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Utilization of fauna resources for therapeutic purposes as a barrier to species justice advocacy in Nigeria

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Efforts to reduce the irrational exploitation of wildlife, aimed at achieving species justice, continue to be challenged by the persistent demand for animal parts and derivatives in formulating alternative medicines in certain regions of Nigeria. This study focuses on the Kuto, Iberekodo, Itoku, and Lafenwa markets in Ogun State, known for the many traditional medical practitioners relying on these markets for alternative remedies. Data were collected through a semi-structured questionnaire distributed randomly to 165 traditional medicinal vendors. The survey identified 49 animal species of conservation concern; these are categorized as follows: two molluscs, two amphibians, two insects, five fish, eight reptiles, nine birds, and 21 mammals. Various animal parts are traded for spiritual empowerment and disease treatment in these markets. This trade negatively impacts conservation efforts and undermines the collective endeavors of all stakeholders to promote species justice in Nigeria.

KEYWORDS

traditional medicine, illegal wildlife trade, species justice, wet market, biodiversity conservation

Introduction

The practice of utilizing wildlife for therapeutic purposes has a long history and is sometimes categorized as “complementary” and “alternative” medicine in certain countries according to [Alves and Alves \(2011\)](#). Medicinal items (plants and animals) are mostly traded in local and traditional city markets, particularly as raw materials ([Monteiro et al., 2010](#); [Alves and Alves, 2011](#)). According to [Alves et al. \(2012a\)](#), local markets typically feature separate areas dedicated to selling medicinal plants and animals. Ethnobotanists

have shown a growing interest in the markets for medicinal plants (Monteiro et al., 2010; Mati and de Boer, 2011). Until recently, however, the trade in animals for medicinal purposes has largely been overlooked. Recent research shows that this area is attracting attention due to a growing market for traditional medicine, mostly operated by herbalists in different marketplaces (Oliveira et al., 2010; Ferreira et al., 2012).

Traditional medicinal practitioners, traders, hunters, poachers, and, occasionally, middlemen are among the many people who make their living from traditional medicine. Many of these individuals rely only on hunting, processing, and trading wildlife as their primary source of income because of their economic and social backgrounds (Soewu, 2008). However, Simmonds (1998) hypothesized that individual species will suffer, and regional or perhaps global conservation may be in jeopardy if enough money is generated from the trade in wild animals. Unfortunately, there is no question that the trade in animals as traditional medicinal recipes will continue to thrive because human ailments will always need to be addressed (Soewu, 2008). This would directly lead to the ongoing loss of these wildlife resources in the wild since most wildlife traded for use in traditional medicine formulations are sourced from the wild (Marshall, 1998). The number of these wild resources is decreasing quite drastically (Anon, 1999).

Traditional medicine formulations remain a crucial source for preventative and curative healthcare, catering to a significant portion of the global population, with approximately 80% still relying on traditional medicine for their primary healthcare needs (Ajagun et al., 2017). Traditional medicine encompasses diverse therapies and practices that vary across countries and regions, sometimes in conjunction with Western medicine (Herman et al., 2018). Animal species are essential ingredients in traditional medicine formulations, including their parts and by-products, such as skin, head, excreta, fur, feathers, bones, glands, etc. These formulations have demonstrated effectiveness in preventing, curing, and managing various diseases like hypertension, diabetes, epilepsy, cancer, convulsions, and mental illness (Friant et al., 2022). Numerous wild species face local or regional extinction due to the increasing demand for wildlife derivatives used in traditional medicine across developing countries (Alves and Rosa, 2007). Some researchers suggest that this demand is closely linked to poverty, urbanization, and associated social challenges (Alves and Rosa, 2010). Additionally, it is important to recognize that many individuals in these countries often lack adequate healthcare services (Fronterias, 2001).

Although unjustifiable, traditional medicine is crucial in healthcare delivery systems, particularly in Nigeria and the southwestern region (Erinoso and Aworinde, 2012). Historically, using animals in traditional medicine was more prevalent in rural areas where healthcare facilities were lacking (Soewu et al., 2012). However, the reliance on wildlife products, often sourced from threatened or endangered species, has placed increased pressure on the wildlife population and, in turn, dwindled the advocacy for species justice. This potentially negatively impacts conservation efforts, especially considering the popularity of wildlife derivatives as an ingredient in many Nigerian dishes and for medicinal purposes (Adebowale et al., 2024; Alarape et al., 2017).

According to recent studies, several animal species are trafficked for therapeutic use in urban areas around the world, particularly in Latin American, Asian, and African nations. Studies reveal both parallels and discrepancies among the chosen animals. El-Kamali (2000), for instance, found 23 species utilized in Central Sudanese traditional medicine, while Sodeinde and Soewu (1999) found 45 species in Nigeria. A total of 44 species were reportedly marketed in herbalist stores in the Eastern Cape region of South Africa by Simelane and Kerley (1998). Additionally, excluding domestic animals, diverse marine invertebrates, and fish, Cunningham and Zondi (1991) reported no less than 79 species of vertebrates in KwaZulu-Natal Province, comprising birds of about 16 species, 18 reptiles, and 45 mammals.

Ngwenya (2001) reported that 132 vertebrate species, including 79 mammals, 32 birds, and 21 reptiles, were traded in KwaZulu-Natal Province. Of them, 50 species, including baboons and mambas, with a few others, were highly sought after. Whiting et al. (2012) found 147 vertebrate species in South Africa, which accounted for roughly 9% of all vertebrate species in the country and 63% of those traded there. Although Ashwell and Walston (2008) reported 47 species in Cambodia, investigations conducted in Brazil found approximately 180 animal species marketed for medical purposes (Alves, 2010). Most of the 100 therapeutics sourced from 68 animals that Nguyen and Nguyen (2008) reported were available in Ho Chi Minh City as gels or dried portions prepared by boiling animal carcasses.

The ongoing use of wildlife for traditional medicine often overlooks the conservation status of the species involved (Alves et al., 2021). Traders and farmers hunt these species without recognizing the importance of wildlife conservation (Damania and Bulte, 2007). The demand stemming from traditional medicine constitutes a significant factor contributing to the overexploitation of various wildlife species populations (Soewu and Adekanola, 2011). Scott et al. (2010) observed that many species used in traditional medicine are at risk of becoming threatened or endangered, with the possibility of extinction if appropriate conservation policies and a demand for species justice are not taken seriously by the relevant authorities.

