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Are local and traditional ecological knowledge suitable tools for informing the conservation of threatened amphibians in biodiversity hotspots?

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ABSTRACT - Globally, amphibians are declining more rapidly than any other vertebrate group. A general shortage of funding for the support of focused scientific studies led us to investigate local and traditional ecological knowledge as an alternative data source for amphibian conservation. In this context, we undertook a questionnaire-based interview survey with forest-dwelling indigenous and non-indigenous communities across the Anamalai Hills, within the southern Western Ghats of India, to gather ecological knowledge on three cryptic and threatened frog species. Our results suggest that local communities possess ecological knowledge of frogs and that the magnitude of this knowledge is influenced by gender, community type, education, and age. Accuracy of local knowledge was primarily influenced by the morphological distinctiveness of the focal species, but cultural association and utilisation were also important factors especially for the enigmatic purple frog *Nasikabatrachus sahyadrensis*, which has uses in medicine and amulets.

INTRODUCTION

India harbours exceptional diversity and endemism of amphibians, with a total of 459 species (Frost, 2020). Most amphibian studies have focused on taxonomy and systematics (e.g. Van Bocxlaer et al., 2009; Biju et al., 2011, 2014) rather than population status, ecology and threats to these species. In the absence of resources for focused scientific studies, alternative data collection approaches to understand key amphibian conservation parameters need to be identified and tested.

Communities develop an array of knowledge and management strategies to exploit the local natural resources on which they depend (Berkes et al., 2000). The collection and assessment of such knowledge from untrained observers therefore represents a potentially cost-effective approach to understand the biology, distribution, population status, and potential threats for otherwise poorly-known and potentially threatened amphibian species. This approach may be particularly important for species that are difficult to detect using standard scientific survey methods, that have limited activity patterns, and/or are rare or possibly extinct (Anadón et al., 2009; Turvey et al., 2010; Meijaard et al., 2011; Stuart, 2012; Ziembicki et al., 2013).

The knowledge that local communities possess can be classified as either traditional ecological knowledge (TEK), a composite set of beliefs, information and practices that are handed over from one generation to another, or local ecological knowledge (LEK), the observations gathered by an individual over a lifetime (Gadgil et al., 1993; Berkes et al., 2000; Gilchrist et al., 2005). These two knowledge categories differ; TEK often relates to beliefs towards species that can lead to their protection, culling or utilisation (Stacey et al., 2012). Whereas LEK, by being observational in nature, can assist in understanding species occurrence, abundance, habitat use and threats (Gilchrist et al., 2005; Anadón et al., 2010; Lescureux et al., 2011), especially for globally threatened and/or elusive species for which very few data are otherwise available (Turvey et al., 2014, 2015; Pan et al., 2015). LEK is particularly useful for understanding status and threats for large-bodied, morphologically distinct species (Turvey et al., 2014) or economically or culturally important species (Jones et al., 2008; Pan et al., 2015). However, collecting and interpreting data about focal species from untrained respondents to establish baselines for conservation is not straightforward (Gilchrist et al., 2005). TEK and LEK data can be affected by errors around species identification or associated encounter details (e.g. timing recall), negative reporting bias, retrospective bias, exaggeration, and/or varying data breadth and quality depending on species and respondent (Davis & Wagner, 2003; Gilchrist et al., 2005; McKelvey et al., 2008; O'Donnell et al., 2010).

Under the Forest Rights Act of India, 2006, indigenous communities in the Western Ghats are permitted to harvest non-timber forest products and freshwater fish sustainably. Indigenous communities in the Western Ghats region of Kerala have been found to utilise 54 wild animal taxa, primarily freshwater fish, herpetofauna and small mammals, for meat and traditional medicine (Kanagavel et al., 2016). Amphibians are known to be used by indigenous communities across the Western Ghats and in other parts of India for medicinal purposes (Tiwari et al., 2013; Narzary &

Bordoloi, 2014; Thomas & Biju, 2015; Kanagavel et al., 2016) and are also the focus of legends and taboos (Harpalani et al., 2015). The area therefore offers an opportunity to investigate the LEK and TEK of amphibians, within a wider continental context where baseline data on amphibian species diversity and distributions are very limited (Molur, 2008). We focused on three poorly-known threatened frog species from southern India, all identified as EDGE (Evolutionarily Distinct and Globally Endangered) species for conservation (Isaac et al., 2012). We aimed to assess whether LEK and TEK can be effective tools for gathering ecological knowledge to inform future amphibian-based conservation initiatives in the Western Ghats.

MATERIALS AND METHODS

Our study was undertaken in three adjoining areas of the Anamalai Hills (Kerala and Tamil Nadu States), within the southern Western Ghats; Valparai (municipality), Topslip (Forest Range) and Munnar (town). These locations are bordered by several protected areas, reserve forests, and private forest fragments (Fig. 1). The primary vegetation of this area, which historically comprised tropical rainforest, has now been transformed into a mosaic of plantations interspersed with fragmented patches of original evergreen forest (Raman & Mudappa, 2003).

