



Facial dysplasia in wild forest olive baboons (*Papio anubis*) in Sebitoli, Kibale National Park, Uganda: Use of camera traps to detect health defects

Camille Lacroix, Nelson Guma, Sabrina Krief

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1 **Facial dysplasia in wild forest olive baboons (*Papio anubis*) in Sebitoli,**
2 **Kibale National Park, Uganda: use of camera-traps to detect health defects**

3
4 **Running title:** Malformations in wild olive baboons

5
6 Camille Lacroix ^{a,b}, Nelson Guma ^c, Sabrina Krief ^{a,b}

7 ^a UMR 7206 CNRS/MNHN/P7, Eco-anthropologie et ethnobiologie, Hommes, et
8 Environnements, Museum national d'Histoire naturelle, Musée de l'Homme, 17 place du
9 Trocadéro, 75116 Paris, France

10
11 ^b Sebitoli Chimpanzee Project, Projet pour la Conservation des Grands Singes, Kibale National
12 Park, Fort Portal, Uganda

13
14 ^c Uganda Wildlife Authority, Kibale National Park, Uganda

15
16 **Corresponding author:** Camille Lacroix
17 camille.lacroix@gmail.com

18
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20
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30

31 # tables: 4

32 # figures: 1

33

34 **Abstract**

35

36 **Background:** Primate populations are in decline, mainly affected by agriculture leading to
37 habitat loss, fragmentation but also chemical pollution. Kibale National Park (Uganda), Sebitoli
38 forest, surrounded by tea and crop fields, is the home range of chimpanzees presenting
39 congenital facial dysplasia. This study aimed to identify to what extent the same phenotypical
40 features are observed in baboons (*Papio anubis*) of this area.

41 **Methods:** A total of 25,390 clips recorded by 14 camera traps between January 2017 and April
42 2018 were analyzed.

43 **Results:** We identified 30 immature and adult baboons of both sexes with nose and lip
44 deformities. They were more frequently observed in the North-Western part of the area.

45 **Conclusions:** A possible effect of pesticides used in crops at the border of their habitat is
46 suspected to alter the embryonic development. This study emphasizes the importance of non-
47 invasive methods to detect health problems in wild primates that can act as sentinels for human
48 health.

49

50 **Key words:** malformation, primate, camera-trap, endocrine disruptor, anthropogenic pressure

51 **Introduction**

52

53 Most primate species are threatened with extinction or declining populations resulting from
54 escalating and unsustainable human activities¹. These activities lead to anthropogenic
55 environmental modifications that could affect wild primates by cascading effects. Non-human
56 primates can act as sentinels of environmental toxics caused by anthropogenic activities.
57 However, exposure to pollution is rarely measured and cases of intoxication rarely reported.
58 Accumulation of heavy metals and levels of lead were measured in different locations and
59 species such as howler monkeys (*Alouatta pigra*)², in urban free-ranging rhesus monkey
60 (*Macaca mulatta*)³ and in long-tailed monkeys (*Macaca fascicularis*)⁴. Levels of serum dioxin
61 were measured on douc langurs (*Pygathrix nigripes*)^{5,6} in Vietnam to understand the
62 consequences of the use of Agent Orange during the war. However, no consequence on the
63 health was observed associated to the levels of lead and dioxin in these studies.

64 The leading causes of primate extinction i.e. habitat loss¹ are mainly due to the conversion of
65 natural forests into agricultural systems. Environmental pollution due to conventional
66 agricultural practices and use of pesticides could directly threaten the health of the surrounding
67 wildlife⁷. Yet few surveys have been conducted to show evidence of exposure to pollutants on
68 animal health due to close proximity to agricultural areas (birds studies⁸⁻¹⁰ but no primates).

