1 Structural equation model analysis of alien bird and plant species richness

We developed our SEM model a priori based on hypothesised relationships from theoretical and empirical evidence (Figure S1). Large residual covariances and high modification indices (and standardised expected parameter change values) identified two missing paths. We respecified the model to include these paths; temperature-human population size and time since colonisation-precipitation. The respecified SEM model satisfied our goodness-of-fit criterion: χ^2 = 40.4, df = 28, *P* = 0.061; Comparative Fit Index (CFI) = 0.985; and Root Mean Square Error of Approximation (RMSEA) lower 90% confidence interval = 0. Path coefficients and parametric bootstrap 95% confidence are shown in Table S1.

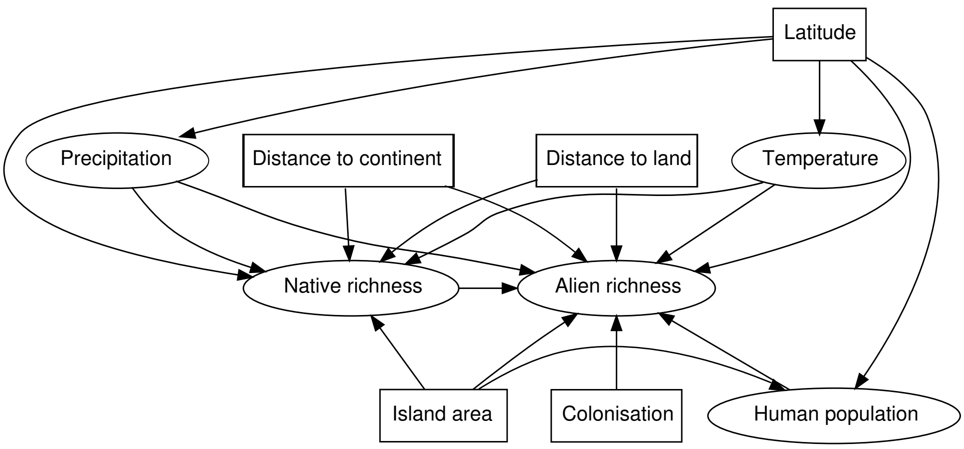

Figure S1. Conceptual path analysis structural equation model. Endogenous variables are shown in ellipses and exogenous variables in boxes; arrows indicate direction of effects.

We simplified the full model step-wise by removing terms with direct path coefficients with parametric bootstrap 95% confidence intervals that included zero. To simplify the path model, we first removed the variable latitude as there was only one direct path effect of latitude on any of the key endogenous variables with confidence intervals that excluded zero (i.e., all substantive total latitude effects were due to the indirect effects of other variables in the model). The one exception was a direct effect of latitude on plant alien species richness, however this estimate was highly imprecise (95% CI -0.850, 0.048). Removing latitude from the model for plants improved the overall model fit (based on the three model simplification criterion) despite the fact that the confidence interval for that term just excluded zero, probably as a result of the dramatic reduction in model complexity that resulted from removing the latitude variable.

Conditional on removing latitude, we then excluded both of the distance from land variables and temperature as exogenous variables to alien species richness, as well as distance from next largest land mass and precipitation exogenous variables to native species richness. In a final step, we excluded exogenous variables for alien species richness from the model for each taxon independently. For birds, we excluded island area and time since colonisation, and for plants we excluded precipitation and time since colonisation. At each stage of model simplification we assessed the goodness-of-fit of the model according to our criterion outlined in our Methods. The criterion were met for both taxon at each stage.

Birds: χ^2 = 19.4, df = 14, *P* = 0.151; CFI = 0.988; and RMSEA lower 90% confidence interval = 0.
Plants: χ^2 = 21.0, df = 14, *P* = 0.101; CFI = 0.982; and RMSEA lower 90% confidence interval = 0.

Table S1. Conceptual structural equation model standardised path coefficient estimates for each taxon. Italicised numbers in parentheses are 95% parametric bootstrap confidence intervals; blue bolding indicates path coefficients with confidence intervals that do not contain zero. Indirect effects are composite effects of all indirect paths in the model for each exogenous variable. Total effects are not shown for exogenous variables that only have a direct path to the endogenous variable (i.e., the total effect equals the direct effect).