Both indigenous (Kadar, Mudhuvar, Malasar, Malai Malasar, Pulayar) and non-indigenous forest-dwelling communities live in the study area. Indigenous communities are defined by their historical occupancy of the area, geographic isolation, distinctive culture and ancient cultural traits (MTA, 2012). Non-indigenous communities are mostly recent settlers from other regions of India. Both indigenous and non-indigenous communities work with the State Forest Department or as labourers in farms and plantations, and collect non-timber forest products (Chandi, 2008; Surendran & Sekhar, 2011). The population of the area has a higher proportion of non-indigenous than indigenous individuals (>13:1; Chandi, 2008; DCO, 2011).

Three threatened EDGE amphibians, endemic to the study area were selected as focal species: the purple frog (Nasikabatrachidae: *Nasikabatrachus sahyadrensis*, Fig. 2A), the black microhylid frog (Microhylidae: *Melanobatrachus indicus*, Fig. 2B), and the toad-skinned frog (Ranixalidae: *Walkerana phrynoderma*, Fig. 2C) (Table 1). These three species vary in their morphological distinctiveness and in the availability of scientific knowledge about them. This provides a useful framework for assessing correlates of potential LEK and TEK variation and usefulness. *Nasikabatrachus sahyadrensis* was described scientifically in 2003 but was already known by indigenous communities and is relatively well studied (Aggarwal, 2004; Table 2). This fossorial frog is morphologically distinct, and is only active above the soil for the annual two-week breeding season (Biju & Bossuyt, 2003; Thomas et al., 2014). It has been consumed by indigenous communities for decades, and these communities possess considerable knowledge about its behaviour and lifecycle (Thomas & Biju, 2015). *Melanobatrachus indicus* is

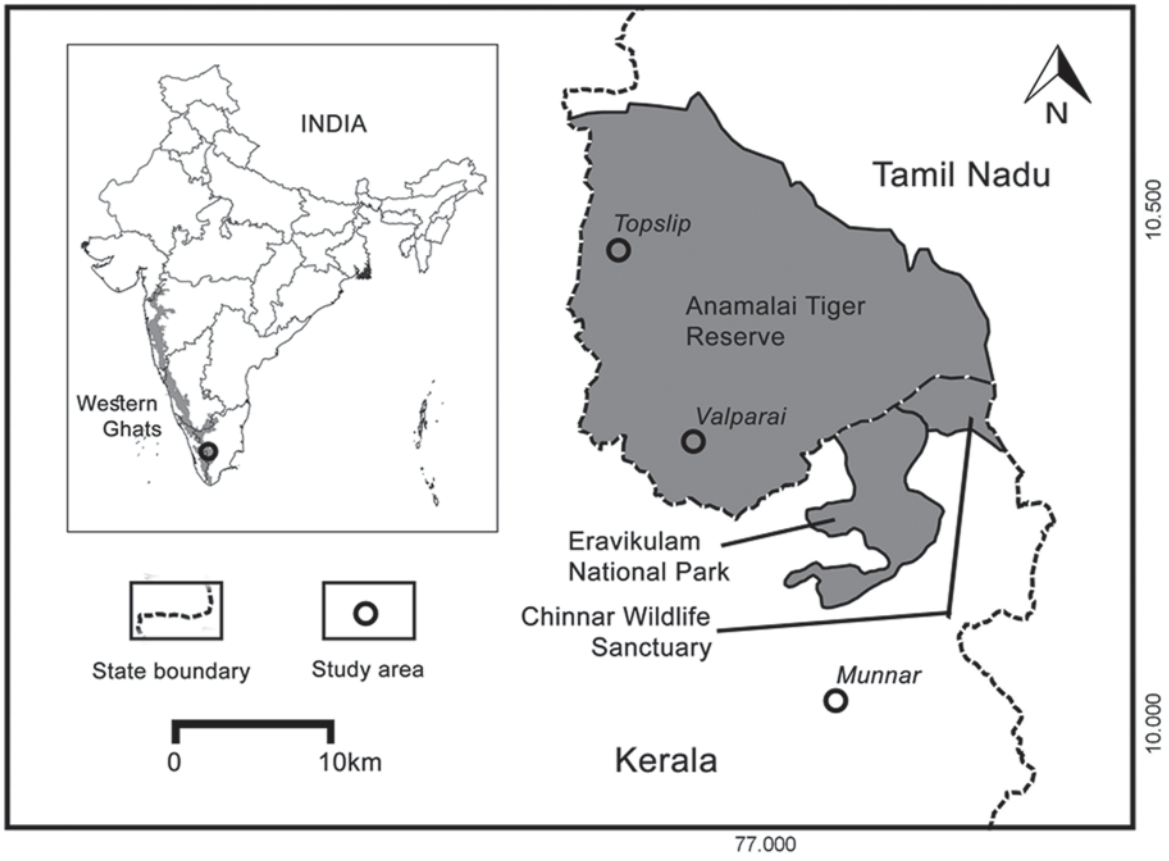

Figure 1. Map of the study area in the southern Western Ghats of India

Figure 2. Focal frog species for the study- **A.** Purple frog *N. sahyadrensis*, **B.** Black microhylid frog *M. indicus*, **C.** Toad-skinned frog *W. phrynoderma*

Table 1. Details of how anuran species are utilised by local communities in the Anamalai Hills, Western Ghats, India

