Density and microhabitat association of *Salea anamallayana* in Eravikulam National Park, Western Ghats, India

V. Deepak & Karthikeyan Vasudevan

Wildlife Institute of India, Dehradun, Uttarakhand, India

Salea anamallayana is an endemic agamid restricted to the high altitudes of the southern Western Ghats. Distance sampling along line transects was used to estimate its density in Eravikulam National Park (ENP). The habitat association of the species was also examined. Thirty-three 100 m transects were laid randomly in four different habitat types. Eighteen were in 12 *shola* patches covering an area of 140.87 ha. The density was 55 individuals ha^{-1} in *shola*. Males, females and juveniles used similar microhabitats in the *shola*. Five transects were laid in each of three other habitats: mid-elevation evergreen forest, tea plantations and eucalyptus plantations. The species was detected only in the tea plantations. Density in tea plantations was estimated to be 65 individuals ha^{-1}. Distance sampling can thus be used to monitor populations of this species. The tea plantations surrounding ENP probably support a sizable population, and conservation and management of a landscape dominated by different land uses in the Western Ghats will be crucial for the species.

Key words: endemic, individuals, *shola*, tea plantation, transects

INTRODUCTION

Salea anamallayana is a slow-moving, arboreal agamid inhabiting the high altitudes of the Anaimalai and Palani hills (Beddome, 1878; Smith, 1935; Bhupathy & Kannan, 1997; Das, 2002). The animals are sexually dimorphic (Smith, 1935) and spectacularly ornamented (Ord & Stuart-Fox, 2006). Information on the species is restricted to locality records and a few accounts of its distribution. There is no information on its population and microhabitat use.

Changes in land use driven by growing economies have deforested and altered landscapes worldwide (Turner et al., 1998; Vitousek et al., 1997). In the Western Ghats of South India, deforestation for expansion of plantations has occurred over a century (Nair, 1991). The landscape level changes and disturbance that are a consequence of deforestation often impact reptiles (Van Rooy & Stumpel, 1995; Glor et al., 2001). There is also growing concern about the under-representation of reptiles among vertebrates in the IUCN Red list (Baillie et al., 2004). It is often misconstrued that reptiles cope better than other vertebrates with rapid anthropogenic changes. This notion stems primarily from lack of population-level studies of rare and endemic reptiles and the impacts of human-modified habitats on them.

Among studies that have attempted to estimate populations of reptiles, the use of distance sampling methods is uncommon. Notably, studies of Madagascar chameleons (Jenkins et al., 1999) and Fijian crested iguanas (Harlow et al., 2001) used transect-based distance sampling to estimate their densities. In this study we report the density of *Salea anamallayana* estimated using transect-based distance sampling. We also identify its habitat associations and consider the implications for the conservation of the species.

MATERIALS AND METHODS

Study site

The study was carried out in Eravikulam National Park (ENP), situated in the high ranges of the Southern Western Ghats in Idukki District, Kerala State. It lies between 10°15'N and 77°5'E , and covers an area of 97 km^2 (Fig. 1). The two distinct physiognomic classes of vegetation within the Park are grasslands and *shola*. Nearly 80% of the area is covered by grassland and the remaining area by *shola* forest and rocky slopes (Karunakaran, 1997). *Shola* is defined as southern montane wet temperate forest surrounded by grasslands (Champion and Seth, 1968). *Shola* are closed evergreen forests of relatively low height (rarely exceeding 6 m). The crowns are usually very dense and rounded and the branches are clothed with mosses, ferns and other epiphytes, and woody climbers are common. There is no marked differentiation in the canopy layers, which form a continuous series of shrubs and large trees (Champion & Seth, 1968). *Shola* are usually found in elevations above 1500 m (Champion & Seth, 1968).

