Ecography

ECOG-01531
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Supplementary material

Appendix 1

Table A1A: Comparison of environmental predictor models while correcting for variation in average body mass. All WLS and SAR models are a significant fit at $p < 0.001$. ΔAIC values represent the difference between each model and the best-fitting model for that analysis. Multivariate models are shown in bold, with their variables listed below.

	WLS		SAR			PGLS			
	ΔAIC		ΔAIC	z		ΔAIC	R^{2*}	b	
Latitude	0	–	217	-20.07	–	3.4 ± 0.2	0.01	9.46E-06	N.S.
Geographic	**7**		**369**			**6.4 ± 0.4**	**0.01**		
Absolute Latitude	1178	–	309	-17.48	–	3.4 ± 0.2	0.01	1.88E-05	N.S.
Altitude	1088	–	592	-3.63	–	4.7 ± 0.4	0.01	1.64E-05	N.S.
Average Climate	**524**		**483**			**7.1 ± 0.3**	**0.01**		
Temperature	684	+	483	11.28	+	4.8 ± 0.3	0.01	1.54E-05	N.S.
Precipitation	872	+	592	3.63	+	5.1 ± 0.3	0.01	6.04E-06	N.S.
Within-Year Var	**675**		**308**			**9.1 ± 0.5**	**0.01**		
Temperature	1134	–	395	17.17	+	5.9 ± 0.3	0.01	-5.55E-07	N.S.
Precipitation	688	+	508	9.86	+	3.2 ± 0.3	0.01	-2.11E-04	N.S.
Among-Year Var	**1158**		**0**			**3.5 ± 0.2**	**0.01**		
Temperature	1178	–	19	26.03	+	3.7 ± 0.3	0.01	1.38E-06	N.S.
Precipitation	1181	–	578	5.24	+	0.0 ±0.0	0.01	-5.54E-02	N.S.

Table A1B: Comparison of environmental predictor models with coastlines removed from spatial analyses and seabirds removed from phylogenetic analyses. All WLS models are a significant fit at $p < 0.001$. ΔAIC values represent the difference between each model and the best-fitting model for that analysis. Multivariate models are shown in bold, with their variables listed below.

	WLS		SAR				PGLS			
	ΔAIC		ΔAIC	z			ΔAIC	R^{2*}	b	
Latitude	237	–	444	2.17	+	*	3.4 ± 0.2	0.01	-4.05E-05	N.S.
Geographic	**32**		**350**				**6.4 ± 0.4**	**0.01**		
Absolute Latitude	369	–	390	7.77	+	***	3.4 ± 0.2	0.01	-2.90E-05	N.S.
Altitude	91	–	403	-6.78	–	***	4.7 ± 0.4	0.01	1.84E-05	N.S.
Average Climate	**0**		**436**				**7.1 ± 0.3**	**0.01**		
Temperature	391	–	440	-2.91	–	**	4.8 ± 0.3	0.01	2.15E-05	N.S.
Precipitation	70	+	446	1.66	+	N.S.	5.1 ± 0.3	0.01	8.12E-06	N.S.
Within-Year Var	**59**		**231**				**9.1 ± 0.5**	**0.01**		
Temperature	393	+	380	8.37	+	***	5.9 ± 0.3	0.01	-8.40E-07	N.S.
Precipitation	137	+	300	12.24	+	***	3.2 ± 0.3	0.01	-2.35E-04	N.S.
Among-Year Var	**28**		**0**				**3.5 ± 0.2**	**0.01**		
Temperature	288	+	84	19.26	+	***	3.7 ± 0.3	0.01	-3.59E-04	N.S.
Precipitation	61	–	369	9.02	+	***	0.0 ± 0.0	0.01	-6.48E-02	N.S.

Table A2: Comparison of relationships between environmental predictor models and SDI calculated from species breeding ranges. Univariate predictor regressions are shown in regular weight text, while multivariate predictor models are shown in bold with their individual component variables listed below. This table compares the goodness of fit for spatial analyses across the global grid using weighted least squares (WLS) and spatial autoregression (SAR), as well as phylogenetic comparative analyses among species using phylogenetic generalized least squares (PGLS). ΔAIC values represent the difference between each model and the best-fitting model for that analysis, with the AIC of PGLS analyses averaged across trees.