	Scientific Name	Status[k]	Habitat[l]	Community Type & No.[m]	Utilisation Type[n]
1	*Nasikabatrachus sahyadrensis*[a, b, c]	EN	Fossorial, active above the ground only for a few weeks during the monsoon	Kadar (27)	Adults and larvae are consumed specifically by children and infants as medicine for skin-based ailments, cold, cough, throat infection, asthma, measles, chicken pox and stomach pain. They are consumed after cooking or after drying and/or powdered or vapours from burning the dried frog are inhaled. Fat tissue/mucous lining is applied on external wounds. Small-sized individuals, skin, limbs, or digit ends are used as amulets for children to reduce fear, when they are unable to sleep at night or who do not speak or walk well.
2	*Melanobatrachus indicus*[a, d, e]	EN	Fallen bark and leaf litter close to streams	Kadar (1)	For those who have a problem with walking, the frog is tied within a small sack and worn around the individual's neck.
3	*Walkerana phrynoderma*[a, f]	CR	Leaf litter	Kadar (0), Mudhuvan (0)	Since it is confused with *Duttaphrynus* sp., this species and others in the same genus could be used as medicine to cure skin burns and other skin-based body ailments.
4	*Rhacophorus pseudomalabaricus*[g]	CR	Understory of rainforests	Kadar (1)	Used as medicine for coughs and as amulets for children who do not speak or walk well
5	*Raorchestes jayarami*[h]	NE	2m above the ground in forest undergrowth	Kadar (3)	Used as medicine for coughs, as general medicine for children and as amulets for children who do not speak or walk well
6	*Raorchestes beddomii*[h]	NT	Moist forest patches, wayside vegetation and tea plantation	Kadar (3)	Used as medicine for coughs, as general medicine for children and as amulets for children who do not speak or walk well
7	*Duttaphrynus melanostictus*[i]	LC	Wide range of habitats	Kadar (2), Mudhuvan (1), Non-indigenous communities (1)	Used as medicine to cure skin burns and other skin-based body ailments
8	*Indosylvirana* sp.[j]		Leaf litter and streams in open secondary and primary forests	Kadar (3)	Used during the rainy season as bait for fishing
9	*Hoplobatrachus tigerinus*[f]	LC	Close to streams, lakes, pools and farms	Non-indigenous communities (5)	Meat is consumed
10	*Fejervarya* sp.		Close to water bodies, muddy areas	Kadar (1), Mudhuvan (1), Non-indigenous communities (1)	Used as bait to catch fish and crabs
11	*Euphlyctis* sp.		Water bodies	Kadar (1), Mudhuvan (1), Non-indigenous communities (1)	Used as bait to catch fish and crabs

[a]Focal species of this study; [b]Biju, 2004; [c]Gururaja, 2012; [d]Biju et al., 2004b; [e]Kanagavel & Tapley, 2013; [f]Biju et al., 2004a; [g]Vasudevan & Dutta, 2000; [h]Biju & Bossuyt, 2009; [i]van Dijk et al., 2004; [j]Biju et al., 2014; [k]IUCN Red List Category- CR: Critically Endangered, EN: Endangered, NT: Near Threatened, LC: Least Concern, NE: Not Evaluated; [l]Habitat according to published scientific literature; [m]Number of respondents who consumed the species; additionally, five respondents used any frog available as bait for capturing fish and crabs; [n]This information is from the current study

distinctively patterned but is rarely encountered and not well studied; some data are available on habitat associations, but its reproductive biology is unknown (Daltry & Martin, 1997; Kanagavel & Tapley, 2013; Table 2) and there are no published accounts of the species being utilised by people. *Walkerana phrynoderma* is an uncommon, rainforest-dependent, ground-dwelling brown frog that bears a superficial resemblance to several other frogs in the region (Biju et al., 2004a; Kanagavel et al., 2018). It has been the focus of a published scientific study and it is known to occur at mid and high elevations with dense canopy cover (Kanagavel et al., 2018). There are no published accounts of the species being utilised by people.

We conducted questionnaire-based interview surveys from August 2013 to May 2016, where LEK data correspond to species presence, associated habitats and locations while

Table 2. Numbers of responses contributing local ecological knowledge on the three focal anuran species and the reliability of response relative to the scientific literaturea

