

## Supplementary Materials for

### **Guns, germs, and trees determine density and distribution of gorillas and chimpanzees in Western Equatorial Africa**

Samantha Strindberg, Fiona Maisels, Elizabeth A. Williamson, Stephen Blake, Emma J. Stokes, Rostand Aba'a, Gaspard Abitsi, Anthony Agbor, Ruffin D. Ambahe, Parfait C. Bakabana, Martha Bechem, Antoine Berlemont, Bruno Bokoto de Semboli, Patrick R. Boundja, Nicolas Bout, Thomas Breuer, Genevieve Campbell, Pauwel De Wachter, Marc Ella Akou, Fidel Esono Mba, Anna T. C. Feistner, Bernard Fosso, Roger Fotso, David Greer, Clement Inkamba-Nkulu, Calixte F. Iyenguet, Kathryn J. Jeffery, Max Kokangoye, Hjalmar S. Kühl, Stephanie Latour, Bola Madzoke, Calixte Makoumbou, Guy-Aimé F. Malanda, Richard Malonga, Victor Mbololo, David B. Morgan, Prosper Motsaba, Gabin Moukala, Brice S. Mowawa, Mizuki Murai, Christian Ndzai, Tomoaki Nishihara, Zacharie Nzooh, Lilian Pintea, Amy Pokempner, Hugo J. Rainey, Tim Rayden, Heidi Ruffler, Crickette M. Sanz, Angélique Todd, Hilde Vanleeuwe, Ashley Vosper, Ymke Warren, David S. Wilkie

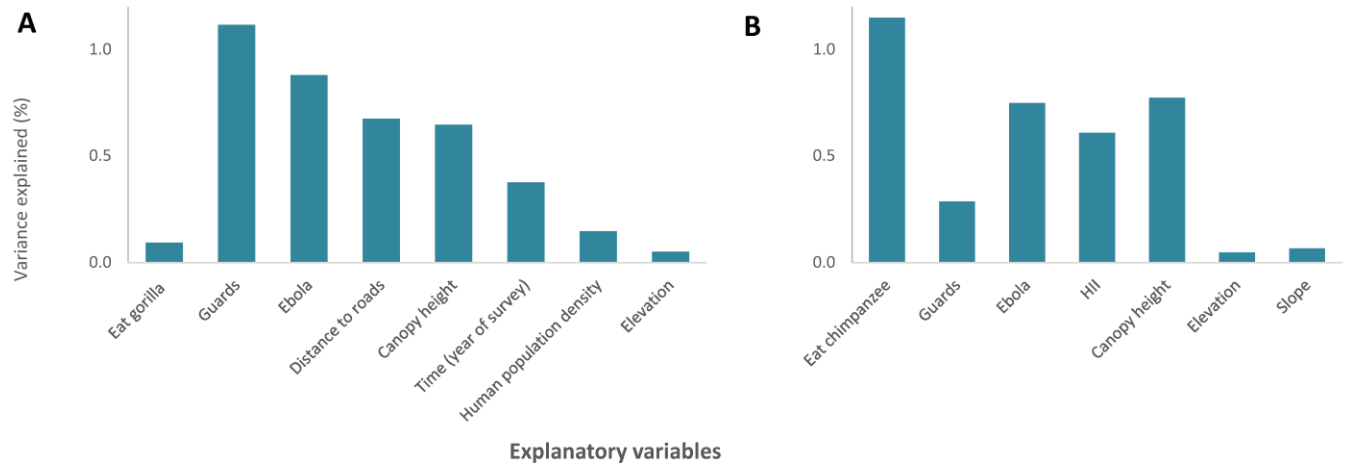
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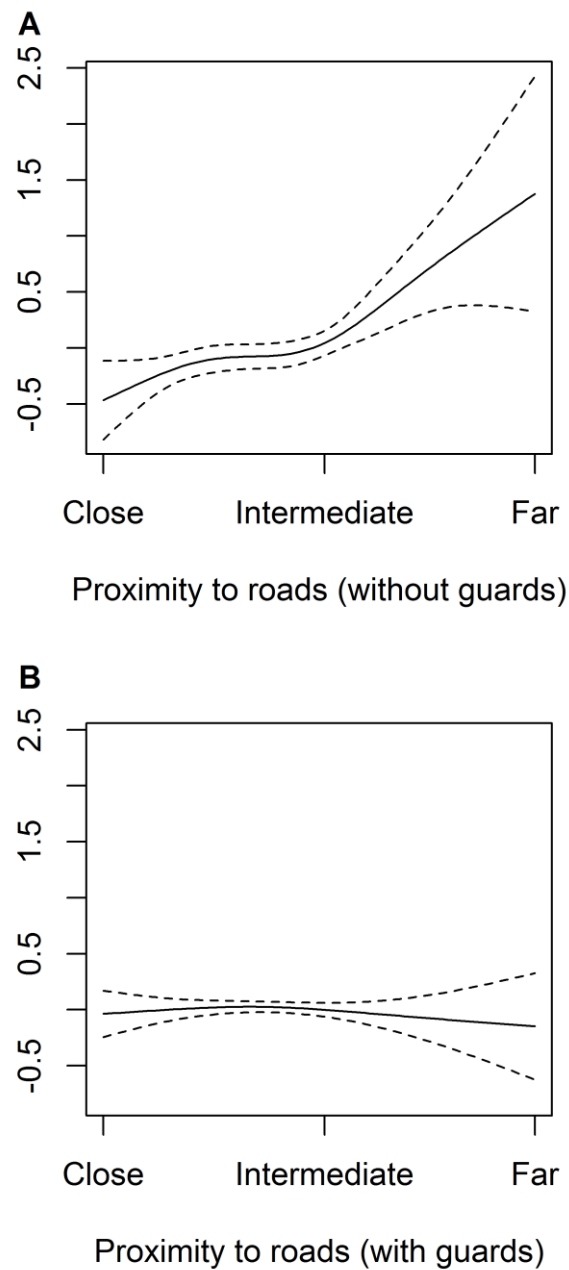
#### **This PDF file includes:**

