Article:

van Lieshout, SHJ orcid.org/0000-0003-4136-265X, Sparks, AM orcid.org/0000-0002-7697-4632, Bretman, A orcid.org/0000-0002-4421-3337 et al. (5 more authors) (2020) Estimation of environmental, genetic and parental age at conception effects on telomere length in a wild mammal. Journal of Evolutionary Biology. ISSN 1010-061X

https://doi.org/10.1111/jeb.13728

Estimation of environmental, genetic and parental age at conception effects on telomere length in a wild mammal

Sil H.J. van Lieshout, Alexandra M. Sparks, Amanda Bretman, Chris Newman, Christina D. Buesching, Terry Burke, David W. Macdonald & Hannah L. Dugdale

Table S1 Metrics of the Wytham badger pruned pedigree (1987 – 2010).

Relationship	*n*	Relationship	*n*
Records	753	Paternal grandmothers	261
Max. pedigree depth	7	Paternal grandfathers	214
Maternities	486	Founders	206
Paternities	458	Mean maternal sibship size	2.48
Full sibs	194	Mean paternal sibship size	2.59
Maternal sibs	691	Non-zero F	29
Paternal sibs	880	F > 0.125	11
Maternal half sibs	497	Mean pairwise relatedness	0.007
Paternal half sibs	686	Pairwise relatedness ≥ 0.125	0.023
Maternal grandmothers	196	Pairwise relatedness ≥ 0.25	0.013
Maternal grandfathers	174	Pairwise relatedness ≥ 0.5	0.004

Table S2 Additive genetic and environmental effects on relative leukocyte telomere length (RLTL) in European badgers, estimated using the 'animal model' with *MCMCglmm* 2.25 (Hadfield 2010). Nine models are presented with random effects for additive genetic and permanent environment variance components (models 1–7, *n*=1248; model 8, *n*=997, model 9, *n*=837). Model 8 only includes offspring in the pedigree that have at least one parent assigned. Subsequently, fixed and random effects are sequentially added to determine their effect on heritability. Values represent the posterior modes and 95% credible intervals of the variance estimates (V_A = additive genetic, V_{PE} = permanent environment, V_{PLATE} = plate, V_{ROW} = Row, V_{CO} = cohort, V_{YEAR} = year, V_{SG} = social group, V_{MAT} = maternal, V_{PAT} = paternal, V_R = residual, V_P = phenotypic). Age = threshold age, h^2 = heritability.