Scientific name	Vernacular name[b]	Community type[c]	Accurate habitats associated with species occuranced	Unreliable habitats associated with species[d]	Known scientific information
Nasikabatrachus sahyadrensis	Kottraan/Kottaan* (Kadar) = 26 Mannu/Manal tavala* (soil/ sand frog; Malasar, Pulayar) = 8 No name = 15 Kunjunni*+ (Mudhuvan) = 11 Makkan/Makachi tavala+ (non-indigenous) = 2 Koku tavala* (beaked frog; Malasar) = 1 Kuyi aamai* (turtle-like; Malasar) = 1	Kadar = 27 Mudhuvan = 19 Malai Malasar, Malasar & Mannan = 11 Pulayar = 4 Non-indigenous = 2	Within the ground and/or found it during digging = 38 First rains, rainy season, rains accompanied by thunder, lightning or hail = 30 Stream & stream bank = 10 Forests = 3 Plantations & Settlement = 4 Water cavity within firewood = 1 On ground = 1 In water = 1	Forests of Kerala = 1 Don't know anything else = 3	Fossorial, active above the ground only for a few weeks during the monsoon, found close to forest streams with rocky pools (Zachariah et al., 2012)
Melanobatrachus indicus	No name = 14 Velladichi tavala* (close to water; *Kadar*) = 4 Thotri tavala* (*Kadar*) = 2 Peckachi tavala* (*Kadar*) = 1 Karin tavala* (black frog; Kadar) = 1 Mara tavala+ (tree frog; Mudhuvan) = 1	Kadar = 13 Mudhuvan = 7 Malai Malasar, Malasar & Mannan = 2 Pulayar = 1 Non-indigenous = 0	Stream and water body = 12 Forest = 6 Rocks & leaf litter = 4 Trees = 3 Bamboo = 2 On rocks and ground = 2 Dry areas = 2 On green plants = 1	Everywhere = 2	Fallen bark close to streams in semi-evergreen forest (Kanagavel & Tapley, 2013)
Walkerana phrynoderma	No name = 2 Porkan tavala* (warty frog; Kadar) = 1 Vadakan tavala+ (Mannan) = 1 Metru tavala* (Kadar) = 1	Kadar = 3 Mudhuvan = 0 Malai Malasar, Malasar & Mannan = 1 Pulayar = 1 Non-indigenous = 0	Evergreen forest = 5 Ground, leaf litter = 3 Close to stream = 2 Mist covered area = 1	Stream, water body & wetland=44 Ground, leaf litter, crevice, rock, grass, bush, bamboo = 18 Forest = 15 Houses, plantations, fields, well = 12 Everywhere = 8 Rainy season = 4 Don't know anything else = 9	Leaf litter in evergreen forest at 1300-1700m asl, where canopy cover is high (Kanagavel et al., 2018)

[a] To safeguard the species, the names of locations have not been mentioned in this table. Researchers and conservationists can apply to the authors for this information; [b] Only those vernacular names associated with accurate LEK data have been mentioned. The meanings for some of the vernacular names were not known by the respondents. The indigenous community that uses the specific name has been mentioned in italics. The names correspond to two local languages – Tamil* and Malayalam+; [c] The total number of respondents belonging to each community type who could accurately identify the specific focal species; [d] The different habitats have been grouped and the total number of respondents for each group has been mentioned

TEK data correspond to the vernacular names of species and to their utilisation. Interviews were held with forest-dwelling indigenous and non-indigenous communities across the three localities. We selected 16 settlements (Valparai=6, Topslip=5, Munnar=5) for surveying using a targeted sampling strategy and then selected the respondents at each settlement using a convenience sampling strategy (Newing, 2011). We undertook a door-to-door survey where each household was visited and conducted interviews face to face in local languages (Tamil or Malayalam). After introducing ourselves, we interviewed any consenting individual over the age of 18. There were both male and female interviewers; to reduce gender-related respondent bias, female respondents were interviewed only by female interviewers (Newing, 2011).

We used a standard questionnaire composed of open ended and closed questions (see Supplementary Material) for all interviews. Interviews took a maximum of 20 minutes to complete. Firstly, we recorded each respondent's socio-economic characteristics. We then showed each respondent un-labelled photographs of the three focal amphibian species, in the same sequence in all interviews. After each photograph was shown, we asked respondents whether they had seen the species, and if they had, about its vernacular name and the associated habitats and locations in which they had seen it. We then asked respondents whether any frogs were utilised, and if so, which species and the type of utilisation. Since we did not know if frog utilisation in general was a sensitive topic or not, we used both direct and indirect questioning approaches, asking both whether respondents utilised frogs themselves and whether they knew of anyone else who utilised them. Finally, we asked respondents whether and why they visited forests, and then asked two separate questions about whether they were interested in protecting forests and frogs in their area.

If respondents were only able to provide very general information (e.g. species is "found everywhere" or is found "in the forests of Kerala"), we considered such data unreliable and excluded them from further analysis. Since *W. phrynoderma* resembles several other frog species, we cross-checked habitat details reported by respondents with the limited scientific information available for this species (Kanagavel et al., 2018), and only retained information from respondents who reported the specific habitat requirements. We calculated the frequency of respondents who had seen

