Impact of tea cultivation on anurans in the Western Ghats

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Declining amphibian populations has been a matter of great concern amongst biologists throughout the world for over a decade. While many factors, including over-harvest and the direct loss of habitats, and the less obvious ones such as UV-B radiation, diseases, chemical contaminants and others have been proposed and studied, there still remain a number of questions that have not been fully answered. One of the major concerns in biodiversity-rich tropical landscapes is the impact of large-scale intensive agriculture, especially tea cultivation. Over 18% of all tea that is grown in India is in the Western Ghats – a biodiversity hot spot. In this article I report a brief study of amphibians of Valparai, a landscape where tea has been intensively cultivated for more than 100 years. The preliminary results of the study suggest the need for long-term holistic research, involving as partners the local tea growers and institutions dedicated to tea research.

OVER a decade ago, the widespread decline of amphibian populations raised an alarm amongst biologists throughout the world[1]. A number of possible reasons for the apparent decline, including habitat loss, over-harvest, UV-B radiation, global warming, diseases and chemical pollution of the environment (mainly pesticides) have since been proposed and analysed[1–10]. Although there are a number of studies providing evidence for environmental pollution and diseases[6–8,10], there is still some debate on how the various factors identified affect amphibian populations[11], and whether subtle environmental influences such as pesticide residues and diseases have had a greater impact on amphibians than the direct loss of habitat[3,4,9,12–15].

Since the first alarm bell rang in 1990 (ref. 1), most of the studies that reported specific reasons for amphibian declines were those conducted in the species-poor temperate regions[16]; many being experimental[11]. Studies of amphibian population declines in the biodiversity-rich tropical landscapes are rather recent[6,7,15]. While these studies kept the alarm bells ringing, questions have been raised, from time to time, on the methodological adequacy of studies that focused on amphibian population declines[11,17].

Beginning in 1990, I have studied amphibians in the Western Ghats[18], Eastern Ghats[19–23], Andaman and Nicobar Islands[24] and the agro-ecosystems of peninsular India[25]. Wherever I have spent time watching amphibians and tried to understand the factors that might limit their distribution and population, it seemed that loss of habitat is the one that is primarily responsible. While there is some understanding on how habitat destruction might lead to the loss of amphibians[6,12–15,26], there are much less scientific data to substantiate the suspected role of pesticides and other polluting chemicals in the process of population decline[8,9]. In fact, during the recently concluded exercise of preparing a National Biodiversity Strategy and Action Plan for the Western Ghats Ecoregion[27], the paucity of data on the impact of pesticides on biodiversity repeatedly emerged as a matter of concern. Further, virtually little has been understood of diseases in amphibians leading to the decline of natural populations[6,7].

In June 2001 I visited Valparai briefly as part of the preparation of the Action Plan. Much of Valparai is under tea cultivation. Tea cultivation consumes a lot of pesticides and may fall only behind cotton in this regard. Unlike cotton, tea is grown in the humid and biodiversity-rich landscapes. It is thus likely to have a direct impact on some of the earth's endemic biodiversity. Despite the note of caution raised by some biologists[28,29], amphibians are widely acknowledged as 'bioindicators' of environmental degradation. Thanks to their bimodal life (life in water and land), complex life history, varied reproductive strategies and highly sensitive skin[6], amphibians tend to be more sensitive to chemical contamination of the environment than most other species of vertebrates. Added to the above considerations, prior experience with the anurans (frogs and toads) of the Western Ghats guided me into taking up the present study.

The Western Ghats is amongst the 25 biodiversity hot spots identified in the world[30]. Three hundred and forty species of vertebrates (36% of all vertebrate species) are endemic to the Western Ghats. Amongst amphibians, 94 of the 121 species (78%) known till date from the ecoregion are endemic[27]. The 121 species apparently represent only a fraction of the amphibian fauna of the

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Western Ghats, as it has been pointed out that at least another 115 species, specimens of which are lying pickled in local biological collections, are yet to be taxonomically described[31]. I had earlier discussed how loss of habitats has led to the local extinction of amphibian species in the Western Ghats leading to the apparent patchy distribution[18]. That direct loss of habitat coupled with more subtle changes in the micro-habitats induced by continuous human interference, and the possible contamination of soil and water by inorganic chemicals used in agriculture lead to local changes in amphibian communities in the Western Ghats, were also discussed[3,4].

