SUPPLEMENTARY MATERIAL for:

Logan CJ, Kruuk L, Stanley R, Thompson A, Clutton-Brock TH. 2016. Endocranial volume is heritable and is associated with longevity and fitness in a wild mammal. *Royal Society Open Science* 3:160622. http://dx.doi.org/10.1098/rsos.160622

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**Supplementary Table S1. The relationships between selected variables:** Pearson’s product-moment correlations between endocranial volume, jaw length, skull length, back leg length, lifetime breeding success, lifetime reproductive success, and longevity (CI=confidence interval, a Bonferroni-Holm correction was applied to p-values to attempt to control for an increase in type 1 errors from conducting multiple tests on the same dataset).

| Correlation                             | Sex    | r    | 95% CI    | t     | df  | p    |
|----------------------------------------|--------|------|-----------|-------|-----|------|
| Endocranial volume – jaw length        | Female | 0.81 | 0.78-0.84 | 32.57 | 547 | <0.001 |
|                                        | Male   | 0.88 | 0.86-0.90 | 44.96 | 584 | <0.001 |
| Jaw length – skull length              | Female | 0.97 | 0.96-0.97 | 86.58 | 501 | <0.001 |
|                                        | Male   | 0.98 | 0.98-0.99 | 112.65| 460 | <0.001 |
| Jaw length – back leg length           | Female | 0.85 | 0.79-0.90 | 16.52 | 105 | <0.001 |
|                                        | Male   | 0.87 | 0.80-0.91 | 15.86 | 82  | <0.001 |
| Lifetime breeding success – lifetime reproductive success | Female | 0.82 | 0.79-0.85 | 33.51 | 546 | <0.001 |
| Lifetime breeding success - longevity | Female | 0.94 | 0.93-0.95 | 63.20 | 546 | <0.001 |
|                                        | Male   | 0.40 | 0.32-0.46 | 10.35 | 578 | <0.001 |
| Lifetime reproductive success - longevity | Female | 0.78 | 0.74-0.81 | 29.02 | 546 | <0.001 |
## Supplementary Table S2. A description of all variables in the full models.