	WLS		SAR			PGLS		
	ΔAIC	R^2	ΔAIC	R^2	z	ΔAIC	R^2*	b
Latitude	779	0.00	92	0.31	5.65	19.5 ± 0.8	0.00	4.20E-06
Geographic	**606**	**0.01**				13.0 ± 0.6	**0.00**	
Absolute Latitude	847	0.00	0	0.31	11.2	18.1 ± 0.6	0.00	6.46E-06
Altitude	610	0.01	59	0.3	8.05	11.2 ± 0.7	0.00	1.81E-07
Average Climate	**627**	**0.01**				**10.7 ± 0.4**	**0.00**	
Temperature	826	0.00	49	0.31	-8.6	22.0 ± 0.6	0.00	1.27E-06
Precipitation	626	0.00	92	0.31	-5.9	0.0 ± 0.0	0.00	2.20E-07
Within-Year Var	**0**	**0.05**				**21.4 ± 0.6**	**0.00**	
Temperature	833	0.00	30	0.31	9.73	16.3 ± 0.5	0.00	3.10E-08
Precipitation	2	0.04	107	0.31	4.16	23.4 ± 0.8	0.00	3.67E-06
Among-Year Var	**713**	**0.01**				**19.0 ± 0.6**	**0.00**	
Temperature	811	0.00	44	0.31	8.95	20.1 ± 0.6	0.00	4.92E-05
Precipitation	785	0.00	117	0.31	-2.7	14.5 ± 0.6	0.00	1.17E-03

* - Refers to adjusted pseudo-R2 values. R^2 values for PGLS analyses should be interpreted cautiously (Symonds and Blomberg, 2014).

Table A3: Comparison of weighted least squared regressions across zoogeographic regions (citation). Significance level is indicated by asterices (N.S. > 0.05, * < 0.05, ** < 0.01, *** < 0.001). Direction of relationship is indicated by a + for a positive relationship, and a – for a negative relationship. Best-fit multivariate models are shaded in light grey, and best-fit predictor variables are shaded in a darker grey.

	Afrotropics				Australian				Madagascan				Nearctic			
	ΔAIC	R^2	p		ΔAIC	R^2	p		ΔAIC	R^2	p		ΔAIC	R^2	p	
Latitude	1636	0.01	***	–	13	0.35	***	–	19	0.10	***	–	328	0.05	***	–
Geographic	**466**	**0.31**	***		**0**	**0.35**	***		**0**	**0.25**	**		**329**	**0.05**	***	
Absolute Latitude	475	0.31	***	–	13	0.35	***	+	19	0.10	***	+	328	0.05	***	–
Altitude	1654	0.00	***	–	517	0.00	N.S.	–	6	0.20	***	+	448	0.00	**	+
Average Climate	**1013**	**0.18**	***		**3**	**0.35**	***		**9**	**0.19**	***		**50**	**0.14**	***	
Temperature	1639	0.01	***	+	10	0.35	***	–	19	0.10	***	–	376	0.03	***	+
Precipitation	1095	0.16	***	+	514	0.00	*	+	23	0.06	**	–	238	0.08	***	–
Within-Year Var	**0**	**0.40**	***		**21**	**0.34**	***		**5**	**0.22**	***		**0**	**0.16**	***	
Temperature	86	0.39	***	–	518	0.00	N.S.	+	17	0.12	***	+	457	0.00	N.S.	+
Precipitation	1616	0.02	***	–	82	0.31	*	–	22	0.07	**	+	13	0.15	***	+
Among-Year Var	**1396**	**0.08**	***		**353**	**0.13**	**		**1**	**0.24**	**		**215**	**0.09**	***	
Temperature	1481	0.06	***	–	359	0.13	***	–	7	0.19	***	+	449	0.00	**	–
Precipitation	1474	0.06	***	–	422	0.08	***	–	29	0.01	N.S.	+	216	0.09	***	+

