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Research article

Zootherapeutic uses of animals and their parts: An important element of the traditional knowledge of the Safi province, Morocco

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ABSTRACT

Ethnopharmacological relevance: The Moroccan population harbors rich traditional knowledge used to treat various human diseases. This is the first study aimed at exploring the ethnozoological practices in Morocco. *Materials and methods*: Data were collected through semi-structured questionnaires to interview 42 traditional healers and merchants of medicinal animals. Collected ethnozoological data were analyzed using appropriate quantitative indices. *Results*: 42 animal species belonging to eight taxonomic groups were gathered, with Mammalia being the most mentioned (15 species), followed by Aves (12 species). *Camelus* sp. (RFC = 0.81), and *Sepia officinalis* (RFC = 0.71), had the highest RFC. With 8.00 units, *Atelerix algirus* was the species with the highest level of therapeutic redundancy. The most important diseases cited were circulatory system disorders (ICF = 1.00), oncology (ICF = 1.00), oro-dental problems (ICF = 0.86), and nervous system disorders (ICF = 0.86). The following animal species gained an FL value of 100 %: *Anas platyrhynchos domesticus* (for skin diseases), *Coturnix coturnix* (for endocrine disorders), *Mustela nivalis* (for gastrointestinal disorders), *Cymothoa exigua* (for nervous system disorders), and *Upupa epops* (for culture-bound diseases). The most versatile species were *Apis* sp. (RI = 100 %) and *Aterix algirus* (RI = 88.89 %). The most culturally important species included *Chamaeleo chamaeleon* (CII = 57.14) and *Atelerix algirus* (CII = 40.48). According to the IAR value, *Cymothoa exigua* (nervous system disorders) and *Upupa epops* (IAR = 1.00) had the highest scores. The highest CAI value was for *Chamaeleo chamaeleon* (CAI = 48.98). *Conclusion*: The local population of the Safi region possesses valuable knowledge about the use of medicinal animals to treat a plethora of health concerns. *Atelerix algirus* and *Chamaeleo chamaeleon* were the most versatile species and were indicated as ideals for being cultural keystone species. They must be prioritized in future research and conservation studies.

Abbreviations: CAI, cultural agreement index; CII, cultural importance index; CITES, convention on international trade in endangered species of wild fauna and flora; FL, fidelity level; IAR, index of agreement on remedies; ICF, informant consensus factor; ICPC, international classification of primary care; IUCN, international union for conservation of nature; RFC, relative frequency citation; RI, relative importance; STR, species therapeutic redundancy; UC, use citation; UV, use value; WHO, world health organization.

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1. Introduction

Throughout history, humans have heavily relied on animals for their basic needs (health care, food, clothes, transport, and religious purposes). Ethnozoology is therefore concerned with studying the past and present interactions of human civilization with animals after the first appearance of humans as a species [1]. The earlier interactions were evidenced by prehistoric cave drawings, rock paintings, and zooarchaeological records [2–5]. Since ancient times, various civilizations have utilized animals and their various parts and products for medicinal purposes. Evidence of these practices can be found in historical written sources, papyri, and classical medicinal compendiums such as Hippocrates, Dioscorides, Avicenna, and Ibn Al Baitar [6–12]. Indeed, of the 252 indispensable drugs selected by the World Health Organization, more than 8 % are of animal origin [13,14]. And also, about 10 % of the medicinal formulations included in the European and Mediterranean medicinal compendiums are of animal origin [15]. Zootherapy, therefore, refers to the use of animals, parts of the animal body, animal metabolites, or animal products for treating human or domestic animal ailments [14].

Several studies have shown the central role of zootherapy in various socio-religious contexts and geographic regions [14,16–22]. In this context, at least 584 animal species are used in healing practices in Latin America [16]. Moreover, numerous medicinal animals have been reported to be used by different ethnic groups in India [21,23–25] and Pakistan [26–31]. Additionally, Kim and Song [32] identified 77 medicinal animal species used by the local population of Jeju Island, Korea, whereas 41 animal species with different ethnozoological values were used in Nepal [33]. In the Mediterranean region, zootherapy has been practiced for centuries and remains a flourishing practice [34–36]. In Africa, zootherapeutical practices are deeply rooted in various ethnocultural contexts, including Ethiopia [37–42], Nigeria [43,44] South Africa [19,45,46], Sudan [18,47], Tanzania [48], Benin [49,50] Angola [51], and Ghana [52,53].

Morocco is a biodiversity hotspot in the Mediterranean region [54]. It has high concentrations of endemic species, particularly in its fauna, with 11 % of species unique to the region. The country is home to over 25,000 identified species, with terrestrial invertebrates (15,293 species) and continental aquatic fauna (1575 species) dominating the landscape. In terms of vertebrates, Morocco has a diverse range, including 105 species of mammals, 449 species of birds, 92 species of reptiles, and 11 species of amphibians [55]. Unfortunately, in Morocco, there has been very little study on the medical applications of animals and their parts or products. Indeed, ethnobiological research has focused mainly on the medicinal uses of plants. Surprisingly, ethnozoological investigations carried out within the framework of ethnological studies at the turn of the century focused primarily on the impact of ethnozoological practices on wildlife conservation [56–60]. To date, only one study has documented the use of animals and animal parts in traditional medicine among Berber communities in the Rif region (northern Morocco) [61]. However, the ethnomedicinal use of animals in other regions of the country has never been reported. Hence, this study sought to provide the first quantitative analysis of primary

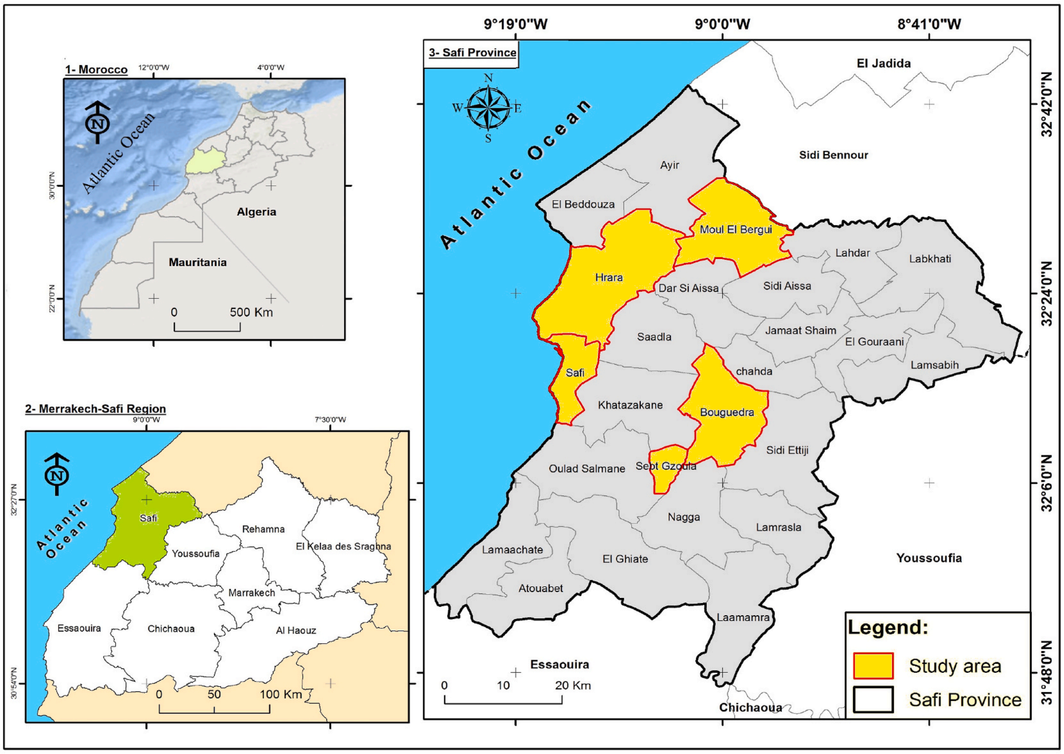

Fig. 1. Map of the study area.

ethnopharmacological data from traditional healers and merchants of medicinal animals in Safi province (west-center of Morocco). This study regarding the traditional knowledge of the medicinal uses of faunal resources by the people of the Safi region is part of a broader research project to document the uses of natural resources among local communities in this region of Morocco [62].

2. Materials and methods

2.1. Study area

The present study was conducted through five selected villages and weekly markets in the Safi Province where animals and derivatives are sold for therapeutic purposes: *Jamaat Shaim*, *Had Hrara*, *Tlat Bougedra*, *Moul El Bergie*, and Safi City (Fig. 1). The study area has been described in detail in our previous study [62].

2.2. Data collection

This ethnozoological prospecting of medicinal animals was carried out from March to June 2022. To collect ethnozoological data, semi-structured questionnaires were used, as described in Heinrich et al. [63] (**Annex**). The questionnaire has two parts: part one includes a query about the socio-demographic data of the people surveyed (age, gender, educational level, experience, and how they learnt about traditional medicine), and the second part covers diverse ethnozoological information (local names of species, parts used, ailments treated, and methods of preparation and administration). The diseases reported by the interviewees were classified in different categories according to the classification used by the WHO's international disease classification (International Classification of Primary Care (ICPC)) [64,65]. Field studies were carried out following the recommended standards [63,66,67].

2.3. Animal's identification

During fieldwork, animal medicinal species were recognized according to their vernacular names. The scientific names and species of animals were characterized following appropriate guides such as Wild Mammals of Morocco [68], The Birds of Morocco [69], and Amphibians and Reptiles of Morocco [70]. All scientific names were checked by the Integrated Taxonomic Information System's "Catalogue of Life: 2008 Annual Checklist. While the majority of the species were recognized at the species level, several species were only identified at the genus level. The International Union for Conservation of Nature (IUCN, 2022) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2022) were consulted to establish the conservation status of animal species.

2.4. Quantitative analysis

The collected ethnozoological information was analyzed using the following indices:

2.4.1. Relative frequency of citation (RFC)

Relative frequency citation has been frequently used in ethnobiology to show the local importance of each species. This index is calculated following the formula [71]:

$$\mathbf{RFC} = \frac{FC}{\mathbf{N}}$$

Where: FC is the number of informants mentioning a useful species; N is the total number of informants in the survey.

2.4.2. Use value (UV)

This index is often employed to infer the relative importance of commonly known species to the informants [72–74]. UV was calculated using the formula [75]:

$$\mathbf{UV} = \sum \frac{\mathbf{U_i}}{\boldsymbol{N}}$$

Where Ui is the number of uses mentioned by each informant for a given species and N is the total number of informants.

