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Use of Technology in Research and Conservation of Northern Lions (*Panthera leo leo*) in Cameroon: Case Studies from Two National Parks

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Abstract

Effective conservation of wildlife in and outside protected areas is based on sound scientific knowledge, usually made available through research. Few researchers focus on large carnivores in Cameroon, especially lions (*Panthera leo leo*), which occur at low densities, and generally range widely over large, remote areas. Unlike other species, research and conservation action on lions require special methods and technology for effective data collection. This paper reports on the use of technology for lion research and conservation in two sites in Cameroon: Waza National Park (Waza NP), and Bouba Njidda National Park (BNNP). We fitted lions with GPS collars, some with satellite download functionality, and others requiring data downloads over a GSM network. Collaring was achieved using a call playback station method to study the spatial ecology and movement patterns of lions, and their potential interactions with local communities. Additionally, we deployed camera traps in Waza National Park to document lion habitat use and occupancy as well as to assess protected area wildlife diversity. In Waza NP, these technologies revealed that lions spent significant periods outside of the park in local communities predating on livestock and causing conflict with people. Whereas we found that carnivore diversity was relatively high, we also documented an alarming amount of illegal anthropogenic pressure inside the park's boundaries, including pastoralism, poaching, and fishing. Our preliminary findings suggest that in and around BNNP, lions also moved into local communities abutting the park,

suggesting a high potential for human-lion conflict and consistent with anecdotal information provided by these communities. The combined use of these technologies yielded new insights relevant to the management of lions and these protected areas, the mitigation of human-lion conflict, and the planning of ranger patrols, all of which would have been otherwise difficult if not impossible to obtain.

Keywords

Conservation Technology, Lion Conservation, Waza National Park, Bouba-Njidda National Park, Cameroon

1. Introduction

Lions (*Panthera leo*) are Africa's largest terrestrial predators; their presence on the landscape is important to maintaining natural ecological processes [1]. Strategies designed to conserve lions also help landscapes to thrive by providing benefits to both wildlife and local communities alike [1]. Prior research has demonstrated that as top predators, lions can significantly contribute to ecosystem services including carbon sequestration, thereby helping to mitigate the negative effect of climate change. Lions do this in part by regulating herbivore populations, thereby influencing the vegetation available that can absorb carbon dioxide [2]. Lions also have important cultural significance worldwide. In Cameroon and other African countries, lions symbolize power, authority, royalty, strength, courage and leadership [3]. Across Africa, they are important economically in attracting tourists to African savannahs, thereby generating revenue for range states [4].

The conservation of lions is challenged by many threats ranging from habitat loss, prey depletion, human-lion conflict, poaching, and illegal wildlife trade, as well as weak governance and law enforcement among range states [5]. Habitat loss in the form of habitat conversion for agriculture and development, and ultimately its fragmentation, can cause lion and other wildlife populations to become isolated from each other, and sparsely distributed across a large landscape. Human population growth and its consequential pressure on natural resources, including arable land, is increasingly restricting lions to existing protected areas [6]. Decreasing prey populations resulting from habitat loss, and poaching for subsistence and for bush meat trade, indirectly pushes lions to prey on domestic livestock, leading to more frequent incidents of human-lion conflict [6]-[9]. This conflict can directly impact lion populations in the form of retaliatory killings from the human communities that live close to them. Compounding these pressures across sub-Saharan Africa, including Cameroon, are those from extensive transhumance pastoralism, which is increasingly having an impact on wildlife habitat and lion behaviour, and has potential to lead to retaliatory or "preventative" killings of lions.

Despite their ecological, cultural and economic relevance, lions have disappeared from most of their historic range. Once ranging widely from Europe to Asia and

throughout Africa, except deserts and the dense rainforests, today this iconic species has disappeared from more than 80% of its historic range, its populations declining by about 60% in two decades [10]. Today, lions are found only in Sub-Saharan Africa, and in the state of Gujarat in western India [11]. Worldwide, they are listed as "Vulnerable" by the global IUCN Red List of Threatened Species. Of the approximately 23,000 lions remaining in Africa, more than 80% reside in East and Southern Africa. Genetic analyses, however, have distinguished two subspecies of lions in Africa: the Southern lion (*Panthera leo melanochaita*) the more widely distributed lion found in East and Southern Africa, and the Northern lion (*Panthera leo leo*) subspecies, which is restricted to West and Central Africa [12]. These latter lions are much more threatened due to their lower population numbers, and the intensity of challenges to their conservation in West and Central Africa; they are thus listed as "Critically Endangered" in West Africa and as "Endangered" in both regions [13]. Despite their rarity, the conservation of these lions is important for their evolutionary uniqueness, the overall maintenance of genetic diversity for the species, and the preservation of this region's biodiversity. Effective conservation efforts however would be best informed as to knowledge of the status, ecology, and behaviour of the species across the region, including their functional role within ecosystems, but particularly by any interactions with local communities living along the periphery of protected areas.

