RESEARCH ARTICLE

Bridging conservation science and traditional knowledge of wild animals: The need for expert guidance and inclusion of local knowledge holders

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Abstract Many people call for strengthening knowledge co-production between academic science and indigenous and local knowledge systems. A major barrier to cooperation seems to be a lack of experience regarding where and how traditional knowledge can be found and obtained. Our key question was whether the expert judgment of academic zoologists or a feature-based linear model is better at predicting the observed level of local familiarity with wild animal species. Neither the zoologists nor the model proved sufficiently accurate (70 and 60%, respectively), with the inaccuracy probably resulting from inadequate knowledge of the local ecological and cultural specificities of the species. This indicates that more knowledge is likely to come from local knowledge than zoologists would expect. Accuracy of targeting the relevant species for knowledge co-production could be improved through specific understanding of the local culture, provided by experts who study traditional zoological knowledge and by local knowledge holders themselves.

Keywords Biodiversity assessments · Conservation policy · Indigenous and local knowledge (ILK) · Knowledge co-production · Knowledge systems · Traditional ecological knowledge (TEK)

INTRODUCTION

Species and ecosystem conservation and the sustainable use of natural resources all require reliable information.

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Most evidence, however, originates from academic science, while other knowledge systems are largely ignored (Tengö et al. 2014; Asselin 2015). Recent evidence shows that indigenous peoples and local communities contribute highly valuable knowledge to conservation science and practices, including achieving conservation targets (Berkes et al. 2000; Huntington 2000; Upreti et al. 2012; Forest Peoples Program et al. 2016).

The use of traditional knowledge in conservation science, practice and policy is, however, limited by a number of epistemological differences, uncertainties of knowledge validation, and power asymmetries (Berkes et al. 2000; Huntington 2000; Nadasdy 2005; Molnár et al. 2008). For these reasons, academic zoologists (i.e., those not familiar with traditional knowledge) are often reluctant (to the point of refusal) to cooperate with local knowledge systems (Gilchrist and Mallory 2007).

Expanding knowledge sources and collaborating with other knowledge systems is supported also in the policy arena by CBD (Convention on Biological Diversity) and IPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services). IPBES emphasizes in its assessments the importance of strengthening dialogue and knowledge co-production between knowledge systems, and of recognizing and respecting the contribution of indigenous and local knowledge (ILK) and Indigenous Peoples and Local Communities (IPLC) to the conservation and sustainable use of biodiversity and nature's contribution to people (Díaz et al. 2015; Lundquist et al. 2015; Pascual et al. 2017). Scientists are motivated (urged) to bridge knowledge systems.

While local knowledge of wild plants (especially medicinal and edible species) is widely respected and used in science (Turner 2014), this is less common in the case of wild animal species (Gilchrist and Mallory 2007).

Ethnozology, as a branch of ethnobiology, studies the interactions between humans and animals, such as traditional ecological knowledge on wild animals (Hunn 2011; Alves 2012). Research into traditional zoological knowledge has ramifications for many other fields, including ethnology, cultural anthropology, monitoring, population biology, conservation biology, biodiversity assessments, and conservation practice and policy (Table 1).

Zoologists and conservationists often seek species-specific local knowledge. A major barrier to cooperation with local knowledge holders seems to be a lack of experience on where and how traditional knowledge (e.g., on wild animal species) can be found and obtained, and how to work together with local knowledge holders to generate new knowledge for conservation (Idrobo and Berkes 2012; Turvey et al. 2014). Zoologists motivated by CBD, IPBES or other organizations to bridge knowledge systems would benefit from having greater advance knowledge of which species are locally known and the depth of this knowledge, enhancing their chances of success (Ens et al. 2015).

In order to make better predictions of the availability of local knowledge on wild animal species, there needs to be greater understanding of how such knowledge may be affected by certain features of the species (e.g. size, abundance, habitat and usefulness).

This paper provides a case study that deals with two questions:

- (1) Is the expert judgment of academic zoologists (with little or no expertise in traditional knowledge) better at predicting the observed level of local familiarity with wild animal species than a feature-based linear model? (Local familiarity here means the proportion of local knowledgeable informants who know the species, and was used as a proxy for knowledge availability); and
- (2) Which are the most useful morphological, ethological, ecological, and cultural features for predicting the level of local familiarity with wild animal species?