Approximately 14.6 km^2 of the Park area is covered by *shola*. The study was carried out in 12 different *shola* patches covering an area of 140.87 ha, located between 1564 and 2212 m a.s.l. Other study sites included large contiguous mid-elevation wet evergreen forest (MEF) from 1100 m to 1407 m, 9.75 ha of tea (*Camellia sinenisis*) plantations from 1690 to 1720 m and 5.15 ha of eucalyptus

Correspondence: Karthikeyan Vasudevan, Wildlife Institute of India, P.O. Box 18, Dehradun 248001, Uttarakhand, India.
E-mail: karthik@wii.gov.in

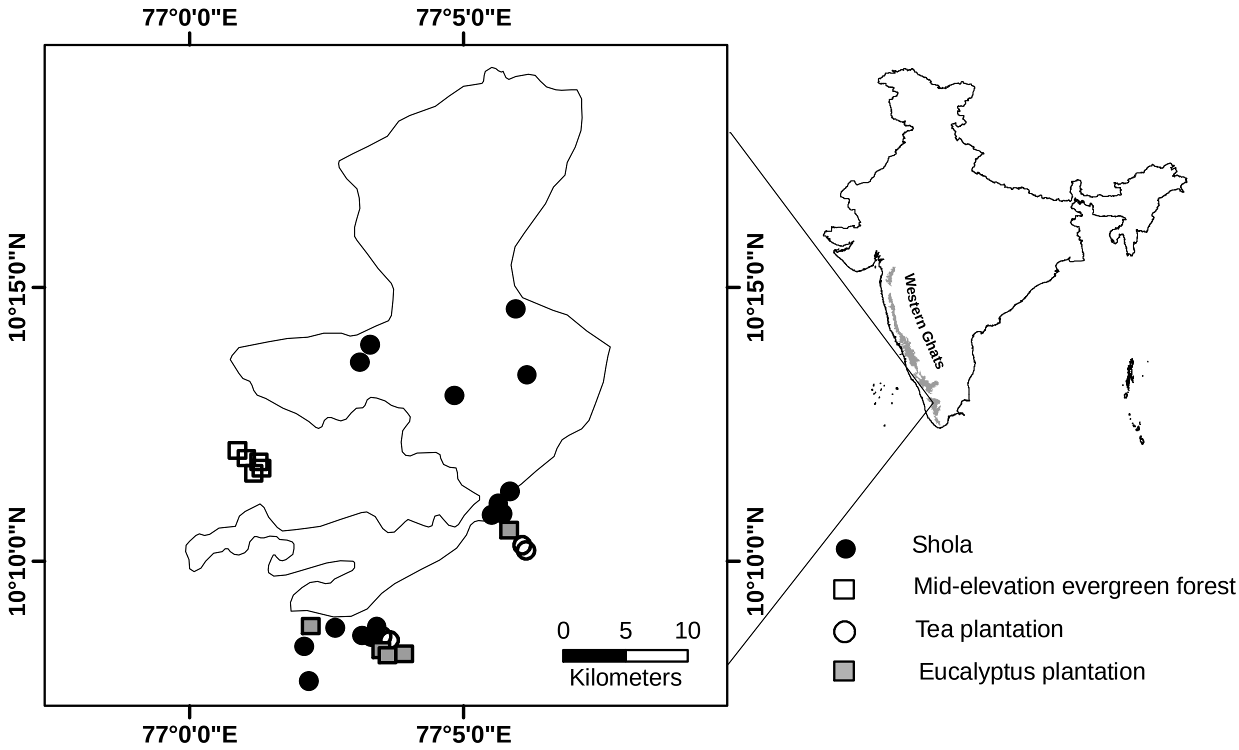

Fig. 1. Map of the study area in the southern Western Ghats showing the location of transects in different habitat types.

plantations from 1760 to 2000 m a.s.l. The tea plantations and the eucalyptus plantations were established nearly 80 years ago. There are four seasons: winter from December to February, summer from March to May, the south-west monsoon from June to August and the north-east monsoon from September to November (Rice, 1984). The study area has a mean annual rainfall of 2700 mm.