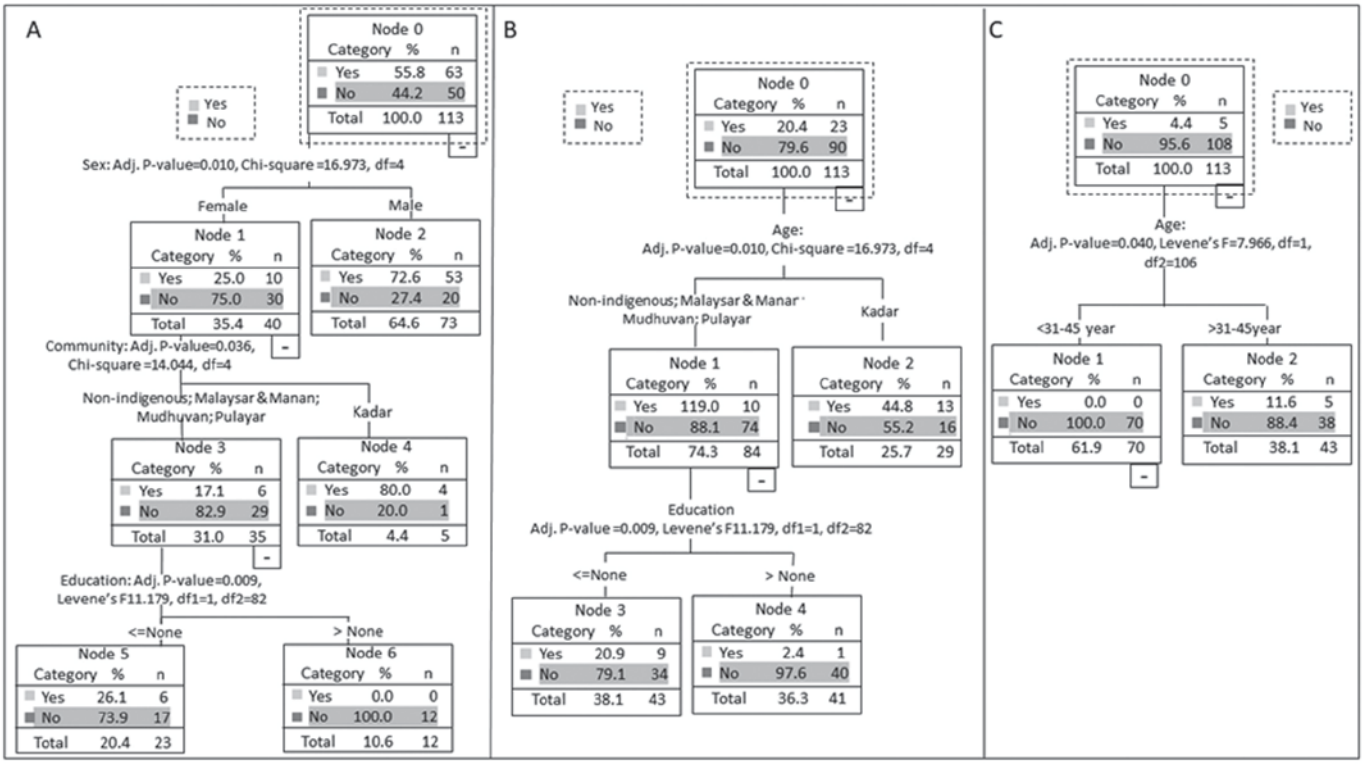

Figure 3. A QUEST decision-tree detailing the socio-economic characteristics that influence whether local individuals have encountered - **A.** Purple frog *N. sahyadrensis*, **B.** Black microhylid frog *M. indicus*, and **C.** Toad-skinned frog *W. phrynoderma*

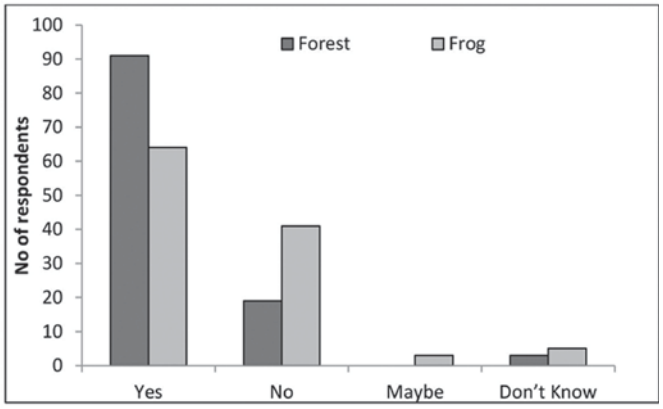

Figure 4. Interest in protecting forests and frogs by local communities in the southern Western Ghats

each focal species in relation to the habitat associations of each species. We assessed reported vernacular names for each species to understand local folk taxonomy of amphibians (cf. Atran et al., 1997).

We explored the relationship between species detection and socio-economic characteristics of respondents using a QUEST decision-tree (Brewer & Rabeni, 2011, Lin & Fan, 2019), to identify appropriate 'experts' for informing future LEK surveys. Decision-tree analyses assist in establishing classifications and QUEST was chosen in this case since it can handle variables with multiple categories. It uses Anova F and Chi-square tests to select variables for splitting and the resultant tree was pruned using the CART algorithm. Then in order to identify appropriate audience groups towards whom future conservation initiatives could be targeted, we calculated the frequency of utilisation of different anuran species by respondents and people they knew. These frequencies were explored using a binomial logistic regression model followed by ad-hoc analysis of deviance (Bond et al., 2017) to show the influence of socio-economic characteristics, experience of seeing focal species, and frequency of forest visits, on amphibian utilisation. Respondent interest in protecting frogs was analysed, also using a binomial logistic regression model, incorporating respondent socio-economic characteristics, experience of seeing focal species and utilising frogs, and interest in protecting forests. The statistical analyses were undertaken using IBM SPSS Statistics 21.0 and R version 3.3.0.

RESULTS

A total of 113 questionnaires were completed with 1 to 15 respondents based at 16 different settlements (Table 3). Of the respondents most were male (65 %, n=73) and most belonged to the Kadar and Mudhuvan indigenous communities (58 %, n=66). Many had no formal education (48 %, n=54) and the majority were involved in non-timber forest product collection, daily-wage labour or farming for their daily livelihood (59 %, n=67). Most visited forests (81 %, n=92) to collect non-timber forest products and fuelwood (76 %, n=86) or for temporary work related to the Forest Department (19 %, n=22).