	Neotropic				Oceanina				Oriental				Palearctic			
	ΔAIC	R^2	p		ΔAIC	R^2	p		ΔAIC	R^2	p		ΔAIC	R^2	p	
Latitude	0	0.14	***	–	63	0.03	**	+	106	0.02	***	–	377	0.03	***	–
Geographic	**33**	**0.12**	***		**0**	**0.19**	***		**117**	**0.01**	***		**263**	**0.05**	***	
Absolute Latitude	49	0.12	***	+	3	0.17	***	–	115	0.01	***	–	380	0.03	***	–
Altitude	346	0.01	***	–	64	0.03	**	+	135	0.00	N.S.	–	554	0.00	***	–
Average Climate	**120**	**0.09**	***		**63**	**0.03**	N.S.		**70**	**0.05**	***		**532**	**0.00**	***	
Temperature	139	0.09	***	–	73	0.00	N.S.	+	118	0.01	***	–	534	0.01	***	+
Precipitation	351	0.00	**	–	61	0.03	***	+	90	0.03	***	+	565	0.00	***	+
Within-Year Var	**218**	**0.06**	***		**38**	**0.10**	**		**0**	**0.09**	***		**0**	**0.09**	***	
Temperature	297	0.02	***	+	46	0.07	***	–	120	0.01	***	–	115	0.08	***	+
Precipitation	254	0.04	***	–	47	0.07	***	–	16	0.08	***	–	243	0.06	***	+
Among-Year Var	**357**	**0.00**	N.S.		**74**	**0.00**	N.S.		**126**	**0.01**	N.S.		**297**	**0.05**	***	
Temperature	356	0.00	N.S.	–	72	0.00	N.S.	–	125	0.01	***	+	354	0.04	***	+
Precipitation	356	0.00	N.S.	–	73	0.00	N.S.	–	136	0.00	N.S.	+	575	0.00	*	+

	Panamanian				Saharo-Arabian				Sino-Japanese			
	ΔAIC	R^2	p		ΔAIC	R^2	p		ΔAIC	R^2	p	
Latitude	19	0.00	N.S.	–	490	0.02	***	–	454	0.00	N.S.	+
Geographic	**5**	**0.05**	N.S.		**475**	**0.03**	***		**73**	**0.40**	N.S.	
Absolute Latitude	19	0.00	N.S.	–	490	0.02	***	–	454	0.00	N.S.	+
Altitude	0	0.04	***	+	508	0.01	**	+	72	0.40	***	–
Average Climate	**0**	**0.06**	***		**412**	**0.07**	***		**37**	**0.43**	***	
Temperature	19	0.06	***	–	494	0.01	***	+	152	0.33	***	+
Precipitation	16	0.01	N.S.	+	497	0.01	***	+	54	0.41	***	+
Within-Year Var	**19**	**0.00**	N.S.		**2**	**0.28**	N.S.		**0**	**0.46**	**	
Temperature	19	0.00	N.S.	+	0	0.00	*	–	453	0.00	N.S.	+
Precipitation	17	0.00	N.S.	+	497	0.28	***	+	9	0.45	***	–
Among-Year Var	**17**	**0.01**	N.S.		**459**	**0.04**	***		**284**	**0.21**	***	
Temperature	18	0.00	N.S.	–	497	0.01	***	+	285	0.00	N.S.	–
Precipitation	16	0.00	N.S.	+	463	0.03	***	–	451	0.20	***	–

Table A4: Comparison of spatial autocorrelation regressions across zoogeographic regions (citation). Significance level is indicated by asterices (N.S. > 0.05, * < 0.05, ** < 0.01, *** < 0.001). Direction of relationship is indicated by a + for a positive relationship, and a – for a negative relationship. Best-fit multivariate models are shaded in light grey, and best-fit predictor variables are shaded in a darker grey.

