# Ethnopharmacology, Ethnomedicine, and Wildlife Conservation

Peter G.R. Coals[1], Vivienne L. Williams[1], Guillermo Benítez[2], François Chassagne[3], Marco Leonti[4*]

[1]School of Animal, Plant & Environmental Sciences, University of the Witwatersrand, Johannesburg 2000, South Africa

[2]Department of Botany, Faculty of Pharmacy, University of Granada, Campus de Cartuja s/n, 18071, Granada, Spain

[3] UMR152 PharmaDev, Institut de Recherche pour le Développement (IRD), Université Paul Sabatier, Toulouse, France

[4]Department of Biomedical Sciences, University of Cagliari, Cittadella Universitaria, 09042, Monserrato (CA), Italy

*Corresponding author, Tel.: +390706758712,

E-mail addresses: marcoleonti@netscape.net; mleonti@unica.it

## Abstract

*Ethnopharmacological relevance:* There are longstanding traditions of animal-derived products being employed as medicines, and they continue to be important in many traditional cultural healthcare practices. However, the populations of numerous so-used animals are known to be threatened with extirpation by such practices. Ethnopharmacological studies documenting these animal-derived drugs are not only interesting from an anthropological standpoint, but they are also relevant from a wildlife conservation perspective – especially since ethnopharmacologists are intermediaries between indigenous and scientific communities, placing them at the forefront of being able to ethically access information to address these issues.

*Methods:* Using the example of documenting culturally acceptable substitute materials for animal products (which ultimately also extends to flora), we explore the intersection of ethnopharmacology, biocultural resources, and wildlife conservation.

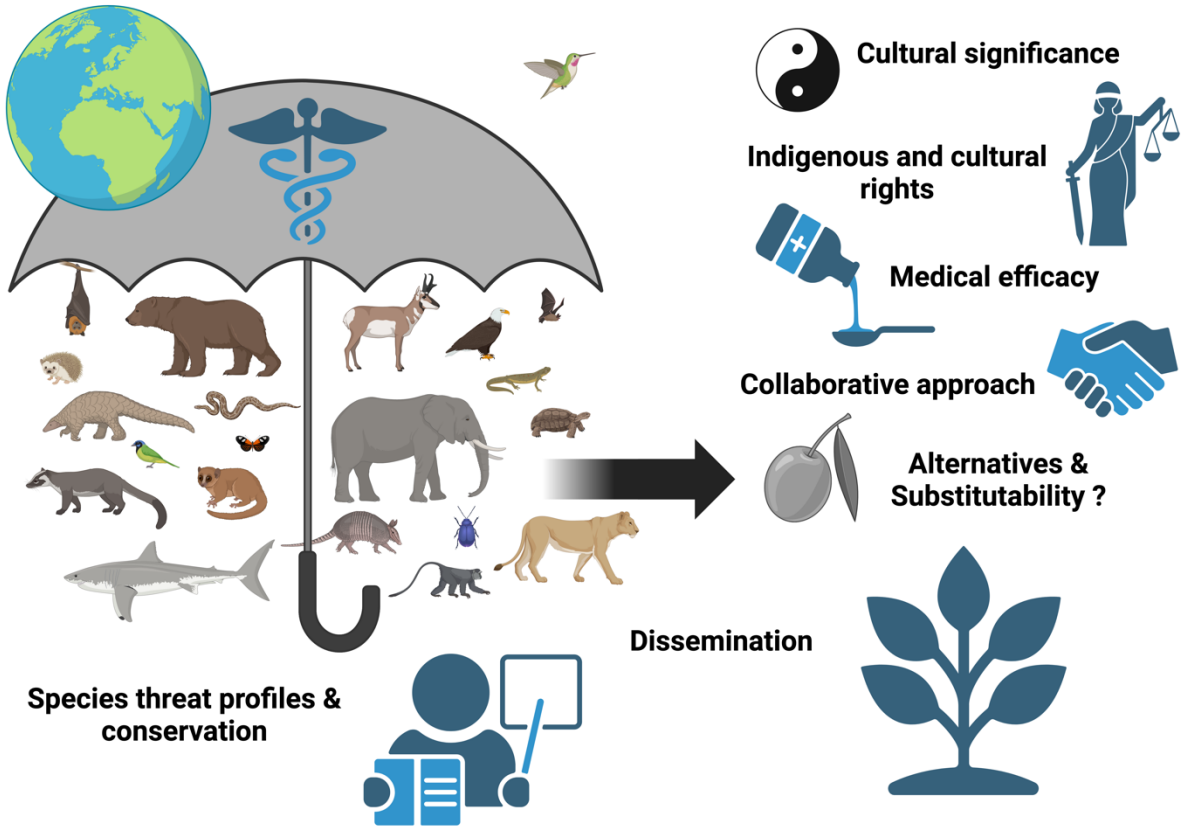
*Results:* Pharmacological efficacy and symbolism are factors influencing the utilization of traditional medicines. Achieving the integration of conservation aims with ethnopharmacology requires a nuanced understanding of both factors, along with fair adjudication when conservation and cultural

aims diverge. Ethnopharmacology is suitably placed for making conservation-orientated recommendations – including investigating more sustainable substitutes for animal products in the context of medical efficacy, and for engaging ethically with local communities to facilitate information generation aimed at protecting the environment and their traditions.