Taxon		Birds			Plants		
Endogenous	Exogenous	Direct	Indirect	Total	Direct	Indirect	Total
Alien	Area	-0.053	**0.569**	**0.515**	-0.244	**0.709**	**0.465**
Species		*(-0.397, 0.276)*	*(0.284, 0.882)*	*(0.345, 0.684)*	*(-0.572, 0.071)*	*(0.419, 1.035)*	*(0.271, 0.648)*
Richness	Human Population	**0.495**			**0.414**		
		(0.172, 0.842)			*(0.088, 0.738)*		
	Native Richness	**0.398**			**0.614**		
		(0.077, 0.697)			*(0.373, 0.849)*		
	Latitude	0.435	-0.207	0.228	**-0.432**	0.557	0.125
		(-0.004, 0.890)	*(-0.755, 0.370)*	*(-0.157, 0.657)*	*(-0.850, -0.048)*	*(-0.034, 1.268)*	*(-0.325, 0.602)*
	Precipitation	**-0.268**	0.015	**-0.253**	-0.030	-0.014	-0.044
		(-0.425, -0.083)	*(-0.034, 0.079)*	*(-0.421, -0.074)*	*(-0.184, 0.117)*	*(-0.115, 0.089)*	*(-0.223, 0.124)*
	Temperature	**0.571**	**0.553**	**1.124**	-0.372	**0.772**	0.400
		(0.105, 1.061)	*(0.242, 0.957)*	*(0.690, 1.602)*	*(-0.900, 0.133)*	*(0.340, 1.292)*	*(-0.097, 0.871)*
	Colonisation	-0.228	**0.112**	-0.116	0.082	0.018	0.100
		(-0.441, 0.005)	*(0.021, 0.236)*	*(-0.334, 0.101)*	*(-0.095, 0.254)*	*(-0.052, 0.100)*	*(-0.069, 0.258)*
	Distance Land	0.011	-0.041	-0.030	0.108	-0.107	0.001
		(-0.170, 0.189)	*(-0.119, 0.012)*	*(-0.210, 0.141)*	*(-0.101, 0.310)*	*(-0.258, 0.026)*	*(-0.248, 0.240)*
	Distance Continent	0.004	**-0.092**	-0.088	0.031	-0.054	-0.023
		(-0.193, 0.214)	*(-0.202, -0.012)*	*(-0.267, 0.113)*	*(-0.170, 0.236)*	*(-0.214, 0.079)*	*(-0.283, 0.224)*
Native	Area	**0.601**			**0.678**		
Species		*(0.470, 0.730)*			*(0.509, 0.836)*		
Richness	Latitude	**0.323**	**-0.636**	**-0.313**	0.152	**-0.610**	**-0.458**
		(0.000, 0.673)	*(-0.962, -0.319)*	*(-0.451, -0.177)*	*(-0.275, 0.628)*	*(-1.074, -0.214)*	*(-0.615, -0.294)*
	Precipitation	0.038			-0.022		
		(-0.085, 0.167)			*(-0.170, 0.145)*		
	Temperature	**0.655**			**0.656**		
		(0.329, 1.009)			*(0.246, 1.152)*		
	Distance Land	-0.103			-0.174		
		(-0.242, 0.035)			*(-0.392, 0.040)*		
	Distance Continent	**-0.232**			-0.088		
		(-0.379, -0.088)			*(-0.321, 0.123)*		
Human	Area	**0.666**			**0.707**		
Population		*(0.555, 0.780)*			*(0.574, 0.847)*		
Size	Latitude	0.074	**-0.553**	**-0.479**	0.254	**-0.836**	**-0.582**
		(-0.221, 0.375)	*(-0.843, -0.297)*	*(-0.600, -0.351)*	*(-0.051, 0.597)*	*(-1.192, -0.541)*	*(-0.733, -0.423)*
	Temperature	**0.591**			**0.890**		
		(0.316, 0.897)			*(0.578, 1.253)*		

1.1 Effects of native plant species richness on alien and native bird species richness

A second stage of analysis was used to examine how relationships between alien and native bird species richness were associated with native plant species richness. The analyses were based on a subset of islands (*n* = 40) for which both bird and plant species richness data were avialable.

We used the final path model identified for bird species richness relationships from the full data set as a starting model, to which we then included the following additional sets of paths: (1) exogenous paths for the effects of native plant species richness on both native and alien bird species richness endogenous variables, and (2) exogenous paths for the effects of island area, temperature, and distance to nearest continental mainland on native plant species richness (as identified for native plant species richness relationships from models fitted to the full data set; Figure S2, Table S2). The SEM model satisfied our goodness-of-fit criterion: χ^2 = 10.1, df = 9, *P* = 0.34; Comparative Fit Index (CFI) = 0.995; and Root Mean Square Error of Approximation (RMSEA) lower 90% confidence interval = 0.