| Variable                        | Description                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| **Fixed effects**               |                                                                                                                                                                                                                                                                                                                                                                                                       |
| Sex                             | Female or Male                                                                                                                                                                                                                                                                                                                                                                                       |
| Jaw length                      | An indicator of body size: Length of the jaw bone in mm from the back to the protruding piece of bone at the bottom of the front incisor                                                                                                                                                                                                       |
| Birth weight                    | Weight in kg at capture was adjusted to estimate birth weight by subtracting the capture age in hours multiplied by 0.01696kg/hr [23]                                                                                                                                                                                                         |
| Birth date                      | The number of days between the birth date and 1 May                                                                                                                                                                                                                                                                                                                                                   |
| Age                             | Age at death, estimated assuming that all individuals are born after 1 May                                                                                                                                                                                                                                                               |
| Maternal location during pregnancy | The study area is divided into six areas: north glen, laundry greens, south glen, mid glen, intermediate and Shamnan Insir. These serve as an indicator of habitat quality: higher quality habitat being north glen and laundry greens and the lower quality habitat being south glen, mid glen, intermediate, and Shamnan Insir [23] |
| Dominance rank (females)        | Available only for females. Calculations from [32] (see Materials and Methods above)                                                                                                                                                                                                                                                  |
| Maternal dominance rank         | Calculations from [32] (see Materials and Methods above)                                                                                                                                                                                                                                                                                   |
| Maternal age at parturition     | The age of the mother when the calf was born calculated as above                                                                                                                                                                                                                                                                        |
| Maternal jaw length             | The jaw length (as above) of the mother as an indicator of body size                                                                                                                                                                                                                                                                     |
| Mother’s reproductive status    | The mother’s status was grouped into 3 categories defined by likely levels of resources available for investment based on amounts invested in offspring in a previous year (as in [21]):                                                                                                                                                        |
| (i) "Low" available investment were Milk Hind and Winter Yeld hinds because both gave birth the year before and their offspring either died in the winter (after 1 October in the previous year; winter yeld) or survived its first year (milk hind).                  |
| (ii) "High" available investment categories were Summer and True Yelds because they either gave birth the year before but the offspring did not survive its first few months (died before 1 October in the previous year; summer yeld) or had given birth at some point, but not in the previous year (true yeld). |
| (iii) High available investment but ‘inexperienced’ was the Naive status where it was a female’s first time giving birth.                                                                                                                                                                                                                     |
| **Random effects**              |                                                                                                                                                                                                                                                                                                                                                                                                       |
| Birth year                      | The year in which the individual was born                                                                                                                                                                                                                                                                                                 |
| Mother’s ID                     | The ID of the subject’s mother                                                                                                                                                                                                                                                                                                           |
| Animal ID                       | The ID of the subject linked to the pedigree through the “ped” function in the model                                                                                                                                                                                                                                                    |
Supplementary Table S3. Fecundity and longevity models run with two variations of modeling relative endocranial volume (relEV: residuals of endocranial volume against jaw length) as fixed effects (either (a) relative endocranial volume or (b) relative endocranial volume + jaw length) show that, with two exceptions, conclusions do not differ from the models used in the text (fixed effects: endocranial volume + jaw length). The exceptions occur in the female LRS and female longevity models where, in both cases, the relative endocranial volume is not significant in the relative endocranial volume only model. This is in contrast with the other two methods of modeling relative endocranial volume, which both show this variable as significant (right side of the table below and in Tables 3 and 4). Random effects show variances and standard deviations (SD).
| Model                  | Variable   | Estimate | SE  | z     | p      | Variable   | Estimate | SE  | z     | p      |
|-----------------------|------------|----------|-----|-------|--------|------------|----------|-----|-------|--------|
| **Male LBS**          | Intercept  | 0.79     | 0.25| 3.17  | 0.002  | Intercept  | 25.019   | 6.13| -4.08 | <0.001 |
| Lifetime breeding success | relEV     | 0.008    | 0.009| -0.88 | 0.38   | relEV      | 0.003    | 0.009| 0.31  | 0.76   |
|                       |            |          |     |       |        | JL         | 0.09     | 0.02| 4.17  | <0.001 |
| **Male Longevity**    | Intercept  | 2.33     | 0.03| 89.96 | <0.001 | Intercept  | -0.33    | 0.66| -0.50 | 0.62   |
| Age at death          | relEV      | 0.0002   | 0.0009| 0.21 | 0.83   | relEV      | 0.001    | 0.001| 1.13  | 0.26   |
|                       | JL         | 0.01     | 0.002| -4.03 | <0.001 |            |          |     |       |        |
| **Female LBS**        | Intercept  | 1.76     | 0.04| 48.77 | <0.001 | Intercept  | -2.94    | 0.85| -3.46 | <0.001 |
| GLM negative binomial with log link | relEV      | 0.0002   | 0.001| 0.12  | 0.91   | relEV      | 0.001    | 0.001| 1.02  | 0.31   |
|                       | JL         | 0.02     | 0.003| 5.56  | <0.001 |            |          |     |       |        |
| **Female LRS**        | Intercept  | 0.93     | 0.04| 22.73 | <0.001 | Intercept  | -5.80    | 1.00| -5.80 | <0.001 |
| GLM negative binomial with log link | relEV      | 0.002    | 0.002| 1.09  | 0.28   | relEV      | 0.003    | 0.002| 2.17  | 0.03   |
|                       | JL         | 0.03     | 0.004| 6.77  | <0.001 |            |          |     |       |        |
| **Female Fecundity**  | Intercept  | 0.88     | 0.05| 19.02 | <0.001 | Intercept  | 1.19     | 1.22| 0.97  | 0.33   |
| Proportion yrs gave birth (first birth to death) | relEV      | -0.002   | 0.002| -0.97 | 0.33   | relEV      | -0.002   | 0.002| -1.00 | 0.32   |
|                       | JL         | 0.001    | 0.005| 0.26  | 0.80   |            |          |     |       |        |
| **Female Longevity**  | Intercept  | 2.43     | 0.02| 104.8 | <0.001 | Intercept  | -1.08    | 0.53| -2.04 | 0.04   |
| Age at death          | relEV      | 0.001    | 0.0009| 1.81 | 0.24   | relEV      | 0.002    | 0.0009| 2.30  | 0.02   |
|                       | JL         | 0.01     | 0.002| 6.68  | <0.001 |            |          |     |       |        |
Supplementary Table S4. Summary pedigree statistics derived using the R package pedantics [33]. F refers to Wright’s inbreeding coefficient.

