# Caecilian diversity of the Western Ghats: In search of the rare animals

## Gopalakrishna Bhatta

Department of Zoology, Sri J.C.B.M. College, Sringeri 577 139, India

The Western Ghats is well known for harbouring 14 endemic species of caecilians (i.e. legless amphibians) out of 15 recorded from the region so far. Ecological diversity of caecilian species was studied through soil excavation and litter-search. A total of 83 individuals belonging to 9 species were collected from 24 collection spots in 8 localities distributed along the Western Ghats. The Chao's index estimates a maximum of 27 species to occur in the Western Ghats whereas the taxonomic literature so far has recorded only 15 species. Field studies and literature review indicated that 10–12°N is the richest latitudinal zone while region 20°N northwards is the poorest in recorded species richness. This pattern coincides with the increasingly drier climate towards North. At the landscape level also, caecilians prefer moist soils rich in organic carbon. Thus, they are quite common not only in evergreen forests but also in orchards of arecanut and coconut which have perennial watersupply but without heavy chemical input.

CAECILIANS are limbless secretive burrowing amphibians. They are probably the earliest land vertebrates and have a long cylindrical body like that of a snake[1]. Instead of epidermal scales, they have rings or annuli on the body. These creatures are generally mistaken for giant earthworms or even for snakes, especially shield tails. As the head and tail prima facie look alike, they are considered as two-headed snakes and most often they become the victims of the spade of farmers.

So far, 205 species of amphibians have been recorded from India[2-4]. Amongst various biogeographic zones, Western Ghats is the richest with 120 species, of which 92 are endemic[2-4]. The Western Ghats with heavy rainfall, fairly moderate temperature, luxuriant growth of vegetation with short dry period provides ideal environmental conditions for the occurrence and abundance of amphibians in general and caecilians in particular. In India, caecilian population consists of 17 species, of which 15 occur in the Western Ghats and of these 14 are endemic[5,6]. Thus, caecilians show one of the highest degrees of endemicity in Western Ghats (92%) in contrast to certain other groups such as birds that are much common, easy to observe, speciose but with very few

endemics (12 out of 507, i.e. 2%)[7]. These creatures feed on earthworms and on the detritus too.

Earlier studies on Indian caecilians were confined to taxonomy, geographical distribution, morphology and reproductive biology; work on ecology and behaviour was meagre[8,9]. For the proper assessment of the status of their occurrence and abundance, extensive systematic survey and an intensive study of the soil and related parameters are essential[2,10]. I report here preliminary work in this direction.

## Materials and methods

In the absence of any established methodology of caecilian sampling, I tried out different search methods. Initially, I extensively surveyed different vegetation types such as evergreen and deciduous forests, grasslands, monoculture plantations, coffee and tea plantations and paddy fields. In particular, orchards of arecanut and coconut, either pure or mixed with coffee, banana, cardamom, etc. were already surveyed at different seasons of the year in 1994. I encountered these creatures only in the evergreen forests and orchards. The preliminary studies carried out at Sringeri and Palakkad in 1995 yielded the same species from the orchards and nearby forests. Besides, orchards had higher density of animals, collection was easier due to greater accessibility and relatively loose soils. Hence, given the time and resource constraints, I chose to survey only orchards, to maximize the efficiency of sampling.

Eight of the sites selected in Western Ghats Biodiversity Network (WGBN)[11] were surveyed for caecilians. They represent eight randomly chosen localities along the foothills of Western Ghats (Table 1). The area of each WGBN study site is approximately 25 km² with a part of it under natural landscape and a part under man-made.