69 The direct or indirect observation of primates is a way to assess their health by looking at
70 potential wounds or malformations. Most primates' deformities described in literature are the
71 result of falls, fights, or wounding by predators¹¹; and some are the collateral consequences of
72 being caught in snares set by poachers¹². However, in Sebitoli area in the northern part of Kibale
73 National Park, Uganda, it has been suggested that the malformations observed have different
74 causes. Indeed, exposition to chemicals used on crops, arboricides such as Agent Orange and
75 pollution from combustion exhaust gases from vehicles could be the cause of the high number
76 of congenital malformations observed in the primates including 16 chimpanzees and six
77 baboons (*Papio anubis*)¹²⁻¹⁵. While chimpanzees are monitored daily in this area, baboons are
78 opportunistically seen and Krief et al.¹⁵ described facial deformities in six baboons captured in
79 a one minute video by a single camera trap.

80 The objective of this survey was to expand spatially and temporally the camera trap network to
81 confirm, better describe the lesions in baboons and evaluate the number, age and sex class of
82 affected individuals sharing the habitat with Sebitoli chimpanzees.

83

84 **Material and methods**

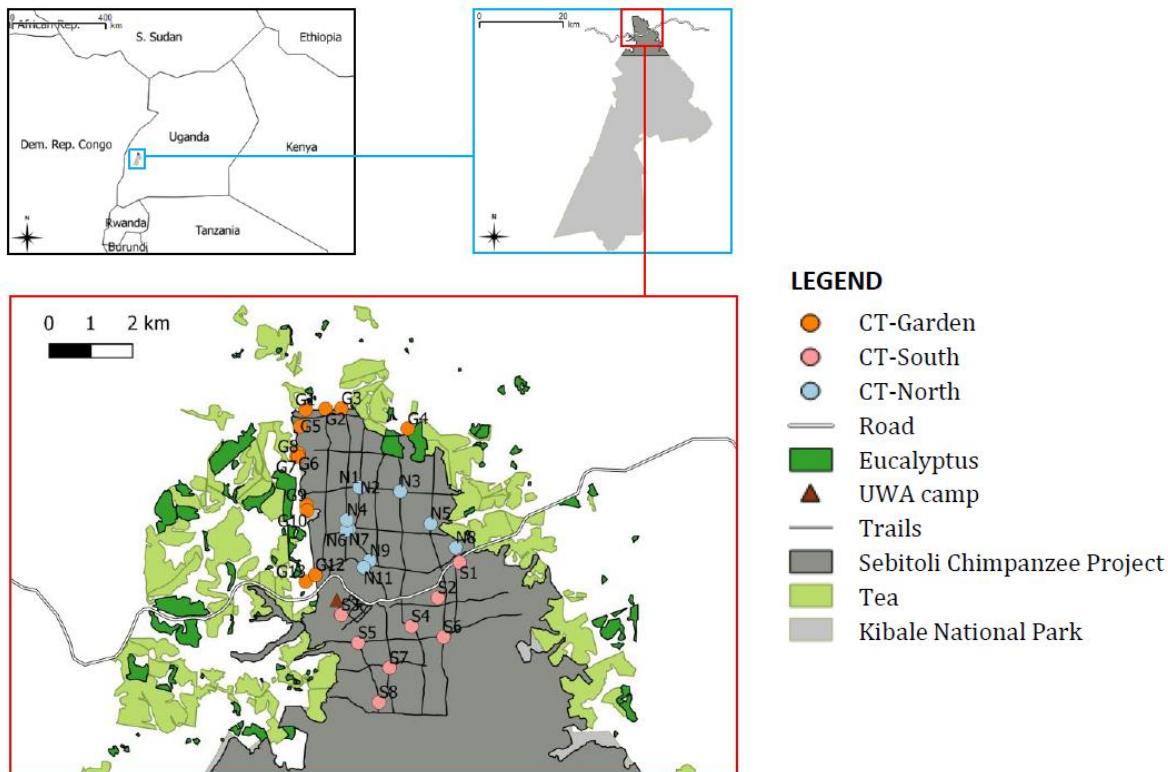
85

86 The study site was the Sebitoli area located at the extreme North part of the Kibale National
87 Park, Western Uganda (795 km^2 , $0^\circ 13' - 0^\circ 41' \text{N}$ and $30^\circ 19' - 30^\circ 32' \text{E}$ ¹⁶). The chimpanzees, and
88 more generally wildlife have been monitored since 2009 by the Sebitoli Chimpanzee Project.
89 This Park is composed of a mid-altitude forest with high plant and animal diversity¹⁷. The
90 Sebitoli area is surrounded by human activity, and in particular, agriculture comprising in the
91 western fringes, small farms with food crops, tea and eucalyptus, and to the East, tea estates
92 and eucalyptus plantations. Phytochemical use differs according to the crops and thus to the
93 area¹⁵. In order to understand if the location and the crop type in contact with the territory of a
94 group of baboons could influence the number of affected individuals, we divided the Sebitoli
95 area into four zones delimited by the tarmac road crossing the chimpanzee home range (20 km^2)
96 in the south¹⁸ and two survey transects that divided the region into equivalent areas in west,
97 east, north and south (Figure 1). We assumed that East and West are differently affected by
98 pesticides and that the road play a “natural” limits between groups of North and South. We
99 counted the malformed individuals encountered in the video clips recorded by the cameras
100 localized in each of the four zones to understand if malformed individuals frequent more often
101 one of the four zones.

102 From January 2017 to April 2018, up to 14 camera traps (CT) equivalent to 4746 CT days were
103 set in the forest (named hereafter “forest-CT”) and in the border of cultivated fields of maize