*Conclusion*: We suggest an integrative approach to ethnopharmacological studies investigating medicinal bioresource use. This approach is considerate of species' conservation profiles, the substitutability and pharmacological efficacy of biocultural resources, indigenous and cultural rights, and a collaborative ethos for stakeholder engagement.

**Keywords**: Zootherapy, substitution, effectiveness, efficacy, animal conservation, health, medicine

**Graphical abstract**




## 1. Introduction

The use of animal products driven by cultural practices, including traditional medicines, can lead to unsustainable harvesting of species, and adversely impact wild populations and the welfare of animals (e.g., Starr et al., 2010; Baker et al., 2013; Nijman and Nekaris, 2016). Animal products are used and

traded across a range of socio-economic and geographic contexts – from urban centres where consumers are well-integrated in the global economy to informal rural markets and local subsistence economies – and are integral to many complex cultural-spiritual traditions practiced by some of the world's most vulnerable communities. Historically, ethnopharmacological field studies have aimed to document such practices for purposes of scholarly inquiry, cultural preservation, and medical insights. In a world where heterogeneous anthropological pressure is persistently exerted on wildlife and other environmental resources, we present a series of considerations concerning the intersection of ethnopharmacology and wildlife conservation – using the example of documenting substitute materials for animal products. These considerations (akin to mindfulness) are not thorough; rather, they serve as provocations for further debate and evaluation. By suggesting the integration of conservation-considerate protocols into future study designs and publications, we hope to advance the discourse on ways that ethnopharmacology can contribute meaningfully to biodiversity conservation.

## 2. Methods and outline

Amidst the heterogeneous human pressures impacting wildlife resources, we explored ideas concerning the intersection of ethnopharmacology and wildlife conservation. Proposed means for achieving wildlife conservation goals include, amongst other measures, supply side-interventions – encompassing substitute species, regulated trade, and wildlife farming (e.g., Bulte and Damania 2005; Phelps et al. 2014), enforced conservation laws leading to replacement and omittance of animal drugs from formulations (Yeshi et al., 2017), and databases proposing plant and mineral-based alternatives such as TAWAP (2024; https://tawap.org/).

Ethnopharmacologists can play important roles as intermediaries between indigenous and scientific communities. They can also assist those conservation scientists who adopt a more wildlife population-centred research approach with collecting interdisciplinary data to: (i) understand the socio-cultural use of species and their derivatives in a different context, (ii) inform population threat assessments via the evaluation of the risks to species posed by some cultural practices, so that long-term sustainability and availability for cultural use can be assessed and endorsed, (iii) report and test culturally acceptable (and effective) substitutable materials, and (iv) report on instances of alien species being adopted into pharmacopoeias (including as substitutes) to allow for a more nuanced evaluation of the impacts of introduced species. These conservation-relevant considerations are not exhaustive, and rather serve as prompts for engaging in further debate and evaluation.

We specifically considered here the role of ethnopharmacology in documenting substitutes and proposing more sustainable alternatives to animal products used in traditional medicines. We begin

by discussing the dynamics of traditional knowledge (section 3), followed by a discussion on pharmacological efficacy (clinical setting), perceived effectiveness, and the symbolism (cultural setting) of animals used in traditional medicines (section 4). In section 4 we also outline the use and discontinuance of animal-derived materials based on their pharmacological efficacy in various parts of the world and emphasise that use of animal-derived material is frequently driven by the symbolic value and perceived effectiveness of the selected material. We thus describe two major (but not exclusive) background considerations in the fair adjudication of potentially competing aims, i.e. that of species to persist, and the rights of people to practice their traditions (section 5) – which we believe are central to conservation-relevant (and socially just) practice. We suggest in section 6 that for wildlife conservation elements to be integrated into ethnopharmacology research, careful consideration should also be given to assessing the relative benefits and harms of the reported practices – to wildlife *and* people (despite the inherent challenges in such assessments). In closing (section 7), we emphasize the importance of considering equitable, collaborative, two-way knowledge exchange between researchers and practitioners/users of traditional medicines – which includes considering research instrument co-design, and information dissemination, with the study participants, in accordance with ethical guidelines for conducting ethnobiological research (Fernandez et al., 2003; International Society of Ethnobiology, 2006). By advocating for the explicit integration of conservation-relevant considerations into future ethnopharmacology study designs and publications, we aim to advance the discourse on how, within the ethnoscience disciplines, ethnopharmacology can make substantive contributions to wildlife conservation initiatives and interventions within the context of cultural practices – some of which may pose sustainability challenges to important biological resources.

## 3. The dynamics of traditional knowledge

In the transdisciplinary ethnosciences, indigenous and traditional knowledge are often considered domains that *de facto* should be protected in their original context within communities (*in situ*) and conserved outside of those communities through research and documentation (*ex situ*) for future generations. However, these traditions of practice also lend themselves to periodic re-investigation and review because culture and traditional knowledge are not static and unchanging (Cunningham and Zondi, 1991). Instead, they are dynamic: i.e., capable of evolving and adapting to internal and external pressures, including environmental changes, and can be transformed or abandoned (Bye et al., 1995), and also deliberately invented (Hobsbawm and Ranger, 2012), leading to adaptations such as the incorporation of new organisms and drugs into pharmacopoeias (e.g., non-native species) and the lifting of cultural restrictions previously imposed on the use of taboo species (Cunningham and

Zondi, 1991). Strategies of enforced change have also been implemented through legislation. Culture may also become formalized and institutionalized, thereby losing its dynamism while continuing its expression as folklore. Historical evidence also indicates, however, that not all traditional knowledge and customs are sustainable, and that not all traditions withstand the development of ethical considerations, evolving moral standards, and/or critical evaluation of medical efficacy. Consequently, some healthcare practices are abandoned following the discovery of more effective alternatives, sustainable production methods and acquisition, or societal rethinking, sometimes accompanying the implementation of new regulations protecting wildlife.