MATERIALS AND METHODS

The reference dataset and the observed level of familiarity

An exceptionally large dataset is available on the local traditional zoological knowledge of three local faunas (171 vertebrate and 212 invertebrate taxa) of Central Europe from which the local knowledge was obtained for the current analysis (see data and methods of data collection in Ulicsni 2012; Ulicsni et al. 2013, 2016): Romania (Nuşfalău), Slovakia (Vyšné Valice and Gemerské

Table 1 Examples of traditional zoological knowledge relevant to the conservation of wild animal species

Topics	References
Folk nomenclature, folk taxonomies, identification of species hitherto unknown to academic science	Diamond and Bishop (1999), Beaudreau et al. (2011)
Location of new populations and habitats of endangered species	Huntington (2000), Rea (2007), Alves (2012), Padmanaba et al. (2013), Ziembicki et al. (2013), Service et al. (2014)
Monitoring data on rare, protected and invasive species, developing monitoring indicators	Huntington (2000), Colding and Folke (2001), Moller et al. (2004), Nadasdy (2005), Turvey et al. (2014), Danielsen et al. (2014)
New information on behaviour, food spectra, life histories and reproductive cycles of less known (and threatened) species, especially on economically/culturally important species	Huntington (2000), Tideman and Gosler (2010), Idrobo and Berkes (2012), Polfus et al. (2014), Voorhees et al. (2014), Tendeng et al. (2016)
Knowledge on the local impacts of resource use on biodiversity (incl. land-use history)	Huntington (2000), Molnár et al. (2008), Tideman and Gosler (2010), Alves (2012), Herrmann et al. (2014)
Old-new extensive land-use practices to be rediscovered for better conservation management	Berkes et al. (2000), Johnson and Hunn (2010), Gilchrist and Mallory (2007), Upreti et al. (2012)
Insights into local population regulation practices of game and fish species, incl. taboos and other social norms	Colding and Folke (2001), Neto and Pacheco (2005), Jacqmain et al. (2005), Rea (2007), Kendrick and Manseau (2008), Silvano and Jørgensen (2008), Alves (2012), FPP et al. (2016)
Local knowledge on how to prevent overexploitation of globally traded species used in medicine, handicrafts, etc.	Neto and Pacheco (2005), Alves (2012), Berkes (2012)
Insights into motivations, decision-making strategies and worldviews (incl. cultural, symbolic and spiritual connections) of local stakeholders on land management to help resolve conflicts about protected areas, large predators, game species, scavengers and “less appreciated species” (e.g. snakes)	Nadasdy (2005), Berkes (2012), Lescureux and Linnell (2013), Morales-Reyes et al. (2017)
Traditional knowledge to be brought into local formal education in a culturally appropriate way to prevent cultural erosion	Kimmerer (2002)

Michalovce), and Croatia (Lug, Vardarac and Kopačevo). No new interviews with locals were conducted for the present case study. All three study areas are characterized by moderate continental climate; the potential vegetation is a closed *Quercus* forest with mosaics of meadows and wetlands. Locals practice traditional, corn-, wheat-, cattle- and fruit-based agriculture in a diverse semi-natural rural environment. The local knowledge of possibly all locally known species was collected during picture-based interviews with 57 highly knowledgeable elderly people (average age 75 years, selected by snowball method) between 2010 and 2012 (see details in Ulicsni 2012; Ulicsni et al. 2013, 2016). We determined the level of observed familiarity, that is, the proportion of local knowledgeable informants who know the species at least moderately, i.e. can list at least 3 independent memes (information units e.g. sound of a species, habitat of a species, smell of the Spanish fly, special food storage mounds of steppe mice) related to the species—an admittedly arbitrary decision. Latin names follow de Jong et al. (2014). Prior informed consent was obtained before all the interviews, and ethical guidelines suggested by the International Society of Ethnobiology (ISE 2006) were followed.

Model estimation of expected familiarity

A linear model was constructed to quantify how particular features (morphological, ethological, etc.; i.e. explanatory variables) contribute to the level of observed familiarity (i.e. the dependent variable). Explanatory variables of the model were represented by 10 relevant features (traits and others) identified by traditional knowledge studies covering whole faunas (e.g. Ellen 2006). These features were size, morphological salience, ethological salience, abundance, habitat, danger to humans, harmfulness, usefulness, richness of national folklore, and nature conservational value. Each feature had 6 categories (0: no importance/no relation, 1: little importance, ..., 5: great importance for humans). Each category of each feature was included as a factor in further analyses. Parametrization was based on published literature data. Only elements of traditional knowledge that are part of an average biologist's or zoologist's knowledge (who are not experts in traditional knowledge) were taken into account during parametrization (e.g., folk songs about ladybirds known to all Hungarians). The elements of this highly shared common knowledge of animal-related folklore were defined by the authors. The explanation of values of the different features is detailed in Table S1.

The species included in this analysis were those for which there was sufficient information (data from at least 20 informants) in our dataset [166 species (Tables S2, S3)]. Bird and fish species were omitted because sufficient data

about these taxa are not yet available (our past interviews focused on lesser-known animal species and less on birds).

For variable selection (i.e. for separating the significant and the redundant variables), a forward stepwise procedure was used, based on the corrected Akaike's Information Criterion (AICc), applying the stepAIC() function of MASS package of R (Venables and Ripley 2002). This resulted in a set of candidate models.

Coefficients of the final linear model were calculated via model averaging. All the candidate models with significant explanatory power (with $\Delta AICc \leq 4$) were included in the model averaging. Using the coefficients, a derived variable—the level of estimated familiarity—was calculated for each species. The level of estimated familiarity for a certain species was calculated as the sum of the values of coefficients of the relevant factors.