2.4.3. Species therapeutic redundancy (STR)

Species therapeutic redundancy (STR) was calculated as proposed by Albuquerque and Oliveira [76] and modified by Medeiros et al. [77]. Briefly, STR was estimated according to the following formula:

$$\mathrm{STR} = (\Sigma \mathrm{Si}/\mathrm{n}) \times \mathrm{W}$$

Where **ΣSi** is the total number of animal species that accomplish a given therapeutic function across therapeutic functions cited for a single species, **n** is the total number of species cited by participants, and **W** is the total number of therapeutic functions accomplished by a given species.

2.4.4. Informant consensus factor (ICF)

The Informant Consensus Factor is used to assess the agreement among informants on the animal species used against a disease category, as originally proposed by Trotter and Logan [78] and modified by Heinrich et al. [65,79]. The ICF is calculated using the following formula:

$$\mathrm{ICF} = \frac{\mathrm{N_{ur}} - \mathrm{N_{ut}}}{\mathrm{N_{ur}} - 1}$$

Where N_{ur} is the number of times an ailment was mentioned in each category and N_{ut} is the number of animal species used.

ICF values range between 0.00 and 1.00. High ICF values indicate that there is a homogeneity of traditional knowledge among informants, while low ICF values indicate a high variation in the use of species [63].

2.4.5. Fidelity level (FL%)

The fidelity level highlights the most important animal species used to cure given diseases by local practitioners [80,81]. The FL was calculated using the following formula:

$$FL(\%) = \frac{(\mathbf{NP} \times \mathbf{100})}{\mathbf{N}}$$

Where Np is the number of respondents who mention the specific animal species used to treat a given disease, and N is the total number of respondents who utilized the animals as medicine for healing any given disease.

2.4.6. Relative importance (RI)

The technique of relative importance (RI), proposed by Bennett and Prance [82], measures the usefulness of ethnomedicinal species. The RI is determined by the number of pharmacological capabilities attributed to each animal species and the number of disease categories it affects [83]. The RI was calculated according to the following formula:

$$\mathbf{RI} = (\mathbf{PP} + \mathbf{AC}) \times \mathbf{50}$$

PP is the number of pharmacological properties attributed to a species divided by the maximum number of properties attributed to the most versatile species. AC is the number of disease categories treated by a given species divided by the maximum number of disease categories treated by the most versatile species. We multiplied the overall scores by 50 to transform them to a scale of 100 [82].

2.4.7. Cultural importance index (CII)

This index is calculated to identify culturally important species as medicines. It was calculated by the total number of informants who mention the use of each animal species divided by the total number of informants [71]. This index is calculated according to the following formula:

$$CII = \sum_{u=u_1}^{u_{NC}} \sum_{I=1}^{I_N} \frac{UR_{ui}}{N}$$

Where NC is the total number of disease categories (for each i species), UR is the total number of use reports for each *i* species, and N is the total number of informants.

2.4.8. Index of agreement on remedies (IAR)

This index highlights the individual importance of the medicinal species [78,84]. The IAR was calculated using the following formula:

$$\mathbf{IAR} = \frac{\mathbf{n_r} - \mathbf{n_a}}{\mathbf{n_r} - \mathbf{1}}$$

Where n_r is the total number of citations registered for species s and n_a is the number of illness categories that are treated with this species.

2.4.9. Cultural agreement index (CAI)

The cultural agreement index (CAI) is calculated as follows [85]:

$$\boldsymbol{CAI} = \boldsymbol{CII} \times \boldsymbol{IAR}$$

Where IAR and CII are calculated as previously mentioned.

3. Results

3.1. Socio-demographic characteristics of the respondents

A total of 42 traditional healers and merchants of medicinal animals were interviewed based on their knowledge of trading zoo-therapeutic products in the province of Safi. Out of these, 128 (66.67 %) were men, and 14 (33.33 %) were women. Among them, 60 % have more than 20 years of experience in trading medicinal animals. Concerning the demography of the informants, 73.8 % were between 40 and 70 years old. Older people (those over the age of 70) account for 9.5 % of the respondents. Table 1 shows that young people (between 25 and 40 years old) represent 16.66 % of the interviewees (Table 1). Regarding their educational backgrounds, most of the informants (40.47 %) had not received any formal education. Only 26.19 % have completed primary school, informal education (19.04 %), or secondary school education (11.9 %). Concerning professional activity, 66 % of the interviewees practiced traditional medicine as a full-time job, while 19.04 % had agriculture as a second professional activity. Relating to the procurement of traditional medicine, 59.52 % of respondents acquired their traditional medicinal knowledge by heredity (familial tradition) and 26.19 % from reading books, particularly traditional Arab medicine books. Concerning the supply source of the medicinal animals sold in the study area, all participants affirmed that the animals were sourced from the wild and bought from regional or national wholesale suppliers.

3.2. Ethnozoological knowledge of medicinal animals

3.2.1. Ethnospecies richness

Our results showed that 42 different animal species, with 325 uses, have been reported by the interviewees as being used for medicinal, magical, or ritual purposes in the study area (Fig. 2). These are arranged in Table 2 with their taxonomic classification, scientific and local names, uses, parts or products used, methods of preparation, and modes of application. These animals were prescribed to treat 118 different kinds of human diseases or conditions, including physiological (80 indications) and culture-bound ailments (30 indications) (Table 2). The listed animals belong to six taxonomic groups. These include 15 species of mammals (36 %), 12 species of birds (29 %), six species of arthropods (14 %), and four species of reptiles (10 %). Additionally, mollusks were represented by two species (5 %), whereas amphibians, echinoids, and fish were each represented by one species (2 %). (Table 3). Of these animals, 17 species (41 %) are used solely for medicinal purposes, 12 species (28.57 %) for magical or ritual practice, and 10 species (24 %) have a mixed use for both therapeutic and spiritual purposes (Fig. 3). Our results also show that 69.4 % of the animal species are reported to treat more than one disease. Altogether, 42 species of medicinal animals in the region (69 %) of the animal species were obtained from the wild, and 13 (31 %) represented domestic animal species.

3.2.2. Animal parts and products, method of preparation, and administration

Our analysis revealed that 20 animal parts or products were indicated as medicinal ingredients by the traditional healers (Fig. 4). Medicines were obtained from whole animals or body parts or products, such as fat, meat, milk, bones, horns, skin, fur, honey, mucus,

Table 1
Demographic profile of ethnomedicinal animals' traditional healers in the Safi province (Morocco).

			N	%
Gender:	Men		128	66.67
	Women		14	33.33
Age:	[25–40]		7	16.66
	[40–55]		16	38.09
	[55–70]		15	35.71
	>70		4	9.52
Educational level:	Illeterate		17	40.47
	Informal education		8	19.04
	Primary school		11	26.19
	Secondary school		5	11.90
	High graduate		1	2.38
Occupation:	Full-time practitioners		28	66.66
	Part-time practitioners:		14	33.33
		Government employs	1	2.38
		Agriculture	8	19.04
		Self employs	2	4.76
		Fqih (spiritual healers)	3	7.14
Experience:	>20 years		25	59.52
	>10 years		5	11.90
	<10 years		12	28.58
Source of knowledge:	Parents		23	54.76
	Books		11	26.19
	Experience		20	47.61
	Others		4	9.52
Supply source:	Trading		42	100
	Hunting		1	2.38

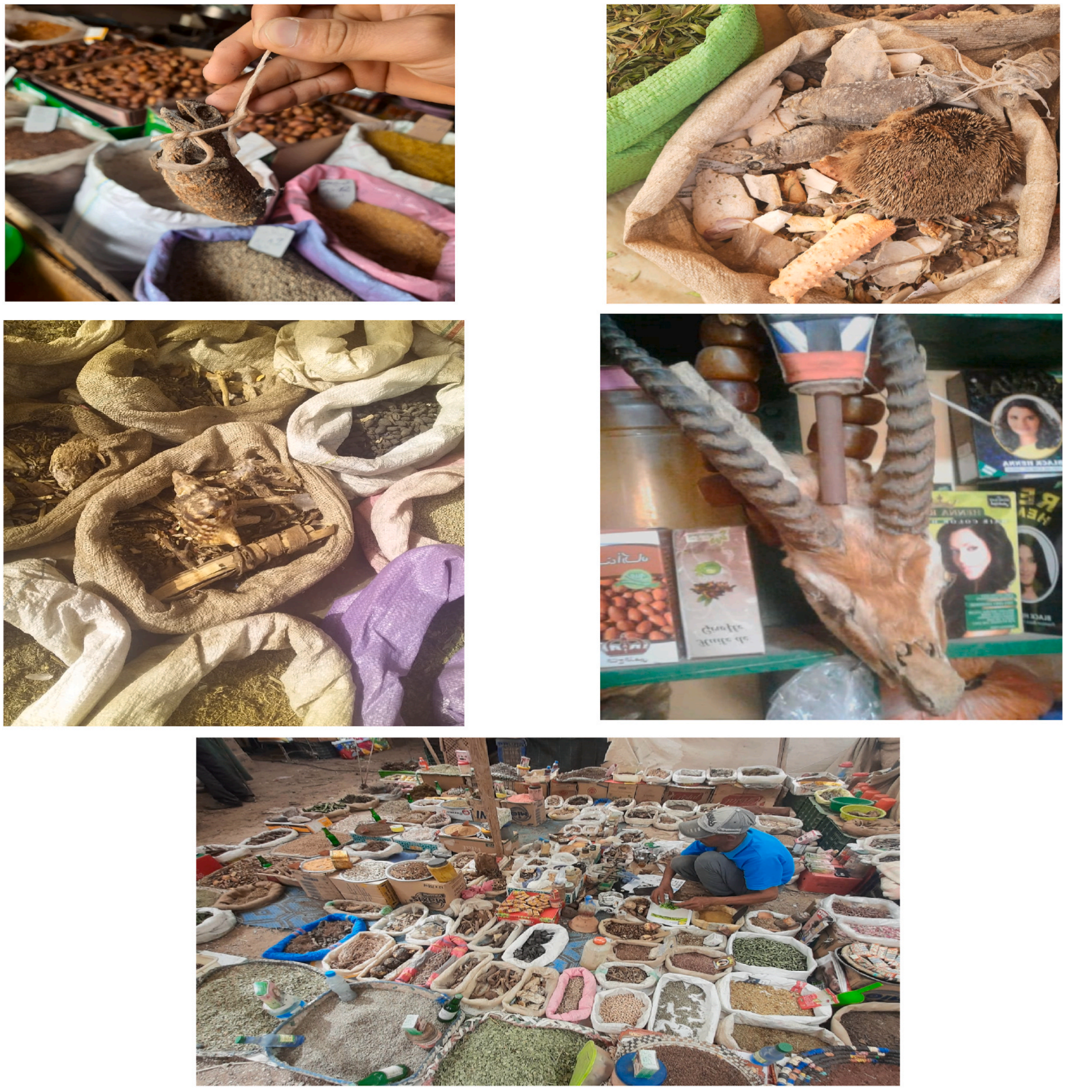

Fig. 2. Photographs from the study area showing some openly traded animal species and an ambulant merchant's display. Photographs by A. Labani.

and eggs. Animal products are the most used (36 %), followed by the entire animal (12 %), fat, and meat (8 % for each). Honey (39 %), eggs (28 %), and urine (14 %) were the most commonly used animal products.