- fig. S1. Percentage variance explained by different variables for (A) western lowland gorillas and (B) central chimpanzees.
- fig. S2. Estimated conditional dependence of chimpanzee nest density on proximity to roads.
- table S1. Parameter estimates of the top-ranked model used to predict (A) western lowland gorilla and (B) central chimpanzee densities across their range.
- table S2. Survey effort for the 82 survey sites included in the analysis.
- table S3. Details of the 82 survey sites included in the analysis.

## Supplementary Materials



**fig. S1. Percentage variance explained by different variables for (A) western lowland gorillas and (B) central chimpanzees.**



**fig. S2. Estimated conditional dependence of chimpanzee nest density on proximity to roads.** The y-axis (nest density) is on the scale of the linear predictor with estimates (solid line) and confidence intervals (dashed lines) shown for **(A)** proximity to roads when there are no guards and **(B)** proximity to roads when guards are present.

**table S1. Parameter estimates of the top-ranked model used to predict (A) western lowland gorilla and (B) central chimpanzee densities across their range.**

|           |                                   |                    |                 |            |                |                |
|-----------|-----------------------------------|--------------------|-----------------|------------|----------------|----------------|
| <b>A.</b> | <b>Covariate</b>                  | <b>Category</b>    | <b>Estimate</b> | <b>SE</b>  | <b>P-value</b> | <b>Signif.</b> |
|           | <i>Canopy height</i><br>(15–25 m) | None               | –0.2959         | 0.2215     | 0.182          |                |
|           |                                   | 1–15 m             | –1.3743         | 0.3447     | <0.001         | *              |
|           |                                   | 25–35 m            | 0.3069          | 0.1373     | 0.026          | ‡              |
|           |                                   | >35 m              | 0.2812          | 0.1657     | 0.090          | §              |
|           | <i>Elevation</i> (high)           | Low                | 0.3801          | 0.2755     | 0.067          | §              |
|           |                                   | Medium             | 0.2632          | 0.2081     | 0.206          |                |
|           | <i>Guards</i> (no)                | Present            | 0.6997          | 0.1074     | <0.001         | *              |
|           | <i>Eat gorilla</i> (no)           | Yes                | –5.5209         | 3.4534     | 0.011          | ‡              |
|           | <i>Ebola</i> (no)                 | Yes                | –1.5330         | 0.2582     | <0.001         | *              |
|           |                                   |                    |                 |            |                |                |
|           | <b>Covariate</b>                  | <b>Interaction</b> | <b>Filter</b>   | <b>EDF</b> | <b>P-value</b> | <b>Signif.</b> |
|           | <i>Time</i> (year of survey)      |                    |                 | 2.947      | 0.003          | †              |
|           | <i>Distance to road</i>           | Without guards     |                 | 1.000      | 0.023          | ‡              |
|           | <i>Distance to road</i>           | With guards        |                 | 2.344      | 0.004          | †              |
|           | <i>HPD</i>                        |                    | Not E. Guinea   | 2.871      | 0.039          | ‡              |
|           | <i>Latitude, Longitude</i>        |                    |                 | 28.285     | <0.001         | *              |
|           |                                   |                    |                 |            |                |                |
| <b>B.</b> | <b>Covariate</b>                  | <b>Category</b>    | <b>Estimate</b> | <b>SE</b>  | <b>P-value</b> | <b>Signif.</b> |
|           | <i>Canopy height</i><br>(15–25 m) | None               | –0.7451         | 0.2432     | 0.002          | †              |
|           |                                   | 1–15 m             | –0.9491         | 0.3042     | 0.002          | †              |
|           |                                   | 25–35 m            | 0.2611          | 0.1570     | 0.014          | ‡              |
|           |                                   | >35 m              | 0.3594          | 0.1767     | 0.003          | †              |
|           | <i>Slope</i> (<0.5°)              | 0.5–2.5°           | –0.0719         | 0.1270     | 0.571          |                |
|           |                                   | 2.5–10°            | –0.1766         | 0.1413     | 0.071          | §              |
|           |                                   | >10°               | –0.0536         | 0.2070     | 0.795          |                |
|           | <i>Elevation</i> (high)           | Low                | –0.2111         | 0.2962     | 0.476          |                |
|           |                                   | Medium             | 0.0336          | 0.2054     | 0.870          |                |
|           | <i>Guards</i> (no)                | Present            | 0.3894          | 0.1174     | <0.001         | *              |

|                            |                      |               |            |                |                |
|----------------------------|----------------------|---------------|------------|----------------|----------------|
| <i>Eat chimpanzee</i> (no) | Yes                  | −3.4093       | 0.5554     | <0.001         | *              |
| <i>Ebola</i> (no)          | Yes                  | −1.3726       | 0.2776     | <0.001         | *              |
|                            |                      |               |            |                |                |
| <b>Covariate</b>           | <b>Interaction</b>   | <b>Filter</b> | <b>EDF</b> | <b>P-value</b> | <b>Signif.</b> |
| <i>HII</i>                 | Cameroon/Congo/Gabon |               | 4.682      | 0.006          | †              |
| <i>HII</i>                 | CAR                  |               | 2.001      | 0.032          | ‡              |
| <i>HII</i>                 | E. Guinea            |               | 1.001      | 0.245          |                |
| <i>Latitude, Longitude</i> |                      |               | 28.671     | <0.001         | *              |

The following are shown for each parametric coefficient in the model: covariate name (with reference categories), estimate, associated standard errors (SE). Any interaction or filtering terms, and estimated degrees of freedom are shown for each smooth term in the model, namely *Time* (year of survey), *Distance to road*, *Human population density* (HPD), *Human Influence Index* (HII), and geographic location (*Latitude, Longitude*). P-values indicating the statistical significance of each term in the model, and significance codes are given (Significance: ‘\*’<0.001, ‘†’<0.01, ‘‡’<0.05 and ‘§’<0.1)

