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Traditional ecological knowledge for great ape conservation in Gabon

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Abstract

Background Traditional ecological knowledge (TEK) held by Indigenous communities is increasingly recognised as a cost effective, locally adapted complement to instrument-based wildlife monitoring. In southern Gabon, hunter trackers routinely distinguish chimpanzee *Pan troglodytes troglodytes* and western lowland gorilla *Gorilla gorilla gorilla* faeces in the field, yet the reliability of these identifications has never been rigorously tested.

Methods Twenty-two experienced Indigenous participants guided systematic surveys across ~ 10 000 ha of unprotected forest near Makatamangoy and Tébé. For every faecal sample encountered, collaborators reached a consensual species identification using their customary criteria (colour, odour, texture, composition, quantity, associated footprints, vegetation disturbance). Samples ($n = 637$) were preserved in RNAlater® and later assigned to species by 12S rRNA mitochondrial sequencing. Agreement between Indigenous and molecular identifications was summarised in a confusion matrix; accuracy, sensitivity, specificity, predictive values and Cohen's κ were calculated. The prevalence of each empirical criterion was expressed as the proportion of interviewees citing it, and species differences were tested with Fisher's exact tests ($\alpha = 0.05$).

Results Indigenous knowledge correctly identified 633 of 637 samples (overall accuracy = 99.37%; $\kappa = 0.987$, $p < 0.001$). Sensitivity was 99.1% for chimpanzee and 99.0% for gorilla, while specificity exceeded 99.6% for both species. Seven primary criteria underpinned identifications; colour (100%) and odour (86.4%) were most frequently evoked. Twelve of 24 sub-criteria differed significantly between species. Chimpanzee faeces were more often described as brown-yellow, soft and abundant with faint heelprints, whereas gorilla faeces were typically black, fibrous, hard and accompanied by pronounced heel and fist prints plus flattened vegetation.

Conclusion Indigenous trackers in Gabon demonstrate near-perfect accuracy in differentiating great ape faeces, validating TEK as a robust, low-cost tool for primate monitoring. Integrating this expertise into participatory conservation programmes could expand surveillance outside protected areas, enhance early detection of demographic or health changes, and strengthen community stewardship of threatened ape populations.

Keywords Traditional ecological knowledge, Great apes, Chimpanzee, Gorilla, Conservation strategies, Gabon

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Background

Indigenous peoples around the world hold rich and deeply rooted bodies of Traditional Ecological Knowledge (TEK), developed over centuries through close interactions with their natural environments. Although no universally accepted definition exists, TEK is commonly understood as a cumulative body of knowledge, practices, and beliefs, passed down culturally across generations, concerning the relationships among living beings (including humans) and their surroundings [1]. These knowledge systems are applied in various domains such as health, agriculture, meteorology, and, increasingly, biodiversity conservation [2–6]. A growing number of studies highlight that TEK can provide effective, sustainable, and low-cost approaches to wildlife monitoring [7, 8]. Its integration into biodiversity management policies has been associated with significantly improved conservation outcomes [9–14], and the direct involvement of Indigenous communities in such programs has been linked to positive ecological impacts [15, 16].

Within this global context, Gabon stands out as a particularly relevant setting. With forest cover estimated at 88–89%, it is one of the most forested countries in the world [17]. It harbours a remarkable diversity of primates between 19 and 21 species including two iconic great apes: the Western lowland gorilla (*Gorilla gorilla gorilla*) and the Central African chimpanzee (*Pan troglodytes troglodytes*) [18]. According to the most recent national census, their respective populations are estimated at approximately 34,764 and 64,173 individuals, distributed across various forest types [19]. Great apes play essential ecological roles, contributing to seed dispersal, forest regeneration [20–22], canopy structuring, and the creation of microhabitats that benefit other species [23, 24]. However, they are severely threatened by habitat degradation (due to logging, mining, and agriculture), poaching, and the emergence of infectious diseases [25–28]. As a result, the Western lowland gorilla is currently classified as *Critically Endangered* and the chimpanzee as *Endangered* on the IUCN Red List [29, 30].

Their conservation thus requires the development and implementation of efficient and sustainable ecological monitoring systems.

Local conservation efforts in Gabon rely primarily on legal frameworks (anti-poaching legislation, creation of protected areas), the deployment of trained personnel for ecological monitoring, and scientific tools such as microscopy and molecular analyses to assess genetic diversity and monitor pathogens [25, 28, 31, 32]. However, the implementation of these techniques remains challenging outside of protected areas due to logistical, financial, and technological constraints. These limitations underscore the need to explore complementary approaches that leverage local human resources and Indigenous knowledge.