We simplified the model (as outlined above by removing terms with direct path coefficients with parametric bootstrap 95% confidence intervals that included zero) by removing: (1) the direct effects of native bird species richness and human population size on alien bird species richness, and (2) the direct effects of island area, temperature and distance from the nearest continental mainland on native bird species richness. The resulting SEM model satisfied our goodness-of-fit criterion: χ^2 = 13.8, df = 11, *P* = 0.24; Comparative Fit Index (CFI) = 0.989; and Root Mean Square Error of Approximation (RMSEA) lower 90% confidence interval = 0.

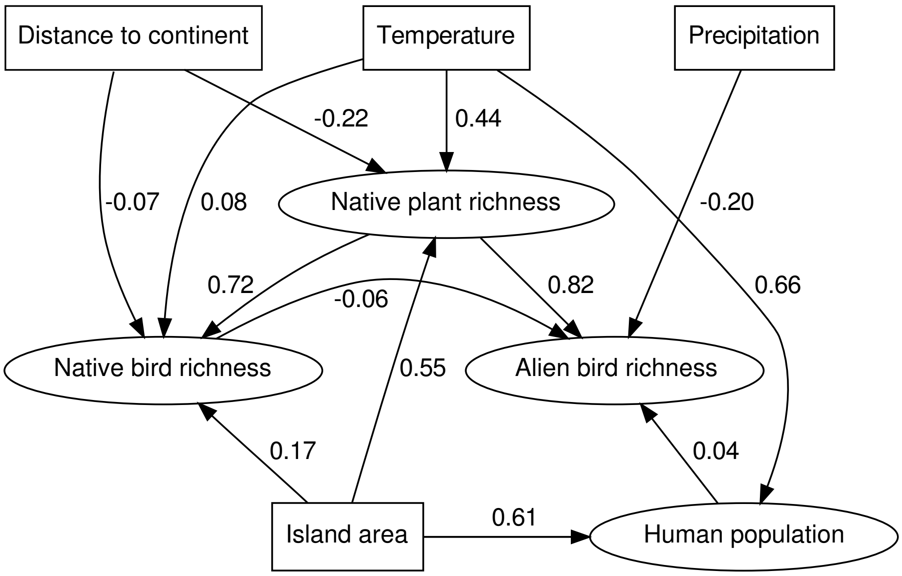

Figure S2. Path analysis model for bird-plant species richness relationships for the most complex model fitted to the subset of 40 islands. Endogenous variables are shown in ellipses and exogenous variables in boxes; arrows indicate direction of effects. The model r^2 values for each endogenous variable in the model are: alien bird species richness 0.70, native bird species richness 0.87, native plant species richness 0.74, human population size 0.86. Standardized path coefficient estimates from the models are shown for each path.

Table S2. Structural equation model standardized path coefficient estimates for the full model of bird-plant inter-relationships. Italicized numbers in parentheses are 95% parametric bootstrap confidence intervals. Indirect effects are composite effects of all indirect paths in the model for each exogenous variable.

Endogenous	Exogenous	Direct	Indirect	Total
Alien Bird	Island Area		**0.446**	
Species			*(0.261, 0.603)*	
Richness	Human Population	0.044		
		(-0.231, 0.338)		
	Native Bird Richness	-0.057		
		(-0.563, 0.425)		
	Precipitation	**-0.201**		
		(-0.385, -0.021)		
	Temperature		**0.366**	
			(0.183, 0.539)	
	Distance Continent		**-0.170**	
			(-0.340, -0.010)	
	Native Plant Richness	**0.818**	-0.041	**0.777**
		(0.337, 1.305)	*(-0.413, 0.302)*	*(0.514, 1.017)*
Native Bird	Island Area	0.174	**0.399**	**0.573**
Species		*(-0.009, 0.369)*	*(0.217, 0.583)*	*(0.394, 0.742)*
Richness	Temperature	0.076	**0.317**	**0.393**
		(-0.093, 0.241)	*(0.153, 0.499)*	*(0.219, 0.576)*
	Distance Continent	-0.070	**-0.162**	**-0.232**
		(-0.227, 0.082)	*(-0.314, -0.022)*	*(-0.422, -0.034)*
	Native Plant Richness	**0.722**		
		(0.483, 0.953)		
Native Plant	Island Area	**0.552**		
Species		*(0.344, 0.733)*		
Richness	Temperature	**0.439**		
		(0.243, 0.617)		
	Distance Continent	**-0.224**		
		(-0.413, -0.033)		
Human	Island Area	**0.607**		
Population		*(0.453, 0.753)*		
Size	Temperature	**0.659**		
		(0.501, 0.822)		

