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The social and cultural roots of whale and dolphin brains

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Supplementary Information

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SUPPLEMENTARY FIGURES

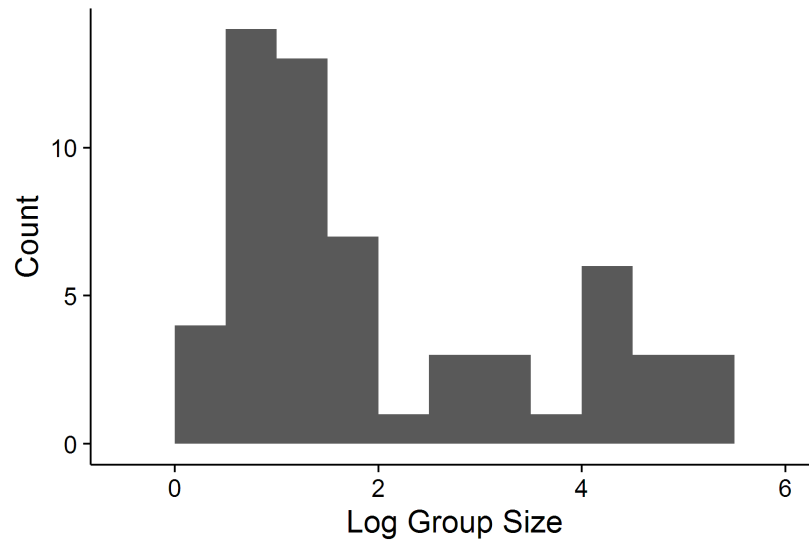


Fig. S1. Histogram of Log Group size across species. Note the three apparent modes (n=58).

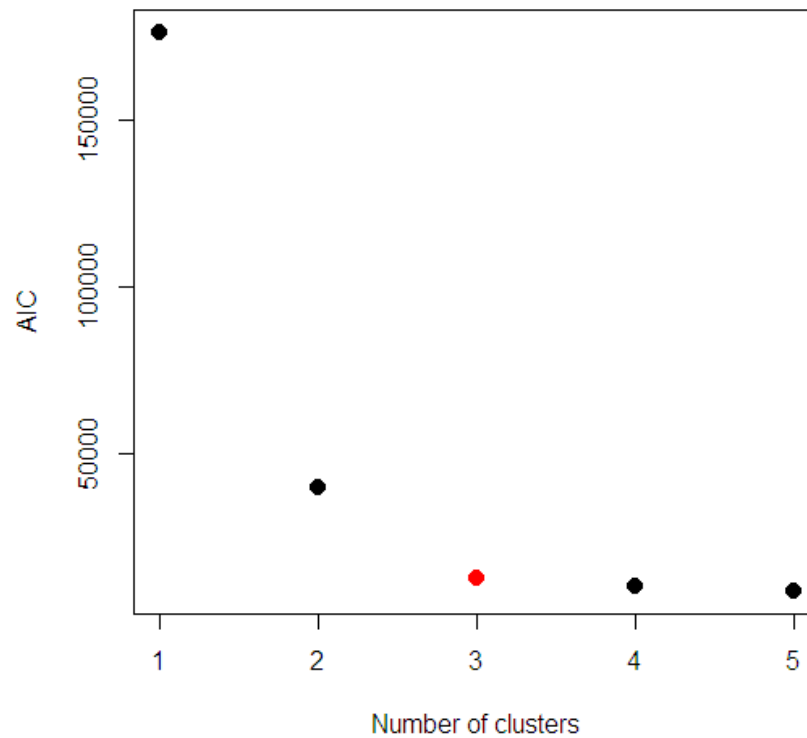


Fig. S2. Scree plot of number of clusters of group size. AIC change indicates that three is the optimal number of categories.