In this perspective, the empirical knowledge held by Indigenous communities particularly those in southern Gabon offers a valuable complementary avenue. These populations have long employed traditional methods to identify great ape species based on their feces, using a diverse set of criteria related to appearance, odour, texture, footprints, and surrounding vegetation. Despite their scientific under-recognition, these techniques hold great potential for non-invasive primate monitoring. Nevertheless, despite growing interest in Indigenous knowledge systems, very few studies have rigorously assessed the effectiveness of these traditional approaches as conservation tools. To our knowledge, this is the first study to examine the potential role of traditional knowledge in biodiversity conservation in the Central African region [33].

Against this background, the present study aims to document and assess the reliability of traditional techniques used by Indigenous communities in southern Gabon to identify great ape species through fecal analysis, with the goal of integrating such knowledge into ecological monitoring and conservation programs. Specifically, the objectives of this study are to: (i) document the empirical criteria used by local populations to distinguish between chimpanzee and gorilla feces in natural settings; and (ii) evaluate the reliability of traditional identifications by comparing them with molecular analyses of fecal DNA, while also assessing the potential for integrating this knowledge into participatory conservation strategies.

Methods

Project description

This study is part of a comprehensive, long-term research program dedicated to the conservation of great apes in Gabon. In addition to its social dimension highlighting the role of local communities and traditional knowledge the project integrates both ecological and health-related components to improve understanding and protection of wild gorilla and chimpanzee populations. From an ecological standpoint, the research focuses on the spatiotemporal distribution of great apes, the characterisation of their ecological niches, and the analysis of key behavioural parameters such as diet composition and habitat use.

Complementing this ecological perspective, the project also addresses critical wildlife health issues in accordance with the One Health approach. Specifically, it investigates the diversity of gastrointestinal parasites, enteric viruses, *Plasmodium* species, and other infectious agents that may circulate in wild apes and pose potential zoonotic risks. By combining ecological monitoring with pathogen surveillance, the program contributes to the development of integrated strategies that link conservation biology with ecosystem and public health objectives.

Study site

The study was carried out mainly in the Haut-Ogooué Province, in southern Gabon, within a vast forested area of approximately 10,000 hectares located near the villages of Makatamangoy and Tébé (Fig. 1). Although unclassified and not part of any officially protected area, this forest remains largely untouched by human activity. It provides a suitable habitat for populations of chimpanzees (*Pan troglodytes troglodytes*) and western lowland gorillas (*Gorilla gorilla gorilla*), which roam freely in the region throughout the year. However, to date, no systematic census has been conducted in the area, and both the population size and density of these great apes remain unknown.

In addition to great apes, the forest is home to a diverse community of wildlife, including other primate species such as *Cercopithecus* spp. and *Colobus* spp., as well as herbivorous mammals.

Collection and preservation of faecal samples

During field expeditions conducted between 2015 and 2024, we carried out five missions, each lasting approximately two weeks, in collaboration with the same 22 Indigenous participants primarily men selected by the village chief for their seniority and deep knowledge of the forest. These individuals, highly skilled in interpreting subtle ecological cues and tracking wildlife, were essential to the study's success. In each mission, participants were divided into four groups of five, joined by two research team members to form teams of seven. The groups then dispersed across distinct forest sectors to ensure broad spatial coverage and maximise faecal sample diversity. Whenever faecal matter was encountered, Indigenous collaborators applied their customary ecological knowledge to identify the species responsible. This process involved a detailed examination of multiple diagnostic features, including the shape, size, consistency, and colour of the feces. Additional attention was given to contextual indicators such as nearby footprints and the condition of the surrounding vegetation subtle but informative signs of recent ape activity. Species identification was determined through group discussion and

