



Agricultural expansion as risk to endangered wildlife: Pesticide exposure in wild chimpanzees and baboons displaying facial dysplasia



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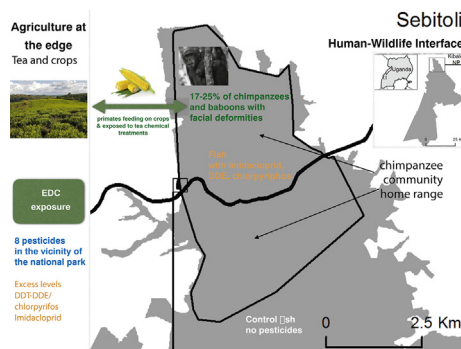
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HIGHLIGHTS

- Agricultural land expansion towards parks exposes wildlife to environmental pollution.
- We studied the human-wildlife interface in Kibale National Park, Uganda.
- Methods used were environmental chemistry, ethnological enquiries, and primatology.
- Numerous chimpanzees and baboons display similar facial deformities and are exposed to agricultural pollutants.
- We propose that the high levels of EDC pollution represent an underestimated threat to endangered chimpanzees.

GRAPHICAL ABSTRACT



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ABSTRACT

Prenatal exposure to environmental endocrine disruptors can affect development and induce irreversible abnormalities in both humans and wildlife. The northern part of Kibale National Park, a mid-altitude rainforest in western Uganda, is largely surrounded by industrial tea plantations and wildlife using this area (Sebitoli) must cope with proximity to human populations and their activities. The chimpanzees and baboons in this area raid crops (primarily maize) in neighboring gardens. Sixteen young individuals of the 66 chimpanzees monitored (25%) exhibit abnormalities including reduced nostrils, cleft lip, limb deformities, reproductive problems and hypopigmentation. Each pathology could have a congenital component, potentially exacerbated by environmental factors. In addition, at least six of 35 photographed baboons from a Sebitoli troop (17%) have similar severe nasal deformities. Our inquiries in villages and tea factories near Sebitoli revealed use of eight pesticides

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(glyphosate, cypermethrin, profenofos, mancozeb, metalaxyl, dimethoate, chlorpyrifos and 2,4-D amine). Chemical analysis of samples collected from 2014 to 2016 showed that mean levels of pesticides in fresh maize stems and seeds, soils, and river sediments in the vicinity of the chimpanzee territory exceed recommended limits. Notably, excess levels were found for total DDT and its metabolite *pp'*-DDE and for chlorpyrifos in fresh maize seeds and in fish from Sebitoli. Imidacloprid was detected in coated maize seeds planted at the edge the forest and in fish samples from the Sebitoli area, while no pesticides were detected in fish from central park areas. Since some of these pesticides are thyroid hormone disruptors, we postulate that excessive pesticide use in the Sebitoli area may contribute to facial dysplasia in chimpanzees and baboons through this endocrine pathway. Chimpanzees are considered as endangered by IUCN and besides their intrinsic value and status as closely related to humans, they have major economic value in Uganda via ecotourism. Identifying and limiting potential threats to their survival such be a conservation priority.

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1. Introduction

The conversion of natural forest to agricultural land exposes wildlife to multiple threats including forest fragmentation, bushmeat hunting, zoonotic diseases, and often environmental pollution due to excessive pesticide usage. In Europe, pesticide-linked poisoning accounted for 6.5% of identified causes of death in wildlife between 1986 and 1998 (data from the SAGIR network, Lamarque et al., 2000). More recent data show reduced fitness of animals living in close proximity to agricultural zones, including areas in Africa (Bro et al., 2015; Ciliberti et al., 2011; Millot et al., 2015). In Africa, the health of non-human primate populations may serve as a valuable indicator of successful ecosystem management, notably for sentinel species (Goldberg et al., 2012). The emblematic chimpanzee (*Pan troglodytes*) is an important species, not only because of the urgent need for its protection, and its phylogenetic position as the closest living relative of humans, but because this species may provide significant information about risks for the health of humans living in the same environment. Furthermore, chimpanzee ecotourism represents an important potential economic resource for a number of countries when correctly conserved and managed.