## 4. Pharmacological efficacy and effectiveness of zootherapeutic remedies

Historically, the (more-or-less) systematic documentation of *materia medica* dates back, in some cultures, over 2000 years. These written sources include a taxonomically diverse array of crude drugs and preparations. Compendia, referred to as 'herbals' or 'herbal books', name the drugs they describe as 'herbal medicines' or 'herbal drugs', regardless of their biological or mineral origin. The custom of reporting animal drugs separately from botanical drugs is a more recent phenomenon (pers. obs., review of academic literature) and not constructive for understanding the consensus and use of *materia medica*.

Crude animal-derived 'herbal' drugs (i.e., zootherapeutic remedies prepared from the body-parts or excreta of fauna) were an important part of these *materia medica* across Europe until the 18$^{th}$/19$^{th}$ centuries, and the teaching of 'pharmaceutical zoology' as a separate course was common in European Pharmacy Schools during this period (see Plans y Pujol, 1870). The relatively uncritical adoption and transmission of 'herbal' remedies facilitated the persistence of pharmacologically ineffective drugs within *materia medica* over an extended period (MacKinney, 1946; Leonti, 2011). Hence, just because herbal and traditional zootherapeutic medicines have been used for a long time doesn't necessarily mean that their long-standing use serves as unequivocal evidence supporting the medical efficacy and biomedical safety of treatments (Helmstädter and Staiger, 2014; EMA, 2024). Efficacy describes the capacity of an agent to produce an effect under standardized conditions, such as in clinical trials, and effectiveness refers to the perceived therapeutic success in real-life practice and within a cultural setting (Last et al., 2001, p. 57-58; Witt et al., 2013). Ethnopharmacological research draws on anthropological data to critically evaluate knowledge regarding the therapeutic use of traditional medicines by employing biological and chemical methods to test medical efficacy and safety (Gertsch, 2009; Heinrich and Jäger, 2015; Weckerle, et al., 2018; Bruhn and Rivier, 2019).

As a consequence of the scientific revolution and advancements in rational thinking, a large number of European and Mediterranean Renaissance herbal drugs were subsequently systematically excluded

from pharmacopoeias and medicinal practices, starting in the 18th century (e.g., mumia powder from ground mummies; Dannenfeldt, 1985). This exclusion was prompted by toxicological concerns and a re-evaluation of their efficacy (Mann, 1984; Martins de Oliveira et al., 2019); crude animal-derived drugs that had constituted a substantial portion of those *materia medica* were progressively excluded from modern 'herbal' medicines. Matthioli's commentaries on Dioscorides' *De Materia Medica* (Matthioli, 1967-1970), for example, included 76 chapters dealing with animal-derived drugs; however, of these zootherapeutic drugs, only wool fat (lanolin), honey, and beeswax are currently included in the European Pharmacopoeia 11.0 (2022). Additionally, in complementary and traditional medicine (CAM), propolis, as well as milk and animal fat, are still in use. Furthermore, and to put validated pharmacological efficacy into another context, only a limited number of traditional animal drugs included in herbals have led to drug discoveries. For instance, the anticoagulant hirudin was isolated from the saliva of the European medicinal leech (*Hirudo medicinalis*; Linnaeus, 1758) at the beginning of the 20th century. Leeches have been used for venesection and blood removal since the 2nd century AD as reported by the Greek scholar Galen; today, recombinant hirudin derivatives serve as anticoagulant drugs (Nowak and Schrör, 2007). Chinese and Japanese medical traditions have recommended the use of bear bile for biliary stone diseases for centuries (Hagey et al., 1993); the bile of various vertebrate species, including humans, contains ursodeoxycholic acid, which can now be produced semi-synthetically and used as a monotherapy for treating gallstone diseases (Hagey et al., 1993; Tonin and Arends, 2018). Another example of a potent animal-derived compound is the toxic monoterpenoid cantharidin, found in Spanish fly (*Lytta vesicatoria*; Linnaeus, 1758), and other blister beetles of the Meloidae family; cantharidin induces strong and long-lasting erections and has therefore been used as an aphrodisiac or for treating erectile dysfunction (Pajovic et al., 2012).

Despite the exclusion of most crude animal-derived drugs from current herbalism, CAM, and official pharmacopoeias in Europe and the US, animal derivatives remain an important source of allopathic medicines (Zhu et al., 2011; Wagner et al., 2007; European Pharmacopoeia 11.0, 2022). These derivatives are, however, obtained through biotechnological methods and via extraction from porcine, bovine, ovine, equine, mouse, and chicken products and organs (Wagner et al., 2007). A wide range of animal-derived products are currently employed in the pharmaceutical and healthcare sectors, including: anti-thrombotics, digestive supplements, lung surfactants, haemostatic agents, vaccines, anti-diarrheal agents, steroids, pituitary and gonadal hormones, plasma volume expanders, immune supplements, immunomodifiers, anti-neoplastics, anti-migraine, anti-hypertensive and hematopoietic agents, ophthalmic medications, anti-rheumatoid agents, anti-venoms, and anaesthetics (Zhu et al., 2011; Wagner et al., 2007; Queensland Health, 2020). Furthermore, derivatives from marine

invertebrates and arthropods also contribute to drug discovery by serving as valuable sources of highly bioactive secondary metabolites (Kiyota, 2021; Dossey, 2010; Seabrooks and Hu, 2017).