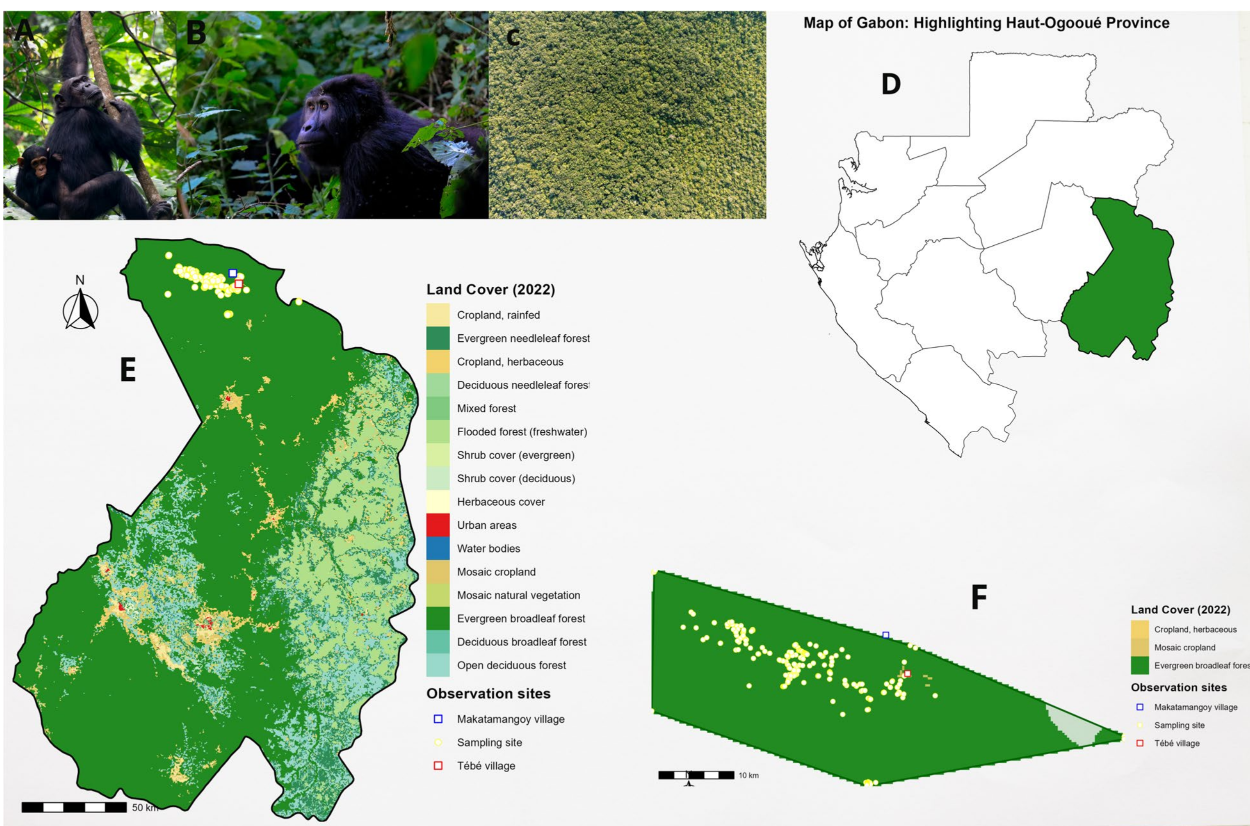

Fig. 1 Study site mapping. **A** Chimpanzee in its natural habitat; **B** Gorilla in its natural habitat; **C** Aerial view of the forest; **D** Map of Gabon highlighting the Haut-Ogooué Province; **E** Map of the Haut-Ogooué Province; **F** Zoomed-in view of the Makatamangoy forest

consensus, reflecting a collective and experience-based decision-making process. All observations and identifications were documented in situ by research staff, who also conducted systematic sample collection for molecular verification.

Each faecal sample identified by Indigenous participants was carefully collected and preserved for subsequent molecular analysis. Samples were immediately placed in RNAlater® solution (Life Technologies, USA) to stabilise DNA integrity and were stored at −80 °C at the Centre Interdisciplinaire de Recherches Médicales de Franceville (CIRMF) until laboratory processing. Each tube was labelled with the collection date, location coordinates, and the field-based species identification, to enable comparison with molecular assignments.

Molecular identification methods

Once the samples were brought back to the laboratory, we conducted precise molecular analyses to confirm or refute the identifications made by our collaborators in the field. The identification of ape species was conducted using faecal DNA extracted with the QIAamp DNA Stool Mini Kit (Qiagen, Courteboeuf, France), in accordance with the methodology outlined in the published literature [25]. To determine the precise provenance of each sample, whether from chimpanzees or gorillas, a comprehensive mitochondrial DNA analysis was conducted in accordance with the protocols established in previous studies [34, 35]. Field-recorded species identifications were confirmed through amplification of a 386-bp mitochondrial DNA fragment of the 12S rRNA gene using primers 12S-L1091 and 12S-H1478. The amplified products (10 µl) were subsequently run on 1.5% agarose gels in TAE buffer. The molecular identification results were compared with the indigenous identifications to assess the accuracy and reliability of traditional knowledge-based species identification.

Qualitative approach to investigate the indigenous knowledge

We conducted semi-structured, face-to-face interviews with 22 experienced hunter trackers from villages in southeastern Gabon who had participated in the faecal-sampling campaigns. All interviewees were fluent in French and renowned locally for their wildlife expertise. Each session lasted ≈ 30 min and followed an interview guide (Annex 1) that explored four domains: (i) personal experience of observing and recognising great ape faeces; (ii) detailed description of the recognition cues employed; (iii) modes of knowledge acquisition and transmission; and (iv) strategies used to resolve uncertainty in the field. Conversations were audio-recorded with prior informed consent and supplemented by systematic field notes. Recordings were later transcribed verbatim for analysis.