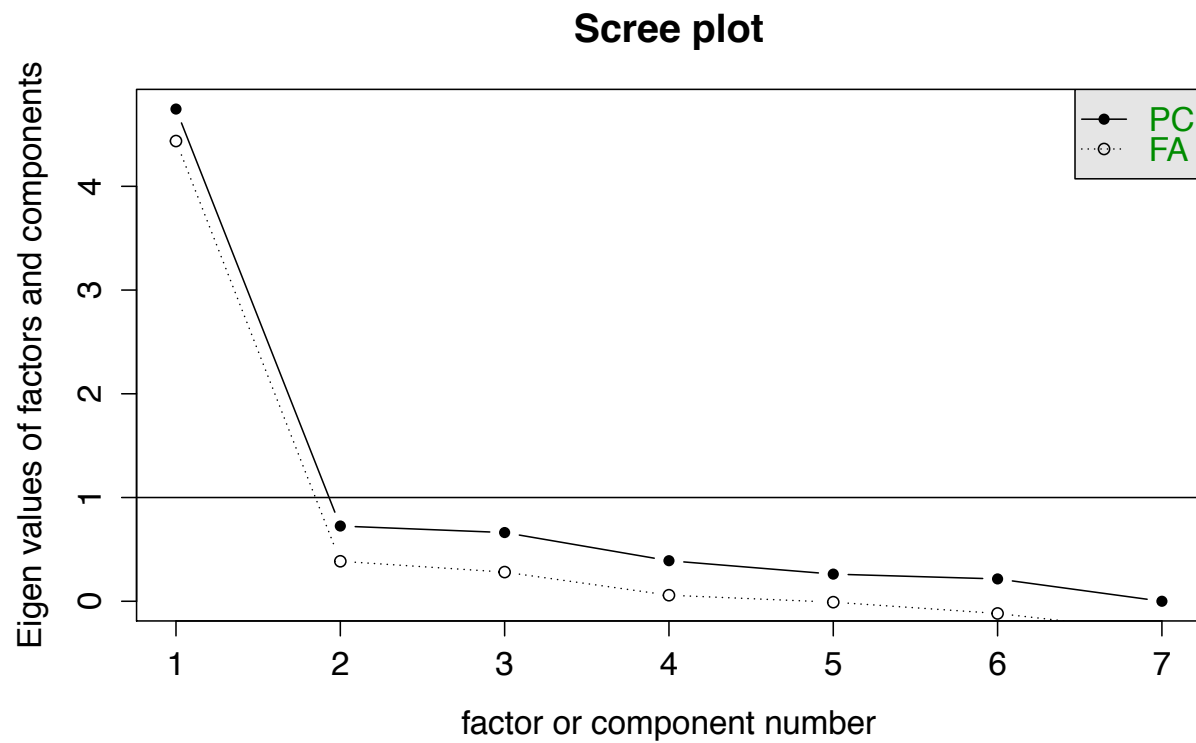


Fig. S3. Scree plot of factor eigenvalues results for the components from the polychoric PCA (n=52 > 50 publications).