Distance sampling

The starting points of eighteen 100 m transects were selected based on a random distance on the perimeter of the *shola* patch from the point where the habitat was initially accessed. Transects were oriented according to the shape of the *shola* to obtain a length of 100 m. Twelve different *shola* patches were selected for distance sampling (Fig. 1). We also laid 15 other such transects, five each in MEF, tea plantations and eucalyptus plantations (Fig. 1). Transects were walked slowly once for one hour by two observers between 1000 and 1200. Sighting angle was recorded using a compass and the distance to the animal was measured using a measuring tape. *Salea anamallayana* has cryptic coloration, but could be sighted because of the slight movements it made in response to the approaching observer. *Salea anamallayana* is slow moving and arboreal, and therefore it was easily sighted on tree trunks and branches in its habitat. The three main assumptions made by distance sampling, i.e. 1) all animals at zero distance from the transect line are detected with certainty, 2) animals are detected at their initial locations and 3) sightings of animals are independent of each other (Buckland et al., 2001), were therefore met in this study. Sampling was carried out between 15 December 2004 and 31 March 2005.

The programme DISTANCE version 4.1 (Thomas et al., 2003) was used to estimate densities of *Salea anamallayana*. The following *a priori* models (key function/series expansion) were used to arrive at density estimates: uniform/cosine, half-normal/hermite polynomial and hazard-rate/simple polynomial. Model selection was based on minimum values of Akaike's information criterion (AIC). The density estimation was made using data pooled over all individuals encountered on the transects. The cut points in the models were adjusted prior to analysis to improve the model fit.

Microhabitat association

Every individual observed was categorized as male, female or juvenile. Males typically have a large crest that extends to the tail. Females have a small crest, and the juveniles are small and lack a crest. All individuals during the study were unambiguously assigned to these categories. Microhabitat variables measured were tree height (TH), perch height (PH), perch diameter (PD), temperature (TEMP), humidity (HUM), canopy opening (CANO) and altitude (ALTD). These variables were recorded for all individuals seen in the *shola*. Tree heights and perch height were initially measured using a calibrated pole and then visual estimation was practised. Periodically the visual estimates were checked using the calibrated pole. Because the trees were stunted and of uniform height, the error associated with measuring heights is expected to be minimal. Perch thickness were measured using a measur-

Table 1. Summary of candidate model used and the model fit in line transect analysis of *Salea anamallayana* in *shola* and tea plantations.

Model	AIC	χ^2	df	*P*	Density	95% confidence limit	
						lower	upper
Shola							
Uniform/ cosine	107.24	0.47	2	0.79	55.18	45.25	67.28
Half-normal/ hermite polynomial	108.39	1.52	2	0.47	57.54	43.13	76.76
Hazard-rate/ simple polynomial	108.89	0.13	1	0.71	44.80	35.27	56.91
Tea plantations							
Uniform/ cosine	57.69	0.15	2	0.93	65.70	35.67	121.00
Half-normal/ hermite polynomial	57.89	0.35	2	0.83	68.69	36.76	128.35
Hazard-rate/ simple polynomial	59.58	0.02	1	0.86	57.27	30.06	109.13

ing tape, surface temperature using a Weksler™ mercury thermometer, canopy cover using a canopy densiometer, humidity with a hygrometer (Huger Co., Germany) and altitude with a Barigo™ (BARIGO Barameterfabrik GmbH, Schwenningen, Germany). The microhabitat variables were divided into three equal classes and a chi-square test for proportions (Gibbons, 1971) was used to test for differences in the proportion of individuals represented in different categories. The microhabitat variables were tested for normal distribution using Kolmogorov-Smirnov tests for normality with alpha = 0.05. TH, PH and PD were normally distributed for different categories of individuals. HUM, CANO, ALTD and TEMP were not normally distributed. HUM and CANO were subjected to arcsin transformation and ALTD and TEMP to natural log transformation. The normalized variables were used in Principal Componenent Analysis with Varimax rotation in order to reduce the variables. Pearson correlations were used to examine the relationship between TH and PH for different categories of individuals. All statistical analyses were done using SPSS 14.0 (Chicago, IL).

