LIMBLESS AMPHIBIANS OF WESTERN GHATS

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1. PREFACE

Most of the people are unaware of these snake like amphibians i.e. caecilians. When laymen are probed about these animals, they generally say that they encounter them here and there. Actually the animal they refer is a snake with blunt tail - a shield tail or a blind snake Typhlops. How I got interested in these creatures is somewhat fascinating. In 1980 at the fag end of my lecture hour while I was narrating the myths regarding snakes, one of the student stood up and said that he has seen double headed snakes and if I wish, he is prepared to bring one to the college the next day. To my surprise it was a caecilian, about which I had no idea of their occurrence in the surroundings of Sringeri.

I chose this animal for my Ph.D. thesis and studied some aspects of ecology and gonadal - interrenal - pituitary interrelationships in the reproductive cycle in one of the caecilian species, i.e. *Ichthyophis beddomei*. In the succeeding years, I reared a few caecilians to study their behaviour.

With myself joining the Western Ghats Biodiversity Network, the interest in these animals once again cropped up when Prof. Madhav Gadgil, Centre for Ecological Sciences, Indian Institute of Science, Bangalore inspired me to take up the survey of caecilians in selected sites of Western Ghats. He also brought me an opportunity to visit the Natural History Museum, London, which helped me to have a detailed comparative study of caecilians across the globe. Prof. Gadgil's encouragement and the co-operation of my colleagues who worked as Investigators in Western Ghats Biodiversity Inventorying Programme at different sites enabled me to conduct a preliminary survey across the Western Ghats and subsequently produce the treatise. I wish, it encourages many others to take interest and widen their knowledge in this field.

2. ACKNOWLEDGEMENTS

Prof Madhav Gadgil, Centre for Ecological Sciences, Indian Institute of Science, Bangalore suggested and encouraged that I conduct survey of caecilians in the Western Ghats He facilitated it by providing financial assistance for the field and lab work through PEW Foundation grant The Principal Investigators at different sites of Western Ghats Biodiversity Network extended all sorts of co-operation either by joining with me in the field survey or by sparing the services of their students The local people and my students Sri Prashanth, Sri Raghuram Shetty and Sri Sampath helped me in the search of animals and in soil samples collection My department attender Sri K. Paddu, his wife Smt. Susheela and daughter Ms. Jyothi all took pains in maintaining the laboratory. Mr. Shekar, a school boy from nearby Taluk was very punctual in supplying the food for caecilians. Dr. Sreenivasamurthy, C. A. and Dr. Nagaraj, M. S. from University of Agricultural Sciences, G.K.V.K., Bangalore spared their valuable time for soil analysis My wife Smt. Pushpalatha, B. dedicated her precious time in giving valuable suggestions and assisting in rearing some species of caecilians for the purpose of behavioural study. The past and present Principals of my College, Prof. M. Krishnappaiah and Prof. T. S. Venkanniah respectively extended kind help. The management of my College graciously provided me the space for establishing the 'live-museum' of caecilians and also permitted to involve myself in research during my free time. Sri. Utkarsh Ghate, Centre for Ecological Sciences, Indian Institute of Sciences, Bangalore extended great help in designing the experiment and in the preparation of manuscript. My colleague Dr. U. S. Aithal critically gone through this report. Mr. Sanjeeva Nayaka produced beautiful illustrations. Ms. Mary Sunitha's timeless efforts in extending secretarial help are praiseworthy. It is the wholehearted support of all of them that has enabled me to come out with this report on 'Caecilians of Western Ghats'. I am indebted to one and all.

3. ABSTRACT

Caecilians are limbless amphibians of great ecological significance. However, their cryptic nature and difficult taxonomy has resulted in such large gaps in our knowledge about them that the amphibian biology is largely described on the basis of the other two orders - Anura and Urodela (frogs and salamanders). India, one of megadiversity countries, is amongst the richest countries in caecilians also and out of 16 species reported from India, 14 all endemic occur in the Western Ghats, one of the worlds 18 biodiversity hotspots.

I present here consolidated account of my fieldwork in the Western Ghats, study of museum holotypes and literature. I used metric multidimensional scaling for 16 species on the basis of 11 morphometric parameters to depict the morphological dissimilarities between species and more so genera. I describe here simple key characteristics for their field identifications and scattered data on 15 other parameters for generating wider interest.

During ecological sampling in 24 collection spots in 8 village landscapes distributed across the Western Ghats, I encountered 83 individuals belonging to 9 species. Altogether I searched for 2600 minutes, and searched in surface litter or dug soil over 2200 sq. m. area with a capture rate of 2 individuals/ hour and 4 individuals/ 100 sq m respectively. I applied Chao's Index to these data to estimate that maximum number of species that may occur on Western Ghats which may be 27. This indicates that there may be nearly as many more species to be discovered as currently known. Field and literature studies revealed 10 - 12°N as the latitudinal zone harbouring greatest recorded species richness and the northern drier latitudes are poorest. Further the caecilian diversity is positively correlated with moisture even at the landscape level. Caecilians were found to occur in everwet soil rich in organic carbon and temperatures around 24.5 ± 1 °C. The clustering of species on the basis of soil parameters showed their commonly shared narrow microhabitat preference that is considerable niche overlap. Nevertheless, it also pointed out subtle differences across species, if any.

Interestingly, the caecilians unlike many frog species are not readily susceptible to extinction with forest depletion as they are common in orchards such as of arecanut and coconut which have perennial water supply but without heavy chemical input. This suggests that some kind of human interventions or landuses may be compatible with conservation of certain elements of biodiversity. Caecilians appear to be promising indicator group for assessing diversity of many such elements.

The rearing of caecilians not only turned out to be successful experiment but also provided unique data on foraging and metabolism. Further, it not only enabled studies on their breeding behaviour but also successful breeding that opens up promising possibilities of ex situ conservation.

Keywords: Herpeto fauna, habitat ecology, biodieography, species diversity, taxonomy, morphometry, soil parameters, behaviour, nutrition, ex situ breeding, conservation.

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1. INTRODUCTION

The amphibians are the first land dwelling vertebrates. Even though the class Amphibia includes 3 orders viz. Anura, Urodela and Gymnophiona, the present day knowledge of amphibian biology is mainly based on the studies of anurans (frogs and toads) and urodeles (salamanders and newts). Difficulty in studying caecilians results in their scientific ignorance which in turn leads to their popular ignorance. Caecilians are rarely encountered by casual naturalists owing to their burrowing, secretive and nocturnal life. Deliberate search in their preferential habitats is a prerequisite for their natural history studies. Since they are burrowing forms, rearing these animals in captivity is also a difficult task. One has to maintain an environment similar to that of its natural habitat which is a laborious work.

1.1 GENERAL BIOLOGY

The caecilians are limbless secretive burrowing amphibians with a long cylindrical body like that of snakes (Fig. 1), but instead of having visible epidermal scales, they have rings or annuli on the body. These creatures are generally mistaken for giant earthworms or snakes. Especially shield tail snakes are often confused with them as both groups share nearly the same habitat and geographical distribution. Of course, shield tails also marginally occur in the drier areas. These blind creatures possess small eyes, sometimes covered with skin, a pair of nostrils at the top of snout and a pair of sensory tentacles on either side of the head. The terminal or subterminal mouth has two rows of teeth on the upper jaw and one or two rows of teeth on the lower jaw. These teeth are modified for holding and cutting the prey. The tongue is fused with the floor of the buccal cavity and it cannot be protruded. The body colour varies considerably across species, having shades of violet, brown, grey and black. Some have bright yellow lateral stripes. The skin is smooth and slimy and in most of the species there are small scales embedded in it. It secretes mucus which is quite toxic to predators. A short tail may or may not be present and the anal opening is longitudinal or transverse. External morphological differences between male and female do not exist. Males have single protrusible copulatory organ - the phallodaeum, which is inserted into the vent of the female during copulation, and hence the fertilization is internal.

The caecilians reported so far from India are all terrestrial and oviparous. The female lays clutch of eggs (the number of eggs vary across species) in a burrow near streams. The eggs are connected to each other with a gelatinous string. The mother coils her body around the egg clutch until they hatch. The larvae have external gills at the time of hatching and soon wriggle into the water. Immediately they loose the gills and metamorphose into terrestrial adults. Most of the caecilians probably have earthworms as the main diet and a few may eat termites and other soil invertebrates. Caecilians are preyed upon by certain large snakes, birds, wildboars and also domestic chickens and pigs (Nussbaum, 1992). Probably the tentacles are used for finding the prey (ibid.).

1.2 HABITAT REQUIREMENTS

Caecilians which live from sea level to different altitudes generally inhabit loose moist soil rich in humus. They are found in decaying wood, moist leaf litter and in piles of decaying coconut leaves, arecanut leaf sheaths and their husks. Some of them are seen at varying depths in the cavities at the bases of roots of banana, coconut and arecanut trees and also at the bases of coffee/ tea plants in plantations. They do occur in compost heaps/ manure pits containing decaying leaves mixed with dung. Caecilians are common in fallow plots of mature areca, banana, coffee, rubber and coconut plantations. Their abundance is enriched by cool temperature, perennial water and high organic content of the soil. During wet season they come close to the surface of the soil, lie beneath rotting vegetation and move about freely at night, while in dry season they take refuge at the edges of the small streamlets or irrigation canals running, through plantation areas. They form tunnels in the loose soil by pressing their head onto the ground. Caecilians are not uncommon in the backyard of farm houses or crossing roads at night in the rainy season. The local farmers generally encounter these animals when they use spades to turn over the soil and kill them believing that they are poisonous snakes.

