SUPPLEMENTARY MATERIALS

Movement reveals reproductive tactics in male elephants

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Supplementary Tables and Figures

Table S1. Total GPS tracking non-musth and musth days by month. Note the low number of musth observations between July and October.

| Month    | Total GPS tracking days |
|----------|-------------------------|
|          | Non-musth | Musth |
| January  | 83         | 73    |
| February | 131        | 44    |
| March    | 128        | 19    |
| April    | 87         | 51    |
| May      | 147        | 119   |
| June     | 102        | 91    |
| July     | 140        | 3     |
| August   | 83         | 3     |
| September| 108        | 7     |
| October  | 129        | 7     |
| November | 148        | 32    |
| December | 117        | 33    |
| Total    | 1,403      | 482   |

Table S2. Model priors for three state-hidden Markov models.

| Model                             | $\beta$ (State 1, State 2, State 3) | $\sigma$ (State 1, State 2, State 3) |
|-----------------------------------|-------------------------------------|-------------------------------------|
| Log-transformed daily mean speed  | -1.0, 0.0, -1.0                     | 0.75, 1.5, 0.75                     |
| Log-transformed 95% MCP           | 1.0, 2.0, 1.0                       | 0.75, 1.5, 0.75                     |
Table S3. Results of the linear mixed-effects models for log-transformed daily mean speed and log-transformed 95% MCP, and the binomial generalised linear mixed-effects model for the proportion of exploratory behaviour per day. Blank cells correspond to variables which were removed from the model and are therefore not significant. Note: Estimates for age are in years centred on a reference point of age 35, whereas the environmental covariates are standardised by removing the mean and dividing by the standard deviation. Marginal ($R^2_{LME(m)}$) and conditional R-squared values ($R^2_{LME(c)}$) were calculated using the methods described in Nakagawa and Schielzeth (2013).

| Fixed-effect        | Log-transformed speed (Estimate [95% CI]) | Log-transformed 95% MCP (Estimate [95% CI]) |
|---------------------|------------------------------------------|--------------------------------------------|
| (Intercept)         | -1.03 [-1.16, -0.91]                     | 1.08 [0.83, 1.33]                          |
| Musth               | 0.40 [0.31, 0.49]                        | 0.84 [0.65, 1.02]                          |
| Age                 | -0.01 [-0.02, 0.00]                      | -0.02 [-0.04, 0.00]                        |
| Age$^2$             |                                          |                                            |
| NDVI                | 0.15 [0.08, 0.23]                        | 0.30 [0.15, 0.45]                          |
| NDVI$^2$            | -0.04 [-0.07, -0.01]                     | -0.07 [-0.14, 0.00]                        |
| Slope               |                                          |                                            |
| Slope$^2$           | -0.01 [-0.02, -0.01]                     | -0.03 [-0.05, -0.01]                       |
| VRM                 | 0.03 [0.01, 0.05]                        | 0.05 [0.00, 0.1]                           |
| VRM$^2$             | -0.03 [-0.05, -0.02]                     | -0.1 [-0.14, -0.07]                        |
| Water               | 0.07 [0.03, 0.11]                        | 0.24 [0.15, 0.34]                          |
| Water$^2$           | -0.01 [-0.01, 0.00]                      | -0.03 [-0.04, -0.02]                       |
| Protected           | 0.16 [0.11, 0.21]                        | 0.36 [0.24, 0.49]                          |
| Musth * Age         | 0.02 [0.01, 0.03]                        | 0.03 [0.00, 0.05]                          |
| Musth * Age$^2$     |                                          |                                            |
| Musth * NDVI        |                                          |                                            |
| Musth * NDVI$^2$    | -0.07 [-0.12, -0.02]                     | -0.12 [-0.22, -0.02]                       |
| Musth * Slope       |                                          |                                            |
| Musth * Slope$^2$   | 0.01 [0.00, 0.02]                        | 0.03 [0.00, 0.05]                          |
| Musth * VRM         |                                          |                                            |
| Musth * VRM$^2$     |                                          |                                            |
| Musth * Water       |                                          |                                            |
| Musth * Water$^2$   |                                          |                                            |
| Musth * Protected   |                                          |                                            |
| $R^2_{LME(m)}$       | 0.22                                     | 0.19                                      |
| $R^2_{LME(c)}$       | 0.46                                     | 0.36                                      |
Table S4. Results of the three-state hidden Markov model of log-transformed daily mean speed (km h\(^{-1}\)) aiming to detect musth in male elephants. The number of observations corresponds to the number of visual observations correctly or incorrectly assigned by the three-state HMM. Note that the values for daily mean speed during the detected states includes all of the data within the detected time frames and thus contains both the false-positive and false-negative results.

