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REPORT

Do frogs really eat cardamom? Understanding the myth of crop damage by amphibians in the Western Ghats, India

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Abstract In the Western Ghats of India, amphibians are culled at cardamom plantations since they are perceived to consume cardamom. To better understand the relationship between amphibians and cardamom, a study was undertaken at these plantations, which harbor numerous threatened and range-restricted amphibians. We undertook questionnaire surveys with 298 respondents at 148 plantations across southern India. Time-activity budget and diet analysis surveys were undertaken to determine whether amphibians really consumed cardamom. The conception that amphibians eat cardamom was found to be widespread especially among small-sized plantations, leading to negative perceptions and a lack of interest in amphibian conservation. The plantation community perceives a substantial economic loss due to amphibians, even though this is non-existent as revealed by our field surveys. These perceptions would lead to a continued intolerance of amphibian presence in plantations. A suitable outreach initiative re-affirming facts and spreading awareness on the positive role of amphibians would need to be conducted to negate this age-old myth.

Keywords Agroforestry · Cardamom plantations · Diet analysis · Frogs · Local perception · Pesticide use

INTRODUCTION

Crop depredation by wildlife is a major type of conflict that results in the loss of basic food supplies for local communities (Karanth and Madhusudan 2002; Woodroffe et al. 2005; Inskip and Zimmermann 2009). It also negatively influences the economic and social well-being of key stakeholders that in turn affects their co-existence with wildlife (Madden 2004). To negate such losses, humans often respond by killing damage-causing animals (Treves and Naughton-Treves 2005). Lethal control of animals perceived as pests, especially large mammals and carnivores, has led to the global extinction of numerous species (e.g., Thylacine, Carolina parakeet, Guadelupe caracara) as well as local extirpations, range collapses, and behavioral changes among others (Distefano 2005; Woodroffe et al. 2005; Gubbi et al. 2014). In some cases, the perceived damage-causing species that are persecuted are actually misunderstood and are not the real causative agents. For example, in Nigeria, giant pangolins (*Smutsia gigantea*) are killed as they are perceived to raid crops even though they are actually insectivorous and feed on invertebrate pests (Ikpa et al. 2009). Such myths among local communities have contributed to the negative profile of wild fauna like in the case of the Balkan lynx (*Lynx lynx martinoi*) and the aye aye (*Daubentonia madagascariensis*). The lynx is thought to be a "blood thirsty animal" that is potentially dangerous to communities even though only a few respondents had seen it (Lescureux et al. 2011). The aye aye is considered a harbinger of death among communities in Madagascar that leads to either the abandonment of entire villages when the animal enters or killing them when encountered (Simons and Meyers 2001).

This could also be the case with anuran amphibians occurring within cardamom plantations in the Western Ghats of India (Kanagavel and Parvathy 2014). Cardamom is the third most expensive spice in the world and possesses a high global demand because of its flavoring and therapeutic properties (Butt et al. 2013). Apart from India, cardamom is grown as a cash crop in parts of Latin

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America, South East Asia, and Sri Lanka (Nair and Kutty 2004). Since at least the 1880s, there has been a myth of frogs and snakes consuming cardamom in the southern part of the Indian subcontinent due to which the cardamom pods are harvested before they ripen completely (Owen 1883).

Preliminary interviews with local communities in the southern region of the Western Ghats revealed that post-metamorphic anuran amphibians were collected and culled before the cardamom harvest season (Kanagavel and Parvathy 2014). This could affect the populations of several highly threatened and range-restricted amphibians such as the Anamalai gliding frog *Rhacophorus pseudomalabaricus* (Critically Endangered) and toad-skinned frog *Indirana phrynoderma* (Critically Endangered; Biju et al. 2004a, b; Kanagavel and Parvathy 2014). Amphibians incidentally are the most threatened vertebrate group in the world due to rapid declines in their population from the synergistic effects of habitat loss, fragmentation, climate change, and diseases like chytridiomycosis (Sodhi et al. 2008; Hoffmann et al. 2010). This is the case in the Western Ghats too, where unfortunately they receive little conservation attention (Robin and Nandini 2012). The myth also disengages the positive role of amphibians as "friends of the farmer" within the agroforestry community as they may provide regulating services in the form of invertebrate pest control and reduced disease transmission (Hocking and Babbitt 2014; Teng et al. 2016).