The research and conservation of free-ranging lions is plagued with challenges, including their low population densities and tendency to range widely across large landscapes [14] [15]. Lions are also nocturnal, can be shy, and generally have limited physical markings suited to individual identification via long distance observations. Furthermore, this research often necessitates extensive fieldwork among scientists in remote, inaccessible, and/or difficult terrains. Compromises to governance schemes and national security as a result of regional armed conflicts in West and Central Africa, including around key protected areas, further compound these challenges [16].

The many obstacles to the conservation of lion and other carnivores, however, present real opportunities for integrating technological tools to overcome them. Technology can enable effective monitoring of lion populations, tracking of their movement, better understanding of their behavior, and facilitation of data collection to address threats, like the intensity of human-lion conflict, and poaching [17]. Technology can also help prevent and/or reduce human-wildlife conflict by alerting management officials and community liaisons as to when lions stray from protected areas into neighbouring communities [18] [19]. In West and Central Africa, research on lions and other carnivores has lagged behind that of other regions. Not surprisingly, the use of different technologies in this context has been slow to evolve in this region. Still, there have been recent camera-trapping surveys of large mammals and pangolins in the Dja Biosphere Reserve [20] [21] and Deng Deng National Park [22]. Similarly, a survey of Waza National Park for lions found that leopards had already disappeared from the park [23].

In northern Cameroon, two lion conservation units that include four national parks are consistently plagued by insecurity due to armed terrorist conflicts and transhumance pastoralism. This has impeded scientists and conservationists working in this area, particularly in the case of Waza National Park, as the presence of such in more recent years have made data collection or engagement increasingly risky and challenging. Use of appropriate technology can help partially address these challenges by facilitating remote monitoring over longer periods, and collecting information valuable to communities, thereby reducing the direct dangers to conservation professionals and scientists.

Beyond camera-trapping, technology like drones, new and advanced forms of remote sensing, and the use of satellite GPS and GSM collars, are providing unprecedented insights into the behaviour of different species, their population dynamics, and their use of habitat. They can also enable more effective responses to threats and challenges in close to real time. The use of satellite GPS telemetry in lion research and conservation is now widespread across other lion range countries. Satellite GPS collars have been used in conservation management of the endangered Asiatic lions [11] and to drive an alert system to mitigate human-wildlife conflict in Botswana's Okavango Delta [14]. In addition, use of a customised Cyber tracker application installed on an android smartphone to record lion locations, has been reported for Pilansberg National Park in South Africa [24]. While countries such as Botswana and South Africa pioneer the integration of more advanced technology in lion research and conservation, Cameroon faces more limited resources and expertise. The aim of this paper is to report the successful use of technology for lion research and conservation and its relevance in two important protected areas of Cameroon: Waza National Park (Waza NP) and Bouba Njidda National Park (BNNP). We also discuss technology's relevance for lion conservation, and its potential for use in real time management to benefit local communities by precluding human-lion conflict or otherwise facilitating coexistence.

2. Materials & Methods

The use of technology in this research occurred in collaboration with technical partners and the government institution in charge of wildlife and protected areas (MINFOF). We followed [25] as adapted from [26] for attaching Satellite GPS and GSM collars to lions at both sites. For the establishment of camera-trap stations in Waza National Park, we followed [27]. Our study sites for this study included two national parks in Cameroon: Waza National Park, and Bouba Ndjidda National Park (**Figure 1**).