**table S2. Survey effort for the 82 survey sites included in the analysis.**

| <b>Survey effort</b>  | <b>Cameroon</b> | <b>CAR</b> | <b>Congo</b> | <b>Equatorial Guinea</b> | <b>Gabon</b> | <b>Angola</b> | <b>Totals</b>           |
|-----------------------|-----------------|------------|--------------|--------------------------|--------------|---------------|-------------------------|
| No. of surveys        | 20              | 1          | 39           | 1                        | 21           | 0             | 82                      |
| % of survey effort    | 33.3            | 3.5        | 30.9         | 2.7                      | 29.5         | 0             | 8,692 km                |
| % total area surveyed | 12.9            | 2.5        | 44.8         | 13.5                     | 26.3         | 0             | 185,973 km <sup>2</sup> |

**table S3. Details of the 82 survey sites included in the analysis.** Site type: BR – biosphere reserve; CR – community reserve; LC – logging concession; NC – not classified; NP – national park; RS – presidential reserve; WR – wildlife reserve; WS – wildlife sanctuary

| No. | Country  | Survey site   | Site type | Survey year | Survey area (km <sup>2</sup> ) | No. transect or recce sections | Effort (km) | Survey method | Effective strip width (m): chimps | Effective strip width (m): gorillas | No. of chimp nests | No. of gorilla nests | Guards |
|-----|----------|---------------|-----------|-------------|--------------------------------|--------------------------------|-------------|---------------|-----------------------------------|-------------------------------------|--------------------|----------------------|--------|
| 1   | Cameroon | Boumba Bek    | NP        | 2004        | 2389                           | 47                             | 46          | Transects     | 12.17                             | 3.36                                | 53                 | 85                   | Yes    |
| 2   | Cameroon | Boumba Bek    | NP        | 2012        | 2079                           | 106                            | 105         | Transects     | 12.17                             | 4.37                                | 118                | 105                  | Yes    |
| 3   | Cameroon | Deng Deng     | NC        | 2009        | 358                            | 26                             | 52          | Transects     | 11.56                             | 7.03                                | 3                  | 72                   | Yes    |
| 4   | Cameroon | Deng Deng     | NP        | 2012        | 384                            | 29                             | 58          | Transects     | 11.56                             | 11.49                               | 9                  | 134                  | Yes    |
| 5   | Cameroon | Lobéké        | NP        | 2009        | 213                            | 85                             | 219         | Transects     | 9.99                              | 2.65                                | 52                 | 119                  | Yes    |
| 6   | Cameroon | Mbam Djerem   | NP        | 2007        | 1037                           | 156                            | 156         | Recces        | 12.18                             | 12.27                               | 0                  | 0                    | Yes    |
| 7   | Cameroon | Mbam Djerem   | NP        | 2009        | 1037                           | 127                            | 117         | Recces        | 12.18                             | 12.27                               | 0                  | 0                    | Yes    |
| 8   | Cameroon | Ngoila Mintom | LC        | 2011        | 9829                           | 376                            | 920         | Transects     | 10.53                             | 2.73                                | 800                | 1004                 | No     |
| 9   | Cameroon | Nki           | NP        | 2004        | 3235                           | 256                            | 240         | Transects     | 7.78                              | 1.57                                | 126                | 227                  | Yes    |
| 10  | Cameroon | UFA 10-008    | LC        | 2005        | 730                            | 77                             | 75          | Transects     | 9.99                              | 1.09                                | 15                 | 33                   | No     |
| 11  | Cameroon | UFA 10-009    | LC        | 2005        | 917                            | 91                             | 91          | Transects     | 9.99                              | 1.09                                | 25                 | 50                   | No     |
| 12  | Cameroon | UFA 10-010    | LC        | 2005        | 669                            | 70                             | 69          | Transects     | 9.99                              | 1.09                                | 13                 | 26                   | No     |
| 13  | Cameroon | UFA 10-012    | LC        | 2005        | 590                            | 76                             | 75          | Transects     | 9.99                              | 1.09                                | 7                  | 14                   | No     |
| 14  | Cameroon | UFA 10-013    | LC        | 2003        | 507                            | 51                             | 52          | Transects     | 9.99                              | 3.43                                | 52                 | 84                   | No     |
| 15  | Cameroon | UFA 10-021    | LC        | 2003        | 660                            | 120                            | 61          | Transects     | 10.53                             | 2.73                                | 32                 | 54                   | No     |
| 16  | Cameroon | UFA 10-023    | LC        | 2006        | 580                            | 86                             | 89          | Transects     | 10.53                             | 2.73                                | 14                 | 19                   | No     |
| 17  | Cameroon | UFA 10-064    | LC        | 2004        | 1155                           | 124                            | 119         | Transects     | 9.99                              | 2.25                                | 73                 | 112                  | No     |
| 18  | Cameroon | UFA 100-65    | LC        | 2008        | 1029                           | 179                            | 178         | Recces        | 11.56                             | 4.69                                | 0                  | 66                   | No     |