The findings of this study reported six modes of preparation of animals, animal parts, and/or animal by-products (Fig. 5). We also observed that the mode of preparation changed depending on the sickness and included cooking (28 % of total preparation), burning (11 %), drying or the use of fresh animal parts or products (7 %), and powdering (6 %). Among the listed animal parts and products, 20 % were used, without any preliminary preparation, as raw materials, while 28 % of the total preparation was taken as mixtures with different kinds of animal or vegetable additives to treat some ailments. To increase their effectiveness, the recipes were combined in the form of a mixture. For example, *Scarabaeus laticollis* urine is mixed with olive oil for treating ear diseases, and the cooked snail is mixed with thyme and rosemary to treat respiratory disorders, etc. Most commonly, such mixtures included olive oil (6 recipes), honey (5 recipes), ghee (3 recipes), *Peganum harmala* (2 recipes), and pomegranate peel (2 recipes).

Various routes of application and administration of medicinal animal preparations are known to the people of the area. Oral application was the most common route (49 % of all applications), followed by topical (dermal) application (29 %), instillation (7 %), and nasal administration (2 %) by inhaling fumes (fumigation) and/or introducing the medicinal preparation into the nose (Fig. 6).

3.2.3. Quantitative ethnozoological analysis: RFC, STR, ICF, RI, CII, IAR, and CAI indices

The RFC values for the different animal species reported in this research varied from 0.021 to 0.81 (Fig. 7). The highest RFC was obtained for the following species: *Camelus* sp. (RFC = 0.81), *Sepia officinalis* (RFC = 0.71), *Chamaeleo chamaeleon* (RFC = 0.69), *Atelerix algirus* (RFC = 0.62), and *Apis* sp. (RFC = 0.60). Low RFC values were obtained for *Uromastyx nigriventris* (RFC = 0.048), *Anas*

Table 2
Checklist of medicinal animals and their body parts used in traditional medicine in Safi Province (Morocco).

Class	Scientific name	Vernacular name	Arabic name	Used part(s)	Form of utilization	Traditional indications	Mode of administration
Amphibians	*Rana* sp.	Frog	الضفدعة	Meat	Cooked and consumed	Antidote against scorpion stings and snake bites	Topical
Amphibians	*Rana* sp.	Frog	الضفدعة	Meat	Cooked and consumed with olive oil	Smallpox	Oral
Arachnida	*Araneae* sp.	Spider	العنكب	Silk	Raw	Wound healing	Topical
Arachnida	*Scorpiones* sp.	Scorpion	العقرب	Whole animal	Burnt powder	Antidote against scorpion stings and snake bites	Local
Arachnida	*Scorpiones* sp.	Scorpion	العقرب	Whole animal	Ashes mixed with butter and camphor	Haemorrhoid	Massage
Arachnida	*Scorpiones* sp.	Scorpion	العقرب	Whole animal	Ashes mixed with water and honey	Renal lithiasis	Oral
Aves	*Anas platyrhynchos domesticus* Linnaeus, 1758	Domestic duck	الكنار	Egg	Raw	Skin burn	Oral
Aves	*Aquila chrysaetos* Linnaeus, 1758	Eagle	النسر	Claws		Magical-religious	
Aves	*Aquila chrysaetos* Linnaeus, 1758	Eagle	النسر	Head		Magical-religious	
Aves	*Aquila chrysaetos* Linnaeus, 1758	Eagle	النسر	Heart		Magical-religious	
Aves	*Caligo eurilochus* Pieter Cramer, 1775	Owl	البومة	Meat	Cooked and consumed	Skin diseases	Oral
Aves	*Caligo eurilochus* Pieter Cramer, 1775	Owl	البومة	Whole animal		Magical-religious	
Aves	*Ciconia* sp.	Stork	اللقلاق	Meat	Cooked and consumed	Respiratory disorders (asthma)	Oral
Aves	*Corvus corax* Linnaeus, 1758	Raven	الغراب	Blood		Magical-religious	
Aves	*Coturnix coturnix* Linnaeus, 1758	Quail	السمان	Egg	Cooked and consumed	Obesity	Oral
Aves	*Falco* sp.	Falcon	الصقر	Meat		Magical-religious	
Aves	*Gallus gallus* Linnaeus, 1758	Chicken	الدجاج	Vitellus	Cooked and consumed	Anaemia	Oral
Aves	*Gallus gallus* Linnaeus, 1758	Chicken	الدجاج	Egg white	Mixed with propolis	Skincare	Topical
Aves	*Gallus gallus* Linnaeus, 1758	Chicken	الدجاج	Blood	Mixed with milk	Antidote against scorpion stings	Oral
Aves	*Gallus gallus* Linnaeus, 1758	Chicken	الدجاج	Gizzard	Cooked and consumed	Galactagogues (stimulates lactation)	Oral
Aves	*Gallus gallus* Linnaeus, 1758	Chicken	الدجاج	Claws		Magical-religious	
Aves	*Gallus gallus* Linnaeus, 1758	Chicken	الدجاج	Egg Shell	Powder, mixed with pomegranate peel	Nosebleed	Nasal
Aves	*Neophron percnopterus* Linnaeus, 1758	Vulture	رخمة	Whole animal		Magical-religious	
Aves	*Pavo cristatus* Linnaeus, 1758	Peacock	الطاووس	Feathers		Magical-religious	
Aves	*Pavo cristatus* Linnaeus, 1758	Peacock	الطاووس	Paw		Magical-religious	
Aves	*Struthio* sp.	Bonetrich	النعامة	Egg		Hyposexual disorders	Oral
Aves	*Struthio* sp.	Bonetrich	النعامة	Meat	Cooked and consumed	Joint pain, arthritis	Oral
Aves	*Struthio* sp.	Bonetrich	النعامة	Feathers		Magical-religious	
Aves	*Struthio* sp.	Bonetrich	النعامة	Egg	Cooked and consumed	Rheumatism	Oral
Aves	*Struthio* sp.	Bonetrich	النعامة	Egg	Cooked and consumed	Digestive disorders	Oral
Aves	*Upupa epops* Linnaeus, 1758	Hoopoe	الهدهد	Feathers		Magical-religious	
Cephalopoda	*Sepia officinalis* Linnaeus, 1758	Cuttlefish	الحبار	Bone	Powder	Teeth whitening, teeth strength	Brushing
Cephalopoda	*Sepia officinalis* Linnaeus, 1758	Cuttlefish	الحبار	Bone	Powder	Eye diseases	Ocular
Cephalopoda	*Sepia officinalis* Linnaeus, 1758	Cuttlefish	الحبار	Bone	Powder	Skin diseases	Local
Crustacea	*Brachyura* sp.	Crabe	السلطعون	Shell	Ashes	Magical-religious	Fumigation

(*continued on next page*)

Table 2 (*continued*)

Class	Scientific name	Vernacular name	Arabic name	Used part(s)	Form of utilization	Traditional indications	Mode of administration
Crustacea	*Cymothoa exigua* Schiødte & Meinert, 1884	Sea lice	قمل البحر	Whole animal	Ashes	Headache, migraine	Fumigation
Echinoidea	*Echinoidea* sp.	Sea urchin	قنفد البحر	Whole animal	Ashes	Magical-religious	Fumigation
Fish	*Physeter macrocephalus* Linnaeus, 1758	Sperm whale	حوت العنبر	Ambergris		Hyposexual disorders	Oral
Fish	*Physeter macrocephalus* Linnaeus, 1758	Sperm whale	حوت العنبر	Ambergris	Mixed with honey	Weight gain, body strength	Oral
Fish	*Physeter macrocephalus* Linnaeus, 1758	Sperm whale	حوت العنبر	Ambergris		Neurological disorders	Topical
Gasteropoda	*Helix pomatia* Linnaeus, 1758	Snail	الحلزون	Whole animal	Cooked and consumed with thyme and rosemary	Respiratory disorders (influenza)	Oral
Gasteropoda	*Helix pomatia* Linnaeus, 1758	Snail	الحلزون	Mucus	Raw	Skincare, cosmetic	Topical
Gasteropoda	*Helix pomatia* Linnaeus, 1758	Snail	الحلزون	Mucus	Cooked and consumed	Respiratory disorders (cough)	Oral
Gasteropoda	*Helix pomatia* Linnaeus, 1758	Snail	الحلزون	Whole animal	Cooked and consumed	Eye diseases	Ocular
Insecta	*Apis* sp.	Bee	النحل	Honey	Raw	Hyposexual disorders	Oral
Insecta	*Apis* sp.	Bee	النحل	Honey	Raw	Anemia	Oral
Insecta	*Apis* sp.	Bee	النحل	Honey	Raw	Toothcare, teeth strength	Oral
Insecta	*Apis* sp.	Bee	النحل	Honey	Raw	Skin burn	Local
Insecta	*Apis* sp.	Bee	النحل	Honey	Raw	Digestive disorders	Oral
Insecta	*Apis* sp.	Bee	النحل	Honey	Raw	Respiratory disorders (asthma, flu)	Oral
Insecta	*Apis* sp.	Bee	النحل	Honey	Mixed with ghee	Gastric ulcer	Oral
Insecta	*Apis* sp.	Bee	النحل	Honey	Raw	Gastric ulcer	Oral
Insecta	*Apis* sp.	Bee	النحل	Honey	Raw	Varicose veins	Oral
Insecta	*Scarabaeus laticollis* Linnaeus, 1767	Scarab dung	الخنفساء	Whole animal	Ashes	Insect repellent	Fumigation
Insecta	*Scarabaeus laticollis* Linnaeus, 1767	Scarab dung	الخنفساء	Urine	Mixed with olive oil	Ear diseases	Instillation
Insecta	*Scarabaeus laticollis* Linnaeus, 1767	Scarab dung	الخنفساء	Urine	Fresh	Eye diseases	Instillation
Mammals	*Atelerix algirus* Lereboullet, 1842	Hedgehog	القنفد	Gallbladder	Mixed with Khôl	Cataract	Ocular
Mammals	*Atelerix algirus* Lereboullet, 1842	Hedgehog	القنفد	Spines	Ashes mixed with olive oil	Haircare	Local
Mammals	*Atelerix algirus* Lereboullet, 1842	Hedgehog	القنفد	Spines	Ashes	Fever	Nasal
Mammals	*Atelerix algirus* Lereboullet, 1842	Hedgehog	القنفد	Intestine	Cooked and consumed	Galactagogues (stimulates lactation)	Oral
Mammals	*Atelerix algirus* Lereboullet, 1842	Hedgehog	القنفد	Whole animal	Cooked and consumed with ghee	Influenza	Oral
Mammals	*Atelerix algirus* Lereboullet, 1842	Hedgehog	القنفد	Whole animal		Magical-religious	
Mammals	*Atelerix algirus* Lereboullet, 1842	Hedgehog	القنفد	Meat	Cooked and consumed	Rheumatism	Oral
Mammals	*Bos taurus* Linnaeus, 1758	Cow	البقر	Gallbladder	Cooked and consumed	Anthelmintic (Taenia)	Oral
Mammals	*Bos taurus* Linnaeus, 1758	Cow	البقر	Milk	Mixed with olive oil	Haircare	Topical
Mammals	*Bos taurus* Linnaeus, 1758	Cow	البقر	Bone	Powder mixed with olive oil	Haircare	Topical
Mammals	*Bos taurus* Linnaeus, 1758	Cow	البقر	Butter	Raw	Skin diseases	Topical
Mammals	*Bos taurus* Linnaeus, 1758	Cow	البقر	Butter	Butter mixed with honey	Antidote against scorpion stings	Topical
Mammals	*Bos taurus* Linnaeus, 1758	Cow	البقر	Butter	Butter mixed with chameleon skin and honey	Fever	Topical