	Afrotropics			Australian			Madagascan			Nearctic		
	ΔAIC	z	p	ΔAIC	z	p	ΔAIC	z	p	ΔAIC	z	p
Latitude	1548	-22.5	**	16.35	-17	***	21.32	-2.5	*	401.7	9.7	***
Geographic	**377**			**1.25**			**0**			**385**		
Absolute Latitude	391	-35.2	***	16.35	17	***	21.32	2.5	*	401.7	9.7	***
Altitude	1540	-4.25	***	126.9	-2.4	*	2.197	5.3	***	476.1	-4.2	***
Average Climate	**853**			**0**			**10.4**			**255**		
Temperature	1522	6	***	1.46	-16.7	***	15.74	-3.6	***	343.2	-12.5	***
Precipitation	957	12.9	***	131.8	0.8	N.S.	23.27	-2	*	296.1	-14.3	***
Within-Year Var	**0**			**0.8**			**7.07**			**0**		
Temperature	71	-46.1	***	131.1	-1.2	N.S.	18.05	3.1	**	173	18.5	***
Precipitation	560	23.8	***	29.84	-12.2	***	19.1	3	**	263.5	17.8	***
Among-Year Var	**991**			**102**			**7.27**			**311**		
Temperature	1011	0.63	N.S.	101.6	-13.2	***	12.56	4.1	***	367.3	11.4	***
Precipitation	992	-14.7	***	117.2	-4	***	27.02	0.7	N.S.	440.5	10.8	***

	Neotropic			Oceanian			Oriental			Palearctic		
	ΔAIC	z	p	ΔAIC	z	p	ΔAIC	z	p	ΔAIC	z	p
Latitude	0	-14.2	***	42.67	0.8	N.S.	53	-1.3	N.S.	237.4	-16.5	***
Geographic	**24.2**			**14**			**52**			**206.5**		
Absolute Latitude	49.7	12.9	***	14.68	-7.3	***	55	0	N.S.	239.4	-16.5	***
Altitude	155	-3.6	***	41.47	1.4	N.S.	51	-2.1	*	486.4	-3	**
Average Climate	**129.1**			**16.7**			**53**			**296.9**		
Temperature	128	-7.8	***	43.26	0.3	N.S.	55	-0.3	N.S.	335	12.9	***
Precipitation	166.4	-1.2	N.S.	14.79	5.5	***	51	2.1	*	428.8	8.2	***
Within-Year Var	**109**			**0.75**			**34**			**347.8**		
Temperature	147.8	5.1	***	31.21	-3.6	***	54	0.7	N.S.	353.9	12	***
Precipitation	129.6	-6.3	***	0	-6.8	***	35	-6	***	482.3	3.7	***
Among-Year Var	**168.4**			**30.1**			**0**			**0**		
Temperature	166.7	-1	N.S.	29.11	-3.9	***	10	6.8	***	37.1	22.4	***
Precipitation	167.7	0.2	N.S.	40.74	-1.6	N.S.	40	3.9	***	481	3.8	***

	Panamanian			Saharo-Arabian			Sino-Japanese		
	ΔAIC	z	p	ΔAIC	z	p	ΔAIC	z	p
Latitude	19.18	-1.2	N.S.	156.3	2	*	24.27	-8.5	***
Geographic	**1.99**			**148**			**0**		
Absolute Latitude	19.18	-1.2	N.S.	156.3	2	*	24.27	-8.5	***
Altitude	0.63	4.5	***	150	-3.2	**	84.95	3.6	***
Average Climate	**0**			**148**			**63.1**		
Temperature	1.04	-4.5	***	146.3	3.7	***	87.69	2.5	*
Precipitation	15.54	2.2	*	156.3	-1.9	N.S.	65.85	5.6	***
Within-Year Var	**14.83**			**0**			**13.2**		
Temperature	20.42	-0.3	N.S.	159.8	-0.6	N.S.	87.58	-2.2	*
Precipitation	12.86	2.8	**	2.33	12.9	***	11.63	-10	***
Among-Year Var	**16.96**			**162**			**30.6**		
Temperature	18.69	1.4	N.S.	159.9	-0.4	N.S.	92.19	0.1	N.S
Precipitation	18.36	1.5	N.S.	160	0.3	N.S.	35.5	-7.7	***

