reader the difference between the two tests. The latter preserves the spatial autocorrelative structure and is therefore a more rigorous statistical test.

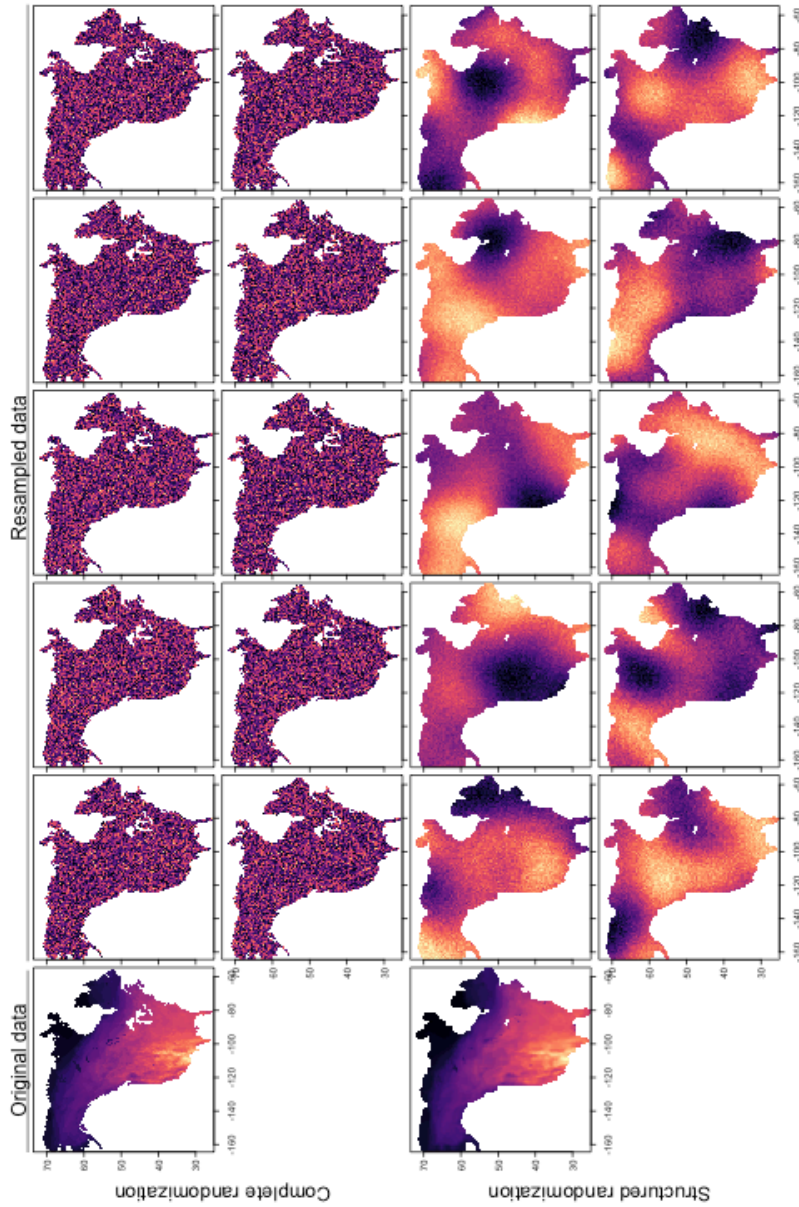


Figure A7. Results for the complete randomizations of the correlations between animal and environmental variables. Every randomization in each comparison had an observed value more extreme than all of randomizations, meaning all had an estimated p -value, $\hat{p} = 0$.