(*continued on next page*)

Table 2 (*continued*)

Class	Scientific name	Vernacular name	Arabic name	Used part(s)	Form of utilization	Traditional indications	Mode of administration
Mammals	*Bos taurus* Linnaeus, 1758	Cow	البقر	Butter	Raw	Haemorrhoids	Topical
Mammals	*Camelus* sp.	Camel	الجمل	Fat	Cooked and consumed	Allergy	Oral
Mammals	*Camelus* sp.	Camel	الجمل	Urine	Fresh	Spleen diseases	Oral
Mammals	*Camelus* sp.	Camel	الجمل	Fat	Cooked and consumed	Liver diseases	Oral
Mammals	*Camelus* sp.	Camel	الجمل	Fur	Ashes	Migraine	Fumigation
Mammals	*Camelus* sp.	Camel	الجمل	Fat	Liquid	Rheumatism	Topical
Mammals	*Camelus* sp.	Camel	الجمل	Fur	Ashes	Nosebleed	Fumigation
Mammals	*Camelus* sp.	Camel	الجمل	Fat	Cooked and consumed	Respiratory disorders (asthma)	Oral
Mammals	*Camelus* sp.	Camel	الجمل	Fat	Cooked and consumed	Respiratory disorders (whooping cough)	Oral
Mammals	*Canis lupus familiaris* Linnaeus, 1758	Dog	الكلبة	Milk	Mixed with honey	Abortion	Oral
Mammals	*Canis lupus familiaris* Linnaeus, 1758	Dog	الكلبة	Teeth		Magical-religious	
Mammals	*Capra aegagrus* Erxleben, 1777	Goat	الماعز	Fur	Ashes, mixed with *Peganum harmala* and pomegranate peel	Nosebleed	Nasal
Mammals	*Capra aegagrus* Erxleben, 1777	Goat	الماعز	Urine	Fresh	Nosebleed	Nasal
Mammals	*Capra aegagrus* Erxleben, 1777	Goat	الماعز	Horn	Ashes mixed with cow's fat	Nosebleed	Local
Mammals	*Cervus elaphus* Linnaeus, 1758	Cerf	الايل	Horn		Magical-religious	
Mammals	*Chiroptera* sp.	Bat	الخفاش	Blood		Magical-religious	
Mammals	*Equus asinus* Linnaeus, 1758	Donkey	الحمار	Hoof		Magical-religious	
Mammals	*Equus asinus* Linnaeus, 1758	Donkey	الحمار	Tongue		Magical-religious	
Mammals	*Equus caballus* Linnaeus, 1758	Horse	الحصان	Milk	Raw	Allergy	Oral
Mammals	*Equus caballus* Linnaeus, 1758	Horse	الحصان	Urine	Fresh	Eczema	Topical
Mammals	*Gazella cuvieri* Ogilby, 1841	Gazelle	الغزالة	Head		Magical-religious	
Mammals	*Gazella cuvieri* Ogilby, 1841	Gazelle	الغزالة	Fur		Magical-religious	
Mammals	*Hyaena hyaena* Linnaeus, 1758	Hyena	الضبع	Brain		Magical-religious	
Mammals	*Mustela nivalis* Linnaeus, 1766	Least weasel	فارة الخيل	Skin	Burn	Digestive disorders	Fumigation
Mammals	*Ovis aries* Linnaeus, 1758	Sheep	الخروف	Viscera	Cooked and consumed	Respiratory disorders (influlenza)	Oral
Mammals	*Ovis aries* Linnaeus, 1758	Sheep	الخروف	Trotter	Ashes mixed with vinegar	Alopecia	Topical
Mammals	*Ovis aries* Linnaeus, 1758	Sheep	الخروف	Gallbladder	Powder	Hair loss	Topical
Mammals	*Ovis aries* Linnaeus, 1758	Sheep	الخروف	Tongue	Cooked and consumed	gastric ulcer	Oral
Mammals	*Vulpes vulpes* Linnaeus, 1758	Fox	الثعلب	Blood		Magical-religious	
Mammals	*Vulpes vulpes* Linnaeus, 1758	Fox	الثعلب	Fur	Cooked and consumed with olive oil	Ear diseases	Auricular
Mammals	*Vulpes vulpes* Linnaeus, 1758	Fox	الثعلب	Fat		Ear diseases	Instillation
Mammals	*Vulpes vulpes* Linnaeus, 1758	Fox	الثعلب	Blood	Raw	Respiratory disorders (asthma)	Oral
Reptilia	*Chamaeleo chamaeleon* Linnaeus, 1758	Chameleon	الحرباء	Skin	Mixed with ghee	Skin diseases	Local
Reptilia	*Chamaeleo chamaeleon* Linnaeus, 1758	Chameleon	الحرباء	Skin		Fever	Topical
Reptilia	*Chamaeleo chamaeleon* Linnaeus, 1758	Chameleon	الحرباء	Blood	Blood	Haircare	Topical
Reptilia	*Chamaeleo chamaeleon* Linnaeus, 1758	Chameleon	الحرباء	Whole animal	Ashes	Magical-religious	Fumigation
Reptilia	*Chamaeleo chamaeleon* Linnaeus, 1758	Chameleon	الحرباء	Egg		Magical-religious	

(*continued on next page*)

Table 2 (*continued*)

Class	Scientific name	Vernacular name	Arabic name	Used part(s)	Form of utilization	Traditional indications	Mode of administration
Reptilia	*Chamaeleo chamaeleon* Linnaeus, 1758	Chameleon	الحرباء	Whole animal	Ashes	Nosebleed	Fumigation
Reptilia	*Ophidia* sp.	Snake	الثعبان	Fat		Exanthema	Topical
Reptilia	*Ophidia* sp.	Snake	الثعبان	Exuvie		Magical-religious	
Reptilia	*Scincus scincus* Linnaeus, 1758	sand fish	سمكة الرمال	Meat	Cooked and consumed	Osteoporosis	Oral
Reptilia	*Scincus scincus* Linnaeus, 1758	sand fish	سمكة الرمال	Fat	Cooked and consumed	Rheumatism	Oral
Reptilia	*Testudo graeca* Linnaeus, 1758	Tortue	السلحفاة	Meat	Steamed meat	Galactagogues (stimulates lactation)	Oral
Reptilia	*Testudo graeca* Linnaeus, 1758	Tortue	السلحفاة	Egg		Magical-religious	
Reptilia	*Testudo graeca* Linnaeus, 1758	Tortue	السلحفاة	Shell		Magical-religious	
Reptilia	*Uromastyx nigriventris* Rothschild & Hartert, 1912	Bell's dabb lizard	الضب	Skin		Magical-religious	
Reptilia	*Uromastyx nigriventris* Rothschild & Hartert, 1912	Bell's dabb lizard	الضب	Fat	Cooked and consumed	Rheumatism	Oral

Table 3
Taxonomic groups of ethnomedicinal animals used in the Safi province (Morocco).

Class	Number of species	%
Mammals	15	35.71
Aves	12	28.57
Arthropods	6	14.28
Reptilia	4	9.52
Amphibians	1	2.38
Echinoida	1	2.38
Mollusks	2	4.76
Fish	1	2.38

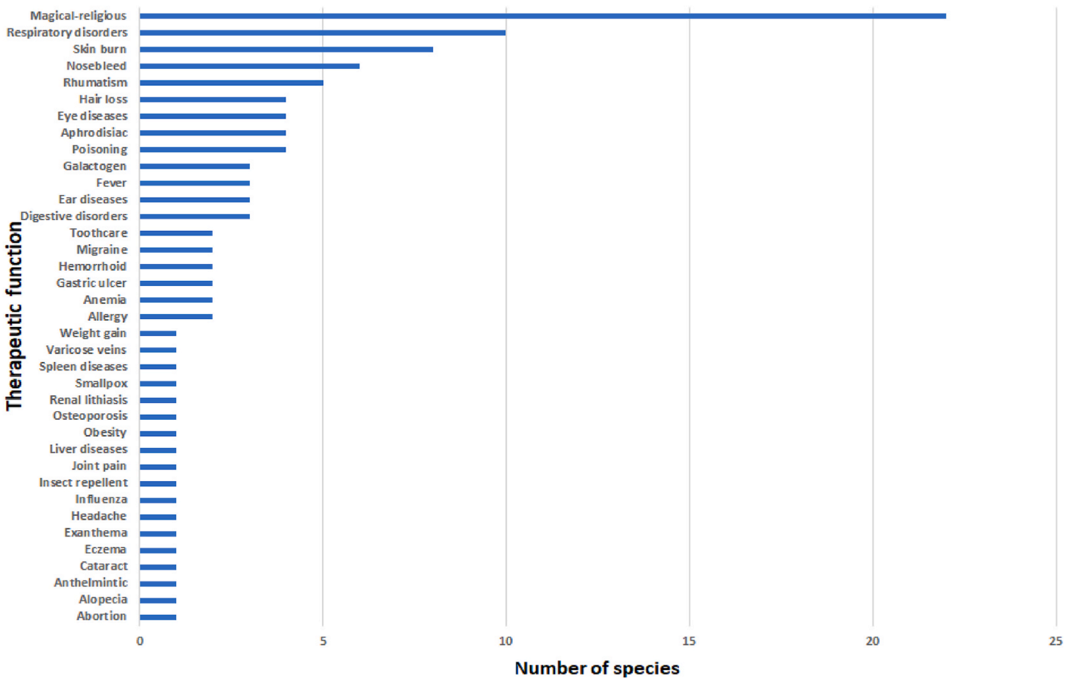

Fig. 3. Number of animal species accomplishing a specific therapeutic function reported by the traditional healers of Safi Province (Morocco).