The differences between the levels of estimated and observed familiarity were calculated for the 81 species selected for the zoologist prediction (see below). We decided arbitrarily to analyse (with Spearman correlation, see below) the top and bottom 20% (the most over- and underestimated species), that is, 2×16 species, in more detail.

Zoologists' expert judgment of local familiarity

81 of the 166 taxa were selected by random stratified sampling for a questionnaire, ensuring that all the main taxonomic groups (mammals, reptiles, amphibians, molluscs, insects and "other invertebrates") were represented. Three roughly equal groups contained species that were locally well known, moderately known and almost unknown (based on Ulicsni 2012; Ulicsni et al. 2013, 2016) (see also Table S2).

We asked 20 zoologists from Hungary and Romania who are familiar with the studied areas (researchers working at universities, museums and research institutes, zoology teachers, governmental and civil conservationists) to complete the questionnaire. Specialists in single species or small taxonomic groups (according to publication lists) were excluded. Of the 42 zoologists who qualified, 20 selected at random were asked to classify each species into four categories based on the level of familiarity they would expect: almost everybody will know the species (3 points), many people (ca. 40–60% of the informants) will know the species (2 points), only a few people will know the species (1 point), or the species will be unknown to locals (0 points). For each species, the average value of the 20 answers was calculated.

Spearman's rank correlation was applied (Table 2) in order to test the statistical dependence between a) the ranking of specific explanatory variables and the level of familiarity expected by zoologists and b) the ranking of

Table 2 The results of Spearman's rank correlation testing the statistical dependence between the ranking of specific explanatory variables and (a) the level of familiarity expected by zoologists, (b) underestimation of local knowledge by zoologists, (c) overestimation of local knowledge by zoologists

(a)			(b)			(c)		
Explanatory variable	ρ	p	Explanatory variable	ρ	p	Explanatory variable	ρ	p
Size	0.2725	**	Size	− 0.2517	*	Size	0.0596	ns
Morphology	0.0776	ns	Morphology	− 0.0426	ns	Morphology	− 0.0328	ns
Ethology	0.3410	***	Ethology	− 0.1212	ns	Ethology	0.0436	ns
Abundance	0.4657	****	Abundance	0.1845	*	Abundance	0.0982	ns
Habitat	0.4894	****	Habitat	− 0.0233	ns	Habitat	0.0419	ns
Usefulness	0.3093	**	Usefulness	0.1005	ns	Usefulness	0.4805	****
Harmfulness	0.0146	ns	Harmfulness	− 1.0714	****	Harmfulness	− 0.0702	ns
Danger	0.2920	**	Danger	− 0.3569	***	Danger	0.2448	*
Folklore	0.0606	ns	Folklore	− 0.0236	ns	Folklore	0.0917	ns
Natcons	0.1144	ns	Natcons	− 0.2129	*	Natcons	0.0275	ns

ns p -value > 0.05 ; * p -value ≤ 0.05 ; ** p -value ≤ 0.01 ; *** p -value ≤ 0.001 ; **** p -value ≤ 0.0001

specific explanatory variables and over- or underestimation of familiarity by zoologists.

Species were ranked according to the observed levels of familiarity based on traditional knowledge holders, and by the level of familiarity predicted by the zoologists. The differences between the two ranks were calculated. Again, we analysed the top and bottom 20% (the most over- and underestimated species), that is, 2×16 species, in more detail.

RESULTS

Following the stepwise variable selection, the key features included in the final linear model were as follows: abundance, folklore, size, habitat, morphology, danger to human and nature conservational value. None of the single features had significant explanatory power (Table S5). The best explanatory power was provided by the combination of the variables listed above (Table S5). The constructed linear model predicted the level of familiarity accurately in ca. 70% of the species (see species close to the axis in Fig. 1). On average the constructed linear model underestimated the level of familiarity by just 2.9%. For individual species, however, the difference between the observed and calculated familiarities was much higher (21.8%). Based on the 2×16 most over- or underestimated species, the chance of overestimation increased with the usefulness of the species, while underestimation increased with the richness of folklore, and also if the size and abundance of the species were below average.

Zoologists' predictions of the level of local familiarity were accurate for ca. 60% of the species (Fig. 2). In the case of the zoologists' predictions, significant

dependencies were found between explanatory variables: size, ethological salience, abundance, habitat, danger to humans, usefulness and the level of familiarity expected by zoologists (Table S2). Overestimation occurred with species characterized by less than expected local usefulness, and less than expected danger to humans; underestimation occurred with species unexpectedly frequently encountered by villagers, more than expected harmfulness, more than expected nature conservational value, and rare small-bodied species.

Nine species were underestimated by both the model and the zoologists: golden flower bug (*Cetonia aurata*), Eurasian weasel (*Mustela nivalis*), earwigs (Dermaptera), chicken cody louse (*Menacanthus stramineus*), Spanish fly (*Lytta vesicatoria*), great silver water beetle (*Hydrous piceus*), slow worm species (*Anguis fragilis* s.l.), engraver beetles (*Ips* spp.), and wildcat (*Felis silvestris*), while also nine species were overestimated by both the zoologists and the model: apple maggot (*Rhagoletis pomonella*), wasp spider (*Argiope bruennichi*), red louse (*Bovicola bovis*), Eurasian beaver (*Castor fiber*), stoat (*Mustela erminea*), European praying Mantis (*Mantis religiosa*), oriental cockroach (*Blatta orientalis*), European rabbit (*Oryctolagus cuniculus*), and European fire-bellied toad (*Bombina bombina*).

