Hindawi Publishing Corporation
ISRN Biodiversity
Volume 2013, Article ID 341687, 8 pages
http://dx.doi.org/10.1155/2013/341687

Research Article

Population, Ecology, and Threats to Two Endemic and Threatened Terrestrial Chelonians of the Western Ghats, India

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Received 23 June 2013; Accepted 19 August 2013

Academic Editors: A. Chistoserdov and L. Luiselli

The Western Ghats part of the Western Ghats-Sri Lanka hotspot harbors two endemic terrestrial chelonians, the Cochin forest cane turtle *Vijayachelys silvatica* and the Travancore tortoise *Indotestudo travancorica*. Population estimates as well as information on the scale and intensity of threats for these chelonians are largely unavailable. This study attempts to address these gaps for two hill ranges of the Western Ghats. Thirty random quadrats at eight forest ranges were surveyed for chelonians and their carapaces recording any found en route and also during opportunistic surveys. Three live *V. silvatica* and 38 *I. travancorica* were subsequently encountered and had overall densities of 0.006 and 0.03 individuals per hectare, respectively. These chelonians were found at quadrats with lower light intensity and soil temperature. Nine carapaces were found during the field surveys: seven the result of human consumption, one trapped in a pit, and another consumed by a wild animal. In addition to field surveys, household surveys in 26 indigenous and nonindigenous human settlements resulted in the observation of one *V. silvatica* and 38 *I. travancorica* including a carapace. Roads were surveyed to assess the threat they posed to chelonians, resulting in the observation of two *I. travancorica* road kills. Increased interactions and discussions between the management authorities and local communities need to be promoted if chelonian conservation is to improve in the landscape.

1. Introduction

The Western Ghats (WG) region in India, part of the Western Ghats-Sri Lanka Biodiversity Hotspot is globally renowned for its diversity of endemic amphibian, reptile, and fish species [1–3]. The two endemic chelonian genera in the WG are represented by the Travancore tortoise (*Indotestudo travancorica*) and the Cochin forest cane turtle (*Vijayachelys silvatica*); both threatened with extinction [4, 5]. The cane turtle is listed as "Endangered" while the Travancore tortoise is "Vulnerable" in the IUCN Red List of Threatened Species [4, 5].

Of these sympatric, cryptic species, Travancore tortoises are known to be more widespread than cane turtles [6, 7]. The Travancore tortoise is found in rocky hills at elevations of 100–1000 m a.s.l. across the southern WG in a multitude of habitats, such as evergreen, semievergreen, bamboo, *Lantana camara* and *Cromolarium glandulosum* bushes, and rubber and teak plantations [8–12]. On the other hand, the Cochin forest cane turtle, known to be a habitat specialist associated with evergreen vegetation, has also been found in semievergreen, deciduous, and bamboo vegetation types at elevations of 180–800 m a.s.l. [12–15]. Cane turtles do not have an affinity to perennial water sources, though they have algal growth on their carapace [12, 15].

Although there are studies which have focused specifically on one or both the species [12, 15], systematic conservation assessments and on-ground conservation action remain lacking. Amidst this scenario of unavailable population estimates and systematic threat assessments [12], we carried out a survey in the forest areas of southern WG, using a combination of ecological and socioeconomic methods, to improve our understanding of the two species.