2 Generalised linear model analysis of alien bird and plant species richness

We assessed three models for alien richness that represented relationships with (1) human population size, (2) native species richness, and (3) island area. We examined interactions in these relationships between two taxa (birds and plants) and between five regions (Atlantic, Pacific, Southern, Indian and Caribbean), as well as additive effects. We also fitted a set of models where region effects were replaced with effects of either (absolute) latitude, distance from continent, distance from the next largest land mass, temperature, precipitation, and time since European colonisation. We allowed for (1) interactions between the two taxa and each explanatory variable, and (2) nonlinearity in latitude relationships with alien species richness. In order to prevent the fitting of overly complex models, we restricted models in the three sets to include only single additional covariates (plus their possible interaction with taxon), or pairs of additional covariates where these represented 'grouped pairs'; these included environmental (temperature and precipitation) or distance (to nearest continent or next largest land mass) pairs of variables. The starting models were:

Alien species richness ~ (*log* Island area * Taxon) * Region
OR
Alien species richness ~ (*log* Island area * Taxon) + ('covariate(s)') * Taxon,

Alien species richness ~ (*log* Native species richness * Taxon) * Region
OR
Alien species richness ~ (*log* Native species richness * Taxon) + ('covariate(s)') * Taxon,

AND
Alien species richness ~ (*log* Human population size * Taxon) * Region
OR
Alien species richness ~ (*log* Human population size * Taxon) + ('covariate(s)') * Taxon

A candidate model set was constructed to assess biologically-relevant hypotheses nested within these models. Specifically, we examined nested models where biogeographic effects were modelled only as a categorial 'Region' effect or only dependent on latitude, environment and distance from land, and where these effects did not differ between the taxa. We also assessed nested models that excluded biogeographic variables and focussed on the key drivers of human population size, native species richness and area. We also examined whether there was any evidence for nonlinear latitudinal gradients (rather than taking the absolute value of latitude that assumes the same linear pattern in both hemispheres) using regression splines. We used restricted cubic splines with 3 degree of freedom to avoid fitting overly complex models given the available sample size.

We used a similar approach to model relationships between native species richness and both island area and human population size. The starting models for these candidate sets were:

Native species richness ~ (*log* Island area * Taxon) * Region
OR
Native species richness ~ (*log* Island area * Taxon) + ('covariate(s)') * Taxon,

AND
Native species richness ~ (*log* Human population size * Taxon) * Region
OR
Native species richness ~ (*log* Human population size * Taxon) + ('covariate(s)') * Taxon

Alien and native species richness counts were modelled initially using generalised linear models with *log* link and Poisson variance. However, there was substantial overdispersion in the mean-variance relationships for models of both alien and native species richness so we fitted all generalised linear models using a negative binomial variance function (and *log* link). Models were ranked using AIC_c.

Fitted relationships and partial residuals were plotted to show relationships from the highest ranked models. Plots show model-averaged partial effects from models with $\Delta AIC_c < 4$.

2.1 Alien species richness

Across the three model sets for alien species richness (Tables S3-S6), by far the best supported models were those that included native species richness as a predictor (Tables S3, S6). The highest-ranked models including island area had $\Delta AIC_c > 22$ larger than the best model for native species richness, while the highest-ranked model including human population size had $\Delta AIC_c \sim 7$ larger than the best model for native species richness.

The model set for the relationship between the richness of alien and native species included eight models with $\Delta AIC_c < 4$ and a cumulative AIC_c weight of 0.96 (Table S3). All eight models included effects of native species richness, taxon, precipitation and temperature. The only other effects in this set of eight models were interactions between taxon and native species richness, taxon and temperature, and precipitation and temperature. Islands have more alien species if they have more native species, are warmer, and have lower precipitation (Figure S3 a-c). For a given native species richness, islands tend to have more alien plant than bird species (Figure S3 a-c).

