

Updates on the Guinea Baboon Populations from the Remote and Arid Areas of Southern Mauritania

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Abstract: The Guinea baboon (*Papio papio*) is a Near Threatened primate endemic to West Africa. During the last 30 years, the species has been disappearing due to habitat loss and hunting. Current research and conservation efforts are mostly restricted to the central/southern areas of the species' geographic range. A significant gap of knowledge exists on the distribution and ecology of the species in the northern part of its distribution, namely in the arid environments of Mauritania. The implications of data deficiency in conservation are particularly relevant for populations inhabiting remote desert wetlands in areas of limited and season-dependent environmental resources. This is the case in Mauritania, where these resources are shared between wildlife and local human communities. We studied the distribution and habitat use of the Guinea baboons in Mauritania and worked with local communities to raise awareness of the importance of wetlands conservation. We report the presence of Guinea baboons in 20 localities that were not known to be part of the primates' distribution in the literature or surveyed in past expeditions. We found the species in a variety of habitats but always in the proximity of permanent and temporary water sources, such as observed in other species of baboons living in similar arid environments. Nevertheless, our observations suggest for the first time that temporary rivers may contribute to the persistence of Guinea baboons' social groups inhabiting areas surrounded by arid environments. To raise awareness of the importance and fragility of desert wetlands in Mauritania and to improve baboon conservation, we organized environmental education activities in rural schools. Our actions were welcomed with great enthusiasm. However, we found that education in these schools is limited by a lack of basic didactic material and infrastructure. Our study highlights the importance of improving the scientific knowledge of the Mauritanian Guinea baboons and the relevance of environmental education in local communities to raise awareness of the extreme fragility of wetland habitats in arid regions.

Key words: Desert primates, conservation, Sahara-Sahel, human footprint, habitat use, environmental education

INTRODUCTION

Knowledge about global biodiversity is still biased and scarce, and a great part of this shortfall is related to the lack of information on the distribution and ecology of species (defined as Wallacean and

Raunkiaeran shortfalls, respectively; Hortal *et al.* 2015). These baseline data are essential for research and conservation projects (Hortal *et al.* 2015). The impact of the Wallacean and Raunkiaeran shortfalls

is worse the more remote the geographic region, and the more elusive the species. Tropical areas of South-West Africa are one of the major global biodiversity hotspots with recognized interest for research and conservation. However, arid and bare areas of North-West Africa (i.e., the Sahara Desert and the Sahel) are among the regions where the above-mentioned shortfalls are most pronounced (Brito *et al.* 2014). This is also due to the harsh climatic conditions, remoteness, and political instability characterizing some North-West African countries, which hamper the development of regular scientific research and long-term conservation management projects (Brito *et al.* 2018).

Mauritania (in North-West Africa) is an example of how all the above-mentioned factors can limit the implementation of scientific research and conservation projects. This desert country is embedded in the Sahara and Sahel ecoregions. There are a few paved roads available, most of which are in the lowlands in the southwest of the country, limiting accessibility to the mountains and inland areas located in northern Mauritania. Additionally, regional conflicts and political instability characterizing the neighboring countries have strongly affected travel security and accessibility to some areas (e.g., the border areas between Mauritania and Mali; Brito *et al.* 2018). Socioeconomic conditions have improved in the last decades (IEP 2021), which may also translate into stronger pressure on the scarce and temporal natural resources of the region. This consequently impacts the non-arid environments (i.e., desert wetlands) and their biodiversity, which could be lost if current climatic and land-use change pressure continues at the current rate.

Despite the growing human population, 75% of Mauritania is classified as one of the wildest areas of the world, where human impact is still limited (Wildlife Conservation Society, cited October 2022). However, just 1% of the country is formally protected in two coastal national parks (Banc d'Arguin and Diawling National Parks) and two Ramsar sites (the coastal Chott Boul and the Lac Gabou in the Tagant plateau) mostly set to protect the migratory and wintering Palearctic birds. Research efforts have increased in Mauritania in the last decades to counteract the Wallacean shortfall (Brito *et al.* 2022 and references therein). Despite the extensive information compiled by Brito *et al.* (2022) on the distribution, diversity, and conservation of mammals, relevant knowledge gaps exist on nonhuman primates occurring in Mauritania, namely the green monkey (*Chlorocebus*

sabaeus), the patas monkey (*Erythrocebus patas*), and the Guinea baboon (*Papio papio*), which remain largely understudied.