Local ecological knowledge

Of the three focal amphibian species, *W. phrynoderma* had reportedly been seen by the greatest number of respondents (77.9 %, n=88), followed by *N. sahyadrensis*

Table 3. Description of the socio-economic characteristics and the numbers of questionnaire respondents from local communities in the Anamalai Hills, Western Ghats, India

	Socioeconomic characteristic	Description	No. of respondents by group (n=113)
1	Interview locality	Regions in which respondents were residing	Munnar = 40 Topslip = 19 Valparai = 54
2	Age	Respondent's age in years	18-30 = 35 31-45 = 35 46 & above = 38 Don't know = 5
3	Gender	Male or female	Male = 73 Female = 40
4	Education	Maximum formal education attained	None = 54 Primary Education (1^{st} -5^{th}) = 23 Secondary Education & above = 36
5	Occupation	Main livelihood of the respondent	Labourer/Farmer/NTFP* collection = 67 Other occupations = 10 Forest Department work = 14 Housewife/ Retired/ Not working = 22
6	Community type	Indigenous/non-indigenous community to which the respondent belonged	Kadar = 29 (Topslip = 6, Valparai= 23) Mudhuvan = 37 (Munnar = 24, Valparai = 13) Malai Malasar, Malasar & Mannan = 18 Pulayar = 17 (Munnar = 6, Topslip = 12 Non-indigenous communities = 12 (Munnar = 10, Topslip = 1, Valparai = 1)

*Non-timber forest product

(59.3 %, n=67) and *M. indicus* (22.1 %, n=25). However, following critical verification of *W. phrynoderma* reports with published ecological data, we only considered five reports (4.4 % of respondents) to represent reliably identified records of this species. Conversely, we only excluded four reports of *N. sahyadrensis* and two reports of *M. indicus* on the basis of dubious identification (final reliable species totals: *N. sahyadrensis*, 55.8 %, n=63; *M. indicus*, 20.4 %, n=23). While a greater proportion of respondents from Topslip reported *N. sahyadrensis* (78.9 %, n=15) followed by Valparai (53.7 %, n=29) and Munnar (47.5 %, n=19), *M. indicus* was reported mostly by respondents from Valparai (29.6 %, n=16) followed by Munnar (15.0 %, n=6) and Topslip (5.3 %, n=1). *Walkerana phrynoderma* was mostly reported from Valparai (7.4 %, n=4) followed by Munnar (2.5 %, n=1). Of the three focal species, only *N. sahyadrensis* was identified by respondents belonging to non-indigenous communities (16.7 %, n=2; Table 3). Respondents who were able to identify the focal species frequently provided information on locations where the species occurred in the study area (Table 2). Respondents described *N. sahyadrensis* as being found beneath the ground (n=38) and mostly encountered during the rainy season (n=30), coming out of the ground only to lay eggs and calling by making loud noises beneath the soil. Respondents reported that *M. indicus* was associated with streams and water bodies (n=12) while *W. phrynoderma* was known from evergreen forests (n=5).

Decision tree analysis indicated different demographic predictors associated with increased likelihood of detecting each of the three focal amphibian species. For *N. sahyadrensis*, respondent gender (P<0.01) was the most powerful predictor, with men more likely to have encountered the species than women (Fig. 3A). Within the subset of female respondents, community type (P=0.04) further improved the predictive power of the model, with female Kadar respondents more likely to have encountered the species than female respondents from other communities. Within the subset of female, non-Kadar communities, education (P<0.01) further improved the model, with respondents lacking formal education more likely to have encountered the species. For *M. indicus*, community type (P=0.01) was instead the most powerful predictor, with Kadar respondents again more likely to have encountered the species (Fig. 3B). Within the subset of non-Kadar communities, education (P<0.01) further improved the predictive power of the model, with respondents lacking formal education again more likely to have encountered the species. For *W. phrynoderma*, age was the only significant predictor (P=0.04), with respondents above 45 years of age more likely to have encountered the species (Fig. 3C).

Traditional ecological knowledge

Vernacular names used for *N. sahyadrensis* were either culturally significant or based on morphology or habitat, whereas *M. indicus* mostly did not have a local name, although some respondents referred to it by its habitat or colour (Table 2). Vernacular names used for *W. phrynoderma* were based on its morphology (Table 2), and respondents used the same vernacular name for other common species of the families Ranixalidae and Bufonidae ('chori/pori thavala' n=20), leading to frequent misidentification with such species and inaccurate ecological association with water bodies, wetlands, and habitats close to human settlements.