The model set for the relationship between alien species richness and human population size revealed 12 models with $\Delta AIC_c < 4$ and a cumulative AIC_c weight of 0.89 (Table S3). All 12 models included effects of human population size and taxon, while nine models also included effects of precipitation. The most likely model in terms of human population size included a negative effect of time since European colonization and its interaction with taxon (more recently colonized islands have more alien bird species, but there is no relationship with alien plant species), but these effects are only included in two of the 12 most likely models (Table S3). Overall, islands have more alien bird species if they are home to more people, were colonised more recently, and are cooler (Figure S3 d-f); they have more alien plant species if they are home to more people, and are warmer (Figure S3 d, f). For a given human population size, islands have more alien plant than bird species (Figure S3).

The model set for the relationship between alien species richness and island area revealed five models with $\Delta AIC_c < 4$ and a cumulative AIC_c weight of 0.85 (Table S4). All models identify effects of island area, taxon, precipitation and temperature on alien species richness: islands have more alien species if they are larger, warmer and drier, while for a given area, islands tend to house more alien plant than bird species (Figure S3 g-i). The three most likely models also included an interaction between temperature and taxon, such that alien plant species richness increases more quickly with temperature than does alien bird species richness.

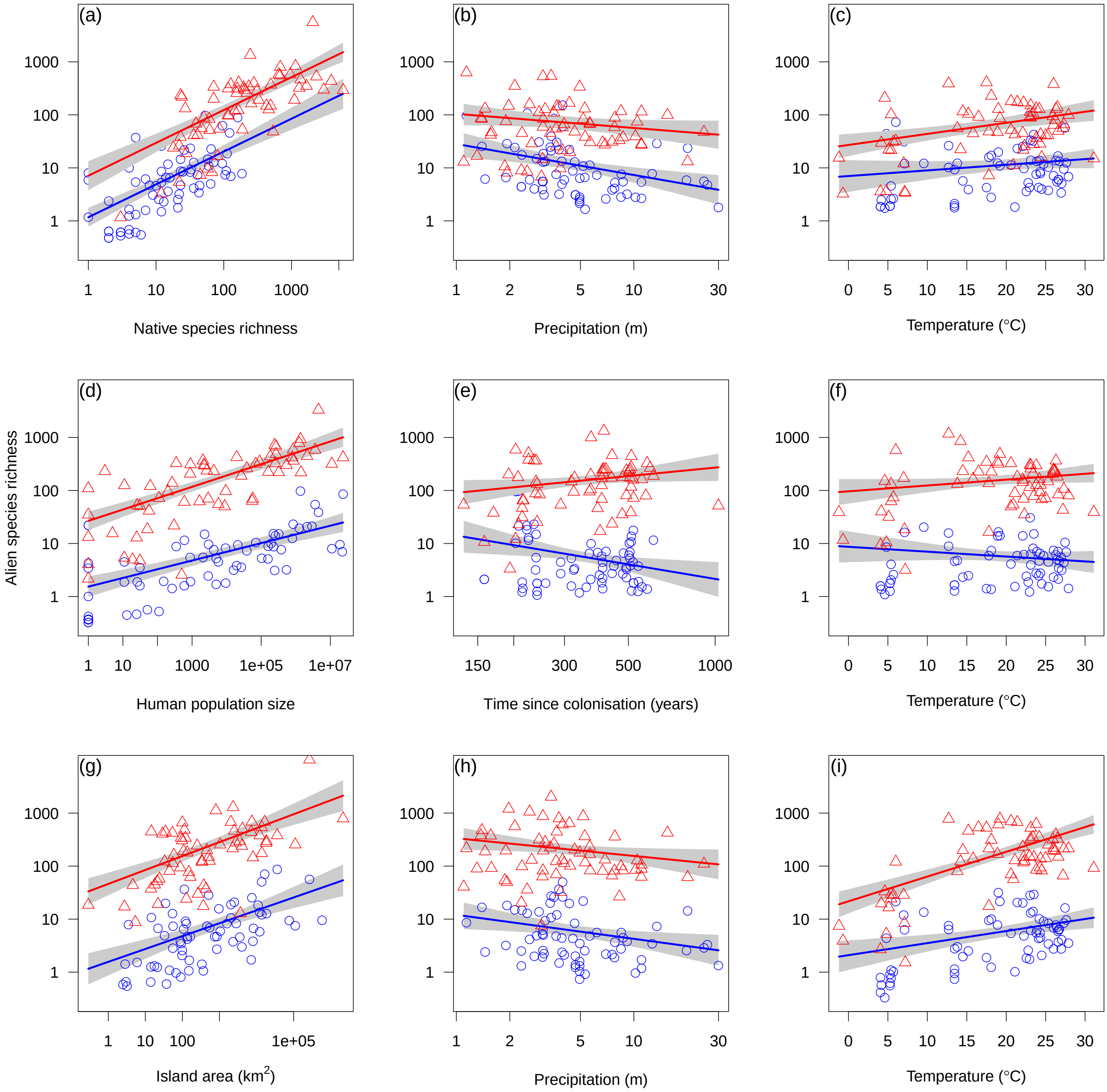

Figure S3. Model fitted estimates of the relationship between alien species richness and: (first row) terms in the highest-ranked model in the native species model set, (a) native species richness, (b) precipitation, and (c) temperature; (second row) terms in the highest-ranked model in the human population model set, (d) human population size, (e) time since European colonisation, and (f) temperature; and (third row) terms in the highest-ranked model in the island area model set, (g) island area, (h) precipitation, and (i) temperature. Red line shows relationship for plants, blue line for birds; points show partial deviance residuals for birds (blue circles) and plants (red traingles). Grey shading shows 95% confidence intervals.