The Guinea baboon (*Papio papio*) is a northwest African endemic species distributed in Mauritania, Mali, Senegal, The Gambia, Guinea-Bissau, The Republic of Guinea, and Sierra Leone (Wallis *et al.* 2020). Baseline information on the distribution limits, habitat use, ecology, and behavior is incomplete, particularly in the northern part of the species distribution (Mauritania; Zinner *et al.* 2021; Brito *et al.* 2022). The known distribution extent of the Guinea baboon in Mauritania is approximately 100,000 km² (Brito *et al.* 2022, Figure 1), of which only 4% is predicted to be suitable for the presence of the species, according to modelling exercises conducted by Vale *et al.* (2015a). Guinea baboons are known to be present in 78 locations, all scattered either on the Mauritanian side of the Senegal River or in one of the three mountain massifs located in the south of the country: the Tagant, the Assaba, and the Afollé (Figure 1) (Brito *et al.* 2022). Previous ecological studies found that the Mauritanian desert populations of Guinea baboons have a distinct ecological niche compared to populations inhabiting the southern and less arid regions of its geographic range. In fact, these northern populations may be ecologically similar to other desert species of the genus *Papio* (i.e., *P. anubis* and *P. hamadryas*) (Vale *et al.* 2015a, Fuchs *et al.*, 2018; Chala *et al.*, 2019; Zinner *et al.*, 2021). The Guinea baboons in Mauritania are typically found close to permanent water bodies, especially near mountain rock pools (locally known as *gueltas*), surrounded by desert-like environments (Vale *et al.* 2015b; Brito *et al.* 2022). The dispersal patterns and population structure of the species were studied in other areas of its distribution (Ferreira da Silva *et al.* 2014, 2018; Kopp *et al.* 2014, 2015). However, population connectivity and the location of potential corridors used for dispersal in the northern part of the species distribution are still unknown (i.e., within and between Mauritanian mountain massifs and the Senegalese and Malian populations) (Kopp *et al.* 2014; Vale *et al.* 2015a).

In southern areas of this species' distribution (e.g., Senegal, Mali, Guinea Bissau, and Republic of Guinea), poaching and mortality caused by farmers and hunters are considered important conservation threats (Wallis *et al.* 2020; Ferreira da Silva *et al.* 2021a,b). However, the interactions between baboons and local communities in Mauritania do not seem to be negative, even if they are sharing the same resources (e.g., water). In fact, there are no records of direct persecution or commercial hunting