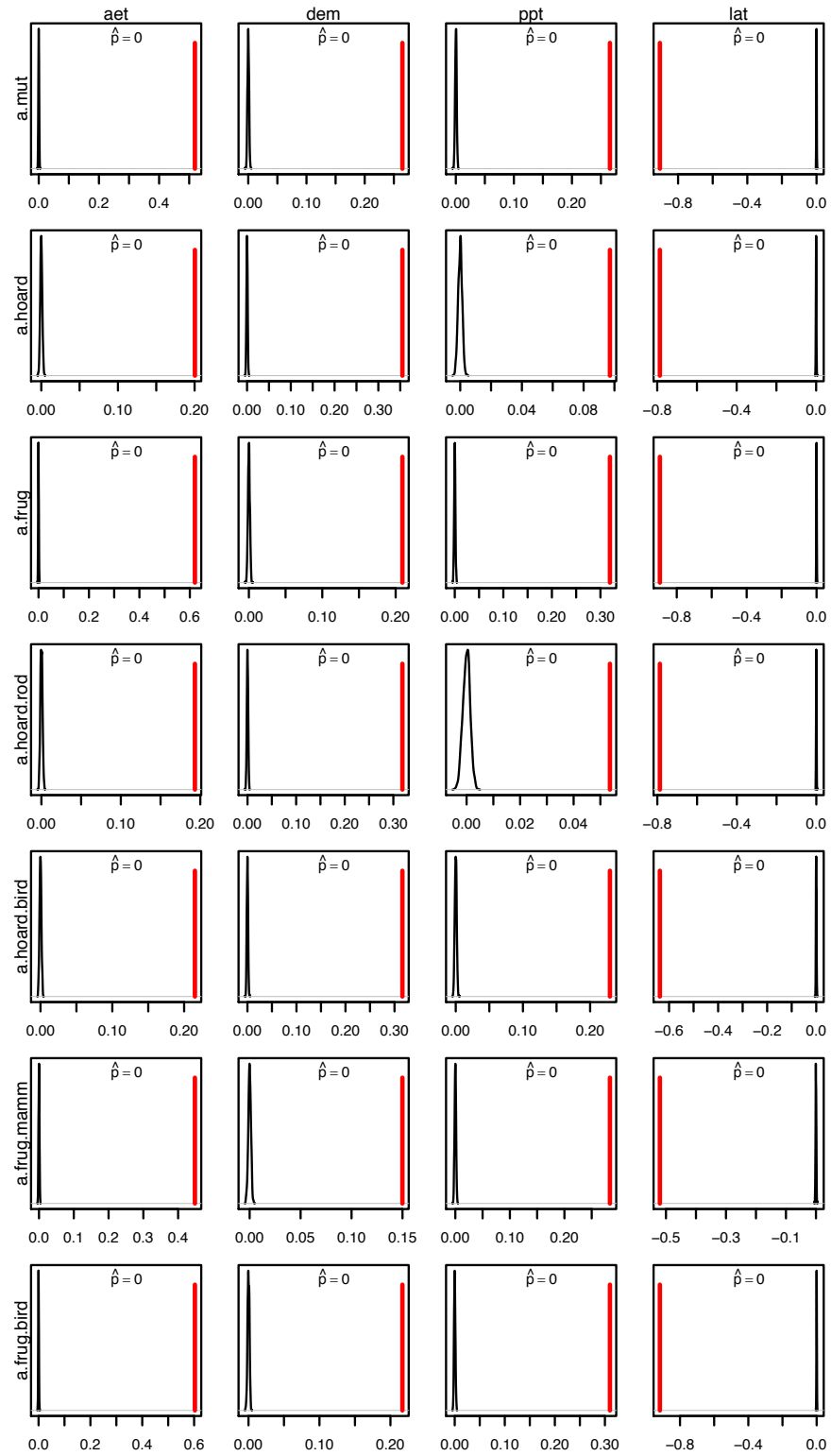


Figure A9. Results for the complete randomizations of the correlations between difference in richness and environmental variables. Every randomization in each comparison had an observed value more extreme than all of randomizations, meaning all had an estimated p -value, $\hat{p} = 0$.