Table S3. Model selection summary table for alien species richness relationship with native species richness model set (only models with ΔAIC_c < 4 are shown). LNat = *log*(Native richness), Tx = Taxon, Pcp = precipitation, Tmp = Temperature; df = degrees of freedom, AIC_c = Akaike's Information Criterion corrected for finite sample size, ΔAIC_c = difference from minimum AIC_c model, $wAIC_c$ = AIC_c weight.

LNat	Tx	LNat:Tx	Pcp	Tmp	Pcp:Tx	Tx:Tmp	df	AIC_c	ΔAIC_c	$wAIC_c$
+	+		+	+			6	1122.72	0.00	0.24
+	+		+	+	+		7	1122.76	0.04	0.23
+	+		+	+		+	7	1123.70	0.99	0.14
+	+		+	+	+	+	8	1124.30	1.58	0.11
+	+	+	+	+			7	1124.76	2.05	0.08
+	+	+	+	+	+		8	1124.97	2.25	0.08
+	+	+	+	+		+	8	1125.97	3.25	0.05
+	+	+	+	+	+	+	9	1126.61	3.89	0.03

Table S4. Model selection summary table for alien species richness relationship with human population size model set (only models with ΔAIC_c < 4 are shown). LHum = *log*(Human population size), Ldst = *log*(distance to mainland), Lat = (absolute) Latitude, Tx = Taxon, Pcp = precipitation, Tmp = Temperature, LTcol = *log*(Time since European colonisation); df = degrees of freedom, AIC_c = Akaike's Information Criterion corrected for finite sample size, ΔAIC_c = difference from minimum AIC_c model, $wAIC_c$ = AIC_c weight.

LHum	Tx	LHum:Tx	Lat	Lat:Tx	Pcp	Tmp	Pcp:Tx	Tx:Tmp	LTcol	LTcol:Tx	df	AIC_c	ΔAIC_c	$wAIC_c$
+	+								+	+	6	1129.65	0.00	0.18
+	+	+			+						6	1130.28	0.63	0.13
+	+				+	+		+			7	1130.53	0.88	0.12
+	+				+						5	1130.76	1.12	0.10
+	+	+							+	+	7	1131.87	2.22	0.06
+	+	+			+	+					7	1132.20	2.55	0.05
+	+	+			+		+				7	1132.33	2.68	0.05
+	+	+			+	+		+			8	1132.49	2.84	0.04
+	+				+		+				6	1132.53	2.88	0.04
+	+		+	+							6	1132.62	2.97	0.04
+	+				+	+	+	+			8	1132.79	3.14	0.04
+	+				+	+					6	1132.80	3.15	0.04

Table S5. Model selection summary table for alien species richness relationship with island area model set (only models with ΔAIC_c < 4 are shown). LAr = *log*(Area), Tx = Taxon, Pcp = precipitation, Tmp = Temperature; df = degrees of freedom, AIC_c = Akaike's Information Criterion corrected for finite sample size, ΔAIC_c = difference from minimum AIC_c model, $wAIC_c$ = AIC_c weight.