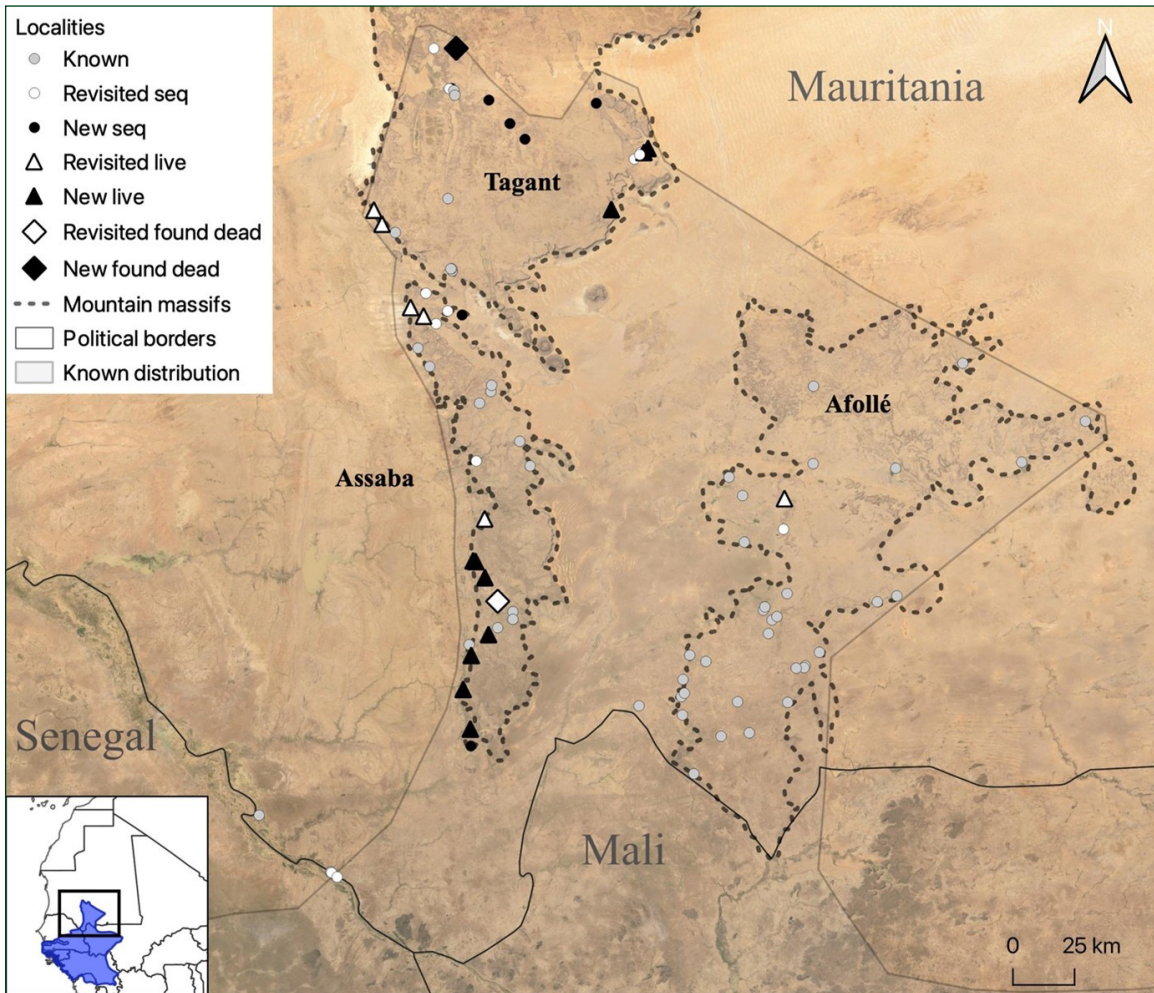


Figure 1. Distribution of baboon localities in the mountain massifs at Southern Mauritania. The 20 new sites where the Guinea baboons were found during the expedition in February and March 2022 are represented by black symbols and the localities where Guinea baboons were found by past expeditions and that were revisited during the expedition are represented by white symbols. Different symbols indicate whether the presence of baboons was validated by molecular analysis of feces (dots), direct observation of social groups (triangles), or finding dead individuals (diamonds). The distribution of the species in Mauritania is delimited by grey areas. Dashed lines indicate the extent of the Tagant, Assaba, and Afollé mountain massif. The inset picture on the bottom left indicates the study area in West Africa, with the polygon indicating the global distribution of the species.

of Guinea baboons in the country, which could be due to dietary taboos and rules of conduct towards wildlife related to the Islamic religion. Nevertheless, water in Mauritania is a limited and valuable resource. The few wetlands available in southern desert-like areas are often overexploited by local communities to maintain crop fields and livestock production, which often results in water shortages and contamination of the water by cattle (Brito *et al.* 2014, 2022; Figure 2). The common use of freshwater sources may increase the risk of pathogen exchange between humans and nonhuman primates and lead to increased mortality of both species (Mathavarajah *et al.* 2021). There is lack of information on the

Guinea baboon in the country but in particular on the northernmost populations of the Tagant (which is the most arid, remote, and under-sampled area), and southern Assaba (which is one of the areas where human presence and related impacts in the ecosystems are greater).

People sharing the same area and resources as primates may not be aware of how their actions could affect the persistence of the species (Ceballos-Mago & Chivers 2010; Dolins *et al.* 2010). Raising awareness of local communities that live close to a primate's preferred habitats has been shown to successfully improve both the interactions between humans and nonhuman primates and



Figure 2. A social group of Guinea baboons and domestic horses drinking from the same *guelta* in the North Afollé mountains. Earlier in the day, before the picture was taken, the cattle owner also drank from the same water pool. More than 90 baboons were seen drinking at this location that same day. Photograph from Cristian Pizzigalli.

the conservation of the primate species (Savage *et al.* 2022). This solution may be particularly valid when conservation budgets are limited and the major threats to the species are related to the local communities and human footprint (Butchart *et al.* 2010). In Mauritania, a better understanding of the impacts that water overexploitation and pollution have on primate populations and on the local biodiversity, in general, may be important for local communities to be willing to find sustainable alternatives, which could benefit both humans and other primates.

Here, we aimed to provide the most updated information on the distribution and habitat use of the Guinea baboons in Mauritania within the context of what was previously known about these remote and understudied populations (but see Brito *et al.* 2022). The objectives of this paper are: i) to provide updated information on the Guinea baboons' distribution in Mauritania, ii) to identify habitats where the species was found and possible threats to their conservation, and iii) to report on a trial environmental education program for local schools initiated to raise awareness about the

importance and fragility of desert mountain rock pools (or *gueltas*).