But while there has been a significant reduction in the number of animal-derived drugs in European and American pharmacopoeias, there has been little such significant reduction in many traditional medicine practices and the extensive zootherapeutic use of animal products remains important to many traditions of socio-cultural medicine across the world – especially in countries where traditional medicine has a strong presence or in communities which depend less on, or who have less access to, western-based primary healthcare. For example, Moorhouse et al. (2022a) reported over 2300 species of wild fauna used in traditional Chinese medicine. Additionally, a survey conducted at a traditional medicine market in Johannesburg, South Africa, identified 147 traded vertebrate species (Whiting et al., 2011). A review based on market surveys conducted in 20 Brazilian cities documented animal medicines deriving from 131 species (however, the actual number of taxa used throughout Brazil is likely much higher) (Ferreira et al., 2013). Closer to Europe, Bellakhdar's (2020) book on the traditional pharmacopeia of Morocco details 227 animal taxa products across 89 chapters.

In contrast to cases where animal-derived medicines have demonstrable medical properties, a considerable proportion of cultural zootherapeutic preparations are pharmacologically inactive (MacKinney, 1946; Still, 2003) and lack medical efficacy, yet are considered by users to be highly effective medicines for treating the recognised disorders. Animal derivatives constitute integral components of complex socio-cultural practices that rely on the symbolic, and often non-consumptive, spiritual and characteristic properties of the animals involved where bodily traits and functions signify utility (Williams and Whiting, 2016). Explanations for the use of crude animal products have included beliefs that the biological and spiritual characteristics and qualities of the animals are transmitted to patients, following the principles of the *Doctrine of Signatures* (De Conconi and Moreno, 1988; Lev, 2002; Fresquet Febrer, 2001). For example, in southern African traditional and spiritual practices, lion (*Panthera leo*; Linnaeus, 1758) parts are used symbolically to confer bravery, strength, and power to the user, and are thus closely associated with traditional royalty (Simelane and Kerley, 1998; Coals et al., 2022). This association may be manifested through the predominantly non-consumptive use of lion claws, teeth, bones, and skin – often as part of tribal regalia (Coals et al., 2022; Williams et al., *in review*). Furthermore, animals have been noted to be used for treating disorders that are difficult to define in Western medical concepts and/or are based on healers' interpretations of causation (some of which are also social rather than medical disorders) (Simelane and Kerley, 1998; Simelane, 2011). Thus, ethnopharmacologists do not typically consider testing the therapeutic efficacy claims associated with animal-derived traditional medicines, such as of the efficacy of charcoaled hedgehogs (Budjaj et al., 2021), tiger's breastmilk, or the whole dried

body of the slow loris (Chassagne et al., 2016), for practical, ethical, and above all, epistemological reasons.

We therefore contend that the symbolic and spiritual use of animal products in traditional therapeutic practices is likely to outweigh the active-ingredient-driven (modern 'Western') conceptions of medicine, and we thus caution against simplistic interpretations of medical efficacy and effectiveness. This raises questions about the degree to which knowledge of the traditional uses of animal products contributes to drug discovery, while acknowledging the need for case-by-case differentiation. While the documentation of animal-derived medicines has the potential to contribute to the preservation of cultural diversity and the development and implementation of protection measures, much of this knowledge is unlikely to meaningfully advance medicinal discoveries for future generations. Nevertheless, symbolism and perceived effectiveness are key drivers in the enduring use of many cultural-spiritual medicines.

## 5. Integrating conservation concerns into ethnopharmacology requires evaluation of competing needs

While having baseline data about the use and trade of traditional medicines can help inform conservation strategies, the practical implementation (i.e., translational measures) of these strategies is often uncertain and beyond the direct control of academic researchers. In light of this, we therefore suggest that, where possible, academic researchers consider making more direct and proactive contributions to conservation endeavours. A short discussion between Nijman and Nekaris (2016) and Chassagne (2017) about reporting animal drugs used in traditional medicine, for example, published in this journal, may not have received the attention it deserved. Nijman and Nekaris (2016) emphasized that the conservation status of the respective animal species should be reported, regardless of whether the animal needs to be killed to obtain the part used as a drug or not. Furthermore, they stressed that the legality of collecting and trading the respective products should also be stated (it should be noted that these statements would be aimed at readers of the journal reports and *not* intended as parochial commentary to indigenous users). Nijman and Nekaris (2016) further reminded researchers to "*provide context about the ethical and legal implications*" when reporting on the use of protected and endangered wildlife in ethnopharmacological surveys (see also Chassagne, 2017). In response to Nijman and Nekaris (2016), Chassagne (2017) pointed out that, according to Article 24 of The United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP), "*indigenous peoples have the right to their traditional medicines and to maintain their health practices, including the conservation of their vital medicinal plants, animals and minerals*". Moreover, contributing to the conservation and sustainable use of biodiversity is an integral aspect of

The Journal of Ethnopharmacology (see: https://www.sciencedirect.com/journal/journal-of-ethnopharmacology/about/aims-and-scope) and encapsulated in a founding objective that investigations of agents used in traditional medicines should not exploit them (Bruhn and Rivier, 2019).