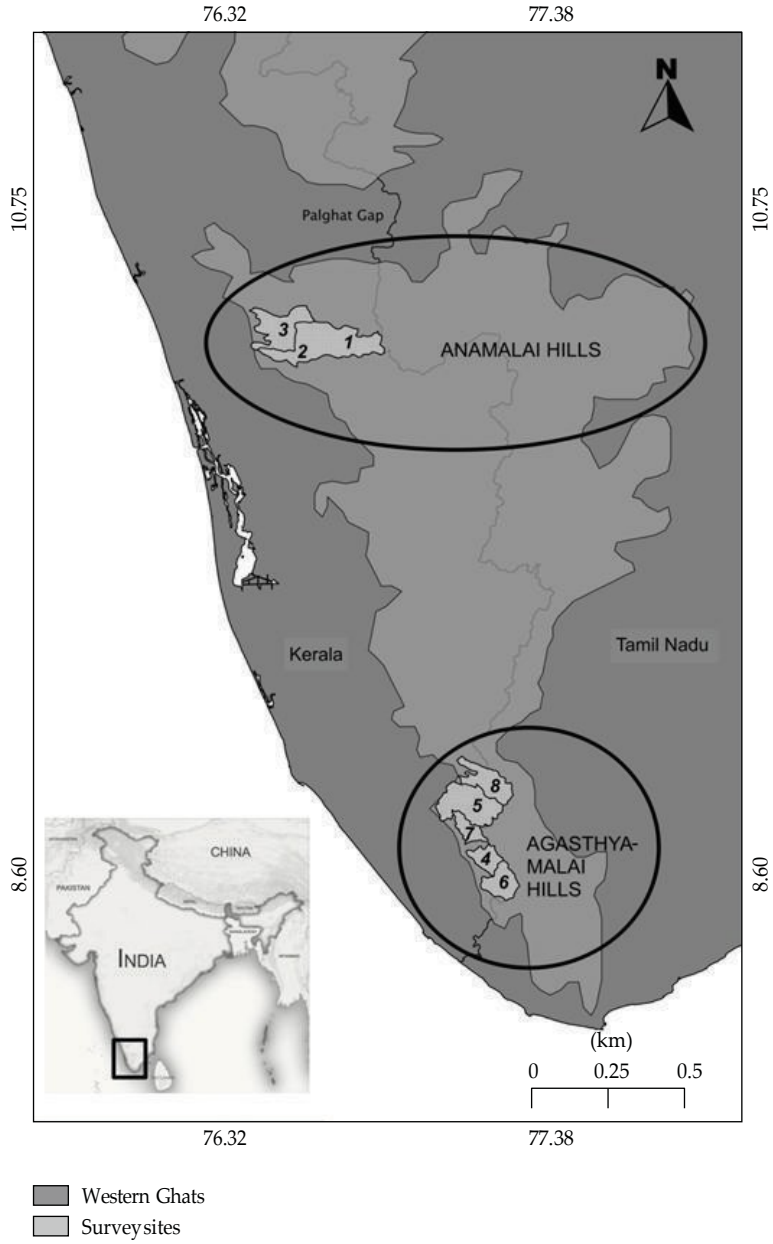

Figure 1: Map of the study area showing the locations surveyed for the focal species in the Anamalai and Agasthyamalai Hills of Western Ghats.

2. Material and Methods

2.1. Study Area. The study was conducted in two hill ranges of the southern WG, the Anamalai and Agasthyamalai Hills. The Anamalai Hills harbor the largest extent of shola grassland [2]. Tree-felling for cardamom, coffee, and tea plantations during the imperial rule (Congreve 1942 cited in [16]) has led to severe forest fragmentation in the Anamalais, home to numerous indigenous communities [17]. The Agasthyamalai Hills spread over 2112 km^2 are relatively undisturbed and contiguous in comparison to the Anamalais and are known for their plant diversity and unique ecosystems like *Myristica* swamps [2, 18, 19].

2.2. Quadrat Surveys. Surveys were conducted in eight forest ranges at four reserve forests (RF) and three wildlife sanctuaries (WLS; Figure 1, Table 1).

Thirty quadrats of two hectares each were visually surveyed for chelonians/shell parts in each of the eight forest ranges anytime between 07:00 h to 21:00 h from December 2010 to December 2011. These quadrats were randomly selected from digitized 1 : 50000, Survey of India toposheets (58 B7, B11, H1, H2, H6) using QGIS 1.7.3. Morphometric measurements (See Supplementary Material available online at http://dx.doi.org/10.1155/2013/341687 Figure S1) were determined using both digital (15 cm, ±0.01 cm accuracy) and dial Vernier calipers (RSK, 30 cm, ±0.02 accuracy).