Zoologists underestimated sand lizard/Balkan wall lizard taxon (*Lacerta agilis/Podarcis taurica*), harlequin ladybird (*Harmonia axyridis*), horse-leech (*Haemopsis sanguisuga*), Hungarian gall wasp (*Andricus hungaricus*), green shield bug/southern green stink bug taxon (*Palomena prasina/Nezara viridula*), bats (Chiroptera) and stone marten (*Martes foina*), while overestimated brown bear (*Ursus arctos*), backswimmers (Notonectidae), adder (*Vipera berus*), European pond turtle (*Emys orbicularis*),

Fig. 1 Level of familiarity with 81 wild animal taxa, calculated by the linear model (percentage of knowledgeable informants expected to know the taxon) and observed locally. The most over- and underestimated 2×16 species (20%) are indicated by red and green marks, respectively (see also Table S4)

Fig. 2 Level of local familiarity with 81 wild animal taxa, as predicted by zoologists (almost all locals know it = 3 points, no locals know it = 0 points) and observed among local knowledgeable informants (%). The most over- and underestimated 2×16 species are indicated by red and green marks, respectively (see also Table S4)

steppe polecat (*Mustela eversmanni*), common fish louse (*Argulus foliaceus*) and true weevils (Curculionidae).

The model underestimated European hornet (*Vespa crabro*), common liver fluke (*Fasciola hepatica*), stag beetle (*Lucanus cervus*), firebug (*Pyrrhocoris apterus*), body louse (*Pediculus humanus humanus*), Colorado potato beetle (*Leptinotarsa decemlineata*) and common clothes moth (*Tineola bisselliella*), while overestimated forest caterpillar hunter (*Calosoma sycophanta*), a family of predatory mites (Parasitidae), Italian striped-bug (*Graphosoma lineatum*), red deer (*Cervus elaphus*), antlions (Myrmeleontidae), steppe mouse (*Mus spicilegus*) and golden jackal (*Canis aureus*).

DISCUSSION

Both the zoologists and the linear model inaccurately estimated the level of local familiarity of ca. 30–40% of the species. Unexpectedly, little difference was found between the accuracy of the model (60%) and that of the zoologists (70%). The list of the most over- and underestimated species overlapped by ca. 50%.

A zoologist's perception of wild animal species differs from that of a local farmer. The two groups perceive different things as interesting, beautiful, valuable or harmful. In some cases, zoologists were unaware if a given species was a provider of a certain ecosystem service or a cause of serious damage at a local level. The model, built upon general zoological knowledge, was also unable to consider local cultural and ecological specialities. Over- or underestimation of certain species were, however, often easy to explain with expertise in traditional zoological knowledge.

The most common cause of knowledge underestimation by both zoologists and the model was the undervaluation of or the lack of information on local socio-economic contexts and beliefs. For example, in the case of the Hungarian gall wasp (*Andricus hungaricus*), besides its use as tanning material, superstitions might play an important role in it being locally well-known: "My mother always compelled me to throw them out (when as a child I was collecting them. It cannot be kept near the house because) hens will not brood." (Ulicsni et al. 2016).

Abandoned practices also contributed to a higher level of familiarity than expected. Although the use of the Mediterranean medicinal leech (*Hirudo verbana*) has considerably declined, knowledge of its former use was passed on effectively. The same is true for the black-coloured carpenter bees (*Xylocopa violacea*, *X. valga*) whose honey bag was widely eaten before the spread of commercial sweets. "If you take it apart there is a small honey sac in the middle. When we were young, we often

caught it to get the honey from them." (Ulicsni et al. 2016). The Spanish fly (*Lytta vesicatoria*) has been used as an aphrodisiac and against rabies: "When someone was bitten by a rabid dog, he had to eat eight..." Many locals still remember this. Today this species is only used as bait for fishing.

Damage caused by a taxon may also affect local people more sensitively than expected, which is why zoologists, who represent another knowledge system and lifestyle, might underestimate familiarity with a species. For example, the damage done to fish caught in a traditional fish trap (called *varsa*) by the great silver water beetle (*Hydrous piceus*) is very conspicuous. The chicken body louse (*Menacanthus stramineus*) is also a very dangerous parasite killing domestic fowl. Almost everybody can identify it and, surprisingly, precisely distinguish it from mites (Gub 1996). Locals argue that the Eurasian weasel (*Mustela nivalis*), the stone marten (*Martes foina*) and the wolf (*Canis lupus*) kill more animals than they could take and eat, behave very annoyingly, and cause a lot of damage. There are also many superstitions surrounding them. For example, it is believed that the Eurasian weasel sucks the udder of cows, causing mastitis. "It bites the udder so it is spoiled." Sometimes it was cured with the skin of the weasel (Ulicsni et al. 2013). Level of familiarity was also overestimated if zoologists were unaware of the fact that local people did not associate damage with the pest that caused it. In these cases, the species had lower familiarity level than expected (e.g. the common fish louse (*Argulus foliaceus*)). Another possible reason for this latter species to be lesser-known is that the old experienced fishermen have died out and their knowledge is lost (Ulicsni et al. 2016).