104 (named hereafter “garden-CT”) that surround the Park (Figure 1). The locations are recorded
105 with a GPS Garmin 64CS and projected on a map¹⁹. The recorded clips are collected every two
106 weeks. We used 13 HD video-traps Reconyx XR-6 Ultrafire™ and 2 HD video-traps Bushnell
107 Trophy Cam HD Max™ with a day/night auto sensor and sound recordings. The settings were:
108 high definition video of 1280×720 pixels, video length of 30 s for Reconyx™ and 60 s for
109 Bushnell™. Video recording started when motion was sensed at a distance of up to 21 m for
110 Reconyx™ and 18 m for Bushnell™; there is a 5 s delay between consecutive triggers. Camera
111 traps were set at least 1 m above the ground and at least 1 m off the trail or on an animal track
112 where we expected the animals to pass. Three CT were set and active at the same location
113 during the entire duration of this study. Other CT were moved in the forest according to (1)
114 presence of mature crops at the edge of the forest in order to record crop feeding events by
115 chimpanzees, baboons and elephants or (2) presence of bees nests visited by chimpanzees in
116 order to obtain footage of tools used for honey harvesting by chimpanzees (3) different events

117 such as stealing and breaking of CT by animals or poachers resulting of some CT being not
118 active during some periods.

119



121 **Figure 1.** Map of the camera-trap study in the Sebitoli Chimpanzee Project, Kibale National Park in Uganda.
122 We placed 13 camera-traps in the garden (CT-Garden), 19 camera-traps in the forest: 11 in the Northern part (CT-
123 North) and 8 in the Southern part (CT-South) of the road that cross the area. The forest is surrounded by eucalyptus
124 and tea plantations.

125

126 For each clip we identified the animal species observed, the number of individuals of each
127 species seen, their activities and the health impairments observed. When successive clips started
128 less than 5 minutes apart with the same species being present, we considered them not to be
129 independent and thus animals were considered to be part of the same group. If it was more than
130 5 min and less than 10 minutes between the clips and we could identify again clearly an
131 individual previously identified (known or because of some features) we also considered those
132 clips as non-independent. For those non-independent clips, we counted the number of
133 individuals that appear for the first time in the given clip and were not seen in the previous clip.
134 By adding the number of individuals that appeared to be different, we could estimate the size
135 of the group. We calculated the relative abundance of the presence of baboons by dividing the
136 number of individuals seen (could be the same individuals over the month) by 100 CT days.

137 The CT days are the days for which the camera was fully operational and could register. It
138 excludes events of CT's stealing and memory card full in few days because of vegetation
139 movement in front of the High Sensitivity Image sensor.