Whilst there may be a generally held desire to honour traditions and cultural practices that may involve the use of animal products, when such practices conflict with conservation aims, particularly the potential persistence of a species, an evaluation of those competing needs is required (Coals et al., 2019). Such evaluations necessitate an acknowledgement of the potential influences and pitfalls of cultural relativism, whereby a potentially damaging activity may be overlooked because of its perceived cultural significance (Dickman et al., 2015). We posit that a *de facto* position of the assumed right to preserve all cultural practices, as presented in many ethnobiological publications, may serve to perpetuate potentially harmful practices, which can ultimately lead to the extinction of fauna *and* traditions. Therefore, enhancing the integration of ethnographic studies with conservation requires evaluating conflicting interests and providing an explicit and objective rationale for preserving practices involving at-risk wildlife (Macdonald et al., 2021), coupled with recognizing that cultural practices and conservation aims will not always be compatible but that they should be resolved in a fair and just manner (Vucetich et al., 2018).

**6. Substitution is not simple but should be considered**

Academic research on the utilisation of traditional medicine should not confine itself only to documenting therapeutic uses for wildlife, as use-based demand has negative consequences for many species. Hence, the cultural and ecological aspects of these practices should also be explored (Alves and Rosa, 2007).

The potential substitution of wild-sourced preparations with those from domestic animals or botanical materials has become a topic of considerable interest in some primarily conservation-focused publications. However, the prevalent use of preference-based surveys and techniques, upon which many findings are based, tends to overlook complexities in real-world markets and dichotomies between what people will *say* and what they *do* (Hinsley and ‘t Sas-Rolfes, 2020). While individuals may express preferences for potentially effective substitutes in experimental and hypothetical scenarios (where effectiveness is not synonymous with efficacy), the conditions for acceptance of such substitutes is uncertain, primarily due to the significant cultural connotations associated with the use of specific materials (Ferreira et al., 2016). For example, although several, allegedly effective, symbolic alternatives ostensibly exist for lion products in southern African spiritual practices, aspects of the lion’s role in spiritual healing have been found to be largely immutable *and*, furthermore, that

ancestral spirits (considered divine messengers between the healers and a higher being) may, during dreams and rituals, be influential in the suggested prescription of some effective alternatives (Coals et al., 2022). Moreover, while botanical substitutions are increasingly widely touted as substitutes by researchers with different world views to the consumers, care must be exercised to ensure that they (and faunal alternatives) are also not sourced from threatened species. Hence, we caution against naïve assumptions that botanical alternatives will automatically be the more acceptable, conservation-friendly, options.

In instances where substitution is a matter of efficacy (e.g., Moorhouse et al., 2022b), pharmacological studies are well-placed to aid in the identification of effective and sustainable substitutes. However, pharmacological efficacy has rarely been established for animal-derived traditional medicines (see above) and clinical trials for this category are generally lacking (Simelane and Kerley, 1998). Conversely, efficacy and safety have been established for numerous botanical drugs, while for others, their efficacy is considered plausible (e.g., EMA, 2024). Thus, available pharmacological and clinical literature can be used to assess evidence of substitute efficacy on a case-by-case basis.

We emphasize that animal-based ethnopharmacological field studies should consider documenting substitutes (sustainable, effective, non-threatened, or otherwise) (Chassagne, 2017). This documentation could be an outcome of questions on substitutes specifically incorporated into the research instruments from the outset, or from information provided unprompted by stakeholders during the course of the research process. Such information is held by traditional healers, consumers, and sellers. The intention is not to question the rights of indigenous peoples to choose their medicines. Rather, we advocate for the documentation of culturally acceptable substitutes (where they exist, and the traditional knowledge has been obtained through informed and consensual ethical research) as part of collaborative systems with communities to address conservation challenges through mutual feedback (for an example concerning the adoption of faux leopard skins by followers of the Shembe Church in South Africa see: Naude et al. 2020). Thus, this approach is not about overriding indigenous peoples' rights to maintain their traditional health-care practises, but rather to actively engage with local communities to facilitate taking steps towards information generation aimed at protecting the environment *and* their traditions.

## 7. Considering the future of ethnopharmacological reporting

In addition to the ongoing global changes that exert pressure on biodiversity, some traditional medicine practices contribute to the decline and extirpation of some animal populations – thereby posing further threats to the persistence of species. Although users may assert the effectiveness of