|    |          |                        |    |      |      |     |     |           |       |       |     |     |     |
|----|----------|------------------------|----|------|------|-----|-----|-----------|-------|-------|-----|-----|-----|
| 19 | Cameroon | UFA 100-65             | LC | 2010 | 449  | 28  | 82  | Transects | 11.56 | 4.69  | 2   | 49  | No  |
| 20 | Cameroon | UFA 100-65             | LC | 2012 | 500  | 30  | 90  | Transects | 11.56 | 4.69  | 3   | 86  | No  |
| 21 | CAR      | Dzanga                 | NP | 2012 | 4620 | 146 | 307 | Transects | 14.39 | 4.03  | 224 | 337 | Yes |
| 22 | Congo    | Bailly North           | NC | 2006 | 4210 | 13  | 27  | Transects | 23.32 | 9.49  | 47  | 61  | Yes |
| 23 | Congo    | Bailly North           | NC | 2011 | 4210 | 30  | 90  | Transects | 20.17 | 8.31  | 32  | 338 | Yes |
| 24 | Congo    | Bailly South           | NC | 2011 | 1920 | 15  | 36  | Transects | 20.17 | 8.31  | 16  | 47  | No  |
| 25 | Congo    | Batanga                | NC | 2007 | 1087 | 21  | 42  | Transects | 23.32 | 16.06 | 13  | 344 | Yes |
| 26 | Congo    | Batanga                | NC | 2012 | 1087 | 29  | 73  | Transects | 23.32 | 16.14 | 0   | 544 | Yes |
| 27 | Congo    | Conkouati              | NP | 2010 | 4520 | 111 | 233 | Transects | 20.17 | 8.31  | 290 | 970 | Yes |
| 28 | Congo    | Conkouati              | NP | 2013 | 4520 | 148 | 72  | Transects | 9.90  | 7.38  | 209 | 39  | Yes |
| 29 | Congo    | Dimonika               | BR | 2009 | 867  | 50  | 50  | Transects | 17.29 | 6.64  | 57  | 49  | No  |
| 30 | Congo    | Kabo & Pokola          | LC | 2006 | 7277 | 37  | 74  | Transects | 20.17 | 8.31  | 181 | 192 | Yes |
| 31 | Congo    | Kabo & Pokola          | LC | 2010 | 7277 | 37  | 93  | Transects | 20.17 | 8.31  | 153 | 538 | Yes |
| 32 | Congo    | Impfondo               | NC | 2008 | 1382 | 22  | 46  | Transects | 23.32 | 7.48  | 30  | 47  | No  |
| 33 | Congo    | Lac Télé north         | CR | 2006 | 2755 | 29  | 58  | Transects | 23.32 | 9.49  | 61  | 390 | Yes |
| 34 | Congo    | Lac Télé north         | CR | 2011 | 2755 | 33  | 66  | Transects | 20.17 | 8.31  | 44  | 426 | Yes |
| 35 | Congo    | Lac Télé south         | CR | 2006 | 1380 | 24  | 47  | Transects | 23.32 | 9.49  | 9   | 52  | Yes |
| 36 | Congo    | Lac Télé south         | CR | 2011 | 1380 | 14  | 35  | Transects | 20.17 | 8.31  | 23  | 10  | Yes |
| 37 | Congo    | Lossi-Kelle            | WS | 2006 | 5052 | 45  | 45  | Transects | 20.69 | 6.49  | 0   | 2   | Yes |
| 38 | Congo    | Loundougou terra firma | LC | 2006 | 2210 | 14  | 28  | Transects | 23.32 | 9.49  | 65  | 45  | Yes |
| 39 | Congo    | Loundougou terra firma | LC | 2010 | 2210 | 34  | 68  | Transects | 20.17 | 8.31  | 116 | 125 | Yes |
| 40 | Congo    | Loundougou swamps      | LC | 2006 | 2515 | 7   | 12  | Transects | 23.32 | 9.49  | 17  | 8   | Yes |
| 41 | Congo    | Loundougou swamps      | LC | 2010 | 2515 | 28  | 56  | Transects | 20.17 | 8.31  | 66  | 156 | Yes |
| 42 | Congo    | Messok-Dja             | LC | 2013 | 1457 | 33  | 67  | Transects | 16.17 | 5.86  | 75  | 75  | No  |