Kibale National Park is a protected area in Western Uganda that is one of the most biodiverse forests in Africa and home to 12 primate species, including the endangered eastern chimpanzee (*Pan troglodytes schweinfurthii*) (Chapman and Lambert, 2000). Kanyanchu, an area situated in the middle of the national park, is an important international chimpanzee ecotourism site. Thirty kilometers north of Kanyanchu lies the northern most region of the park, Sebitoli. The home range of the Sebitoli chimpanzee community is surrounded by industrial tea plantations, small scale agriculture including maize gardens, and is split by a tarmac road. In a buffer 2.5 km zone around their home range, tea plantations cover 24.1% (21.5 km² out of 89.2 km²) and eucalyptus plantations cover 3.8% of the buffer (3.4 km²; Bortolamiol et al., 2013). Thus, this community of chimpanzees and other sympatric wildlife have to cope with proximity to high-density human populations (~300 inhabitants/km²; Hartter, 2009) and dense traffic on the tarmac road crossing their home range (Cibot et al., 2015). Potential inbreeding due to spatial isolation, unsustainable agriculture practices, and misuse of pesticides are among the issues that may directly threaten health of wildlife in this area and in Africa generally.

During the first years of our monitoring, we discovered that 12 out of the 60 identified wild chimpanzees in Sebitoli suffered from anomalies, including reduced nostrils, cleft lip, and limb deformities. In addition, some individuals exhibited reproductive problems (no cycle and swelling of the genital area, no dependent offspring) and hypopigmentation. This syndrome likely has a congenital basis that could be due to or exacerbated by environmental factors (Krief et al., 2014, 2015). Within the same park, primates, including chimpanzees, have been observed and studied for more than 25 years. In three sites (Ngogo, Kanyawara, Kanyanchu, home ranges of more than 300 chimpanzees), wild chimpanzees are daily monitored, and no anomalies of this type have been reported before we discovered the deformities observed in chimpanzees in Sebitoli.

However, as soon as we noticed that chimpanzees were exhibiting unusual phenotypes in Sebitoli, we did a bibliographical review on wild primate cases of such deformities and interviewed our colleagues about such anomalies in their study sites. Two primate cases were reported. First, D. Watts and J. Mitani from Ngogo research site sent us several photos of a male chimpanzee with an abnormal lip that we submitted for diagnosis to a specialized medical team, who reported the condition as a cleft lip (Krief et al., 2015). To our knowledge and after careful bibliographical review, this is the only reported case of wild chimpanzees having a facial dysplasia outside the Sebitoli area. Secondly, there is a documented case of a female baboon in Kibale National Park missing all but the most basal part of her upper jaw and nose, with the authors proposing that the arhinia was congenital (Struhsaker et al., 2011).

Here, our goal is to determine the cause of the phenotypical impairments of the primates in this area and to understand whether they can be related to the environmental pollution of their habitat. Motivated by the larger proportion of the individuals that suffer from anomalies in Sebitoli in contrast to other regions in Kibale National Park and Africa, we explored the hypothesis that chimpanzees and other primates in Sebitoli may be exposed to chemicals used on neighboring crops that could instigate or exacerbate developmental impairments. This hypothesis is strengthened given that Sebitoli, chimpanzees regularly visit crop fields and feed on maize (stems and seeds) and plantains and they live in close proximity with tea monocultures. Small fields and gardens with varied, rotating crops, including maize, are also found in the surrounding area. Frequently, between two and six maize gardens are close enough to the edge of the forest to be accessible to chimpanzees and baboons.

As chimpanzees are a threatened species, no invasive biological sampling is allowed. Therefore, as a first step, we verified whether or not Sebitoli chimpanzees are exposed to pollutants that could affect development and contribute to their abnormal phenotypes. To this end we used environmental analysis on the one hand and fish from different areas of the park as sentinels on the other hand.

2. Material and methods

2.1. Study site

The Sebitoli area is located in the north of Kibale National Park (795 km²; 0°13' to 0°41'N and 0°19' to 30°32'E; Chapman and Lambert, 2000). This section of Kibale was commercially logged in the 1970s, leading to damage of about 50% of the trees (Struhsaker, 1997). Today, a large proportion (70%) of this area of the park is degraded or regenerating forests and only 14% represents old-growth forest (Bortolamiol et al., 2014).

2.2. Methods

2.2.1. Description and records of non-human primates (NHP) affected by physical anomalies

The chimpanzees and baboons were observed without resorting to invasive methods and without interaction with the researchers. We

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