| Name     | Age (years) | Three-state HMM | Musth observations | Daily mean speed (km h\(^{-1}\)) during detected state |
|----------|-------------|-----------------|--------------------|----------------------------------------------------------|
|          |             | Detected musth length (days) | SD of detected length (days) | Non-musth | Musth | Total % correct | Non-musth | Musth | % Change | Non-musth | Musth | % Change |
|          |             | Correct | Incorrect | % Correct | Correct | Incorrect | % Correct | Mean | Standard deviation |
| Nehru    | 28          | 17      | 23.6     | 9        | 0      | 100      | 0 1      | 0     | 90   | 0.37 | 0.38 | 3 | 0.14 | 0.14 | -3 |
| Edison   | 31          | 49      | 0.7      | 0        | 0      | -        | 7 0      | 100   | 100  | 0.28 | 0.66 | 131 | 0.12 | 0.31 | 162 |
| Theresai | 33          | 30      | 28.9     | 4        | 1      | 80       | 3 0      | 100   | 88   | 0.42 | 0.50 | 19 | 0.23 | 0.20 | -12 |
| Winston  |             | 31      | 50       | 27.5     | 27     | 7        | 79 2      | 2     | 50   | 76   | 0.49 | 0.76 | 63 | 0.26 | 0.53 | 38 |
|           | 32          | 30      | 33.1     | 15       | 7      | 68       | 0 2      | 0     | 63   | 0.42 | 0.43 | 3 | 0.26 | 0.25 | -5 |
|           | 32          | 86      | 2.4      | 5        | 9      | 36       | 8 0      | 100   | 59   | 0.34 | 0.56 | 66 | 0.11 | 0.23 | 116 |
|           | 34          | 83      | 17.3     | 1        | 3      | 25       | 5 0      | 100   | 67   | 0.22 | 0.56 | 154 | 0.12 | 0.32 | 177 |
| Apollo   | 38          | 13      | 10.9     | 10       | 0      | 100      | 1 0      | 100   | 100  | 0.53 | 0.73 | 38 | 0.21 | 0.16 | -24 |
| Esidai   | 38          | 93      | 13.7     | 18       | 4      | 82       | 17 0     | 100   | 90   | 0.32 | 0.61 | 92 | 0.16 | 0.23 | 48 |
|           | 39          | 105     | 6.7      | 1        | 6      | 14       | 8 0      | 100   | 60   | 0.17 | 0.49 | 184 | 0.06 | 0.22 | 235 |
| Kenyatta | 42          | 72      | 0.0      | 15       | 0      | 100      | 8 0      | 100   | 100  | 0.34 | 0.85 | 151 | 0.20 | 0.36 | 77 |
|           | 43          | 50      | 2.8      | 11       | 0      | 100      | 13 0     | 100   | 100  | 0.29 | 0.64 | 124 | 0.11 | 0.26 | 143 |
| PrettyBomBom | 44     | 67      | 1.7      | 18       | 1      | 95       | 12 3     | 80    | 88   | 0.33 | 0.62 | 87 | 0.15 | 0.21 | 36 |
| Mungu    | 47          | 88      | 5.2      | 28       | 1      | 97       | 20 0     | 100   | 98   | 0.25 | 0.63 | 152 | 0.10 | 0.29 | 206 |
| Matt     | 52          | 27      | 0.9      | 0        | 0      | -        | 2 0      | 100   | 100  | 0.29 | 0.67 | 134 | 0.12 | 0.36 | 196 |
| Total count/ mean value | 51* | 10.4* | 162 | 39 | 84* | 106 | 8 | 84* | 90* | 0.34* | 0.61* | 91* | 0.15* | 0.25* | 89* |
| Under 35 | 40* | 18.3* | 61 | 27 | 77* | 25 | 5 | 66* | 86* | 0.36* | 0.53* | 56* | 0.17* | 0.24* | 57* |
| Over 35  | 59* | 5.1* | 101 | 12 | 88* | 81 | 3 | 97* | 94* | 0.33* | 0.66* | 114* | 0.14* | 0.26* | 111* |