RESULTS

Density

Out of 76 individuals of *S. anamallayana* found in *shola* habitat, 47 (32 males and 15 females) were detected using distance sampling. The species was found in 17 of the 18 transects that were sampled in the *shola* habitat. The uniform/cosine model was selected as the most parsimonious model that could fit the data. This model estimated 55.18 individuals ha^{-1} (95% CI: 45.25 and 67.28) in *shola* habitat (Fig. 2; Table 1). In the other habitats sampled it was found only in tea plantations and not in the MEF and eucalyptus plantations. Twenty-five individuals (14 males and 11 females) were observed in tea plantations. The uniform/cosine model estimated 65.7 individuals ha^{-1} (95% CI: 35.67 and 121.00) in tea plantations (Fig. 3; Table 1). There were no significant differences in *S. anamallayana* densities among *shola* and tea plantations (Table 1). The detection probabilities in *shola* and tea plantations were 0.50 and 0.51, respectively. If we assume that all *shola* habitats were equal in quality for the

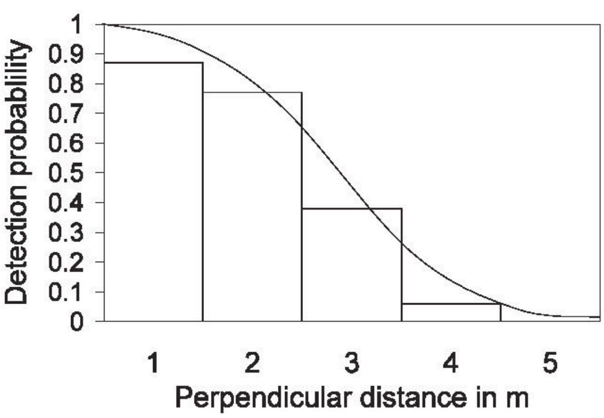

Fig. 2. Distance function curve for *Salea anamallayana* in *shola*.

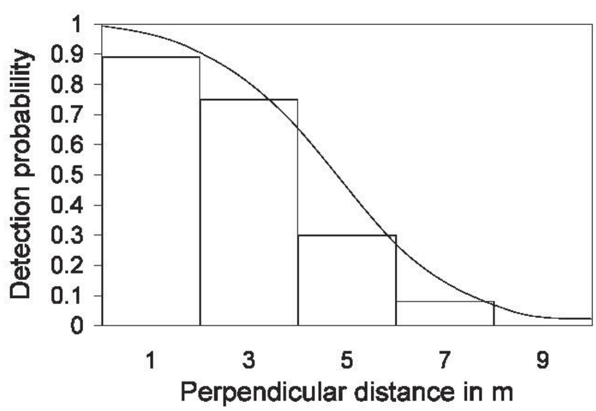

Fig. 3. Distance function curve for *Salea anamallayana* in tea plantations.

Table 2. Percentage compositions of habitat variables used by different age-sex classes of *Salea anamallayana*.

Habitat variables (in class intervals)	Male % (n=39)	Female % (n=24)	Juvenile % (n=14)
Tree height (m)			
0–3.0	38.2	41.2	20.6
3.1–6.1	63.6	24.2	12.1
6.2–9.2	55.6	22.2	22.2
χ^2, df = 2	4.3	2.6	1.0
Perch height (m)			
0.0–1.4	42.4	36.4	21.2
1.5–2.9	55.9	32.4	11.8
>2.9	66.7	11.1	22.2
χ^2, df = 2	2.1	2.1	1.2
Perch thickness (cm)			
0.0–20.0	50.8	33.3	15.9
20.1–40.1	54.5	18.2	27.3
>40.1	50.0	50.0	0.0
χ^2, df = 2	0.0	1.3	1.2
Moisture (%)			
55–66	40.0	33.3	26.7
67–78	53.4	31.0	15.5
>78	66.7	33.3	0.0
χ^2, df = 2	1.1	0.0	1.6
Altitude (m)			
1678–1899	47.3	34.5	18.2
1900–2121	53.8	23.1	23.1
2122–2343	75.0	25.0	0.0
χ^2, df = 2	2.1	0.1	2.0
Temperature (°C)			
16.0–20.0	54.5	32.7	12.7
21.0–25.0	44.4	27.8	27.8
26.0–30.0	33.3	33.3	33.3
χ^2, df = 2	0.9	0.1	2.7
Canopy opening (%)			
7.0–23.0	52.5	32.5	15.0
23.1–39.1	42.9	33.3	23.8
>39.1	60.0	26.7	13.3
χ^2, df = 2	1.0	0.2	0.9