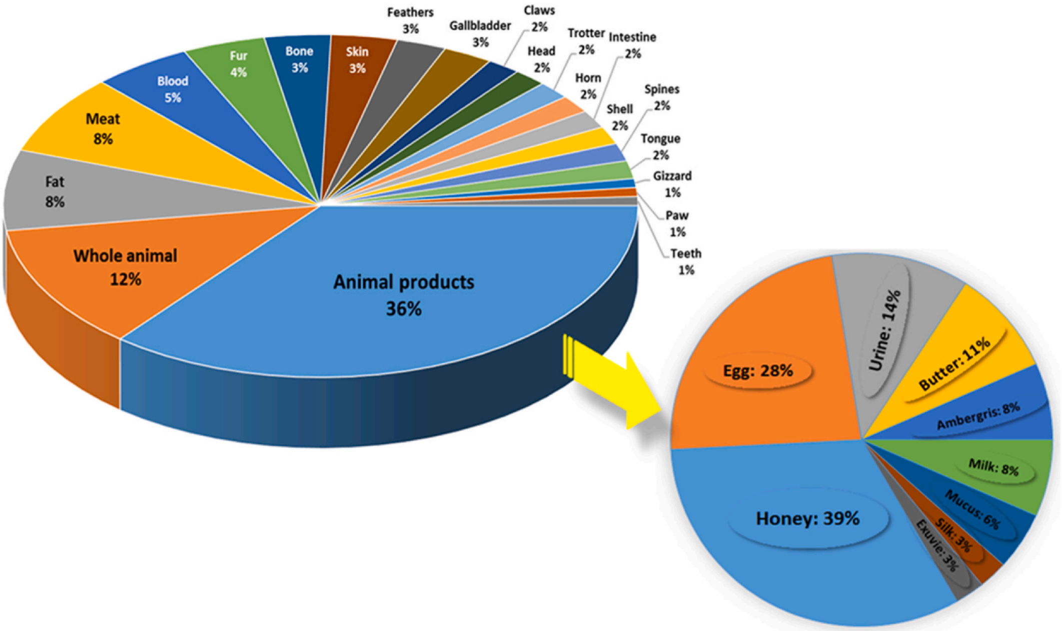

Fig. 4. Used parts and products of ethnomedicinal animals used in the Safi province (Morocco).

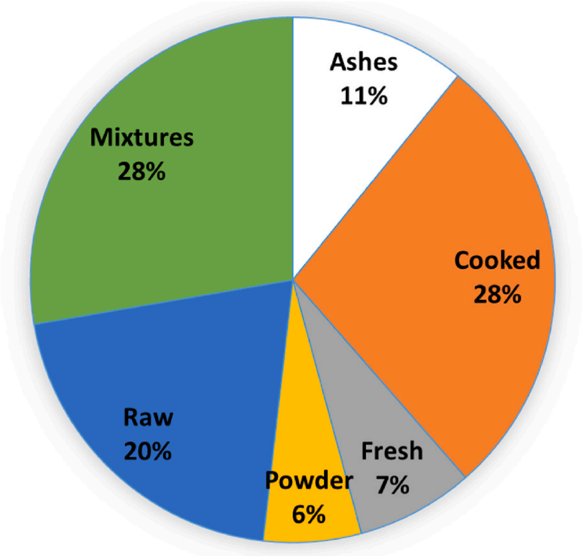

Fig. 5. The preparation methods of ethnomedicinal animals used in the Safi province (Morocco).

platyrhynchos domesticus (RFC = 0.024), *Chiroptera* (RFC = 0.024), *Falco* sp. (RFC = 0.024), *Hyaena hyaena* (RFC = 0.024), *Pavo cristatus* (RFC = 0.024), and *Cervus elaphus* (RFC = 0.021).

Also, our results show that the UV for the animal species reported in this study varies from 0.02 to 0.21. The species with the highest UV values were *Apis* sp. (UV = 0.21), *Camelus* sp. (UV = 0.19), *Aterlerix algirus* (UV = 0.17), and *Bos taurus* (UV = 0.14). Low UV (UV = 0.02) was recorded for 20 animal species, including *Capra aegagrus*, *Cervus elaphus*, *Corvus corax*, *Cymothoa exigua*, *Equus asinus*, *Gazella cuvieri*, *Hyaena hyaena*, *Mustela nivalis*, *Neophron percnopterus*, *Pavo cristatus*, and *Upupa epops.*

In addition, the species with the highest level of therapeutic redundancy were *Atelerix algirus* with 8.00 units, *Gallus gallus* with 6.42 units, *Apis* sp. with 5.52 units, *Chamaelea chamaeleon* with 5.23 units, and *Struthio* sp. with 4.16 units (Fig. 8). *Mustela nivalis* (STR = 0.07 units), *Cymothoa exigua* (STR = 0.05 units), and *Coturnix coturnix* (STR = 0.02 units) had the lowest level of therapeutic redundancy.

On the other hand, the documented medicinal animal species were used to cure 118 ailments, which were classified into 16 disease

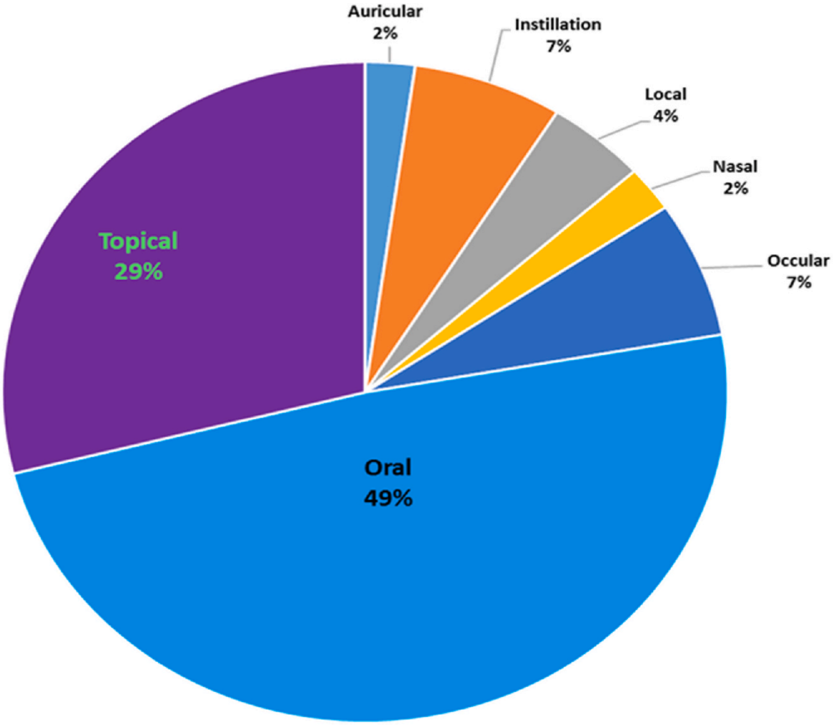

Fig. 6. The administration modes of ethnomedicinal animals used in the Safi province (Morocco).

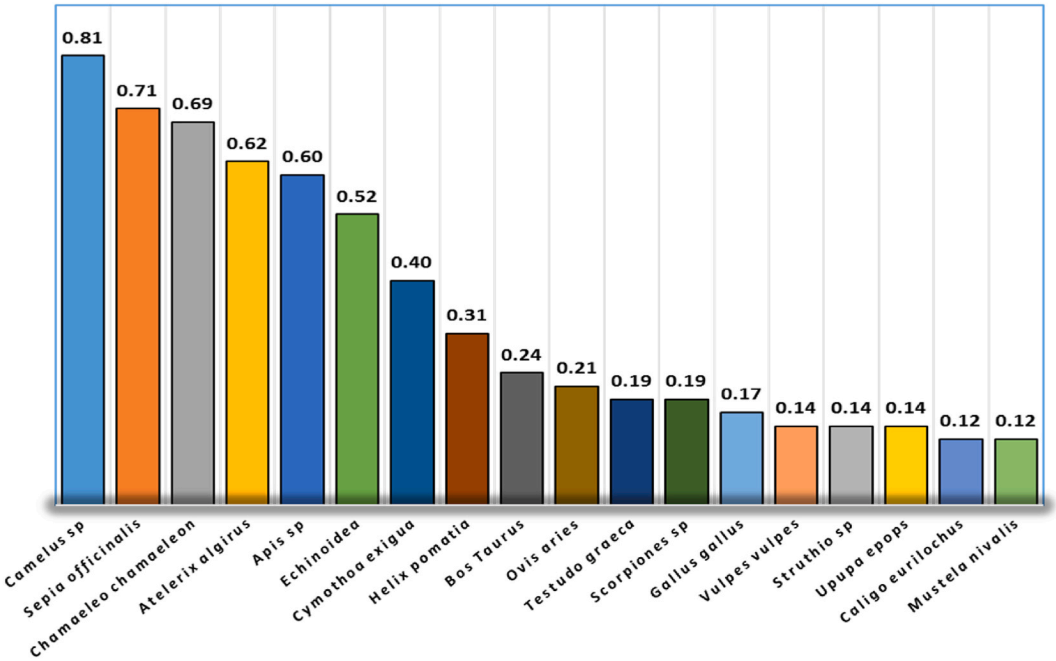

Fig. 7. Relative frequency citation values of the most used medicinal animals in the Safi Province (Morocco).

categories (Table 4). The ICF values for the various disease categories varied from 0.25 to 1.00 (Table 4). The highest ICF values are found for circulatory system disorders (ICF = 1.00), oncology (ICF = 1.00), oro-dental problems (ICF = 0.86), nervous system disorders (ICF = 0.86), genitourinary system disorders (ICF = 0.85), eye ailments (ICF = 0.79), and culture-bound diseases (ICF = 0.79). The lowest ICF values were attributed to respiratory system disorders (ICF = 0.59) and poisoning (ICF = 0.43).