Table 1: Population density and frequency of chelonians/shell parts encountered in the wild and at human settlements.

Number	Protected area	*Indotestudo travancorica*				*Vijayachelys silvatica*		
		Density*	Wild	Settlement	Shell	Density*	Wild	Settlement
1	Vazhachal range, Vazhachal RF[a]	0.03	8	5	8	0.02	1	1
2	Athirapilly range,Vazhachal RF[a]	0.03	5	5	1	0	—	—
3	Chalakudy RF[a]	0.03	12	—	—	0.02	1	—
4	Peppara WLS[b]	0	0	9	—	0	—	—
5	Kulathupuzha RF[b]	0.05	7	0	1	0	—	—
6	Neyyar WLS[b]	0.02	1	12	—	0	—	—
7	Palode RF[b]	0.03	2	6	—	0	—	—
8	Shendurney WLS[b]	0.05	3	0	—	0.02	1	—

* Individuals per hectare, [a]Anamalai Hills, and [b]Agasthyamalai Hills.

Measures beyond 25 cm were measured using a tape (150 cm, ±0.1 cm accuracy). The chelonian's weight was determined using a weighing balance (6 kg, ±0.001 kg accuracy).

From each quadrat, time, terrain (whether within leaf litter and/or bark, cavity or in the open), activity of the chelonian when encountered, algal presence, and the number of ticks were recorded. The soil and air temperature as well as the cloacal temperature of the chelonian were determined using a digital thermometer (Eurolab, 50° C–300° C, ±0.1 ° C accuracy). For cloacal temperature, the thermometer probe was placed at the cloacal aperture. Humidity and light intensity were determined using a digital hygrometer (TempTec 241A, 0–100%, ±1% accuracy) and luxmeter (LX-101, 0–50,000 lux, ±1 lux accuracy), respectively. The geographical coordinates and elevation of the point of location, water sources, and bamboo/cane clusters closest to the encountered chelonians were determined using a Garmin GPS 62S. The distance between the chelonians and the water sources and cane/bamboo clusters was calculated using QGIS 1.7.3. The extent of leaf, herb, shrub, and canopy cover was rated on a qualitative scale of "absent, low, medium, and high." Whether the stratum was wet, moist or dry, rocky terrain, or on a slope at the point of location was also determined. Depth of the leaf litter was determined using a measuring tape (150 cm, ±0.1 cm accuracy). Morphological and environmental data were also collected in case a chelonian/shell part was encountered enroute to a quadrat as well as during opportunistic surveys.

2.3. Household and Road Surveys. To identify households where chelonians were kept, indigenous and nonindigenous settlements were surveyed using a referral sampling strategy (local informants and respondents from parallel interview surveys) [7, 20]. Accompanied by local informants, referred households were visited, and residents were requested to allow both morphometric data (Figure S1) and cloacal temperature to be recorded from the chelonians. A total of 26 settlements (seven nonindigenous and 19 indigenous) were surveyed in the process.

Major highways and smaller roads passing through the forest ranges were surveyed once in each of the eight forest ranges for any road-killed chelonians.

2.4. Analysis. The population density of each species encountered at a site was calculated [21]. The overall population density was the average of the population density of each species across all the sites surveyed. The overall relative abundance of each species was calculated by dividing the total number of individuals of a specific species by the total number of individuals of both the species.

Mann-Whitney U or Kruskal-Wallis test and indepen- dent samples t-test or ANOVA were used to test for dif- ferences between quadrats that harbored chelonians and those that did not. In case frequencies among any group were less than five, Chi-square and Fisher's exact test were undertaken.

Morphometric differences and differences in habitat preferences between sexes as well as morphometric differences between individuals encountered in the wild and in settlements were also determined. R.2.14.0 was used for the Shapiro-Wilk test and Fisher's exact test, while SPSS 11.5 was used for all the other statistical tests.