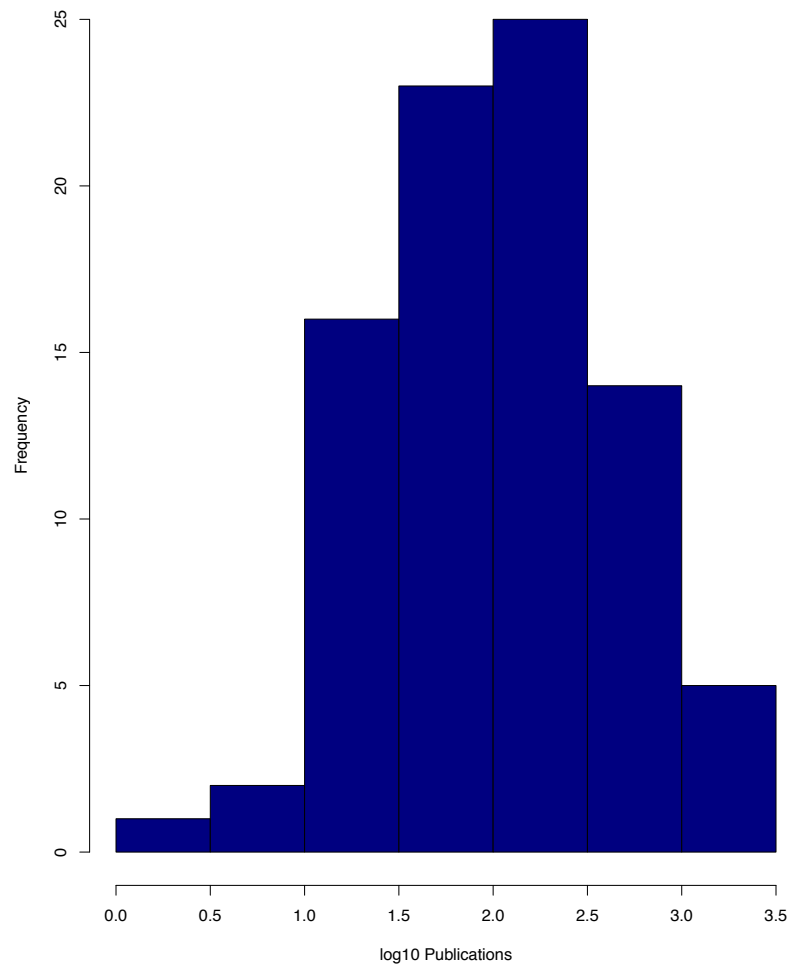


Fig. S4. Histogram of research effort across species. We limited our analyses to species with at least fifty studies ($\log_{10}= 1.67$) to try to remove biases caused by limited observations ($n=86$).

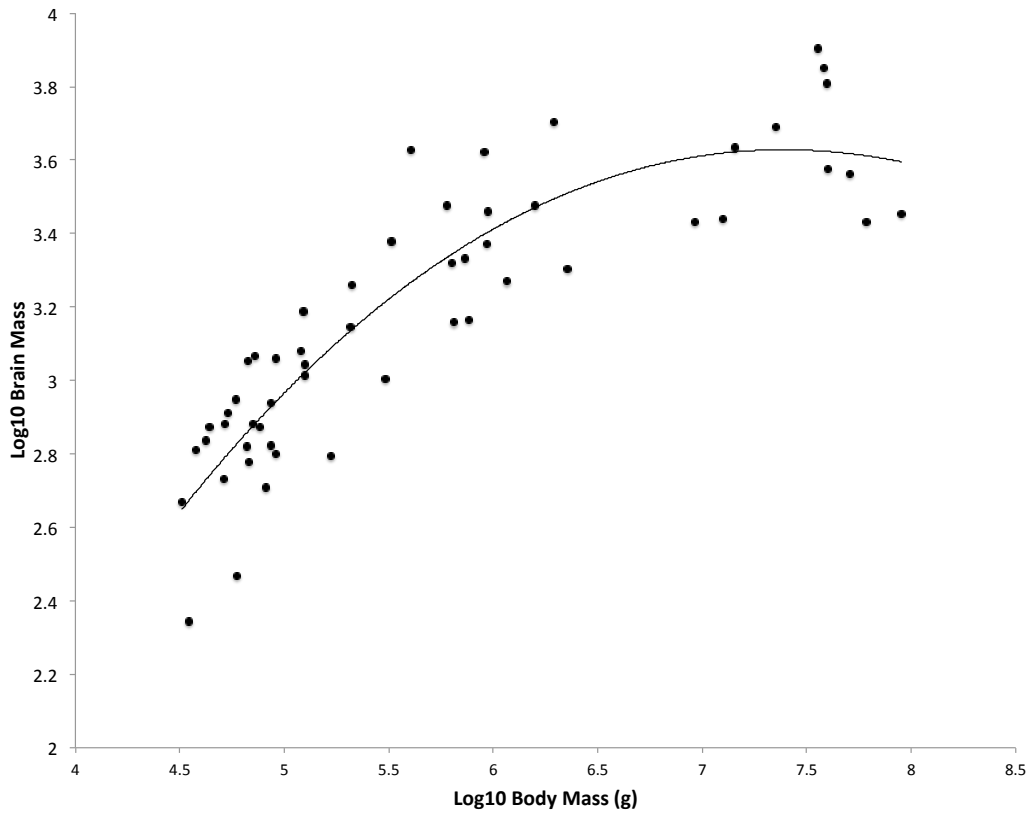


Fig. S5. Log brain mass vs. log body mass in 55 cetacean species for which data are available. The trendline shows a cubic polynomial relationship.