This study therefore aims to understand in detail the myth of cardamom consumption by frogs to inform their conservation outside the protected area network in the Western Ghats-Sri Lanka Biodiversity Hotspot through interviews with the agroforestry community. The study also investigates whether frogs really consume cardamom by directly observing frogs within cardamom bushes, as well as through dietary analyses to determine what they consumed. Of the 7510 described anuran amphibians, only one species, i.e., *Xenohyla truncate* from Brazil is known to actively consume fruits apart from opportunistic herbivory by other species (Silva and Britto-Pereira 2006; AmphibiaWeb 2016). Of the species that are perceived to consume cardamom, the diet of *Indirana* spp. is not known, whereas *Rhacophorus* and *Duttaphrynus* (Bufonidae) species primarily consume insects followed by arachnids, gastropods, and diplopods (Solé et al. 2005, Santana and Juncá 2007, Rahman et al. 2013, Kanagavel and Parvathy 2014). However, plant material (leaves, seeds) has been found in a few individuals of *Bufo granulosus* (Bufonidae) and the rationale for such consumption is not well understood (Santana and Juncá 2007).

MATERIALS AND METHODS

Study area

The study (interview survey) was conducted in the Western Ghats region of the southern Indian states of Karnataka, Kerala and Tamil Nadu, where small cardamom (*Elettaria cardamomum*) is extensively grown as a cash crop. In this region, cardamom is grown in tropical wet or moist forests within an elevation range of 600–1500 m asl under considerable canopy cover as it is a shade-tolerant species. The annual mean rainfall at these plantations fluctuates from 1670 to 3000 mm, while the annual mean temperature is around 26 °C (Murugan et al. 2009). The state of Kerala is the highest producer of cardamom in India (11 350 t from 39 660 ha), while the neighboring Karnataka (1800 t from 25 050 ha) and Tamil Nadu (850 t from 5160 ha) also contribute a sizeable produce (Spices Board India 2016a).

The field surveys to determine whether frogs consumed cardamom was conducted at two privately owned cardamom plantations located close to the town of Munnar in the Idukki district of Kerala. The two plantations cumulatively cover 0.53 km^2 and have retained some evergreen canopy trees to serve as shade for their cardamom plants. Numerous small streams run across the plantations, which harbor a wide variety of amphibians. The plantations are frequently visited by daily wage workers (who believe in the 'myth') and help maintain it by planting, de-weeding, spraying pesticides, and harvesting cardamom.

Questionnaire Survey

Questionnaire surveys were undertaken from July 2014 to February 2015 with owners, administration staff, and workers of cardamom plantations across the three states. A total of 298 questionnaires were completed with respondents who belonged to 148 plantations (Tables 1, 2). In Karnataka, two (Kodagu, Chikmagalur) of the four districts where cardamom is grown were surveyed, while in Tamil Nadu both districts (Theni, Nilgiris) where the crop is grown were surveyed (Fig. 1). However, in Kerala only one (Idukki) of the four districts was chosen (Fig. 1). These districts and the specific towns within them were chosen using a convenience sampling strategy based on their ease of access, and where social conflicts were absent. The individual plantations were selected through a targeted sampling strategy (Newing 2010) based on the details available from the regional offices of the Spices Board of India (2016b)—a governmental institution involved in the development and promotion of spices grown in the country. The total number of respondents surveyed from each plantation depended on the number of individuals present

Table 1 Characteristics of cardamom plantations surveyed in South India and myth of cardamom loss due to consumption by frogs

	Plantation characteristics	No of plantations in %/range, mean ± SE (n = 148)
1	State in south India (% of plantations)	Karnataka = 48.5%, Kerala = 37.8%, Tamil Nadu = 13.5%
2	Age of the plantation (year)	Young (1–20 years) = 35.4%, moderate (21–50 years) = 36.1%, old (51–100 years) = 28.5%
3	Plantation size (acre)	Small (0.01–5 acre) = 70.3%, medium (6–25 acre) = 20.9%, large (26–750 acre) = 8.8%
4	Ownership type (% of plantations)	Private = 98.6%, Corporate = 1.4%
5	Average harvest per acre per year (kg)	1–25 000, 361.2 ± 169.1
6	Monthly pesticide expenditure (INR)	0–240 000; 16 309.98 ± 2548.17
7	Monthly fertilizer expenditure (INR)	0–1 200 000; 47 379.24 ± 16 340.06
8	Perception of cardamom consumption by frogs	Yes = 66.2%, No = 33.8%
9	Perceived cardamom consumption by frogs per acre per year (kg)	0–6000, 84.2 ± 60.2
10	Prevention methods used to reduce cardamom consumption by frogs	Yes = 6.8%, No = 93.2%

Table 2 Characteristics and responses to the questionnaire by the respondents working at cardamom plantations in South India