METHODS

Study area

The study area encompasses the administrative regions of Tagant, Guidimaka, Gorgol, Brakna, Assaba, and Hodh Ech Chargui in southern Mauritania, where the mountain massifs of Tagant, Assaba, and Afollé are located (Figure 1). The regions' climate is characterized by a dry and cool season from November to February and a dry, hot season, from March to June (Brito & Pleguezuelos 2020). Precipitation is scarce and seasonal, occurring in a single wet period from July to October, with maximum rainfall in August and September (Brito & Pleguezuelos 2020). Vegetation is scarce in the north and southeast, where the area intersects the Sahara Desert, and it progressively increases southwards, changing into Sahelian Acacia and West Sudanian savanna corresponding to a higher rainfall pattern. Despite the unique biodiversity of the region, the only protected area is the Ramsar site *Lac*

Gabou et le Réseau Hydrographique du Plateau du Tagant. The area is remote, with no anthropogenic infrastructures, and was recently affected by regional conflict caused by political instability (Brito *et al.* 2018). Although the country is currently politically stable, a safety buffer zone persists on the border with Mali, hampering field surveys in the area and southeast Afollé (Figure 1).

Field survey

A 21-day field survey took place between February and March 2022, during the dry and cold season. We visited sites where baboons were known to be present in the Tagant, Assaba, and Afollé mountains (in white in Figure 1) along with other locations that were considered to have a high probability for the species' occurrence, based on species distribution models (Vale *et al.* 2015a), personal knowledge, and through inquiring of local people. We define "location" as geographically independent sites (usually harboring a water source) that had a name given by local communities and that were usually separated by a minimum of 2 km and removed from other localities by landscape features (such as dunes or hills). These sites were reached with a 4x4 off-road vehicle equipped for overland fieldwork. When social groups of baboons were observed, individuals were counted if visibility allowed. Preference was given to situations in which the social group was moving and crossing an area visible to the observer. When individuals were not detected (observed or heard), the area was actively surveyed to gather evidence of indirect presence (e.g., footprints, feces). The geographic positioning of each locality was recorded using a Garmin handheld device (GPS). Fecal samples were collected non-invasively and stored in 96% ethanol until DNA extraction following Ferreira da Silva *et al.* (2018). Field surveys were conducted in areas not formally protected. Expeditions and non-invasive sampling of biological material were carried out in accordance with national laws and authorized by the Ministry of Environment and Durable Development of Mauritania (permit 2012-827/MDAPMCEDD/SG).

DNA barcoding

DNA was extracted from feces following an adaptation from the Costa *et al.* (2017) extraction method. This DNA extraction protocol is designed to retrieve a large yield of DNA and uses the E.Z.N.A. Tissue extraction kit (Omega Bio-tek; Norcross, GA) and a larger quantity of fecal material in the first step. DNA extracts were eluted in 200 µl AE Buffer and

stored at -20 °C. Negative controls were included in all the extraction procedures and in subsequent PCRs. Samples were processed in dedicated low-quality DNA facilities at the BIOPOLIS-CIBIO research center (<https://cibio.up.pt/en/about/>) equipped with positive air pressure and UV lights. A 490 bp fragment of the mitochondrial (mt) DNA control region (hyper-variable region I) was amplified by Polymerase Chain Reaction (PCR) and sequenced bi-directionally using the primers L15437 and H15849 (Hapke *et al.* 2001). PCR reagents final solution of 10 µl included 5 µl QIAGEN Multiplex PCR Master Mix, 1 µl primers mix, and 2.5 µl of pure water. The amount of DNA used in the reaction was 1.5 µl. PCR cycling conditions were optimized for the project samples. The PCRs started with an activation step (15 min at 95 °C), followed by 40 cycles of denaturation at 94 °C for 30 s, annealing at 59 °C for 90 s and extension at 72 °C for 60 s and it included a final extension of 30 min at 60 °C. PCR procedures were performed in a Bio-Rad T100™ Thermal Cycler. Pre- and post-PCR manipulations were conducted in physically separated rooms, always including negative controls to monitor for contamination. PCR products were purified using ExoSAP-IT PCR clean-up Kit (GE Healthcare, Piscataway, NJ, USA). Sequences were generated for both strands following the BigDye Terminator v3.1 Cycle sequencing protocol. Sequencing products were analyzed in a 3130 XL Genetic Analyzer (Applied Biosystems, Carlsbad, CA, USA). Sequences were visually corrected using Geneious® v. 4.8.5 (Kearse *et al.* 2012) and were compared with vouchers deposited in GenBank using Basic Local Alignment Search Tool (B.L.A.S.T.; Boratyn *et al.* 2012) to confirm species identity.