Tea (*Camellia sinensis*) is often singled out as the greatest threat to tropical montane ecosystems, especially to lower organisms, including amphibians[3]. Since tea grows best in the humid, biodiversity-rich parts of the world, it has attracted a large number of pests. The literature states that over 300 species of arthropods, 58 species of fungi and 130 species of plants infest tea cultivation in India alone, necessitating the continuous application of heavy doses of pesticides[32]. And, despite the international markets' concern on the human health hazards posed by the toxic residues in tea, not less than 30 different pesticides are used[33].

Estimates suggest that around 4,00,000 ha is under tea cultivation in India. While Assam and West Bengal top the list amongst the Indian states, in the Western Ghats, Kerala, Tamil Nadu and Karnataka are the primary cultivators of tea; together they cultivate 73,669 ha amounting to 18% of the country's tea gardens. In the Western Ghats, tea grows between elevations of 300 and 2300 m ASL and within rainfall regimes of 90–750 cm per annum[34], coinciding with the biodiversity-rich rainforests and the endemic montane *shola*-grassland ecosystems[27].

Valparai is a hill town in the Anaimalai Hills of Tamil Nadu (the Western Ghats, south of the Palghat Gap). It receives an annual rainfall of around 450 cm, spread more or less throughout the year. And as with most parts of the Western Ghats, the rainfall reaches its peak intensity around the months of July–August. The terrain being hilly, is also cool during most of the year with average summer (March–April) temperature in the range of 12–29°C, and average relative humidity of 53.3–92.4% (ref. 35). Temperature frequently drops to well below 10°C during the winter months, especially between December and February.

The practice of tea cultivation in Valparai began in 1897 (ref. 34) and since then has expanded to be the largest agglomeration of corporate sector-owned tea estates anywhere in the Western Ghats. Presently, tea cultivation is spread over approximately 11,000 ha, managed by the Bombay–Burma Trading Company, Tata Tea Ltd, Hindustan Lever Ltd (HLL), Parry Agro, P. K. Tea, Tantea (Tamil Nadu Forest Department) and a few others, including NEPC (United Planters' Association of Southern India (UPASI)/P. Selvasundaram, pers. commun.). Although at present the landscape is quite fragmented with mere traces of the original vegetation, judging by the structure of forests in the adjacent Indira Gandhi Wildlife Sanctuary (and the remnant patch in Puthuthottam Estates Pvt Ltd), it may be inferred that Valparai was once dominated by medium-high elevation rainforests. And, thanks to its proximity to the Indira Gandhi Wildlife Sanctuary, wildlife, including an occasional leopard (*Felis pardus*), small herds of elephants (*Elephas maximus*), large herds of the gaur (*Bos gaurus*), giant squirrel (*Ratufa indica*) and troops of endemic primates, including the lion-tailed macaque (*Macaca silenus*) and Nilgiri langur (*Tachypithecus johnii*) are encountered in and around the tea estates. While many species of rain forest birds typical of the Western Ghats are commonly seen in the tea-dominated landscape[36], larger frugivores, especially hornbills (Bucerotidae) and pigeons (*Ducula*, *Treron*, *Columba*) and raptors, including owls, are scarce (personal observation). Interestingly, I observed very few reptiles during my visits.

Since 1927, UPASI has guided the cultivation of tea in the Western Ghats, especially those within the limits of the private estates. UPASI has also set out guidelines on the use of pesticides, listing out only those that are recommended for use in tea along with the permitted levels of residues in the final products[32,37] (Table 1). According to information provided by Selvasundaram of UPASI, the tea estates in Valparai more or less strictly adhere to UPASI's recommendations. Spraying insecticides during April, May, October and December, is recommended[32]. However, pesticides are sprayed in the months of March and June, locally (personal observation).

Field data on anurans that I discuss here, are primarily from the Pacchamalai Estate of Tata Tea Ltd. The Pacchamalai Estate is at an altitude of around 1200 m ASL and part of the over 1500 ha of tea cultivation managed by Tata Tea Ltd in Valparai. First- and second-order streams flow through intensive tea cultivation in many

Table 1. Pesticides commonly used on tea and the maximum residue level (MRL) permitted by the European Union Regulation[32,37].