I sampled each of these eight localities for a few days during monsoon (i.e. June to September) of 1995. At each collection spot, the soil around the bases of coconut and arecanut trees was excavated to a depth of about 5 to 45 cm for searching the animals. In some areas, simple turning of the piled up rotting leaves of coconut or arecanut leaf sheaths resulted in the sighting of

183

**Table 1.** Localities, geography, climate, sampling efforts and species encountered

| Site no. | Locality | Latitude (°N) | Longitude (°E) | Altitude (m ASL) | Rainfall (mm/yr) | Dry months (/yr) | Duration (min) | Area searched (m²) | No. of spp. | Species abbr. | No. of individuals |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Supegao | 18.25' | 73.45' | 300 | 3000 | 7 | 210 | 175 | 2 | inb, ibd | 3 |
| 2 | Mala | 13.02' | 75.15' | 200 | 6000 | 5 | 120 | 100 | 1 | ibd | 3 |
| 3 | Mala | 13.02' | 75.15' | 200 | 6000 | 5 | 90 | 75 | 1 | iml | 1 |
| 4 | Neggu | 14.33' | 74.39' | 600 | 3000 | 6 | 55 | 45 | 1 | ibd | 4 |
| 5 | Neggu | 14.33' | 74.39' | 600 | 3000 | 6 | 60 | 60 | 1 | ibd | 1 |
| 6 | Neggu | 14.33' | 74.39' | 600 | 3000 | 6 | 150 | 125 | 1 | iml | 1 |
| 7 | Badal | 14.28' | 74.29' | 100 | 4000 | 6 | 120 | 90 | 1 | ibd | 9 |
| 8 | Badal | 14.28' | 74.29' | 100 | 4000 | 6 | 60 | 50 | 1 | ibd | 1 |
| 9 | Kigga | 13.26' | 75.10' | 800 | 6000 | 5 | 120 | 95 | 1 | ibd | 3 |
| 10 | Kigga | 13.26' | 75.10' | 800 | 6000 | 5 | 125 | 100 | 1 | ibd | 4 |
| 11 | Kigga | 13.26' | 75.10' | 800 | 6000 | 5 | 60 | 50 | 1 | ibd | 1 |
| 12 | Kigga | 13.26' | 75.10' | 800 | 6000 | 5 | 45 | 36 | 1 | ibd | 1 |
| 13 | Karimba | 11.00' | 76.32' | 300 | 5000 | 4 | 235 | 192 | 3 | isp2,itr,ibd | 6 |
| 14 | Karimba | 11.00' | 76.32' | 300 | 5000 | 4 | 80 | 80 | 2 | iml,isp2 | 4 |
| 15 | Karimba | 11.00' | 76.32' | 300 | 5000 | 4 | 195 | 180 | 1 | iml | 1 |
| 16 | Karimba | 11.00' | 76.32' | 300 | 5000 | 4 | 110 | 85 | 1 | isp3 | 1 |
| 17 | Karimba | 11.00' | 76.32' | 300 | 5000 | 4 | 185 | 180 | 1 | un | 8 |
| 18 | Thiruambadi | 11.15' | 76.10' | 800 | 4000 | 4 | 175 | 160 | 2 | un,ilg | 5 |
| 19 | Thiruambadi | 11.15' | 76.10 | 800 | 4000 | 4 | 95 | 75 | 1 | ilg | 1 |
| 20 | Thiruambadi | 11.15' | 76.10' | 800 ᵥ. | 4000 | 4 | 55 | 45 | 2 | un,ilg | 8 |
| 21 | Thiruambadi | 11.15' | 76.10' | 800 | 4000 | 4 | 110 | 85 | 1 | un | 3 |
| 22 | Thiruambadi | 11.15' | 76.10' | 800 | 4000 | 4 | 50 | 48 | 1 | un | 1. |
| 23 | Vithura | 8.40' | 77.10' | 300 | 2000 | 3 | 65 | 60 | 1 | gra | 7 |
| 24 | Vithura | 8.40' | 77.10' | 300 | 2000 | 3 | 35 | 30 | 1 | gra | 6 |
| | | | | | Mean | | 108.54 | 92.54 | 1.3 | | 3.45 |
| | | | | | s.d. | | 56.02 | 49.14 | 0.5 | | 2.59 |
| | | | | | total | | 2605 | 2221 | 9 | | 83 |

inb, *Indotyphlus battersbyi*; ibd, *Ichthyophis beddomei*; itr, *I. tricolor*; iml, *I. malabarensis*; isp 2, 3, *I.* species 2, 3; ilg, *I. longicephalus*; gra, *Gegeneophis ramaswami*; un, *Uraeotyphlus narayani*.

caecilians. The area covered and time spent for searching, the altitude of the locality, the soil and atmospheric temperature are provided in Table 1. The soil samples from the places where caecilians inhabited were collected and got analysed at the Agricultural University, Gandhi Krushi Vigyaan Kendra, Bangalore for physical and chemical parameters (Table 2).