Model	Parameters	V_A	V_{PE}	V_{PLATE}	V_{ROW}	V_{CO}	V_{YEAR}	V_{SG}	V_{MAT}	V_{PAT}	V_R	h^2
1	RLTL = $V_A + V_{PE}$	$1.514*10^{-5}$ ($3.251*10^{-9}$– $2.903*10^{-3}$)	$1.195*10^{-5}$ ($1.727*10^{-10}$– $2.252*10^{-3}$)								$3.278*10^{-2}$ ($2.940*10^{-2}$– $3.514*10^{-2}$)	$3.847*10^{-4}$ ($9.000*10^{-8}$– $8.442*10^{-2}$)
2	RLTL = $V_A + V_{PE}$ + Age + Season	$1.994*10^{-5}$ ($9.028*10^{-11}$– $2.574*10^{-3}$)	$1.551*10^{-5}$ ($1.386*10^{-11}$– $2.141*10^{-3}$)								$3.173*10^{-2}$ ($2.888*10^{-2}$– $3.475*10^{-2}$)	$3.408*10^{-4}$ ($2.974*10^{-9}$– $7.599*10^{-2}$)
3	RLTL = $V_A + V_{PE}$ + Age + Season + $V_{PLATE} + V_{ROW}$	$1.371*10^{-5}$ ($8.968*10^{-11}$– $2.679*10^{-3}$)	$8.569*10^{-6}$ ($4.241*10^{-10}$– $2.157*10^{-3}$)	$1.842*10^{-3}$ ($7.412*10^{-4}$– $3.728*10^{-3}$)	$2.281*10^{-4}$ ($2.168*10^{-7}$– $2.087*10^{-3}$)						$2.960*10^{-2}$ ($2.682*10^{-2}$– $3.248*10^{-2}$)	$3.589*10^{-4}$ ($2.636*10^{-9}$– $7.943*10^{-2}$)
4	RLTL = $V_A + V_{PE}$ + Age + Season + $V_{PLATE} + V_{ROW}$ + V_{CO}	$1.544*10^{-5}$ ($2.218*10^{-9}$– $1.816*10^{-3}$)	$6.133*10^{-6}$ ($1.152*10^{-9}$– $1.739*10^{-3}$)	$2.014*10^{-3}$ ($7.811*10^{-4}$– $3.681*10^{-3}$)	$2.541*10^{-4}$ ($3.329*10^{-14}$– $2.050*10^{-3}$)	$1.755*10^{-3}$ ($7.539*10^{-4}$– $5.310*10^{-3}$)					$2.898*10^{-2}$ ($2.617*10^{-2}$– $3.124*10^{-2}$)	$3.445*10^{-4}$ ($5.715*10^{-8}$– $5.102*10^{-2}$)
5	RLTL = $V_A + V_{PE}$ + Age + Season + $V_{PLATE} + V_{ROW}$ + $V_{CO} + V_{YEAR}$	$8.043*10^{-6}$ ($4.165*10^{-12}$– $1.571*10^{-3}$)	$5.448*10^{-6}$ ($1.352*10^{-9}$– $1.528*10^{-3}$)	$1.898*10^{-3}$ ($1.011*10^{-3}$– $4.073*10^{-3}$)	$3.323*10^{-4}$ ($6.150*10^{-9}$– $2.372*10^{-3}$)	$1.147*10^{-3}$ ($3.697*10^{-4}$– $3.632*10^{-3}$)	$1.196*10^{-2}$ ($4.353*10^{-3}$– $2.470*10^{-2}$)				$2.574*10^{-2}$ ($2.339*10^{-2}$– $2.807*10^{-2}$)	$2.284*10^{-4}$ ($8.823*10^{-11}$– $3.443*10^{-2}$)
6	RLTL = $V_A + V_{PE}$ + Age + Season + $V_{PLATE} + V_{ROW}$ + $V_{CO} + V_{YEAR} + V_{SG}$	$4.427*10^{-6}$ ($4.073*10^{-10}$– $1.455*10^{-3}$)	$8.682*10^{-6}$ ($3.660*10^{-10}$– $1.522*10^{-3}$)	$1.874*10^{-3}$ ($9.780*10^{-4}$– $4.132*10^{-3}$)	$3.104*10^{-4}$ ($8.686*10^{-9}$– $2.325*10^{-3}$)	$1.215*10^{-3}$ ($4.251*10^{-4}$– $3.651*10^{-3}$)	$1.027*10^{-2}$ ($4.887*10^{-3}$– $2.563*10^{-2}$)	$3.283*10^{-6}$ ($1.556*10^{-10}$– $7.129*10^{-4}$)			$2.554*10^{-2}$ ($2.355*10^{-2}$– $2.817*10^{-2}$)	$1.786*10^{-4}$ ($1.122*10^{-8}$– $3.214*10^{-2}$)
7	RLTL = $V_A + V_{PE}$ + Age + Season + $V_{PLATE} + V_{ROW}$ + $V_{CO} + V_{YEAR} + V_{SG}$ + $V_{MAT} + V_{PAT}$	$8.544*10^{-6}$ ($1.012*10^{-9}$– $1.185*10^{-3}$)	$8.635*10^{-6}$ ($3.867*10^{-10}$– $1.227*10^{-3}$)	$2.035*10^{-3}$ ($9.682*10^{-4}$– $4.117*10^{-3}$)	$5.146*10^{-4}$ ($6.728*10^{-7}$– $2.456*10^{-3}$)	$1.210*10^{-3}$ ($2.855*10^{-4}$– $3.360*10^{-3}$)	$1.161*10^{-2}$ ($4.662*10^{-3}$– $2.586*10^{-2}$)	$2.560*10^{-6}$ ($3.780*10^{-10}$– $6.397*10^{-4}$)	$1.119*10^{-5}$ ($7.704*10^{-12}$– $1.352*10^{-3}$)	$5.819*10^{-6}$ ($6.900*10^{-11}$– $1.107*10^{-3}$)	$2.525*10^{-2}$ ($2.322*10^{-2}$– $2.783*10^{-2}$)	$7.660*10^{-5}$ ($2.033*10^{-8}$– $2.580*10^{-2}$)
8	RLTL = $V_A + V_{PE}$ + Age + Season + $V_{PLATE} + V_{ROW}$ + $V_{CO} + V_{YEAR} + V_{SG}$ + $V_{MAT} + V_{PAT}$	$6.550*10^{-6}$ ($3.662*10^{-11}$– $1.033*10^{-3}$)	$5.740*10^{-6}$ ($4.314*10^{-10}$– $1.064*10^{-3}$)	$1.866*10^{-3}$ ($7.640*10^{-4}$– $3.900*10^{-3}$)	$5.874*10^{-4}$ ($6.255*10^{-5}$– $3.739*10^{-3}$)	$1.459*10^{-3}$ ($8.142*10^{-5}$– $3.594*10^{-3}$)	$1.083*10^{-2}$ ($5.096*10^{-3}$– $2.859*10^{-2}$)	$7.111*10^{-6}$ ($1.153*10^{-11}$– $1.148*10^{-3}$)	$6.540*10^{-6}$ ($6.564*10^{-10}$– $1.656*10^{-3}$)	$4.610*10^{-6}$ ($1.073*10^{-11}$– $1.361*10^{-3}$)	$2.648*10^{-2}$ ($2.338*10^{-2}$– $2.833*10^{-2}$)	$1.293*10^{-4}$ ($6.117*10^{-10}$– $2.159*10^{-2}$)
9	Juvenile RLTL = V_A + V_{PE} + Age + Season + $V_{PLATE} + V_{ROW} + V_{CO}$ + $V_{YEAR} + V_{SG} + V_{MAT} + V_{PAT}$	$1.270*10^{-5}$ ($1.787*10^{-9}$– $1.800*10^{-3}$)	$1.120*10^{-5}$ ($1.308*10^{-9}$– $2.119*10^{-3}$)	$1.566*10^{-3}$ ($6.601*10^{-4}$– $3.729*10^{-3}$)	$4.296*10^{-5}$ ($9.762*10^{-9}$– $1.435*10^{-3}$)	$1.767*10^{-3}$ ($1.347*10^{-4}$– $5.652*10^{-3}$)	$8.607*10^{-3}$ ($3.172*10^{-3}$– $2.303*10^{-2}$)	$3.139*10^{-6}$ ($1.736*10^{-9}$– $9.264*10^{-4}$)	$5.353*10^{-6}$ ($3.911*10^{-12}$– $1.401*10^{-3}$)	$5.807*10^{-6}$ ($1.214*10^{-9}$– $1.159*10^{-3}$)	$2.492*10^{-2}$ ($2.278*10^{-2}$– $2.886*10^{-2}$)	$2.490*10^{-4}$ ($4.057*10^{-8}$– $4.009*10^{-2}$)