2.1. Waza National Park

Waza National Park (Waza NP) occurs in the Sahel Savannah biome of the Far North Region of Cameroon between latitudes 10˚50'N and 11˚40'N, and between longitudes 14˚20'E and 15˚00'E. It lies in close proximity to Cameroon's borders with Nigeria to the West, and Chad to the East (**Figure 1**). Waza NP still hosts a

rich diversity of mammals including emblematic species like northern lion (*Panthera leo leo*), elephant (*Loxodonta africana*), giraffe (*Giraffa camelopardalis*), spotted hyaena (*Crocuta crocuta*), stripped hyaena (*Hyaena hyaena*), roan antelope (*Hippotragus equinus*), topi (*Damaliscus topi*) and western kob (*Kobus kob kob*). Unfortunately, several other carnivores may have already disappeared from the park. The openness of the park's habitat makes photography and other types of tourism an attraction in the region and indeed, when the area was still considered safe, relatively large numbers of tourists from all over the world regularly visited [28]. The presence of a rich avifauna, including migratory birds from Europe wintering in this park, also provides fertile ground for research and opportunities for bird watching, factors which guide decision making and conservation efforts. About 70% of the WNP's 1700 km2 total area is dominated by clayey soils, and approximately 40% of the park is inundated with rain and flood waters from the River Logone, mostly during the wet season. This flooding can make access difficult at certain times of the year, thereby restricting when research can take place using more conventional approaches. However, to truly have a comprehensive understanding of the ecology and behavior of lions in this park, studies should cover all seasons.

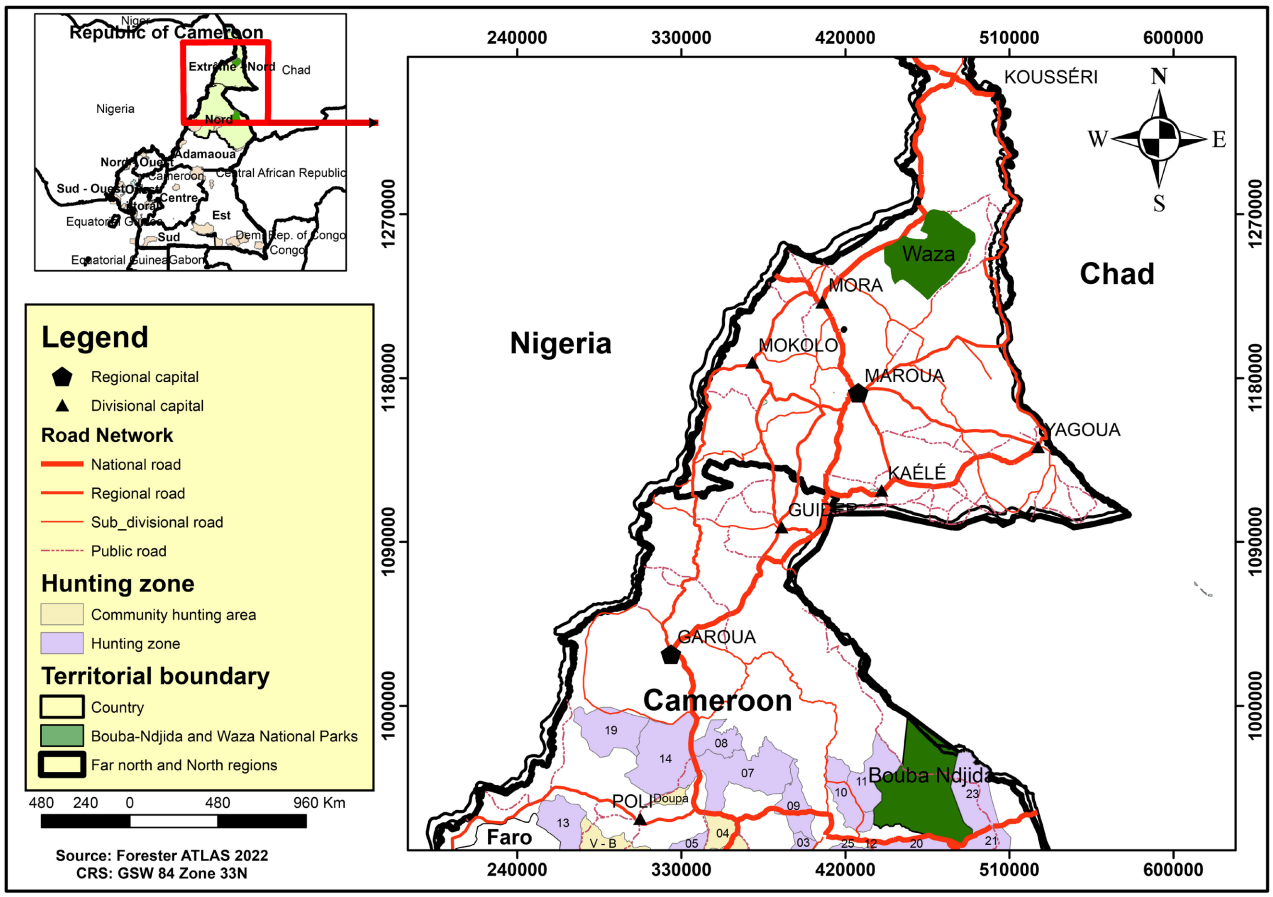

Figure 1. Map of study sites: Waza National Park and Bouba Ndjidda National Park, Cameroon.