3. Results

3.1. Quadrat Surveys. A total of 240 quadrats were surveyed (90 at Anamalai Hills and 150 at Agasthyamalai Hills); 90 each during monsoon and premonsoon and 60 during post-monsoon. The elevation varied from 54 to 1079 m a.s.l., air temperature 20.4 to 36.8° C, soil temperature 18.5 to 34.6° C, humidity 36% to 90% and light intensity 0 to 1026 lux during the survey period. The vegetation types sampled ranged from dry and moist deciduous, semievergreen, evergreen, and riparian forests to grassland and plantations (including cashew, cocoa, coconut, rubber, and teak).

Eighteen out of 240 quadrats surveyed were occupied by the two focal species. *Indotestudo travancorica* were encountered in 15 quadrats occupying an overall density of 0.03 individuals per hectare, while *V. silvatica* was encountered at three quadrats occupying an overall density of 0.006 individuals per hectare (Table 1). The overall relative abundance of *I. travancorica* was 0.83, whereas that of *V. silvatica* was 0.17.

Light intensity (Mann-Whitney U test, $U = 1682.5$, $P = 0.003$, and $n = 25$) and soil temperature (Mann-Whitney

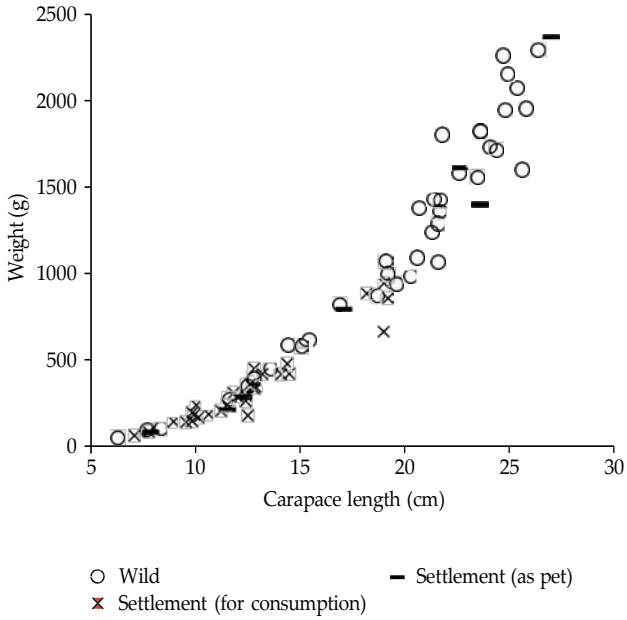

Figure 2: Difference in sizes of *Indotestudo travancorica* encountered in the wild and at human settlements.

U test, U = 1450.5, P = 0.04, and n = 38) were found to vary significantly, being lower in quadrats where chelonians occurred (65.4 ± 54.8 lux and 24.2 ± 0.5° C resp.) than where they did not occur (202.1 ± 23.6 lux and 25.4 ± 0.2° C).

The two species also differed in the terrains they occupied (Fisher's exact test, χ^2 = 4.3, P = 0.03, and n = 38); *V. silvatica* were encountered on flat terrains (100%), while *I. travancorica* were found more often on sloped terrains (67%).

Twenty-three living and nine carapaces of *I. travancorica* were also found enroute to the quadrats. Six adult charred carapaces were found on a hillock at Vazhachal range, one adult carapace was found beside a forest stream in Kulathupuzha RF, and another adult carapace was found in a pit dug up and later deserted by the Kerala State Electricity Board to lay cable posts in the Athirapilly range. One juvenile *I. travancorica* carapace was found in Vazhachal range with marks made by an unidentified, carnivorous species.

3.2. Household and Road Surveys. One adult female *V. silvatica* and 37 *I. travancorica* (31 juvenile, five adult females, and one adult male) were found in the households that were surveyed (Table 1). Holes were found to be made in the posterior part of the animal's carapace that assisted in tying them to posts. Seven out of the 37 tortoises were pets while the rest, including the single *V. silvatica*, were meant for consumption on attaining larger sizes (Figure 2). Some of the pet tortoises alone weighed above 1000 g and had carapaces longer than 20 cm (Figure 2). An intact shell of *I. travancorica* devoid of any damage, being used as a decorative household item, was also shown.