Altogether I spent over 2600 minutes in merely excavating or litter-searching an area of 2200 m² distributed over 24 collection spots from 8 localities. This yielded 3.5 ± 2.5 specimens and 1–2 species per site. In all, I encountered 9 species from a total of 83 individuals sampled in the 8 areas. The most dominant species *Icthyophis beddomei* occurred in 6 out of 8 localities and contributed more than a third (31) of the total (83) individuals. Six out of 9 species encountered only in a single locality and one each from two and three localities.

Extrapolating the number of species in a community or a region based on sampling is a question of great scientific interest. For this purpose, by using the parameters of lognormal distribution is one popular, older method[12], which requires data on over 200 individuals.

The other option is to use recently discussed Chao index, which is the least negatively biased estimater of the total species richness than Simpson's, Shanon's and other indices of diversity[12]. Besides, it can work reasonably well with small sample sizes. Chao's estimate of species richness of the population is given as follows:

$$S_{\text{expected}} = S_{\text{observed}} + \frac{(S_{\text{one sample}})^2}{2 \times (S_{\text{two samples}})},$$

where $S$ denotes species richness, for the target population.

## Results and discussions

Figure 1 shows that the mean of Chao's estimate increases with increasing number of localities sampled, as expected. However, as the figure indicates, the upper limit of the range – 27 species – is nearly the same irrespective of whether collection is from 4, 5, 6 or 7 localities drawn randomly. At this stage, I am not sure if this upper limit would ever be reached but it does sug-

