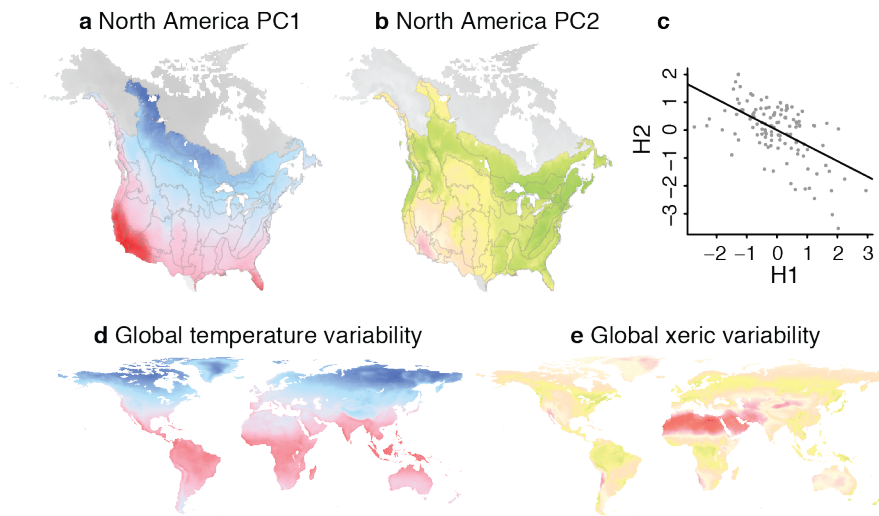


In the format provided by the authors and unedited.

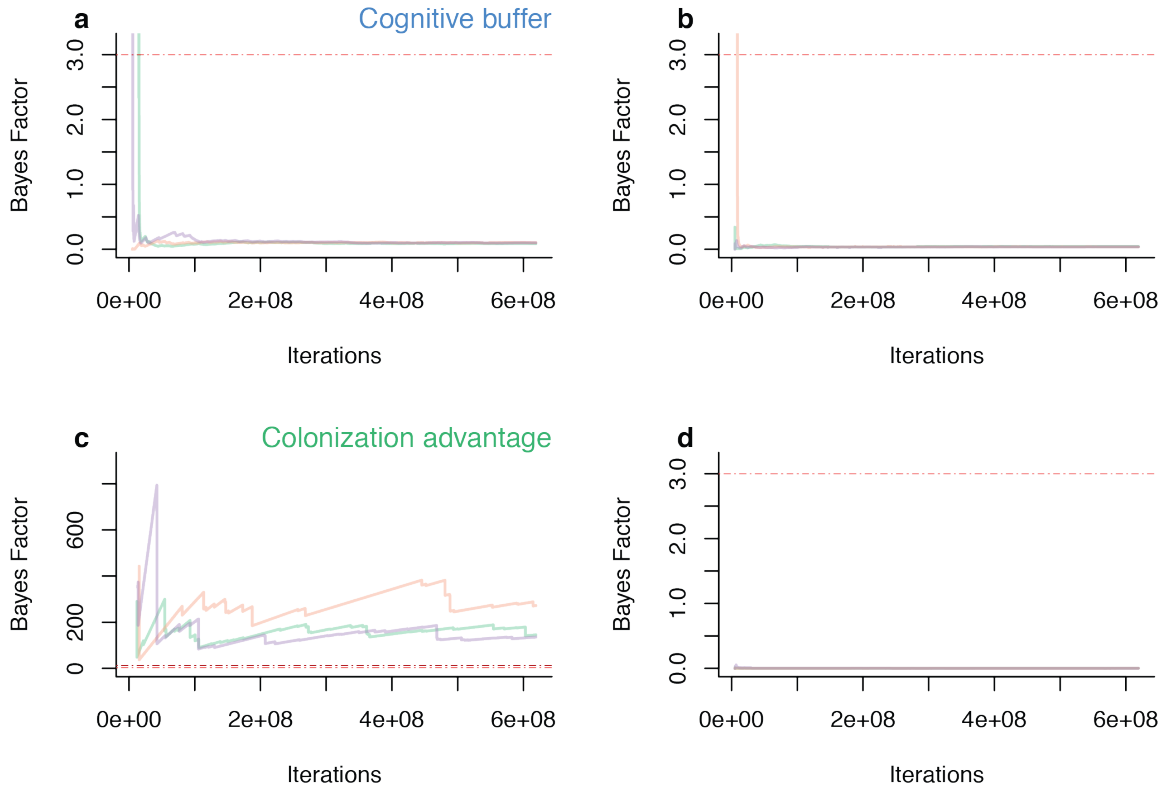
Big brains stabilize populations and facilitate colonization of variable habitats in birds