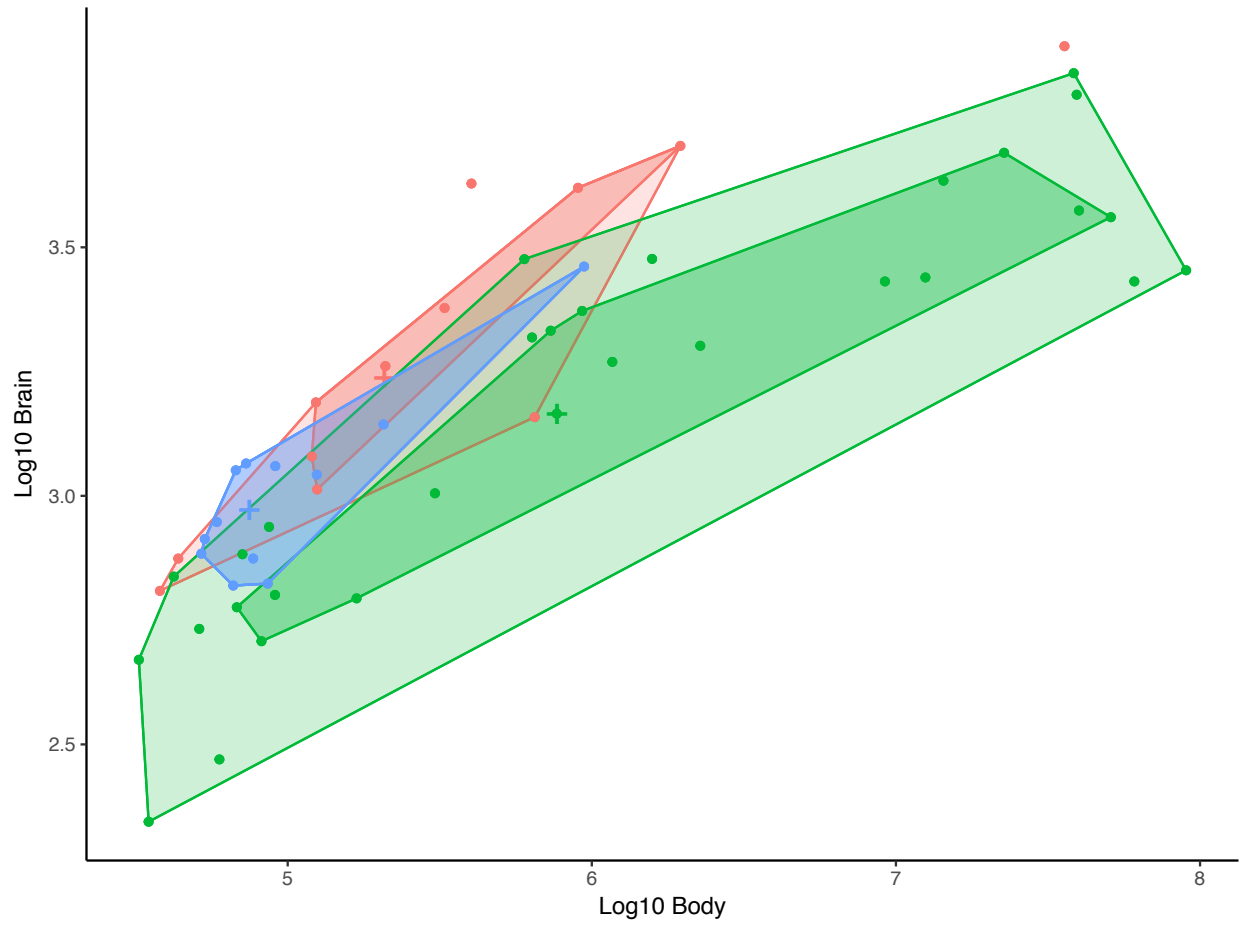


Fig. S6. A bagplot showing the distribution of brain size versus body size across different social categories. Red is mid-sized groups, green ephemeral groups and blue mega-pods (n=54).