Habitat use

We combined the information on the habitats where the species was observed in the 2022 expedition with information collected during previous expeditions (2007 to 2020, 78 localities described in Brito *et al.* 2022). Data based on indirect signs of presence - such as fecal samples - were validated by DNA barcoding. We classified the habitats where the presence of baboons was confirmed into seven different categories, as illustrated in Figure 3: a) Permanent river: all localities within 1 km distance from the Senegal River; b) Springs: groundwater point of exit, most of the time with permanent (often running) water and thick vegetation; c) *Gueltas*: mountain rock pools usually located at the bottom of waterfalls; d) Floodplains (*tamourts*): permanent or temporary flat areas that form in the proximities



Figure 3. Habitat use. The six different categories of habitats, in order from the top left: a) the Senegal River; b) spring in the Assaba; c) a rock pool (*guelta*) in the Tagant mountain; d) a floated area (*tamourt*) in the south of Assaba; e) a canyon temporary river (*oued*) in the Tagant; and f) an open oued in the Afollé. Photographs a-d and f by Cristian Pizzigalli; photograph e by Simone Giachello.

of mountain massifs; e) Dry river canyons (*oueds*): temporary riverbeds often covered by soft sand and rocks or boulders situated at the bottom of canyons and surrounded by steep mountain slopes; and f) Open *oueds*: temporary riverbeds situated in open areas, sometimes located at the exit of canyon *oueds* where the riverbed is almost exclusively soft sand.

Environmental education and outreach

We produced a poster divided into four sections addressing: i) the ecosystem services provided by

gueltas to human populations; ii) the relevance of *gueltas* for wildlife; iii) the threats to *guelta* conservation (i.e., water overexploitation and contamination); iv) recommendations for the maintenance of *gueltas* (i.e., preventing domestic animals from defecating into water or not leaving trash in the proximity of *gueltas*) (Figure 4). We designed the poster with graphic content to reach a broad range of age and literacy. We translated the poster to English, French, and Hassaniya (the local ethnic language), and printed 33 color copies (11

Save your guelta, ensure your future!

Importance for humans

- Pivotal source of water for cattle and agriculture during arid seasons
- Allow the persistence of "green areas" with spontaneous trees and fruit-trees
- Provide refreshment and shelter for wildlife and humans
- Often the only source of fresh water for villages
- Source of fish

Importance for the environment

- Hold high number of animals and plants species, including unique species not found anywhere in the world
- Only source of water for wildlife
- Provide refugia under climate change
- Crucial for long term conservation of Sahara-Sahel animals and plants

How we can save them

- Avoiding cattle and human ejections inside, or in the proximity of guelta
- Avoiding washing with soap inside, or in the proximity of guelta
- Take your garbage with you when you leave a guelta
- Optimize the use of water
- Protect the trees in the proximity of guelta
- Reduce fishing and hunting

Threats

- Unregulated overexploitation of the water and other resources (i.e. timber and fishery)
- Plastic pollution
- Water contamination by cattle and human ejections
- Water pollution by chemicals
- Hunting
- Droughts

Living on the edge!

Figure 4. The English version of the poster distributed during our outreach activities at local schools and villages.

for each language) on A3 (297 x 420 mm) paper. All posters were laminated to increase their durability. Both the lectures and poster design were prepared by the Department of Biology of the University of Nouakchott (Mauritania) in collaboration with the research group BIODESERTS, CIBIO, Porto University, Portugal. The targeted audience of our posters were school students and staff, and people visiting centers of interest in the local communities (such as bakeries and grocery shops). We distributed two copies of each poster version to each school that agreed to participate in the educational activity. While visiting the schools, we gathered information on the number of students and teachers, main academic topics taught, and challenges faced.

RESULTS

We covered ca. 4,000 km encompassing the whole extent of Guinea baboon distribution in the Tagant and Assaba mountains (Figure 1) and visited two known localities in the Afollé. We observed live individuals in 18 localities (Figure 1) and collected 279 fecal samples. Of those samples, 213 were successfully DNA extracted and sequenced for the targeted mtDNA fragment. The 490 bp fragment of the mtDNA control region showed 98.18% and 97.17% match to a voucher for a Guinea baboon deposited in NCBI GenBank database (accession number KC312735.1). This indicates that the mtDNA sequences obtained from samples in Mauritania are over 97% identical to the Guinea baboon nucleotide sequences deposited in NCBI GenBank, confirming that the sequences were from the same species.