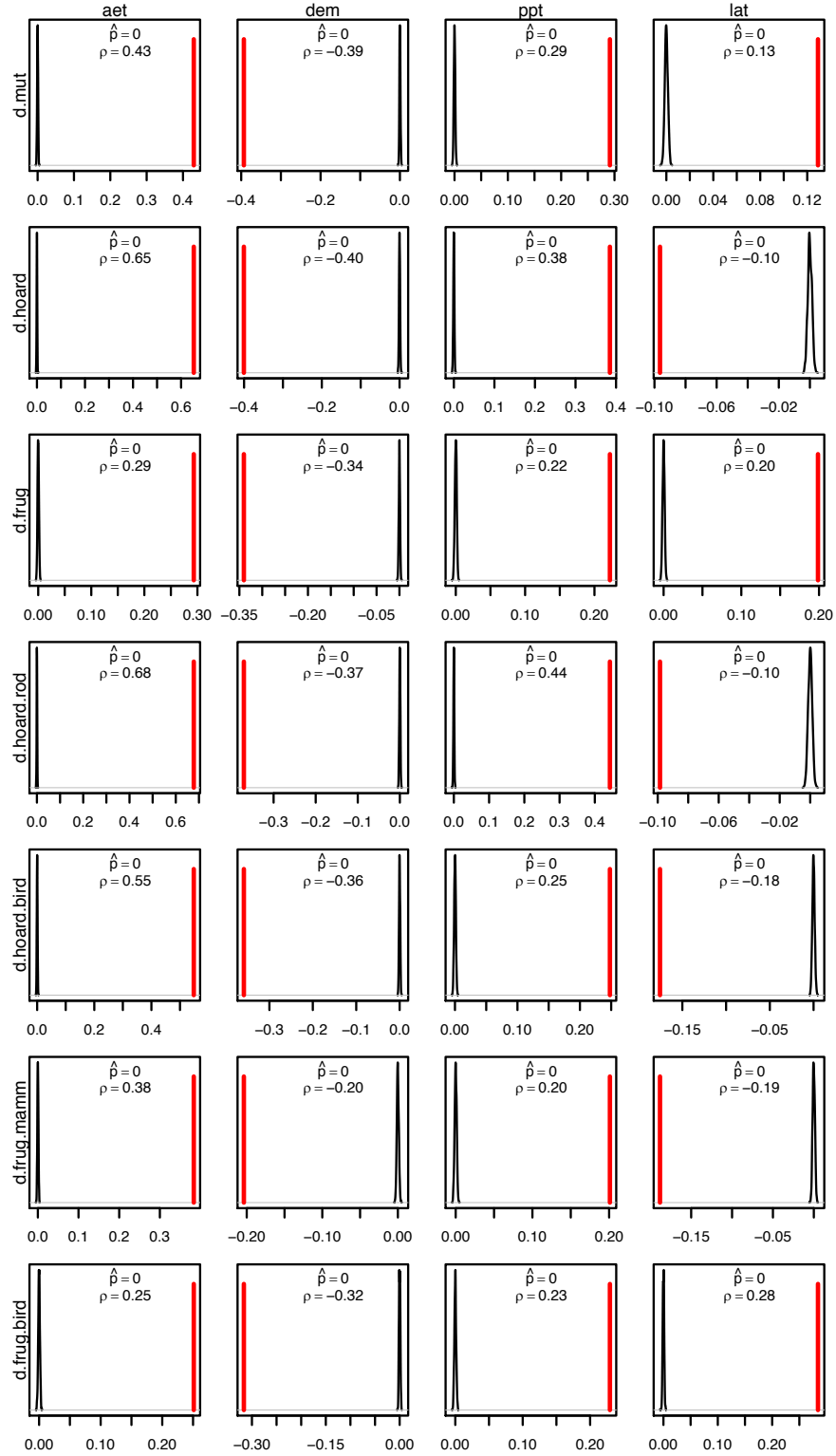


Figure A10. Results for the complete randomizations of the correlations between plant and environmental variables. Every randomization in each comparison had an observed value more extreme than all of randomizations, meaning all had an estimated p -value, $\hat{p} = 0$.