Research on lions began in WNP in the late 1990s [29] and continued from the late 2000s [30]. The use of telemetry-based movement tracking was ultimately incorporated in lion research in Waza NP as one of the first projects to investigate the spatial ecology of lion in West or Central Africa. However, it soon became clear that beyond basic questions of habitat use and home range size, telemetry had great potential to be used in addressing human-lion conflict over livestock depredation. We collared four lions with GPS collars (from VECTRONICS Aerospace) that allowed data to be downloaded via satellite; in addition, three more lions were collared with African Wildlife Tracking (AWT) GPS collars, which allow data to be downloaded over a GSM mobile network. In addition, all collars also carried VHF transmitters that allowed researchers to conveniently locate lions in the field as necessary using a handheld antenna and receiver. In total we collared four female and 3 male lions between 2007 and 2010 in Waza NP for results reported in this paper.

We also deployed camera traps in Waza NP with the aim of recording lion behavior and estimating density, as well as survey all wildlife species that might serve as natural prey to lions in the park. During a rapid survey which lasted for 6 weeks, we deployed 63 camera traps (Stealth Cam MC2-GV) with the goal of maximizing sampling coverage over the entirety of the park, *i.e.*, the minimum distance between any two stations at 7.55 km in 2009. Cameras were again deployed in the field to a lesser extend in 2021 during a month, for a rapid biodiversity and threat survey.

2.2. Bouba Ndjidda National Park

We conducted similar research in Bouba-Ndjidda National Park (BNNP), a key hotspot for lion conservation in Cameroon; BBNP is part of the larger Benoue Protected Area complex, and also a critical part of the larger Bouba Ndjidda–Sena Oura landscape. BNNP is situated in the North Region of Cameroon between latitudes 08˚21'N - 09˚00'N and longitudes 14˚25'E - 14˚55'E (**Figure 1**). It includes a total surface area of 2200 km2, and is surrounded by five trophy hunting zones. The Benoue complex is one of the largest strongholds for northern lions in Central and West Africa. Other prominent wildlife in this park includes elephant (*Loxondonta africana*), leopard (*Panthera pardus*), spotted hyaena (*Crocuta crocuta*) giraffe (*Giraffa camelopardalis*), Derby's eland (*Taurotragus derbianus*), waterbuck (*Kobus ellipsiprymnus*), topi (*Damaliscus lunatus korrigum*) buffalo (*Syncerus caffer*), western kob (*Kobus kob kob*) among others. In BNNP, we fitted three GPS satellite collars from African Wildlife Tracking (AWT) on lions; one adult female, and two adult males in 2024. The collaring protocol was similar to that used in collaring lions in Waza National Park. We used speakers to broadcast amplified prey distress calls to attract lions for collaring; these efforts were then followed by chemical immobilization protocols in accordance with established best practices for large carnivores [31] [32]. Although attaching such collars to lions is fairly routine in East and Southern Africa [33]-[35], to our knowledge, this effort rep-

resented the first deployments of GPS collars on lions in BNNP.

From the study in Waza NP, lion home range, lion population estimates and lion prey preference have been previously published. Aspects considered in this paper include carnivore diversity, anthropogenic pressure, lion behavior while in BNNP, preliminary lion behavior and its application to patrols and human wildlife management were considered. The comparison of findings of the use of technology in these two sites is novel.

3. Results & Discussion

We analyzed the GPS Satellite and GSM collar data from Waza NP using ARCGIS software (ESRI), another important technological tool at our disposal; this helped us to produce robust and detailed lion home range maps. We found that lions spent a significant amount of time outside the park among peripheral communities, suggesting potential for conflict with humans sharing the same space as reported earlier by [36]. These findings allowed us to further investigate the relationship between lions and livestock and in particular, where depredations may have occurred. After analyses of GPS coordinate clusters from collars that indicated lions spent 4 hours at night in one location, we prioritized search of these areas using a handheld GPS unit. This allowed us to identify livestock carcasses in communities outside as well as inside the park, and to determine that the same lions preying upon livestock also preyed on native species inside Waza NP. Following these findings, we were able to direct more management efforts towards raising awareness among pastoralists on how to coexist with lions, particularly the keeping of livestock in enclosures at night after herding during the day. These technologies also allowed us to recommend increased surveillance and engagement with communities by park authorities; however, these options frequently suffer from lack of funds, administrative and socio-political ties, as well as corruption [5].