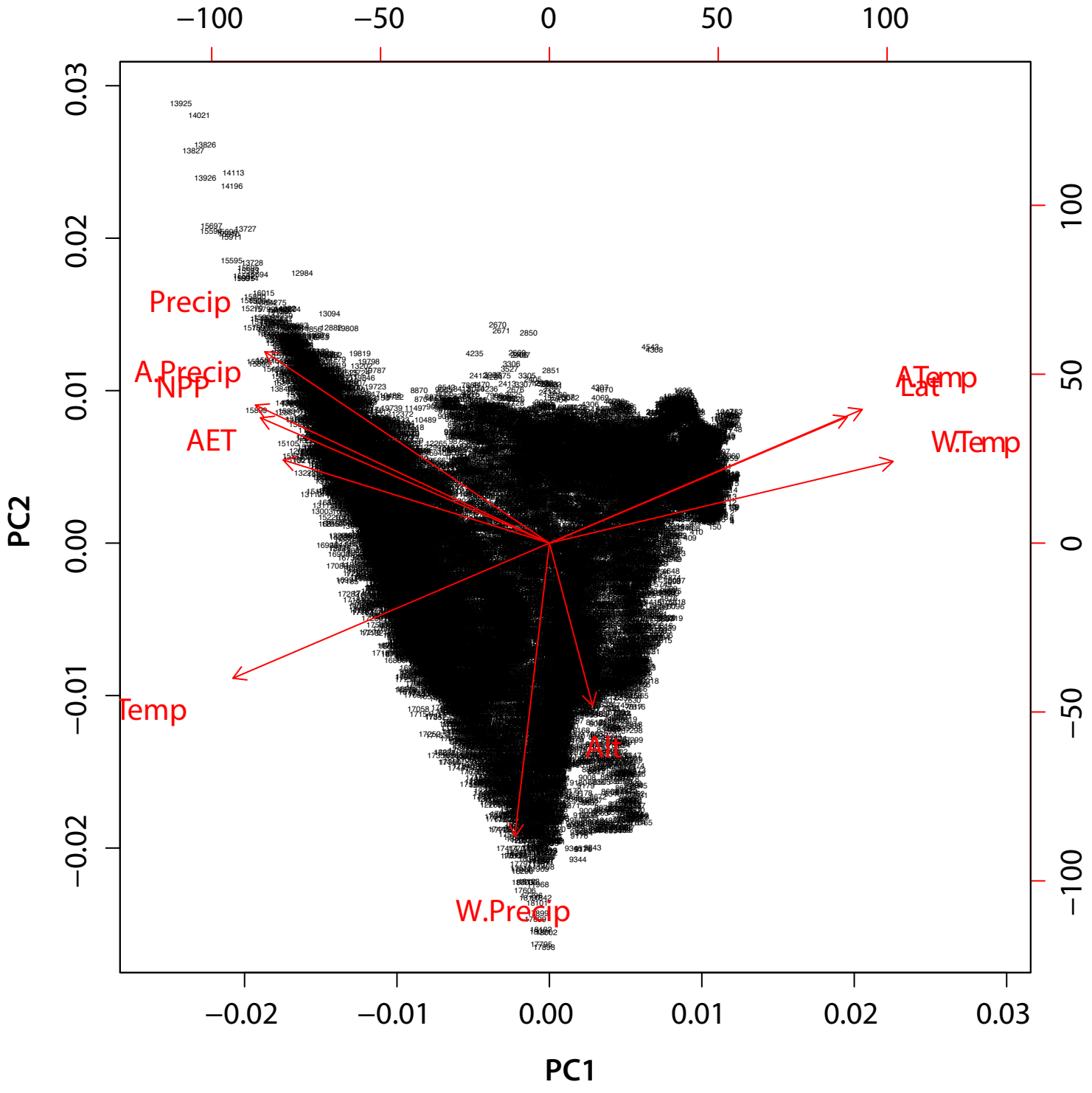

Figure A1: Exploratory principle components analysis of climate predictor variables. Net Primary Productivity (NPP) and Actual Evapo-Transpiration (AET) were excluded from further analyses as they closely correlate with Precipitation. The prefixes "W" and "A" refer to within-year and among-year climate variation, respectively.