1.3 EVOLUTIONARY SIGNIFICANCE

Current theories regarding amphibian evolution have been substantiated based on the characters of anurans and urodeles. The information on physiology, ecology, life history and behaviour of caecilians must be available before any sound conclusions on amphibian evolution could be drawn (Wake, 1968; Lofts, 1974, 1984; Nussbaum and Wilkinson, 1989; Saidapur, 1989). The caecilians are the first vertebrates to live permanently on land and are evolved from air breathing lobe-finned fishes. These ancient amphibians gave rise to present day amphibians on one hand and reptiles on the other (Maurice and Burton 1988), thus they link fishes, amphibians and reptiles. The caecilians must be the direct surviving descendants of those primitive amphibians which had lived about 400 million years ago. This is quite evident by the relationship seen in the degenerate scales found in the caecilian skin and also the similarity between caecilian skull with that of giant amphibians lived in the past. Hence further study on caecilians is essential from the evolutionary perspective as they are a link with large extinct amphibians.

2. EARLIER WORK

2.1 GLOBAL DIVERSITY

Caecilians comprise one of the three extant orders of amphibians. Being pantropical in distribution caecilians are found mainly in America from Mexico to northern Argentina, parts of Africa and the Seychelles Islands; and Southeast Asia from South China, India and Sri Lanka to South Phillipines. (Wake 1986; Maurice and Burton 1988; Hedges et al 1993). There are approximately 175 species of caecilians belonging to some 36 genera and 6 families (Duellman and Trueb 1986; Nussbaum and Wilkinson 1989; Wake 1993). Of the six families, Rhinatrematidae and Ichthyophiidae are considered to be relatively primitive, Scolecomorphidae, Caeciliidae and Typhlonectidae as advanced and Uraeotyphlidae as somewhat intermediate between the primitive and advanced caecilians (Nussbaum 1992). The characteristics of primitive caecilians are - terminal mouth, numerous skull bones and scales, a short tail and the primary annuli subdivided into secondary and tertiary annuli. A recessed mouth, reduction in the number of skull bones and scales, absence of tail and tertiary annuli are considered as important features of advanced caecilians. The Uraeotyphlids - the transitional caecilians possess both primitive and advanced characteristics. Numerous skull bones and scales, a short tail are primitive, and recessed mouth, tentacles very far forward of the eyes, the presence of primary and secondary annuli, a dual jaw closing mechanism are advanced features in them.

2.2 STUDIES OUTSIDE INDIA

A perusal of literature on caecilians indicate that most of the earlier studies which are quite limited are concentrated around taxonomical and morphological details. (Taylor 1960a, 1960b, 1961, 1964, 1965, 1968, 1969a, 1969b, 1969c, 1969d, 1969e, 1969f, 1970a, 1970b, 1970c, 1970d, 1970e, 1972, 1973, 1974, 1977a, 1977b; Wake 1970, 1972, 1977, 1980, 1986, 1993; Nussbaum 1979, 1983; Nussbaum and Wilkinson 1989; Duellman and Trueb 1986; Wilkinson 1989, 1992; Exbrayat 1989a, 1989b, 1992, 1993; Hedges et al 1993; Hass et al 1993). Information concerning the ecology, ethology and reproduction biology of caecilians is meager (Wake 1977, 1980; Nussbaum 1983, 1984; Exbrayat and Delsol, 1985; Hebrard et al 1992; Ducey et al 1993). This is because caecilians are rarely encountered in the field (Parker, 1960) due to their secretive mode of life and nocturnal habit, although they are quite common in suitable habitats (Maurice and Burton 1988).

The caecilian diversity was known very little prior to the publication of Taylor's monumental monograph "Caecilians of the World" (Taylor 1968). Despite this publication, much remains to be known. There are too few specimens available in museums to assess the validity of many species or to confidently decide whether some specimens represent undescribed species. Many species are represented by one or a few specimens. Some of which were collected more than hundred years ago and are without explicit information on locality and environment (Nussbaum and Wilkinson, 1989).

2.3 STUDIES IN INDIA

The earlier studies on Indian caecilians are confined to taxonomy and geographical distribution (Boulenger 1890; Alcock 1904; Annandale 1909; Seshachar and Iyer 1932; Seshachar 1939a; Seshachar and Ramaswami 1943,; Abdulali 1954; Taylor 1960a, 1960b, 1961, 1964, 1968, 1970e; Daniel 1963; Tikader 1964; Jaisingh 1978; Rahman and Rajagopal 1978; Gundappa et al 1981; Balakrishna et al 1982a, 1982b; Gundappa 1985; Bhatta 1986, 1997; Pillai 1986; Das and Whitaker 1990; Krishnamurthy and Katre, 1993) morphology and biology of reproduction (Seshachar 1936, 1937a, 1937b, 1938, 1939b, 1940, 1941, 1942a, 1942b, 1943, 1945, 1948; Ramaswami 1942, 1943, 1944, 1947, 1980; Seshachar et al 1982; Bhatta 1986; Masood-Parveez 1987; Josekumar and Oomen, 1989; Sutharam and Oomen, 1989; Masood-Parveez et al 1992, 1994; Masood-Parveez and Nadkarni 1991, 1993a, 1993b) and little work on ecology and behavioural aspects (Gundappa 1985; Bhatta 1986, 1997). By the above cited literature it is clear that no sincere efforts have been made to survey the caecilian population in India. Their distribution and habitat requirements are very poorly known. To make the proper analysis of the status of Indian caecilians, there is the necessity of extensive systematic survey of the humid forested areas of Western Ghats, North-East India and Eastern Ghats (Inger and Dutta 1987). Further an intensive study of the soil and related factors is also essential to understand the microhabitat of these burrowing forms (Ravichandran and Pillai 1996).

2.4 WESTERN GHATS DIVERSITY

Western Ghats have been identified as one of the 18 hotspots of biodiversity in the world, and highly endemic amphibian fauna is an important factor in the selection (WCMC, 1988) India is known to harbour around 205 species of amphibians of which 120 occur in the Western Ghats (Daniels, 1992, 1997). So far 17 species of caecilians (Table 1) are reported from India (Taylor, 1968; Pillai, 1986), out of which 3 genera and 14 species are endemic to Western Ghats. But in North East India around 53 species of anurans and only 2 species of caecilians are reported (Inger and Dutta 1987). As Western Ghats and North East India have similar climatic conditions with almost equal rainfall, it is reasonable to predict more of caecilian diversity in the latter region also. Thus there is a need for the extensive exploration of these creatures in North East India. The particulars of different species of caecilians found in India, their locality of collection and source of references are presented in Table - 2. The localities of caecilian collection are depicted in Fig. 2. All the three groups of caecilians (Nussbaum 1992) - primitive, advanced and transitional are represented in India. It is quite interesting to note that Uraeotyphlids, the transitional caecilians are found only in India and nowhere else. To understand the significance of such a restricted distribution, detailed study of the members of this family is very essential.

An important question that arises here is, although there occur a few species of caecilians on the Western Ghats why most of these are endemic to it? Probably the present day caecilian fauna represents relict of the earlier much wide-spread peninsular Indian population during the geological history when rain forests were spread upto Rajasthan and Bengal till Pliocene (Meher Homji 1989). With the onset of the Himalayas and monsoon climate after the humid peninsular Indian plate forced unto the Asian plate after mid - Miocene, most of the peninsular India dried up except the Western Ghats. Naturally, much of the humid zone biota that was sheltered in the Ghats could survive and evolve to a limited extent. Unlike most birds, amphibians are poor dispersers, with restricted geographical ranges (Daniels 1992, Daniels et al 1992). This might have resulted in such a large proportion of the locally adapted and confined species.

2.5 TAXONOMIC DRAWBACKS

Incorrect taxonomic identity is a serious drawback in much of the work done so far. As elsewhere in the World, in India also all striped forms of *Ichthyophis* were wrongly classified as *Ichthyophis glutinosus* and unicoloured forms as *Ichthyophis monochrous* (Taylor, 1961). In fact these two forms never existed in India at all (Taylor, 1968). Gundappa et al (1981) reported the occurrence of *I. glutinosus* in India. Taylor (1968) has stated that "very many references on the literature to *Ichthyophis glutinosus* in India refer wholly or in part to *Ichthyophis beddomei*". Dutta (1987) quoting Nussbaum and Gans (1980) stated that the distribution of *I. glutinosus* is restricted only to Sri Lanka and Gundappa et al (1981) might have confused either *I. beddomei* or *Ichthyophis tricolor* to that of *I. glutinosus*. Despite repeated search for *I. glutinosus* in the localities from where Seshachar (1936) and Gundappa et al (1981) have reported them, I failed to find even a single individual of the above said species. On the other hand, I could sight individuals of other species of yellow striped form i.e. *I. beddomei* in these localities. It is therefore possible that the mentioned authors have indeed mistaken *I. beddomei* for *I. glutinosus*. Even Balakrishna et al (1982b) and Revanasiddaiah et al (1982) also reported *I. glutinosus* at Somwarpet and Malige range of Karnataka state respectively. I feel careful observations is required to confirm the presence of *I. glutinosus* in India.