Camera traps captured three large carnivore species in Waza NP, as well as nine smaller carnivore species (**Table 1**). We also recorded eight additional small to large mammals in the park. Interestingly, we documented the striped hyaena (*Hyaena hyaena*) in Waza NP, which had not been recorded for quite some time; prior to our survey, it was unclear if this species was still present. Conversely, our previous work concluded that the leopard (*Panthera pardus*) had surprisingly been extirpated from this ecosystem [23] after camera-traps deployed across the entirety of Waza NP failed to record them. Most surprisingly perhaps, and useful to park managers, was the level of anthropogenic pressure we found inside the park. Ignoring blank photos and false triggers caused by wind, blowing vegetation, and falling leaves, approximately 31% of the 906 photos recorded were of humans and cattle inside the park.

Some challenges were encountered during our survey, for example, Waza NP largely lacks a network of navigable tracks, which made installation of camera-traps quite difficult. In addition, the type of cameras we used required regular

changing of batteries and memory cards, which added further to the pressure on human resources. Newer, more advanced cameras, including those integrating use of solar power and allowing remote access to images, would certainly increase performance and efficiency in the future. A more robust network of roads and drivable tracks would also facilitate more efficient deployment and monitoring of research equipment, thereby enhancing both surveillance and data collection efforts. Regardless, the data we collected via camera-trapping ultimately revealed exciting ecological patterns and conservation issues that were relevant to park management, and which would have been very challenging to obtain without its integration.

Table 1. Large and small carnivores captured on camera traps in Waza National Park.

Species	Scientific name	IUCN Status	National Status
Lion	*Panthera leo leo*	Endangered (En)	Class A
Striped hyaena	*Hyaena hyaena*	Near threatened (NT)	Class B
Spotted hyaena	*Crocuta crocuta*	Least concern (LC)	Class B
Jackal	*Canis aureus*	Least concern (LC)	Class B
Serval	*Leptailurs serval*	Least concern (LC)	Class B
African civet	*Civettictis civetta*	Least concern (LC)	Class B
African wild cat	*Felis silvestris*	Least concern (LC)	Class B
Honey Badger	*Mellivora capensis*	Least concern (LC)	Class C
Genet	*Genetta genetta*	Least concern (LC)	Class B
White tailed mongoose	*Ichneumia albicauda*	Least concern (LC)	Class C
Egyptian mongoose	*Herpestes ichneumon*	Least concern (LC)	Class C
Banded mongoose	*Mungos mungo*	Least concern (LC)	Class C

Preliminary analysis of tracking data for lions fitted with GPS satellite and GSM collars in Bouba Ndjidda NP (BNNP) revealed important insights into lion ranging and movement patterns. For example, we found that lions moved out of the park and into neighbouring communities, which is consistent with the potential for conflict with people over livestock. Notably, real-time monitoring of collared lions is now being integrated into a decision-support system designed to guide targeted ranger patrols, and inform local communities about lion proximity. We believe this will enhance the coexistence efforts around BNNP and its peripheral zones, including potentially enhancing benefits to the Sena-Oura Biosphere Reserve in Chad.

Despite the tremendous value that lion collars provided, we also encountered challenges during the collaring and monitoring process. For example, the limitations in GSM coverage precluding regular data transmission, difficulties in locating lions for capture due to their low population density, all presented us with logistical considerations. Risk of collar failure in harsh environmental conditions may occur in the course of time as observed in Waza NP and also reported by

other researchers [37]. However, this work allowed us to build local capacity for future collaring and monitoring operations, facilitate effective trans boundary collaboration between Cameroonian and Chadian conservation teams, and generate a baseline dataset valuable for long-term conservation planning in the Bouba Ndjidda-Sena Oura landscape. Through the use of this technology, we were also able to effectively target community engagement activities, as more local people are now more involved in lion monitoring and early warning initiatives.