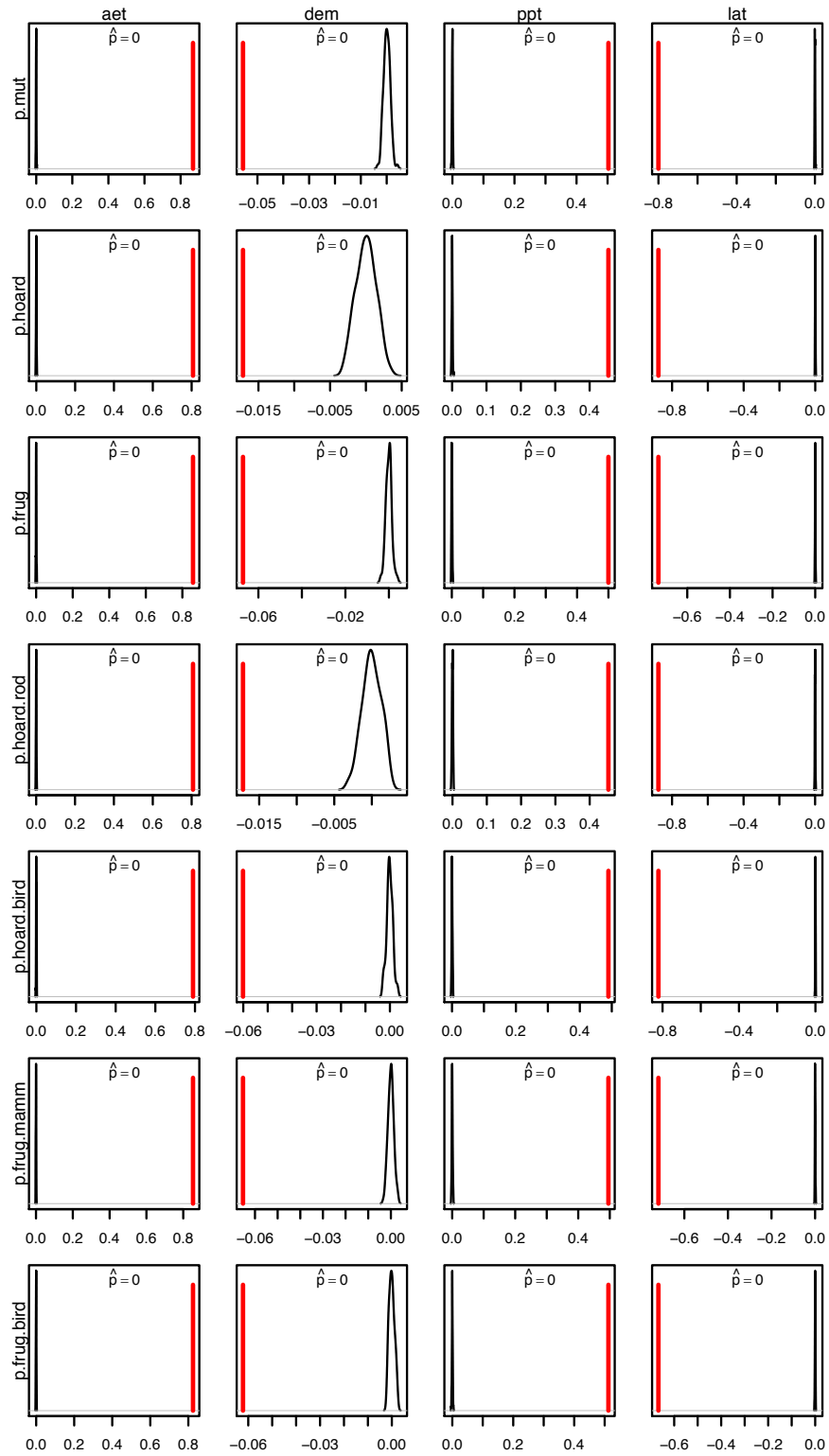


Figure A11. Results for the structured randomizations of the correlations between animal and environmental variables. Within each panel, the distribution represents the randomized Spearman's correlation coefficient, ρ ; vertical black lines represent the observed Spearman's correlation coefficient, ρ^* ; shaded areas represent parts of the distribution that were more extreme than ρ^* ; the \hat{p} is the randomizations $\geq \rho^*$; and if $\leq 5\%$ of the randomizations were more extreme than ρ^* then we interpret that as statistically significant and color the statistical font red rather than black.