The reasons for the widespread confusion in identifying the caecilian species arise because a) the process of identification often involves only superficial observation of morphological characters, b) most of the described species are known only by a single or two individuals thus the information on the variation of their characters is scarce, c) non availability of these holotypes/ paratypes in the Indian museums for confirmation and d) lack of field guides for confirming the minute details. In my view, tackling the last problem in itself would help to resolve the other three, by way of encouraging in-depth research, increasing collections and scientific debates.

3. CLUES FOR FIELD IDENTIFICATION

3.1 METHODOLOGY

The systematic studies on caecilian ecology are rare in India, limited to the work of Gundappa et al (1981); Balakrishna et al (1982a, 1982b); and Bhatta (1986, 1997). One of the major reasons behind this lacunae is the dearth of a field guide and resultant scientific and popular ignorance about the subject. Though Daniel (1963) has published "Field Guide to the Amphibians of Western India", it primarily focuses on anurans. With my observation of holotypes of Indian Caecilians deposited in the Natural History Museum, London and subsequent field studies (Bhatta, 1997), I attempt here to consolidate all the relevant literature on Indian caecilians, with focus on the Western Ghats. I hope that these attempts to prepare modified simplistic field guide would enable all naturalists to easily identify the animal in the field.

Here, I provide the distinctive features of the four genera of caecilians of India on one hand (Table 3 and Fig. 3) and the parameters of variation amongst 16 different species regarding 26 morphological and morphometric characters on the other hand (Table 4). The detailed information on all these aspects is based on available literature (Taylor, 1968 and Pillai, 1986) and my own work (Bhatta, 1997). However, I have collected and processed the literature to estimate the mean and standard deviation of the values for each parameter regarding each species so as to enable future studies to look for significance of variation, while confirming old species or proposing new ones.

3.2 MORPHOLOGICAL DISTINCTIVENESS

Out of 26 parameters 11 which are more important had informaiton for each species. These includes - total length, tail length, distance from eye to tentacle, width of head, width of body, length by width, total folds, premaxillary-maxillary teeth, prevomeropalatine teeth, dentary teeth and splenial teeth. We estimated mean values on the above parameters for each of the 16 species. We normalized all these values by scaling from 0-100 on each parameter. We then calculated euclidian distance between each pair of species based on these normalized values as follows:

$$ED_{jk} = \sqrt{\sum_{x=i}^{s} (x_{ij} - x_{ik})^2}$$

where ED = euclidian distance between species j and k, x_{ij} is the value of parameter x for species j and x_{ik} is its value for species k. We then ordinated all the species using metric multidimensional scaling. The first axis explained 38% of the variation while the second explained 32%. Figure 4 clearly illustrates the morphometric differences between the four genera. The tail-less caecilians belonging to the genera Gegeneophis and Indotyphlus together form one cluster and the Uraeotyphlus spp. with less number of body folds and short body length form another separate group. Most of the members of the genus Ichthyophis with almost similar morphometric values come together into a single group. The largest Indian caecilian *I. malabarensis* which ranks highest on most of the parameters occupies the extreme position in the biplot. If information on all the 26 parameters becomes available, the taxonomic classification may become more objective, using such modern techniques.

3.3 GENUS LEVEL IDENTIFICATION

I also provide here a brief description of caecilian species of Western Ghats to enable researchers to identify them without killing. Of course the data available for each of the species in the literature are too meager to generate a detailed field guide for species level identification. To reach that stage, it would require detailed surveys, collections, validation of earlier described species and new descriptions, if any.

The most ideal period for searching the caecilians is the rainy season, after the rain water percolates down considerably so as to originate springs. Eventhough caecilians are nocturnal animals, we find them during day time also taking shelter beneath the rotten vegetation or in similar ecological conditions described earlier. After sighting an individual, first of all, one has to ascertain that the animal definitely is a caecilian, by looking into the rings (annuli) on the body. Taking the animal on hand is the necessary for the identification to the species level. Eventhough they wriggle out to escape from our hold, they do not bite. The individuals belonging to the genera *Ichthyophis* and *Uraeotyphlus* possess pointed tail and longitudinal vent (Fig. 3), whereas those of the genera *Gegeneophis* and *Indotyphlus* have blunt terminus with transverse vent. With the exception of unicoloured forms of the genus *Ichthyophis*, all other known species of caecilians are no longer than 30cm in body length. The description given below would help to assign the individuals to species level.

3.4 BRIEF DESCRIPTION OF WESTERN GHATS SPECIES

Here I provide the morphological details of caecilians, mainly with reference to the body colour, yellow banding pattern and the status of nuchal grooves. I have examined 9 species of them thoroughly and my observation is in conformity with the earlier reports. As I did not encounter *I. bombayensis, I. subterrestris, U. malabaricus, U. menoni and U. oxyurus* during my field visit, I have summarized their description as per Taylor (1968). As explained earlier, there is no firm evidence to assume that *I. glutinosus* occur in India, I therefore refrain from giving its morphological details.

1. *Ichthyophis beddomei*:

Body violet brown on the dorsum and light brown on the venter. A yellow lateral stripe passes along the body from tip of tail to the head, the stripe bifurcates at mouth angle, one branch reaches tip of snout along the upper lip and other reaches the tip of chin along the lower jaw. The yellow stripe widens just opposite the first collar, then becomes narrow and again widens and continues thereafter as such till the tip of tail. Body short and broad. Eyes distinct. Tentacular aperture very close to lip. Its distance from eye and nostril almost equal. Nostrils nearly terminal but barely visible when viewed from above head. The snout extends slightly beyond the mouth. The first nuchal groove distinct on both dorsal and ventral surfaces; second nuchal groove is not clear on dorsal surface and the third nuchal groove distinguishable on the dorsal but not on the median ventral region. The second collar groove bears two well defined folds dorsally. <u>Range</u>: Karnataka, Kerala and Maharashtra.

2. *Ichthyophis bombayensis*:

A large unicoloured species with elongate tapering tail. Body dark brown above and somewhat lighter brown below. Lateral yellow bands absent. Head rather small and narrower than the body. Eyes distinct and surrounded by a whitish ring. Tentacular aperture close to lip. It is nearer to the eye than the nostril. The first nuchal groove distinct ventrally, at the sides and preceded dorsally by a distinct strongly curved fold on the back of the head. Second nuchal groove clear on the venter, at the sides but not dorsally. Third groove crosses on the dorsal side visible laterally and partly crosses the venter. Range: Maharashtra and Karnataka.

3. *Ichthyophis longicephalus*:

Body dark violet brown on the dorsum and some what lighter on the venter. A yellow lateral stripe extends from tip of tail to posterior margin of second collar. Small yellow patches occur at the sides of second collar, first collar and on the angle of jaws. On the venter each annulus is broken in the middle and results in a longitudinal midventral line extending from collar to vent. Body short and broad. Head is comparatively longer. Eyes distinct. Tentacular aperture closer to lip. They are much closer to eye than to nostril. Nostrils nearly terminal and visible from above. The snout extends a little beyond mouth. The first nuchal groove clear ventrally and laterally and dim dorsally. The first collar is completely fused with the second on the dorsum. The second nuchal groove is distinct on the ventral surface and extends up laterally upto the level of angle of mouth. The second collar bears two incomplete folds dorsally. <u>Range</u>: Kerala.

4. *Ichthyophis malabarensis*:

The largest known Indian caecilian species with unicoloured form. Dark brown above and venter light cream white. The tip of tail dark, nearly black from the vent to tip. No lateral yellow stripe. Head narrower than the body. Eyes visible. Tentacular aperture near the lip and is closer to eye than to nostril. The first nuchal groove clear ventrally and becomes slightly angulate dorsally. The second nuchal groove convex below and distinct on sides of neck. The third nuchal groove clear on sides of neck and dim on the dorsal surface. There are three transverse folds on the dorsum of the second collar. Range: Kerala and Karnataka.

5. *Ichthyophis peninsularis*:

Unicoloured form. Dorsal side greyish lavender and ventral light cream coloured. No lateral yellow stripe. A large species with broad, short head relatively long tail. Eyes visible. Tentacles nearer to eyes than to nostrils. The first nuchal groove clear dorsally, laterally and ventrally. The second nuchal groove well defined on the ventral surface and on the sides of head. The third groove more or less distinct, except mesially below. Range: Kerala, Karnataka and Tamil Nadu.

6. *Ichthyophis subterrestris*:

A moderate sized species with dark violet-lavender colour on the dorsum and lavender brown on the venter. There is no lateral yellow stripe. The head is elevated posteriorly. Eyes distinct. The tentacle nearer to eye and close to lip. The first nuchal groove distinct on both dorsal and ventral surfaces. The second is not clear on the dorsum. Range: Kerala.

7. *Ichthyophis tricolor*:

Body violet brown above. A yellow lateral stripe extends from the head to the tip of tail, not broken on the neck, but widens on the collars. At the angle of the jaws, it forks, and the yellow band continues along the jaw upto to the eye on the dorsal surface tip of the snout. A broad white ventral stripe present on the venter. Head with slightly projected snout Eyes distinct. Tentacles at the edge of lip, nearer to the eye than to the nostril. The first nuchal groove distinct on the ventral surface, passes up at the sides, but do not meet on the mid dorsal line. The second nuchal groove clear on ventral surface and at the sides of neck but not dorsally. There are two transverse folds on the dorsum of the second collar. Range: Kerala.