Statistical analysis

To analyse the data collected from the interviews, we employed a comprehensive approach that integrated both qualitative and quantitative methods. First, participants'responses were transcribed and organised into key themes based on the questions asked. A thematic analysis was conducted to identify recurring patterns, revealing general trends in the criteria used for fecal identification. Reliability of Indigenous identifications was evaluated against molecular assignments (reference standard). We constructed a 2 ×2 confusion matrix and derived overall accuracy, sensitivity, specificity, positive and negative predictive values, and Cohen's κ with 95% confidence intervals.

To assess the importance of the criteria used by Indigenous communities in identifying great ape feces, we calculated, for each criterion, the proportion of individuals who mentioned it. Responses were coded in binary form (1 =criterion mentioned, 0= not mentioned), and each criterion was analysed independently. This approach allows us to estimate the frequency with which each criterion is used across the surveyed population, regardless of the total number of criteria cited by any given participant. It therefore reflects the proportion of individuals for whom a particular criterion plays an active role in fecal identification, providing a direct measure of its representativeness or individual-level popularity. To assess species-specific patterns in the use of empirical criteria by Indigenous participants, we conducted a comparative frequency analysis between chimpanzees and gorillas. Differences in citation frequencies between the two species were computed and expressed as a delta (Δ), defined as the proportion for chimpanzees minus that for gorillas. To evaluate whether observed differences were statistically significant, we applied Fisher's exact test to each criterion using 2× 2 contingency tables. Criteria with p-values below 0.05 were considered significantly different between species. This analysis allowed us to identify potentially discriminative traits relevant for species-specific fecal identification in natural settings.

Results

Demographic profile and social organisation of the participants

The participants in this study were Indigenous hunter-farmers residing in the villages of Makatamangoy and Tébé, located in southeastern Gabon. Their livelihoods are centred around two primary subsistence activities: small-scale agriculture and bushmeat hunting. Households typically cultivate staple crops such as cassava

(*Manihot esculenta*), taro (*Colocasia esculenta*), and bananas (*Musa* spp.). These communities are socially organised under the leadership of a village chief, who also selected the participants for this study based on their expertise in wildlife tracking and ecological interpretation.

A total of 22 male participants took part in the study. They had a mean age of 45.9 years (range: 30–62) and reported an average of 28 years of experience in identifying animal species based on faecal traces. The vast majority (86.4%) stated that they acquired their skills through observation and learning from elders, while 13.6% reported being self-taught through long-term field experience. On average, participants reported tracking wildlife and specifically encountering great ape faeces approximately 2.36 times per week, with individual frequencies ranging from 1 to 5 such encounters during tracking activities each week (Table 1).

Concordance between indigenous identifications and molecular results

Out of the 637 fecal samples analysed, 633 were correctly identified by Indigenous participants when compared to molecular results, yielding an overall accuracy of 99.37%. Specifically, 331 of 332 samples identified as chimpanzee feces were molecularly confirmed, while 302 of 305 samples identified as gorilla feces were accurate. Sensitivity and specificity were 99.10% and 99.67%, respectively. Cohen's Kappa coefficient was 0.987 ($p < 0.001$), indicating almost perfect agreement between Indigenous identifications and molecular analyses (see Table 2).

Key criteria for faecal identification

In our interviews, participants revealed that seven main criteria are used to identify primate species based on fecal samples: colour, odour, composition, texture, quantity, footprints, and the condition of surrounding vegetation.

Table 1 Descriptive statistics of participants'age, duration of involvement, frequency of identification, and methods of skill acquisition

Variable	Mean	Median	Standard deviation	Minimum	Maximum
Participant Age (years)	45.9	45	8.75	30	62
Duration of involvement in observation (years)	28.0	25.5	8.95	15	45
Frequency of identification (times per week)	2.36	2	1.26	1	5
Methods of Skill acquisition					
Observation of elders and parents	19	0.864			
Self-learning	3	0.136		NA	

Table 2 Concordance between Indigenous identifications and molecular results for great ape fecal samples ($n = 637$)

Confusion matrix

Indigenous identification	Molecular: Chimpanzee	Molecular: Gorilla	Total
Chimpanzee	331 (True positive)	1 (False positive)	332
Gorilla	3 (False negative)	302 (True negative)	305
Total	334	303	637

Performance metrics

Statistic	Value
Overall accuracy	99.37%
95% Confidence interval	98.4–99.83%
Sensitivity (Chimpanzee)	99.10%
Specificity (Gorilla)	99.67%
Positive predictive Value	99.70%
Negative predictive Value	99.02%
Balanced accuracy	99.39%
Cohen's Kappa	0.987
Kappa significance (p)	< 0.001
McNemar's test (p)	0.6171

The confusion matrix compares Indigenous identifications of fecal samples to molecular confirmations. Performance metrics evaluate the accuracy of traditional identifications, and Cohen's Kappa quantifies agreement beyond chance. The high Kappa value indicates near-perfect concordance

All participants (100%) identified colour as the most important factor for distinguishing species, while odour was a key criterion for 86.4% of them. The composition of the feces was noted by 81.8% of respondents as a distinguishing factor, and texture was considered important by 72.7%. Footprints left near the feces were deemed useful by 40.9% of participants. Additionally, the condition of the surrounding vegetation was considered significant by 36% of the participants, while the quantity of fecal matter was mentioned as a relevant factor by 22.7%. (see Fig. 2).