According to Nurse (2013), wildlife laws are essential to promote species justice because they enable the modern criminal justice system to extend beyond traditional human-centered notions of justice, which often focus on punishment or rehabilitation. These laws incorporate both restorative and reparative principles for humans and non-human animals. However, the legal protection of wildlife is often primarily driven by their economic or property value. As a result, these legal safeguards are generally limited to situations where the use of animals aligns with human interests, such as when animals are utilized for food or subjected to other forms of commercial exploitation, like the trade in skins, body parts, or derivatives.

Despite the efforts of federal and state governments and NGOs to combat wildlife and forest crimes through the establishment of agencies and the utilization of the legal system, Nigeria continues to face significant challenges in curbing wildlife trafficking across its borders. NGOs in Nigeria have made several efforts to establish a

sustainable species justice system by ensuring that the national government takes its various laws, frameworks, and policies on wildlife matters seriously. These measures are allegedly enforced by the National Environmental Standards and Regulations Enforcement Agency (NESREA). They are guided by international agreements like CITES to control wildlife exploitation. The duties assigned to NESREA in Nigeria include biodiversity preservation, environmental protection, and the advancement of sustainable natural resource management. The agency works with stakeholders domestically and abroad to enforce environmental norms and laws. Protecting Nigeria's land, water, air, forests, and wildlife is part of its goal. As stated in Sections 7(a), (c), and (e) of its Act, one of its primary duties is to prevent wildlife crime. While Section 7(c) focuses on respecting international agreements on a range of environmental challenges, such as incorporating the culture of the species justice system, Section 7(a) requires the implementation of environmental legislation. Guidelines governing biodiversity protection, sustainable ecosystem management, and the utilization of natural resources are enforced by Section 7(e) (Gbadegegin, 2023).

Nigeria's primary wildlife protection law is the Endangered Species (Control of International Trade and Traffic) Act (ESA), established in 1985 and revised in 2016. The ESA aims to protect endangered species by regulating hunting, capturing, and trading activities. Species classified as threatened require special permission for exceptions. Section 6 bans harmful practices, including the use of toxic substances and explosives. Violators face heavy fines: ₦5,000,000 for first-category species and ₦1,000,000 for second-category animals, with repeat offenders risking jail time. Despite these measures, illegal exploitation of protected species, such as pangolins, remains a significant problem (Gbadegegin, 2023).

According to Gbadegegin (2023), Nigeria adheres to the Protection of Endangered Species in International Trade Regulation 2011 (PESITR) in line with CITES, regulating the trade of live specimens, leather, jewelry, and medicinal products to protect endangered species. Trade involving Appendix II species requires permits, while Appendix I species are prohibited except under special circumstances. Enforcement is handled by the Nigerian Customs Service and the National Wildlife Enforcement Monitoring Unit, with penalties including fines of up to ₦5 million and imprisonment for 3 years for individuals and up to ₦21 million for companies, with senior executives facing up to 7 years in prison for violations. Section 7(3) criminalizes possessing, selling, or displaying unlawfully obtained specimens.

Despite the various measures taken to address the issue of illegal wildlife exploitation and trade, Nigeria has been a major source and transit nation for wildlife products that have been illegally traded in the last 10 years. In its World Wildlife Crime Report (WWCR) 2020, the United Nations Office on Drugs and Crime (UNODC) stated that the quantity of pangolin scales seized at Nigerian ports increased dramatically from 2 tons in 2015 to 51 tons in 2019. Nigeria is a major player in the illicit ivory trade, as Nigerian ports handle about 25% of all seized ivory globally. Nigeria confronts major obstacles in strengthening its ability to handle wildlife

trafficking and sustain species justice, even though national and state governments have tried to address wildlife and forest criminality by creating specialized agencies and legal frameworks (Gbadegegin, 2023). Considering the conservation status of numerous animal species involved in the illegal wildlife trade and the subsequent utilization for medical purposes (Alves et al., 2010), it is imperative to conduct more comprehensive inventories of the species involved, along with an analysis of the ecological and health impacts of their use which drive the illegal exploitation (Ferreira et al., 2009). This study examines the unjustifiable therapeutic use of wildlife derivatives and proposes a framework for a species justice system to address the ongoing exploitation of these species in southwestern Nigeria.

Methodology

Study area

The research was conducted in Abeokuta, the capital of Ogun state, positioned between longitude 3°30' north and 3°37' east and latitude 7° and 7°5' north. Situated on the east bank of the Ogun River, Abeokuta is located 77 km north of Lagos by railway or 130 km by water (Oluremi et al., 2021). The town is characterized by two significant rivers, the Ogun and Oyan rivers, which converge north of Abeokuta. The altitude of Abeokuta ranges between 0 and 200 m above sea level within the lowland area (Soaga et al., 2014). Abeokuta is recognized for its trade in palm oil, lumber, natural rubber, yams, rice, cassava, maize, cotton, fruits, and shea butter. It is a crucial export hub for cocoa, palm products, fruit, and kola nuts. Positioned beneath the Olumo Rock, housing caves and shrines, the town relies on Oyan River Dam for water supply, although its reliability is inconsistent. The dam is situated in Ogun State's Abeokuta North local government area, approximately 20 km northwest of the state capital (Aluko, 2018). Abeokuta serves as the headquarters of the Federal Ogun-Oshun River Basin Authority, overseeing the development of land and water resources for Lagos, Ogun, and Oyo states. Responsibilities include irrigation, food processing, and electrification. Local industries in Abeokuta encompass fruit canning plants, plastics, breweries, sawmills, and an aluminum products factory. South of the town are the Aro granite quarries (Aderogba et al., 2012).

Research design

The study employed a survey approach similar to those used by Adeola (1992), Soewu et al. (2012), and Adebowale et al. (2024) to gather relevant data from the appropriate participants. Before initiating the study, the researchers conducted a pilot survey to identify and establish the rationale for selecting the study area. The research drew on findings from Soewu et al. (2012) and Adebowale et al. (2024), who reported significant wildlife trade transactions occurring in various markets within Ogun State. However, their

studies did not address some critical markets located near viable forest ecosystems, as they primarily focused on markets close to human habitation. Given that the proximity of wet markets to forested areas could increase wildlife hunting, potentially leading to quick sales in these markets, as suggested by [Ijose \(2018\)](#), we determined that such locations would be ideal for our study.

By employing a stratified sampling method, we identified several markets with potential wildlife trade. We then spent 2 weeks monitoring market transactions in our pilot study. After consistently observing wildlife and its derivatives being traded, we identified four markets where these activities are most prevalent: Kuto, Iberekodo, Itoku, and Lafenwa. At these markets, we noted the presence of traditional medicinal vendors who facilitate the illicit trade of wildlife. They were arranged in stalls where they sold wildlife derivatives and other processing ingredients. To gather accurate data, we conducted a population census of these vendors to determine their number. This helped us to establish the quantity of samples we needed to collect. Our focus was specifically on vendors selling wild animals, whether whole or in parts.

