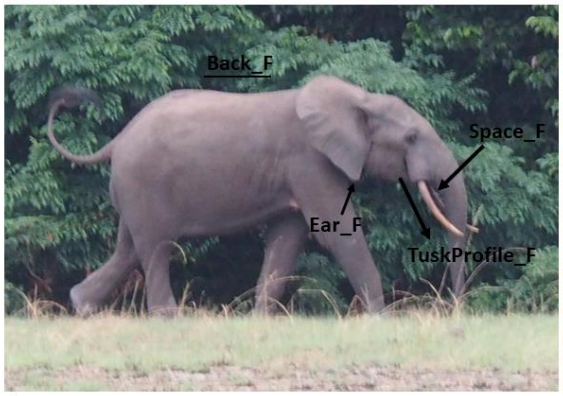
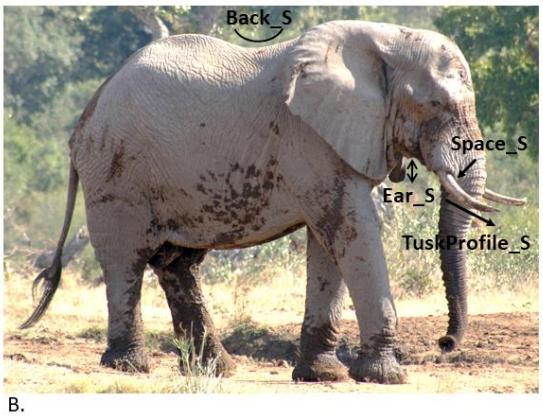
Phenotypical characterization of African savannah and forest elephants with special emphasis on hybrids: the case of Kibale National Park, Uganda

JULIE BONNALD, RAPHAËL CORNETTE, MAËLLIE PICHARD
EDWARD ASALU and SABRINA KRIEF

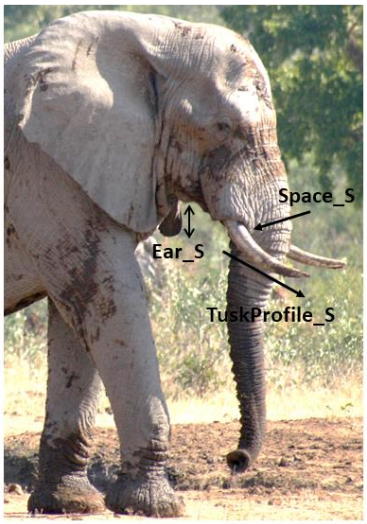
SUPPLEMENTARY FIG. 1 Photos illustrating classifications of variables used in the species assignment key. Photos were taken (A) in Gabon by Le Bomin S, (B) and (C) in South Africa by Baer F, (D) in Congo by Ménard N, (E) in Sebitoli, Kibale National Park, Uganda by camera traps from the Sebitoli Chimpanzee Project, (F) in Kenya by Poudron JF, (G) in Congo by Lacroux C, (H) in Sebitoli, Kibale National Park, Uganda by camera traps from the Sebitoli Chimpanzee Project. Ear_S: Ear below the mandible; Ear_F: Ear above or at the mandible; Space_S: No space between the tusks and the trunk; Space_F: Space between the tusks and the trunk; TuskProfile_S: Tusks pointing forward; TuskProfile_I: Intermediate orientation of the tusks; TuskProfile_F: Tusks pointing downward; TuskFront_S: Tusks directing outward; TuskFront_F: Tusks directing inward or parallel; Forehead_S: Narrow temporal fossae; Forehead_F: Wide temporal fossae; Back_S: Concave back curvature; Back_I: Intermediate back curvature; Back_F: Straight back curvature.