|    |           |                        |    |      |       |     |     |           |       |       |     |     |     |
|----|-----------|------------------------|----|------|-------|-----|-----|-----------|-------|-------|-----|-----|-----|
| 43 | Congo     | Mokabi                 | LC | 2006 | 2669  | 15  | 29  | Transects | 23.32 | 9.49  | 7   | 8   | No  |
| 44 | Congo     | Mont Fouari            | WR | 2005 | 816   | 184 | 169 | Recces    | 17.29 | 6.64  | 0   | 13  | No  |
| 45 | Congo     | Ngombe-Ntokou-Pikounda | LC | 2007 | 17731 | 78  | 156 | Transects | 19.99 | 5.46  | 337 | 730 | Yes |
| 46 | Congo     | NNNP south             | NP | 2006 | 2696  | 14  | 31  | Transects | 23.32 | 9.49  | 65  | 46  | Yes |
| 47 | Congo     | NNNP south             | NP | 2010 | 2696  | 32  | 80  | Transects | 20.17 | 8.31  | 193 | 83  | Yes |
| 48 | Congo     | NNNP north             | NP | 2006 | 1266  | 6   | 12  | Transects | 23.32 | 9.49  | 95  | 27  | Yes |
| 49 | Congo     | NNNP north             | NP | 2010 | 1266  | 32  | 80  | Transects | 20.17 | 8.31  | 187 | 125 | Yes |
| 50 | Congo     | Odzala north           | NP | 2005 | 6086  | 30  | 30  | Transects | 20.69 | 6.49  | 7   | 27  | Yes |
| 51 | Congo     | Odzala north           | NP | 2012 | 6086  | 41  | 103 | Transects | 20.69 | 6.49  | 27  | 93  | Yes |
| 52 | Congo     | Odzala south           | NP | 2005 | 7681  | 43  | 43  | Transects | 20.69 | 6.49  | 50  | 210 | Yes |
| 53 | Congo     | Odzala south           | NP | 2008 | 7681  | 39  | 64  | Transects | 20.69 | 6.49  | 134 | 203 | Yes |
| 54 | Congo     | Odzala south           | NP | 2012 | 7681  | 42  | 105 | Transects | 20.69 | 6.49  | 135 | 270 | Yes |
| 55 | Congo     | Ogooué-Leketi          | LC | 2009 | 1484  | 29  | 73  | Transects | 18.92 | 19.55 | 168 | 93  | Yes |
| 56 | Congo     | Sangha                 | LC | 2006 | 1015  | 8   | 14  | Transects | 23.32 | 9.49  | 38  | 31  | Yes |
| 57 | Congo     | Sangha                 | LC | 2010 | 1015  | 25  | 75  | Transects | 20.17 | 8.31  | 80  | 163 | Yes |
| 58 | Congo     | Tanga                  | NC | 2009 | 2789  | 43  | 160 | Transects | 23.32 | 14.59 | 7   | 325 | No  |
| 59 | Congo     | Tchimpounga            | WS | 2009 | 239   | 48  | 24  | Transects | 15.93 | 8.31  | 192 | 0   | No  |
| 60 | Congo     | Zanaga                 | LC | 2012 | 2276  | 41  | 123 | Transects | 18.92 | 19.55 | 245 | 109 | Yes |
| 61 | E. Guinea | Nationwide             | NC | 2011 | 25169 | 83  | 235 | Transects | 17.86 | 7.95  | 304 | 55  | No  |
| 62 | Gabon     | Batéké                 | NP | 2006 | 2037  | 411 | 411 | Recces    | 18.92 | 19.55 | 12  | 0   | Yes |
| 63 | Gabon     | Birougou               | NP | 2006 | 1977  | 40  | 81  | Transects | 20.19 | 16.26 | 105 | 207 | Yes |
| 64 | Gabon     | Ivindo                 | NP | 2004 | 2972  | 75  | 42  | Transects | 18.72 | 17.42 | 20  | 56  | Yes |
| 65 | Gabon     | Ivindo                 | NP | 2008 | 2972  | 27  | 68  | Transects | 14.41 | 6.98  | 98  | 50  | Yes |
| 66 | Gabon     | Ivindo buffer south    | LC | 2009 | 921   | 22  | 49  | Transects | 18.72 | 9.9   | 57  | 63  | Yes |