Specific identification criteria for chimpanzee and gorillas feces

Participants reported that chimpanzee feces were frequently identified by their abundance, with 77.3% indicating a high quantity and 68.2% noting a moderate amount. The colour of the feces was typically described as ranging from brown to yellow (77.3%), with some variations from green to brown observed by 45.5%. In terms of olfactory characteristics, a strong odour was noted by 81.8% of participants, while 50% reported a more varied scent. The texture of chimpanzee feces was often characterised as pasty (63.6%) or soft (59.1%). Footprints found around the feces served as a distinguishing feature, with 59.1% of respondents observing less pronounced heel marks and 50% noting faint fist prints. Additionally, the composition of the feces, particularly the presence of mixed plant material, was mentioned by 50% of participants. Environmental disturbances, such as slightly disturbed vegetation near the feces, were also commonly observed, reported by 40.9% of respondents (see Fig. 3A).

For gorillas, colour was the most common distinguishing feature, with 68.2% identifying the feces as black and 45.5% as greenish-brown. Composition was also critical, with 72.7% noting high fibre content and 59.1% acknowledging mixed plant materials as significant indicators. Footprints around the faeces were significant markers, with large heel prints cited by 81.8% of respondents and fist prints by 77.3%. Olfactory characteristics were important, as 72.7% of participants reported varied odours. Additionally, the feces' texture was generally described as hard by 72.7% of respondents. Signs of environmental disturbance, such as broken or flattened vegetation, were noted by 59.1%, indicating possible gorilla presence (see Fig. 3B).

Comparative analysis of faecal identification criteria for chimpanzees and gorillas

Out of the 24 empirical criteria assessed, twelve showed statistically significant differences in their use