We prepared a questionnaire for the main survey based on the information gathered from the pilot study. This questionnaire was designed and tested to determine the time required to collect data from vendors and assess the inventory of wildlife derivatives available at each market stall. The results from this trial provided us with an estimate of the time needed to collect data from each market. The questionnaire was designed to gather information about the participants' socio-demographic characteristics, including age, gender, and marital status. Additionally, it covered topics related to using animals in traditional medicine, specifically focusing on the types of animals used, the specific parts of the animals utilized, and the therapeutic purposes for which they are employed.

Data collection

The study was conducted over a 3-month period, from February 2022 to April 2022. The Kuto, Iberekodo, Itoku, and Lafenwa markets in Abeokuta were purposefully selected as they represent the four major markets frequented by artisans and vendors specializing in traditional remedies, as shown in [Figure 1](#). These markets were chosen for their proximity to significant forest ecosystems. Based on information from our pilot study, a purposive and convenient sampling technique was used to identify market vendors who primarily trade in wildlife parts and derivatives for traditional medicine and other uses within the selected stalls. The markets typically operate 5 days a week. We approached the vendors in the morning when hunters brought fresh wildlife carcasses, as emphasized by [Alarape et al. \(2017\)](#). This timing is ideal, as transactions peak during this period, making monitoring inventories and the scale of transactions easier.

Before administering the survey questionnaire, the vendors received a comprehensive overview of the study's objectives and potential implications. A translator was provided to ensure that all vendors fully understood the information in the form of consent. Those who expressed discomfort with the nature of the study were excluded from the data collection process. Primary data was collected through a semi-structured survey questionnaire conveniently administered to traditional medicinal market sellers willing to participate in the research. A total of 165 questionnaires were distributed among the respondents. Additionally, the scale of their stocks was assessed through open-ended questions.

During our visits to the selected markets for this study, we conducted a thorough inventory of every item found at each stall to compare it with information provided by the vendors. We recorded every species observed in the market, including its local name. We

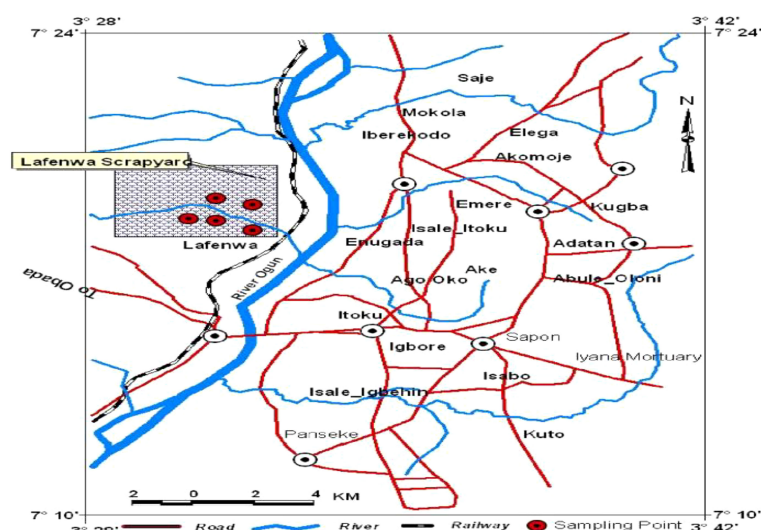


FIGURE 1

Map showing the geographical coordinates of the markets in Abeokuta, Ogun State, Nigeria. Source: field survey, 2022.

consulted scientific publications to align the indigenous names with the accepted English and scientific names. Additionally, we employed the Village Contact Survey (VCS) approach to help identify some species. To assist the traditional medicine vendors in recognizing animals by their local names where animal parts are paraded without proper identification, we provided published identification guides and encyclopedias, which included photographs and distinguishing characteristics of the species. Once a local name was established, we compared it with scientific and common English names (Soewu et al., 2012).

The study focused on animals identified by at least three respondents. In the questionnaire, we asked questions to explore key issues related to the trade of wildlife used in traditional medicine. The vendors were requested to identify the most traded species and the ailments for which these species are believed to provide remedies. Additionally, they were asked about the impact of traditional medicine on wildlife conservation. The questionnaire also included a section aimed at gathering insights into the vendors' attitudes and perceptions regarding the use of traditional medicine. This criterion was established to ensure consistency and significance in the information provided. We referred to the CITES appendices for global listings to assess the status of trade and conservation for the species observed during the survey. We also reviewed the Endangered Species (Control of International Trade and Traffic) Decree No. 11 of 1985 to understand the current conservation status of these species within Nigeria (Soewu et al., 2012).

We employed a two-stage approach for data presentation, utilizing fundamental methods such as cross-tabulations and descriptive statistics. A data presentation technique established by Field (2000) guided this study. Section A of the questionnaire focuses on the socio-demographic characteristics of the participants. Section B provides information about the animal species and their derivatives commonly traded for alternative medicine purposes as well as the illnesses associated with these animal parts sold in markets. Section C examines the implications of traditional medicine on conservation, while Section D includes questions about the respondents' attitudes and perceptions toward the use of traditional medicine. The results were organized and tabulated for visual presentation. One effective way to clearly and succinctly illustrate the main conclusions from the statistical study was by using tables to present the data.

Results

Table 1 displays the demographic information of the study participants. The findings reveal that 32.7% of the respondents were male, while 67.3% were female. Regarding age distribution, 39.4% of participants were within the 21–40 age bracket, 44.2% fell within the 41–60 range, and 16.4% were over 60. Regarding marital status, 1.8% of the respondents identified themselves as single, 67.9% were married, 20.2% were widowed, and 10.3% were separated. On the educational front, most respondents completed primary education (38.2%) and secondary education (37.0%). Furthermore, 16.4%

obtained a post-secondary diploma or NCE, while 2.4% held a bachelor's degree. Notably, only 6.1% of the population reported no formal education.

In terms of religion, Islam was the predominant faith among the respondents with 51.5%, followed by Christianity at 29.7%, and

TABLE 1 Demographic characteristics of the respondents.