Thirty-eight respondents (33.6 %) reported that they utilised frogs themselves, mostly *N. sahyadrensis* (n=27). A larger proportion of respondents from Valparai utilised frogs (38.9 %, n=21) followed by Munnar (30.0 %, n=12) and Topslip (26.3 %, n=5). The focal species were utilised only by the Kadar indigenous communities (Table 1). Other non-focal anurans were also mostly utilised by the Kadars and to a small extent by Mudhuvans. Non-indigenous communities depended on common, widely distributed species (Table 1). Frogs were used for general consumption and medicine (n=28), as amulets to reduce fear among children (n=12), and as bait to catch freshwater fish and crabs (n=8) (Table 1). Only indigenous communities utilised amphibians for traditional medicine while non-indigenous communities used them for general consumption and as bait (Table 1). Thirty-two respondents (28.3 %) stated that they knew of other individuals or communities that utilised frogs, including *N. sahyadrensis*, *Hoplobatrachus tigerinus* and *Indosylvirana* sp., which were eaten and used as medicine (n=23), as bait for fishing (n=6), or for other reasons (n=3, perceived export of frog legs). Analysis of deviance performed on the logistic regression model revealed that community type (df = 5, P<0.001) and gender (df = 1, P<0.001) were the most statistically significant factors predicting utilisation of

Table 4. The influence of several explanatory variables on the utilisation of frogs (dependent variable). Analysis of deviance performed on a logistic regression model fitted to explain the effect of explanatory variables listed in the table. The result indicates significant change in deviance (P<0.05) with the addition of the variables 'Gender' and 'Community' type to the model.

	df	Deviance	Residual df	Residual deviance	*P*(>Chi)
Null			96	127.95	
Interview localitya	2	2.57	94	125.38	0.276
Age	2	3.08	92	122.31	0.215
Gender	1	11.45	89	106.08	<0.001
Education	2	4.78	90	117.53	0.092
Community	5	33.58	84	72.49	<0.001
N. sahyadrensis sighting	1	2.47	83	70.02	0.116
M. indicus sighting	1	0.02	82	70.00	0.897
W. phrynoderma sighting	1	1.12	81	68.89	0.291
Forest visit	1	0.97	80	67.91	0.324

Table 5. The influence of several explanatory variables on interest of local communities in protecting frogs (dependent variable). Analysis of deviance performed on a logistic regression model fitted to explain the effect of explanatory variables listed in the table. The result indicates significant change in deviance (P < 0.05) with the addition of the variables 'Interview locality' and interest in 'Protecting forests' to the model.

	df	Deviance	Residual df	Residual deviance	*P*(>Chi)
Null			96	128.97	
Interview localitya	2	8.51	94	120.46	0.014
Age	2	1.16	92	119.30	0.560
Gender	1	3.79	91	115.51	0.051
Education	2	2.20	89	113.31	0.333
Community	5	10.42	84	102.89	0.064
N. sahyadrensis sighting	1	2.79	83	100.10	0.095
M. indicus sighting	1	0.01	82	100.09	0.915
W. phrynoderma sighting	1	0.93	81	99.16	0.335
Forest visit	1	0.12	80	99.04	0.731
Use of frogs	1	2.75	79	96.29	0.098
Protecting forests[e]	1	41.92	78	54.38	<0.001

frogs (Table 4), with utilisation more common in the Kadar community and by men.

Local support for conserving forests and frogs

Respondents were more interested in protecting forests than frogs (Fig. 4). Respondent interest in protecting forests was the most statistically significant factor predicting interest in protecting frogs (df=1, P<0.001) followed by interview locality (Table 5). Respondent interest in protecting frogs was nested within their interest in protecting forests, as all respondents who wanted to protect frogs also wanted to protect forests and not vice versa, and interest in protecting frogs was higher at Topslip (72.2 %) and Valparai (71.4 %) than at Munnar (42.1 %).

DISCUSSION

Local ecological knowledge

LEK has not often been gathered to provide researchers with information about herpetofauna. Community-based surveys have rarely been used to assess the conservation status or to obtain other conservation-relevant data for amphibians, and so far, have only been applied to very large-bodied "charismatic" taxa such as the giant salamander (*Andrias davidianus*) (Pan et al., 2015). Indeed, researchers have sometimes previously ignored LEK of amphibians, as in the case of the enigmatic *N. sahyadrensis*, which was well known to local communities long before its formal scientific description (Aggarwal, 2004). Our study demonstrates that despite this lack of past attention, LEK can be a suitable tool for collecting conservation-relevant information on focal amphibian species, in this case especially for *N. sahyadrensis*. Accurate collection of LEK has been shown in previous studies to be greatly improved if the focal species is morphologically distinct and easily identifiable even to non-trained observers, is non-cryptic, and has an exclusive vernacular name (Anadón et al., 2009; Pillay et al., 2011). Of the three focal species included in our study, *N. sahyadrensis* and *M. indicus* are both morphologically distinct, and each indigenous community had an exclusive vernacular name for *N. sahyadrensis*, which could account for why it was locally the best known of the three focal species. *Nasikabatrachus sahyadrensis* was also the only focal species that was known among non-indigenous communities and this reveals its potential as an effective conservation flagship among local communities (Kanagavel et al., 2017a) who dwell close to forests. Conversely, *W. phrynoderma* resembles many other frogs, and had no consistently used vernacular name, consequently the majority of LEK that we collected for *W. phrynoderma* was considered to be unreliable. We conclude that LEK-based surveys may only provide limited data on morphologically indistinct amphibian species. Accuracy of identification may have been improved if we had used control images of locally occurring amphibian species that are morphologically similar to *W. phrynoderma*, and we encourage further investigation of the ability of local respondents to differentiate between similar species using this approach in future LEK-based amphibian surveys.