140 We tried as far as possible to determine the sex and the class of age (adapted from Packer²⁰;
141 Rose²¹) for the olive baboons: infant (0 to 1 year, carried by mother), juvenile (1 to 4 years,
142 small and not carried by mother) and mature (i.e., sexually mature individual including adult
143 and sub-adult more than 4 years). The class of age of an individual reported corresponds to its
144 first observation during the study period. Sex determination of juveniles and infants from
145 camera trap videos was often difficult; therefore, this age category is generally classed as
146 unknown sex. When individuals looked very similar and cannot be morphologically
147 differentiated, we assumed that they were the same individual seen on different occasions. We
148 defined mother-infant pair when an infant has been seen carried by its mother.

149 For individuals with physical features related to health impairment, we extracted a screen shot
150 from the video-clip and described them as precisely as possible. We classified the abnormalities
151 related to fur color (depigmentation), malformation or wound (presence of blood, pus or scab).
152 We specified the body part affected: the head, the limbs, the trunk, the tail or the genitals. For
153 facial malformations, parts of the face affected are mentioned as followed: nasal bone, nostrils,
154 lip, ectopic apertures on the nasal bone and others features.

155 The baboons were observed without resorting to invasive methods and without interaction with
156 the researchers. We adhered to the research protocols defined by the guidelines of the Uganda
157 Wildlife Authority (UWA), which were also approved by the Muséum national d'Histoire
158 naturelle (Memorandum of Understanding MNHN/UWA/Makerere University SJ 445-12).

159

160 **Results**

161

162 Out of 34 species identified, olive baboons were observed on 3,238 clips out of 25,390 clips
163 recorded in 4,746 days by 14 cameras over an area covering about 20 km². We saw 4,906
164 baboons over 2,204 clips in the forest-CT clips (abundance relative per 100 CT-days = 118.8)
165 against 1,645 baboons over 1,034 clips in the garden-CT clips (abundance relative per 100 CT
166 days = 266.2).

167

168 **Table 1.** Individuals observed with particularities classed by the localization and the type of the
 169 particularity.

Localization	Face	Limbs	Trunk	Tail	Genital	Total
Depigmentation	1	-	-	-	-	1
Malformation	30	1	1	-	-	32
Malformation/wound	-	-	-	6	-	6
Wound	4	7	2	1	1	15
Total	35	8	3	7	1	54

170
 171 Out of the 6551 occurrences when a baboon can be seen, we identified 54 different individuals
 172 affected by physical defects (Table 1). Among them, 30 individuals were displaying facial
 173 dysplasia: 25 had malformed nostrils, 12 had ectopic apertures on the nose, 10 had an
 174 interruption of the nasal bone and three had others defects. The detailed description of the
 175 individuals presenting facials deformities is available in Table 2 as well as a screen capture of
 176 the face for each of them. Each individual was seen a mean of 2.8 times ranging from 1 to 14
 177 times in 12 different locations (seven in the forest and five in the garden) over 33 CT locations
 178 during the entire study period. None of the individuals with facial dysplasia had wounds or
 179 infections. The lesions observed at different occasions did not change: they did not increase or
 180 decrease in size or severity. Most of the individuals with facial deformities were mature
 181 baboons (n=20) with nine males, eight females and three of unknown sex. We observed nine
 182 juveniles and one infant carried by a non-malformed mother. For two adult females affected
 183 (Ind 2 & Ind 3), we could properly observe their infants who did not have visible malformations.
 184 The females were mostly affected at the nostrils (n=7), the nasal bone (n=3) and by having
 185 ectopic apertures (n=2). The males had also mostly malformed nostrils (n=8), but ectopic
 186 apertures (n=7) were more frequent than nasal bone deformity (n=3). There is no apparent effect
 187 of gender.