Variable	Frequency	Percentage
Gender		
Male	54	32.7
Female	111	67.3
Age		
21–40	65	39.4
41–60	73	44.2
Above 60	27	16.4
Marital status		
Single	3	1.8
Married	112	67.9
Widower	33	20.2
Separated	17	10.3
Education		
No formal	10	6.1
Primary	63	38.2
Secondary	61	37.0
Post-secondary/NCE	27	16.4
Bachelor	4	2.4
Religion		
Christianity	49	29.7
Islam	85	51.5
Traditional	31	18.8
Income		
≥N30,000	24	14.5
N31,000–N60,000	66	40.0
N61,000–N90,000	55	33.3
N91,000–N120,000	14	8.5
N121,000	6	3.6
Market		
Itoku	70	42.5
Lafenwa	35	21.2
Kuto	30	18.2
Iberekodo	30	18.2

18.8% identified themselves as traditional worshipers. In terms of income derived from the sales of animals used for medicinal purposes, 40.0% of the respondents reported earning between ₦31,000 and ₦60,000 (\$21–\$40) monthly, 33.3% earned between ₦61,000 and ₦90,000 (\$41–\$60), 8.5% earned between ₦91,000 and ₦120,000 (\$61–\$80), and 3.6% earned ₦121,000 (\$81) or more each month.

Molluscs species and parts used for therapeutic purposes

Table 2 presents the molluscs utilized in traditional medicine within the study area, revealing the presence of two species. The participants identified the entire freshwater snail (*Pila ovata*) as an ingredient in preparations to treat strokes. Furthermore, the African giant snail (*Achatina achatina*) is recognized for its diverse beneficial components, including its meat, shell, and mucus, which are employed to address various health concerns. These concerns encompass weak bones, measles, stroke, fibroids, complications during childbirth, diabetes, hypertension, convulsions, and fertility issues.

Amphibian species and parts used for therapeutic purposes

Table 3 highlights the amphibians used in traditional medicine in the study area, focusing on two species. The findings reveal that the entire European common frog (*Rana temporaria*) is a crucial ingredient in remedies aimed at promoting strong bones. The African common toad (*Amietophrynus regularis*) is likewise recognized for enhancing bone strength. This toad is also employed as an anti-poison agent and is believed to be effective in preventing bedwetting.

Insect species and parts used for therapeutic purposes

Table 4 presents information on the insect species employed in traditional medicine, focusing on two species available for purchase in the study area. The respondents indicated that the honeybee (*Apis mellifera*), including its sting and feces, is a key component in remedies for pain, cough, cold, and rheumatism. Additionally, the entire common wasp (*Vespula vulgaris*) treats skin infections.

Fish species and parts used for therapeutic purposes

Table 5 details the use of various fish species in traditional medicine and highlights five species that can be purchased in the study area. The electric fish (*Malapterurus electricus*), snakehead (*Parachanna obscura*), African knife fish (*Xenomystus nigri*), and redbelly tilapia (*Tilapia zillii*) are commonly employed for the treatment of infertility in both men and women, utilizing therapeutic components such as the entire body, bones, and fins of the fish. In contrast, the African catfish (*Clarias gariepinus*) is specifically valued for its bones and fins to address infertility in both genders and to alleviate rheumatism.

Reptilian species and parts used for therapeutic purposes

A range of reptiles and their body parts are employed in traditional medicine to address various physical ailments and spiritual concerns, as outlined in Table 6. The complete body of the common green iguana (*Iguana iguana*) is utilized for treating fever, pain, and ulcers as well as for protective purposes and enhancing business success. Similarly, the entire body of the agama lizard (*Agama agama*) is used to alleviate epilepsy, cough, sore throat, and convulsions. Furthermore, the whole body of the Senegal chameleon (*Chamaeleo senegalensis*) is sought after for its reputed magical properties, anti-poison attributes, and effectiveness in relieving pain and tumors.

Various parts of the Gaboon viper (*Bitis gabonica*), including its entire body, head, fat, shed skin, tail, and flesh, are utilized in traditional medicine to address a range of conditions such as paralysis, stroke, skin infections, complications during labor, pain, convulsions, eye infections, and cancer. The African rock python (*Python sebae*) is thought to offer protection against malevolent forces, promote wealth, and assist in the healing of broken bones. The Nile monitor (*Varanus niloticus*), particularly its whole body and skin, is employed to treat tumors and liver diseases and is also considered an antidote for poisoning.

There is a belief that certain creatures offer protection against malevolent influences and manipulation—for instance, the Nile crocodile (*Crocodylus niloticus*), including its entire body, head, and tail, is utilized to alleviate weakness and rheumatism and ward off evil. Similarly, the African spurred tortoise (*Centrochelys sulcata*), encompassing its entire body, head, and shell, is

TABLE 2 Molluscs species and parts used for therapeutic purposes.

S/N	Common Name	Scientific name	Part/product used	Traditional uses	IUCN status
1.	African giant snail	<i>Archachatina marginata</i>	Meat, shell, mucus	Weak bone, measles, stroke, fibroid, easy delivery, diabetes, hypertension, stroke, convulsion, fertility	Not evaluated
2.	Freshwater snail	<i>Bithynia tentaculata</i>	Whole body	Stroke	Least concerned

TABLE 3 Amphibian species and parts used for therapeutic purposes.

S/N	Common name	Scientific name	Part used	Traditional uses	IUCN status
1.	European common frog	<i>Rana temporaria</i>	Whole body	For strong bones	Least concerned
2.	African common toad	<i>Bufo regularis</i>	Whole body	For strong bones, anti-poison, to stop bed wetting	Least concerned

TABLE 4 Insect species and parts used for therapeutic purposes.

S/N	Common name	Scientific name	Part/product used	Traditional uses	IUCN status
1.	Honeybee	<i>Apis mellifera</i>	Whole, sting, feces	To treat pain, cough, cold, and rheumatism	Data deficient
2.	Common wasp	<i>Vespula vulgaris</i>	Whole, skin	To treat skin infections	Least concerned

employed as a remedy for poisoning and convulsions. Additionally, it is sought after for favor, protection, and even perceived enhancement of sexual vitality.

Avian species and parts used for therapeutic purposes

In traditional medicine, various birds and their components are employed for various health-related purposes, as outlined in Table 7. The complete body of the Senegal lark-heeled cuckoo (*Centropus senegalensis*) is utilized for stroke treatment. Different parts of the gray parrot (*Psittacus erithacus*), including its eggs, feathers, head, and entire body, address infertility in women, appease malevolent spirits, and reduce inflammation. The domestic pigeon (*Columba livia*), encompassing its flesh, feathers, and whole body, is incorporated in love potions and for treating paralysis. The spotted eagle owl's fresh head and complete body (*Bubo africanus*) alleviate dizziness, prevent accidents, and attract good fortune.