Name/type of pesticide/dosage	MRL (mg kg^{-1})
Organochlorine compounds	
Dicofol 18.5EC (1000 ml/ha)	20.0
Endosulfan 35EC (1000 ml/ha)	30.0
Organophosphorous compounds	
Ethion 50EC (750 ml/ha)	2.0
Quinalphos 25EC (750 ml/ha)	0.1
Chlorpyrifos 20EC (1000 ml/ha)	0.1
Synthetic pyrethroids	
Deltamethrin 2.8EC (500 ml/ha)	5.0
Weedicides	
Paraquat 24% (1500–2250 ml/ha)	0.1
Glyphosate (1750 ml/ha)	0.1
Fungicides	
Copper oxychloride (210–350 g/ha)	Not available

Table 2. Amphibians observed within the tea estates of Valparai

Family	Species	Wet season	Dry season
Bufonidae	*Bufo melanostictus*	Many observed throughout the estates; adults calling and laying eggs	None observed
Rhacophoridae	*Philautus variabilis*	Hundreds calling	None heard
	Rhacophorus pseudomalabaricus	One adult near Tantea guest house	None observed
Ranidae	*Euphylctis cyanophlyctis*	A few observed	Adults calling; metamorphosing tadpole observed
	Indirana beddomii	One observed near Tantea guest house	None observed
	Nyctibatrachus beddomii	Many calling	None heard
	Nyctibatrachus sp.	Many calling near Tantea guest house	A few calling near Tantea guest house
	Rana temporalis	One observed near Tantea guest house	None observed
	Rana aurantiaca	A few males observed; some calling	A few metamorphosing tadpoles
	Limnonectes brevipalmata	Many adults and juveniles; males calling, showing signs of breeding	Many adults, juveniles, newly emerged frogs and tadpoles of various stages; a few males were calling
	Limnonectes keralensis	A few adults observed	A few adults and juveniles observed
	Limnonectes limnocharis	A few adults observed	Many juveniles and newly emerged frogs
	Limnonectes nilagirica	A few adults observed	Unable to separate juveniles and newly emerged frogs from *L. limnocharis*

Table 3. Characteristics of two first-order streams sampled

Attribute	Location 1	Location 2
Approximate size	200 m × 60 m	100 m × 20 m
Number of quadrats	5 (10 m × 10 m)	5 (10 m × 10 m)
Habitat type	Tea-bordering stream; submerged–emergent grass in dense mats; eucalyptus-plantation bordering; patches of ferns and *Lycopodium* in marsh	Tea bordering; submerged–emergent grass in dense mats
Proximity to second-order stream	Not immediate	Immediate
Substrate	Mud	Sand and rock
Flow of water	Gentle	Rapid
Fish fauna	Abundance of *Puntius melanampyx*, *Xiphophorus maculatus*	*P. melanampyx* (abundant), *Danio aequipinnatus* (frequent), *Rasbora daniconius* (rare), *X. maculatus* (rare)
Tadpoles	At least one per sample	None per sample
Others	Herds of gaur (6–27)	None

parts of the estate. These are perennial and create extensive grassy swamps in the uncultivated valleys during the rains. Judging by the topography of the study locations, I assumed that any chemical run-off from the tea cultivation should automatically reach the swamps, affecting all aquatic life within the habitat. I limited sampling of anurans to the months of May and June (three visits; six days) and March (one visit; four days); the wet and dry seasons of Valparai. I came across 13 species of anurans (Table 2). In order to understand how anurans with different life-history strategies respond to tea cultivation, I focused my study on first-order streams that flowed through tea plantations (two locations; Table 3), and patches of tea bushes (many) for stream-breeding species and those species with direct development, respectively. Since tea bushes are rather uniformly spaced and homogeneous in structure, I randomly searched individual bushes at night when most frogs were calling. I used a combination of transects (100–500 m) and quadrats (10 m × 10 m) for sampling the streams and marshes[6]. I sampled tadpoles with a small hand-drawn net (1.0 m × 0.5 m). In order to avoid killing specimens for the sake of identification, I photographed as many individuals as possible, and recorded the calls using a hand-held tape recorder. Those individuals that posed difficulty in identification despite the above effort have only been tentatively identified. These are however a few species of *Limnonectes*, juveniles of which when found together, are hard to separate in the field.