One reason for underestimating level of familiarity might be that zoologists considered morphological salience of a species more important than its impact (e.g. use and harm). Namely, they expected the morphologically more salient species to be better known. The wasp spider (*Argiope bruennichi*) and the European praying mantis (*Mantis religiosa*) are morphologically very striking species but have no actual impact on humans, so they are little-known by locals. Unexpectedly, locals have learnt even the names of these species, mostly in school and from media (Ulicsni et al. 2016).

Size seemed to be an important factor if it was a distinguishing feature from other similar (related) species, like for the large stag beetle (*Lucanus cervus*) among bugs and the European hornet (*Vespa crabro*) among smaller wasps.

One reason for overestimation might be that zoologists based their predictions on their knowledge of natural and urban areas rather than rural agricultural landscapes. If a species was abundant in urban areas but rare in rural ones and zoologists did not know that, they overestimated the

level of familiarity. A good example is the oriental cockroach (*Blatta orientalis*). It does not occur in rural areas in our region, people cannot encounter it, and do not know what it is (Ulicsni et al. 2016).

Some of the locally better known species have only appeared in the recent past in our region. Zoologists did not expect the locals to recognize them, e.g. the harlequin ladybird (*Harmonia axyridis*). Surprisingly, locals did know that it appeared 5–7 years ago and they did not mistake it for other ladybird species. Another of this kind of newcomer taxa was the green shield bug/southern green stink bug taxa (*Palomena prasina/Nezara viridula*). Local people put them into the same folk taxon and have already observed that one winter is needed to change colour from green to brown (Ulicsni et al. 2016).

In summary, the most common causes of underestimation by both zoologists and the model were undervaluation and an insufficient understanding of local values, beliefs and ecology. Another reason for underestimation was that zoologists considered the morphological salience of a species as more important than its impact (e.g. use or harm). Neither dangerous species nor species of high nature conservation value were consistently over- or underestimated. Unexpectedly, legal protection or endangerment had only minimal impact on the level of familiarity of the species. Biró et al. (2014) also show that many rare, threatened and thus protected plant species are less well known than expected, as these are most frequently small and non-utilized species that are rare also at the local scale.

Knowledge loss has a high impact on the available local traditional knowledge in our region, especially in more industrialized and urbanized areas (Biró et al. 2014). On the other hand, there is still a considerable amount (comparable to many tropical and boreal regions) of actively used traditional ecological knowledge in the economically marginal areas utilized with extensive land-use practices in East-Central Europe (Molnár et al. 2008; Biró et al. 2014). However, this traditional knowledge is fading rapidly, and most of it may be lost in the next decades.

It is a well-known phenomenon that knowledge about a species can be heavily influenced by the needs, practices and worldview of local cultural groups (Alves 2012; Berkes 2012). There are many examples from different cultures around the world of unexpectedly salient species. For example, in the tropics, the larvae of some weevil species play a significant role in human diet as they are the main source of essential tryptophan. As a result, locals know a lot about these species, their habitats, behaviour, etc. (Ramos-Elorduy et al. 2002). In East Africa, there is a unique traditional use for whirligig beetles (Gyrinidae) and predaceous diving beetles (Dytiscidae), as a stimulant for breast growth (Kutalek and Kassa 2005). Fruits and roots hoarded for the winter by rodents are exploited for food by

several local Siberian communities (Ståhlberg and Svanberg 2010), resulting in these rodent species and their habitat and behaviour being well known and distinguished.

There are several limitations to our study. For the zoologists, the ordinal scale had only four categories, as they argued they could not estimate the level of familiarity more precisely. The accuracy of the model could be increased by using a larger sample size. However, the sample size used was limited by the number of species known to the local communities studied and the number of taxa with sufficient information in our dataset. Data on observed familiarity may not be totally accurate either. Interviewing 57 people about more than 350 species is time-consuming, not to mention tiring for the informants. On the other hand, the unexpectedly large (50%) overlap between the zoologists and the model regarding the most inaccurately estimated species corroborates the robustness of our analysis (50% is far from being a random pattern). We are also aware that in the local community, the level of familiarity does not necessarily correlate with the depth, richness and usefulness of traditional knowledge, and that knowledge erosion might affect depth of knowledge more than the mere recognition of a species (Biró et al. 2014).