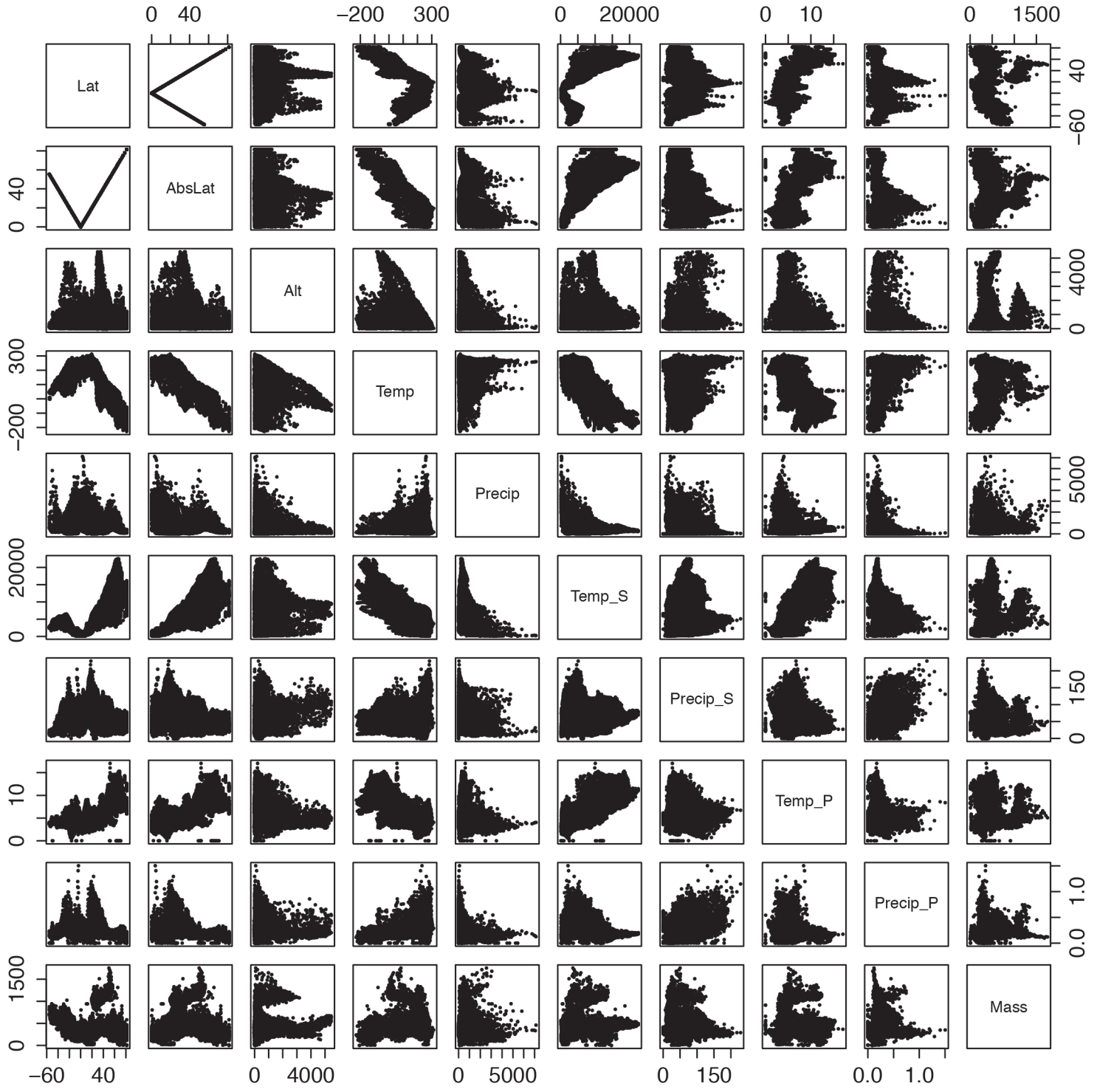

Figure A2: Relationships among predictor variables included in modeling global variation in SDI.