Back_F
Space_F
Ear_F
TuskProfile_F

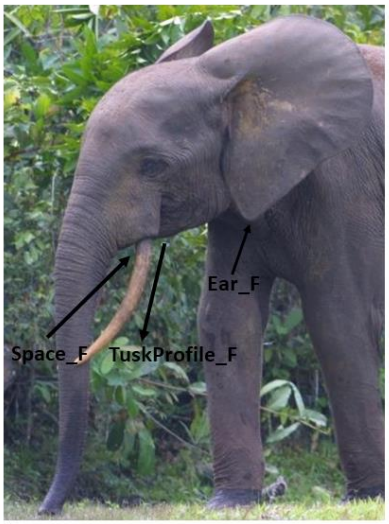
A.


Back_S
Space_S
Ear_S
TuskProfile_S

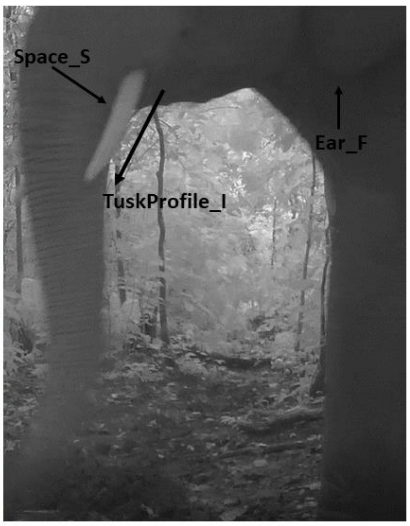
B.


Space_S
Ear_S
TuskProfile_S

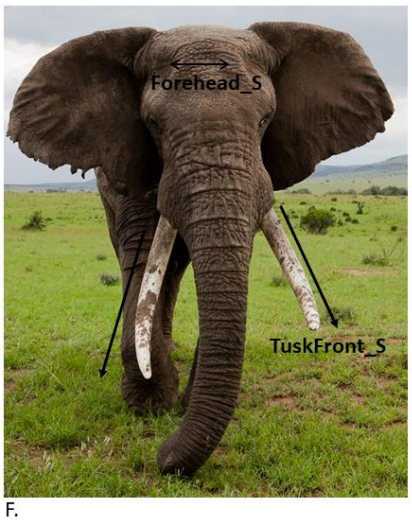
C.


Ear_F
Space_F
TuskProfile_F

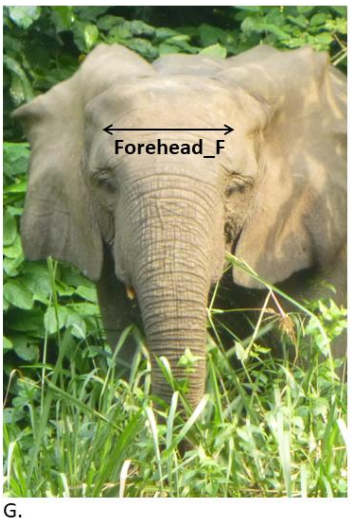
D.


Space_S
Ear_F
TuskProfile_I

E.


Forehead_S
TuskFront_S

F.


Forehead_F

G.


TuskFront_F

H.

SUPPLEMENTARY MATERIAL 1 Authors and location of the reference photos used to test the morphological criteria.