Distribution

We identified 20 new localities where Guinea baboons were present, nine of which are situated in the Tagant and 11 in the Assaba mountains. We confirmed the presence of baboons using DNA barcoding in nine sites (six in the Tagant and three in the Assaba; triangles Figure 1), by direct observations in 11 (four in the Tagant and seven in the Assaba; circles and crosses in Figure 1), and by finding a dead individual in Tagant (cross in Figure 1). In addition, we re-confirmed the presence of the species in 17 localities that were visited in previous surveys; in five by direct observation (one in the Tagant, three in the Assaba and one in the Afollé), and in 13 by DNA barcoding of fecal samples collected. Out of the 15 localities where we observed social groups, four were in the Tagant massif, 10 in the Assaba (two in the north, and eight in the South), and one in the Afollé. In 59% of the localities

visited we spotted fewer than 40 individuals. Out of the 15 localities where we observed social groups, four were in the Tagant massif, 10 in the Assaba (two in the north, and eight in the South), and one in the Afollé. Social group size ranged between 15 to 90 individuals. We observed the smallest social groups in the Tagant (from 15 to 32 individuals) and the biggest in the Assaba and Afollé (from 15 in the north Assaba to 90 in the Afollé). It was not possible to distinguish between males and females while counting.

Habitat use

All observations were made in the proximity of water bodies except for the skull of a dead baboon found on a hill 7.8 km from the closest *guelta* in the Assaba. Of the 98 known localities where the species is known to be present, five are along the Mauritanian side of the Senegal River (Figure 3a); six are springs (Figure 3b); 24 are *gueltas* (Figure 3c); four are *tamourts* (Figure 3d); 30 are canyons *oueds* (Figure 3e); and 26 are open *oueds* (Figure 3f). We observed individuals at the *gueltas* only during sunrise and sunset and in some cases during the night. Baboons were observed next to springs only around midday. During the 2022 expedition, we directly observed baboons in eight localities out of 20 in the proximity of dry *oueds* foraging on *Acacia* sp. pods or grass stems.

Environmental education in schools and outreaching

We contacted five schools (three in the Tagant, one in the Assaba, and one on the border between Mauritania and Senegal). All the schools are located close to *gueltas* used by baboons or to relevant conservation areas for baboons (e.g., the Tagant plateau or the area between the Senegal River and the southern Assaba). The number of students enrolled at the schools visited varied from 159 to approximately 1,000, and the number of teachers was between two to 26 (Table 1). All the school directors and teachers contacted were interested in our project and immediately agreed to include the environmental education material in the academic programs. Directors also highlighted some factors hampering the good implementation of educational activities. Table 1 lists the problems reported by the director of each school. The key challenges include the lack of drinkable water, restrooms, desks, electricity, and basic didactic materials (i.e., notebooks, books, and pencils), but also poor regular and public transportation for students living in the neighboring villages. Although all the schools have

Table 1. Schools visited during our environmental education activities. The table shows the school identification code, name of mountain massif where the schools were located, if activities of environmental education was carried out in schools in the past (yes/no), number of teachers and students and a list of the main problems and challenges mentioned by the school directors.

School ID	Mountain	Environmental education	Number of teachers in the school	Number of students	Problems
1	Tagant	no	10	253	<ul style="list-style-type: none"> • No desks • No electricity • Lack of school material (i.e., educational books, notebooks and pencils) • Classrooms overcrowded • No water
2	Tagant	no	16	663	<ul style="list-style-type: none"> • No desks • No electricity • Lack of school material • Classrooms overcrowded • No water
3	Tagant	no	2	159	<ul style="list-style-type: none"> • Classrooms overcrowded • No bathroom • Lack of school materials • Under-staffed • No public or private transportation • No water
4	Assaba	no	3	310	<ul style="list-style-type: none"> • No desks • No electricity • Lack of school material • Classrooms overcrowded
5	Senegal river	no	15	800 > 1000	<ul style="list-style-type: none"> • Lack of school material • Under-staffed • No public or private transportation • No water • Unbearably hot and humid during most of the academic year

teachers of geography, mathematics, and science, no school had included environmental education in their didactic activities. Beyond schools, we contacted shepherds, laundry people, and other people encountered at *gueltas*. One bakery in the Assaba mountain, an establishment visited daily by individuals of the community, also agreed to display one of the French poster

DISCUSSION

This study provides presence and habitat use data that helps fill the knowledge gap on the understudied Guinea baboon populations inhabiting the northernmost region of the species' distribution. Together with the 279 genetic samples collected and our environmental education activities, these data lay the groundwork for future conservation studies and environmental management projects aimed at preserving the populations of Guinea baboons inhabiting these extreme environments.