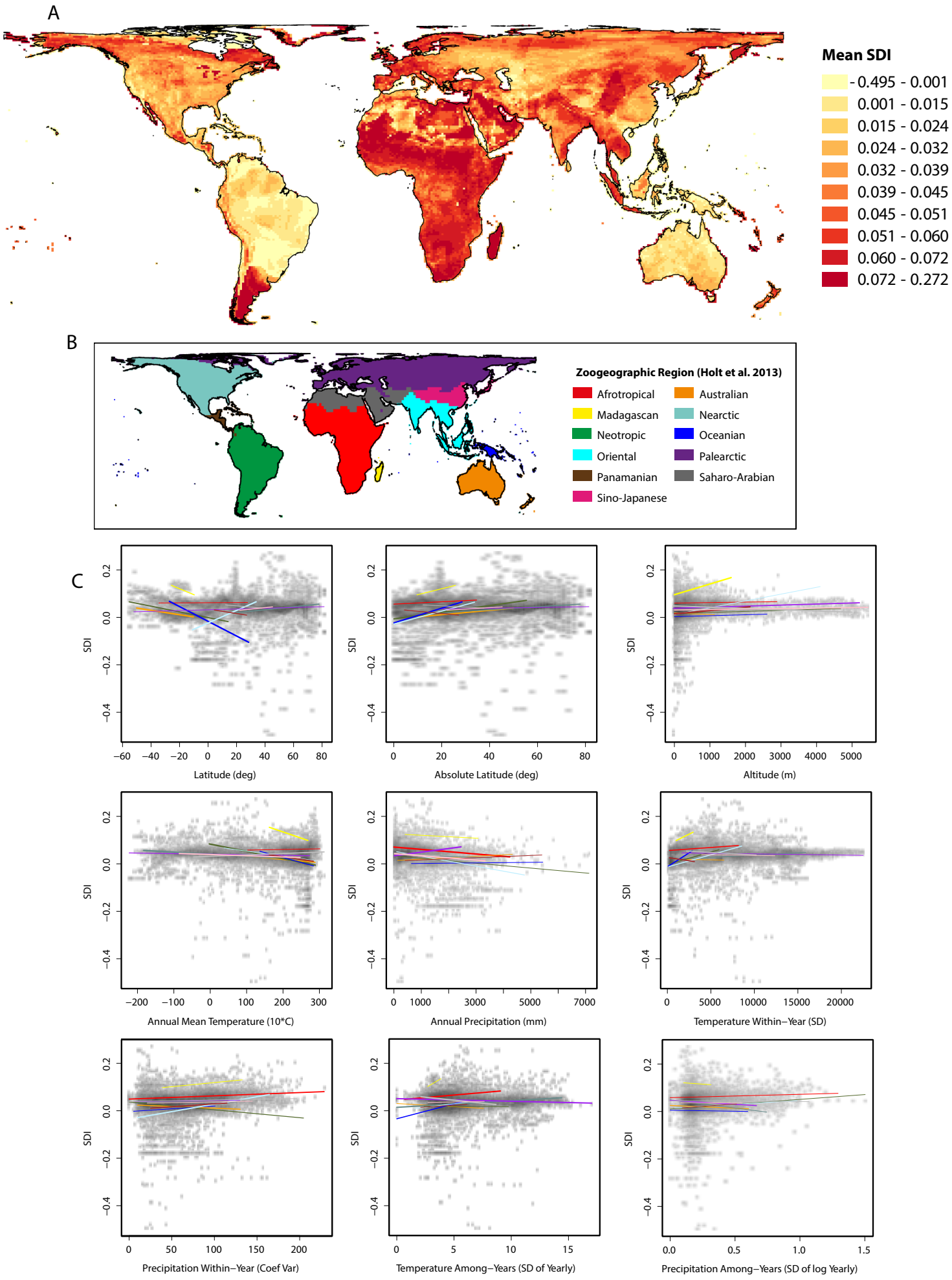

Figure A3: Using only breeding distributions, the global distribution of sexual size dimorphism and its climate correlates. (A) Mean Sexual Dimorphism Index (SDI) of species in each cell of a 1° equivalent equal area grid, with color classes representing 10%-ile bins. (B) Zoogeographical regions, as described by Holt et al. (2013). (C) Scatterplots of SDI versus the ecological predictor variables examined in this study; these have been rasterized to show point density. Trend lines represent sampling-weighted correlations for each zoogeographical region, which is labeled by color. Line width indicates model rank, with thicker lines representing more closely fitting models for that region.