Two *I. travancorica* road kills were encountered—one juvenile at Athirapilly range close to the ticket counter for tourists and an adult close to the Kanithadam check post at

3.3. Vijayachelys silvatica. A total of four adult female *V. silvatica* were found, the details of which are provided in Tables 1 and 2. Due to the small sample size of *V. silvatica* encountered, no further analysis could be undertaken (For indetail information on the associated environmental variables see Supplementary Material Table S1).

3.4. Indotestudo travancorica. A total of 27 adult and 11 juvenile *I. travancorica* were encountered during the field surveys, the details of which are presented in Tables 1 and 3. The sex ratio (male : female) was 1 : 2 in the Anamalai Hills and 1 : 0.7 in the Agasthyamalai Hills (For indetail information on the associated environmental variables see Supplementary Material Table S2).

Morphometric differences were found between male and female *I. travancorica* with respect to shell height (Mann-Whitney U test, U = 34.5, P = 0.009, and n = 35) and bridge length (Mann-Whitney U test, U = 34.5, P = 0.02, and n = 35), being longer in females (8.9 ± 0.3 and 9.3 ± 0.2) than in males (8.0 ± 0.2 and 8.5 ± 0.2).

Peppara WLS.

At the two hill systems, tortoises differed in the habitats they were encountered at (Fisher's exact test, $\chi^2 = 13.2$, $P = 0.03$, and $n = 38$), algal growth (Fisher's exact test, $\chi^2 = 4.4$, $P = 0.03$, and $n = 38$) and vegetation type (Fisher's exact test, $\chi^2 = 8.6$, $P = 0.03$, and $n = 38$). They were found more often within leaflitter and/or bark in the Anamalai Hills ($n = 18$) than in the Agasthyamalai Hills ($n = 4$). Only those encountered in the Anamalais ($n = 7$) had algal growth on their carapace. Thirty-six percent of the tortoises in the Anamalais were found in moist deciduous forests whereas in the Agasthyamalai Hills, 54% were found in an ecotone of moist deciduous and semievergreen forests. Moreover, these chelonians were found in semievergreen forests (32%) only at Anamalai Hills and in evergreen forests (7.7%) and their ecotone with semievergreen forests (15.4%) only at Agasthyamalai Hills.

Significant differences were found between the carapace length (Mann-Whitney U test, $U = 270$, $P < 0.001$, and $N = 75$) and weight (Mann-Whitney U test, $U = 249.5$, $P < 0.001$, and $N = 75$) between tortoises encountered in the wild and those in human settlements. Individuals found at settlements had a relatively smaller carapace length, weighed less, and also did not have any ticks on them in comparison to the wild individuals (Figure 2, Table 3).

3.5. Microhabitat Description. Air (Kruskal-Wallis Test, $\chi^2 = 17$, $P < 0.0001$, and $N = 38$), soil (ANOVA, $F = 3.8$, $P = 0.03$, and $N = 38$) and cloacal temperatures (ANOVA, $F = 5.5$, $P = 0.008$, and $N = 38$) varied significantly for the different seasons (Figure 3(a)). Significant differences were found between the time period the wild individuals were encountered and their cloacal temperature (ANOVA, $F = 6.4$, $P = 0.004$, and $N = 38$), air temperature (Kruskal Wallis test, $\chi^2 = 7.4$, $P = 0.02$, and $N = 38$), and whether the individuals were present on a slope or not (Fisher's exact test, $\chi^2 = 6.2$, $P = 0.04$, and $N = 38$). Cloacal temperatures of wild individuals were lower in the evening followed by morning and higher in the afternoon, (Figure 3(b)). Individuals were

Table 2: Morphometrics and cloacal temperatures of *Vijayachelys silvatica* encountered during the study.