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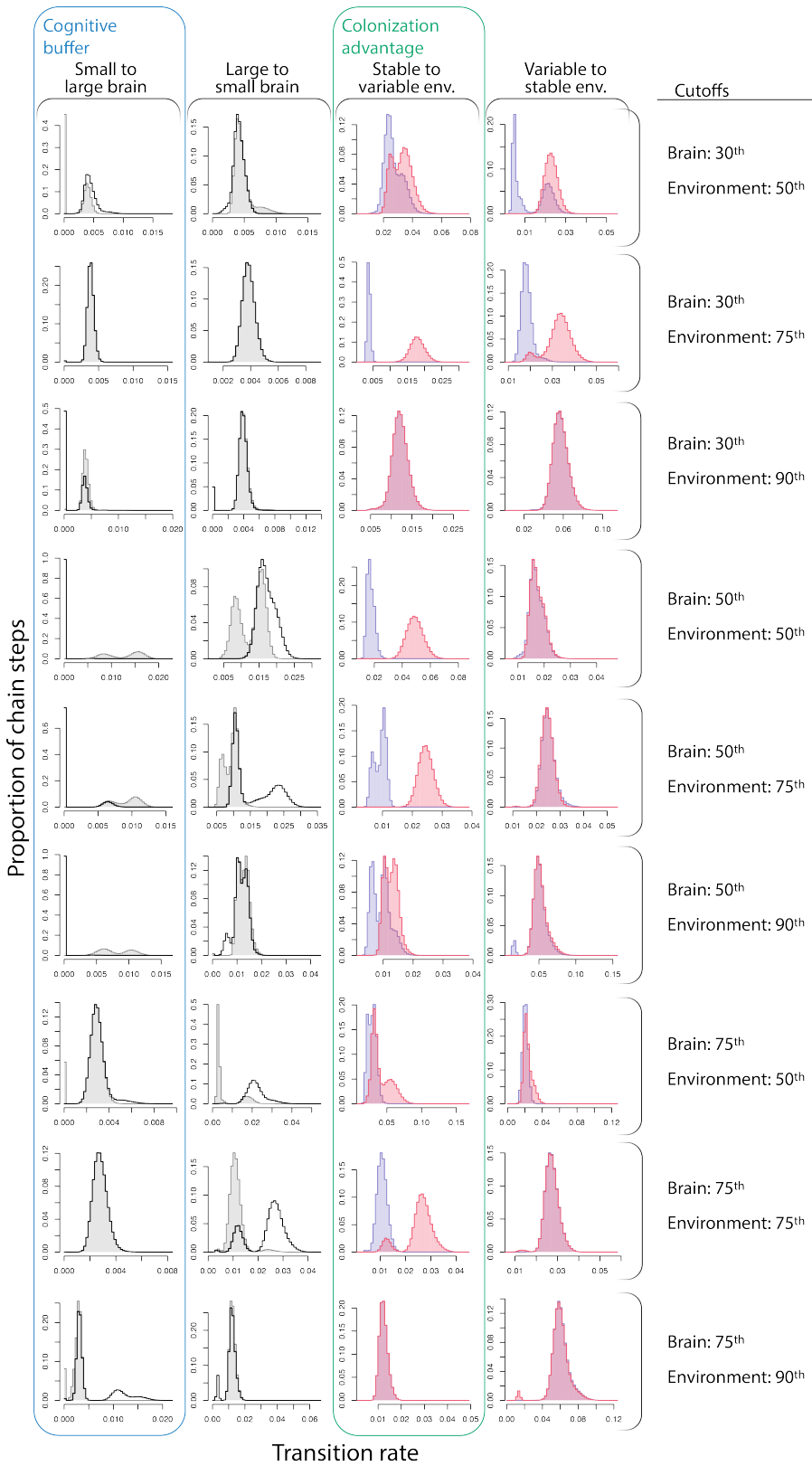
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Supplementary Figure 1: **Continental and global patterns in environmental variables.** **a-b**, PCA of environmental variables across North America returned two composite environmental variables. Low values of the first component (**a**) were associated with cold environments with variable, unpredictable temperatures (in blue); high values were found in hot environments with variable and unpredictable precipitation patterns (in red). Low values of the second component (**b**) were associated with arid, unproductive environments (in red) while high values represented wet areas with high but variable and unpredictable net primary productivity (in green). PC values are shown in color only within Bird Conservation Regions that included sufficient population data for at least one species (outlined in grey). **c**, Species-specific weighted averages for these components (H1 and H2, see text) are highly correlated ($r = -0.56$). **d-e**, Environmental variables were also properly summarized with two principal components at a global scale. **d**, In this case, regions that scored higher in temperature variability (depicted as bluer) exhibit colder, seasonally variable, and more unpredictable temperatures. **e**, Regions that scored high in xeric variability (depicted as redder) exhibit increasingly arid and unproductive conditions and more unpredictable rainfall.