species, we estimate that the *shola* habitat alone in the Eravikulam National Park might support 80,562 individuals, with upper and lower 95% confidence limits of 98,229 and 66,065 individuals respectively. Using the same assumption, we estimate that the tea plantations in the landscape might support 634 individuals, with upper and lower 95% confidence limits of 339 and 1150 individuals, respectively.

Microhabitat association

Seventy-six individuals (39 males, 24 females and 13 juveniles) were recorded in *shola* during the study including the 45 encountered in the *shola* transects. The proportions of individuals in different categories (i.e. males, females and juveniles) were not significantly influenced by microhabitat variables (Table 2). The first two axes of the PCA explained 71% of the variation in the data (Table 3). The categories of individuals did not separate from distinct groups along the axes (Fig. 4). The microhabitat variables TH, PH, PD and ALTD have high absolute correlation with the first axis. The correlations between TH and PH for males (r=0.74, n=39, P<0.01), females (r=0.65, n=24, P<0.01) and juveniles (r=0.94, n=13, P<0.01) were significant.

Table 3. Factor loadings on the principal components (PC) for each habitat variable derived from PCA.

Variable	PC1	PC2
Tree height (m)	*0.949*	–0.225
Perch height (m)	*0.832*	–0.274
Perch diameter (cm)	*0.759*	0.064
Altitude (m)	*0.609*	*–0.670*
Temperature (°C)	0.175	0.486
Humidity (%)	0.179	0.085
Canopy cover (%)	–0.143	*0.958*

Factor loadings >0.5 are in italic.

DISCUSSION

Salea anamallayana has been considered to inhabit the montane *shola* habitat exclusively (Bhupathy & Kannan, 1997). However, the present study shows that a large population of this endemic species survives in intensively managed tea plantations. Line transect sampling proved a reliable method for estimating density of the species in Eravikulam National Park. Our density estimates show that the Park provides protection for critical habitat and therefore a sizable population of the species exists in the area. Since the densities in *shola* and tea plantations were not significantly different, substantial populations of the species might exist in intensively managed tea plantations in the region outside the protected area. The population of the species outside the protected area needs to be documented. Detectability is a critical factor in density estimation and it is influenced by the behaviour of the species, the habitat structure and visibility (Reed, 1995). In the present study detection probabilities in the *shola* and tea plantations did not differ. We speculate that detection might be different in the two sexes, because males are conspicuous and can be spotted easily. The influence of edge effects on the density of the species in the *shola* habitat is not known. These aspects need detailed investigation before the method can be used as a population monitoring technique for the species in the study area.

Salea anamallayana are restricted to the higher altitudes (>1500m) of the Western Ghats (Bhupathy & Kannan, 1997). Tea plantations that occur in this elevation range are suitable habitats for the species. However, eucalyptus plantations in the same elevation range are not suitable habitats because we did not encounter the species in them. Within *shola* habitat, microhabitat variables did not influence the proportions of males, females and juveniles found there, suggesting that the species did not show any segregation for these microhabitats.