Measurements	Wild (n = 3)			Settlements (n = 1)
	Range	$\bar{x}$	SD	
Carapace length (CL; cm)	11.5–12.2	11.8	0.4	12.2
Carapace width (CW; cm)	8.3–9.8	9.0	0.8	9.0
Plastron length (PL; cm)	9.3–10.8	10.2	0.8	10.0
Plastron width (PW; cm)	5.5–6.7	6.0	0.6	6.3
Bridge length (BL; cm)	3.7–4.1	3.9	0.2	4.0
Shell height (SH; cm)	4.3–4.5	4.4	0.1	4.0
Weight (g)	192–267	219	41.7	206
Cloacal temperature (°C)	23.3–30.7	26.8	3.7	29.5
Ticks	0–2	1.3	1.2	2
Algal growth		Yes = 3		Yes = 1

Table 3: Morphometrics and cloacal temperatures of *Indotestudo travancorica* encountered during the study.

Measurements	Wild (n = 38)			Settlements (n = 37)			Carapaces (n = 10)		
	Range	$\bar{x}$	SD	Range	$\bar{x}$	SD	Range	$\bar{x}$	SD
Carapace length (cm)	6.3–26.4	19.6	5.4	7.1–27.0	13.4	4.5	10.7–28.3	18.0	7.3
Carapace width (cm)	6.2–17.6	12.9	2.8	6.7–17.1	9.8	2.1	8.0–20.6	13.1	4.9
Plastron length (cm)	5.0–20.7	14.9	3.8	5.7–18.0	10.5	2.8	7.2–23.3	17.5	4.8
Plastron width (cm)	2.9–16.8	8.5	2.5	3.3–10.1	6.3	1.6	4.6–14.7	10.5	2.9
Bridge length (cm)	2.8–11.2	7.6	1.9	3.1–10.0	5.7	1.5	3.9–6.6	5.3	1.9
Height (cm)	3.1–10.5	8.1	1.7	3.3–9.9	6.2	1.4	4.6–7.6	6.3	1.5
Weight (g)	53–2298	1207.7	647.6	66–2371	46.5	475.8	NA		
Cloacal temperature (°C)	17.6–33.1	26.7	3.3	23.0–31.7	27.9	2.4	NA		
Ticks	0–7	1.8	2.0	0–2	0.1	0.4	NA		
Algal growth		Yes = 18.4%			Yes = 8.1%			NA	

more likely to be found on slopes in the morning (88.9%) and afternoon (59.3%) than in the evening (0%).

4. Discussion

4.1. Population Estimates. Our estimates suggest low population densities for both species, contrary to previous studies where *V. silvatica* was found at densities between 0.1–0.6 individuals per hectare [12, 15] and *I. travancorica* was known to be more widespread than *V. silvatica* [22]. This could have resulted from a difference in sampling strategy, time of survey, observer bias, or sparse distribution [23]. It could also have been the result of collection of chelonians for consumption by local communities, and the effect of forest fires such as in the case of the Chalakudy Forest Division where three or four major forest fires had broken out (Babu, Chalakudy, pers. comm.) since past fieldwork [15].

Our study suggests that *I. travancorica* is indeed more abundant and widespread than *V. silvatica* in terms of the habitats they occur in. This is also concurrent with parallel interview surveys with local communities [7]. *Indotestudo travancorica* may be more closely associated with water sources than *V. silvatica*, as reported in the literature ([15] but see [12]). *Vijayachelys silvatica* were found at slightly higher humidity, lower light intensity, and mostly where the canopy cover was high in comparison to *I. travancorica*, which was largely associated with medium canopy cover. *Vijayachelys silvatica* were more active on flat terrains while *I. travancorica* may be occupying slopes.