	Audience characteristics and responses	No of respondents in % (n = 298)
1	State in south India	Kerala = 36.6%, Karnataka = 37.6%, Tamil Nadu = 25.8%
2	Age (year)	18–40 = 28.9%, 41–60 = 55.7%, >60 = 15.4%
3	Gender	Male = 61.1%, Female = 38.9%
4	Income (INR)	1–7500 = 69.8%, 7501–15 000 = 19.4%, >15 000 = 10.8%
5	Education	Primary = 35.9%, High School = 37.2%, Graduate = 12.1%, No formal education = 14.8%
6	Job pursued at the plantation	Worker = 41.3%, Worker who also owned plantation = 24.8%, Owner = 21.8%, Administration = 12.1%
7	What do you think about frogs?[a]	Positive = 16.4%, Negative = 37.9%, Mixed = 5.4%, Neutral = 40.3%
8	Do you think frogs need to be protected?	Yes = 39.6%, No = 29.9%. Do not harm frogs = 21.5%, Do not know = 9.1%
9	Do frogs consume cardamom?	Yes = 59.5%, No = 40.5%
10	Have you seen frogs consuming cardamom?	Yes = 36.6%, No = 63.4%
11	Have you heard from anyone that frogs eat cardamom?	Yes = 63.8%, No = 36.2%
12	How much cardamom do you think the frogs eat per acre?	Estimate provided in kg = 36.2% (0–6000 kg, 147.9 ± 71.8 kg); Estimate provided in a qualitative scale = 8.7% (Minimal = 63.4%, Moderate = 7.7%, High = 26.9%); Do not know = 55.1%
13	Which are the frogs that consume cardamom?*	*Duttaphrynus* sp. = 25.2%, *Clinotarsus curtipes* = 10.7%, *Rhacophorus* sp. = 8.1%, *Raorchestes* sp. = 5.0%, *Nyctibatrachus* sp. = 2.0%, Miscellaneous = 4.0%
14	Do you do anything to prevent it?	Yes = 5.7%, No = 94.3%
15	What do you do?	Timely harvest = 1.0%, Spray pesticide/medicine (endosulfan, 'timit') = 3.4%, kill frogs = 1.3%
16	How often do you do?	Monthly = 3.3%, Weekly = 0.4%, Yearly = 0.4%, whenever frogs are sighted/frog population increases = 1.6%
17	How many frogs do you collect?	Two responses, One stated that he collected 10 frogs while another stated that spraying pesticides killed all the frogs

[a] *Positive* frogs are good, eat insects, good for fields, *Negative* pest, eat cardamom, cause disgust, diseases, and allergies, reduces farm yield, snake population increases from their presence, scared of them, *Mixed* good and bad effects, *Neutral* living being, not harmful to us, no opinion

* % are calculated individually for each species since numerous respondents stated more than one species. In-detail descriptions of the amphibian species are provided in Appendix S2