188
 189 Sixteen individuals (8 adult males, 3 adult females, 1 adult unknown sex and 4 immature
 190 unknown sexes) were seen in association on 17 times in non-independent clips (Table 3). The
 191 troops of baboons were not habituated and clearly identified in this study but those associations
 192 of recognizable baboons allowed us to establish a draft of troops. We identified a possible troop
 193 that included those sixteen individuals only visible in five locations of CT in the North.

194

Table 2. Listed individuals with facial malformations with the picture taken from a screen capture of a video clip.

Description of the individual			Description of the individual malformed features						Number of times seen	Location of camera trap concerned
Code	Class of age	Sex	Nasal bone	Number of nostril	Shape of nostril(s)	Additionnal Appertures	Other	Picture		
Ind 1	Inf	X	Interrupted	1	central & deformed	-	Lips deformed		3	S8
Ind 2	Ad	F	Interrupted	1	central & round	Bottom left	-		12	N4, N5, N6, G3, G9, G11
Ind 3	Ad	F	Interrupted	1	central & triangular	-	-		14	N4, N6, G2, G8, G9, G11, G10
Ind 4	Juv	X	Interrupted	2	asymmetric (left larger)	-	Lips twisted		1	S8
Ind 5	Juv	X	-	1	central & triangular	-	-		3	S1, N4, N8
Ind 6	Ad	M	Interrupted	2	-	Bottom central	-		1	N6

195

Table 2. (Continued)

Description of the individual			Description of the individual malformed features						Number of times seen	Location of camera trap concerned
Code	Class of age	Sex	Nasal bone	Number of nostril	Shape of nostril(s)	Additionnal Appertures	Other	Picture		
Ind 7	Ad	M	-	2	asymmetric (right larger)	Slit in the middle of the nose	-		6	N4, N6, S8
Ind 8	Ad	F	-	1	central & round	-	-		1	S8
Ind 9	Juv	X	-	2	-	-	Asymmetric frown		6	N4, N6, G2, G9
Ind 10	Ad	M	-	2	asymmetric (left larger)	Slit in the middle of the nose	-		5	N4, N6, G2, G9
Ind 11	Juv	X	-	1	central & round	-	-		5	N4, N6, S2
Ind 12	Juv	X	-	1	central & deformed	-	-		2	N4, G2

Table 2. (Continued)

Description of the individual			Description of the individual malformed features						Number of times seen	Location of camera trap concerned
Code	Class of age	Sex	Nasal bone	Number of nostril	Shape of nostril(s)	Additionnal Appertures	Other	Picture		
Ind 13	Ad	F	-	2	narrow and asymmetric (left higher)	-	-		2	N4
Ind 14	Ad	M	Interrupted	2	-	Bottom	-		1	N6
Ind 15	Juv	X	-	1	no nasal septum	-	-		1	N4
Ind 16	Ad	M	Interrupted	2	-	Bottom central	-		2	N4
Ind 17	Ad	M	-	1	no nasal septum	-	-		2	N4, G2
Ind 18	Ad	M	-	2	asymmetry (right larger)	Slit in the left side of the nose	-		2	N4, N6

Table 2. (Continued)

Description of the individual			Description of the individual malformed features						Number of times seen	Location of camera trap concerned
Code	Class of age	Sex	Nasal bone	Number of nostril	Shape of nostril(s)	Additionnal Appertures	Other	Picture		
Ind 19	Ad	M	Pleated	2	narrow and asymmetric (left longer)	-	-		1	N5
Ind 20	Ad	M	-	2	asymmetry (left larger and higher)	-	-		3	N8
Ind 21	Ad	M	-	1	no nasal septum	In the top middle of the two nostrils	-		2	N8, S2
Ind 22	Ad	M	-	2	flat nose	-	-		1	G2
Ind 23	Juv	X	Interrupted	2	-	Slit on top of the nose	-		1	G2
Ind 24	Ad	X	-	2	flat nose	-	-		1	G9

Table 2. (Continued)