*After accounting for the effects of repeated individual
Table S5. Results of the three-state hidden Markov model of log-transformed 95% MCP aiming to detect musth in male elephants. The number of observations corresponds to the number of visual observations correctly or incorrectly assigned by the three-state HMM.

| Name     | Age (years) | Change point SD | Non-musth | Musth | Total % correct |
|----------|-------------|-----------------|-----------|-------|-----------------|
|          |             |                 | Correct   | Incorrect | % Correct | Correct | Incorrect | % Correct |           |                |
| Nehru    | 28          | 21.0            | 9         | 0      | 100             | 0       | 1         | 0         |           | 90              |
| Edison   | 31          | 15.1            | 0         | 0      | 0               | 7       | 0         | 100       |           | 100             |
| Theresai | 33          | 37.5            | 4         | 1      | 80              | 3       | 0         | 100       |           | 88              |
| Winston  | 31          | 20.0            | 16        | 18     | 47              | 4       | 0         | 100       |           | 53              |
|          | 32          | 38.1            | 20        | 2      | 91              | 0       | 2         | 0         |           | 83              |
|          | 32          | 4.3             | 8         | 6      | 57              | 7       | 1         | 88        |           | 68              |
|          | 34          | 8.6             | 0         | 4      | 0               | 5       | 0         | 100       |           | 56              |
| Apollo   | 38          | 64.4            | 8         | 2      | 80              | 1       | 0         | 100       |           | 82              |
| Esidai   | 38          | 8.3             | 20        | 2      | 91              | 16      | 1         | 94        |           | 92              |
|          | 39          | 7.3             | 2         | 5      | 29              | 8       | 0         | 100       |           | 67              |
| Kenyatta | 42          | 0.0             | 15        | 0      | 100             | 8       | 0         | 100       |           | 100             |
|          | 43          | 3.5             | 11        | 0      | 100             | 13      | 0         | 100       |           | 100             |
| PrettyBomBom | 44      | 1.1             | 18        | 1      | 95              | 12      | 3         | 80        |           | 88              |
| Mungu    | 47          | 4.3             | 28        | 1      | 97              | 20      | 0         | 100       |           | 98              |
| Matt     | 52          | 1.4             | 0         | 0      | 0               | 2       | 0         | 100       |           | 100             |
| Total count/ mean value | | | 17.2* | 159 | 42 | 82* | 106 | 8 | 85* | 89* |
| Under 35 | | | 22.8* | 57 | 31 | 76* | 26 | 4 | 68* | 86* |
| Over 35  | | | 13.5* | 102 | 11 | 86* | 80 | 4 | 96* | 91* |

*After accounting for the effects of repeated individuals
Figure S1. Relationship between log-transformed daily standard deviation of speed, log-transformed daily mean speed, sinuosity index, log-transformed 95% MCP and proportion of exploratory behaviour for the all GPS tracked days used in the linear mixed-effects model analysis.
Figure S2. Relationship between all of the continuous covariates for the all GPS tracked days used in the linear mixed-effects model analysis. Covariates include the age at observation (years), daily mean NDVI, daily mean slope (degrees), daily mean vector ruggedness measure (VRM) and daily mean distance to water (km).
Figure S3. Autocorrelation of residuals (a-b) without and (c-d) with an autoregressive lag-1 correlation (corAR1) structure. Plots show the linear mixed-effects model of (a, c) log-transformed daily mean speed and (b, d) log-transformed 95% MCP. Note the autocorrelation in plots a-b, which is resolved by adding the corAR1 autocorrelation structure (c-d).
Figure S4. Posterior predictive checks of model fit of the three-state hidden Markov model for log-transformed daily mean speed aiming to detect musth periods in bull elephants.
**Figure S5.** Raw data illustrating the relationship between daily mean speed (km h\(^{-1}\)) and (B) 95% MCP (km\(^2\)), and age (years) in musth (red) and non-musth (blue).
Figure S6. Three-state hidden Markov model results of the model for log-transformed 95% MCP aiming to detect musth periods in bull elephants. Plots show the untransformed 95% MCP (km²) with the detected musth periods shaded in red. Grey shaded area indicates the corresponding credible interval (±95%). Visual observations of the bull in musth or non-musth are denoted by the red and blue lines at the base of the plot. Plots are ordered by age from youngest to oldest.