Table S3 Parameter estimates from mixed model testing paternal and maternal age at conception (PAC & MAC, respectively) effects on offspring relative leukocyte telomere length (Z-score) in European badgers. β = direction and magnitude of effect, S.E. = standard error, 95% CI = 95% confidence interval, reference terms in brackets = reference level for factors; * = interaction. Significant parameters (95% CI does not overlap zero) are in bold.

Parameter (reference level)	β	S.E.	95% CI
Intercept	-0.012	0.129	-0.265 to 0.240
Age (≤ 29 months)	-0.016	0.070	-0.154 to 0.125
(>29 and ≤ 65 months)	**0.180**	**0.081**	**0.023 to 0.335**
(>65 and ≤ 112 months)	**-0.176**	**0.072**	**-0.319 to -0.037**
(> 112 months)	**0.125**	**0.055**	**0.019 to 0.235**
Sex (Female)	-0.021	0.094	-0.205 to 0.159
Season (Spring)			
Summer	0.091	0.107	-0.117 to 0.298
Autumn	-0.020	0.192	-0.382 to 0.372
Winter	0.012	0.252	-0.464 to 0.527
PAC	0.046	0.067	-0.087 to 0.174
MAC	-0.029	0.061	-0.152 to 0.085
Sex (Female) * PAC	-0.018	0.092	-0.207 to 0.170
Sex (Female) * MAC	-0.009	0.097	-0.199 to 0.182

Random effect estimates (variance): Cohort ($1.920*10^{-2}$), Social group ($2.116*10^{-2}$), Year ($5.795*10^{-2}$), Plate ($6.640*10^{-2}$), Row ($1.613*10^{-2}$), Individual ID ($3.938*10^{-8}$), Mother ID ($3.021*10^{-10}$), Father ID ($1.440*10^{-8}$), Residual ($8.503*10^{-1}$).

Table S4 Parameter estimates from mixed model testing paternal and maternal age at conception (PAC & MAC, respectively) effects on offspring relative leukocyte telomere length (Z-score) in European badgers (without the interaction between PAC/MAC and sex). β = direction and magnitude of effect, S.E. = standard error, 95% CI = 95% confidence interval, reference terms in brackets = reference level for factors. Significant parameters (95% CI does not overlap zero) are in bold.

Parameter (reference level)	**β**	**S.E.**	**95% CI**
Intercept	-0.011	0.128	-0.264 to 0.239
Age (≤ 29 months)	-0.017	0.069	-0.153 to 0.124
(>29 and ≤ 65 months)	**0.180**	**0.081**	**0.024 to 0.334**
(>65 and ≤ 112 months)	**-0.176**	**0.072**	**-0.318 to -0.038**
(> 112 months)	**0.126**	**0.055**	**0.020 to 0.235**
Sex (Female)	-0.020	0.095	-0.208 to 0.162
Season (Spring)			
Summer	0.090	0.106	-0.116 to 0.296
Autumn	-0.019	0.192	-0.378 to 0.374
Winter	0.011	0.252	-0.464 to 0.527
PAC	0.036	0.048	-0.055 to 0.133
MAC	-0.033	0.050	-0.134 to 0.062

Random effect estimates (variance): Cohort (1.866*10^{-2}), Social group (2.108*10^{-2}), Year (5.777*10^{-2}), Plate (6.633*10^{-2}), Row (1.602*10^{-2}), Individual ID (2.666*10^{-7}), Mother ID (<1.000*10^{-12}), Father ID (<1.000*10^{-12}), Residual (8.469*10^{-1}).

Table S5 Parameter estimates from mixed model testing paternal and maternal age at conception (PAC & MAC, respectively) effects on offspring relative leukocyte telomere length (Z-score) in European badgers (only using cub measurements). β = direction and magnitude of effect, S.E. = standard error, 95% CI = 95% confidence interval, reference terms in brackets = reference level for factors; * = interaction. Significant parameters (95% CI does not overlap zero) are in bold.

Parameter (reference level)	**β**	**S.E.**	**95% CI**
Intercept	0.040	0.210	-0.372 to 0.442
Age (≤ 29 months)	0.060	0.220	-0.377 to 0.474
Sex (Female)	-0.108	0.139	-0.371 to 0.153
Season (Spring)			
Summer	0.057	0.291	-0.505 to 0.635
Autumn	-0.862	0.669	-2.131 to 0.474
Winter	-0.429	0.943	-2.198 to 1.354
PAC	-0.040	0.092	-0.224 to 0.145
MAC	-0.073	0.084	-0.242 to 0.098
Sex (female) * PAC	0.186	0.132	-0.075 to 0.441
Sex (female) * MAC	0.013	0.140	-0.247 to 0.286

Random effect estimates (variance): Cohort ($8.221*10^{-2}$), Social group ($<1.000*10^{-12}$), Plate ($1.669*10^{-1}$), Row ($3.728*10^{-2}$), Mother ID ($<1.000*10^{-12}$), Father ID ($3.631*10^{-3}$), Residual ($6.391*10^{-1}$).