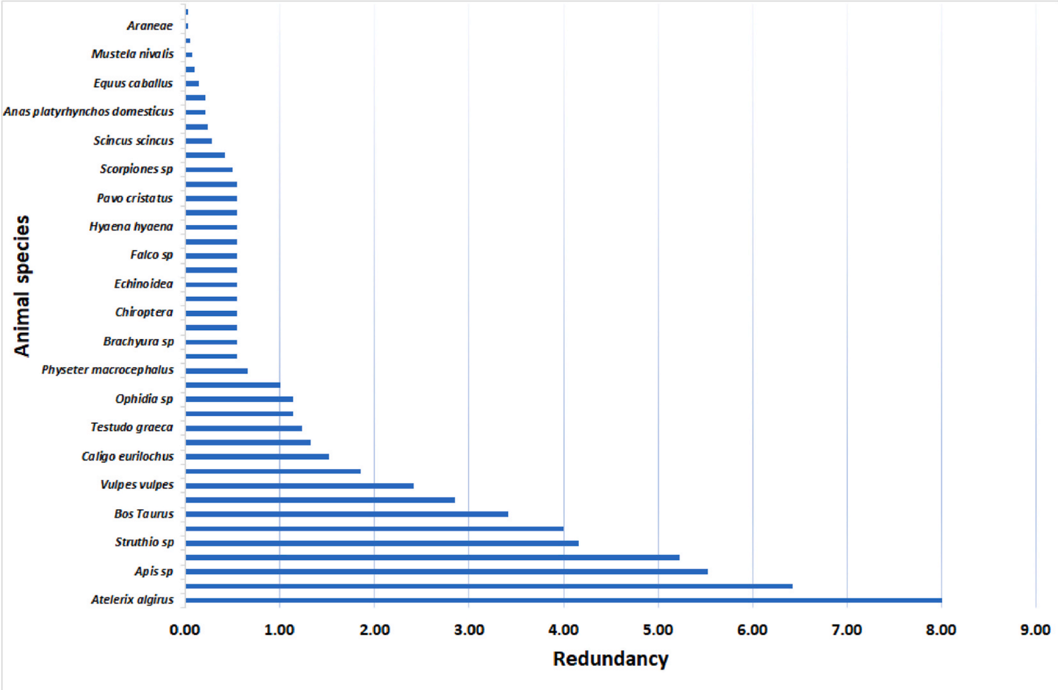

Fig. 8. Species therapeutic redundancy for some animal species cited by participants in Safi province (Morocco).

Table 4
Ailment's categories and their respective ICF values.

No.	Disease category	Use citations (N_{ur})	Taxon (N_{ut})	ICF
1	Circulatory system disorders	2	1	1.00
2	Oncology	3	1	1.00
3	Oro-dental problems	15	3	0.86
4	Nervous system disorders	29	5	0.86
5	Genitourinary system disorders	41	7	0.85
6	Eye ailments	15	4	0.79
7	Culture-bound diseases	101	22	0.79
8	Gastro-intestinal ailments	25	7	0.75
9	Skin diseases	58	18	0.70
10	Haircare ailments	10	4	0.67
11	Immune diseases	4	2	0.67
12	Skeleto-muscular ailments	15	6	0.64
13	Ear, nose, and throat ailments	27	11	0.62
14	Endocrinal disorders and ailments	6	3	0.60
15	Respiratory system disorders	18	8	0.59
16	Poisonings	8	5	0.43

ICF, Informant Consensus Factor **Nur**, number of use reports for a particular ailment category **Nut**, the number of taxa used for an ailment category by all informants.

Overall, our results depicted three grade levels of FL values: high FL (70–100 %), intermediate FL (50–70 %), and low FL (<50 %) (Table 5). Notably, this study revealed that 17 animal species were found to have a FL of 100 %. This is the case, for example, of *Anas platyrhynchos domesticus* (skin diseases), *Coturnix coturnix* (endocrinal disorders), *Mustela nivalis* (gastrointestinal disorders), *Cymothoa exigua* (nervous system disorders), and *Upupa epops* (culture-bound diseases).

According to our results, the IR value ranged from 11.81 to 100 % (Table 6). The most versatile and resourceful species were *Apis* sp. (RI = 100 %), *Aterix algirus* (RI = 88.89 %), *Camelus* sp. (RI = 88.19 %), *Bos taurus* (RI = 64.58 %), and *Chamaeleo chamaeleon* (RI = 59.03 %). Low RI values (RI = 11.81 %) were recorded for 17 medicinal animals, including *Corvus corax*, *Hyaena hyaena*, and *Upupa epops*.

The results showed that the CII obtained for the 42 useful animal species ranged from 2.38 to 57.14 (Table 6). The highest CII value was for *Chamaeleo chamaeleon* (CII = 57.14), *Atelerix algirus* (CII = 40.48), and *Cymothoa exigua* (CII = 40.48).

In this study, we have documented a high value (IAR = 1.00) of IAR for 11 animal species: *Cymothoa exigua* (nervous system disorders), *Upupa epops* (culture-bound diseases), *Mustela nivalis* (gastrointestinal disorders), *Araneae* (skin diseases), *Aquila chrysaetos*

Table 5
Fidelity level values of medicinal animal species used against a given ailment category in the Safi province (Morocco).

Disease Category	Animal species	Np	N	FL (%)
Circulatory system disorders	*Apis* sp.	2	25	8.0
Dental care ailments	*Sepia officinalis*	13	30	43.3
	Atelerix algirus	1	26	3.8
Skin diseases	*Anas platyrhynchos domesticus*	1	1	**100.0**
	Araneae sp.	4	4	**100.0**
	Rana sp.	2	3	66.7
	Helix pomatia	8	13	61.5
	Caligo eurilochus	5	10	50.0
	Capra aegagrus	2	4	50.0
	Equus caballus	1	2	50.0
	Ovis aries	5	10	50.0
	Bos Taurus	4	10	40.0
	Scorpiones sp.	2	5	40.0
	Scarabaeus laticollis	1	3	33.3
Ear, nose, and throat ailments	*Capra aegagrus*	2	4	50.0
	Scarabaeus laticollis	1	3	33.3
	Vulpes vulpes	2	6	33.3
	Camelus sp.	8	34	23.5
	Gallus gallus	2	9	22.2
Endocrinal disorders and ailments	*Coturnix coturnix*	3	3	**100.0**
	Scincus scincus	1	2	50.0
	Scorpiones sp.	1	5	20.0
	Physeter macrocephalus	1	6	16.7
Eye ailments	*Sepia officinalis*	12	30	40.0
	Scarabaeus laticollis	1	3	33.3
Gastrointestinal disorders	*Mustela nivalis*	5	5	**100.0**
	Testudo graeca	4	8	50.0
	Apis sp.	10	25	40.0
Genitourinary system disorders	*Apis* sp.	22	25	88.0
	Struthio sp.	5	6	83.3
	Physeter macrocephalus	4	6	66.7
	Canis lupus familiaris	1	2	50.0
	Scorpiones sp.	2	5	40.0
Immune system diseases	*Equus caballus*	1	2	50.0
Culture-bound diseases	*Aquila chrysaetos*	3	3	**100.0**
	Brachyura sp.	3	3	**100.0**
	Chiroptera sp.	1	1	**100.0**
	Corvus corax	2	2	**100.0**
	Falco sp.	1	1	**100.0**
	Gazella cuvieri	3	3	**100.0**
	Hyaena hyaena	1	1	**100.0**
	Neophron percnopterus	3	3	**100.0**
	Ophidia sp.	4	4	**100.0**
	Pavo cristatus	1	1	**100.0**
	Upupa epops	6	6	**100.0**
	Echinoidea	21	22	95.5
	Chamaeleo chamaeleon	22	29	75.9
	Equus asinus	3	4	75.0
	Canis lupus familiaris	1	2	50.0
	Testudo graeca	4	8	50.0
	Vulpes vulpes	3	6	50.0
Nervous system disorders	*Cymothoa exigua*	17	17	**100.0**
	Camelus sp.	9	34	26.5
Oncology ailements	*Camelus* sp.	*3*	34	8.8
Poisonings	*Scorpiones* sp.	2	5	40.0
	Rana sp.	1	3	33.3
	Struthio sp.	2	6	33.3
Respiratory system disorders	*Ciconia*	2	2	**100.0**
	Ovis aries	2	10	20.0
Skeleto-muscular system disorders	*Scincus scincus*	1	2	50.0
	Struthio sp.	2	6	33.3
	Uromastyx nigriventris	1	3	33.3

Np: number of informants for the category disease; **N**: total number of informants cited for the animal or products.

(culture-bound diseases), *Coturnix coturnix* (endocrinal disorders), *Gazella cuvieri* (culture-bound diseases), *Brachyura* sp (culture-bound diseases), *Neophron percnopterus* (culture-bound diseases), *and Corvus corax* (culture-bound diseases) (Table 6).

Chamaeleo chamaeleon (CAI = 48.98), *Cymothoa exigua* (CAI = 40.48), *Echinoidea* (CAI = 36.28), and *Atelerix algirus* (CAI = 30.76) gained the highest CAI values, whereas *Gazella cuvieri* and *Struthio* sp. have the lowest CAI values (CAI = 7.14) (Table 6).

Table 6
Quantitative indices of medicinal ethnospecies used in the Safi province (Morocco).