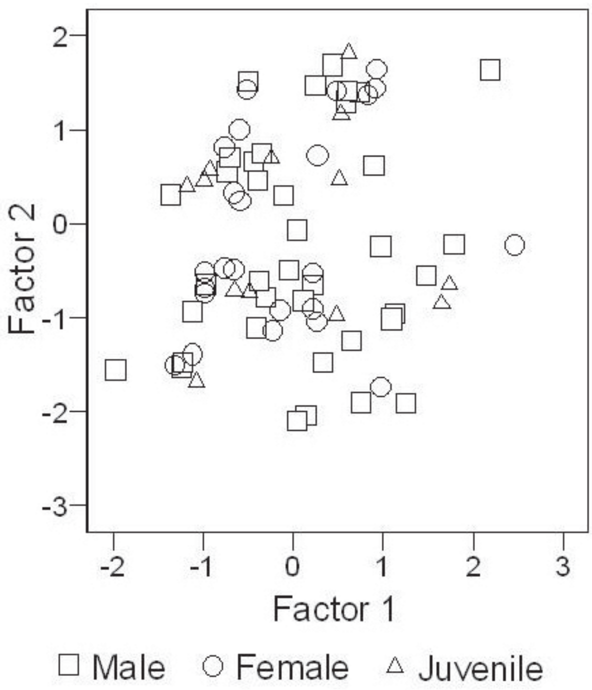

Fig. 4. Scatter plot of 76 *Salea anamallayana* individuals using the first two factors obtained using PCA.

Principal components analysis also showed no difference between groups based on the microhabitats they used. Males, females and juveniles used perches on trees in relation to the tree height. The correlation suggests a probable trade-off between the benefits of basking and costs related to exposure to predation.

Studies have indicated that the geometric configuration of a habitat can serve as a key stimulus in the selection of habitats by reptiles (e.g. Diaz & Carrasal, 1991; Hadden & Westbrooke, 1996; Heatwole, 1977). Fifteen (14 males and one female) of the 25 individuals found in the tea plantations were found on the shade trees (*Grevillea* sp.). In plantations, tea (*Camellia sinensis*) might provide shelter and protection, and the silver oak (*Grevillea* sp.) probably provides perches for basking. This might be one of the many factors that influence their occupancy of the tea plantations.

Distance sampling served as an effective method in estimating densities of the species and it can be used for monitoring their populations in the Western Ghats. It is evident that the species has adapted to live in the tea plantations and is locally abundant where it occurs, yet it might be vulnerable to a variety of threats, such as road traffic, shade tree management and pesticides in tea plantations. Conservation and management of such areas in the Western Ghats will be crucial for the species in a landscape that is dominated by plantation crops.

ACKNOWLEDGEMENTS

The study was conducted as a part of the Master's programme in Bharathidasan University. We thank K. Thiyagesan (Faculty, A.V.C. College) for his valuable inputs in the study, S. Swetharanyam (Head of Department, Department of Zoology, A.V.C. College) for his support in getting the permission from the Kerala Forest Department and M. Varadharajan (Principal, A.V.C. College) for his continuous support. We also thank the Kerala Forest Department for providing permission to carry out this work, B.S. Corrie (IFS, Chief Conservator of Forests (Wildlife), Kerala) and R.P. Thomas (Wildlife Warden, Eravikulam National Park) for providing accommodation inside the Park, S. S. Kumar (Ranger, Eravikulam National Park) for logistical support, the Wildlife Institute of India for supporting this study, B. Pandav for his comments on the manuscript, and A. Harihar for his support during analysis.

REFERENCES

Baillie, J.E.M., Bennun, L.A., Brooks, T.M., Butchart, S.H.M., Chanson, J.S., Cokeliss, Z., Hilton-Taylor, C., Hoffmann, M., Mace, G.M., Mainka, S.A., Pollock, C.M., Rodrigues, A.S.L., Stattersfield, A.J. & Stuart, S.N. (2004). *A Global Species Assessment.* Gland: IUCN – The World Conservation Union.

Beddome, R.H. (1878). Description of a new genus of tree-lizards from the high ranges of the Anamallays. *Proceedings of the Zoological Society of London* 1877, 153–154.

Bhupathy, S. & Kannan, P. (1997). *Status of Agamid Lizards in the Western Ghats of Tamil Nadu, India. SACON Technical Report No. 5.* Tamil Nadu: Salim Ali Centre for Ornithology and Natural History.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. & Thomas, L. (2001). *Introduction to Distance Sampling: Estimating Abundance of Biological Populations.* Oxford: Oxford University Press.