Table S6 Parameter estimates from mixed model testing paternal and maternal age at conception (PAC & MAC, respectively) effects on offspring relative leukocyte telomere length (Z-score) in European badgers (only using cub measurements and without the interaction between PAC/MAC and sex). β = direction and magnitude of effect, S.E. = standard error, 95% CI = 95% confidence interval, reference terms in brackets = reference level for factors; * = interaction. Significant parameters (95% CI does not overlap zero) are in bold.

Parameter (reference level)	**β**	**S.E.**	**95% CI**
Intercept	0.032	0.212	-0.388 to 0.437
Age (≤ 29 months)	0.054	0.219	-0.368 to 0.466
Sex (Female)	-0.103	0.138	-0.365 to 0.157
Season (Spring)			
Summer	0.067	0.289	-0.486 to 0.639
Autumn	-0.860	0.664	-2.113 to 0.470
Winter	-0.360	0.933	-2.126 to 1.380
PAC	0.055	0.064	-0.072 to 0.179
MAC	-0.064	0.065	-0.196 to 0.066

Random effect estimates (variance): Cohort ($7.980*10^{-2}$), Social group ($1.297*10^{-3}$), Plate ($1.625*10^{-1}$), Row ($4.936*10^{-2}$), Mother ID ($<1.000*10^{-12}$), Father ID ($9.624*10^{-4}$), Residual ($6.385*10^{-1}$).

Table S7 Parameter estimates from mixed model testing within- and between-parent effects for fathers (PAC) and mother (MAC) on offspring relative leukocyte telomere length (Z-score) in European badgers. β = direction and magnitude of effect, S.E. = standard error, 95% CI = 95% confidence interval, β_W = within-individual effect, β_B = between-individual effect, reference terms in brackets = reference level for factors. Significant parameters (95% CI does not overlap zero) are in bold.

Parameter (reference level)	**β**	**S.E.**	**95% CI**
Intercept	-0.008	0.127	-0.257 to 0.240
Age (≤ 29 months)	-0.013	0.069	-0.149 to 0.127
(>29 and ≤ 65 months)	**0.182**	**0.080**	**0.028 to 0.336**
(>65 and ≤ 112 months)	**-0.179**	**0.072**	**-0.322 to -0.040**
(> 112 months)	**0.124**	**0.055**	**0.019 to 0.234**
Sex (Female)	-0.026	0.095	-0.214 to 0.154
Season (Spring)			
Summer	0.086	0.107	-0.122 to 0.294
Autumn	-0.018	0.192	-0.378 to 0.372
Winter	0.011	0.252	-0.465 to 0.524
PAC (β_W)	0.045	0.047	-0.046 to 0.142
MAC (β_W)	0.012	0.047	-0.078 to 0.106
PAC (β_B)	0.016	0.048	-0.075 to 0.114
MAC (β_B)	-0.048	0.050	-0.144 to 0.050

Random effect estimates (variance): Cohort ($1.459*10^{-2}$), Social group ($2.134*10^{-2}$), Year ($5.414*10^{-2}$), Plate ($6.777*10^{-2}$), Row ($1.606*10^{-2}$), Individual ID ($<1.000*10^{-12}$), Mother ID ($<1.000*10^{-12}$), Father ID ($5.001*10^{-9}$), Residual ($8.511*10^{-1}$)

Table S8 Additive genetic and environmental effects on relative leukocyte telomere length in European badgers of all ages, estimated using *ASReml-R*. Est. = fixed effect estimate, Prop. = proportion of variance explained, S.E. = Standard error, h^2 = heritability. Age parameters refer to threshold model where Age 1 = ≤29 months old, Age 2 = >29 and ≤65 months old, Age 3 = >65 and ≤112 months old and Age 4 = >112 months old. Variance components are: V_A = additive genetic, V_{PE} = permanent environment, V_{CO} = cohort, V_{YEAR} = year, V_{SG} = social group, V_{MAT} = maternal, V_{PAT} = paternal, V_R = residual, V_{PLATE} = plate, V_{ROW} = row. Total phenotypic variance (V_p) = $3.970*10^{-2}$. Reference terms in brackets = reference level for factors. Significance of fixed effects was determined through Wald Z tests, and for random effects through twice the difference in log-likelihood. Significant parameters ($p < 0.05$) are in bold.