The short duration of the study and the limited funds/facilities available did not permit me to collect samples of soil and water, and eggs and adults of selected anuran species for analysis of pesticide residues. Using a portable 'water testing kit', I tested 12 samples of water collected from the study locations and in the neighbourhood for some simple chemical parameters (Table 4). Since the kit permits only crude estimates, I have not attempted to analyse differences between the samples collected during

the wet and dry seasons. The averages presented in Table 4 are calculated across the seasons.

Despite the fact that around half the species of anurans were represented by only one or a few individuals during the study, the 13 species encountered within tea estates are representative of a remarkable diversity (Table 2). In many parts of the southern Western Ghats where I have put in comparable efforts in the past, I had always encountered around 13 species. The 30–40 species that Vasudevan *et al.*[38] have reported as the probable size of the amphibian fauna of the Anaimalais, are more likely the result of a greater coverage of the different habitats in the landscape. A long-term study of the tea estates is likely to add many more species to the 13 already listed. I am able to suggest this with some confidence, since the tree frog *Rhacophorus pseudomalabaricus* that was for the first time discovered and described from the rain forests of the Indira Gandhi Wildlife Sanctuary in the year 2000 (ref. 39), and since has not been reported from elsewhere, occurred within the tea plantations (Table 2). The presence of two species in the endemic genus *Nyctibatrachus* is also noteworthy. I identified these by the calls and tend to suspect the presence of a third species as well. Presence of rare species is generally taken as an indication of a species-rich local biodiversity.

In more a quantitative sense, *Philautus variabilis* is apparently the most abundant species of amphibians in tea cultivation. My estimates range from 200 to 400 calling males per hectare during the wet season. In theory, there should be an equal number of females, and when young and immature individuals are taken into account, the density could be much higher. Interestingly, this species of bush frog is the only amphibian that I came across inside tea bushes. It is also one of the species in the Western Ghats known to lay eggs on leaves, from which young frogs directly develop[40].

In June 2002, when the rains were rather continuous, amphibians started breeding in Valparai. Estate workers of Pacchamalai, who were familiar with the landscape, guided us to the two locations described in Table 3. The streams were overflowing, flooding the grass in both locations. Location 1 was rather flat and large enough to be used as a football field when dry. This site was also attractive to large herds of gaur, that sampling amphibians at night became impossible. Common Indian toads (*Bufo melanostictus*) were breeding in both the locations. Many pools of water had strings of freshly-laid eggs and bright yellow males wrestling over a female. Although there were adults of *Rana aurantiaca* and *Limnonectes brevipalmata* calling in location 1 (better known as the Bison Swamp), I did not see them actually breeding. However, at location 2 (Hydel Pump) there were eggs and tadpoles of what I suspected to be one of the *Limnonectes* spp. – three species, viz. *Limnonectes keralensis*, *L. limnocharis* and *L. nilagirica* present at this site. *Rana aurantiaca* was absent.

During the dry month of March 2003, I was surprised by the total absence of *B. melanostictus* and *P. variabilis*. However, there were frogs in the two stream locations. In the Bison Swamp, a few metamorphosing/freshly emerged young of *R. aurantica* were observed during the day. *L. brevipalmata* was abundant. Five quadrats (10 m × 10 m) sampled along the stream yielded as many as 51 individuals of this species of aquatic-breeding frog. Interest-

Table 4. Summary of chemical parameters of the twelve water samples tested

Variable	Mean	SD
pH	6.45	0.45
Chloride (mg l^{-1})	26.67	9.85
Alkalinity (mg l^{-1})	15.83	5.15
Hardness (mg l^{-1})	18.33	7.18
Calcium (mg l^{-1})	7.5	7.53
Magnesium (mg l^{-1})	10.83	6.69
Phosphate (mg l^{-1})	0.29	0.23
Iron (mg l^{-1})	0.41	0.22

Intensive tea cultivation in the Western Ghats.

Bufo melanostictus – male in breeding condition.

Limnonectes brevipalmata – the most common aquatic breeding frog.

Philautus variabilis – the most abundant frog in tea cultivation.

Rana aurantiaca – male in breeding condition.

ingly, 39% of these was freshly-emerged young less than 1.0 cm in snout-vent length, 33% juveniles (1.0–1.5 cm snout-vent length), the rest were equally represented by immature and adult frogs. In 15 samples in the stream, I caught 14 tadpoles in various stages – limbless to fully developed limbs. Except one *Euphlyctis cyanophlyctis* tadpole that was ready to emerge, all others were that of *L. brevipalmata*.