341 animal-derived medicines, the strictly therapeutic efficacy of most of these medicines has not been
342 tested and remains questionable, with use often driven by complex, culture-specific, traditions of
343 practice, ancestral guidance, and symbolic connotations. Consequently, we suggest that field
344 researchers adopt a collaborative approach to explore the possibility of establishing consensus
345 regarding culturally accepted alternative *materia medica* (of whatever origin) especially those that
346 can be sourced from non-threatened species that can be harvested more sustainably. A first step would
347 be to investigate the nexus of traditional uses of biological and inorganic substances used by specific
348 communities so that possible convergent uses and consensus can be pinpointed, and substitutability
349 can be assessed in collaboration with healers, sellers, and consumers. Feedback on more effective
350 substitutes and alternatives are more likely to be accepted when proposed in a culturally respectful
351 and inclusive manner, particularly by considering the culture-specific symbolism of the species
352 intended for replacement. While indigenous cultures, rural and urban populations have the right to
353 maintain their traditional health practises, we contend, however, that they have also the right to be
354 kept apprised of the scientific evaluations of their customs and of the environmental impacts of their
355 practices. Thus, within the domain of 'conservation-conscious ethnopharmacology', we suggest an
356 integrative approach to ethnopharmacological studies investigating medicinal bioresource use (**Fig.**
357 **1**). This approach is considerate of species' conservation profiles, the substitutability and
358 pharmacological efficacy of biocultural resources, respect for indigenous and cultural rights, and a
359 collaborative ethos for stakeholder engagement.
360
361


**Figure 1**. Considerations for integrating wildlife conservation-conscious factors into ethnopharmacology research, using the example of potential substitutions for animal products.

**Author contributions:** PGRC, VLM, GB, FC and ML all conceptualized and wrote the article.

**Competing Interest Statement:** The authors declare no competing interest.

**References**

Alves, R.R., Rosa, I.M., 2007. Biodiversity, traditional medicine and public health: where do they meet? J. Ethnobiol. Ethnomed. 3, 14. Doi: 10.1186/1746-4269-3-14.

Baker, S.E., Cain, R., van Kesteren, F., Zommers, Z.A., D'Cruze, N., Macdonald, D.W., 2013. Rough trade: animal welfare in the global wildlife trade. Bioscience 63, 928–938. doi: 10.1525/bio.2013.63.12.6.

Bellakhdar, J., 2020. La Pharmacopée Marocaine Traditionnelle. Médecine Arabe Ancienne et Savoirs Populaires. 2nd ed. Le Fenec, Casablanca.

Bruhn, J.G., Rivier, L., 2019. Ethnopharmacology – A journal, a definition and a society. J. Ethnopharmacol. 242, 112005. Doi: 10.1016/j.jep.2019.112005.

Budjaj, A., Benítez, G., Pleguezuelos, J.M., 2021. Ethnozoology among the Berbers: pre-Islamic practices survive in the Rif (northwestern Africa). J. Ethnobiol. Ethnomed. 17, 43. Doi: 10.1186/s13002-021-00466-9.

Bulte, E.H., Damania, R., 2005. An economic assessment of wildlife farming and conservation. Cons. Biol. 19, 1222–1233.

Bye, R., Linares, E., Estrada, E., 1995. Biological diversity of medicinal plants in Mexico, in Phytochemistry of Medicinal Plants. Arnason, J.T., Mata, R., Romeo, J.T., (Eds.). Plenum Press, New York, pp. 65–82.

Chassagne, F., 2017. Role of ethnopharmacologists in the conservation of endangered animal species. J. Ethnopharmacol. 207, 268–270. doi: 10.1016/j.jep.2017.06.041.

Chassagne, F., Hul, S., Deharo, E., Bourdy, G., 2016. Natural remedies used by Bunong people in Mondulkiri province (Northeast Cambodia) with special reference to the treatment of 11 most common ailments. J. Ethnopharmacol. 191, 41–70. doi: 10.1016/j.jep.2016.06.003.

Coals, P., Burnham, D., Loveridge, A., Macdonald, D.W., 't Sas-Rolfes, M., Williams, V.L., Vucetich, J.A., 2019. The ethics of human–animal relationships and public discourse: a case study of lions bred for their bones. Animals 9, 52. doi: 10.3390/ani9020052.

Coals, P.G., Mbongwa, N.S., Naude, V.N., Williams, V.L., 2022. Contemporary cultural trade of lion body parts. Animals 12, 3169. doi: 10.3390/ani12223169.

Cunningham, A.B., Zondi, A.S., 1991. Use of animal plants for commercial trade in traditional medicine. Institute of Natural Resources, Rep. 76, 1–40.

Dannenfeldt, K.H., 1985. Egyptian mumia: the sixteenth century experience and debate. Sixt. Century J. 16, 163–180. https://doi.org/10.2307/2540910.

De Conconi, J., Moreno, J.M., 1988. The utilization of insects in the empirical medicine of ancient Mexicans. J. Ethnobiol. 8, 195–202.

Dickman, A., Johnson, P.J., Van Kesteren, F., Macdonald, D.W., 2015. The moral basis for conservation: how is it affected by culture? Frontiers Ecol. Environ. 13, 325–331. https://doi.org/10.1890/140056.

Dossey, A.T., 2010. Insects and their chemical weaponry: new potential for drug discovery. Nat. Prod. Rep. 7, 1737–1757. doi: 10.1039/c005319h.

EMA, European Medicines Agency, 2024. https://www.ema.europa.eu/en/search?search_api_fulltext=Committee%20on%20Herbal%20Medicinal%20Products%20%28HMPC%29

Fernandez, C.V., Kodish, E., Weijer, C., 2003. Informing Study Participants of Research Results: An Ethical Imperative. IRB: Ethics & Human Research, 25, 12–19. https://doi.org/10.2307/3564300

Ferreira, F.S., Fernandes-Ferreira, H., Léo Neto, N.A., Brito, S.V., Alves, R.R.N., 2013.The trade of medicinal animals in Brazil: current status and perspectives. Biodivers. Conserv. 22, 839–870 https://doi.org/10.1007/s10531-013-0475-7.