8. *Uraeotyphlus malabaricus*:

Body short and stout, violet coloured on the dorsal surface and lighter shade of violet on the ventral. Eye distinct and surrounded by a cream ring (sometimes one eye distinct and other dim). Tentacle scarcely visible from above, nearer to nostril than to eye. It is closer to mouth than to the nostril. Small cream areas are present about nostril, tentacle, tip of snout and its underside. The upper and lower lip and the two jaws are also cream in colour. A cream white spot is present at vent. The tip of tail is whitish. The first collar very dim, not distinguishable above and vaguely evident ventrally. The first collar fused with second collar. Second collar more clear, incompletely grooved posteriorly with a slightly visible transverse folds across the dorsum. Range: Kerala.

9. *Uraeotyphlus menoni*:

Medium sized species with slate-grey colour on the dorsum and whitish, blotched with grey on the venter. Eyes distinct and surrounded by a narrow white ring. Tentacles not visible from above, closer to the nostril than to the eye. Nostrils distinctly visible from above. The head is light violet coloured, the tip of the snout above and below cream white with light mottling on top of the head. The chin and throat are with indefinite greyish marks. The tip of tail is cream coloured. The first nuchal groove less distinct above and clearly defined below. The second groove is not clear dorsally but visible laterally and ventrally. The second collar is well defined dorsally and laterally, but ventrally it is fused with the first body annulus. Range: Kerala.

10 *Uraeotyphlus narayani*:

Steel grey above, pale and flesh coloured on the ventral surface. In between the chin and tail a median greenish line present. Eyes distinct with a whitish areola. Nostril visible directly above the head. The distance from eye to nostril and eye to tentacle almost identical. Tentacular aperture below the nostril and not visible from directly above head. Tip of tail whitish. The tip and ventral part of snout cream. No light spot at tentacle or nostril. The first nuchal groove distinct ventrally and laterally, and less clear dorsally. The second nuchal groove clear ventrally and extends up on the sides to the level of the mouth. The third nuchal groove visible on the dorsum and sides of neck. Range: Kerala and Karnataka

11. *Uraeotyphlus oxyurus*:

A thick bodied species with narrower head and a short tail. Body moderately dark brown. Eyes very small but distinct with a light white ring. Tentacle below nostril, closer to nostril than to eye. Nostrils visible from directly above head. The tip of tail white. The chin and throat are very light brown. The first nuchal groove very dim across the head. The second collar fused to first primary fold on venter. A single fold across the back part of the second collar. Range: Kerala,

12. *Gegeneophis carnosus*:

A small species with body flesh coloured on both surfaces. Terminal width less than body width Body ends on blunt shield. Eyes invisible. The tentacular aperture below and behind the nostril Nostrils nearly terminal and not visible from directly above head. The terminus is narrowed. The first nuchal groove clear an the ventral surface and dim on the dorsal part. The second collar distinct above, partly divided by a dorsal transverse groove, while on the ventral surface it is partially fused with the first primary annulus. Range: Kerala.

13. *Gegeneophis ramaswamii*:

Larger species with body greyish on the dorsal surface and light grey on the ventral surface. Terminus of body wider than elsewhere which ends bluntly. Tentacles behind and below the nostril, not visible from directly above the head. Eyes invisible. The first and second nuchal grooves are distinct on the dorsum, venter and at the sides. There is a short transverse groove on the first collar. Range: Kerala.

14. *Indotyphlus battersbyi*:

A species with slender elongate body. Body pale flesh coloured on both dorsal and ventral surfaces. Eyes concealed and invisible. Body ends in a blunt shield. The first nuchal groove distinct on the dorsum, while the second nuchal groove clear on both the surfaces. Range: Maharashtra.

4. ABUNDANCE, DIVERSITY AND DISTRIBUTION

4.1 SYSTEMATIC SAMPLING OF DIVERSITY

Despite the much proclaimed rarity of caecilians, studies on their population densities and diversity estimates are lacking, both nationally and globally. I therefore decided to undertake systematic sampling of these cryptic creatures to provide some estimates, or `educated guesses', to say the least. Being the member of Western Ghats Biodiversity Research Network (Gadgil 1996), I got an opportunity to survey the caecilians in the Western Ghats. In the absence of any established methodology of caecilian sampling, I tried out different search methods. Gradually, I developed my own procedure, which I discuss here. As it maximizes the encounter rate while keeping the record of time, area and strata; I feel it would be worth following in future studies by myself and others.

4.2 SELECTING HABITAT TYPES

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 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 showed the presence of 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. My observations of a large number of caecilians in the orchards rather than in the forest is in conformity with that of Nussbaum (1984) and Hebrard et al (1992). Due to the time and resource constraints I chose to survey only orchards, to maximize the efficiency of sampling.

4.3 SAMPLING LOCALITIES AND SPOTS

Eight of the sites selected in Western Ghats Biodiversity Network (WGBN) were surveyed for caecilians. They represent eight randomly chosen localities along the foothills of Western Ghats (Table 5). The area of each WGBN study site is approximately 25 sq. km with a part of it under natural landscape and a part under manmade.

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 caecilians. The area covered and time spent for searching, the altitude of the locality, the soil and atmospheric temperature are provided in Table 5 and 6, Fig. 5 and 6.

As the investigators had established a good rapport with the local people at different sites of WGBN, we could easily approach the privately owned orchards. The search involves digging of the soil at the bases of arecanut or coconut trees, and also turning up and down of the organic nutrients supplied to the plants. This is likely to damage the roots of these plants and requires active cooperation of the land owners.

Altogether I spent over 2600 minutes in merely excavating or litter-searching an area of 2200 sq.m. 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 8 areas. The most dominant species *Ichthyophis 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 were encountered only in a single locality and one each from two and three localities. Thus my field experience strongly endorse the opinion expressed by Maurice and Burton (1988) and Nussbaum (1992) that caecilians are not rare and endangered. A few animals were brought to the laboratory for the species identification and the same are being reared in the captivity for studying the behaviour by simulating the possible natural conditions.

4.4 ESTIMATING SPECIES RICHNESS

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 (Ludwig and Raynolds, 1988), which requires data on over 200 individuals. The other option is to use recently discussed Chao index, which is the least negatively biased estimate of the total species richness than Simpson's, Shanon's and other indices of diversity (Colwell and Coddington, 1995). Besides, it can work reasonably well with small sample sizes. Chao's estimate of species richness of the population is given as follows:

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

Where S denotes species richness, for the target population.

Fig. 7 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 realized but it does suggest 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 a good chance of discovering newer species with additional sampling.

4.5 DISTRIBUTIONAL PATTERN

Caecilians were encountered all over the altitudinal range surveyed - 15m to 700m 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 2500m (Taylor, 1968; Nussbaum, 1984 and Hebrard et al., 1992) The present sampling levels are too inadequate to determine whether different species have characteristic, different elevational ranges and preferences.

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 (Fig. 8). 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 negatively correlated with the length of the dry period which increases northwards, just like in case of frogs and toads (Daniels 1992)

5. PREFERRED SOIL CONDITIONS

5.1 SYSTEMATIC SOIL SAMPLING

During my WGBN investigations described earlier, I also collected soil samples from the same spots as the caecilians. These samples were analyzed at the Agricultural University, Gandhi Krushi Vigyaan Kendra, Bangalore for the following parameters:

1) Moisture % was calculated by gravimetric method.

2) pH was measured for 1:2.5 soil : water suspension using a pH meter.

3) Electrical conductivity was measured for the clear filtration of the 1:2.5 soil : water extract using a conductivity bridge.

4) Organic carbon content was determined by the Walkley and Black's rapid titration method (1934).

5) Exchangeable calcium and magnesium content were determined by complexometric titration method using standard EDTA solution after extracting Ca & Mg from soil using neutral 1N ammonium acetate solution.

6) Available potassium content was extracted from the soil using neutral 1N ammonium acetate extractant and then determined using a flame photometer.

7) Total nitrogen content of soil was estimated by the Kjeldahl's digestion and distillation procedure.

8) Available nitrogen was determined by the alkaline permanganate method.

9) Available sulphur content of soil was determined turbido metrically after extraction using Morgan's reagent.

10) Trace elements like Ferrous, Manganese, Zinc and Copper were extracted from soil by shaking 10g of soil with 20ml of DTPA extractant for 2 hours and then filtered. The clear filtrate was fed to atomic absorption spectrophotometer to determine the concentration of Fe, Mn, Zn Cu using appropriate hallow cathode lamps.

5.2 SITING LOCATIONS

During my studies, the caecilians occurred anywhere from the surface of the topsoil to a depth of around 45 - 60cm in the rainy season and at the edges of 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.