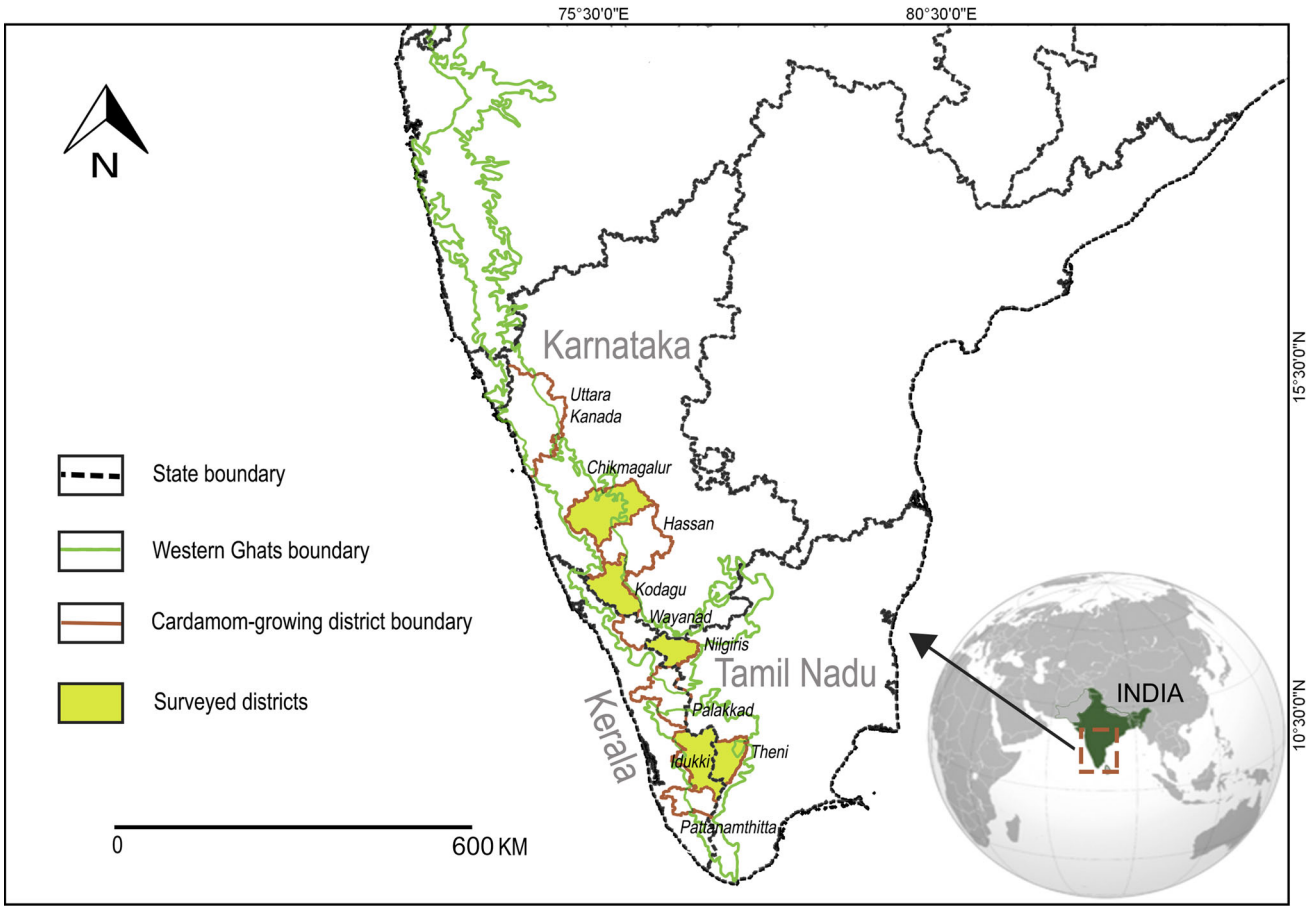

Fig. 1 Map showing the surveyed areas among the cardamom-growing districts in the Western Ghats region of south India

at the plantation when the interviewers visited. A minimum of one respondent up to a maximum of five from each plantation were interviewed. On receiving a verbal consent, the questionnaire (Appendix S1) was conducted face to face with the respondent, which took 15–35 min to complete.

The socio-economic characteristics of the respondents and details of the plantations were firstly requested, including the amount spent per acre on pesticides and fertilizers, followed by the respondents' general perception of frogs and whether frogs needed protection. The respondents were then asked in-depth questions to understand the myth of cardamom consumption by frogs. Whether they had seen frogs consuming cardamom or had heard of it from someone else was queried to understand whether this perception was backed by their own observations. The respondents were then questioned regarding the amount of cardamom they perceived was consumed including a description of the frogs and their associated habitats. Lastly, the respondents were requested to detail the preventive measures they undertook to prevent frogs from consuming cardamom.

Information on the plantation's characteristics was primarily considered from an administrator or owner. In cases where such individuals were not interviewed, the details from the working population were used. The means and frequencies of the groups into which some of the characteristics were classified were calculated using IBM SPSS Statistics 21.0 for Windows (Table 1). The remaining data were summarized to reflect the perceptions at a plantation scale. In case any respondent from the plantation believed in the 'myth,' it was extrapolated to the entire plantation. The perceived extent of cardamom consumption by frogs and the management ensued was similarly analyzed at a plantation scale. A binary logistic regression model was used to analyze whether the characteristics of the plantations influenced the presence of the myth.

The frequencies of the different groups into which the characteristics of the respondents and their responses to the questions were classified into were computed (Table 2). Mann–Whitney *U* tests were used to explore the different perceptions towards the myth within the varying general perception of frogs and their protection. A mixed-effects logistic regression with plantation size as a random effect

was used in R 3.3.2 to analyze the characteristics of the respondents that influenced the myth (Table 3, R Core Team 2016). This model was used to control for the effect that local respondents in the same plantation or area would have on one another and balance any additional weight plantation size would have on the analysis. The binary response variable used in the model was whether respondents believed or did not believe in the myth that frogs consume cardamom. Spearman's rank correlation was undertaken to determine if there were any correlations between the socio-economic characteristics.

Field survey

When *D. melanostictus* or *R. pseudomalabaricus*, species associated with cardamom consumption (Kanagavel and Parvathy 2014), were encountered within a proximity of 2 m to a cardamom plant, the individual was observed to determine whether it consumed cardamom or not. Towards this, its behavior was recorded as a time-activity budget, i.e., the percentage of time spent to perform its different activities. The frog's activities (resting, non-locomotory movement, locomotory movement, feeding, and vocalizing) along with its duration were recorded over half-hour periods using the focal animal sampling technique (Altmann 1974, Smart et al. 2014). These activities were determined from the results of pilot surveys during two survey nights, which were used to develop the list of different activities displayed. In case the individual moved away from sight, the observations were recorded only up to the corresponding time period. Frogs were not marked specifically for identification and those observed on different days were treated as different individuals. We used red light to observe frogs as it causes minimal disturbance to their activity (Dayananda and Wickramsinghe 2013) during the cardamom harvest season (September–November) in 2014 between 18:00 and 22:30.