Table 2. Soil parameters from study sites

| Site no. | Locality | Soil temp. (°C) | Relative humidity (%) | pH | Electrical conductivity (dS/m) | Organic C (%) | Exchang. Ca Cmol(p+) /kg | Exchang. Mg Cmol(p+) /kg | Available K$_2$O (kg/ha) | Available P$_2$O$_5$ (kg/ha) | Total N (%) | Available S (ppm) | Exchangeable Na (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Supegao | 25.5 | 95.02 | 6.46 | 1.67 | 7.98 | 14.4 | 4.64 | 1370 | 31.45 | 0.65 | 65.55 | 144.4 |
| 2 | Mala | 26 | 42.95 | 6.47 | 0.53 | 2.76 | 3.33 | 2.63 | 371 | 69.02 | 0.19 | 36.33 | 140 |
| 3 | Mala | 26 | 56.78 | 6.59 | 0.77 | 4.84 | 5.51 | 4.9 | 1740 | 27.36 | 0.03 | 29.36 | 157.5 |
| 4 | Neggu | 26 | 42.1 | 6.63 | 0.77 | 6.62 | 7.79 | 6.65 | 734 | 90.26 | 0.46 | 54.15 | 102 |
| 5 | Neggu | 26 | 42.1 | 6.64 | 0.2 | 2.21 | 4.55 | 2.01 | 198 | 30.22 | 0.04 | 29.21 | 76.6 |
| 6 | Neggu | 26 | 65.64 | 6.93 | 0.48 | 6.02 | 10.6 | 3.678 | 103 | 75.15 | 0.39 | 53.64 | 100.6 |
| 7 | Badal | 26.5 | 34.98 | 6.99 | 0.47 | 4.58 | 6.65 | 5.86 | 296 | 332.89 | 0.11 | 27.07 | 81.9 |
| 8 | Badal | 26 | 54.92 | 7.04 | 0.49 | 7.93 | 12.2 | 6.39 | 1034 | 111.91 | 0.03 | 65.55 | 111.6 |
| 9 | Kigga | 22.5 | 38.45 | 7.05 | 0.22 | 2.29 | 4.29 | 1.71 | 1223 | 23.28 | 0.15 | 57 | 146.6 |
| 10 | Kigga | 25.5 | 45.41 | 6.09 | 0.32 | 2.84 | 3.94 | 2.89 | 405 | 7.76 | 0.23 | 21.37 | 87 |
| 11 | Kigga | 25.5 | 50.59 | 5.89 | 0.42 | 5.13 | 5.69 | 1.92 | 381 | 31.85 | 0.35 | 47.73 | 111.8 |
| 12 | Kigga | 22.5 | 19.35 | 6.52 | 0.32 | 2.76 | 4.11 | 1.49 | 465 | 123.35 | 0.19 | 32.77 | 135.6 |
| 13 | Karimba | 25 | 40.69 | 7.35 | 0.64 | 4.11 | 1.49 | 1.14 | 84 | 153.57 | 0.27 | 37.05 | 74.4 |
| 14 | Karimba | 24 | 29.54 | 6.59 | 0.54 | 1.78 | 5.43 | 0.26 | 461 | 241.79 | 0.12 | 28.5 | 74.4 |
| 15 | Karimba | 24 | 29.22 | 6.97 | 0.29 | 2.03 | 5.08 | 1.49 | 409 | 253.2 | 0.08 | 34.2 | 105 |
| 16 | Karimba | 24 | 39.62 | 7.04 | 0.18 | 2.37 | 3.76 | 3.5 | 1740 | 46.15 | 0.20 | 29.1 | 111.6 |
| 17 | Karimba | 24 | 29.22 | 6.97 | 0.29 | 2.3 | 5.08 | 1.49 | 409 | 253.2 | 0.08 | 34.2 | 105 |
| 18 | Thiruambadi | 23 | 58.1 | 7.67 | 0.58 | 4.45 | 8.49 | 5.6 | 3528 | 256.5 | 0.06 | 35.62 | 150.9 |
| 19 | Thiruambadi | 24 | 48.43 | 6.81 | 0.39 | 5.3 | 9.8 | 2.54 | 1072 | 144.59 | 0.45 | 59.14 | 157.5 |
| 20 | Thiruambadi | 24.5 | 58.1 | 6.31 | 0.14 | 3.39 | 3.06 | 3.33 | 940 | 96.8 | 0.02 | 22.08 | 120.3 |
| 21 | Thiruambadi | 24 | 37.5 | 5.46 | 0.08 | 3.9 | 6.65 | 5.16 | 960 | 8.98 | 0.24 | 26.36 | 144 |
| 22 | Thiruambadi | 22 | 35.57 | 6.59 | 0.27 | 3.9 | 5.08 | 4.11 | 400 | 42.47 | 0.29 | 21.38 | 131.3 |
| 23 | Vithura | 25.5 | 41.14 | 5.91 | 0.04 | 1.36 | 2.1 | 1.31 | 188 | 8.17 | 0.11 | 17.81 | 17 |
| 24 | Vithura | 25.5 | 28.73 | 6.39 | 0.08 | 1.7 | 2.28 | 1.31 | 103 | 15.52 | 0.1 | 19.95 | 76.6 |
| | Mean | 24.72 | 44.33 | 6.64 | 0.42 | 3.86 | 5.89 | 3.17 | 775.5 | 103.14 | 0.20 | 36.88 | 110.98 |
| | SD | 1.28 | 15.23 | 0.48 | 0.33 | 1.87 | 3.17 | 1.82 | 751.7 | 95.02 | 0.16 | 14.55 | 33.48 |
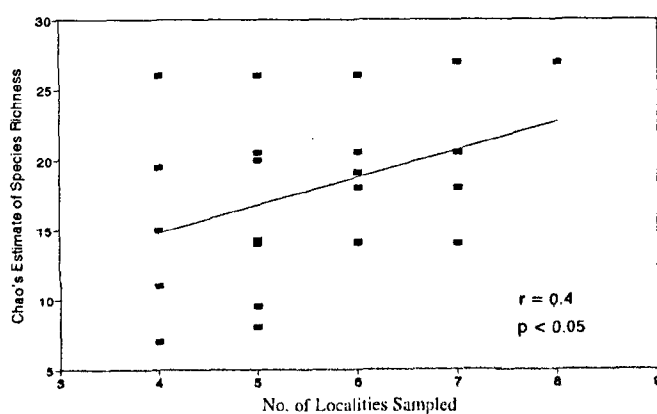


Figure 1. Species richness extrapolation. Chao's estimate of total species richness in the caecilian community of the Western Ghats. The number of randomly picked sites varies from 4 to 7. Mean value for each set has a positive correlation with the number of sites indicating that more the samples, the greater is the estimate of expected species in the entire population. However, the upper range of the estimate has remained nearly at a constant level of about 27 species.

gest that further sampling is likely to add a few new species. In fact, even data from 4 randomly chosen localities yielded a mean Chao's estimate of 15, and this itself equals the total recorded species so far. So there is

good chance of discovering newer species with additional sampling.