LAr	Tx	LAr:Tx	Pcp	Tmp	Pcp:Tx	Tx:Tmp	df	AIC_c	ΔAIC_c	$wAIC_c$
+	+		+	+		+	7	1145.35	0.00	0.40
+	+		+	+	+	+	8	1147.40	2.04	0.14
+	+	+	+	+		+	8	1147.50	2.15	0.14
+	+		+	+			6	1148.00	2.65	0.11
+	+		+	+	+		7	1149.08	3.72	0.06

Table S6. Model selection summary table for alien species richness relationship - all candidate models from above sets included (only models with ΔAIC_c < 4 are shown). LHum = *log*(Human population size), LAr = *log*(Area), LNat = *log*(Native richness), Lat = (absolute) Latitude, Rg = Region, Tx = Taxon, LdC = *log*(Distance to continent), LdL = *log*(Distance to next largest land mass), Pcp = precipitation, Tmp = Temperature, LTcol = *log*(Time since European colonisation); df = degrees of freedom, AIC_c = Akaike's Information Criterion corrected for finite sample size, ΔAIC_c = difference from minimum AIC_c model, $wAIC_c$ = AIC_c weight.

LHum	Rg	Tx	LHum:Tx	LdC	LdL	Lat	Pcp	Tmp	Pcp:Tx	Tx:Tmp	LTcol	LNat	LNat:Tx	LAr	LAr:Tx	df	AIC_c	ΔAIC_c	$wAIC_c$
		+					+	+				+				6	1122.72	0.00	0.23
		+					+	+	+			+				7	1122.76	0.04	0.22
		+					+	+		+		+				7	1123.70	0.99	0.14
		+					+	+	+	+		+				8	1124.30	1.58	0.10
		+					+	+				+	+			7	1124.76	2.05	0.08
		+					+	+	+			+	+			8	1124.97	2.25	0.07
		+					+	+		+		+	+			8	1125.97	3.25	0.04
		+					+	+	+	+		+	+			9	1126.61	3.89	0.03

2.2 Native species richness

Models for native species richness in terms of island area (Table S7) were far more strongly supported than models in terms of human population size (Table S8). The most likely model for the latter predictor had $\Delta AIC_c \sim 10$ higher than the best model overall. The model set for the relationship between native species richness and island area revealed nine models with $\Delta AIC_c < 4$ and a cumulative AIC_c weight of 0.87 (Table S7). All nine models identified effects of area, taxon and temperature. In general, islands have more native species if they are larger and warmer, while islands tend to house more native plant than native bird species for a given area (Figure S4). There is some indication that native species richness is higher on drier islands (Table S7, Figure S4).