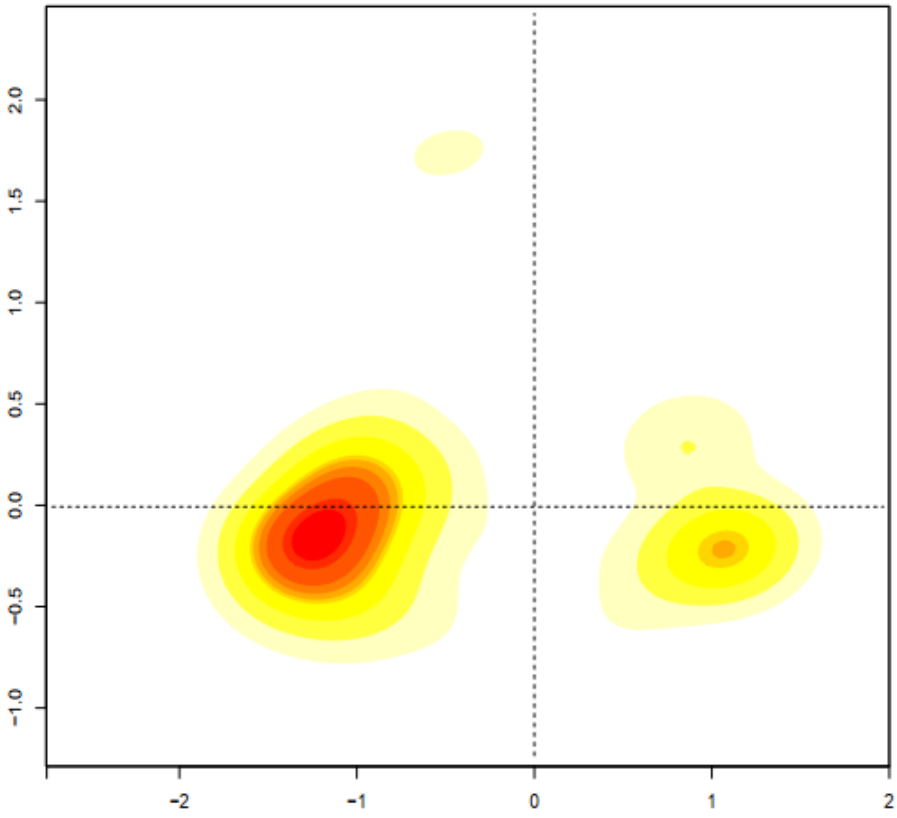
In order to test our combination of criteria, we selected a set of photos representing 171 savannah elephants and 125 forest elephants of known geographical origin, and where only one of the two elephant species is found.

Photos were graciously provided by independent photographers, who carefully tried to select different individuals, and we used additional images from websites to complete the set of forest elephant photos:

Savannah elephants were photographed in South Africa (61 individuals, by Frédéric Baer, Jean-François Poudron, Muriel Caslant, Gian Marco Gesulfo and Camille Lacroux), in Botswana (22 individuals by Jean-François Poudron), in Kenya (26 individuals by Jean-François Poudron), in Tanzania (17 individuals by Jean-François Poudron), in Zimbabwe (21 individuals by Jean-François Poudron and Camille Lacroux), and in Namibia (24 individuals by Camille Lacroux).

Forest elephants were photographed in Republic of Congo (11 individuals by Nelly Ménard and Camille Lacroux and 8 individuals from WCS 96 elephant website), in Gabon (4 individuals by Sylvie Le Bomin), in Central African Republic (9 individuals by Shelly Masi and 68 individuals from WCS and Andrea Turkalo website), in Cameroon (9 individuals by Malenoh Sewuh Ndimbe/ZSL Cameroon/Dja Faunal Reserve and 15 individuals by Bethan Morgan/Ebo) and in Democratic Republic of Congo (1 individual from African Wildlife Foundation website).