Trait: Relative leukocyte telomere length (*n* = 1248 measurements; 612 badgers) ASReml-R				
	Est.	**S.E.**	**F-value**	**p-value**
Fixed effects				
Intercept	0.4796	$2.933*10^{-2}$		
Age 1	$-2.888*10^{-4}$	$6.920*10^{-4}$	0.174	0.677
Age 2	**$2.156*10^{-3}$**	**$6.755*10^{-4}$**	**10.18**	**0.001**
Age 3	**$-2.570*10^{-3}$**	**$8.358*10^{-4}$**	**9.454**	**0.002**
Age 4	**$4.766*10^{-3}$**	**$2.036*10^{-3}$**	**5.481**	**0.019**
Season (Spring)			**3.627**	**0.013**
Summer	**$2.448*10^{-2}$**	**$1.123*10^{-2}$**		
Autumn	**$1.841*10^{-2}$**	**$1.799*10^{-2}$**		
Winter	**$-5.365*10^{-2}$**	**$2.521*10^{-2}$**		
Random effects	**Est. (S.E.)**	**h^2/Prop. (S.E.)**	**χ^2**	**p-value**
V_A[a]	$5.110*10^{-9}$ ($2.260*10^{-10}$)	$1.286*10^{-7}$ ($1.420*10^{-8}$)		
V_{PE}[a]	$7.610*10^{-9}$ ($3.360*10^{-10}$)	$1.914*10^{-7}$ ($2.115*10^{-8}$)		
V_{CO}	**$1.411*10^{-3}$ ($6.970*10^{-4}$)**	**$3.551*10^{-2}$ ($1.750*10^{-2}$)**	**16.92**	**<0.001**
V_{YEAR}	**$1.161*10^{-2}$ ($4.230*10^{-3}$)**	**0.292 ($7.632*10^{-2}$)**	**79.94**	**<0.001**
V_{SG}	$1.494*10^{-4}$ ($2.163*10^{-4}$)	$3.761*10^{-3}$ ($5.458*10^{-3}$)	0.700	0.403
V_{MAT}	$5.086*10^{-4}$ ($5.612*10^{-4}$)	$1.280*10^{-2}$ ($1.414*10^{-2}$)	0.544	0.461
V_{PAT}	$1.974*10^{-4}$ ($3.658*10^{-4}$)	$4.968*10^{-3}$ ($9.214*10^{-3}$)	0.412	0.521
V_R	$2.585*10^{-2}$ ($1.142*10^{-3}$)	0.651 ($7.189*10^{-2}$)		
V_{PLATE}[b]	**$2.085*10^{-3}$ ($7.034*10^{-4}$)**		**46.11**	**<0.001**
V_{ROW}[b]	**$4.354*10^{-4}$ ($3.256*10^{-4}$)**		**8.824**	**0.003**

[a] Significance not tested because variance components were at boundary

[b] Measurement error and not biological variance so no proportion and associated standard error provided

Table S9 Additive genetic and environmental effects on relative leukocyte telomere length (Age ≤ 29 months) in European badgers, estimated using *ASReml-R*. Est. = fixed effect estimate, Prop. = proportion of variance explained, S.E. = Standard error, h^2 = heritability. Variance components are: V_A = additive genetic, V_{PE} = permanent environment, V_{CO} = cohort, V_{YEAR} = year, V_{SG} = social group, V_{MAT} = maternal, V_{PAT} = paternal, V_R = residual, V_{PLATE} = plate, V_{ROW} = row. Total phenotypic variance (V_p) = $3.910*10^{-2}$. Reference terms in brackets = reference level for factors. Significance of fixed effects was determined through Wald Z tests, and for random effects through twice the difference in log-likelihood. Significant parameters ($p < 0.05$) are in bold.

Trait: Early-life relative leukocyte telomere length (*n* = 837 measurements; 556 badgers) ASReml-R				
	Est.	**S.E.**	**F-value**	**p-value**
Fixed effects				
Intercept	0.4771	$2.874*10^{-2}$		
Age	$1.120*10^{-4}$	$8.403*10^{-4}$	0.018	0.894
Season (Spring)			**2.933**	**0.033**
Summer	**$1.576*10^{-2}$**	**$1.398*10^{-2}$**		
Autumn	**$1.516*10^{-2}$**	**$2.408*10^{-2}$**		
Winter	**$-7.998*10^{-2}$**	**$3.150*10^{-2}$**		
Random effects	**Est. (S.E.)**	**h^2/Prop. (S.E.)**	**χ^2**	**p-value**
V_A	$1.280*10^{-4}$ ($1.075*10^{-3}$)	$3.271*10^{-3}$ ($2.746*10^{-2}$)	0.014	0.906
V_{PE}[a]	$8.770*10^{-9}$ ($5.560*10^{-10}$)	$2.240*10^{-7}$ ($2.569*10^{-8}$)		
V_{CO}	**$1.945*10^{-3}$ ($1.138*10^{-3}$)**	**$4.970*10^{-2}$ ($2.862*10^{-2}$)**	**11.13**	**<0.001**
V_{YEAR}	**$1.004*10^{-2}$ ($4.062*10^{-3}$)**	**0.257 ($7.890*10^{-2}$)**	**40.45**	**<0.001**
V_{SG}	$2.412*10^{-4}$ ($3.169*10^{-4}$)	$6.162*10^{-3}$ ($8.107*10^{-3}$)	0.879	0.348
V_{MAT}[a]	$2.710*10^{-9}$ ($1.720*10^{-10}$)	$6.924*10^{-8}$ ($7.940*10^{-9}$)		
V_{PAT}[a]	$2.360*10^{-9}$ ($1.500*10^{-10}$)	$6.024*10^{-8}$ ($6.907*10^{-9}$)		
V_R	$2.679*10^{-2}$ ($1.699*10^{-3}$)	0.684 ($7.846*10^{-2}$)		
V_{PLATE}[b]	**$1.771*10^{-3}$ ($7.239*10^{-4}$)**		**19.49**	**<0.001**
V_{ROW}[b]	$1.942*10^{-4}$ ($2.461*10^{-4}$)		1.319	0.251

[a] Significance not tested because variance components were at boundary

[b] Measurement error and not biological variance so no proportion and associated standard error provided