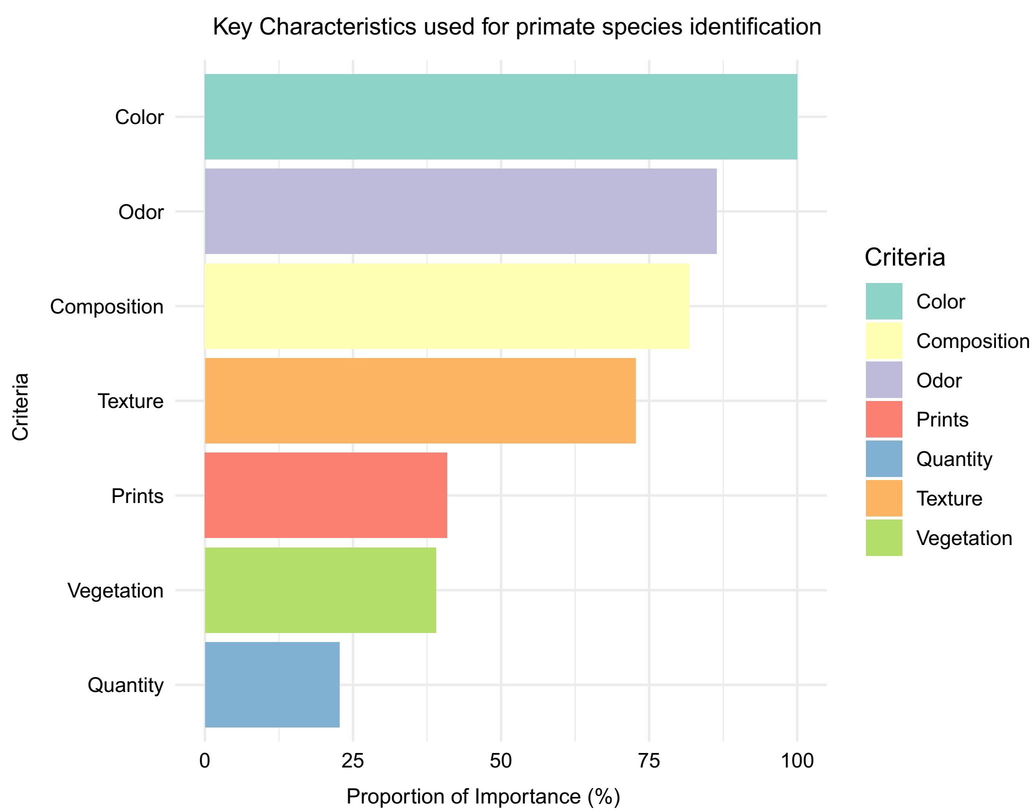

Fig. 2 General criteria used to identify great ape feces

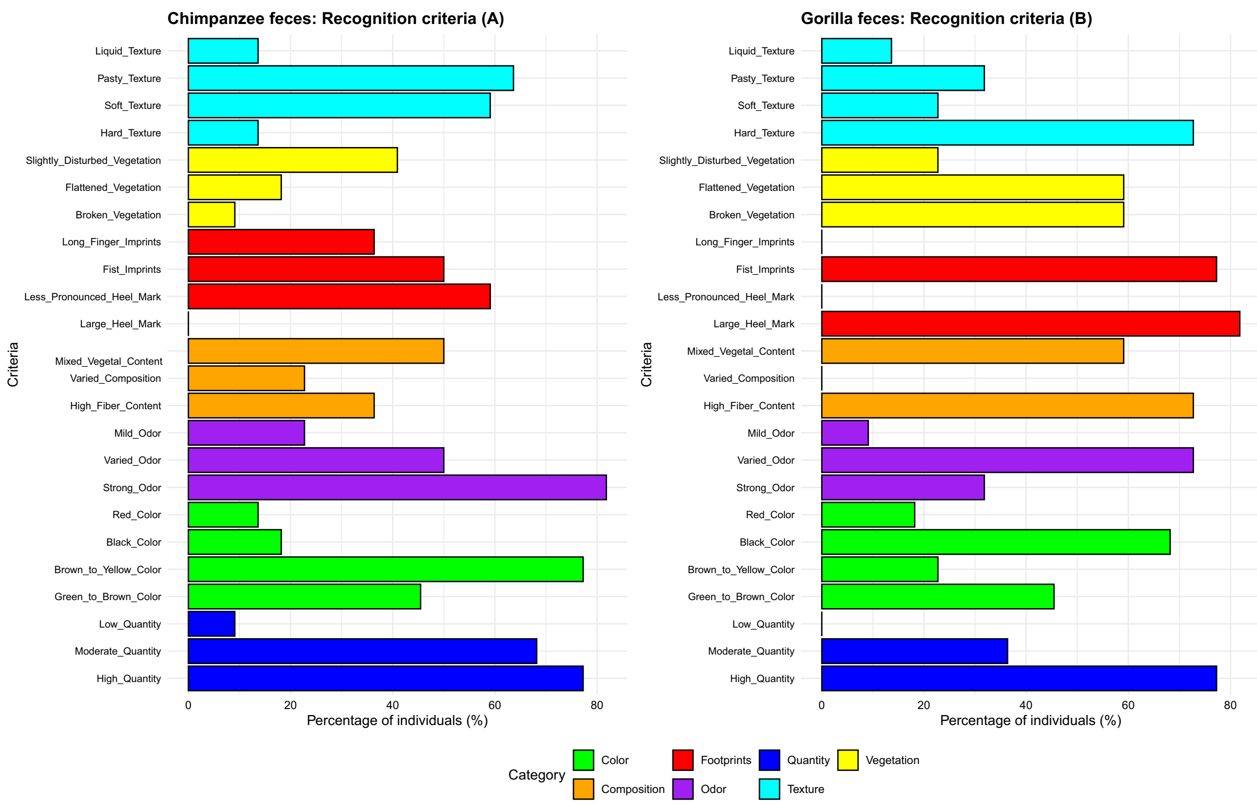

Fig. 3 Frequency of criteria used for species-specific identification of great ape feces. (Legend: Liquid_Texture: Fluid and without a defined shape; Pasty_Texture: Neither firm nor liquid, with a paste-like consistency; Soft_Texture: soft but well-formed; Hard_Texture: Firm and compact; Mixed_Vegetal_Content: Includes both plant fibers and undigested fragments of fruits and seeds; Varied_Composition: Composed of various plant residues such as fruits and leaves, and occasionally includes traces of animal protein, such as hairs or insect fragments; High_Fiber_content: Often contains undigested plant fiber from leaves, stems, and fruits)

between chimpanzees and gorillas ($p < 0.05$), indicating species-specific identification cues. In terms of colour, brown to yellow was more frequently associated with chimpanzee feces, whereas black colouration was more often linked to gorilla feces. Regarding odour, participants more commonly attributed a strong odour to chimpanzee feces. For composition-related cues, rich vegetal fibre content and varied composition were significantly more associated with gorilla feces. With respect to footprint evidence, less pronounced heel-prints and long fingerprints were more frequently reported for chimpanzees, while pronounced heel-prints were strongly associated with gorillas. Concerning vegetation disturbance, flattened vegetation and broken or bent vegetation were more often linked to gorilla feces. Finally, in terms of texture, soft texture was more often mentioned for chimpanzees, whereas hard texture was significantly associated with gorilla feces (see Fig. 4; Annex 2).