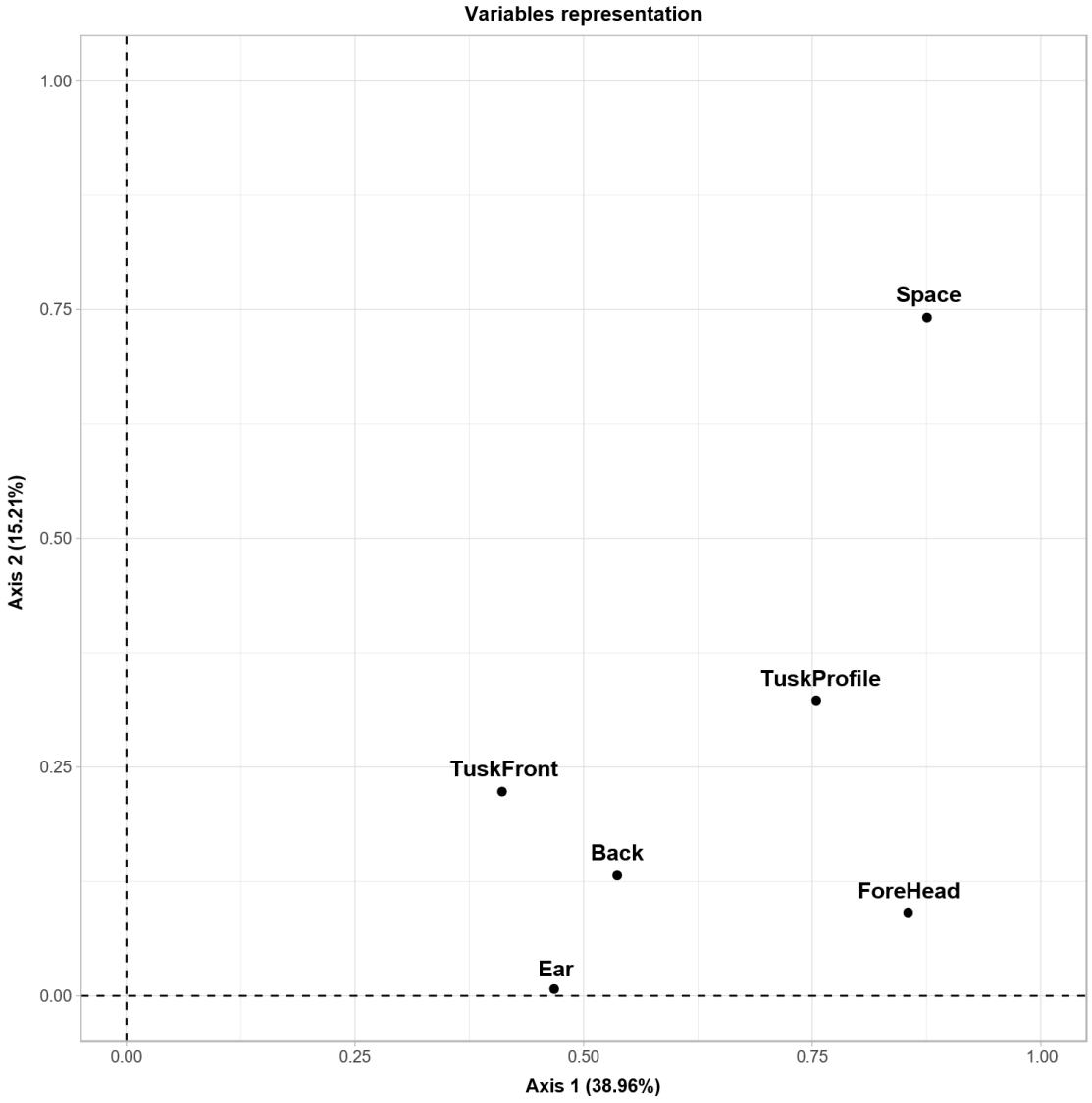
SUPPLEMENTARY FIG. 2 Multivariate Kernel Density Estimation allows, thanks to the differences in density of the data, to provide a global visualization of the structure of the data in order to highlight groups for example. Here, we observe two main groups are well marked along axis 1 and a third one in the positive part of the second axis. This analysis was carried out on the first two axes of the Multiple Correspondence Analysis (figure 3) using the "kde" function of the "ks" package (Chacón & Duong, 2018).



SUPPLEMENTARY TABLE 1 Species assignment key to determine elephant phenotype. The six criteria are divided into main criteria and secondary criteria, in which F indicate the forest state of the variable, S the savannah state, I the intermediate state, X the variable not seen and * whatever the state. The number indicates how many criteria of this state is needed to meet the conditions. For example: “main criteria (2F & 1I) and secondary criteria (*)” means that among the three main criteria, two are in the forest state and one in the intermediate state, and the secondary criteria can be in any state. This combination gives us the forest phenotype.