To specifically analyze the diet of the two species, stomach flushing was undertaken post 20:30 h in 32 different individuals (Table 4) during June 2016 as per the technique detailed by Solé et al. (2005). In contrast to their technique which was undertaken in a laboratory with captured amphibians, we conducted it directly in the field and released the individuals immediately after stomach flushing. The contents were later identified in a laboratory under a stereo microscope (Olympus SZ61, 2.0×–270×) and photographed.

RESULTS

Questionnaire survey

Although the perception of cardamom consumption by anuran amphibians was present at most of the plantations (66.2%, Table 1), none of the plantation characteristics influenced the presence of this myth. Very few plantations (6.8%) used measures to eradicate anurans to reduce the perceived consumption of cardamom because of the myth. The mean perceived loss of cardamom due to this myth (84.2 ± 60.2 kg per acre) was considerable in comparison to the perceived annual yield (361.2 ± 169.1 kg per acre; Table 1).

Most of the respondents (59.5%) believed that frogs consumed cardamom and co-incidentally most respondents either had a neutral (40.3%) or negative (37.9%) perception towards frogs (Table 2). Most respondents also believed that frogs should be protected (39.6%) or not harmed (21.5%), but a sizeable proportion also felt that they should not be protected (29.9%). The perception towards the myth was found to vary with the perceptions towards frogs in general (Mann–Whitney U test, $U = 9114.0$, df = 298, $P = 0.03$) and their protection (Mann–Whitney U test, $U = 9159.0$, df = 298, $P = 0.04$). Most of the respondents

Table 3 Parameters for the mixed-effects logistic regression model (AIC = 350.1, log likelihood = −167.1, number of fixed effects = 6) used to predict the characteristics of local communities ($n = 298$) that influenced the myth that amphibians consumed cardamom

Fixed effects	Estimate	SE	Z	*P*
Intercept	2.32	0.98	2.36	0.02
State in south India	−0.85	0.19	−4.42	<0.01
Age	0.18	0.20	0.87	0.39
Gender	−0.29	0.32	−0.92	0.36
Income	0.02	0.24	0.09	0.93
Education	0.21	0.13	1.61	0.11
Occupation	−0.36	0.15	−2.43	0.02

Plantation size is the random effect variable (variance = 0.09, SD = 0.30) used in the model; binary response variable is whether respondents believe or do not believe in the myth that frogs consume cardamom

who believed in the myth had a negative opinion (60.2%) than a positive one (6.3%) towards frogs (neutral = 26.7%, mixed = 6.8%). A larger extent of respondents who believed in the myth did not think frogs needed to be protected (38.1%) in comparison to those who thought they needed to be protected (31.8%, do not harm it = 20.5%, don't know = 9.6%).

Respondent characteristics, namely the state they belonged to and occupation at the plantation, influenced belief in the myth (Table 3). The myth was not as widely popular among the respondents from Tamil Nadu (31.2%) as in the case of those from Karnataka (69.1%) and Kerala (69.7%). The myth was also more prevalent among workers cum owners (72.6%) and workers (59.8%) than among the administrators (52.8%) and owners (47.7%). There was a considerable reduction in the prevalence of this myth as the plantation size (random effect variable) increased (small = 68.3%, moderate = 48.4%, large = 54.2%). There were significant correlations between the different socio-economic characteristics (Table 5).

Most respondents who believed the myth stated that frogs ate cardamom by breaking open the ripe capsule with their mouth and discarded it after consuming the seeds within. Frogs were believed to get attracted to the aroma and sweet taste of the ripe cardamom. When ripe, the respondents stated that cardamom capsules needed little pressure to break open. While most respondents either stated that frogs ate only the seeds, sucked on the seed coat, or 'spat out' the capsule, some also stated that they swallowed the entire capsule. A few also mentioned that frogs made a hole in the capsule with their pointed snout and then sucked out the seeds. One respondent stated that frogs liked to break open the capsules for 'sport' since they did not consume it sometimes. The respondents who did not believe in the myth stated that it was rodents (rats, squirrels) that ate cardamom, but frogs took the blame as they were seen inside cardamom bushes. They stated that the myth was a general misconception and that frogs came close to cardamom pods only to eat the insects attracted to the ripe cardamom and flowers.