4.2. Vijayachelys silvatica. Similar to past studies [12, 24], most individuals encountered were not found associated with water sources and, being crepuscular, were inactive in leaflitter when encountered in the afternoon. While we encountered them mostly in semievergreen vegetation, *V. silvatica* is known to be a habitat specialist occurring in evergreen and semievergreen vegetation [9, 12]. All the wild individuals were found within or close to bamboo/cane clumps. While few studies suggest that bamboo/cane occurred in *V. silvatica* habitat [9, 14], others suggest there might not be a close association with this vegetation type [12, 24]. The turtles were found to occupy moist areas, which could promote algal growth on their carapace. The wild individuals were also found in areas where the herb and shrub cover were low in contrast to the previous studies [9, 24].

4.3. Indotestudo travancorica. The species is known to be crepuscular [25], which suggests why most of the individuals encountered during our surveys were inactive. Also, the tortoises could indeed be more active in the evenings and during the monsoons as the cloacal temperatures were higher than the air and soil temperatures during these intervals

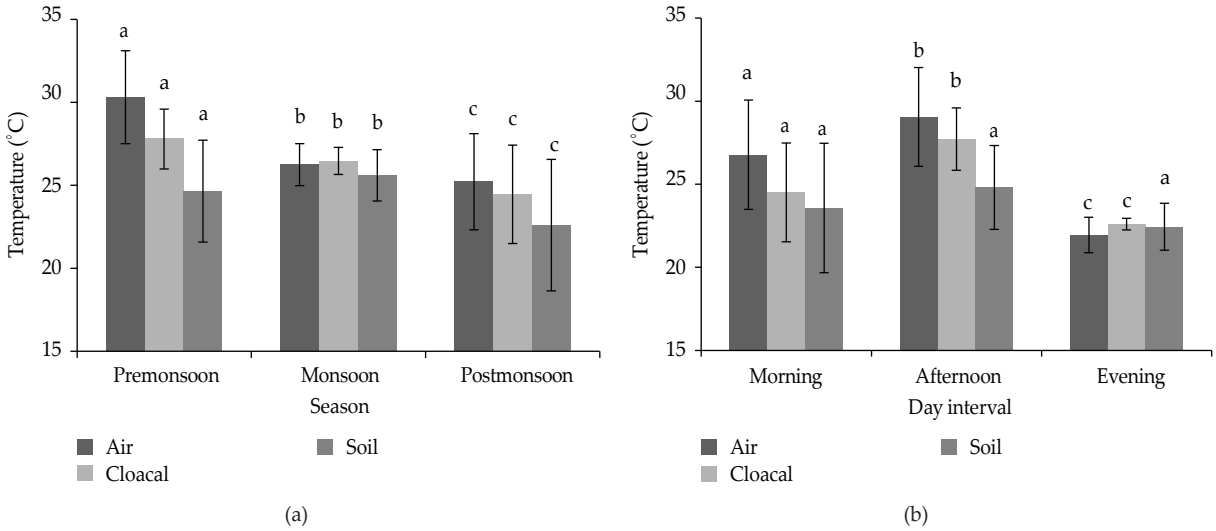

Figure 3: Variation in cloacal temperatures of *Indotestudo travancorica* with respect to air and soil temperatures during different (a) seasons (air temperature $P < 0.0001$, cloacal temperature $P = 0.008$ and soil temperature $P = 0.03$) and (b) day intervals (air temperature $P = 0.02$ and cloacal temperature $P = 0.004$). Different superscript letters indicate significant differences.

(Figures 3(a) and 3(b)). Similar to Ramesh [11], we found differences in shell height between gender but not anal fork length, which was not measured by us. We also found differences in bridge length. Individuals were found to be mostly using leaf litter, followed by leaf litter and bark and rock/mud cavities to conceal themselves as observed previously [23]. As observed by Ramesh [11], ticks were found attached either to the carapace or tail area of a large proportion of the tortoises ($n = 24$).