Distribution updates

Our field survey adds 20 new localities to the known distribution of Guinea baboons in Mauritania, increasing the distribution of the species to 98 known locations. In other areas of the species distribution (i.e., Senegal), the home range (HR) may vary between 20 and 100 km, with a daily travel distance (DTD) between 0.5 and 13 km, and with a smaller home range and daily travel distance always recorded during the dry season (Zinner *et al.* 2021). However, the hamadryas baboon (or desert baboon; *P. hamadryas*), which mostly inhabits the desert areas of East Africa and the Arabian Peninsula, is known to have a broader spectrum of variability in both HR (from 4 to 129.3 km) and DTD (from 1 to 19.2 km) (Zinner *et al.* 2021 and references therein). Because the home range of the Guinea baboon has never been estimated in Mauritania, we cannot assure that the 98 localities where baboons were observed correspond to 98 independent social groups. Further studies are needed to understand if Mauritanian Guinea baboons' home range and daily travel distance most resemble those of the southern populations of the species or those of the desertic hamadryas baboons.

Guinea baboons were observed in more localities in the Assaba massif (38), followed by the Afollé (36) and the Tagant (22). The records for additional localities where baboons occur validate the presence of this primate in the northernmost limit of the species distribution (namely, in the center of the Tagant mountain massif), where its presence was predicted by the modelling exercises of Vale *et al.* (2015a) but had not been empirically confirmed. The habitat in this area of the Tagant is characterized by arid rocky canyons located at the edge of the Sahara Desert. These canyons host the seasonal hydrographic sub-basin of the endorheic Gabbou River (Campos *et al.* 2012) that, beyond the scattered permanent *gueltas*, contains water from July to October. Considering the ecological requirements of the Guinea baboon, thought to be dependent on permanent water sources on a daily basis, these often-permanent small wetlands could function as steppingstone ecological corridors for populations inhabiting the western and eastern sides of Tagant plateau (Figure 1), otherwise separated by approximately 100 km of arid habitats of bare rocks and sand. Other relevant new localities discovered were the ones in the south of the Assaba mountains. The previously known southernmost limit of the distribution in the Assaba was located north of the road starting at M'bout that crosses the mountain plateau in the south to reach Kankossa and Kiffa

(Brito *et al.* 2022). These populations are located approximately 120 km away from those located south on the Mauritanian side of the Senegal River. The new localities reported here extend the currently known local distribution of Guinea baboons in the Assaba mountains about 50 km southwards, now approximately 70 km from the Senegal River populations. However, the area that extends between these new Mauritanian populations (Figure 1) has been proposed as a putative barrier by Vale *et al.* (2015a), due to increasing urbanization and consequent habitat changes. Our results highlight the importance of assessing the population structure and genetic connectivity within Mauritanian populations and between Mauritanian, Senegalese, and Malian populations, using for instance landscape genetics studies (e.g., Razgour *et al.* 2020). It would be important for conservation management to better understand how the landscape affects the movement behavior of this species. Such studies would reveal the levels of reproductive isolation of these populations as well as locate putative ecological corridors that should be preserved to enhance the continuation of population connectivity.

Habitat use

Our records show that Mauritanian baboons may be present in other types of habitats than *gueltas*. Most of the habitats in which baboons were observed were dry riverbeds - "canyon *oueds*" or "open *oueds*" (Figures 2e and 2f). The apparent preference for dry riverbeds by baboons over *gueltas* could be related to avoidance of humans and cattle that visit *gueltas* during the daytime. Although we do not have any record of direct persecution, the presence of humans and cattle at *gueltas* could be perceived by baboons as threatening. Supporting this hypothesis is the fact that social groups were observed at *gueltas* only during sunset and right before sunrise when shepherds were not present. A second cause could be that food available at the *gueltas* is limited and, once depleted, baboons could be forced to forage at locations relatively far from water sources. Additionally, dry *oueds* may play a role as preferred dispersal corridors since these habitats could be used to find water, food, and new social groups by dispersing individuals. The disproportional importance of permanent and temporary wetlands for both human persistence and biodiversity conservation in deserts and arid environments has been previously addressed (Velo-Anton *et al.* 2014; Vale *et al.* 2015b; Brito & Pleguezuelos 2020). However, temporary rivers have been overlooked despite being ecologically important to assure

ecosystem services and processes (Acuña *et al.* 2017). For example, the riparian vegetation characterizing temporary streams provides shelter and foraging sites for wildlife and livestock and may be used as corridors during migration or dispersal by large mammals and birds (Steward *et al.* 2012). There is an urgent need for innovative management actions for the conservation of temporary streams and desert wetlands (Acuña *et al.* 2017). Future studies should explore the importance of these habitats for Mauritanian Guinea baboons and for other primates occurring in the same areas. For instance, it is known that patas monkeys (*Erythrocebus patas*) are present in most of the localities where Guinea baboons are also found (Brito *et al.* 2022). However, it is unknown to what extent these species share and/or compete for the same territory and/or natural resource, and whether specific conservation measures are needed to ensure the persistence of both species in the country.