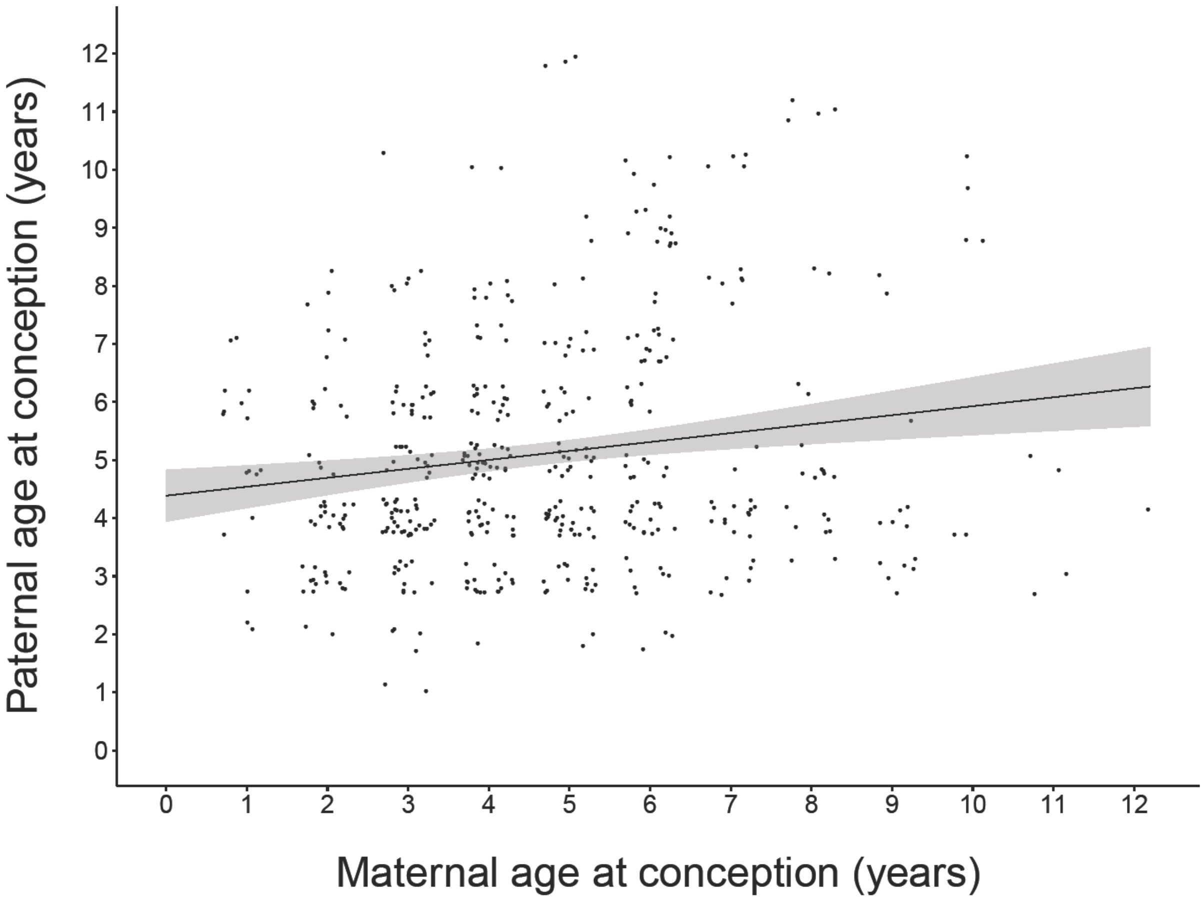

Figure S1 Scatterplot showing the correlation between paternal and maternal ages at conception for badgers with relative leukocyte telomere length measures at any age (*n* = 471 samples; 240 badgers). Parental ages are integers, jittered for clarity on the amount of data.