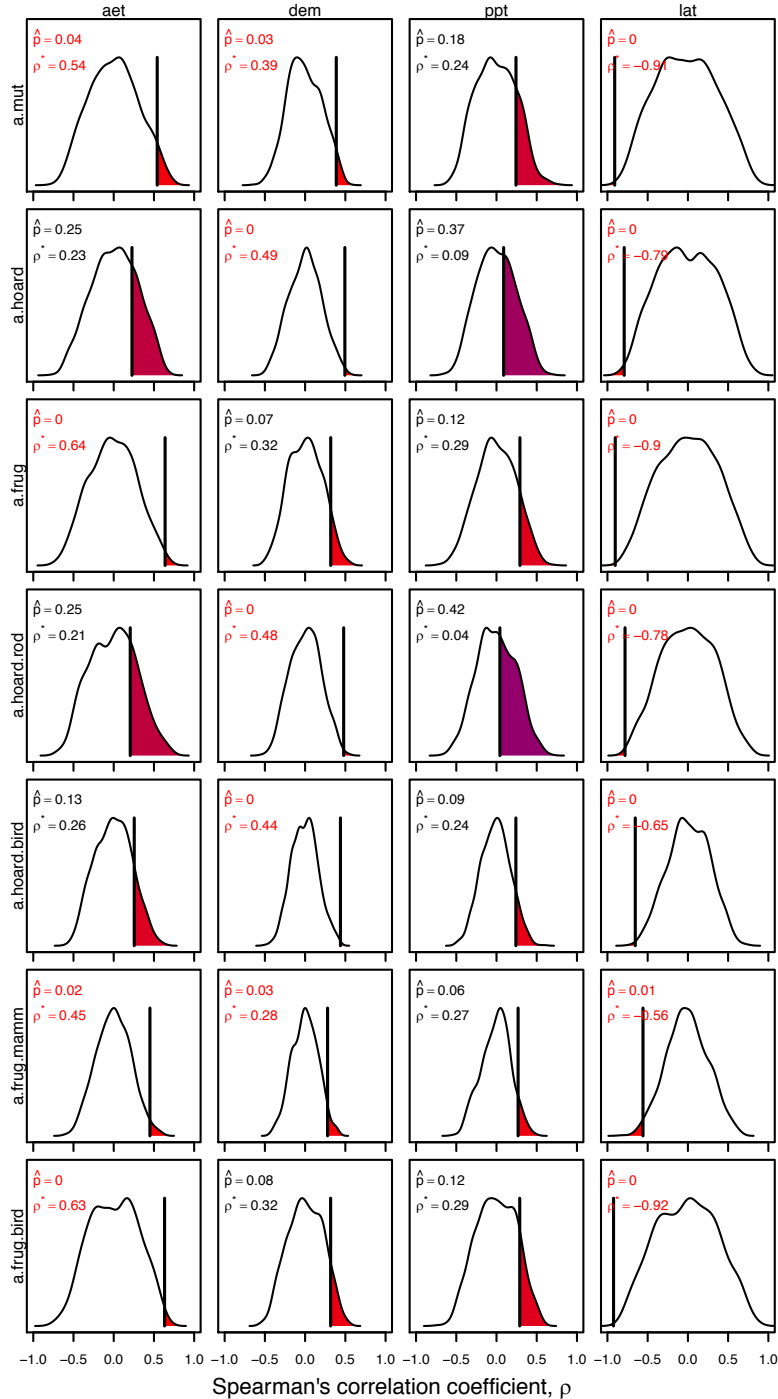


Figure A12. Results for the structured randomizations of the correlations between animal and plant variables. Within each panel, the distribution represents the randomized Spearman's correlation coefficient, ρ ; vertical black lines represent the observed Spearman's correlation coefficient, ρ^* ; shaded areas represent parts of the distribution that were more extreme than ρ^* ; the $\hat{\rho}$ is the randomizations $\geq \rho^*$; and if $\leq 5\%$ of the randomizations were more extreme than ρ^* then we interpret that as statistically significant and color the statistical font red rather than black.