The caecilians occurred from the surface to a depth of around 45–60 cm in the rainy season and at the edges of
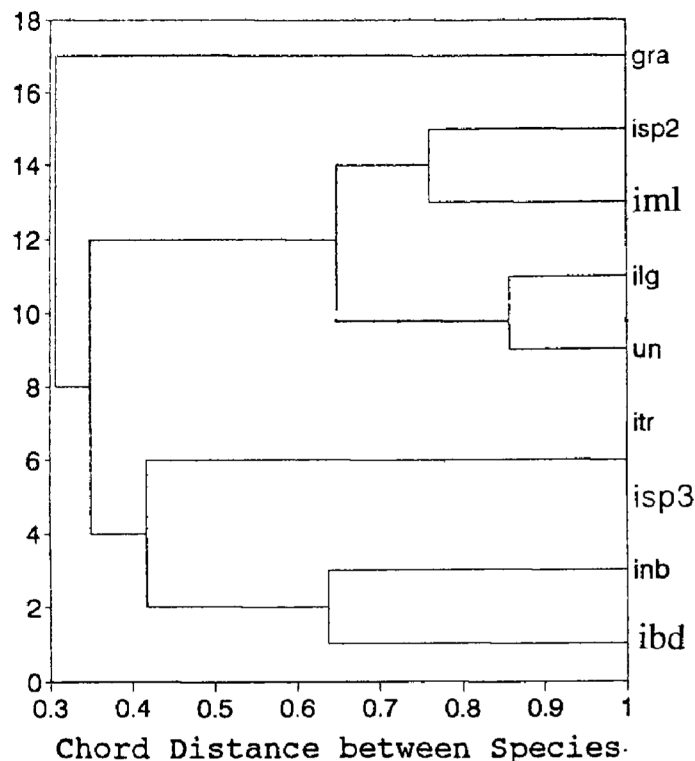
**Figure 2.** Clustering of species using soil parameters. The average linkage dendrogram of species on the basis of chord distances between them calculated using their relative mean soil parameter values does not show separate clusters. This indicates that caecilians seem to differ only moderately and in fact tend to have some niche overlap in terms of soil preference. inb, *Indotyphlus battersbyi*; ibd, *Ichthyophis beddomei*; itr, *I. tricolor*; iml, *I. malabarensis*; isp 2, 3, *I.* species 2, 3; ilg, *I. longicephalus*; gra, *Gegeneophis ramaswami*; un, *Uraeotyphlus narayani*.

streams or irrigation canals during dry season. Orchards with high organic matter content had more number of animals than other gardens. Generally, caecilians were seen in the orchards with perennial source of water. Caecilians were very few or absent in the orchards without organic content/and were never seen in the gardens which had used either chemical fertilizers or lime. The absence of caecilians in the soils with low organic content may be due to dearth of food – either earthworms or detritus.

Caecilians were encountered all over the altitudinal range surveyed – 15 m to 700 m from the mean sea level. Further, as a group, caecilians are known to be widely distributed from the sea level to an elevation of more than 2500 m (refs 5, 14, 15). The present sampling levels are too inadequate to determine if different species have characteristic, different elevational ranges and preferences. Figure 2 illustrates the dissimilarity in the soil parameters of the collection spots of different species, expressed as single linkage clustering based on chord distance, calculated using matrix of 9 species and 14 soil parameters. The chord distance is given as:

$$d_{ij} = \sqrt{2\left(1 - \frac{(\Sigma x_{ij}\Sigma x_{ik})}{\sqrt{(\Sigma x_{ij}^2 \Sigma x_{ik}^2)}}\right)},$$

where $d_{ij}$ is the chord distance, $x_{ij}$ and $x_{ik}$ are abundance values of species in transects $j$ and $k$ respectively. As the dendrogram in Figure 2 shows, there are no separate clusters. Thus, the caecilian species seem to differ only moderately from each other and have some niche overlap in terms of soil preference. However, this topic requires much more intensive research as our sample size is limited.