|    |       |                    |    |      |       |     |     |           |       |       |     |     |     |
|----|-------|--------------------|----|------|-------|-----|-----|-----------|-------|-------|-----|-----|-----|
| 67 | Gabon | Kivoro             | LC | 2008 | 2511  | 177 | 168 | Transects | 15.13 | 15.13 | 36  | 39  | No  |
| 68 | Gabon | Loango             | NP | 2006 | 1907  | 212 | 213 | Transects | 19.24 | 15.23 | 91  | 124 | Yes |
| 69 | Gabon | Lopé               | NP | 2004 | 4445  | 47  | 36  | Transects | 17.08 | 8.11  | 38  | 35  | Yes |
| 70 | Gabon | Lopé               | NP | 2008 | 4445  | 49  | 125 | Transects | 17.08 | 8.11  | 357 | 267 | Yes |
| 71 | Gabon | Lopé-Waka corridor | LC | 2008 | 2910  | 24  | 60  | Transects | 23.99 | 19.19 | 144 | 66  | Yes |
| 72 | Gabon | Mayombe            | LC | 2010 | 2716  | 37  | 93  | Transects | 19.24 | 15.23 | 24  | 202 | No  |
| 73 | Gabon | Mayumba            | NP | 2011 | 266   | 66  | 63  | Recces    | 19.24 | 15.23 | 99  | 52  | Yes |
| 74 | Gabon | Minkébé            | NP | 2004 | 7544  | 60  | 69  | Transects | 10.53 | 6.49  | 14  | 25  | Yes |
| 75 | Gabon | Minkébé            | NP | 2012 | 11539 | 13  | 39  | Transects | 10.53 | 6.49  | 9   | 2   | Yes |
| 76 | Gabon | Moukalaba-Doudou   | NP | 2011 | 609   | 60  | 177 | Transects | 23.32 | 9.49  | 101 | 502 | Yes |
| 77 | Gabon | Monts de Cristal   | NP | 2005 | 5096  | 404 | 408 | Recces    | 10.47 | 8.86  | 546 | 154 | No  |
| 78 | Gabon | Mwagné             | NP | 2004 | 3160  | 80  | 80  | Recces    | 10.53 | 6.49  | 0   | 25  | Yes |
| 79 | Gabon | Mwagné             | NP | 2012 | 1581  | 12  | 25  | Transects | 10.53 | 6.49  | 5   | 0   | Yes |
| 80 | Gabon | Pongara            | NP | 2006 | 722   | 39  | 36  | Transects | 19.24 | 15.23 | 2   | 23  | Yes |
| 81 | Gabon | Waka               | NP | 2006 | 1066  | 289 | 301 | Recces    | 23.99 | 19.19 | 362 | 884 | Yes |
| 82 | Gabon | Wonga Wongué       | PR | 2011 | 4025  | 9   | 23  | Transects | 19.24 | 15.23 | 5   | 3   | Yes |