The flesh of the house sparrow (*Passer domesticus*) is thought to relieve weakness and fever, while the blood and flesh of the cattle egret (*Bubulcus ibis*) are utilized to treat dysentery. The quail (*Coturnix coturnix*), particularly its legs, head, and meat, is utilized in various traditional treatments to promote early walking in children, enhance memory, and improve sexual potency. Similarly, different parts of the common ostrich (*Struthio camelus*), including feathers, meat, head, legs, and eggs, address fertility issues, protect children against negative spiritual influences,

and alleviate asthma symptoms. The hooded vulture (*Necrosyrtes monachus*) is used in its entirety for a range of purposes, including the treatment of insanity and poor vision, protection against malevolent influences, enhancement of fertility in women, appeasing witches, and assisting in the search for marital partners.

Mammalian species and parts used for therapeutic purposes

Table 8 presents the mammals utilized in traditional medicine within the study area, illustrating species diversity with 21 identified for sale. The respondents reported that the whole straw-colored fruit bat (*Eidolon helvum*) and the striped mouse (*Lemniscomys striatus*) are used in treatments for stroke and to promote business success. Additionally, the complete bodies of the house mouse (*Mus musculus*), giant rat (*Cricetomys gambianus*), and cane rat (*Thryonomys swinderianus*) are believed to enhance fertility. Various parts of the pangolin (*Phataginus tricuspis*), including the head, scales, bones, tail, and female internal organs, are associated with various applications. These include spiritual protection and treating conditions such as rheumatism, financial rituals, convulsions, bleeding, male aphrodisiac effects, anemia, healing old wounds, managing strokes, and providing pain relief.

The entire body and meat of the squirrel (*Xerus erythropus*) are utilized to treat convulsions. At the same time, the African grass rat (*Arvicanthis niloticus*) is known for its effectiveness in alleviating stomach pain. The skin of the crested porcupine (*Hystrix cristata*),

TABLE 5 Fish species and parts used for therapeutic purposes.

S/N	Common name	Scientific name	Part/product used	Traditional uses	IUCN status
1.	Electric fish	<i>Malapterurus electricus</i>	Whole, bones, fins	To treat infertility in both men and women, retentive memory	Least concerned
2.	African catfish	<i>Clarias gariepinus</i>	Whole, bones, fins	To treat infertility in both men and women, rituals and rheumatism	Least concerned
3.	Snakehead	<i>Parachanna obsura</i>	Whole, bones, fins	To treat infertility in both men and women	Least concerned
4.	African knife fish	<i>Xenomystus nigri</i>	Whole, bones, fins	To treat infertility in both men and women	Least concerned
5.	Redbelly tilapia	<i>Tilapia zilli</i>	Whole, bones, fins	To treat infertility in both men and women	Least concerned

TABLE 6 Reptilian species and parts used for therapeutic purposes.

S/N	Common name	Scientific name	Part/product used	Traditional uses	IUCN status
1.	African spurred tortoise	<i>Centrochelys sulcata</i>	Whole body, head, back	Used as an anti-poison, also used to treat convulsion, for protection, to seek favor, and for sexual enhancement	Endangered
2.	Nile monitor	<i>Varanus niloticus</i>	Whole body, skin	To treat tumors and liver diseases, anti-poison, to treat pain, and protection against evil influences and manipulation	Least concerned
3.	Common green iguana	<i>Varanus varus</i>	Whole body	Used to treat fever, pain, and ulcer, for protection, to boost business	Least concerned
4.	Nile crocodile	<i>Crocodylus niloticus</i>	Whole body, head, tail	Weakness and rheumatism, preventing evil	Vulnerable
5.	Agama lizard	<i>Agama</i>	Whole body	Epilepsy, cough, sore throat, convulsions	Least concerned
6.	Gaboon viper	<i>Bitis gabonica</i>	Whole body, head, fat, shed skin, tail, flesh	To treat paralysis, stroke, skin infection, easy delivery, pain, convulsion eye infection, and cancer	Least concerned
7.	African rock python	<i>Python sabae</i>	Whole, head, fat, tail	Protection against evil, wealth, broken bone	Near threatened
8.	Senegal chameleon	<i>Chamaeleo chamaeleon</i>	Whole body	Used for magic power, anti-poison, to cure pain and tumor	Least concerned

when combined with other herbs, serves as a fortifying agent. Various parts of the common fox (*Vulpes pallida*), spotted hyena (*Crocuta crocuta*), African civet (*Civettictis civetta*), and bushbuck (*Tragelaphus scriptus*) are employed to address ear diseases, fulfill spiritual needs, provide protection, and treat strokes, respectively. Furthermore, the penis, skull, and head of the gorilla (*Gorilla gorilla*) are esteemed as potent sex enhancers and antidotes. Lastly, the serval cat (*Leptailurus serval*) is believed to be effective in treating skin diseases, warding off evil influences, serving as an aphrodisiac, and attracting good fortune.

The African buffalo (*Syncerus caffer*) head and lion (*Panthera leo*) fat and skin are reported to be employed in traditional medicine

for treating conditions such as strokes, keloids, pain, and tumors, respectively. As observed in Figure 3, the skull, head, and forearm of Sclater's monkey (*Cercopithecus sclateri*) are utilized for their protective qualities against accidents, aiding in the treatment of bone fractures and assisting in the pursuit of marital partners. Similarly, the patas monkey's head, forelimbs, and hind limbs (*Erythrocebus patas*) are believed to offer protection against mishaps and are thought to enhance good fortune. Additionally, the bones and horn of the African savanna elephant (*Loxodonta africana*) are used to promote growth and treat skin infections, while fat derived from wild boars (*Sus scrofa*) is applied in the treatment of paralysis, joint pain, burns, and fractures.

TABLE 7 Avian species and parts used for therapeutic purposes.

S/N	Common name	Scientific name	Part/product used	Traditional uses	IUCN status
1.	Senegal lark-heeled cuckoo	<i>Eremophila alpestris</i>	Whole body	To treat stroke	Least concerned
2.	Gray parrot	<i>Psittacus erithacus</i>	Egg, feathers, head, whole body	To treat infertility in women, to appease witches, to treat inflammation	Endangered
3.	Domestic pigeon	<i>Columba livia</i>	Flesh, feather, whole body	For making love concoctions and treating paralysis	Least concerned
4.	Spotted eagle-owl	<i>Bubo africanus</i>	Fresh head, whole body	To cure dizziness, for the prevention of accidents, and for fortune rousing	Least concerned
5.	House sparrow	<i>Passer domesticus</i>	Flesh	To cure weakness and fever	Least concerned
6.	Cattle egret	<i>Ardeola ibis</i>	Blood, flesh	To cure dysentery	
7.	Quail	<i>Coturnix</i>	Leg, head, flesh	To make treatment for a child to walk early, to enhance memory, and to improve sexual power	Least concerned
8.	Common ostrich	<i>Struthio camelus</i>	Feather, flesh, head, leg, egg	To treat fertility, to protect children from bad spirits, to treat asthma	Least concerned
9.	Hooded vulture	<i>Necrosyrtes monachus</i>	Whole body	To cure insanity, and poor vision, to protect against evil influences, fertility for women, for appeasing witches, seeking marital partners	Critically endangered