The distribution pattern of different species of caecilians based on my own surveys as well as literature indicates that the latitudinal zone 10–12° is the richest and 20–30° is the poorest (Figure 3). Admittedly neither myself nor the other researchers have sampled the northern latitudes to the extent of southern region. This is primarily due to initial experience that the species catch is less in the North. Further research would throw more light on the prevailing belief that the distribution and diversity of caecilians in Western Ghats is nega-
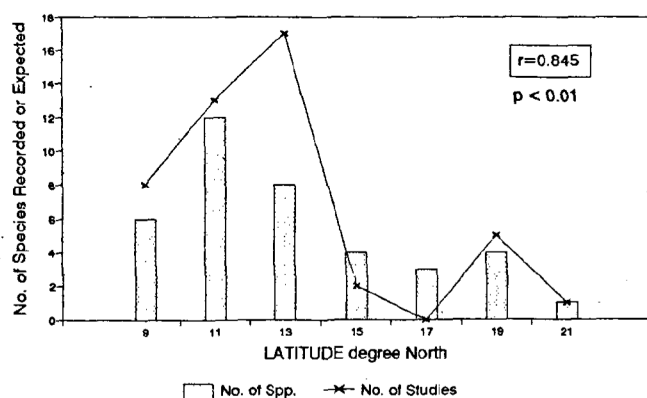
**Figure 3.** Regional distribution pattern. The figure shows the number of recorded species expected/reported to occur in each latitudinal zone of the Western Ghats. The assumption here is that a species is quite likely to occur in all the latitudinal zones in between its known northernmost and southernmost locations. Even if this is not the actual pattern for all species as some of the species may show clumped distribution, the trend that species richness reduces with decreasing dry period as seen here, might not change much.

tively correlated with the length of the dry period which increases northwards, just like in case of frogs and toads.

1. Maurice and Burton, R., in *Encyclopedia of the Animal Kingdom*, Macdonald & Co. London, 1988, p. 470.
2. Inger, R. F. and Dutta, S. K., *J. Bombay Nat. Hist. Soc.*, 1986, 83, 135–146.
3. Daniels, R. J. R., *J. Biogeogr.*, 1992, 19, 521–529.
4. Daniels, R. J. R., *Cobra*, 1997, 27, 1–25.
5. Taylor, E. H., *The Caecilians of the World*, University of Kansas Press, Lawrence, 1968, p. 848.
6. Pillai, R. S., *Rec. Zool. Surv. India*, 1986, 84, 229–242.
7. Daniels, R. J. R., Joshi, N. V. and Gadgil, M., *Proc. Nat. Acad. Sci. USA*, 1992, 89, 5311–5315.
8. Bhatta, G., Ph D thesis, Karnatak University, Dharwad, 1986, pp. 281.
9. Gundappa, K. R., Ph D thesis, University of Mysore, 1985, p. 100.
10. Ravichandran, M. S. and Pillai, R. S., *Zoo's Print*, 1986, 11, 1–3.
11. Gadgil. M., *Curr. Sci.*, 1996, 70, 36–44.
12. Ludwig, J. A. and Raynolds, J. F., *Statistical Ecology: A Primer on Methods and Computing*, John Wiley & Sons, New York, 1988.
13. Colwell, R. and Coddington, J. A., in *Biodiversity Measurement and Estimation* (ed. Hawksworth, D.), Chapman and Hall, London, 1995, pp. 101–118.
14. Nussbaum, R. A., in *Biogeography and Ecology of the Seychelles Islands* (ed. Stoddart, D. R.), Junk Pub., The Hague, 1984, pp. 379–415.
15. Hebrard, J. J., Maloty, G. M. O. and Alliangana, D. M. I., *J. Herpetol.*, 1992, 26, 513–515.