Environmental education also plays an important role in the conservation of these habitats. The lack of superficial water flow for most of the year could lead to the disregard of temporary rivers (Acuña *et al.* 2017). Environmental education and outreach activities for both general audiences and policymakers could raise awareness of the importance of these fragile and overlooked ecosystems.

Environmental education and outreaching

The schools contacted during environmental education activities are all located in strategic areas for the conservation of Guinea baboons and Mauritanian wetlands. Three are located at the Tagant foothills, the edge of the northernmost limit of the distribution of the species, which is also the area with the highest aridity index (Zomer *et al.* 2022) and lowest water availability. The schools in southern Assaba and on the Senegal Riverbank are located in areas of high human environmental interference and intense activities. The connectivity between Mauritanian, Senegalese, and Malian baboon populations, thought to be in a steppingstone manner (Vale *et al.* 2015a), may be negatively impacted by local extinctions caused by human-related habitat degradation. To achieve global conservation goals, it is important to work with local communities to attain a satisfactory level of societal development (Berkes 2004; Savage *et al.* 2022). The environmental education and outreach activities carried out by our team attracted great interest among all people contacted, including shepherds, laundry people (who often clean sheets and clothes in *gueltas*, *tamourts*, and rivers),

bakeries (often community hotspots in villages), school directors, and students. After an introduction to the ecosystem services that *gueltas* provide to humans and wildlife and their threats, the audiences immediately welcomed our proposed activities. This was particularly true for school directors and teachers who were willing to collaborate to develop future environmental education programs. However, they also highlighted challenges affecting the implementation of activities, including lack of desks, electricity, and basic didactic material (i.e., notebooks, books, and pencils), as well as poor public transportation, lack of drinkable water, and restrooms. We highlight that the involvement of national and international NGOs operating in themes related to social development and education improvement (i.e., <http://www.unaltrmondo.it/> and <http://UkClub.it/>) would contribute to the achievement of United Nations Organization Sustainable Development Goals (Savage *et al.* 2022). The collaboration with local and international NGOs could also be a useful support for local communities by carefully designing effective conservation projects (see also <https://www.chimbo.org/our-work/>), which can act as a catalyst for attracting funds and the attention of policymakers and international associations for nature conservation (i.e., IUCN).

CONCLUSIONS

Our study provides insights into the distribution and habitats occupied by Mauritanian Guinea baboon populations but also highlights the lack of environmental education in Mauritanian schools and the urgent need for basic didactic conditions. The reporting of new localities where the Guinea baboons occur might be relevant for the preservation of population connectivity in remote and arid areas. The recorded localities are already under the conservation umbrella of the Ramsar site *Lac Gabou et le Réseau Hydrographique du Plateau du Tagant*, which represents an opportunity to define management actions for Mauritanian Guinea baboons' conservation inside a protected area. However, additional monitoring activities and research are needed to identify ecological corridors and to predict the impact of future climate change and increasing human presence on these change-prone ecosystems. Our study also provides preliminary results on the importance of habitats other than *gueltas* for Guinea baboons, such as temporary rivers, often neglected in the discussion of population connectivity. Additional research is needed to confirm the role of these

habitats in dispersal and foraging activities. Lastly, to the best of our knowledge, the environmental education activities described here were the first highlighting the conservation of a nonhuman primate species in the country. Environmental education in Mauritanian schools is lacking and the sub-optimal conditions of buildings are challenging the development of didactic activities. The scientific community partnered with humanitarian organizations could act to fulfill these needs. We recommend that environmental education activities be developed and implemented before climate change and increasing human pressure irreversibly affect the Mauritanian baboon populations and their fragile ecosystems.

Supporting information

Since the species is threatened in other areas of its distribution by active and intense hunting by poachers traveling between countries, we omitted the names of people or localities where this research was implemented. This information can be provided through direct request to the authors.

ACKNOWLEDGMENTS

We would like to thank L. Khalatbari and B. Alard for their help in the revision of the poster translation. This study was supported by The Rufford Foundation on the scope of the project “Living on the edge” (Grant number 36007-1), and Primate Conservation Incorporated (Grant number 1723). JCB, MJFS and CP are supported by FCT-Fundação para a Ciência e Tecnologia (CEECINST/00014/2018/CP1512/CT0001, CEECIND/01937/2017, 2020.05054.BD, respectively). None of the funding entities were involved in the study design, data collection, analysis or interpretation of data, writing, or decision to submit this manuscript.

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Received: 2 November 2022

Accepted: 24 December 2022