Discussion

The findings of this study provide compelling evidence for the accuracy and ecological validity of Traditional Ecological Knowledge (TEK) held by Indigenous trackers in southern Gabon. Out of 637 faecal samples collected during systematic surveys, 633 were correctly identified by local experts, corresponding to an overall accuracy of 99.37%. Disaggregated analysis confirmed high concordance across taxa, with 331 of 332 chimpanzee samples and 302 of 305 gorilla samples correctly classified. The performance metrics sensitivity (99.1%), specificity (99.7%), and Cohen's Kappa ($\kappa = 0.987$, $p < 0.001$) demonstrate near-perfect agreement with molecular results, a level rarely attained in non-invasive wildlife monitoring. The remarkable accuracy of participant identifications appears to stem from many years of observation and knowledge transmission, as participants had on average of 28 years of experience (see Table 1) This exceptionally high concordance validates the capacity of Indigenous

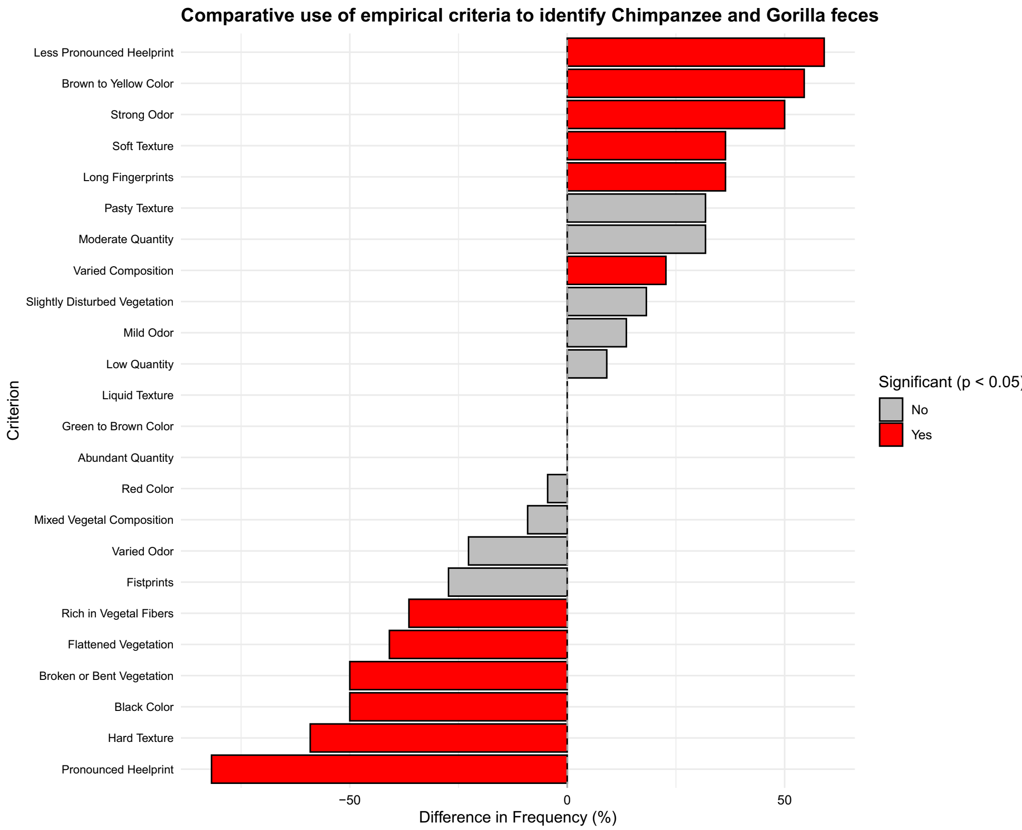

Fig. 4 Comparative use of empirical criteria to identify Chimpanzee and Gorilla feces. Each bar represents the difference in frequency of mention for a given empirical criterion between chimpanzee and gorilla feces, as reported by Indigenous participants. Positive values indicate criteria more frequently cited for chimpanzees, while negative values reflect those more commonly associated with gorillas. Criteria in red are statistically significant ($p < 0.05$) and may serve as discriminating features between the two species

knowledge systems to generate reliable ecological data. Previous studies have highlighted the scientific value of TEK in biodiversity assessment [36–39], and our results provide quantitative support for its formal integration into conservation frameworks particularly in regions with limited technical infrastructure.

The diagnostic process employed by participants rested on seven primary cues: Colour, odour, texture, composition, quantity, footprints, and vegetation disturbance. Each of these criteria is rooted in a biologically meaningful trait, reflecting a detailed ethological and ecological understanding. Colour, cited by all participants, emerged as the most consistent and salient feature. Its variation mirrors diet: fruit-based intake produces lighter, yellowish feces typical of chimpanzees, while fibrous, leaf-rich diets yield darker excreta seen in gorillas [40, 41]. Odour also played a critical role participants distinguished species by scent alone, revealing a level of sensory acuity developed through sustained environmental exposure.