Our results expand the lower altitudinal extent of the species to 85 m. While differences are bound to arise at the two hill ranges due to variations in vegetation, our results suggest that tortoises in the Anamalai Hills utilised leaflitter and bark to conceal themselves more than those in the Agasthyamalai Hills. The tortoises were largely found in deciduous forests and an ecotone of moist deciduous and semievergreen forests, as is the case of previous surveys [9, 10]. However, Ramesh [11] detected more tortoises around wet evergreen forests, which could have resulted from varying sampling intensities in the different forest types, or because species distribution is unaffected by vegetation types but by the overall region as such. No chelonians were found around tree buttresses or thickets of *Lantana camara*/*Chromolaena glandulosum*, unlike previous studies [23, 25]. Our study also agrees with previous investigations suggesting that the species are found in rocky terrains on inclined surfaces [8, 9] and individuals could be moving towards inclined terrains in order to conceal themselves during the day while returning to flat terrains in the evening.

Most individuals were also found within or close to reed bamboo. The tortoises' association with bamboo thickets has been recounted by local communities and to an extent by earlier field surveys, but its high dependence on such vegetation is evident from 91% of their diet being composed of grass and bamboo remains [9, 12].

4.4. Threats and Chelonian Conservation. The study provides evidence that larger individuals of *I. travancorica* are immediately consumed by local communities while younger individuals are collected and reared till they reach sizes suitable for consumption (>1 kg) (Figure 2). Human collection and associated consumption of *V. silvatica* were found to be negligible in comparison to *I. travancorica*, which could be due to the increased difficulty in detection or smaller population sizes [9, 13, 26]. It could also have resulted from local taboos of bad luck and being unable to find any forest produce in the encountered area, similar to perceptions towards the slender loris *Loris lydekkerianus* [27], which inhibits consumption of *V. silvatica*. The consumption of *I. travancorica* from the wild could be affecting some populations as larger sized individuals (>27 cm) [11] were not found during our surveys. Similar to Bhupathy and Choudhury's [10] study undertaken two decades earlier, field surveys at Peppara and Neyyar WLS resulted in either none or a single detection while parallel surveys at human settlements resulted in more detections. Especially since the natural growth and survival rate of *I. travancorica* may not be high [28], efforts need to be undertaken to reduce collection of adult females and supplement existing populations through ex situ initiatives. The frequency of road kills is currently negligible in comparison to the extent of human consumption, which could also have resulted from insufficient surveys. However, vehicular traffic around the Athirapilly waterfalls should be managed beforehand to preempt instances of road kill of chelonians and other species. Chelonian deaths from development activities justify that future initiatives in forest areas need to be thoroughly monitored by the Forest Department, and existing pits need to be filled up immediately to stop them from functioning as death traps for numerous other species too.

The profile of these chelonians also needs to be enhanced through campaigns, in order to improve their appreciation

and consequential conservation attention, especially among local communities and individuals with no educational qualification and mid-level incomes [29].

5. Conclusion

In spite of historic and continued use by indigenous communities, chelonians have not been extirpated from the landscape. Existing consumption rates could have probably caused local extirpation around human settlements as most wild chelonians in the area were found far away from human settlements. Utilization by local communities may need to be reduced to prevent further decline of these species [10], and such a policy would need to be developed through in-depth discussions with communities on sustainable harvest and management of this natural resource.

Acknowledgments

The first author would like to thank P. A. Kanagavel and Vijayalakshmi for their assistance in field logistics, S. Rajkumar for assistance during field surveys, Krishna Kumar for information on field sites, K. H. Amita Bachan for sharing shape files, Josin Tharian for toposheets, Susanna Paisley, Peter Bennett and Jonathan Baillie for their help during the project's formulation, Helen Meredith for her comments on the draf t of the paper, and the academic editors—A. Chis- toserdov and L. Luiselli for their comments which improved the final manuscript. The study was carried out with an official permission of the Kerala State Forest and Wildlife Department (WL 12-7326/2010) and financially supported by the Zoological Society of London (ZSL) Erasmus Darwin Barlow Expedition Grant 2010 and Rufford Small Grant for Nature Conservation (9190-1) to the first author.

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