Discussion

Demographic characteristics of traditional medicine vendors

The research reveals that most participants involved in this trade were female, accounting for 67.3% of the sample. This finding is consistent with a study conducted in Ogun State, which found that 95% of traditional medicine traders were women (Soewu and Ayodele, 2009). Similarly, a research by Adebowale et al. (2021) in Ikire, Osun State, Nigeria, indicated that 55.9% of the respondents were female. This highlights the gender roles in the illegal trade of wildlife derivatives in Nigeria. Typically, men are solely responsible for hunting wildlife in the forest at night due to the effort required. They then bring the hunted animals out for women to sell during the daytime (Ijose, 2018). Regarding age distribution, the largest group of respondents (43.7%)

fell within the 41–60 age range, while 39.4% were in the 21–40 age range. This pattern indicates that the traditional medicine vendors in the study area comprise various age groups, with a significant number in their productive years. This raises concerns, as their active age status could lead to continuing this behavior over time. It aligns with Soewu's (2008) observation that using wild animals in traditional medicine is prevalent across all ages and genders.

A notable percentage of the respondents were married (67.9%), with a majority adhering to the Muslim faith (51.5%). The high proportion of married traders suggests that many serve as heads of households or bear financial responsibilities that may influence their involvement in the wildlife trade. This observation is consistent with findings from Osunsina et al. (2022), who identified similar trends. The educational background of the respondents varied, with 38.2% having completed primary education and 37% having attained secondary education. Literacy levels may affect the respondents' perspectives on natural

TABLE 8 Mammalian species and parts used for therapeutic purposes.

S/N	Common name	Scientific name	Part/product used	Traditional uses	IUCN status
1.	Straw-colored fruit bat	<i>Eidolon helvum</i>	Whole body	To treat stroke	Near threatened
2.	Striped mouse	<i>Hybomys trivigatus</i>	Whole body	To boost business	
3.	Pangolin	<i>Manis tricuspis</i>	Head, scale, bones, tail, internal female organs	For the treatment of spiritual protection, rheumatism, financial rituals, convulsions, bleeding, aphrodisiac for men, anemia, healing of old wounds, fertility for women, stroke, and pain	Vulnerable
4.	Giant rat	<i>Cricetomys gambianus</i>	Whole body	Used for fertility	Least concerned
5.	Squirrel	<i>Funisciurus pyrrhopus</i>	Whole body, meat	To treat convulsion	Least concerned
6.	House mouse	<i>Mus musculus</i>	Whole body	Used for fertility.	Least concerned
7.	Cane rat	<i>Thryonomys swinderianus</i>	Whole body	Used for fertility	Least concerned
8.	Crested porcupine	<i>Hystrix cristata</i>	Skin	Used for fortification	Least concerned
9.	African grass rat	<i>Arvicanthis niloticus</i>	Whole body, meat	To treat stomach pain	Least concerned
10.	Common fox	<i>Canis spp.</i>	Whole body, bone, meat	Treatment of ear diseases	Least concerned
11.	Spotted hyena	<i>Crocuta</i>	Whole body, leg, head, bone	Spiritual purpose, To fight witches	Least concerned
12.	Gorilla	<i>Gorilla</i>	Penis, skull, head	Sexual enhancement, anti-poison	Critically endangered
13.	Serval cat	<i>Leptailurus serval</i>	Skin, carcass, male organs, head	Skin diseases, protection against evil influence, aphrodisiacs, fortune rousers	Least concerned
14.	African buffalo	<i>Synecerus caffer</i>	Head	To treat stroke	Near threatened
15.	Lion	<i>Panthera leo</i>	Fat, skin	Keloids, pain, tumor	Vulnerable
16.	Sclater's monkey	<i>Cercopithecus sclateri</i>	Skull, head, forearm	Prevention of accidents, bone fractures, and seeking marital partners	Endangered
17.	Patas monkey	<i>Erythrocebus patas</i>	Head, fore and hind limbs	For the prevention of accidents, fortune rousers	Near threatened
18.	African savanna elephant	<i>Loxodonta africana</i>	Bone, horn	Stunted growth, skin infection	Endangered
19.	African civet	<i>Civettictis civetta</i>	Whole, leg, head, meat	Protection	Least concerned
20.	Bushbuck	<i>Tragelaphus scriptus</i>	Whole, leg, head	Stroke	Least concerned
21.	Wild boar	<i>Sus scrofa</i>	Fat	Used to treat paralysis, joint pain, burns, and fractures	Least concerned

resource conservation. In this situation, the ongoing involvement in the illegal wildlife trade for traditional medicine persists mainly because most vendors lack access to advanced education. This educational gap deprives them of vital information about the serious consequences of the continuous exploitation and trade of wildlife on the environment. This reinforces Osunsina's (2010) argument that individuals with higher educational attainment are more likely to support and engage in conservation efforts and species justice endeavors.

The variety of fauna species found in the study area

Figure 2 showcases examples of wildlife products available for purchase in the market. Much like this study, numerous investigations have underscored the importance of zootherapy in various rural communities throughout Nigeria. The trade in traditional medicinal mixtures is widely embraced among the Yoruba population in Ogun State, as evidenced by this research. Traditional medicine vendors identified 49 animal species in their day-to-day trading activities, surpassing the figures reported in similar studies by Abubakar et al. (2015). In comparison, research conducted in Puna and the semi-arid region of northeastern Brazil recorded approximately 17 and 25 species, respectively (Hernandez et al., 2015).

A study conducted in Ethiopia found that approximately 23 animals and/or their parts are utilized in traditional medicines by the Degu tribes in the Tigray region (Kendie et al., 2018). A similar investigation at the Bode Wildlife Market also documented 33 different species (Adebowale et al., 2024). The species identified in this survey comprise two molluscs,

two amphibians, two insects, five fish, eight reptiles, nine birds, and 21 mammals. This showcases a remarkable diversity of wild animals employed in unjustifiable traditional medicine, underscoring the strong cultural significance of these practices in the region and prompting the vendors to intensify their hunting and sourcing activities to satisfy this growing need. This trend aligns with the findings of Ijose (2018), who observed that the rising commercial demand for wildlife products has led to excessive harvesting, further endangering already threatened species. However, the increasing demand for such products substantially threatens vulnerable wildlife species and weakens species' justice advocacy.