| Category                        | Value  |
|---------------------------------|--------|
| Records                         | 1715   |
| Maternities                     | 1241   |
| Paternities                     | 1088   |
| Full sibs                       | 60     |
| Maternal sibs                   | 1573   |
| Maternal half sibs              | 1513   |
| Paternal sibs                   | 3632   |
| Paternal half sibs              | 3572   |
| Maternal grandmothers           | 736    |
| Maternal grandfathers           | 667    |
| Paternal grandmothers           | 380    |
| Paternal grandfathers           | 390    |
| Maximum pedigree depth (number of generations) | 7      |
| Founders                        | 456    |
| Mean maternal sibship size      | 2.44   |
| Mean paternal sibship size      | 3.78   |
| Non-zero F                      | 55     |
| F>0.125                         | 1.00   |
| Mean pairwise relatedness       | 0.005  |
| Pairwise relatedness >=0.125    | 0.02   |
| Pairwise relatedness >=0.25     | 0.007  |
| Pairwise relatedness >=0.5      | 0.002  |
Supplementary Table S5. Full model outputs (R package: lmerTest, function: lmer): the significant variables were kept and formed the reduced models upon which the animal models (Table 1) were run.

| Variable                                                                 | Estimate | Standard Error | t    | p       |
|-------------------------------------------------------------------------|----------|----------------|------|---------|
| Model 1: all ages (n=488)                                               |          |                |      |         |
| Intercept (females, age 0, mother’s location at parturition: Intermediate, mother’s reproductive status: milk/winter yield) | 132.25   | 34.46          | 3.83 | <0.001  |
| Males                                                                   | 15.13    | 2.31           | 6.55 | <0.001  |
| Age                                                                     | 7.67     | 4.40           | 1.74 | 0.08    |
| Age 2                                                                   | 17.27    | 7.18           | 2.40 | 0.02    |
| Ages 3+                                                                 | 23.76    | 8.22           | 2.89 | 0.004   |
| Jaw length                                                              | 0.68     | 0.10           | 6.98 | <0.001  |
| Birth weight                                                            | 2.83     | 0.96           | 2.94 | 0.003   |
| Birth day in season                                                     | -0.11    | 0.08           | -1.47| 0.14    |
| Mother’s age at parturition                                             | -0.20    | 0.38           | -0.52| 0.60    |
| Mother’s jaw length                                                     | -0.06    | 0.13           | -0.51| 0.61    |
| Mother’s location at parturition:                                       |          |                |      |         |
| Laundry greens                                                          | 4.87     | 5.35           | 0.91 | 0.36    |
| Mid glen                                                                | -4.52    | 3.93           | -1.15| 0.25    |
| North glen                                                              | -7.50    | 3.52           | -2.13| 0.03    |
| South glen                                                              | -6.16    | 5.28           | -1.17| 0.24    |
| Shamman Insir                                                           | -4.33    | 3.76           | -1.15| 0.25    |
| Mother’s reproductive status:                                           |          |                |      |         |
| Naïve                                                                   | -0.14    | 3.34           | -0.04| 0.96    |
| Summer/true yields                                                      | 2.72     | 2.43           | 1.12 | 0.26    |
| Random effects:                                                         |          |                |      |         |
| Birth year                                                              | 9.54     | 3.09           | NA   | NA      |
| Mother’s ID                                                             | 97.26    | 9.86           | NA   | NA      |
| Residual                                                                | 375.46   | 19.38          | NA   | NA      |

Model 2: adults only (n=249)