Supplementary Figure 2: **Running values of Bayes Factors across iterations for extended MCMC chains with 50th percentile brain threshold and 75th percentile environment threshold. a-d**, Bayes factors calculated across iterations for testing support for differences between: the transition to large brains in stable vs variable environments (**a**); the transition to small brains in stable vs harsh environments (**b**); the transition to variable environments in small vs large brained species (**c**); the transition to stable environments in small vs large brained species (**d**). Purple, green, and orange lines represent results for three independently run replicates. Dashed red lines indicate the minimum Bayes Factor indicating good (BF = 3) or strong (BF = 12) support differences between rates. While effective sample sizes in these models had not reached 1,000 by 600 million iterations, it is nevertheless clear that the conclusions to support (**c**) or reject (**a**, **b**, and **d**) all of these transition rate differences are remarkably stable.



Supplementary Figure 3: **Posterior distributions of transition rates estimated with reversible-jump MCMC analysis.** Plots within each column depict the posterior distributions for the transition rate of a particular trait, with the color of each distribution depicting the state of the second trait: gray distributions indicate rates of brain size transition within stable environments, black outlined distributions indicate rates of brain size transition within variable environments, purple distributions indicate rates of environmental transition for small brained species, and pink distributions indicate rates of environmental transition for large brained species. Columns highlighted in blue and green represent transition rates relevant to testing the cognitive buffer and colonization advantage hypotheses respectively. Rows represent the results from rjMCMC analyses performed using different cutoffs to distinguish small from large brained species and stable from variable environments (see methods; cutoffs provided in right margin).

Supplementary Table 1: Phylogenetic Generalized Least Squares regression analysis of population stability estimated with a consensus tree*.

	β	SE	t	p
(Intercept)	-0.17	0.07	-2.33	0.02
H1 ^{2†}	0.06	0.04	1.67	0.10
Migration	-0.03	0.03	-1.32	0.19
Relative brain size	-0.01	0.05	-0.23	0.82
log(Longevity)	0.03	0.02	1.30	0.19
Migration:H1 ^{2†}	0.05	0.01	3.60	< 0.001
log(Longevity):H1 ²	-0.06	0.02	-3.89	< 0.001
Relative brain size:H1 ²	0.08	0.02	4.91	< 0.001

df = 118 $\lambda = 0.61$

* Only terms present in the final reduced model are presented here (see text for details).

† H1² is the quadratic term of composite measure, H1, which captures various aspects of environmental variability. Low values of H1 represent cold seasonal habitats with unpredictable temperatures; high values represent warm habitats characterized by variable and unpredictable patterns of precipitation.

Supplementary Table 2: Summary of principal component analysis of environmental variables in our global analysis[†].

	Loadings		Uniqueness
	PC1	PC2	
Temp predictability	-0.94	0.03	0.11
log Temp variance	0.94	-0.04	0.11
Mean temp	-0.91	0.10	0.16
NPP predictability	0.71	0.63	0.10
log Precip variance	-0.68	-0.54	0.24
Precip predictability	0.27	-0.83	0.24
log Mean precip	-0.35	-0.82	0.20
log Mean NPP	-0.45	-0.80	0.16
log NPP variance	0.13	-0.78	0.37
Cumulative variance	0.44	0.81	

[†] Loadings for main contributors to each component are highlighted in boldface type. PC1 was included in analyses as temperature variability; PC2 was included as xeric variability.

Supplementary Table 3: Results from models of correlated trait evolution performed using reverse-jump MCMC in BayesTraits v2. For these analyses, species were classified as having either small or large encephalization based on brain size residuals calculated from PGLS regression with Pagel's λ transformation. Rates related to the predictions of the cognitive buffer hypothesis are highlighted in blue; rates related to the predictions of the colonization advantage scenario are highlighted in green. The dependence of particular transition rates in one trait on the state of the second trait were assessed by calculating Bayes Factors (BF) and the proportion of chain steps that set the rate of interest as equal under both states of the second trait (P).