Texture and composition further supported species recognition. Soft, water-rich boluses in chimpanzees contrast with the compact, fibrous dung of gorillas differences that align with known variations in gut morphology and digestive strategy [41–43]. These differences may also indicate physiological responses to diet quality and seasonal variation. The state of surrounding vegetation and footprint impressions added contextual clues: gorilla dung was often accompanied by large heel and fist prints, trampled plants, and disturbed substrates, consistent with their larger body size and terrestrial foraging behaviour [44, 45].

The discriminative power of these empirical traits was statistically supported, with twelve of the 24 assessed sub-criteria differing significantly between species. Importantly, these cues are ecologically anchored rather than anecdotal, suggesting that Indigenous identification is not heuristic guesswork but a process of inference based on ecological signals. This distinction is critical for designing participatory monitoring tools. Our findings allow for the formalisation of an evidence-based field guide that prioritises the most discriminatory traits potentially enhancing training modules for conservation practitioners and community rangers.

Nevertheless, the accuracy of species identification based on feces may be limited by environmental conditions. Decomposition, rainfall, and other factors can alter key characteristics, hence the need to use molecular methods, particularly in contexts where identification ambiguities may arise [34]. However, the strong correlation observed in this study suggests that Indigenous methods remain robust.

The broader significance of our findings lies in the potential for a hybrid monitoring model. TEK not only offers a low-cost alternative in resource-limited areas but also enhances the temporal and spatial reach of surveillance efforts. Its integration can improve early detection of demographic changes, disease emergence, and habitat use patterns, thereby enriching conservation baselines [9]. Moreover, incorporating Indigenous expertise strengthens cultural sovereignty by recognising and legitimising experiential knowledge, a critical ethical dimension of equitable conservation.

The relevance of social representation theory [46, 47] reinforces this position. Indigenous interpretations of ecological signs are not distorted approximations of scientific data but rather coherent systems that operate with different premises and serve different purposes [46, 48]. This plurality of epistemologies should not be viewed as hierarchical but complementary each offering unique insights into complex ecological phenomena. Thus, our results extend the theory of social representations in three ways. First, they document an instrumental representation whose primary function is technical action (high-precision species diagnosis). Second, by comparing indigenous classifications to molecular genetics, we provide rare evidence for the empirical validity of these representations in the context of natural resources. Third, the process we propose illustrates the complementarity of experiential and scientific knowledge, moving the discussion beyond coexistence to the concrete coproduction of conservation data.

Future research should examine the resilience and adaptability of TEK in the face of environmental change. As climate shifts alter species distributions, phenology, and resource availability, it is vital to understand how Indigenous communities perceive, interpret, and respond to these changes. Equally important is the transmission of TEK across generations understanding how knowledge is preserved or eroded can guide policies aimed at sustaining both biodiversity and cultural heritage. These efforts are key to developing conservation strategies that are not only scientifically rigorous but also socially inclusive and adaptive.

Conclusion

This study provides the first quantitative validation of Indigenous faecal-based identification of great apes in Central Africa and shows that local trackers can match molecular diagnostics with >99% accuracy. Such performance underscores the value of TEK for rapid, non-invasive, and cost-efficient monitoring in regions where logistical or financial barriers limit formal surveillance. By formally recognising and incorporating this expertise into conservation frameworks, managers can (i) extend monitoring coverage beyond protected areas, (ii) foster co-management schemes that bolster community ownership of conservation objectives, and (iii) accelerate the detection of population declines or emerging disease threats. Future work should explore training modules that standardise TEK-based protocols, evaluate scalability across different cultural contexts, and quantify the socio-ecological benefits of sustained community engagement in great ape conservation.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13002-025-00792-2.

Additional file 1.

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Author contributions

Conceptualisation: MHMD, LB and DSE; Methodology: PMN, DOE, CMK MHMB, LB, DSE, JZN, APK and NMLP; Fieldwork mission: MHMB, LB, BN and APK; Data compilation and analysis: DOE, MHMB, LB, JZN, CP and CMK; Original draft writing: MHMB, NLP and PMN; Revision and editing: DOE, JZN, CMK, NMLP, SED, PIN, BN and LB; Supervision: LB, NB and PIN. All authors read and approved the final version.

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Availability of data and materials

Data are provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate

The participants in this study all gave their consent regarding the use and documentation of their data and the information they provided on their empirical knowledge.

Consent for publication

Not applicable.

Competing interests

I declare that the authors have no competing interests as defined by BMC, or other interests that might be perceived to influence the results and/or discussion reported in this paper.

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