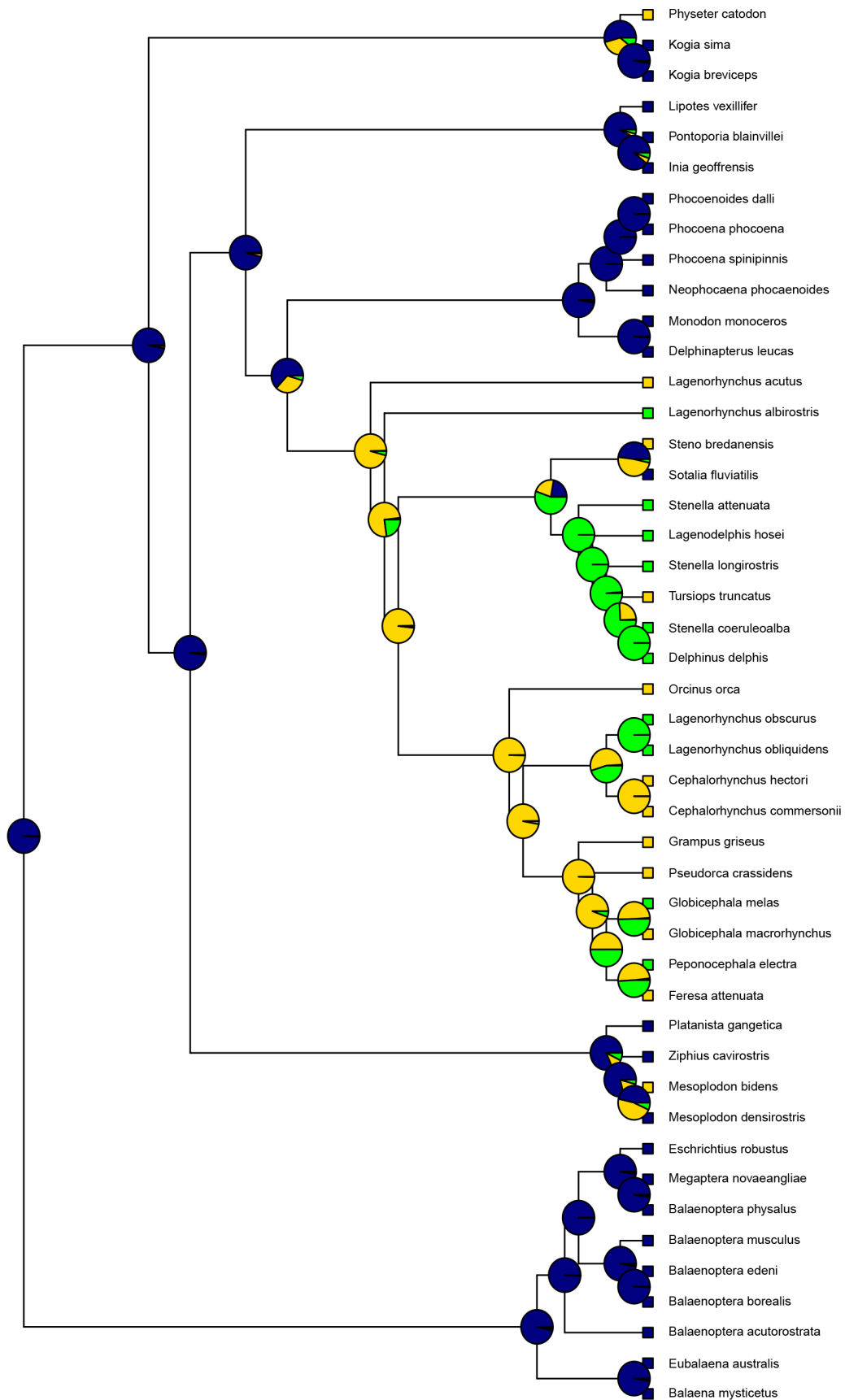


Fig. S7. Ancestral state reconstruction for social organization using the *ace* function in the *ape* package. Blue represents ephemeral social grouping patterns, green mid-sized groups and yellow large mega-pods (n=46).