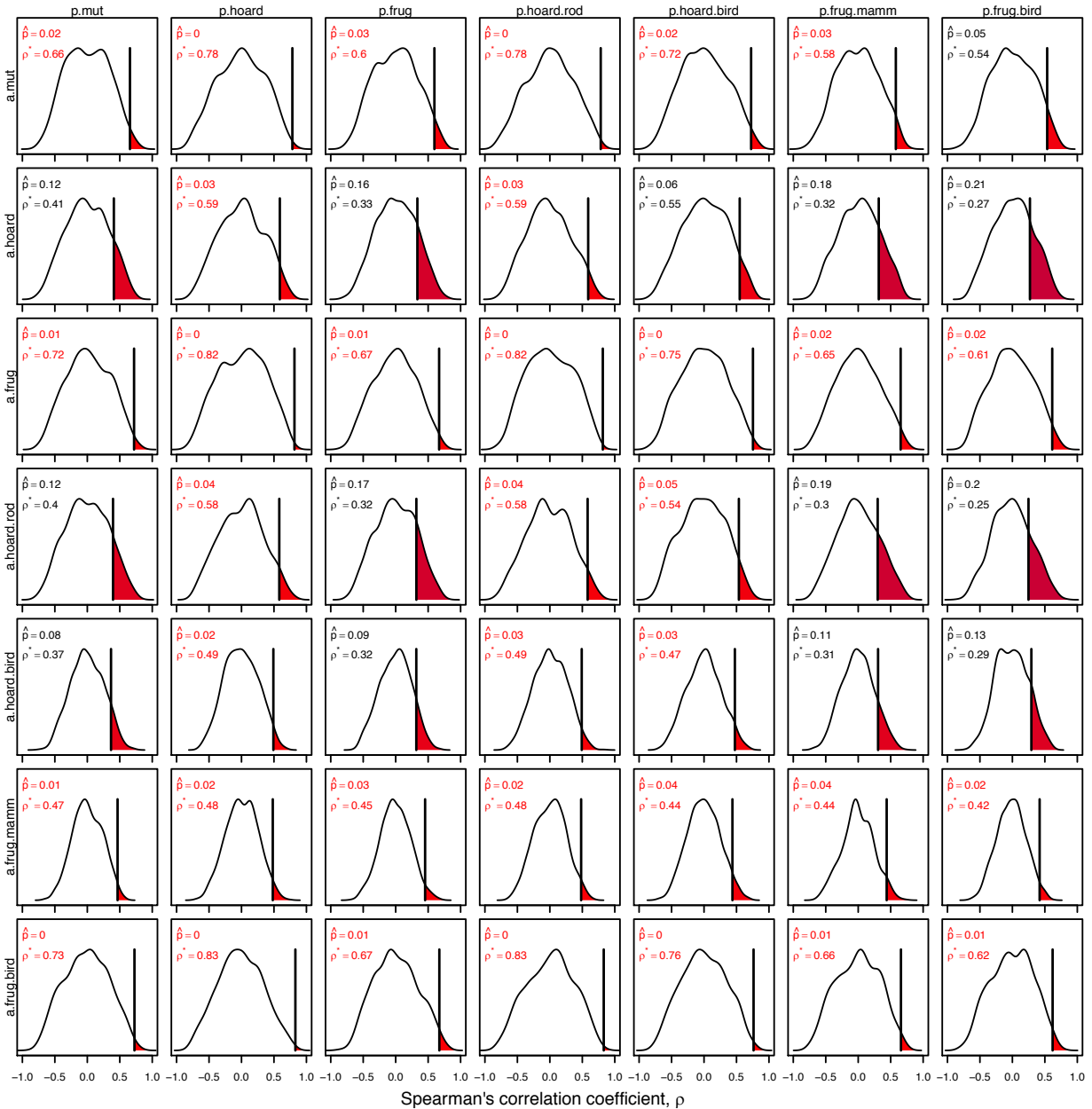


Figure A13. Results for the structured randomizations of the correlations between the difference in richness and environmental variables. Within each panel, the distribution represents the randomized Spearman's correlation coefficient, ρ ; vertical black lines represent the observed Spearman's correlation coefficient, ρ^* ; shaded areas represent parts of the distribution that were more extreme than ρ^* ; the $\hat{\rho}$ is the randomizations $\geq \rho^*$; and if $\leq 5\%$ of the randomizations were more extreme than ρ^* then we interpret that as statistically significant and color the statistical font red rather than black.