CONCLUSIONS AND RECOMMENDATIONS

Local familiarity of 30–40% of the species was significantly under- or overestimated by the zoologists and the linear model. This high level of uncertainty shows that it may be unrealistic to expect academic zoologists with limited understanding of traditional zoological knowledge to identify adequate target species for knowledge co-production and thus bridge knowledge systems. It also raises ethical issues, for example, how correct it is to push scientists preparing assessments (e.g., in CBD or IPBES) to do reviews in areas they are not familiar with; how often it can lead to unethical uses and interpretations of traditional knowledge, and thus to biased statements in the assessments. This way both the local and external experts are treated unfairly which hinders the possibilities of the effective knowledge co-production.

Cooperative research based on more than one knowledge system can unite the benefits of different ontological and epistemological systems. For example, traditional zoological knowledge is often considered a useful complement to scientific approaches to wildlife research and conservation (Huntington 2000; Moller et al. 2004; Prado et al. 2013). Cooperative research can eliminate knowledge gaps, which can benefit all stakeholders who are actively involved in the process (Raymond et al. 2010). Cooperation can decrease the power imbalance between the representatives of knowledge systems, thereby contributing to

the involvement of the local community and the wider use of knowledge in nature conservation (Raymond et al. 2010; Tengö et al. 2014; FPP et al. 2016). We argue that bias and underestimation of local knowledge can hinder these processes, can lead to less efficient cooperation and even waste resources, for example, if communication of conservationists is not adjusted well to the knowledge locals have of target species and species groups.

When selecting teams of authors for IPBES assessments, increasing attention (although still not enough) is paid to including experts on Indigenous and Local Knowledge in order to bridge knowledge systems. It is our sincere hope that traditional knowledge holders and their knowledge can thus more effectively promote the protection of species and habitats and the sustainable use of biodiversity, and increase awareness of the need for conservation. For example, better understanding of local knowledge of wild flora and fauna could help develop more complex community-based conservation programmes. Inclusive conservation approaches can take into account not only the knowledge of locals but also local economic and socio-cultural aspects (e.g., perceptions based on local values and beliefs). Better recognition of local knowledge could also help the preservation and transmission of local knowledge necessary for the continuation of local—often still sustainable—land-use practices.

We argue that researchers of traditional and local knowledge can function as bridging experts in these activities, aiding zoologists and conservationists who seek target species for knowledge co-production. Meanwhile, zoologists would have the opportunity to decolonize their approaches, open up to traditional knowledge, and learn how to work in collaboration with local people. We believe that a more efficient bridging of knowledge systems could increase the chances of success and lead to improved cooperation between conservation practice, academic science, and indigenous and traditional knowledge holders.

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REFERENCES

- Alves, R.R.N. 2012. Relationships between fauna and people and the role of ethnozoology in animal conservation. *Ethnobiology and Conservation* 1: 1–69.
- Asselin, H. 2015. Indigenous forest knowledge. In *Routledge Handbook of Forest Ecology*, ed. K. Peh, R. Corlett, and Y. Bergeron, 586–596. New York: Earthscan, Routledge.
- Beaudreau, A.H., P.S. Levin, and K.C. Norman. 2011. Using folk taxonomies to understand stakeholder perceptions for species conservation. *Conservation Letters* 4: 451–463.
- Berkes, F. 2012. *Sacred ecology*, 3rd ed. New York, USA: Routledge.
- Berkes, F., J. Colding, and C. Folke. 2000. Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications* 10: 1251–1262.
- Biró, É., D. Babai, J. Bódis, and Z. Molnár. 2014. Lack of knowledge or loss of knowledge? Traditional ecological knowledge of population dynamics of threatened plant species in East-Central Europe. *Journal for Nature Conservation* 22: 318–325.
- Colding, J., and C. Folke. 2001. Social taboos: “invisible” systems of local resource management and biological conservation. *Ecological Applications* 11: 584–600.
- Danielsen, F., P.M. Jensen, N.D. Burgess, I. Coronado, S. Holt, M.K. Poulsen, R.M. Rueda, T. Skielboe, et al. 2014. Testing focus groups as a tool for connecting indigenous and local knowledge on abundance of natural resources with science-based land management systems. *Conservation Letters* 7: 380–389.
- de Jong, Y., M. Verbeek, V. Michelsen, Bjørn P. de Place, W. Los, F. Steeman, N. Bailly, C. Basire, et al. 2014. Fauna Europaea—all European animal species on the web. *Biodiversity Data Journal* 2: e4034.
- Diamond, J., and K.D. Bishop. 1999. Ethno-ornithology of the Ketengban people, Indonesian New Guinea. In *Folkbiology*, ed. D.L. Medin and A. Scott, 17–45. Cambridge: MIT Press.
- Díaz, S., S. Demissew, C. Joly, W. Lonsdale, N. Ash, and A. Larigauderie. 2015. The IPBES conceptual framework—connecting nature and people. *Current Opinion in Environmental Sustainability* 14: 1–16.
- Ellen, R. 2006. *The cultural relations of classification: An analysis of Nuaulu animal categories from central Seram*, vol. 91. Cambridge: Cambridge University Press.
- Ens, E.J., P. Pert, P.A. Clarke, M. Budden, L. Clubb, B. Doran, C. Douras, J. Gaikwad, B. Goth, S. Leonard, J. Locke, J. Packer, G. Turpin, and S. Wason. 2015. Indigenous biocultural knowledge in ecosystem science and management: Review and insight from Australia. *Biological Conservation* 181: 133–149.
- Forest Peoples Programme, the International Indigenous Forum on Biodiversity and the Secretariat of the Convention on Biological Diversity. 2016. Local Biodiversity outlooks. Indigenous peoples’ and local communities’ contributions to the implementation of the strategic plan for biodiversity 2011–2020. A complement to the fourth edition of the Global Biodiversity Outlook. Moreton-in-Marsh, England.
- Gilchrist, G., and M. Mallory. 2007. Comparing expert-based science with local ecological knowledge: What are we afraid of? *Ecology and Society* 12: 1.
- Gub, J. 1996. Erdő-mező állatai a Sóvidéken. [In Hungarian: Animals of forests and meadows in Sóvidék]. Korond: Firtos Művelődési Egylet.
- Herrmann, T.M., P. Sandström, K. Granqvist, N. D’Astous, J. Vannar, H. Asselin, N. Saganash, J. Mameamskum, G. Guanish, J.B. Loon, and R. Cuciurean. 2014. Effects of mining on reindeer/caribou populations and indigenous livelihoods: Community-based monitoring by Sami reindeer herders in Sweden and First Nations in Canada. *The Polar Journal* 4: 28–51.