SUPPLEMENTARY TABLES (EXCEPT FOR TABLES S1 AND S2)

Table S3. Individual loadings on the first PCA component. Total SS loadings 4.87. We control for research effort.

Behaviour	Loadings
Alliances	0.97
Alloparenting	0.76
Interspecific Cooperation	0.77
Group Hunting	0.78
Social Play	0.82
Social Transfer	0.88
Complex Vocalisations	0.84

Table S5. The relationship between cetacean brain size and three indices of sociality. Group size and brain size are log10 transformed. Pair-wise comparisons between a baseline category of aggregations with cohesive and mega-pods are reported. F values reported for the global term for social organisation. The coefficient, C.I. and lambdas were all estimated using model averaging across 1,000 trees. ANOVA statistics are derived from a marginal test from the gls model with the consensus tree.

Brain Measure	Factor		Estimate	C.I.	d.f.	F	p	λ
Brain Size	Group size		-0.037 ± 0.37	-0.11, 0.04	1,44	1.77	1.76	0.99
	Quadratic group size	Log Group	0.32 ± 0.14	0.04, 0.60	2,43	3.91	0.03	0.95
		LogGroup^2	-0.05 ± 0.02	-0.09, -0.01				
	Social category	Mega-pods	0.18 ± 0.16	-0.13, 0.49	2,43	4.46	0.02	0.99
		Communities	0.34 ± 0.15	0.04, 0.63				
Residual Brain Size	Group size		-0.005± 0.02	-0.04, 0.03	1,44	0.15	0.70	0.87
	Quadratic Group Size	Log group	0.27 ± 0.06	0.146, 0.393	2,43	9.77	0.03	0.72
		Log group^2	-0.041± 0.009	0.06, -0.023				
	Social category	Mega-pods	0.07 ± 0.07	-0.07, 0.22	2,43	4.19	0.02	0.86
		Communities	0.16 ± 0.06	0.03, 0.30				
EQ	Group size		-0.05 ± 0.12	-0.29, 0.18	1,44	0.12	0.73	0.84
	Quadratic Group Size	Log group	0.719 ± 0.487	-0.24, 1.67	2,43	1.38	0.26	0.77
		Log group^2	-0.12 ± 0.07	-0.26, 0.03				
	Social category	Mega-pods	0.14 ± 0.53	-0.89, 1.16	1,43	0.86	0.43	0.84
		Communities	0.44 ± 0.48	-0.51, 1.38				

Table S6. PGLS regression for the relationship between log brain size, residual brain size and EQ, and corrected social repertoire, diet, and latitude. Corrected social repertoire, diet, and latitude are treated as dependent variables. The coefficient, C.I. and lambdas were all estimated using model averaging across 1,000 trees. ANOVA statistics are derived from a marginal test from the gls model with the consensus tree.

Dependent	Brain Measure	Estimate	C.I.	d.f.	F	p	λ
Corrected Social repertoire	Log Brain	0.43 ± 0.48	-0.50, 1.38	1,44	0.81	0.37	0.22
Diet		0.37 ± 0.32	-0.25, 1.01		1.31	0.26	0.31
Latitude		76.75 ± 17.18	43.08, 110.42		4.53	<0.001	0.93
Corrected Social repertoire	Residual Brain	2.36 ± 0.64	1.11, 3.62	1,44	13.57	<0.001	0.00
Diet		1.13 ± 0.44	0.268, 2.00	1,44	2.57	0.01	0.00
Latitude		85.28 ± 37.90	10.99, 159.57	1,44	4.46	0.04	0.99
Corrected Social repertoire	EQ	0.30 ± 0.09	0.11, 0.48	1,44	10.18	0.003	0.00
Diet		0.08 ± 0.07	-0.05, 0.21	1,44	1.52	0.22	0.00
Latitude		-4.51 ± 6.15	-16.57, 7.56	1,44	-0.92	0.37	1.00

Table S7. Global model for brain size showing all possible predictors. Body size, brain size and group size all log10 transformed. The coefficient, C.I. and lambdas were all estimated using model averaging across 1,000 trees. Anova statistics are derived from a marginal test from the gls model with the consensus tree.