| Variable                                                                 | Estimate | Standard Error | t    | p       |
|-------------------------------------------------------------------------|----------|----------------|------|---------|
| Intercept (females, age 0, mother’s location at parturition: Intermediate, mother’s reproductive status: milk/winter yield) | 101.72   | 53.16          | 1.91 | 0.06    |
| Males                                                                   | 19.49    | 4.14           | 4.71 | <0.001  |
| Age                                                                     | 0.29     | 0.43           | 0.67 | 0.50    |
| Jaw length                                                              | 0.69     | 0.15           | 4.57 | <0.001  |
| Birth weight                                                            | 1.02     | 1.44           | 0.71 | 0.48    |
| Birth day in season                                                     | 0.02     | 0.12           | 0.20 | 0.84    |
| Mother’s age at parturition                                             | -0.56    | 0.57           | -0.98| 0.33    |
| Mother’s jaw length                                                     | 0.14     | 0.19           | 0.73 | 0.47    |
| Mother’s location at parturition:                                       |          |                |      |         |
| Laundry greens                                                          | 10.05    | 8.74           | 1.15 | 0.25    |
| Mid glen                                                                | -1.82    | 5.27           | -0.35| 0.73    |
| North glen                                                              | -7.24    | 5.35           | -1.35| 0.18    |
| South glen                                                              | -5.21    | 7.28           | -0.72| 0.48    |
| Shamman Insir                                                           | 1.04     | 5.70           | 0.18 | 0.86    |
| Mother’s available investment:                                          |          |                |      |         |
| Naïve                                                                   | 5.67     | 4.95           | 1.15 | 0.25    |
| Summer/true yields                                                      | 9.41     | 3.56           | 2.64 | 0.009   |
| Random effects:                                                         |          |                |      |         |
| Birth year                                                              | 5.06     | 2.25           | NA   | NA      |
| Mother’s ID                                                             | 121.94   | 11.04          | NA   | NA      |
| Residual                                                                | 384.32   | 19.60          | NA   | NA      |
Supplementary Table S6. Summary statistics of endocranial volumes in relation to sex and age. Juveniles: 0-2 years, adults: 3+ years; SD: Standard Deviation, CV: coefficient of variation.

| Age   | Sex    | n  | Mean (ml) | SD (ml) | CV   |
|-------|--------|----|-----------|---------|------|
| Juveniles | Females | 213 | 261       | 30      | 11.58|
|        | Males  | 303 | 276       | 33      | 12.12|
| Adults | Females | 336 | 328       | 25      | 7.96 |
|        | Males  | 277 | 356       | 26      | 7.36 |

Supplementary Table S7. Offspring juvenile survival rate and endocranial volume. GLM: LRS as a proportion of LBS as the response variable and endocranial volume and jaw length as fixed effects with a binomial distribution and logit link (SE: Standard Error, z: z statistic, p: p-value).

| Variable          | Estimate | SE  | z    | p     |
|-------------------|----------|-----|------|-------|
| Intercept         | -4.44    | 1.34 | -3.32| <0.001|
| Endocranial Volume | 0.002    | 0.002 | 1.22 | 0.22  |
| Jaw length        | 0.01     | 0.005 | 2.54 | 0.01  |

**Dominance rank**

We used dominance ranks from [32], which were calculated following [47] using data from 1974-1995. Dominance data only exist for females. Intra-cohort rank was controlled for age to distinguish among dominance and developmental effects and calculated as follows: the number of unrelated females of equal age or older that a focal individual threatened or displaced + 1 divided by the number of unrelated females of equal age or younger that a focal individual threatened or displaced + 1. Intra-cohort rank was then divided by the number of females in the cohort for a final score between 0 and 1 with higher numbers being more dominant.

There was very little dominance rank data, therefore a separate model on this small dataset (n=51 all ages, n=49 adults) was run to determine whether dominance rank or mother’s dominance rank should be included in the reduced model. The full model was the same as above except sex was removed because no males had rank data, and dominance rank and mother’s dominance rank were added as fixed effects. Dominance rank and mother’s dominance rank were not significant variables in this version of the full model, therefore they were not included in the reduced models (Supplementary Table S8).
Table S8. Full model outputs showing that dominance rank and mother’s dominance rank were not variables to include in the reduced models for the animal model.