Tadpoles were not encountered in the Hydel Pump stream. There were however many frogs in the grass that bordered the stream. I treated these frogs collectively as *Limnonectes* spp. (excluding *L. brevipalmata* that was absent). Densities were comparatively lower than that in the Bison Swamp. In five quadrats (10 m × 10 m) I observed 40 individuals; 17.5% being less than 1.0 cm snout-vent length and 22.5% with 1.0–1.5 cm snout-vent length. Majority (47.5%) were in the category of immature and adults; the latter only 15%.

The present preliminary investigations have provided some interesting insights. The first is that despite the apprehensions about possible environmental contamination, tea estates tend to support a fairly high diversity of amphibians. Second, the amphibians that I observed within the tea estates clearly fall into two categories: seasonal–explosive breeders that breed during the wet season and tend to disperse or stay dormant during the drier seasons (*B. melanostictus* and *P. variabilis*), and extended breeders that breed throughout the year, except during the driest months (*Limnonectes* spp. and *R. aurantiaca*). Species of *Limnonectes* tend to breed many times during the wet season as evidenced by the size-distribution of the individuals sampled. Elsewhere, *L. keralensis* that I studied in captivity, proved to be an extended breeder in that a single pair laid eight clutches over a period of five months[41]. Very little has been documented on the breeding habits of *R. aurantiaca*[25], that I am unable to decipher whether the species has an extended tadpole stage, or those few tadpoles and newly emerged frogs that were observed in March were part of an exceptionally late brood.

While analysing the impact of tea on anurans in Valparai, it would not be possible to treat species richness and the apparent life-history strategies independently. For instance, the breeding habits of the bush frog *P. variabilis* provide little protection to the eggs, when the tea bushes are sprayed with pesticides. Nevertheless, this species has been able to survive in large numbers. Although it cannot be fully explained, survival of the bush frog may partly be attributed to the timing of its breeding. It breeds during the wettest part of the year, when there is little application of pesticides. As the bush frog stays dormant during the part of the year, probably under leaf litter and barks, when most of the foliar applications of pesticides take place, it may hardly be exposed to pesticides directly.

More striking than the bush frog is the habit of the toad *B. melanostictus*. This species is the most widely distributed species in India, practically inhabiting all habitats, including urban homes, and an explosive breeder that lays as many as 40,000 eggs at a time. These eggs hatch and go through a rapid metamorphosis to become young toads in 21–90 days (normally around 45 days). Young toads disperse far and wide[25]. What is interesting, however, is whereas it is common to see toads of this species

foraging in most parts of south India during summer nights, none were observed during March in the study area.

Worldwide, the most observed declines in amphibian populations have been in those species that have an aquatic larval stage[6]. Amongst the anurans observed in the tea estates of Valparai, *B. melanostictus, R. aurantiaca* and *Limnonectes* spp. have an aquatic larval stage. Interestingly, these species breed profusely within small watersheds that directly drain extensive tea cultivation and may often be contaminated with fertilizers and pesticides. The data provided in Table 4 indicate that the water is generally 'good', as the pH is within the best range for amphibians (in fact water/soil that tends to be acidic, although ideal for tea[34], is bad for amphibians), and the rest of the chemistry as measured, is well within the 'safe for drinking' standards[42]. The use of rock phosphate as a fertilizer in tea has probably led to the increase in phosphate concentration in water (Table 4). Phosphate levels tend to be low in natural forests (0.01–0.04 mg l^{-1}), but increase to 0.15–1.0 mg l^{-1} in farmlands[43].

Recent studies have shown that insecticides such as DDT, dieldrin and malathion affect the immune systems[8], and the herbicide atrazine, at such small doses as 0.1 parts per billion, causes reversal of sex in amphibians[10]. Ironically however, the permitted residue of atrazine in processed tea is 0.1 parts per million[32] – 1000 times higher than what is safe for an amphibian! While atrazine, DDT and dieldrin are not among the pesticides recommended for tea, malathion is occasionally used to control green fly, a sucking pest of minor importance in tea[32]. Breakdown of immune systems in amphibians can make them vulnerable to diseases. Lips has reported anurans dying in large numbers with no apparent symptoms in tropical America[6,7]. While I have witnessed such events in a polluted marsh in Chennai during my study in Valparai, dead amphibians (except occasional road kills) were not found.