Specie's name	UC	UV	RFC	% CII	IAR	CAI	% RI	STR
Anas platyrhynchos domesticus	1	0.02	0.024	2.38		0.00	11.81	0.21
Apis sp.	25	0.21	0.595	28.57	0.71	20.24	100.00	5.52
Aquila chrysaetos	3	0.02	0.071	7.14	1.00	7.14	11.81	0.54
Araneae	4	0.02	0.095	9.52	1.00	9.52	11.81	0.02
Atelerix algirus	26	0.17	0.619	40.48	0.76	30.76	88.89	8.00
Bos Taurus	10	0.14	0.238	16.67	0.78	12.96	64.58	3.42
Brachyura sp.	3	0.02	0.071	7.14	1.00	7.14	11.81	0.54
Caligo eurilochus	5	0.05	0.119	21.43	0.89	19.05	17.36	1.52
Camelus sp.	34	0.19	0.810	33.33	0.82	27.27	88.19	4.00
Canis lupus familiaris	2	0.05	0.048	4.76	0.00	0.00	23.61	1.14
Capra aegagrus	4	0.02	0.095	9.52	0.67	6.35	18.06	0.10
Cervus elaphus	1	0.02	0.021	1.38		0.00	11.81	0.54
Chamaeleo chamaeleon	29	0.12	0.690	57.14	0.86	48.98	59.03	5.23
Chiroptera	1	0.02	0.024	2.38		0.00	11.81	0.54
Ciconia	2	0.02	0.048	4.76	1.00	4.76	11.81	0.21
Corvus corax	2	0.02	0.048	4.76	1.00	4.76	11.81	0.54
Coturnix coturnix	3	0.02	0.071	7.14	1.00	7.14	11.81	0.02
Cymothoa exigua	17	0.02	0.405	40.48	1.00	40.48	11.81	0.05
Echinoidea	22	0.02	0.524	38.10	0.95	36.28	18.06	0.54
Equus asinus	4	0.02	0.095	9.52	0.67	6.35	18.06	0.54
Equus caballus	2	0.05	0.048	4.76	0.00	0.00	23.61	0.14
Falco sp.	1	0.02	0.024	2.38		0.00	11.81	0.54
Gallus gallus	7	0.14	0.167	21.43	0.50	10.71	58.33	6.42
Gazella cuvieri	3	0.02	0.071	7.14	1.00	7.14	11.81	0.54
Helix pomatia	13	0.12	0.310	23.81	0.75	17.86	52.78	2.85
Hyaena hyaena	1	0.02	0.024	2.38		0.00	11.81	0.54
Mustela nivalis	5	0.02	0.119	11.90	1.00	11.90	11.81	0.07
Neophron percnopterus	3	0.02	0.071	4.76	1.00	4.76	11.81	0.54
Ophidia sp.	4	0.05	0.095	9.52	0.67	6.35	17.36	1.14
Ovis aries	9	0.10	0.214	16.67	0.67	11.11	47.22	1.85
Pavo cristatus	1	0.02	0.024	2.38		0.00	11.81	0.54
Physeter macrocephalus	4	0.07	0.095	4.76	0.40	1.90	41.67	0.66
Rana sp.	3	0.02	0.071	4.76	0.50	2.38	18.06	0.23
Scarabaeus laticollis	3	0.07	0.071	4.76	0.00	0.00	35.42	0.42
Scincus scincus	2	0.05	0.048	2.38	0.00	0.00	23.61	0.28
Scorpiones sp.	8	0.07	0.190	9.52	0.50	4.76	47.92	0.5
Sepia officinalis	30	0.07	0.714	28.57	0.90	25.62	41.67	1.00
Struthio sp.	6	0.12	0.143	11.90	0.60	7.14	46.53	4.16
Testudo graeca	8	0.05	0.190	19.05	0.86	16.33	23.61	1.23
Upupa epops	6	0.02	0.143	14.29	1.00	14.29	11.81	0.54
Uromastyx nigriventris	2	0.05	0.048	4.76	0.50	2.38	23.61	1.33
Vulpes vulpes	6	0.10	0.143	14.29	0.60	8.57	40.97	2.42

Note: **UC**: use citation, **UV**: use value, **RFC**: relative frequency citation, **CII**: cultural importance index, **IAR**: index of agreement on remedies, **CAI**: cultural agreement index, **RI**: relative importance, **STR**: species therapeutic redundancy.

3.3. Conservation aspects of animal wildlife

According to our data, 69 % of the animal species were obtained from the wild, and 31 % were domestic animals. Among the wild animals sold in the Safi province for their medicinal or magical virtues, 13 species are listed as conservation concerns by the International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species (version 2022). Endangered (EN) species included *Falco* sp. and *Neophron percnopterus*. *Hyaena hyaena* is also considered near-threatened (NT). *Gazella cuvieri*, *Physeter microcephalus*, *Struthio* sp., *Testudo graeca*, and *Uromastyx nigriventris* are listed as vulnerable (VU) (Table 7).

4. Discussion

Our study reported the use of forty-two animal species for both medicinal and spiritual purposes by the local population in the Safi region (Morocco). During this study, 42 traditional healers were interviewed for their traditional knowledge about the medicinal uses of animal species. Sociodemographic variables play a crucial role in shaping traditional knowledge about the use of natural resources [42,86–89]. Factors such as age, gender, education, and psychosocial variables are important for analyzing ethnozoological data [90–93]. Concerning the socio-demographic characteristics of the respondents, our study showed that the majority (66.77 %) were men. This finding aligns with a study conducted in the Rif region of Morocco, which found that the majority of participants were men (50 men compared to 21 women) [61]. This trend of traditional local knowledge can be attributed to cultural background as well as the gender-based division of labor and space. Women have greater knowledge in caring for family health, while men are responsible for gathering animal resources. Cultural norms also dictate that local practitioners pass on their ethnomedicinal expertise primarily to

Table 7
Some animal species used as medicine in Safi Province (Morocco), their status in Morocco, and their national and international protection status.

Species name	ICUN Statut	Population trend	Protected in Morocco	CITES Appendix
Apis sp.	NT	Decreasing		
Atelerix algirus	LC	Unknown	No	
Chamaeleo chamaeleon	LC	Stable		
Coturnix coturnix	LC	Decreasing		
Falco sp.	EN	Decreasing		
Gazella cuvieri	VU	Decreasing		
Hyaena hyaena	NT	Decreasing	Yes	
Neophron percnopterus	EN	Decreasing		
Physeter macrocephalus	VU	Unknown		
Struthio sp.	VU	Decreasing		
Testudo graeca	VU	Unknown	Yes	II
Upupa epops	LC	Decreasing		
Uromastyx nigriventris	VU	Decreasing	Yes	II

LC = least concern; **NT** = near threatened; **VU** = vulnerable; **EN** = endangered.

their sons. Our findings align with a study conducted in the Jimma Arjo district in Western Ethiopia, which revealed that the main source of learning ethnozoological practice for the majority of healers is their father (36.11 %), followed by their mother (19.44 %) [39]. The data shows that 73.8 % of respondents aged 40 to 77 indicate that traditional knowledge tends to increase with age. This finding aligns with previous studies (Ahmad et al., 2021; Wendimu and Tekalign, 2023) that have reported similar results. Our study also found that information is primarily passed down vertically, from parents to sons (54.76 %), rather than horizontally within the same generation. These findings are quite similar to observations made in previous studies reporting similar demographics [37,40,42,86,94,95].

A majority of the interviewees (40.47 %) were illiterate, while only 2.38 % had a high level of graduate education. These findings are consistent with a study conducted in Mali, where 66.3 % of participants were found to be illiterate [96]. Similarly, a study in Northwest Ethiopia reported a high rate of illiteracy among traditional healers (66.3 %) [37]. Another study among the indigenous people of Wolaita in Southern Ethiopia also revealed that 52.5 % of participants were illiterate [97]. However, our findings differ significantly from a study conducted in central Punjab, Pakistan, which reported an illiteracy rate of 15 % [30]. The high rates of illiteracy among the respondents may be attributed to the socioeconomic conditions in the study area. It is possible that individuals with limited opportunities in the job market turn to zootherapy practices as a means of subsistence and additional income. Previous research has indicated a higher likelihood of economically disadvantaged populations using zoological resources in folk medicine [24,98].

Forty-two animal species have been identified for treating a total of 118 human diseases or conditions. These include 80 indications of physiological ailments and 38 indications of culture-bound ailments. Culture-bound ailments are defined as culture-specific syndromes, also known as folk illnesses. They refer to a collection of psychiatric and somatic symptoms recognized as distinct diseases only within a particular society or culture. Among the animals, 17 species (41 %) were solely used for medicinal purposes, 12 species (28.57 %) were employed in magical or ritual practices, and 10 species (24 %) had a dual purpose of therapeutic and spiritual use. Medicinal animal species include 15 species of mammals (36 %), 12 species of birds (29 %), six species of arthropods (14 %), and four species of reptiles (10 %). Mammals were the most commonly used by the local community, possibly due to their availability. These findings align with previous studies conducted among various ethnic communities globally, including Mexico [99], Brazil [83,100], Ethiopia [39,95,101], India [20,21,24], Korea [32], Pakistan [27,30], and South Africa [22,102]. However, our results differ significantly from a study conducted in Benin, which reported that insects accounted for 64.7 % of the listed animal species [50].

Medicines were derived from various sources, including whole animals (12 %) or their body parts and products (36 %). Animal products are the most commonly used (36 %), followed by the entire animal (12 %), fat, and meat (8 % each). Our analysis revealed that traditional healers commonly use honey (39 %) and eggs (28 %) as treatment components. This is likely due to the cultural and dietary practices of the local population. These findings are consistent with previous reports from different ethnic communities worldwide [20,27,32,37,99]. The therapeutic activities of preparations based on animal-derived parts or products have been approved in both in vivo and in vitro models, including whole animal [103], cow's urine [104,104–108], animals' oil [109–114], animal skin [115], animal horns [116,117], and camel milk [118].

The methods of preparation included cooking (28 %), burning (11 %), drying or using fresh animal parts or products (7 %), and powdering (6 %). Animal parts and products were often used as mixtures (28 %) or as raw materials (20 %). Recipes were often combined to enhance their effectiveness. For example, *Scarabaeus laticollis* urine was mixed with olive oil to treat ear diseases, and cooked snail was mixed with thyme and rosemary to treat respiratory disorders. These mixtures commonly included olive oil (6 recipes), honey (5 recipes), ghee (3 recipes), *Peganum harmala* (2 recipes), and pomegranate peel (2 recipes). Similar medicinal preparations have been reported in different geographical and socio-cultural contexts [22,25,32,119,120].

The most common route of administration was oral (49 % of all applications), followed by topical application (29 %). As previously mentioned, our analysis revealed that traditional healers commonly use honey, eggs, and urine as treatment components. This is likely due to the cultural and dietary practices of the local population. Since these remedies are consumed as food products, the oral route is the most commonly used. Several studies have also found that the oral route is the most widely utilized method of administering prepared treatments [32,34,119,121].

Quantitative analysis of ethnobiological data is used to evaluate the cultural or relative popularity, importance, or usefulness of medicinal animal species [122–125]. This analysis involves the use of several indices. However, the usefulness and interpretation of these indices have often been criticized for their lack of reliability [126,127]. To avoid drawing false conclusions, it is important to consider the objectives and scope of the study. In this investigation, we analyzed the data gathered during field studies using ten quantitative indices.