Factor	*λ	*Estimate	*C.I.	d.f.	F	p
Body Size	1.0	0.41 $\pm$ 0.05	0.32, 0.50	9,37	313.23	<0.001
Group Size		0.13 $\pm$ 0.08	-0.03, 0.29		16.86	0.002
Group^2		-0.015 $\pm$ 0.01	-0.04,0.008		15.17	0.004
Social category	Community	0.02 $\pm$ 0.10	-0.17, 0.22		0.33	0.72
	Mega-pods	-0.10 $\pm$ 0.15	-0.39, 0.20			
Corrected social repertoire		0.02 $\pm$.015	-0.009, 0.049		0.01	0.93
Diet		-0.017 $\pm$ 0.026	-0.07, 0.03		3.72	0.06
Latitude		0.001 $\pm$ 0.0006	-0.0002, 0.002		2.25	0.13

Table S8. Top models for each variable.

Group	Model	AIC	Lambda	weight
	1 repertoire_score	143.37	0.74	0.14
	2 Latitude+repertoire_score	143.91	0.74	0.11
	3 repertoire_score+Diet	144.36	0.75	0.09
	4 repertoire_score+LOG_BRAIN	145.16	0.74	0.06
	5 Latitude+repertoire_score+Diet	145.21	0.75	0.06
	6 LOG_BODY+repertoire_score	145.37	0.74	0.05
Body				
	1 log_group+group2+LOG_BRAIN	12.27	0.93	0.20
	2 LOG_BRAIN	13.88	1.00	0.09
	3 log_group+group2+repertoire_score+LOG_BRAIN	14.01	0.91	0.08
	4 Latitude+log_group+group2+LOG_BRAIN	14.23	0.94	0.07
	5 log_group+group2+Diet+LOG_BRAIN	14.27	0.94	0.07
Latitude				
	1 LOG_BRAIN	459.20	0.93	0.14
	2 group2+LOG_BRAIN	460.31	0.92	0.08
	3 log_group+LOG_BRAIN	460.36	0.93	0.08
	4 Diet+LOG_BRAIN	460.96	0.92	0.06
	5 repertoire_score+LOG_BRAIN	461.12	0.93	0.05
	6 LOG_BODY+LOG_BRAIN	461.13	0.93	0.05
Diet				
	1 LOG_BODY+LOG_BRAIN	104.93	0.00	0.08
	2 LOG_BODY+Latitude+LOG_BRAIN	105.09	0.00	0.07
	3 Latitude	106.37	0.22	0.04
	4 LOG_BODY+Latitude	106.45	0.00	0.04
	5 LOG_BODY+group2+LOG_BRAIN	106.60	0.00	0.03
	6 LOG_BODY+log_group+LOG_BRAIN	106.82	0.00	0.03
	7 LOG_BODY+log_group+group2+LOG_BRAIN	106.91	0.00	0.03
Brain				
	LOG_BODY+log_group+group2+Latitude+repertoire_score	-59.45	0.62	0.24
	2 LOG_BODY+log_group+group2+Diet+Latitude+	-58.56	0.53	0.16

	repertoire_score			
3	LOG_BODY+log_group+group2+Latitude	-58.52	0.64	0.15
4	LOG_BODY+log_group+group2+ repertoire_score	-58.16	0.67	0.13
5	LOG_BODY+log_group+group2+Diet+Latitude	-57.94	0.56	0.11
	LOG_BODY+log_group+group2+Diet+			
6	repertoire_score	-57.67	0.53	0.10