| Variable | Estimate | Standard Error | t  | p     |
|----------|----------|----------------|----|-------|
| All ages model (n=51) |           |                |    |       |
| Intercept (mother’s location at parturition: Intermediate, mother’s reproductive status: milk/winter yeld) | 179.70 | 113.61 | 1.58 | 0.12  |
| Ages 3+ | -27.29 | 18.89 | -1.45 | 0.15  |
| Jaw length | 1.11 | 0.21 | 5.22 | <0.001 |
| Birth weight | -3.67 | 2.89 | -1.27 | 0.21  |
| Birth day in season | 0.05 | 0.37 | 0.14 | 0.89  |
| Dominance rank | -3.39 | 11.09 | -0.31 | 0.76  |
| Mother’s dominance rank | -6.54 | 3.42 | -1.91 | 0.07  |
| Mother’s age at parturition | -1.26 | 1.57 | -0.81 | 0.42  |
| Mother’s jaw length | -0.13 | 0.39 | -0.33 | 0.74  |
| Mother’s location at parturition: |           |                |    |       |
| Laundry greens | -26.67 | 24.23 | -1.10 | 0.28  |
| Mid glen | -17.49 | 10.03 | -1.74 | 0.09  |
| North glen | -2.18 | 9.93 | -0.22 | 0.83  |
| Shamman Insir | -12.45 | 10.98 | -1.13 | 0.26  |
| Mother’s reproductive status: |           |                |    |       |
| Naïve | 6.33 | 9.96 | 0.64 | 0.53  |
| Summer/true yelds | 11.13 | 6.88 | 1.62 | 0.11  |
| Random effects: | Variance | Std. Deviation |    |       |
| Birth year | 116.00 | 10.77 | NA | NA   |
| Mother’s ID | 154.00 | 12.41 | NA | NA   |
| Residual | 156.50 | 12.51 | NA | NA   |
| Adult only model (n=49) |           |                |    |       |
| Intercept (mother’s location at parturition: Intermediate, mother’s reproductive status: milk/winter yeld) | 147.92 | 124.66 | 1.19 | 0.25  |
| Age | 0.44 | 0.77 | 0.57 | 0.57  |
| Jaw length | 1.06 | 0.24 | 4.25 | <0.001 |
| Birth weight | -3.58 | 2.94 | -1.22 | 0.23  |
| Birth day in season | 0.11 | 0.39 | 0.28 | 0.78  |
| Dominance rank | -2.42 | 11.44 | -0.21 | 0.83  |
| Mother’s dominance rank | -6.36 | 3.57 | -1.79 | 0.09  |
| Mother’s age at parturition | -1.21 | 1.60 | -0.75 | 0.45  |
| Mother’s jaw length | -0.11 | 0.40 | -0.27 | 0.79  |
| Mother’s location at parturition: |           |                |    |       |
| Laundry greens | -32.02 | 25.99 | -1.23 | 0.23  |
| Mid glen | -18.67 | -18.67 | -1.79 | 0.09  |
| North glen | -3.19 | 10.31 | -0.31 | 0.76  |
| Shamman Insir | -13.49 | 11.84 | -1.14 | 0.26  |
| Mother’s reproductive status: |           |                |    |       |
| Naïve | 7.09 | 10.24 | 0.69 | 0.49  |
| Summer/true yelds | 12.07 | 7.06 | 1.71 | 0.09  |
| Random effects: | Variance | Std. Deviation |    |       |
| Birth year | 119.30 | 10.92 | NA | NA   |
| Mother’s ID | 150.50 | 12.27 | NA | NA   |
| Residual | 167.10 | 12.93 | NA | NA   |
Supplementary Figure S1. The pedigree pruned to the deer whose endocranial volumes were measured (red lines = maternities, blue lines = paternities) and their relevant relatives. Each row represents one generation, from 0 through 7.
Further analyses of age-related variation in endocranial volume

We graphically compared endocranial volume vs age curves for individuals that died because they were shot outside the study area (n=129 females, n=178 males), which are a more random sample, with those that died of natural causes (n=493 females, n=489 males) in an initial analysis to ensure that the causes of natural deaths did not bias the results (R package: FlexParamCurve, function: pn.mod.compare [48]; R package: lattice, function: xyplot [49]). The curves for non-shot and shot deer were not different from each other (Supplementary Figure S2). Therefore, we can reliably determine adult status using all data (curves of best fit: female shot=richardsR31.lis, non-shot=richardsR12.lis; male shot=richardsR11.lis, non-shot=richardsR12.lis).

Supplementary Figure S2. Absolute endocranial volume by age in females (A) and males (B) that died of natural causes (filled circles, black line) or because they were shot (open triangles, light gray line).
Supplementary Figure S3. Adult female (3+ years) age at first reproduction was not associated with relative endocranial volume (A), whereas those females with larger relative endocranial volumes lived longer from age at first reproduction to death (B). Relative endocranial volume = residuals of endocranial volume against jaw length, shaded region = 95% Bayesian credible intervals, see Table 3 for analyses).

Supplementary Figure S4. Lifetime breeding (A, B) and reproductive success (C) for absolute endocranial volume in adults (3+ years) without accounting for jaw length.
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