Interestingly, the microhabitat conditions of all the four genera collected in this study were not similar. The individuals of the genus *Ichthyophis* were found mainly in the moist soil at the bottom of coconut/ arecanut trees, while *Gegeneophis* occurred in the wet soil of marshy area. The single *Indotyphlus* was found at the edge of the stream in the littered moist soil in an indigenous forest. *Uraeotyphlus* were found both in moist and wet soils. The members of same species were found at different depths at different localities. In the succeeding non rainy season, these caecilians were seldom seen in the same habitat (Bhatta 1986) and they show local migration in search of moist condition. This is quite evident by my own earlier records (Bhatta 1986, 1997) collection of six individuals of *I. beddomei* with egg clutches in March 1996 at the edges of irrigation canal.

5.3 SOIL PARAMETERS

All the eight species collected in this study are invariably adults and no immature young ones were seen in the habitat of adults. Perhaps they occur in different habitats. Loose moist soil (Nussbaum 1984) is a prerequisite to the caecilians, as these animals cannot burrow in the hard soil in the absence of any specialized burrowing organs. As the soils rich in humus are known to have high water holding capacity, the soil samples collected from different localities showed 30 to 95% of moisture (Fig. 9). The soil analysis report (Table 6) indicates that in all the places the soil is found to be in the acidic/ neutral range Electrical conductivity which appears very low indicates that these sites receive high rainfall. Exchangeable Ca and Mg shows that the soil has low base concentration. Rather high level of organic carbon, available nitrogen and low value of available phosphorus are the characteristics of acidic nature of soils. The present report confirms the earlier findings of soil analysis (Gundappa et al 1981; Bhatta 1986) in Sringeri area. Thus acidic/ neutral, moist soil with high organic carbon may be indispensable for the occurrence/ abundance of caecilians. During our present survey we did not encounter them in the soils lacking the above characteristics

The temperature of the soil recorded at different localities ranged between 23.5 - 25.5°C. In all the sites the soil temperature was invariably 1° less than that of the atmosphere This difference observed between soil and atmospheric temperature is in conformity with that of Gundappa et al (1981) and Hebrard et al (1992). The latter have recorded the soil temperature at Taita hills which was 10° less than that of the recorded mean temperature for *I. glutinosus* by Gundappa et al (1981). The temperature recorded by me is in agreement with that of Gundappa et al (1981) and my earlier observation (Bhatta 1986). As the temperature is bound to change with elevation and the fact that caecilians are collected at different elevations, temperature alone cannot be considered as an important factor governing their distribution.

5.4 SIMILARITIES AND DIFFERENCES

Fig. 10 illustrates the relationship between species based on dissimilarity in the soil parameters of the collection spots. The complete linkage clustering is based on chord distance between all pairs of species calculated using matrix of 9 species and 14 soil parameters. The chord distance is given as:

$$d = \sqrt{2 \quad (1 - \frac{(\Sigma x_{ij} \Sigma x_{ik})}{(\Sigma x^2_{ij} \Sigma x^2_{ik})})}$$

where d is the chord distance between species, x_{ij} and y_{ik} are abundance values of species on in transects j and k respectively. As the dendrogram in Fig. 10 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 sizes are limited.

6. GENERAL ACTIVITY, FORAGING AND BREEDING

Having collected some specimens and brought them to the laboratory for the identification purpose and with my past experiences of rearing caecilians, I got an idea of rearing these in captivity. The result is the formation of `live museum' of caecilians wherein 8 species of them are successfully reared for the last 2 years. The purpose is to study the general behaviour of these interesting creatures which is hitherto unknown. Some of the behaviours observed in the last two years and also earlier (Bhatta 1986) are worth discussing in the light of certain doubts that have arised in the minds of caecilian researchers in the recent publications (Wake 1977, Nussbaum 1984, Wilkinson 1983, Breckenridge et al 1987).

6.1 GENERAL ACTIVITY

Individuals of all the species reared by me showed movement at different hours of night on the surface of the soil. Fresh or new holes seen every next morning further confirmed that they are active at night. Eventhough they are least disturbed in dim light, they remain motionless for a moment when subjected to bright light, but soon start burrowing into soil and disappear within a fraction of minute. During rest of the time, they remain concealed inside the soil in tunnels or keep out their heads outside the tunnels and when disturbed immediately they retreat into the tunnels. Ceacilians show some movement on the surface even during day time if they are kept in dark and it will be interesting to study the biological rhythm in these animals. When we catch them by head region, if half of the body is inside the soil, they retreat by their rear end and get escaped from our hold. This behaviour and the similarity between head and tail in general appearance have made the people to call this as `Immande havu' in Kannada or `Irthali mori' in Malayalam. The tunnels which are long and branched show the mucus coating on the inner walls. Caecilians prefer to move inside the preformed tunnels rather than creating new ones. This is evident by the number of holes on the surface, which remains same for considerable time. It is worth investigating whether caecilians confine themselves to a particular area and live inside the preformed tunnels in their natural habitat. Some of the similar observations are noticed by Breckenridge et al (1987) in *I. glutinosus*. The caecilians when handled produced mucus to get escaped, but this never caused any sneezing effect or other as reported by Gadow (1958). There is no sexual dimorphism in caecilians. During breeding season, female can be distinguished from the male, by the movement of yolky eggs in the abdominal cavity. Males can also be differentiated from female by the phallodaeum which gets protruded when the vent region of the male is pressed gently.

6.2 FORAGING BEHAVIOUR

In captivity, when reared together, the different species live together without harming each other or showing cannibalistic behaviour. However, this requires further study by keeping the animals in starved condition, as cannibalistic behaviour is reported by Seshachar and Iyer (1932) in *I. glutinosus*. No fighting has been observed between the individuals either for food or sex. Normally caecilians eat away earthworms one by one at a time. But when they remain in tunnels, with head protruded out if entangled earthworms are offered in front of them by hand, they snatch away the entire mass and soon withdraw into the tunnel and the sound of eating earthworms can be heard outside. Our study (unpublished data) shows that the food consumption need not be proportionately more, related to the body size. Small sized *Gegeneophis ramaswamii* eats more earthworms than relatively large sized *I. beddomei* and *U. narayani*. Some of them may be partially detritivorous also (Breckennidge et al., 1987; Hebrard et al., 1992) and this may be the reason for eating less of animal food. Food consumption may be even related to the breeding/ non breeding season of the animal.

6.3 BREEDING BEHAVIOUR

i) Mate recognition/ courtship/ copulation:

Courtship behaviour has been reported in only a few species of aquatic caecilians (Wilkinson 1983; Barrio 1969; Murphy et al 1977). But no reports are available on burrowing caecilians except my own earlier observations (Bhatta 1986). At several times when male and female are placed together in an aquarium without soil the individuals of *I. beddomei* showed copulation irrespective of the breeding/ non breeding season. In this animal some sort of mate recognition/ courtship is observed. When a male advances towards another individual by sliding its ventral surface beneath the ventral surface of the others in an antero-posterior direction, if the other individual happens to be the female it co-operates and assists the male to press its cloaca and insert the phallodaeum on its vent. If they do not become successful in the first attempt, the process gets repeated 2 to 3 times until finally the male becomes able to insert the phallodaeum into the vent of the female. By chance if the other happens to be another male it rejects the offer. The copulation lasts for about 40 to 45 minutes. As rightly pointed out by Wilkinson (1983) there is no twisting/ coiling of each other or climbing one above the other in caecilians during copulation. They are connected together by their rear ends only and showed a minimal movement during the copulation, though occasionally each used to drag the other. At the end of copulation the female pulls rigorously to get away from the male.

ii) Egg laying and parental care:

A number of egg clutches were collected along with the mother from the nature during different periods of the year - *I. beddomei* eggs between January to April and *I. malabarensis* eggs in August - September. Seshachar (1936) reported December - March as the breeding period of *I. glutinosus* while Wake (1977) quoting Sarasin and Sarasin reported it to be from

July through September. I am more than convinced that Seshachar has definitely mistaken *I. beddomei* for *I. glutinosus* as my own observation has revealed that in December - March the *I. beddomei* is with mature ova. Thus Wake's (1977) observation that these workers were dealing with different species is correct. The number of eggs in the egg clutches that I have collected varied between the individuals belonging to same species and also between different species. The egg clutches of *I. beddomei* collected in the year 1996 contained 24, 29, 28, 6, 13 & 16 eggs and they weighed 5.2, 5.8, 7.5, 1.7, 2.9 and 3.1 grams respectively. The egg clutches of *I. malabarensis* contained 80 - 100 eggs. The size of the eggs and the volume of the egg clutches differed in *I. beddomei* and *I. malabarensis*. In *I. malabarensis* which is larger in size than *I. beddomei* the size of the eggs were larger and volume of egg clutch was greater than that of *I. beddomei*. From our observations it appears that there may be clutch size - clutch volume - body size relationships atleast among different species in caecilians also. But this requires observations of eggs of many more species. It is interesting to notice that in a given egg clutch all the eggs were of same size and showed same stages of development in both *I. beddomei* and *I. malabarensis*. In captivity eventhough *I. beddomei* and *I. malabarensis* showed different pattern of coiling, the acts involved in the parental care were almost the same. The mother used to remain coiled around the egg clutch for most of the time and keep them moist. She was changing the position of egg clutches by taking them to different places and also rotating them now and then. When five females and 5 egg clutches were put together they guarded different egg clutches at different times. Even a single mother was seen guarding 3 egg clutches belonging to three different mothers at a time. Perhaps mother is incapable of distinguishing her own clutch. As the parental care advanced, mothers used to abandon the egg clutches at latter stages of development. Balakrishna et al (1982) reported the presence of two egg clutches with eggs in advanced stage of development without the mother guarding them. Thus, it seems that the parental care does not last long throughout the period of embryonic development. It is a matter to be investigated thoroughly. In captivity when the mother abandons the egg clutches, proper care has to be taken to keep them wet to avoid fungal growth. I got gentle hit on two occasions when I tried to take away the egg clutch from the custody of mother. In one instance, after this event mother started holding the egg clutch by biting the jelly string. Sanderson (cited in Salthe & Mecham, 1974) reported similar type of behaviour in *Idiocranium russelli*, where the female defended the egg clutches by spitting water at him. The observation that all the eggs were in the same stages of development in both *I. beddomei* and *I. malabarensis* and their simultaneous hatching within a day or two after reaching the hatching stage indicate that the eggs are laid within a short span of time irrespective of the number of eggs laid. I have noticed *I. beddomei* laying a clutch of 23 eggs within 36 hours of time in captivity. The hatched larvae were out in water for two days, lost their external gills and invaded into the soil as observed in *I. glutinosus* (Breckenridge et al 1987).