In the future, we hope to expand our collaring efforts to include a larger sample size, and better capture intra-population variability in lion space use. We also plan to integrate combined use of GPS data with camera-trap surveys and community-reported sightings to improve efforts to reduce human-lion conflict, as well as build long term trans-boundary cooperation between conservation efforts in Cameroon and Chad. In the short term however, the GPS lion movement data we collect could also highlight community needs relevant to the design of a regional land use plan, and hint at the location of future potential wildlife corridors; this would help strengthen the resilience of lion populations in the face of accelerating habitat fragmentation and human population expansion [38]. We believe the use of satellite collars represents a transformative step toward science-based conservation of lions in BNNP, which is paving the way for more informed management interventions and enhanced coexistence with human communities.

3.1. Comparative Use of Technology in Waza NP and BNNP

Some of our key preliminary findings and challenges associated with the GPS collaring initiative in Bouba Ndjidda National Park (BNNP) were similar to those we obtained from Waza National Park (Waza NP). For example, for both parks, our data indicated that lions frequently moved outside protected area boundaries and into adjacent community lands. This increased the potential for human-lion conflict resulting from livestock depredations and indeed, we could confirm this on occasion in both parks through analysis of GPS cluster points. The logistical challenges for technology in both parks were similar, including limited accessibility, harsh environmental conditions, remoteness and its relevance to signal coverage, all of which likely impacted these studies. Additionally, our camera trap surveys in Waza NP highlighted significant anthropogenic pressures-including pastoralism and poaching, which the lion collar data for the BNNP seemed to indicate was also true for that park. We should note, however, that whereas our research in Waza NP has benefited from a larger sample of collared lions and a longer, multi-annual history of using technology-based monitoring, our efforts in BNNP are only at a preliminary stage. As such, sample sizes are still small. Despite the asymmetrical investment in these two sites, our findings from each highlight the importance of adaptive management and multi-site comparisons to achieve bigger lion conservation insights in northern Cameroon, a geographical region that has received little such attention otherwise. In fact, insights gained from our more extensive work in Waza NP has already informed the design and implementation

of monitoring strategies in BNNP, despite comparably less data directly from the latter park. Moreover, this data will likely remain important in the context of human-lion conflict interventions throughout the northern part of the country.

3.2. Limitation of the Studies

The findings of these studies and their inferences face some methodological limitations such as small sample size which restricts statistical analysis. Unequal monitoring histories between parks introduce variability in sampling effort. Also acquiring data was hindered by poor GSM coverage which interrupted real-time transmission and data recovery. Finally, the restricted camera-trap survey window limited our ability to capture long-term seasonal trends.

4. Conclusion

Our studies demonstrated the importance of technological tools like GPS satellite collars and camera traps as being cost-effective, practical, and almost invaluable to lion research and conservation planning in Cameroon's national parks and adjacent trans-boundary habitats and protected areas. We found that lions frequently moved beyond park boundaries and that this sometimes led to increased conflict with local communities. In addition, through the use of camera traps in Waza NP, we for the first time were able to record the diversity of carnivore and other mammal species still present in the park. We were also able to document the substantial anthropogenic pressure that now exists on Waza NP through our records of people and their livestock inside the park. The use of technology in BNNP allowed us to enhance local capacity among rangers in addressing human-lion conflict by integrating real-time monitoring of collared lion movement. It also helped to facilitate broader trans-boundary collaboration between professionals in Cameroon and Chad by generating a baseline dataset with relevance to long-term lion conservation in the larger Bouba Ndjidda-Sena Oura landscape. The technology we used also helped us foster more targeted community engagement of local people adjacent to BNNP, who benefitted from knowing when lions were using their lands and/or moved close to their livestock. The application of these technologies therefore more effectively informed conservation planning among rangers and Ministry officials, and allowed for more targeted management interventions. Future efforts should prioritize the integration of advanced, durable equipment, and a robust signal infrastructure, to facilitate effective research and surveillance. We further believe that the continued investment in both technological innovation and human resource development is essential for the effective conservation of lions in Cameroon, and the promotion of their coexistence with local communities. Finally, we believe that growing human capacity development should build on international networks and partnerships that promote the continuous integration of technological advancements in alignment with new forward-looking national and international policies concerning their use in conservation, and shift in the focus of funding to support this alignment.

Ethics Statement

All research described above was done with permission from the relevant authorities, including the Ministry of Forestry and Wildlife, Ministry of Scientific Research and Innovation of Cameroon as well as CITES. Camera trap images of individually identifiable people were deleted after they were recorded. Lion immobilization took place following strict protocols to protect the safety of people and the welfare of the animals under the veterinary expertise of Wildlife Veterinary Doctors.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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