Description of the individual			Description of the individual malformed features						Number of times seen	Location of camera trap concerned
Code	Class of age	Sex	Nasal bone	Number of nostril	Shape of nostril(s)	Additionnal Appertures	Other	Picture		
Ind 25	Ad	F	-	2	asymmetry (left higher)	Slit in the left side of the nose	-		1	N8
Ind 26	Juv	X	-	1	central & round	Slits under the nose	-		1	G9
Ind 27	Ad	F	-	2	twisted on the right side	-	-		2	G9, N6
Ind 28	Ad	F	Interrupted	1	central & triangular	-	-		1	G9
Ind 29	Ad	X	-	2	flat nose and asymmetric (left larger)	-	-		1	G11
Ind 30	Ad	X	-	1	central & round	Slit on top of the nose	-		1	G11

Note: Ad : mature individuals, Juv : Juveniles, Inf : Infant, M : Male, F : Female, X : Sex unknown, - : normal feature

201 **Table 3.** Association of individuals with facial malformations observed in non-independent clips.

Individuals together	Group size	Where
Ind 2 & Ind 3 & Ind 5 & Ind 10 & Ind 15	29	N4
Ind 2 & Ind 3	13	N6
Ind 2 & Ind 3	18	G9
Ind 2 & Ind 3	20	N6
Ind 2 & Ind 13	4	N4
Ind 2 & Ind 14	22	N6
Ind 2 & Ind 18	20	N6
Ind 3 & Ind 7	25	N4
Ind 3 & Ind 23	43	G2
Ind 3 & Ind 24	8	G9
Ind 5 & Ind 21	58	N8
Ind 7 & Ind 9	32	N4
Ind 9 & Ind 10	21	N6
Ind 9 & Ind 11	25	N6
Ind 11 & Ind 13 & Ind 16 & Ind 17	24	N4
Ind 16 & Ind 18	23	N4

202

203 Individuals with facial defects are relatively more abundant in the two zones in North and more
204 precisely the North-Western area of Sebitoli (Table 4).

205

206 **Table 4.** Distribution in Sebitoli of malformed individuals.

Position	Number of individuals seen	Number of ct	Number of days filmed	Abundance
N/W	23	21	1406	1,63584637
N/E	6	4	804	0,74626866
S/W	3	4	1085	0,2764977
S/E	5	4	833	0,6002401

207 Note: Abundance = Number of individuals seen/ 100 CT-days

208

209 **Discussion**

210

211 Facial deformities affected 30 olive baboons of both sexes and all the classes of age in Sebitoli,
212 confirming the opportunistic footage by camera trap in 2014 of six olive baboons presenting
213 facial malformations in a troop of 35 individuals¹⁵. There were no wounds, pus or blood likely
214 excluding infection by *Treponema pallidum*²². For individuals seen several times, there was no
215 evolution of the lesions during the study period, and the naso-oro-facial defects are observed in

very young individuals suggesting congenital origins of those malformations. The baboons appeared otherwise to be healthy, integrated into social groups, and apparently reproducing as two females with dysplasia were carrying non-malformed infants. Malformations also occurred in other parts of the body as an infant had severely malformed limbs causing locomotor issue and an adult male had a hunchback but those could be related to malnutrition or trauma. Spontaneous malformations occur in a variety of non-human primates in captivity but at low rate (0.3%-0.9%) (*Papio* sp.^{23,24}; *Macaca* sp.^{24,25};). Clefts of the palate and/or of the upper lip are very rare in wild non-human primates but have been observed in several species in captivity including Strepsirrhines (*Varecia variegata*²⁶) as well as in Haplorrhines, including New World monkeys (*Callithrix jacchus*²⁷; *Saimiri* sp.^{28,29}), Old World monkeys (*Macaca* sp.^{30,31}; *Papio* sp.³²; *Mandrillus sphinx*³³), and great apes (*Gorilla* sp.³⁴). In Sebitoli, the large number of individuals of all age and sex classes with facial defects (n=30) observed in the relatively small area studied (20 km²), the absence of other cases reported in the national park covering 795 km² likely indicate an etiology related to a local cause. Olive baboons usually live in multi-male, multi-female groups or "troops", ranging in size from 15 to 150 individuals³⁵⁻³⁷. In adjacent troops of olive baboons, all males emigrated from their natal troop in order to mate after they reach sexual maturity and can return for short period of time^{20,38-40} whereas nearly all females remained in their natal troop⁴¹ making the females the basis of troop identity. One-male groups also exist and can be the majority encountered⁴². The home range of forest olive baboons has been rarely studied and was estimated at roughly 390 ha and 520 ha³⁵ which is small compared to the average home range of 3,890 ha given by DeVore⁴³ for savannah baboons. The five locations of CT where we had seen the sixteen individuals in association represented an area of 522 ha, so we can estimate that they are part of the same larger troop. Thus, in a single group estimated to count 58 individuals, one out of four individuals is affected.