7. CONSERVATION SCENARIO

7.1 DYNAMICS IN FORESTS AND AGRICULTURE

There is much apprehension about biodiversity losses resulting from rampant tropical deforestation, amphibians being considered as acutely suffering from it, due to their intricate dependence on narrowly defined microhabitats (Daniels 1991). My studies however shows that although the caecilians have restricted microhabitat conditions, these are available not only in the forests but also in some manmade ecosystems viz. the irrigated, organically manured orchards. Thus, they my not be as susceptible to extinction with forest loss as anurans, whose forest dwelling species are found much less frequently in agricultural ecosystems.

Apart from deforestation, forest degradation caused by unsustainable harvest of forest products is thought to be harmful to the forest dwelling amphibia (*ibid.*) For instance, collection of leaf litter is supposed to be detrimental to the amphibian population. The caecilian studies only seem to confirm this. Further, the excessive tree-felling leads to the opening of the forest canopy and exposure of the forest bed to the sunlight, causing high radiation, increased temperatures and drier soil surface environment. This would ill-affect the caecilian populations also like that of anurans. The same opinion has been expressed by Nussbaum (1984) for Seychellean amphibians.

The collection of leaf-litter from the forest bed however has one unforeseen benefit. Dumping of this leaf manure at the base of arecanut plants helps availing the caecilians the required microhabitat conditions, provided that the irrigation is year-round and chemical fertilizers or pesticides are not used. Because of the belief that the prevailing yellow leaf disease in arecanut trees throughout Western Ghats is caused due to the extensive utilization of chemical fertilizers, the farmers have started to use organic manure only. This is a good sign as far as the preservation of the habitat is concerned, but the spraying of Bordeaux mixture onto the arecanut to get rid of fungal attack is a matter of great concern. Because this chemical gets mixed with the water, pollutes the soil and makes it unsuitable for the living of these sensitive creatures. Hebrard et al (1992) opined that mechanical disturbance in the cultivated land and the use of agricultural chemicals as the reasons for the low population of caecilians on agricultural land.

7.2 ECOLOGICAL SIGNIFICANCE

The caecilians are an interesting group from biodiversity assessment point of view as they are specialized, have promising indicator value and are not very difficult to collect. Although these require considerable amount of effort for identification, if reliable and illustrated identification keys become available, their study along the Ghats can best be attempted through a network of distributed researchers. People in the villages whose orchards harbour many such caecilians with a couple of species or good population densities can be reliably identified for social or economic rewards for nature conservation (Gadgil and Rao 1995). For, caecilian populations point out to higher organic content, high earthworm populations and good habitat for probably several unknown soil invertebrates. All this cannot be sustained unless one overlooks the huge short term profits of intensive agriculture and instead, invests special efforts in more natural farming. There are, of course positive signs of this already happening, as large farmers are increasingly becoming aware of long term impact of chemical intensive agriculture. The small farmers without much capital to invest have to be contended with more organic manure. The rewards for special conservation efforts as indicated by caecilians abundance might boost these nature friendly strategies.

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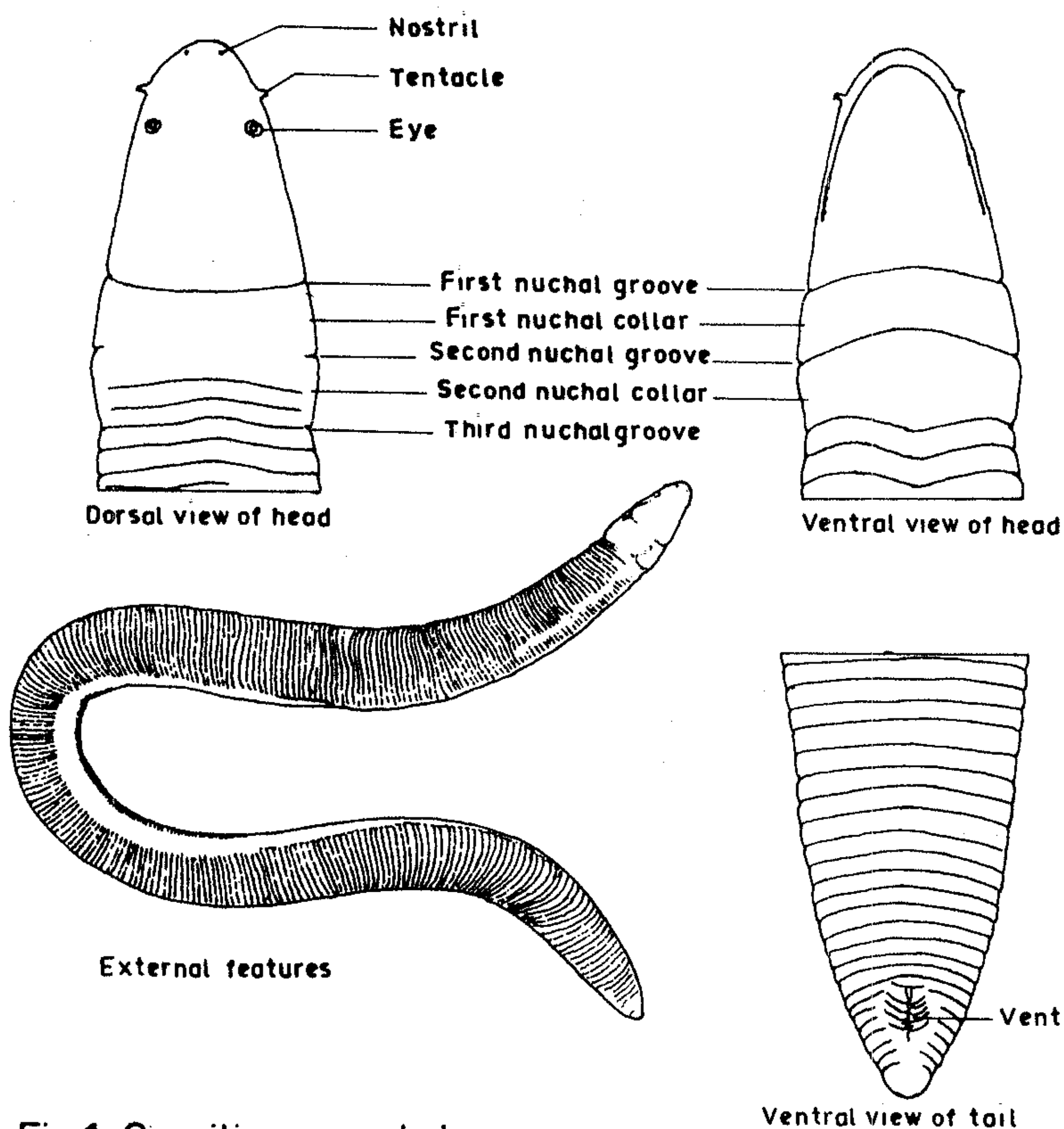

Fig.1. Caecilian morphology.