While fewer respondents stated that they had seen frogs consuming cardamom (36.2%), most stated that they had heard of this perception from someone else (63.8%). When asked to describe what they had seen, respondents mostly stated that they had seen frogs near broken cardamom capsules and assumed that the frogs had consumed the seeds. Some stated that since they consumed cardamom at night, they only saw the broken capsules the following morning, along with frogs in the vicinity. One respondent stated that she had seen frogs close to broken capsules, which would run away when approached. Some mentioned that frogs had teeth similar to humans and they bit open the capsules unlike rodents (rats, squirrels), which they stated made holes. Two respondents also stated that they had seen seeds inside a frog's gut but had not observed the frog eating it. Respondents who had heard of the myth from other people described that the usual response from individuals working in a cardamom plantation when they saw an open capsule of cardamom was '*Tavala adichu*' (Malayalam), '*Tavala adichirichi*' (Tamil), or '*Kappe hodithu*' (Kannada). While this literally means that a frog has 'hit' the crop, it means that frogs have eaten the cardamom.

The frogs that were most frequently associated with cardamom consumption belonged to the genera *Duttaphrynus, Clinotarsus*, and *Rhacophorus* (Table 2). While most of the anuran amphibians associated with the myth were large-sized, respondents also referred to small-sized species ($\approx$2 cm; Appendix S2). While most of these species were common, there were five that are of conservation concern (Appendix S2).

Respondents perceived a considerable loss to their annual cardamom yield due to the consumption by anuran amphibians (147.9 $\pm$ 71.8 kg; Table 2). However, very few

Table 4 Food composition and frequency of prey items consumed by amphibians accused of consuming cardamom in plantations of Kerala

	Food item	*Duttaphrynus melanostictus* (n = 18)	*Rhacophorus pseudomalabaricus* (n = 14)
1	Hymenoptera (wasps and ants)	104	2
2	Coleoptera (beetles)	16	1
3	Lepidoptera (moths and butterflies)	3	0
4	Araneida (spiders)	4	0
5	Blattodea (termites)	10	0
6	Orthoptera (crickets)	0	1
7	Stone	Yes	No
8	Leaf and algae	Yes	No
	Weight (g)[a]	0.17 $\pm$ 0.03	0.08 $\pm$ 0.02

[a] Average weight $\pm$ SE

Table 5 Spearman's rank correlation between the socio-economic characteristics of the plantation community ($P < 0.05$*, $P < 0.01$**, $n = 298$)

Socio-economic characteristic	State	Age	Gender	Income	Education	Occupation	Plantation size
State	1						
Age	−0.72	1					
Gender	0.05	−0.09	1				
Income	−0.34**	0.1	−0.24**	1			
Education	0.02	−0.08	0.03	0.06	1		
Occupation	−0.17**	0.15*	−0.45**	0.35**	0.15*	1	
Plantation size	0.02	0.01	0.08	0.20**	0.13*	−0.08	1

(5.7%) stated that they mitigated this, which was largely undertaken on a monthly basis (3.3%) by spraying chemicals (3.4%) rather than killing frogs (1.3%; Table 2).

Field survey

Over a period of 12 days, a total of 20.07 h were spent observing the activity of 20 individuals belonging to *D. melanostictus* ($n = 17$; 16.77 h) and *R. pseudomalabaricus* ($n = 3$; 3.30 h) during the cardamom harvest season when the cardamom fruits were ripe. Both the species were observed moving within and around cardamom plants, where they were seen perched on stalks and leaves and resting and foraging around the cardamom pods. However, neither of the species were observed feeding on the cardamom. Collectively, the frogs were mostly observed resting for 99.4% (19.95 h) of the total time. The total time spent performing the other activities was 0.12 h. The maximum was spent in non-locomotory movement (0.07 h), followed by locomotory movement (0.04 h), feeding (0.01 h), and vocalizing (0.01 h). While foraging was not observed in *R. pseudomalabaricus*, *D. melanostictus* were observed feeding on arthropods. The dietary analysis of the stomach contents collected after flushing 32 individuals did not reveal any cardamom, whole or partial (Fig. 2; Table 4). Arthropods (Hymenoptera and Coleoptera) were the most commonly consumed prey among both species, while stones, dry portions of leaves, and algae were found in the contents collected from *D. melanostictus*.

DISCUSSION

Our results reveal the widespread occurrence of the myth of cardamom consumption by anuran amphibians in southern India, which has led to a negative profile for frogs in the region and consequential lack of interest towards their conservation. Amphibians are continued to be blamed as being cardamom pests, which is the exact opposite of their actual role in these agroforestry systems, as potential regulators of invertebrate pests and disease transmission (Hocking and Babbitt 2014). In 1987, India had banned the large-scale export of frog legs from the country to counter the rising pest populations in rice fields and the consequential ecological and economic effects of increased pesticide use (Altherr et al. 2011). The presence of 'myths' towards anuran amphibians is known to have resulted in an increase of negative attitudes and persecution among respondents in Portugal (Ceríaco 2012). Most respondents in our study had actually heard of the myth from other individuals rather than having seen it for themselves. A few respondents had also acknowledged that rodents and not frogs consumed cardamom and that it was a myth passed on across generations of the agroforestry community. Amphibians occur within these plantations due to the habitat provided by the cardamom plants and the available arthropod prey base. The presence of dry leaf portions, algal matter, and stones in the stomach contents of *D. melanostictus* is related to the accidental ingestion of such material by this terrestrial species while capturing prey (Balint et al. 2008).