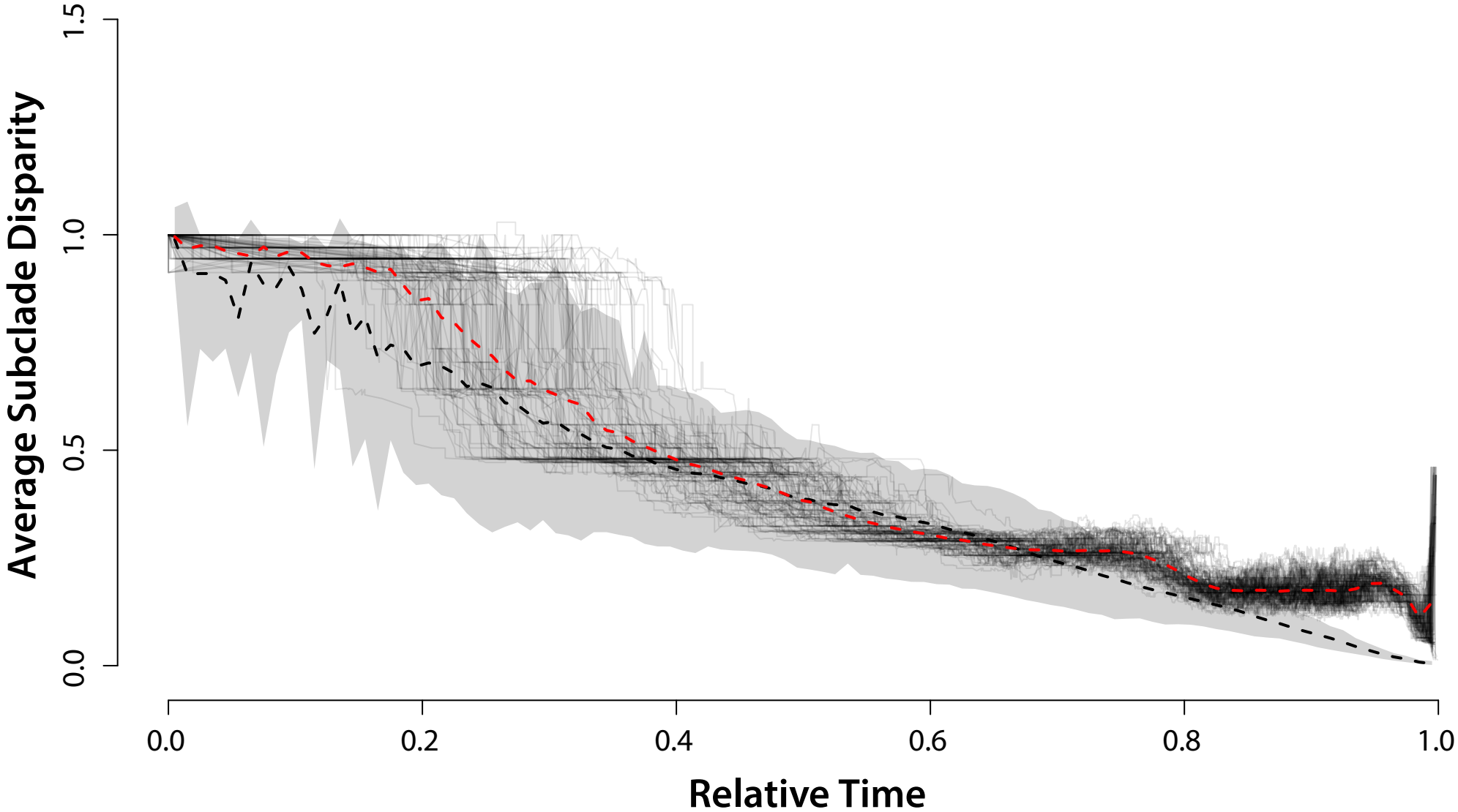

Figure A4: Disparity-through-time (DTT) plot of SDI for all birds. Black lines represent DTT trajectories for each of 100 trees sampled from Jetz et al. (2012), and the dotted red line is an average of these. The grey shaded area represents the 95% confidence interval of null expectation based on simulations under a Brownian motion model (see Harmon et al. 2003), and the dotted black line is an average of these. Clades originating in periods with low values of subclade disparity tend to occupy narrow, non-overlapping portions of character space. Thus, the early decrease in this value suggests that sexual size dimorphism diversified early among avian lineages (albeit not earlier than expected by chance), notably between the values 0.2 and 0.4 on the Relative Time axis.