What happens to the pesticides used in tea cultivation? The heavy rainfall (450 cm per year) might just wash most pesticides from exposed surfaces. Studies undertaken by UPASI have provided the half-life period of a selected set of insecticide residues in tea. Commonly-used insecticides such as ethion, dicofol, endosulfan, quinalphos, chlorpyriphos and deltamethrin (Table 1) have a half-life of 1.48–2.95 days. Sprayed leaves can be safely harvested for processing between 3 and 12 days[37]. The hot and humid climate of the tropical hills might break down the residues in the soil and other organic matter even more rapidly. UPASI has initiated a programme to monitor pesticide residues in the soil and water within tea cultivations. The results, when available, would shed more light on some of these issues.

Cases of amphibians being infected by a chytridiomycete fungus have been reported from tropical America. According to Lips[7], this is a 'ubiquitous' fungus found in water- and soil-infecting algae, plants and insects. Report of this fungus infecting the skin of amphibians, is apparently the first case of chytrid infection on vertebrates. I have never seen any fungus growing on tadpoles or adult frogs. Fungal infections are common in freshwater fish in both the wild and in aquariums. Irrigation tanks and reservoirs in agricultural landscapes around Chennai often contain hundreds of infected fish during summer (personal observation). Fish in all the streams in Valparai were generally healthy. If ubiquitous fungi, such as the chytrid discussed above infect plants and animals alike, would they not succumb to the periodic spraying of fungicides in tea estates? If that is the case, does the use of fungicides offer a healthy environment for amphibians in tea estates?

Availability of habitats may indeed be the main factor that determines the apparent pattern of distribution of anurans in Valparai. The difference in the community of anurans, between the two streams studied, may be attributed to the differences in the habitat structure. Whereas the Bison Swamp had a muddy substrate with dense growth of ferns and *Lycopodium*, the Hydel Pump stream had rocky bottom and rapid flow of water (Table 3). Streams with rocky substrate permit the breeding of only a few species of specialized amphibians in the Western Ghats. These species are, by and large, rare and localized[18]. Besides the general absence of riverine frogs in the genus *Micrixalus*[25], the scarcity of large-sized frugivorous birds[36] and reptiles[44] may all be due to the non-availability of appropriate habitats within the study area.

Introduced fishes have also posed a threat to amphibians, especially the aquatic stages[6]. The tropical American live-bearing *Xiphophorus maculatus* (the well-known platy, popular in aquariums) has been introduced in Pachamalai Estate (personal observation). This species, thanks to its colour pattern, has fully naturalized and become sympatric with the equally brightly-coloured native barb *Puntius melanampyx*. In the two streams that I had studied, the barb was the most abundant fish and at least in one, the platy was equally abundant (Table 3). Platy is not a predatory fish. However, its close relative, the mosquito fish (*Gambusia affinis*), widely introduced in India for the control of mosquitoes, is known to destroy amphibian eggs[45]. How exactly this introduced fish spreads through the landscape and impacts the native aquatic biodiversity, especially of anurans, needs to be studied in future.

Finally, to fully understand the factors responsible for the decline in amphibian populations, long-term research becomes inevitable. Such research often goes well with appropriate partnership[13]. There is already a sense of concern amongst the tea growers in Valparai about the need to protect and restore natural habitats. The extensive rainforest fragment in the Puthuthottam Estates Pvt Ltd premises, is the best example. The largest single population of the endangered lion-tailed macaque, anywhere in

the Anaimalais, is present within this estate (Ajith Kumar, pers. commun.). HLL has initiated the process of enriching fragments of 'fuel forests' that are maintained within the estates in Valparai with native rainforest tree-species. These fragments are now being protected as 'biodiversity plots'. There is also a coordinated effort, guided by UPASI, to minimize the use of pesticides in tea cultivation and shift towards organic farming, though in a much smaller scale. My brief study in Valparai has helped me reach out to scientists in UPASI and members of the Anaimalais Biodiversity Conservation Association – a body of committed planters representing the corporate sector. As a first exercise, I have prepared a CD on the amphibians of Valparai, illustrating ten common species with photographs and simple clues to field identification. It is my hope that in the years to come, the preliminary results reported here and the Valparai eco-restoration model will help conservation of natural ecosystems, and hence biodiversity, of the region.

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