Traditional utilization of molluscs and its conservation implications

The research underscores the potential of snails in addressing various health issues, including hypertension, facilitating smoother childbirth, managing convulsions, and enhancing fertility. Bonnemain (2005) points out that snails are often linked to femininity and fertility, with traditional beliefs suggesting that they can expedite delivery, combat female scrofula, and, when prepared appropriately with milk, offer therapeutic benefits for conditions such as spasms associated with spitting blood in tuberculosis and the burning sensation linked to nephritis. Furthermore, snails play a crucial ecological role in nutrient cycling and the maintenance of soil health. However, excessive harvesting from their natural environments disrupts ecosystem balance, adversely affecting soil fertility and biodiversity. The slow reproductive rate of certain snail species renders them particularly vulnerable to overexploitation.



FIGURE 2
Body parts of birds displayed for sale in the study area. Source: field survey, 2022.



FIGURE 3
Body parts of mammals displayed for sale in the study area. Source: field survey, 2022.

Utilization of fish in traditional medicine and its conservation implications

The presence of fish as a less prominent species in the study area can be attributed to its inland location, with a notable absence of large bodies of water such as rivers, lakes, or coastlines. As a result, fishing does not play a significant role in the region's economy. However, the literature highlights the importance of utilizing fish and their by-products in medicinal formulations, as [Ehinmore and Ogunode \(2013\)](#) noted. The study revealed that several fish species are recognized for their effectiveness in treating various illnesses within traditional medicine—for example, all the bodies, bones, and fins of *Parachanna obscura*, *Xenomystus nigri*, and *Tilapia zilli* are employed to address infertility issues in both men and women. *Clarias gariepinus* is particularly significant in treating infertility for both genders, and it is also utilized in rituals and to alleviate rheumatism. According to [Orilogbon and Adewole \(2011\)](#), practitioners of traditional medicine, fish farmers, and herbal vendors widely acknowledge the varied applications of *Clarias* in traditional healing. This includes its role in treating numerous ailments and its involvement in sacrifices, rituals, festivals, and ceremonies.

The *Malapterurus electricus* fish is thought to play a role in enhancing memory and promoting mental well-being. Incorporating fish into traditional medicine significantly influences healthcare delivery systems within communities. This

underscores the heavy reliance on traditional therapies during illness, especially in the absence of Western medical treatments ([Zhang and World Health Organization, 2000](#)). However, despite their recognized medicinal value, the overexploitation of certain fish species raises serious conservation concerns. Issues such as overfishing, habitat destruction, and pollution have led to declining freshwater fish populations, with some already classified as vulnerable or near threatened. Species like *Parachanna obscura* and *Xenomystus nigri* are increasingly at risk due to habitat degradation and unsustainable harvesting practices for both consumption and traditional medicine use.

Reported uses of amphibians in traditional medicine and conservation concerns

Using animals and their body parts for medicinal purposes dates to ancient times ([Mishra et al., 2011](#)). Anurans, including frogs and toads, have played a significant role in materia medica ([Satiro et al., 2024](#)). The chemical secretions produced by these amphibians benefit human health, exhibiting antibacterial, antiprotazoal, and various therapeutic properties ([Zahari et al., 2017](#)). The skin secretions of many anurans, including frogs and toads, contain peptides known for their antibacterial effects ([Gupta et al., 2017](#)). Research indicates that *Rana temporaria* is recognized as a vital component in formulating remedies to improve bone strength. Similarly, *Bufo regularis* is acknowledged to contribute to bone health and is used as an anti-poison remedy believed to prevent bedwetting effectively.

According to [Govender et al. \(2012\)](#), extracts obtained from the scraped skin secretions of the giant leaf frog (*Phyllomedusa bicolor*) are utilized in Chinese folk medicine to treat conditions such as depression, stroke, seizures, and cognitive decline related to diseases like Alzheimer's. While frogs and toads possess significant medicinal properties, overharvesting these species for traditional medicine poses a significant threat to their survival. This observation is supported by [Phaka et al. \(2025\)](#), who highlighted that amphibians are among the most endangered vertebrate groups globally, with their populations declining due to habitat loss, climate change, pollution, and diseases such as chytridiomycosis. The unregulated collection of these species exacerbates the situation, pushing some closer to extinction.

Utilization of insects in traditional medicine and associated conservation concerns

The extensive use of honeybees, specifically *Apis mellifera*, to treat coughs and colds is a widespread tradition among Nigerian tribes. Individuals willingly undergo bee stings annually, believing that it contributes to maintaining good health ([Carpena et al., 2020](#)). Furthermore, the venom extracted from bees is sometimes injected into individuals dealing with rheumatic pain and arthritis. Bees and their by-products are undeniably among the most utilized insects for therapeutic purposes ([Kwon et al., 2021](#)). Due to their extensive

use, a chemical analysis of bees' composition and venom has been conducted to assess their antibacterial and anti-arthritis properties (Meyer-Rochow, 2017).

Similarly, the common wasp (*Vespula vulgaris*) addresses skin infections. These practices align with the findings of Jugli et al. (2020), who reported the utilization of honey from bees and wasps for treating coughs and colds and remedies for spider bites and allergies among the Wancho and Tangsa tribes, respectively. Flanjak et al. (2024) reported that excessive collection of honey, beeswax, and venom can weaken bee colonies, making it harder for them to reproduce and maintain healthy populations. Since bees play a crucial role in pollinating wild and cultivated plants, their decline has a ripple effect on biodiversity. If these threats continue, the loss of bees could reduce crop yields and harm the overall health of ecosystems.

Traditional utilization of reptiles: implications for wildlife conservation

The research uncovered the utilization of eight reptile species in traditional medicine, with these species occasionally being sold in their entirety but more commonly being dissected into various parts such as flesh, skin, tail, eyes, head, tooth, cloaca, fat, rattle, and carapace. Notably, a single reptile can provide a diverse array of raw materials. The harder components, including bones, snake rattles, and skin, are typically sun-dried, grated, and crushed to form a powder. This powder is often consumed as a tea or incorporated into meals. Alternatively, the fat and oil derived from these reptiles can be ingested or applied topically as ointments, depending on the ailment being treated (da Nóbrega Alves et al., 2008).