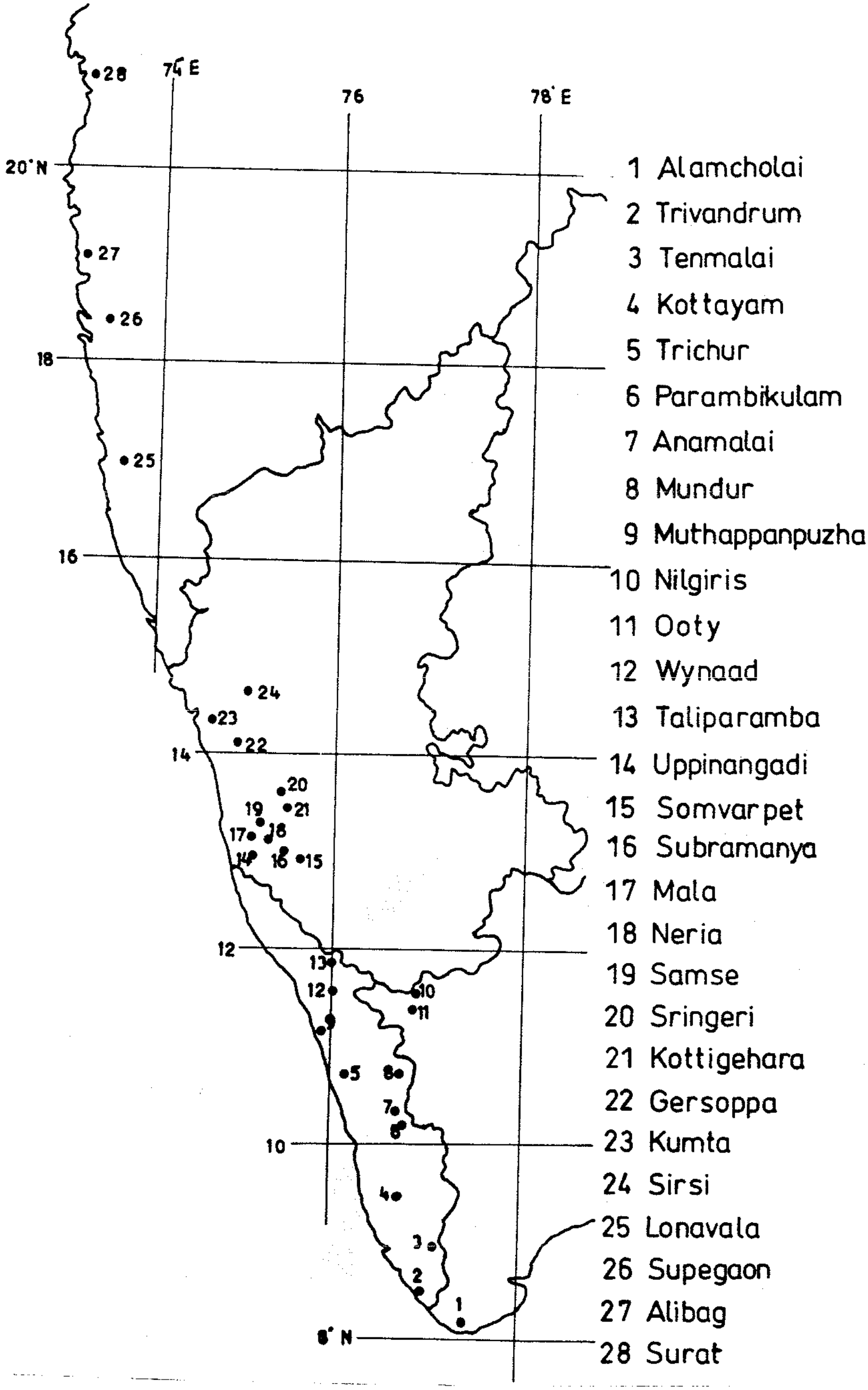

FIGURE 2. LOCALITY MAP SHOWING CAECILIAN DISTRIBUTION

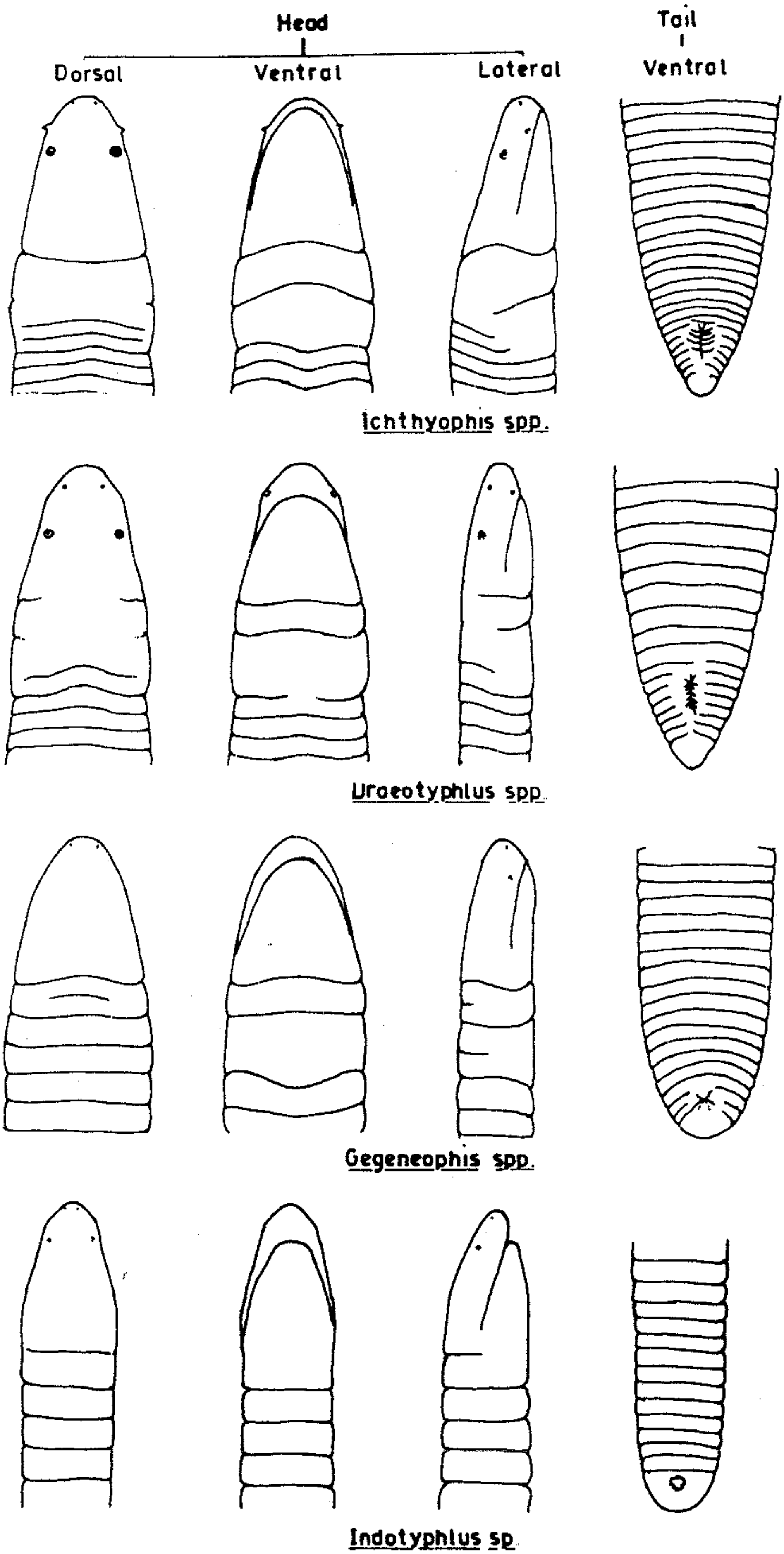

FIGURE 3. DISTINCTIVE FEATURES OF CAECILIAN GENERA

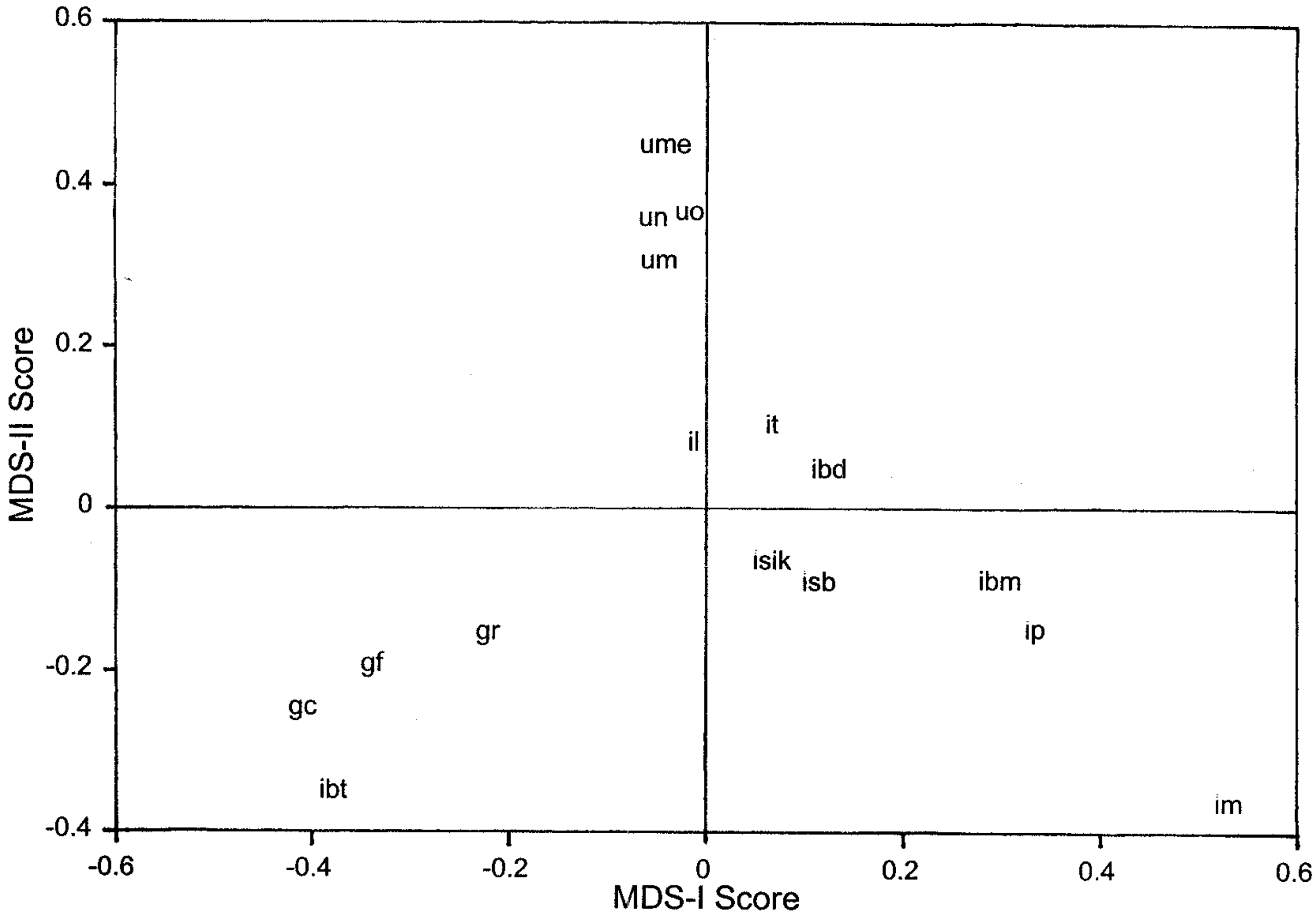