- Hunn, E.S. 2011. *Ethnozoology, Ethnobiology*, 83–96. Hoboken, New Jersey: Wiley.
- Huntington, H.P. 2000. Using traditional ecological knowledge in science: Methods and applications. *Ecological Applications* 10: 1270–1274.
- Idrobo, C.J., and F. Berkes. 2012. Pangnirtung Inuit and the Greenland shark: Co-producing knowledge of a little discussed species. *Human Ecology* 40: 405–414.
- International Society of Ethnobiology. 2006. International Society of Ethnobiology Code of Ethics (with 2008 additions). <http://ethnobiology.net/code-of-ethics/>.
- Jacqmain, H., L. Bélanger, R. Courtois, T. Beckley, S. Nadeau, C. Dussault, and L. Bouthillier. 2005. Proposal to combine Cree and scientific knowledge for improved moose habitat management on Waswanipi Eeyou Ashtchee, northern Québec. *Alces* 41: 147–160.
- Johnson, L.M., and E.S. Hunn. 2010. Landscape ethnoecology: Reflections. In *Landscape ethnoecology. Concepts of biotic and physical space*, ed. L.M. Johnson and E.S. Hunn, 279–297. New York, NY: Berghahn Books.
- Kendrick, A., and M. Manseau. 2008. Representing traditional knowledge: Resource management and Inuit knowledge of barren-ground caribou. *Society and Natural Resources* 21: 404–418.
- Kimmerer, R.W. 2002. Weaving traditional ecological knowledge into biological education: A call to action. *BioScience* 52: 432–438.
- Kutalek, R., and A. Kassa. 2005. The use of gyrinids and dytiscids for stimulating breast growth in East Africa. *Journal of Ethnobiology* 25: 115–128.
- Lescureux, N., and J.D. Linnell. 2013. The effect of rapid social changes during post-communist transition on perceptions of the human-wolf relationships in Macedonia and Kyrgyzstan. *Pastoralism* 3: 1–20.
- Lundquist, C.J., A. Baldi, M. Dieterich, K. Gracey, E.K. Kovacs, J. Schleicher, T. Skarin, E. Sterling, and B.-G. Jonsson. 2015. Engaging the conservation community in the IPBES process. *Conservation Biology* 29: 1493–1495.
- Moller, H., F. Berkes, P.O.B. Lyver, and M. Kislalioglu. 2004. Combining science and traditional ecological knowledge: Monitoring populations for co-management. *Ecology and Society* 9: 2.
- Molnár, Z., S. Bartha, and D. Babai. 2008. Traditional ecological knowledge as a concept and data source for historical ecology, vegetation science and conservation biology: A Hungarian perspective. In *Human nature. Studies in historical ecology and environmental history*, ed. P. Szabó and R. Hedl, 14–27. Brno: Institute of Botany of the ASCR.
- Morales-Reyes, Z., B. Martín-López, M. Moleón, P. Mateo-Tomás, F. Botella, A. Margalida, J.A. Donazar, G. Blanco, et al. 2017. Farmer perceptions of the ecosystem services provided by scavengers: What, who and to whom. *Conservation Letters* (early view). <https://doi.org/10.1111/conl.12392>.
- Nadasdy, P. 2005. *Hunters and bureaucrats: Power, knowledge, and aboriginal-state relations in the southwest Yukon*. Victoria: UBC Press.
- Neto, E.M.C., and J.M. Pacheco. 2005. Utilização medicinal de insetos no povoado de Pedra Branca, Santa Terezinha, Bahia, Brasil. *Biotemas* 18: 113–133.
- Padmanaba, M., D. Sheil, I. Basuki, and L. Nining. 2013. Accessing local knowledge to identify where species of conservation concern occur in a tropical forest landscape. *Environmental Management* 52: 348–359.
- Pascual, U., P. Balvanera, S. Díaz, G. Pataki, E. Roth, M. Stenseke, R.T. Watson, E.B. Dessane, et al. 2017. Valuing nature's contributions to people: The IPBES approach. *Current Opinion in Environmental Sustainability* 26: 7–16.
- Polfus, J.L., K. Heinemeyer, and M. Hebblewhite. 2014. Comparing traditional ecological knowledge and western science woodland caribou habitat models. *Journal of Wildlife Management* 78: 112–121.