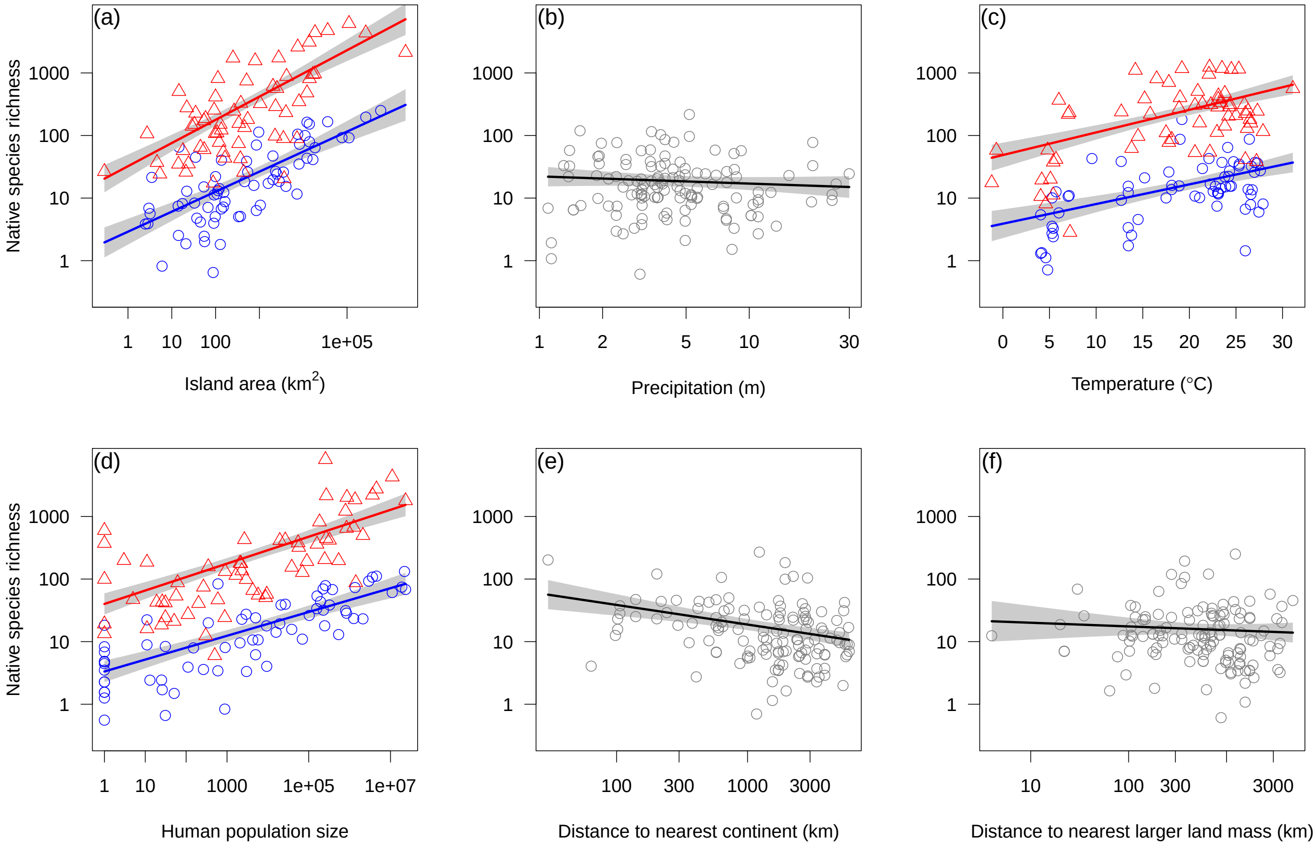

Figure S4. Model fitted estimates of the relationship between native species richness and: (first row) terms in the highest-ranked model in the island area model set, (a) island area, (b) precipitation, and (c) temperature; (second row) terms in the highest-ranked model in the human population model set, (d) human population size, (e) distance to nearest continent, and (f) distance to nearest larger land mass. Red line shows relationship for plants and blue line for birds; points show partial deviance residuals for birds (blue circles), plants (red traingles). Black lines and grey circles are used for common relationships and residuals across taxa, respectively. Grey shading shows 95% confidence intervals.

Table S7. Model selection summary table for native species richness relationship with island area model set (only models with ΔAIC_c < 4 are shown). LAr = *log*(Area), Tx = Taxon, Pcp = precipitation, Tmp = Temperature; df = degrees of freedom, AIC_c = Akaike's Information Criterion corrected for finite sample size, ΔAIC_c = difference from minimum AIC_c model, $wAIC_c$ = AIC_c weight.

LAr	Tx	LAr:Tx	Pcp	Tmp	df	AIC_c	ΔAIC_c	$wAIC_c$
+	+			+	5	1318.54	0.00	0.23
+	+	+		+	6	1319.47	0.94	0.14
+	+		+	+	6	1319.58	1.05	0.14
+	+			+	6	1320.43	1.89	0.09
+	+	+	+	+	7	1320.45	1.92	0.09
+	+	+		+	7	1321.55	3.01	0.05
+	+		+	+	7	1321.55	3.02	0.05
+	+		+	+	7	1321.58	3.04	0.05
+	+	+	+	+	8	1322.36	3.82	0.03

Table S8. Model selection summary table for native species richness relationship with human population size model set (only models with ΔAIC_c < 4 are shown). LHum = *log*(Human population size), Tx = Taxon, LdC = *log*(Distance to continent), LdL = *log*(Distance to larger land mass); df = degrees of freedom, AIC_c = Akaike's Information Criterion corrected for finite sample size, ΔAIC_c = difference from minimum AIC_c model, $wAIC_c$ = AIC_c weight.

LHum	Tx	LHum:Tx	LdC	LdL	LdC:Tx	df	AIC_c	ΔAIC_c	$wAIC_c$
+	+		+			5	1328.49	0.00	0.36
+	+	+	+			6	1329.81	1.32	0.18
+	+		+	+		6	1330.19	1.69	0.15
+	+		+		+	6	1330.69	2.19	0.12
+	+	+	+	+		7	1331.55	3.05	0.08
+	+	+	+		+	7	1331.91	3.42	0.06

3 References

R Core Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.