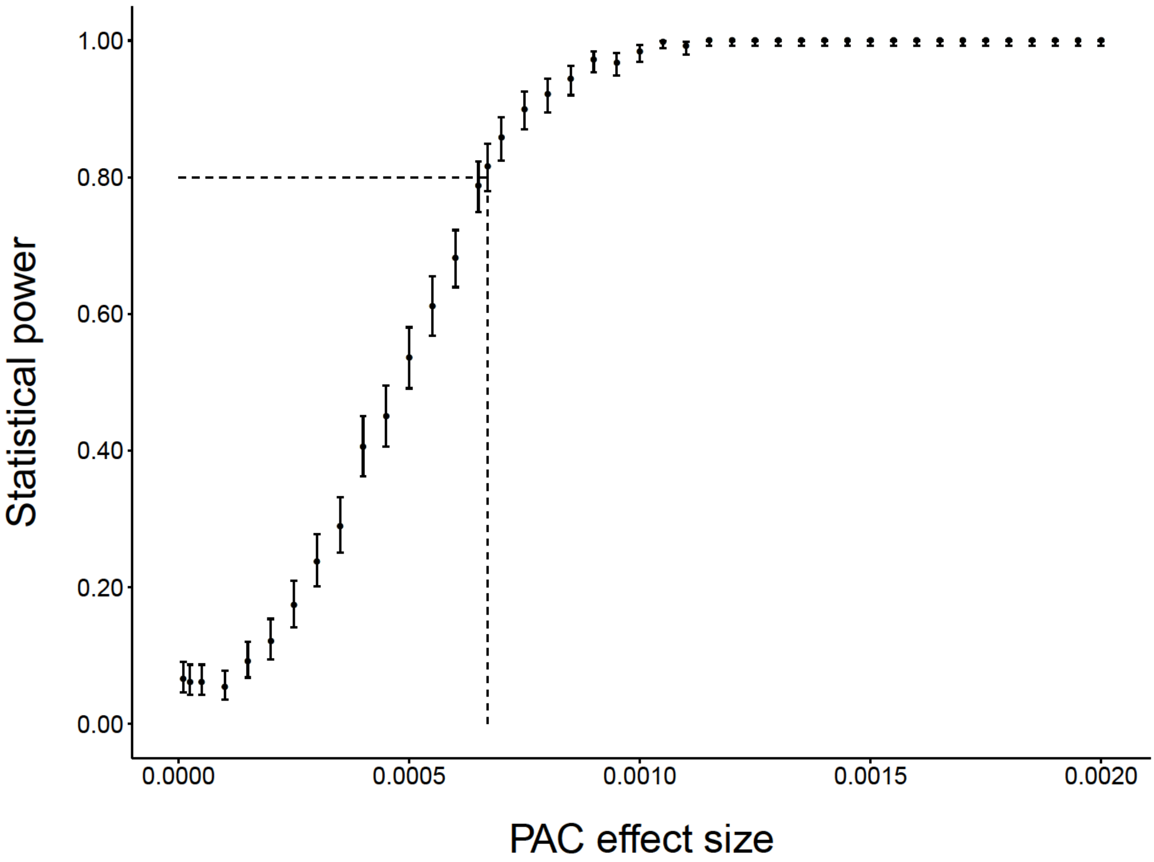

Figure S2 Statistical power to detect paternal age at conception (PAC) effect sizes in our European badger dataset using *simr* 1.0.5 (Green & MacLeod 2016). Point estimates and error bars show mean power with associated 95% confidence intervals estimated from 500 simulations. Dashed line represents ≥80% power to detect a PAC effect size of ≥0.00067, with the specifications of our model and structure of our data. This is similar to a correlation coefficient of 0.131 (where correlation coefficient = $(\beta_{PAC} * SD_{PAC})/SD_{RLTL}$ = (0.00067*24.57207)/0.1254953).

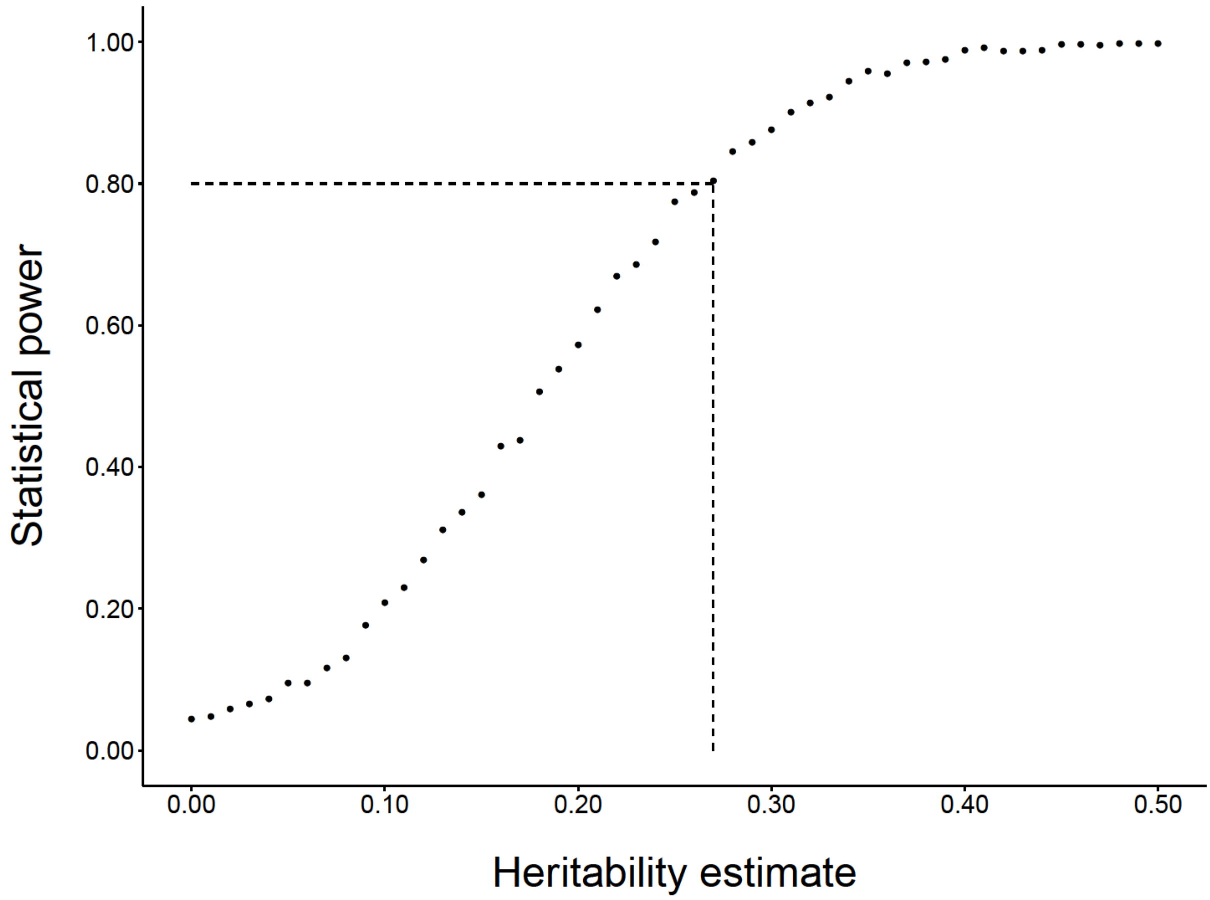

Figure S3 Statistical power to detect varying heritability estimates of telomere length in the European badger with our dataset (*n* = 1248 measurements; 612 badgers) and pruned pedigree structure using *pedantics* 1.7 (Morrissey & Wilson 2010). Point estimates show mean power estimated from 1000 simulations. Dashed line represents ≥80% power to detect a heritability estimate of ≥0.27, with the specifications of our model and structure of our data.