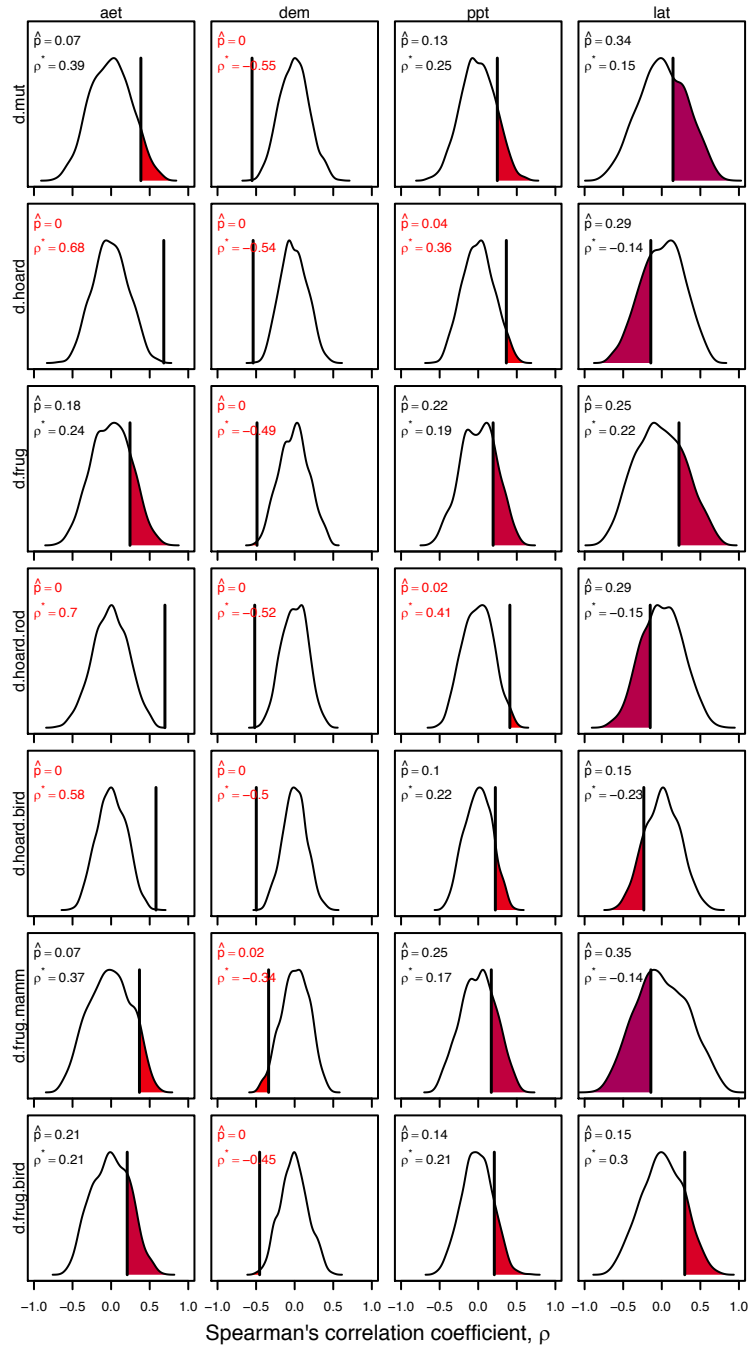


Figure A14. Results for the structured randomizations of the correlations between the plant and environmental variables. Within each panel, the distribution represents the randomized Spearman's correlation coefficient, ρ ; vertical black lines represent the observed Spearman's correlation coefficient, ρ^* ; shaded areas represent parts of the distribution that were more extreme than ρ^* ; the \hat{p} is the randomizations $\geq \rho^*$; and if $\leq 5\%$ of the randomizations were more extreme than ρ^* then we interpret that as statistically significant and color the statistical font red rather than black.