Ferreira, F.S., Brito, S.V., de Oliveira Almeida, W., Alves, R.R.N., 2016. Conservation of animals traded for medicinal purposes in Brazil: Can products derived from plants or domestic animals replace products of wild animals? Reg. Environ. Change 16, 543–551. https://doi.org/10.1007/s10113-015-0767-4.

Fresquet Febrer, J.L., 2001. El uso de animales y de productos de origen animal en el tratamiento de las enfermedades.In López Piñero, JM, Los animales en la ciencia y la vida humana. Ilustraciones zoológicas de un milenio (siglos XI-XXI). Fundación Bancaja, Valencia. Pp: 92–111.

European Pharmacopoeia 11.0, 2022. Index, p. 4443–4478. https://www.edqm.eu/en/european-pharmacopoeia-ph.-eur.-11th-edition#{%22468819%22:[6]}

Gertsch, J., 2009. How scientific is the science in ethnopharmacology? Historical perspectives and epistemological problems. J. Ethnopharmacol. 122, 177–183. doi: 10.1016/j.jep.2009.01.010.

Hagey, L.R., Crombie, D.L., Espinosa, E., Carey, M.C., Igimi, H., Hofmann, A.F., 1933. Ursodeoxycholic acid in the Ursidae: biliary bile acids of bears, pandas, and related carnivores. J. Lipid Res. 34, 1911–1917.

Heinrich, M., Jäger, A.K., 2015. Ethnopharmacology. Chichester: JohnWiley & Sons.

Helmstädter, A., Staiger, C., 2014. Traditional use of medicinal agents: a valid source of evidence. Drug Discov. Today 19, 4–7. doi: 10.1016/j.drudis.2013.07.016.

Hinsley, A., 't Sas-Rolfes, M., 2020. Wild assumptions? Questioning simplistic narratives about consumer preferences for wildlife products. People Nat. 2, 972–979. https://doi.org/10.1002/pan3.10099.

Hobsbawm, E., Ranger, T., 2012. The Invention of Tradition. Hobsbawm, E. and Ranger, T. (Eds.). Cambridge, Cambridge University Press.

International Society of Ethnobiology (ISE), 2006. International Society of Ethnobiology Code of Ethics (with 2008 additions). http://ethnobiology.net/code-of-ethics/

Kiyota, H., 2021. Marine Natural Products. Kiyota, H. (Ed.) Springer, Singapore.

Last, J., Spasoff, R.A., Harris, S.A., 2001. Dictionary of Epidemiology, 4th ed. Oxford University Press, Oxford.

475
476 Leonti, M., 2011. The future is written: impact of scripts on the cognition, selection, knowledge and
477 transmission of medicinal plant use and its implications for ethnobotany and ethnopharmacology. J.
478 Ethnopharmacol. 134, 542–555. doi: 10.1016/j.jep.2011.01.017.
479
480 Lev, E., 2002. The doctrine of signatures in the medieval and Ottoman Levant. Vesalius 8, 13–22.
481
482 Macdonald, D.W., Harrington, L.A., Moorhouse, T.P., D'Cruze, N., 2021. Trading animal lives: ten
483 tricky issues on the road to protecting commodified wild animals. BioScience, 71, 846–860. doi:
484 10.1093/biosci/biab035.
485
486 MacKinney, L., 1946. Animal Substances in Materia Medica. A study in the persistence of the
487 primitive. J. Hist. Med. Allied Sci. 1, 149–170.
488
489 Martins de Oliveira, T.D., Rodrigues, E., Casu, L., Benítez, G., Leonti, M., 2019. The historical
490 development of pharmacopoeias and the inclusion of exotic herbal drugs with a focus on Europe and
491 Brazil. J. Ethnopharmacol. 240, 111891. doi: 10.1016/j.jep.2019.111891.
492
493 Mann, R.D., 1984. Modern drug use: An Enquiry on Historical Principles. Lancaster, UK: MTP Press
494 Limited.
495
496 Matthioli, P.A., 1967-1970. I Discorsi di M. Pietro Andrea Matthioli. Sanese, Medico Cesareo, et del
497 Serenissimo Principe Ferdinando Archiduca d'Austria & c. Nelli Sei Libri Di Pedacio Dioscoride
498 Anazarbeo della Materia Medicale. Vincenzo Valgrisi, Venezia, 1568, Reprinted in Facsimile.
499 Stabilimento Tipografico Julia, Rome.
500
501 Moorhouse, T.P., Zhou, Z.M., Shao, M.L., Zhou, Y., Elwin, A., D'Cruze, N.C., Macdonald, D.W.,
502 2022a. Substitutes for wildlife-origin materials as described in China's "TCM" research literature.
503 Glob. Ecol. Conserv. 34, e02042. https://doi.org/10.1016/j.gecco.2022.e02042.
504
505 Moorhouse T.P., D'Cruze, N.C., Sun, E., Elwin, A., Macdonald, D.W., 2022b. What are TCM
506 doctors' attitudes towards replacing animal-origin medicinal materials with plant-origin alternatives?
507 Glob. Ecol. Conserv. 34, e02045. https://doi.org/10.1016/j.gecco.2022.e02045.
508