MAIN CRITERIA			**SECONDARY CRITERIA**			**Phenotype**
C1	C2	C3	C4	C5	C6	
4+X						Unknown
3F			*			Forest
2F & 1I			*			Forest
2F & 0S			0S			Forest
2F & 0S & 0I			1S			Forest
1F & 0S & 1I			1+F & 0S & 0I			Forest
3S			*			Savannah
2S & 1I			*			Savannah
2S & 0F			0F			Savannah
2S & 0F & 0I			1F			Savannah
1S & 0F & 1I			1+S & 0F & 0I			Savannah
2S & 1F			*			Intermediate
1S & 2I			*			Intermediate
2F & 1S			*			Intermediate
1F & 2I			*			Intermediate
3I			*			Intermediate
1F & 1S & 1I			*			Intermediate

SUPPLEMENTARY FIG. 3 Correlation between variables and principal dimensions. Ear: Ear length; Space: distance between the tusks and the trunk; TuskProfile: Tusk orientation (from profile); TuskFront: Tusk orientation (from front); Forehead: Temporal fossa; Back: Back curvature.



SUPPLEMENTARY TABLE 2 Pivot table of the results of the Kmeans analysis and the results of the species assignment key. Kmeans analysis was made using the Sebitoli data set with non-available data replaced by the most frequent variable. Individuals that were not assigned by the species assignment key (n=110) have been removed. All specimens assigned to the forest species using the species assignment key were found in group 3. No savannah elephants were found in this group, but 50% of the individuals with intermediate phenotypes were included. Group 2 is composed of 78.5% of individuals assigned to the savannah elephant phenotype, 15.5% of individuals assigned to the intermediate phenotypes, and no individuals with the forest elephant phenotype. Group 1 comprised 34.5% of specimens assigned to the intermediate phenotypes and 21.5% of those assigned to the savannah phenotype. The three groups obtained from the K-means analysis partially correspond to the three groups (forest, savannah, and intermediate) obtained from the species assignment key, with group 1: intermediate phenotypes, group 2: savannah phenotype, and group 3: forest phenotype.

Species assignment key	**Kmeans analysis**			
Phenotype	**Group 1**	**Group 2**	**Group 3**	***Total***
Forest	0	0	72	72
Intermediate	105	47	152	304
Savannah	47	172	0	219
Total	**152**	**219**	**224**	**595**

SUPPLEMENTARY MATERIAL 2 Study of age and sex biases in the K-means analysis.

We then investigated two biases that could explain the partial match between the two assignment methods. The age classification was significantly different from that expected between the three K-means groups (Table A) (Pearson's Chi-squared test with simulated p-value based on 10,000 replicates, X-squared=41.392; df=NA; p-value=9.999e-05). However, sex doesn't seem to influence the division among the three K-means groups (Table B) (Pearson's Chi-squared test, X-squared=4.4407, df=4, p-value=0.3496).

TABLE A Pivot table age classification and K-means analysis results.

Age classification	**Kmeans analysis**			
	Group 1	**Group 2**	**Group 3**	***Total***
Adult	104	182	191	477
Subadult	59	59	37	155
Juvenile	21	37	10	68
Infant	0	5	0	5
Total	**184**	**283**	**238**	**705**

TABLE B Pivot table sex and K-means analysis results.

Sex	**Kmeans analysis**			
	Group 1	**Group 2**	**Group 3**	***Total***
Female	80	122	110	312
Male	63	105	93	261
NA	41	56	35	132
Total	**184**	**283**	**238**	**705**

Reference

Chacón, J. E. & Duong, T. (2018). Multivariate kernel smoothing and its applications. CRC Press.