- Prado, H.M., R.S.S. Murrieta, C. Adams, and E.S. Brondizio. 2013. Complementary viewpoints: Scientific and local knowledge of ungulates in the Brazilian Atlantic forest. *Journal of Ethnobiology* 33: 180–202.
- Ramos-Elorduy, J., J.M. Pino-Moreno, and J. Morales. 2002. Análisis químico proximal vitaminas y nutrientes inorgánicos de insectos consumidos en el Estado de Hidalgo, México. *Folia Entomológica Mexicana* 41: 15–29.
- Raymond, C.M., I. Fazey, M.S. Reed, L.C. Stringer, G.M. Robinson, and A.C. Evelyn. 2010. Integrating local and scientific knowledge for environmental management. *Journal of Environmental Management* 91: 1766–1777.
- Rea, A.M. 2007. *Wings in the desert: A folk ornithology of the Northern Pimans*. Tucson: University of Arizona Press.
- Service, C.N., M.S. Adams, K.A. Artelle, P. Paquet, L.V. Grant, and C.T. Darimont. 2014. Indigenous knowledge and science unite to reveal spatial and temporal dimensions of distributional shift in wildlife of conservation concern. *PLoS ONE* 9: e101595.
- Silvano, R., and J. Valbo-Jørgensen. 2008. Beyond fishermen's tales: Contributions of fishers' local ecological knowledge to fish ecology and fisheries management. *Environment, Development and Sustainability* 10: 657.
- Ståhlberg, S., and I. Svanberg. 2010. Gathering food from rodent nests in Siberia. *Journal of Ethnobiology* 30: 184–202.
- Tendeng, B., H. Asselin, and L. Imbeau. 2016. Moose (*Alces americanus*) habitat suitability in temperate deciduous forests based on Algonquin traditional knowledge and on a habitat suitability index. *Écoscience* 23: 77–87.
- Tengö, M., E.S. Brondizio, T. Elmqvist, P. Malmer, and M. Spierenburg. 2014. Connecting diverse knowledge systems for enhanced ecosystem governance: The multiple evidence base approach. *Ambio* 43: 579–591.
- Tidemann, S., and A. Gosler. 2010. *Ethno-ornithology: Birds, indigenous peoples, culture and society*. London: Earthscan.
- Turner, N.J. 2014. *Ancient pathways, ancestral knowledge: Ethnobotany and ecological wisdom of indigenous peoples of North-western North America*. Montreal and Kingston: McGill-Queen's University Press.
- Turvey, S.T., C. Fernández-Secades, J.M. Nuñez-Miño, T. Hart, P. Martinez, J.L. Brocca, and R.P. Young. 2014. Is local ecological knowledge a useful conservation tool for small mammals in a Caribbean multicultural landscape? *Biological Conservation* 169: 189–197.
- Ulicsni, V. 2012. Folk knowledge of non-domestic animals among ethnic Hungarians in North-Western Romania. BSc Thesis, Szegedi Tudományegyetem Természettudományi és Informatikai Kar Ökológiai Tanszék, Szeged, Hungary [in Hungarian].
- Ulicsni, V., I. Svanberg, and Z. Molnár. 2013. Folk knowledge of non-domestic mammals among ethnic Hungarians in North-Western Romania. *North-Western Journal of Zoology* 9: 383–398.
- Ulicsni, V., I. Svanberg, and Z. Molnár. 2016. Folk knowledge of invertebrates in Central Europe-folk taxonomy, nomenclature, medicinal and other uses, folklore, and nature conservation. *Journal of Ethnobiology and Ethnomedicine* 12: 47.
- Upstey, Y., H. Asselin, Y. Bergeron, F. Doyon, and J.F. Boucher. 2012. Contribution of traditional knowledge to ecological restoration: Practices and applications. *Écoscience* 19: 225–237.

- Venables, W.N., and B.D. Ripley. 2002. *Modern applied statistics with S*, 4th ed. New York: Springer.
- Voorhees, H., R. Sparks, H.P. Huntington, and K.D. Rode. 2014. Traditional knowledge about polar bears (*Ursus maritimus*) in Northwestern Alaska. *Arctic* 67: 523–536.
- Ziembicki, M.R., J.C.Z. Woinarski, and B. Mackey. 2013. Evaluating the status of species using Indigenous knowledge: Novel evidence for major native mammal declines in northern Australia. *Biological Conservation* 157: 78–92.

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