509 Naude, V.N., Balme, G.A., Rogan, M.S., Needham, M.D., Whittington-Jones, G., Dickerson, T.,
510 Mabaso, X., Nattrass, N., Bishop, J.M., Hunter, L., O'Riain, M.J., 2020. Longitudinal assessment of
511 illegal leopard skin use in ceremonial regalia and acceptance of faux alternatives among followers of
512 the Shembe Church, South Africa. Cons. Sci. Pract. 2, e289.
513
514 Nijman, V., Nekaris, K.A., 2016. Provide context when reporting on the use of protected and
515 endangered wildlife in ethnopharmacological surveys. J. Ethnopharmacol. 194, 577–579. doi:
516 10.1016/j.jep.2016.10.066.
517
518 Nowak, G., Schrör, K., 2007. Hirudin--the long and stony way from an anticoagulant peptide in the
519 saliva of medicinal leech to a recombinant drug and beyond. A historical piece. Thromb. Haemost.
520 98, 116–119.
521
522 Phelps, J., Carrasco, L.R., Webb, E.L., 2014. A framework for assessing supply-side wildlife
523 conservation. Cons. Biol. 28, 244–257.
524
525 Plans y Pujol, 1870. Lecciones de Farmacozoología. Barcelona, Librería de Luis Niubó.
526
527 Queensland Health, 2020. https://www.health.qld.gov.au/__data/assets/pdf_file/0024/147507/qh-
528 gdl-954.pdf
529
530 Pajovic, B., Radosavljevic, M., Radunovic, M., Radojevic, N., Bjelogrlic, B., 2012. Arthropods and
531 their products as aphrodisiacs – review of literature. Eur. Rev. Med. Pharmacol. Sci. 16, 539–547.
532
533 Seabrooks, L., Hu, L., 2017. Insects: an underrepresented resource for the discovery of biologically
534 active natural products. Acta Pharm. Sin B. 7, 409–426. doi: 10.1016/j.apsb.2017.05.001.
535
536 Simelane, T., 2011. Are traditionally used resources within conservation areas a function of their
537 sizes? Nat. Resources. 2, 130–139.
538
539 Simelane, T.S., Kerley, G.I.H., 1998. Conservation implications of the use of vertebrates by Xhosa
540 traditional healers in South Africa. S. Afr. J. Wildl. Res. 28, 121–126.
541

542 Starr, C., Nekaris, K.A.I., Streicher, U., Leung, L., 2010. Traditional use of slow lorises Nycticebus
543 bengalensis and N. pygmaeus in Cambodia: an impediment to their conservation. Endang. Species
544 Res. 12, 17–23. Doi: 10.3354/esr00285
545
546 Still J., 2003. Use of animal products in traditional Chinese medicine: environmental impact and
547 health hazards. Complement. Ther. Med. 11, 118–122. doi: 10.1016/s0965-2299(03)00055-4.
548
549 TAWAP, 2024. https://tawap.org/ (accessed: 16.04.2024).
550
551 Tonin, F., Arends, I.W.C.E., 2018. Latest development in the synthesis of ursodeoxycholic acid
552 (UDCA): a critical review. Beilstein J. Org. Chem. 14, 470–483. doi: 10.3762/bjoc.14.33.
553
554 Vucetich, J.A., Burnham, D., Macdonald, E.A., Bruskotter, J.T., Marchini, S., Zimmermann, A.,
555 Macdonald, D.W., 2018. Just conservation: What is it and should we pursue it? Biol. Cons. 221, 23–
556 33. https://doi.org/10.1016/j.biocon.2018.02.022
557
558 Wagner, H., Vollmar, A., Bechthold, A., 2007. Pharmazeutische Biologie 2. Wissenschaftliche
559 Verlagsgesellschaft, mbH, Stuttgart.
560
561 Weckerle, C.S., de Boer, H.J., Puri, R.K., van Andel, T., Bussmann. R.W., Leonti, M., 2018.
562 Recommended standards for conducting and reporting ethnopharmacological field studies. J.
563 Ethnopharmacol. 210, 125–132. doi: 10.1016/j.jep.2017.08.018.
564
565 Whiting, M.J., Williams, V.L., Hibbitts, T.J., 2011. Animals traded for traditional medicine at the
566 Faraday Market in South Africa: species diversity and conservation implications. J. Zool. 284, 84–
567 96.
568
569 Witt, C.M., 2013. Clinical research on traditional drugs and food items - the potential of comparative
570 effectiveness research for interdisciplinary research. J. Ethnopharmacol. 147, 254–258.
571
572 Williams, V.L., Whiting, M.J., 2016. A picture of health? Animal use and the Faraday traditional
573 medicine market, South Africa. J. Ethnopharmacol, 179, 265–273. doi: 10.1016/j.jep.2015.12.024.
574

575 Yeshi, K., Morisco, P., Wangchuk, P., 2017. Animal-derived natural products of Sowa Rigpa
576 medicine: their pharmacopoeial description, current utilization and zoological identification. J.
577 Ethnopharmacol. 207, 192–202. doi: 10.1016/j.jep.2017.06.009.
578
579 Zhu, F., Qin. C., Tao, L., Liu, X., Shi, Z., Ma, X., Jia, J., Tan, Y., Cui, C., Lin, J., Tan, C., Jiang, Y.,
580 Chen, Y., 2011. Clustered patterns of species origins of nature-derived drugs and clues for future
581 bioprospecting. Proc. Natl Acad. Sci. USA. 108, 12943–12948. doi: 10.1073/pnas.1107336108.
582