Champion, G.H. & Seth, S.K. (1968). *A Revised Survey of the Forest Types of India.* Dehradun: Natraj.

Das, I. (2002). *A Photographic Guide to Snakes and Other Reptiles of India.* London: New Holland.

Diaz, J.A. & Carrasal, L.M. (1991). Regional distribution of a Mediterranean lizard: influence of habitat cues and prey abundance. *Journal of Biogeography* 18, 291–297.

Gibbons, J.D. (1971). *Nonparametric Statistical Inference.* New York: McGraw-Hill.

Glor, R.E., Flecker, A.S., Bernard, M.F. & Power, A.G. (2001). Lizard diversity and agricultural disturbance in a Caribbean forest landscape. *Biodiversity and Conservation* 10, 711–723.

Hadden, S.A. & Westbrooke, M.E. (1996). Habitat relationships of herpetofauna of remnant buloke woodlands of the Wimmera plains, Victoria. *Wildlife Research* 23, 363–372.

Harlow, P.S. & Biciloa, P.N. (2001). Abundance of the Fijian crested iguana (*Brachylophus vitiensis*) on two islands. *Biological Conservation* 98, 223–231.

Heatwole, H.F. (1977). Habitat selection in reptiles. In *Biology of Reptilia. Ecology and Behaviour*, 137–155. Gans, C. & Tinkle, D.W. (eds). New York: Academic Press.

Jenkins, R.K.B., Brady, L.D., Huston, K., Kauffmann, J.L.D., Rabearivony, J., Raveloson, G. & Rowcliffe, J.M. (1999). The population status of chameleons within Ranomafana National Park, Madagascar and recommendations for future monitoring. *Oryx* 33, 38–46.

Karunakaran, V.P. (1997). *Ecological Studies on the Grassland of Eravikulam National Park, Kerala.* Ph.D. thesis. Rajkot: Saurashtra University.

Nair, S.C. (1991). *The Southern Western Ghats: A Biodiversity Conservation Plan.* New Delhi: Indian National Trust for Art and Cultural Heritage (INTACH).

Ord, T.J. & Stuart-Fox, D. (2006). Ornament evolution in dragon lizards: multiple gains and widespread losses reveal a complex history of evolutionary change. *Journal of Evolutionary Biology* 19, 797–808.

Reed, J.M. (1995). Using statistical probability to increase confidence of inferring species extinction. *Conservation Biology* 10, 1283–1285.

Rice, C.G. (1984). *The Behavior and Ecology of Nilgiri Tahr (*Hemitragus hylocrius *Ogilby, 1938).* Ph.D. thesis. College Station, TX: Texas A & M University.

Smith, M.A. (1935). *Fauna of British India, Including Ceylon and Burma. Reptilia and Amphibia. Vol II: Sauria*. London: Taylor and Francis.

Thomas, L., Laake, J.L., Strindberg, S., Marques, F.F.C., Buckland, S.T., Anderson, D.R., Burnham, K.P., Hedley, S.L., Pollard, J.H. & Bishop, J.R.B. (2003). *UK: Distance 4.1. Release 2.* St Andrews: Research Unit for Wildlife Population Assessment, University of St Andrews. www.rupwa.stand.ac.uk/Distance

Turner, M.G., Carpenter, S.R., Gustafson, E.J., Naiman, R.J. & Pearson, S.M. (1998). Land use. In *Status and Trends of the Nation's Biological Resources, Vol. 1*, 37–61. Mac, M.J., Opler, A., Puckett Haecker, C.E. & Doran, P.D. (eds). Washington D.C.: National Biological Services.

Van Rooy, P.T.J.C. & Stumpel, A.H.P. (1995). Ecological impact of economic development on Sardinian herpetofauna. *Conservation Biology* 9, 263–269.

Vitousek, P.M., Mooney, H.A., Lubchenco, J. & Melillo, J.M. (1997). Human domination of earth's ecosystem. *Science* 277, 494–499.

Accepted: 7 January 2009