In Nigeria, animal products play a significant role in cultural ceremonies, traditional rituals, and pharmacopeia, as elucidated by Leo Neto et al. (2009). Animals and their various parts are employed as charms to ameliorate or address various conditions—for instance, the Senegal chameleon (*Chamaeleo senegalensis*) is highly sought after for its believed magical properties, anti-poison attributes, and its alleged ability to alleviate pain and tumors. This aligns with the research conducted by Alves et al. (2012c), affirming that the entire Senegal chameleon is used to confer invincibility upon the recipient, protecting against adversaries or enchantments. However, the overharvesting of *Chamaeleo senegalensis* for traditional medicine and rituals has caused a decline in its population, putting it at risk of disappearing from local areas. Because chameleons depend on their camouflage and slow movements to stay safe, they are especially vulnerable to overexploiting (Stuart-Fox et al., 2006).

Additionally, reptiles and their components serve as offerings to appease and invoke spirits and ancestral deities—for example, the head of the African python (*Python sebae*) is employed for invocation and safeguarding against witches. These findings resonate with the work of Alves et al. (2012b). According to Muhammad et al. (2022), fats derived from pythons are predominantly used to address issues such as scars, rheumatism, back pain, burns, and waist pain. However, *Python sebae* is already

classified as “near threatened” by the IUCN due to habitat destruction and overhunting for its skin and meat. The continued use of its body parts in traditional medicine exacerbates its population decline, further threatening its survival in the wild. The excessive harvesting of reptiles for traditional medicine decreases their population and disrupts their important roles in nature—for example, snakes help control rodent populations, while chameleons are key in keeping insect numbers in check. If overexploitation continues, it could trigger a chain reaction in the ecosystem, harming biodiversity and destabilizing the environment (Dufour et al., 2022; Morton et al., 2021).

Conservation challenges in the use of birds for traditional medicine

Nine bird species are currently available in the markets, with offerings including various body parts like the whole body, flesh, head, leg, and eggs for therapeutic purposes. Notably, the procurement of vital organs from specific species involves the sacrifice of the entire animal. This practice places immense pressure on avian populations, leading to substantial declines in their numbers and disrupting the ecological balance. The prevailing socio-cultural practices among the indigenous people have contributed to a pronounced decrease in the population of avian species, irrespective of their body organs and therapeutic value. Continuous harvesting of these birds for traditional medicine exacerbates the decline of already vulnerable species, potentially pushing some toward local or even global extinction (Adegbola et al., 2024).

It is imperative to underscore that some of the identified bird species fall into categories such as least concerned, endangered, and critically endangered according to the IUCN Conservation Status Classification. Harvesting endangered or critically endangered species speeds up their decline, making recovery more difficult and risking biodiversity and species endeavors. Removing birds from their natural habitats can also disrupt food chains, hinder seed dispersal, and disturb ecosystem balance, further threatening their survival. Promoting species justice advocacy at all levels is essential to address these challenges and reduce overdependence on excessive wildlife harvesting for traditional medicinal practices.

Reported uses of mammals in traditional medicine and conservation concerns

All of the mammalian species identified for sale in this region are indigenous. Interestingly, mammals appear to be more prominently utilized compared to other species. This preference might stem from the shared characteristics between humans and mammals, suggesting that certain traits can be replenished in humans when deficient due to illness. This discovery underscores the significance of local biodiversity in traditional medicine, aligning with the observations of Alves and Rosa (2006), who noted that the faunal composition, accessibility, and availability

directly shape the types of zootherapeutic products traded in a particular region.

However, procuring animals from the wild and markets poses a serious conservation concern, as excessive and unregulated harvesting can lead to population declines and local extinctions. Poorly regulated collection practices can potentially contribute to the extinction of endangered species, as highlighted by El Hajj and Holst (2020). Many species mentioned exhibit multiple uses and are employed in treating various ailments—for instance, different body parts of *Bitis gabonica* are utilized to address paralysis, stroke, and skin infections, facilitate easy delivery, alleviate pain, manage convulsions, treat eye infections, and combat cancer. *Python sebae*, specifically the whole body, head, fat, and tail, protects against evil and wealth and mends broken bones. *Chamaeleo chamaeleon*, when used as a whole body, is believed to confer magical powers and anti-poison properties and is utilized in treating pain and tumors. *Varanus varus* is employed to treat fever, pain, and ulcers as well as for protective purposes and to enhance business prospects.

Conclusion

This study highlights the incessant overexploitation of wildlife species in traditional medicine across southwestern Nigeria and its significant negative effect on species justice advocacies. The findings show that various animal species, including some that are classified as vulnerable or endangered, are actively traded for their perceived medicinal benefits. However, the unregulated nature of this trade poses a serious threat to conservation, as continuous exploitation could lead to population declines and even extinction. To address this issue, species justice advocacy and effective policy development are urgently needed to regulate wildlife harvesting, trade, and use in traditional medicine.

The government should prioritize the enforcement of existing wildlife protection laws by providing the necessary resources and authority to the agencies responsible for their implementation. This includes equipping these agencies with advanced technologies, training personnel adequately, and increasing funding for conservation efforts. Non-governmental organizations (NGOs) should mobilize several species justice movements nationwide. By doing so, it would rest assured that these regulations are not merely words on paper but are actively enforced to combat the threats facing wildlife. Strengthening collaboration between governmental bodies, local communities, and conservation organizations will also be crucial in fostering a comprehensive approach to wildlife conservation, ultimately leading to a significant and positive impact on biodiversity preservation and ecosystem health. Public awareness, species justice campaigns, and educational programs should also be introduced to inform traditional medicine practitioners, traders, and consumers about the environmental consequences of unsustainable wildlife use. These initiatives should also promote ethical and scientifically backed alternatives to ensure biodiversity conservation and the rational continuity of traditional healing practices.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The animal study was approved by the Department of Forestry and Wildlife Management at the College of Environmental Resources Management, Federal University of Agriculture, Abeokuta, Nigeria. The study did not involve the handling or use of live animals. The research methodology focused on conducting interviews and surveys with vendors and traditional practitioners to gather insights into the fauna species commonly used in medicinal practices. All data collection was carried out with full respect for participants' privacy and cultural beliefs. Participation in the study was entirely voluntary, and informed consent was administered and obtained from each participant before their involvement. Each participant signed a consent form confirming that they understood the study's purpose, agreed to participate voluntarily, and acknowledged their right to withdraw from the study at any time without any consequences. The study was conducted in accordance with the local legislation and institutional requirements.

Author contributions

TA: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. OI: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. BI: Conceptualization, Methodology, Project administration, Resources, Visualization, Writing – original draft. OA: Conceptualization, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. OO: Conceptualization, Methodology, Supervision, Validation, Visualization, Writing – review & editing. IO: Conceptualization, Resources, Supervision, Validation, Visualization, Writing – review & editing. AS: Data curation, Formal Analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fcosc.2025.1551597/full#supplementary-material>

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