Our results help to identify local expert groups who possess greater levels of knowledge about different focal amphibian species. These groups could be preferentially targeted in future studies that aim to collect additional amphibian-related data. In our study, men provided LEK that corresponded more closely with existing knowledge of *N. sahyadrensis* than women, possibly because men are more involved with hunting activities in the Western Ghats (Kanagavel et al., 2016), and likely visit forests more frequently. The Kadar communities had better knowledge of both *N. sahyadrensis* and *M. indicus*, possibly because they have greater cultural

associations with *N. sahyadrensis*. Their livelihoods are more forest-dependent and both the species occur in their traditional lands, increasing the possibility of encountering them. The positive relationship between respondent age and level of LEK about *W. phrynoderma* is consistent with the well-known phenomenon seen in many LEK studies where older respondents are more knowledgeable of local environmental conditions (e.g., Papworth et al., 2009; Turvey et al., 2010). The demographic predictors varied for the three amphibians which could be explained by the different local distribution ranges of the species that may not be present within the traditional lands occupied by all the communities. Moreover, the communities also differ in their extent of dependence on forests and the frequency of their visits to surrounding forests. This means that 'expert' groups would vary based on the species concerned and more relevant data could be collected across multiple species by focusing on major predictors, e.g. males, the Kadar community, respondents above 45 years of age etc..

Traditional ecological knowledge

Folk nomenclatures are based on morphology, use of the species, social constructs, economic importance, and ecology (Newmaster et al., 2007; Ulicsni et al., 2013; Berlin, 2014). For large plants and animals, vernacular names are mostly exclusive for a species, since the majority of species within these groups are distinctly identifiable (Atran, 1998; Souza & Begossi, 2007; Ulicsni et al., 2013). However, this is not the case for small vertebrates, many of which appear superficially similar to untrained observers. Hence they are typically grouped together under a single name, making indigenous taxonomy less reliable for species-specific identification (Forth, 2009; Beaudreau et al., 2011). In our study, *N. sahyadrensis* is well recognised among numerous indigenous and non-indigenous communities and has distinct vernacular names that are based on culturally significant attributes and direct awareness of the species by each indigenous community. This distinctive and charismatic amphibian may therefore represent a potential flagship species for building local community interest in amphibians and their conservation (Bowen-Jones & Entwistle, 2002).

Melanobatrachus indicus is distinct and associated with specific vernacular names based on body colour and habitat. However, it is relevant only for the Kadar community who themselves associated with it little, resulting in reduced ecological knowledge of the species. Although *W. phrynoderma* was found to have only a general vernacular name based on body morphology and colour which is shared with many other anuran species, this frog grouping was known to local communities as these species are incorrectly perceived to be pests of cardamom (*Elattaria cardamomum*), a major high-value crop in the region (Kanagavel & Parvathy, 2014; Kanagavel et al., 2017b). The differences between the local communities in how they refer to the three focal species highlight the role of cultural and utilitarian values in shaping TEK as well as LEK (Atran, 1998; Beaudreau et al., 2011).

TEK of amphibian utilisation is better documented than LEK detailing amphibian ecology, since amphibians are utilised by many cultures world-wide and for many different reasons (Adeola, 1992; Alves & Souto, 2011). Our study highlights the traditional and subsistence use of frogs by indigenous communities in the Western Ghats. It also reveals the cultural association of indigenous communities with frogs from their intricate utilisation in traditional medicine. This use is absent in non-indigenous communities who are recent settlers from other parts of the country. Frog utilisation did not appear to be a sensitive issue in the communities investigated in our study, as respondents appeared happy to discuss this subject openly. The rationale for the use of frogs among indigenous communities in this study, especially in treating skin burns, was similar to that reported for other communities from North India (Negi & Palyal, 2007). *Nasikabatrachus sahyadrensis* was the most notable species utilised by indigenous communities in the region, and this should be taken into consideration while formulating conservation plans for this species. Our results identify distinct user groups and rationale for utilisation of this endangered frog, providing an important baseline for further research, stakeholder discussions (Kanagavel et al., 2013), and development of culturally appropriate conservation interventions. We recommend that more research should be focused on the use of amphibians by local communities, to identify more species that may be important to communities and for which useful knowledge may therefore be collected.

Local support for conserving forests and frogs

Although there has been an increase in scientific research on Indian amphibians, there is very little awareness about the status of amphibians among regional forest departments (Kanagavel et al., 2017c) and local communities; two groups of stakeholders that are integral to successful amphibian conservation. Interest in amphibian protection among local communities has, until now, not been well-understood. Our results suggest that for an amphibian-based community conservation initiative to be effective, it must be linked to protection of forests, since a significant proportion of community livelihoods depend directly on the continued presence of forests, and local respondents were only interested in frog conservation within the wider concept of forest protection. Such programmes could be initiated at Topslip and Valparai as determined by our study since the interest of respondents in protecting frogs was greater at these localities. Respondents at Munnar showed a reduced interest in frog conservation, due to the widespread misperception of frogs as pests of cardamom (Kanagavel et al., 2017b). Clearly an educational campaign to improve the profile of frogs among local communities is required in Munnar (Kanagavel et al., 2017a).

Our study demonstrates that the knowledge of local communities can potentially be used to gather reliable information on the ecology and distribution of amphibian species that are morphologically distinctive, have a specific local name, and are associated with specific cultural and/or utilitarian values. We also highlight patterns of folk utilisation of frogs in the southern Western Ghats and provide new insights into respondent typology that can assist in future LEK-related amphibian research.

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