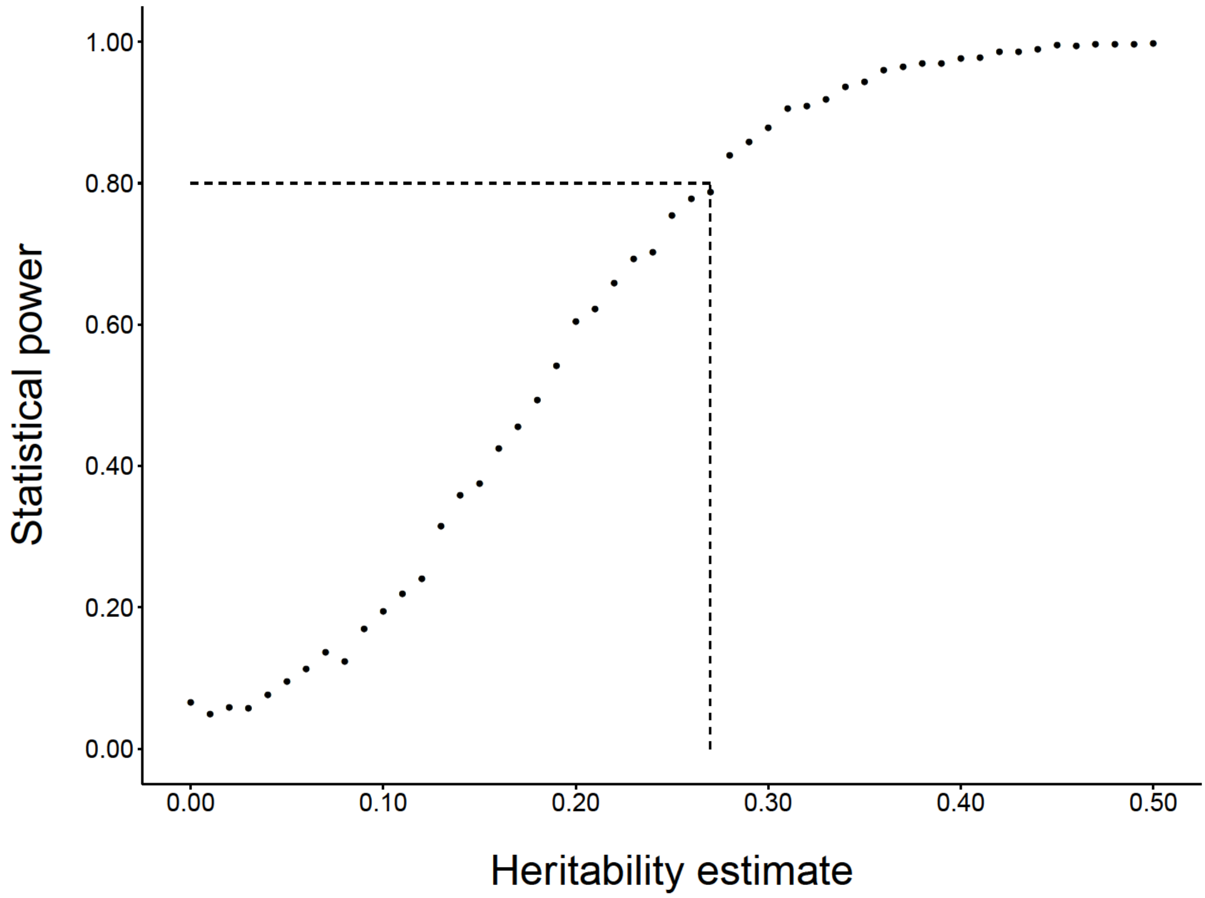

Figure S4 Statistical power to detect varying heritability estimates of juvenile telomere length (≤29 months old) in the European badger with our dataset (*n* = 837 measurements; 556 badgers) and pruned pedigree structure using *pedantics* 1.7 (Morrissey & Wilson 2010). Point estimates show mean power estimated from 1000 simulations. Dashed line represents ≥80% power to detect a heritability estimate of ≥0.28, with the specifications of our model and structure of our data.

References

Green P., MacLeod C. J. (2016). simr: an R package for power analysis of generalized linear mixed models by simulation. *Methods in Ecology and Evolution*, *7*, 493-498. https://doi.org/10.1111/2041-210x.12504

Hadfield J. D. (2010). MCMC methods for multi-response generalised linear mixed models: the MCMCglmm R package. *Journal of Statistical Software*, *33*, 1-22. https://doi.org/10.18637/jss.v033.i02

Morrissey M. B., Wilson A. J. (2010). pedantics: an r package for pedigree-based genetic simulation and pedigree manipulation, characterization and viewing. *Molecular Ecology Resources*, *10*, 711-719. https://doi.org/10.1111/j.1755-0998.2009.02817.x