Brain cutoff	Env. cutoff	Brain	Environment	Mean	SD	BF	P
30 th	50 th	Small to large	Mild	0.002	0.002	0.04	0.54
		Small to large	Harsh	0.004	0.001		
		Large to small	Mild	0.005	0.001	0.01	0.89
		Large to small	Harsh	0.004	0.001		
		Small	Mild to harsh	0.027	0.006	0.02	0.64
		Large	Mild to harsh	0.033	0.007		
		Small	Harsh to mild	0.012	0.008	0.06	0.42
		Large	Harsh to mild	0.023	0.003		
30 th	75 th	Small to large	Mild	0.004	0.000	< 0.01	> 0.99
		Small to large	Harsh	0.004	0.001		
		Large to small	Mild	0.004	0.000	< 0.01	> 0.99
		Large to small	Harsh	0.004	0.000		
		Small	Mild to harsh	0.004	0.001	57.02**	< 0.01
		Large	Mild to harsh	0.018	0.002		
		Small	Harsh to mild	0.018	0.003	0.32	0.12
		Large	Harsh to mild	0.033	0.007		
30 th	90 th	Small to large	Mild	0.004	0.001	0.04	0.50
		Small to large	Harsh	0.002	0.002		
		Large to small	Mild	0.004	0.001	< 0.01	0.95
		Large to small	Harsh	0.004	0.001		
		Small	Mild to harsh	0.012	0.002	< 0.01	> 0.99
		Large	Mild to harsh	0.012	0.002		
		Small	Harsh to mild	0.057	0.008	< 0.01	0.99
		Large	Harsh to mild	0.057	0.008		
50 th	50 th	Small to large	Mild	0.012	0.004	3.15*	0.01
		Small to large	Harsh	< 0.001	0.001		
		Large to small	Mild	0.013	0.004	0.03	0.58
		Large to small	Harsh	0.017	0.003		
		Small	Mild to harsh	0.017	0.003	88.63**	< 0.01
		Large	Mild to harsh	0.049	0.006		

		Small	Harsh to mild	0.017	0.003		
		Large	Harsh to mild	0.017	0.003	< 0.01	0.96
50 th	75 th	Small to large	Mild	0.009	0.002	0.10	0.31
		Small to large	Harsh	0.002	0.003		
		Large to small	Mild	0.009	0.002	0.04	0.52
		Large to small	Harsh	0.016	0.006		
		Small	Mild to harsh	0.009	0.002	184.11**	< 0.01
		Large	Mild to harsh	0.024	0.003		
		Small	Harsh to mild	0.025	0.003	< 0.01	0.95
		Large	Harsh to mild	0.025	0.003		
50 th	90 th	Small to large	Mild	0.008	0.002	2.76	0.02
		Small to large	Harsh	< 0.001	0.001		
		Large to small	Mild	0.013	0.002	0.01	0.88
		Large to small	Harsh	0.012	0.003		
		Small	Mild to harsh	0.009	0.003	0.03	0.57
		Large	Mild to harsh	0.013	0.002		
		Small	Harsh to mild	0.049	0.011	< 0.01	0.95
		Large	Harsh to mild	0.052	0.009		
75 th	50 th	Small to large	Mild	0.003	0.001	< 0.01	0.94
		Small to large	Harsh	0.003	0.001		
		Large to small	Mild	0.007	0.007	0.17	0.20
		Large to small	Harsh	0.022	0.005		
		Small	Mild to harsh	0.029	0.006	0.03	0.61
		Large	Mild to harsh	0.041	0.014		
		Small	Harsh to mild	0.020	0.003	0.01	0.75
		Large	Harsh to mild	0.024	0.005		
75 th	75 th	Small to large	Mild	0.003	0.001	< 0.01	> 0.99
		Small to large	Harsh	0.003	0.001		
		Large to small	Mild	0.011	0.003	0.12	0.26
		Large to small	Harsh	0.024	0.007		
		Small	Mild to harsh	0.011	0.002	0.31	0.12
		Large	Mild to harsh	0.025	0.006		
		Small	Harsh to mild	0.027	0.003	< 0.01	0.99
		Large	Harsh to mild	0.027	0.004		
75 th	90 th	Small to large	Mild	0.003	0.001	0.02	0.72
		Small to large	Harsh	0.006	0.004		
		Large to small	Mild	0.012	0.002	< 0.01	0.91
		Large to small	Harsh	0.012	0.003		
		Small	Mild to harsh	0.012	0.002	< 0.01	> 0.99
		Large	Mild to harsh	0.012	0.002		
		Small	Harsh to mild	0.061	0.009	< 0.01	0.97
		Large	Harsh to mild	0.060	0.011		