Frogs in the southern Western Ghats incriminate themselves as potential crop pests merely through their spatial proximity to cardamom plants and broken cardamom pods. Local communities have constructed the myth because they have not necessarily observed the true agents of cardamom consumption or the natural processes that cause pods to split. The sharing of observations of sighting frogs next to broken pods by local individuals could have further developed the myth and increased its spread through rumors. The reduced aesthetic appeal and negative perception towards frogs and toads (Batt 2009; Kanagavel et al. 2014) could have further eased the facilitation of this myth.

The existence of this myth has proved to be detrimental for anuran amphibians occurring in the cardamom plantations. The agroforestry community at large perceives a substantial economic loss due to anuran amphibians even though it is non-existent. This perceived economic loss would lead to continued intolerance of amphibian presence

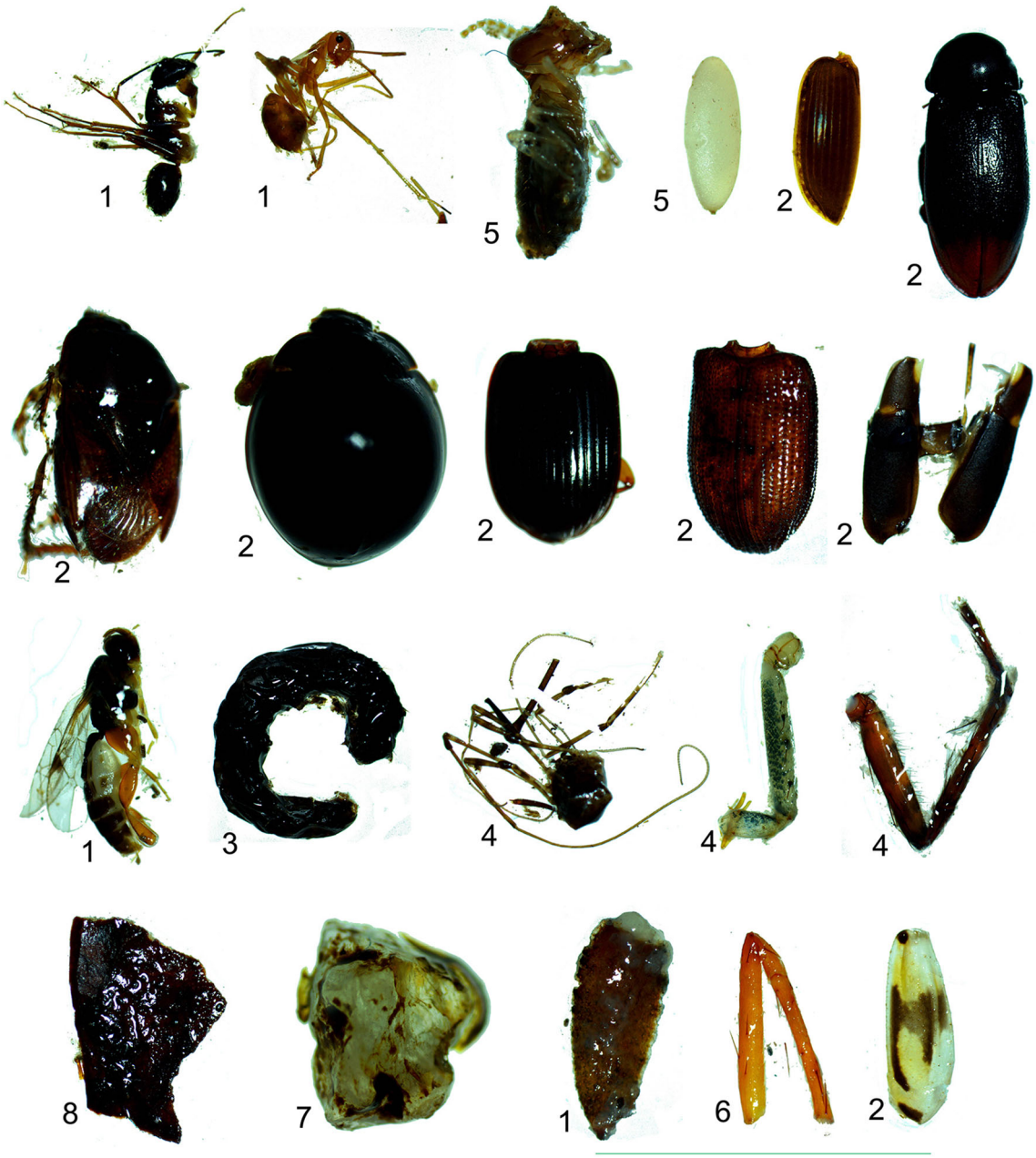

Fig. 2 Food composition of amphibians accused of consuming cardamom in cardamom plantations of Kerala. The *numbers* correspond to prey type in Table 4. The items highlighted with the *green line* are prey specific to *Rhacophorus pseudomalabaricus*, the rest being *Duttaphrynus melanostictus*