Only one other case of facial deformity concerning an olive baboon has been documented in the south of the park where a female was missing the most basal part of the upper jaw and nose⁴⁵. In addition, there are no cases of similar lesions described in areas without exposition to agrochemicals. This indicates that pesticide exposure could contribute to the facial dysplasia observed in olive baboons as it was suspected for chimpanzees^{12,13,15}. The fact that the two primate species -chimpanzees and olive baboons- in exactly the same range suffer from the same deformities strengthens the chemical pollution hypothesis. In addition, both species regularly feed on crops^{46,47}. In this study area, the crop fields are mostly in the North-western part, between 2 and 4 km away from the road. The most abundant proportion of malformed

249 individuals was also found in the north-western patches suggesting that the chemicals on food
250 crops associated with those sprayed on tea, could be indeed responsible. The most affected troop
251 of baboons is living in the Northern location where they are not exposed to road pollution. This
252 is in favor of an etiology related to pesticides rather than combustion gas exposition. According
253 to previous analyses, maize used in this area and consumed by this troop was coated with
254 imidacloprid¹⁵. In addition, maize stem and maize seed samples from Nyakabingo and
255 Kyawankada, the two locations at the far north of the study area, were tested positive for
256 chlorpyrifos¹⁵. In these two locations, farmers also reported using 2,4 D amine on maize.
257 Glyphosate is used in every tea estate including the one in Eastern part of the home range¹⁵.
258 The fact that affected baboons are more often observed in the Western part than Eastern part of
259 the range seems to support an effect of pesticides used in maize or glyphosate associated with
260 other chemicals rather than an effect attributed to glyphosate alone. It is the possible unique
261 combination of pesticides, fungicides, herbicides, and fertilizers used in those food crops that
262 could have contaminated water, soil and plants and in consequence affected the wildlife of the
263 park¹³.

264 In response to crop-raiding, farmers usually chased primates, probably causing the baboons of
265 this area to fear human contact. They tend to rapidly flee when humans are near⁴⁸ making them
266 difficult to observe, individually identify, and study. The use of camera traps is very convenient
267 to overcome this difficulty⁴⁹. It is an important tool that allows studying primates without
268 exacerbating potential threats to the species like the transmission of zoonotic diseases⁵⁰⁻⁵², and
269 the potential exposure to poachers⁵³. While also mitigating the negative impacts of habituation,
270 the use of camera-traps can overcome the limitations of direct observations by filming in
271 accessible areas^{54,55} and rare or elusive individuals without the potential human presence
272 bias^{56,57}; in a relatively short period of time⁴⁹. However the counting of individuals in a group,
273 the individual health and behavioral monitoring to estimate the effect of the phenotypical
274 defects would be necessary; there are impossible with this type of indirect survey.
275 Technological advances have led to widespread adoption of camera traps to survey wildlife
276 distribution, abundance and behavior^{58,59} and recently health¹⁵. Indeed, an opportunistic footage
277 by camera trap in 2014 had raised the issue of capturing facial malformations by camera trap
278 with six olive baboons in Sebitoli¹⁵. Our study on a larger scale confirmed the interest of using
279 camera-traps to survey the health of wildlife and improve our knowledge about the insidious
280 threat of pollution.

281

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293

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