The Relative Frequency of Citation (RFC) determines the relative importance of species based on the number of times they were mentioned by informants. In this study, the species with the highest RFC values were *Camelus* sp., *Sepia officinalis*, *Chamaeleo chamaeleon*, *Atelerix algirus*, and *Apis* sp., indicating their importance to the local population. On the other hand, *Uromastyx nigriventris*, *Anas platyrhynchos domesticus*, Chiroptera, *Falco* sp., *Hyaena hyaena*, *Pavo cristatus*, and *Cervus elaphus* had low RFC values. However, it is important to note that low RFC values for animal species may not necessarily mean they are unimportant locally, but rather that most people are not aware of their therapeutic potential.

The Use Value Index (UV) determines whether ethnozoological species have versatile uses and are considered highly important by the local population [71,128,129]. The species with the highest UV values in this study were *Apis* sp., *Camelus* sp., *Atelerix algirus*, and *Bos taurus*. These species are well-known in the local population for their therapeutic properties and are widely used. On the other hand, 20 animal species, including *Capra aegagrus*, *Cervus elaphus*, *Corvus cor*ax, *Cymothoa exigua*, *Equus asinus*, *Gazella cuvieri*, *Hyaena hyaena*, *Mustela nivalis*, *Neophron percnopterus*, *Pavo cristatus*, and *Upupa epops*, had low UV values (UV = 0.02). The low UV values for these species suggest that traditional knowledge about their uses may be fading away over time.

The concept of species therapeutic redundancy (STR) was first applied to examine animal-based remedies. The STR was estimated using the utilitarian redundancy model [76,77,130,131]. The species with the highest level of therapeutic redundancy were *Atelerix algirus*, *Gallus gallus*, *Apis* sp., *Chamaeleo chamaeleon*, and *Struthio* sp. These species can be considered the most versatile medicinal animals within the local traditional medicinal system because they share various therapeutic activities with other species. On the other hand, *Mustela nivalis*, *Cymothoa exigua*, and *Coturnix coturnix* had the lowest level of therapeutic redundancy, indicating that these species have specific or non-redundant therapeutic activities in the indigenous medicine of the Safi region.

The informant consensus factor (ICF) measures the agreement between informants and the animal species used to treat a particular illness [64,65]. The ICF value theoretically ranges from 0 to 1, with a high value indicating agreement among informants and a low value indicating disagreement. In our study, the highest ICF values were observed for circulatory system disorders, oncology, orodental problems, nervous system disorders, genitourinary system disorders, eye ailments, and culture-bound diseases. On the other hand, respiratory system disorders and poisoning had the lowest ICF values. The high ICF values for circulatory system disorders, oncology, genitourinary system, oro-dental problems, nervous system disorders, eye ailments, and culture-bound diseases in our study can be attributed to the high prevalence of these conditions in the study area, as well as improved communication among informants regarding their treatment. Since there is a correlation between the effectiveness of traditional remedies and the value of the ICF, the results of the ICF can be particularly useful in selecting animal species for future investigations [78]. Similar trends have been reported in previous studies conducted on different ethnic groups [20,23,83,132,133]. However, our findings differ significantly from those reported in other studies conducted elsewhere. For example, in Korea, genitourinary system disorders and poisonings ranked the highest [32], and in India, genitourinary system disorders, poisoning, liver complaints, and nervous system disorders were the most common [24]. In Pakistan, general body weakness, pyrexia, arthritis, and skin diseases were reported as the most common ailments [31]. Similarly, in Ethiopia, bad spirits, tuberculosis, impotency, and measles were reported as the most common diseases [37]. These discrepancies can be explained by the geographical locations of the various regions, the cultural heritages of the local populations, dietary customs, and healthcare accessibility.

The Fidelity Level Index (FL) analyzes the use of animal species for therapeutic purposes. It determines the extent to which a species is used for a specific therapeutic category, showing the relative healing potential of animals [80,81]. High FL values indicate that a species is primarily used for treating a single therapeutic category, while low FL values suggest that animals are used for multiple ailments. The FL values range from 0 to 100 %. This study identified 17 animal species with an FL of 100 %. For instance, *Anas platyrhynchos domesticus* is relied upon for treating skin diseases, *Coturnix coturnix* for endocrinal disorders, *Mustela nivalis* for gastrointestinal disorders, *Cymothoa exigua* for nervous system disorders, and *Upupa epops* for culture-bound diseases. There is a strong association between a specific animal and a particular condition, as the local population highly depends on these species.

The relative importance index (RI) was calculated using the number of therapeutic functions associated with a species and the number of diseases it can heal [82]. This index measures the usefulness of medicinal species and identifies those that align closely with the cultural practices of the study area [71,83]. The most versatile and resourceful species, with high RI values, include *Apis* sp., *Aterix algirus*, *Camelus* sp., *Bos taurus*, and *Chamaeleo chamaeleon*. These animals are likely to be abundant and easily accessible in the study area. In contrast, 17 medicinal animals, such as *Corvus corax*, *Hyaena hyaena*, and *Upupa epops*, had low RI values.

The cultural importance index (CII) highlights species that share a strong connection with the culture of the research region, recognizing their significance in the local knowledge [71]. *Chamaeleo chamaeleon*, *Atelerix algirus*, and *Cymothoa exigua* obtained the highest CII values, indicating that these species hold great importance in the local culture due to their medicinal properties. These ethnospecies can be considered cultural keystone species [131,134,135]. On the other hand, *Uromastyx nigriventris* and *Anas platyrhynchos domesticus* had the lowest values, suggesting that they are of minor importance to the communities being studied, as they are less known for their healing properties.

The Index of Agreement on Remedies (IAR) aids in identifying diseases treated with specific animal-based therapies [78,84]. This study documented a high value (IAR = 1.00) for 11 animal species: *Cymothoa exigua* (nervous system disorders), *Upupa epops* (culture-bound diseases), *Mustela nivalis* (gastrointestinal disorders), Araneae (skin diseases), *Aquila chrysaetos* (culture-bound diseases), *Coturnix coturnix* (endocrinal disorders), *Gazella cuvieri* (culture-bound diseases), *Brachyura* sp. (culture-bound diseases), *Neophron* *percnopterus* (culture-bound diseases), and *Corvus corax* (culture-bound diseases). The high IAR values reported for these 11 animal species imply that all informants believe that these animals can primarily be used to treat specific disorders. To preserve this valuable traditional knowledge, it is essential to carefully document it.

The cultural agreement index (CAI) was calculated by combining CII and IAR values [85]. This index helps assess the cultural relevance of medicinal animals and determine the level of consensus on animal knowledge in the research region. *Chamaeleo chamaeleon*, *Cymothoa exigua*, Echinoidea, and *Atelerix algirus* obtained the highest CAI values, while *Gazella cuvieri* and *Struthio* sp. had the lowest CAI values. From this study, we can conclude that the culturally significant animal species mentioned have received high agreement across interviewees regarding the same illness category.

According to our data, 69 % of animal species were obtained from the wild, while 31 % were domestic animals. These trends align with practices found in other indigenous medical systems worldwide [18,20,22,31,61,94,98,102,132]. Thirteen species of wild animals sold in the Safi province for their medicinal or magical properties are included on the International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species (version 2022). Among these species, *Falco* sp. and *Neophron percnopterus* are considered endangered (EN), while *Hyaena hyaena* is classified as near-threatened (NT). *Gazella cuvieri*, *Physeter microcephalus*, *Struthio* sp., *Testudo graeca*, and Uromastyx nigriventris are listed as vulnerable (VU). *Testudo graeca* and *Uromastyx nigriventris* are also protected by national regulations within Morocco as they are included in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

It is important to note that the utilization of these animal species in traditional medicine can have additional implications, potentially compounding the negative effects caused by other threats such as climate change, pollution, and habitat fragmentation. The illegal trade of wild animals for their medicinal properties is a matter of concern for wildlife resources. This can be seen in examples such as *Atelerix algirus* [59], *Testudo graeca* [57,60], *Upupa epops* [136], and *Uromastyx nigriventris* [58]. Appropriate conservation procedures and long-term planning for their sustainable use are necessary.

5. Conclusion

The Moroccan population harbor rich traditional knowledge used to heal various human diseases. In this study, we provide the first quantitative investigation of the use of animal species for their therapeutic virtues in the Safi province (Morocco). We conclude that zootherapy is still a thriving practice in the study area. The scientific evaluation of this indigenous heritage requires further investigation. In the socio-economic context, the natural (local biodiversity) and human (accumulation of experiences) potentials could be regarded as drivers for the region's sustainable development. Thus, offering a source of income, in particular, to socio-economically marginalized populations. It is also crucial to note that the use of therapeutic animals in illness treatment is not without danger. Harmful pathogens, which are frequently linked with zoonotic illnesses, can be transferred to humans by consuming animal tissues, products, and excrement. As a result, it is vital to raise public awareness about the hazards of more common zoonotic diseases like rabies and tuberculosis. Despite legal protection in Morocco and through CITES, several of these animal species are commonly sold, sometimes in open markets, for their therapeutic benefits throughout the country. The escalating demand may lead to overexploitation and the loss of many rare animal species. From a conservation viewpoint, vulnerable and threatened medicinal animal species should receive urgent attention.

CRediT authorship contribution statement

Ahmed Lemhadri: Writing – original draft, Software, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Taoufiq Benali:** Visualization, Validation, Supervision, Project administration, Investigation, Formal analysis, Conceptualization. **Wondimagegnehu Tekalign:** Writing – review & editing, Validation, Supervision. **Abenezer Wendimu:** Writing – review & editing, Validation, Supervision, Software, Data curation.

Ethical approval and consent to participate

The ethics approval was obtained from the Cadi Ayyad University Institutional Ethical Review Board (CER-UCA-00123/22). The methods of obtaining ethnobiological data followed the guidelines set by the International Society of Ethnobiology Code of Ethics for this research. All respondents were given a brief explanation of the study's purpose, and written informed consent was obtained before the interviews. All studies were done in accordance with the Nagoya Protocol on the Convention on Biological Diversity on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from Their Use. All participants retain their right to use and author traditional knowledge, and any use of this information for purposes other than scientific publication requires further prior authorization from traditional owners, as well as an agreement on access to benefits derived from subsequent use.

Consent for publication

This manuscript doesn't contain any person's data, and further consent for publication is not required.

Availability of data and materials

The datasets generated and analyzed during the current study are included in the body of this paper.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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