in and around the plantations. This is of serious concern since numerous highly threatened and range-restricted amphibians like *Rhacophorus pseudomalabaricus* and *Nasikabatrachus sahyadrensis* not only occur in these plantations but also use these habitats as breeding grounds (Biju and Bossuyt 2003; Harpalani et al. 2015). Such plantations are also sites from where new anurans like *Raorchestes uthamani*, *Micrixalus adonis*, and *Beddomixalus bijui* have been described (Zachariah et al. 2011; Abraham et al. 2013; Biju et al. 2014). While the species commonly accused of consuming cardamom may not be threatened, there are other species especially those belonging to the genus *Rhacophorus* which are of conservation concern. There are also species like the Critically Endangered *Indirana phrynoderma* which are morphologically similar to the non-threatened species and could be targeted due to this perception (Kanagavel and Parvathy 2014). Unfortunately, local communities have little cultural association with frogs, which being profound in the case of species like the Asian elephant (*Elephas maximus*) has

resulted in tolerance even during high economic losses (Kanagavel et al. 2014, 2016; Jasmine et al. 2015). Since cardamom plantations are important refuges for amphibians, targeting the existent negative attitudes in these agroforests is critical if amphibian conservation is to have an impact outside the protected area network.

Socio-economic characteristics were found to influence the myth among the agroforestry community and our study identifies specific audience groups towards whom outreach campaigns can be targeted. Owners and administration staff at large-sized plantations had a reduced belief in the myth, which could be the result of increased levels of education and income that correlated with these factors. However, the reason of its reduced prevalence in Tamil Nadu in comparison to the other states is not well understood. It could have resulted from its correlation with the respondents' occupation or due to the small sample size. While education has affected folklore towards reptiles in a similar manner, it has a reverse effect with respect to amphibians in Portugal (Ceríaco 2012). Age also had a major influence on folklore in Portugal, with older individuals associating with it much more strongly, which was not the case in this study. Using this information, a suitable outreach initiative re-affirming that frogs do not consume cardamom and the positive role of anuran amphibians in an ecosystem targeted at small-sized plantations in Karnataka and Kerala would strongly improve the profile of amphibians among the agroforestry community in this biodiversity-rich region.

Although culling of frogs may not be a general practice currently, the use of pesticides at the plantations not only seems to control their population by itself as perceived by the community, but is also purposely used at times to do so. Since cardamom plantations extensively use pesticides (Murugan et al. 2011), research needs to be initiated to determine their effect on amphibian populations especially the aquatic larval stages. With respect to other plantations that often occur within the same landscape as cardamom plantations, Daniels (2003) noted that commendable amphibian diversity continued to exist in tea plantations (i.e., in Valparai, Tamil Nadu) despite regular pesticide use and habitat manipulation. On the contrary, Gurushankara et al. (2007) observed high numbers of morphologically abnormal amphibians at coffee plantations followed by paddy fields and water bodies and none in forest habitats. The effects of pesticides are not restricted to specific classes but are based on the active substance and formulation additives (Brühl et al. 2013). They are known to cause tadpole and adult mortality, malformations, reduction in size and mass, and delay in metamorphosis (Egea-Serrano et al. 2012; Brühl et al. 2013; Sparling et al. 2015). Their effect ranges from 100% mortality within one hour of application to 40% after a week (Brühl et al. 2013). However, amphibians have been found to be resistant to certain pesticides, which become a significant threat only at relevant concentrations (Kerby et al. 2010; Egea-Serrano et al. 2012).

CONCLUSION

Cardamom consumption by frogs is indeed a myth as has been validated by our field surveys. The myth is still widespread in south India and though it does not lead to incessant killing when encountered, it is a source of negative perceptions and attitudes towards anuran amphibians in the Western Ghats Biodiversity Hotspot. This age-old perception must therefore not be further neglected and this study provides information of importance to formulate conservation measures. A simple outreach campaign targeted at the agroforestry community would reverse the negativity towards amphibians in the region and build local support for their conservation. Follow-up studies on the diet of amphibians could be undertaken to demonstrate their positive role in controlling invertebrates around cardamom plantations.

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