FIGURE 4. ORDINATION OF SPECIES USING MORPHOMETRIC PARAMETERS

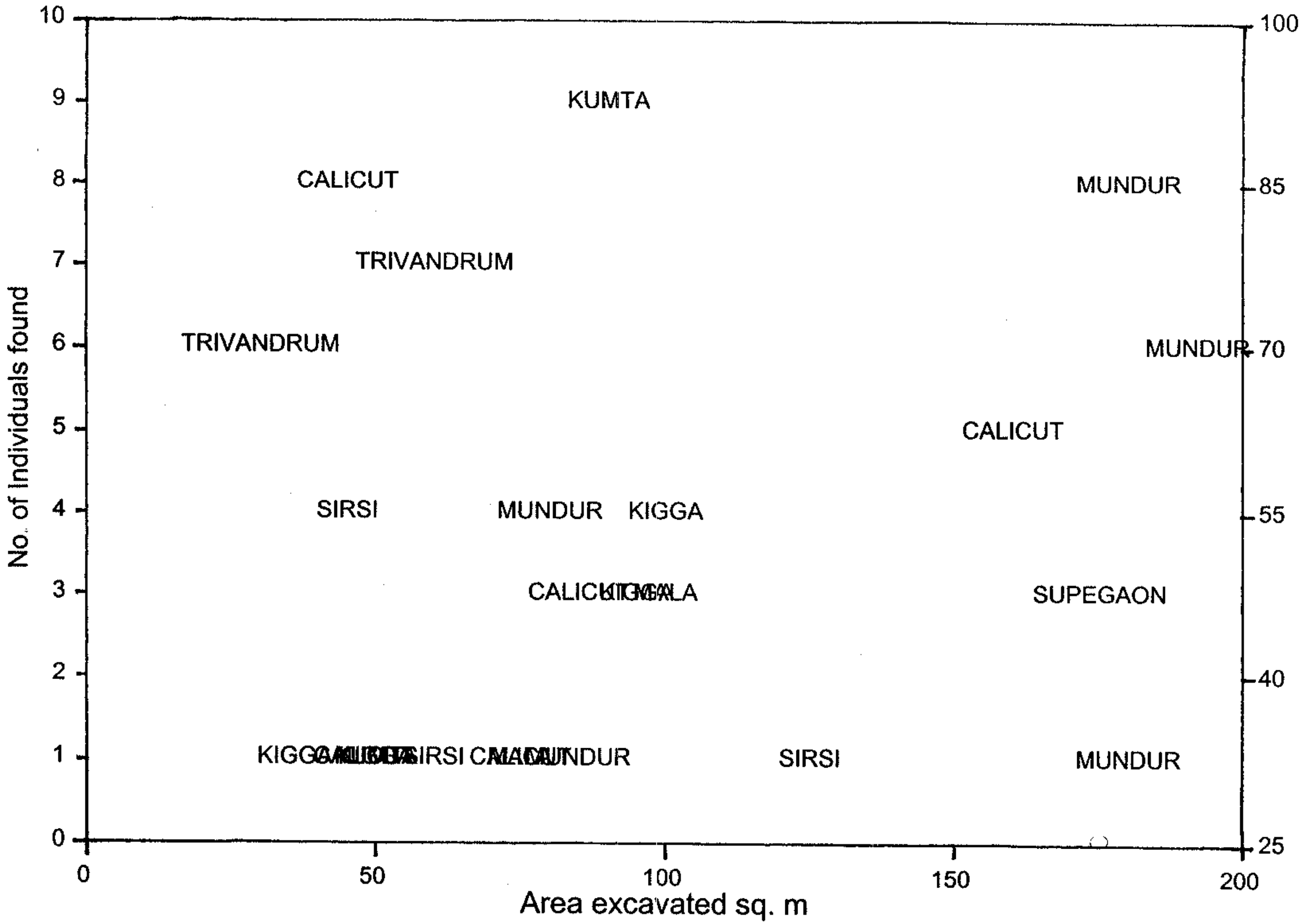

FIGURE 5. SPATIAL DENSITY OF INDIVIDUALS

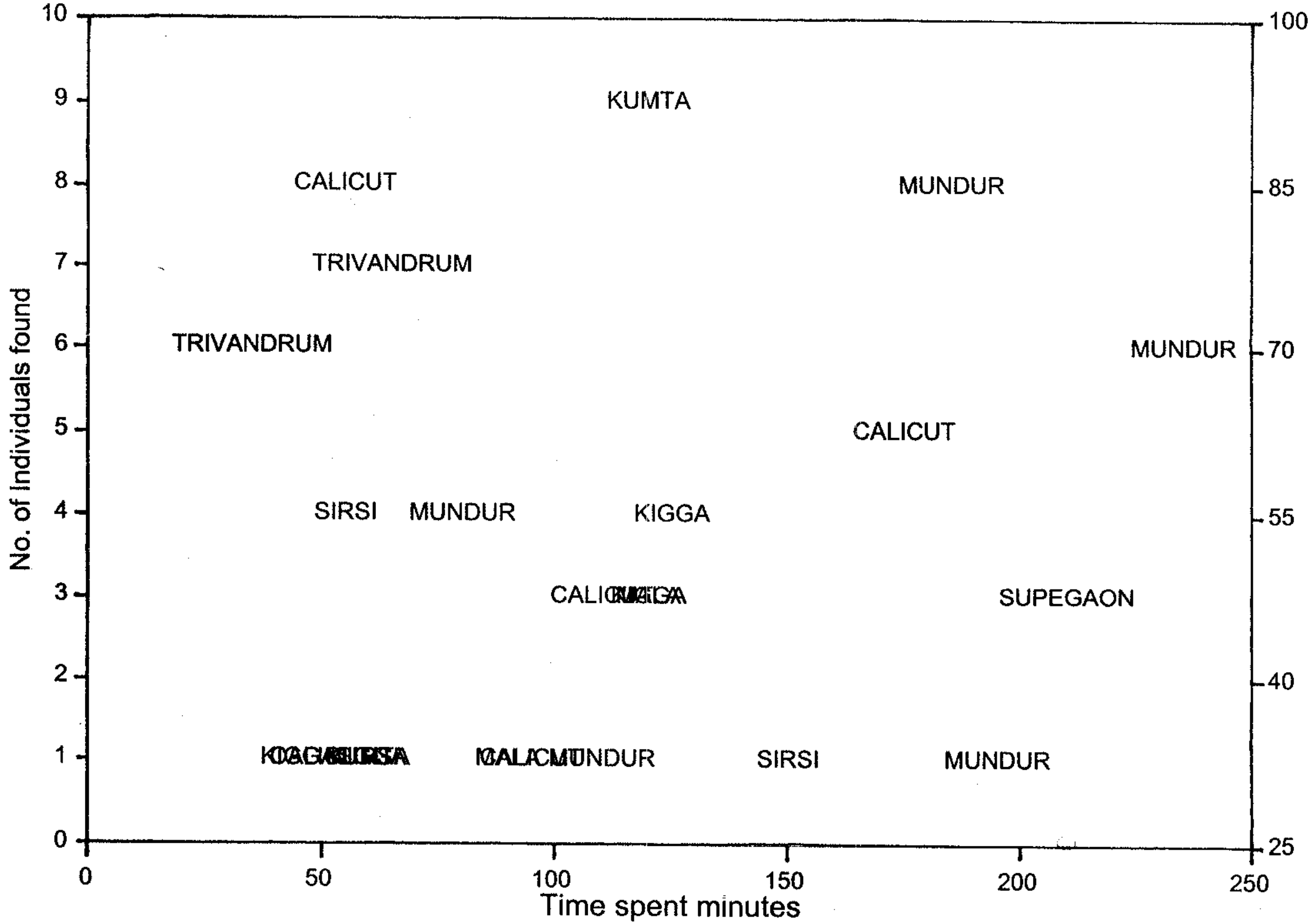

FIGURE 6. TIME RATE OF ENCOUNTER OF INDIVIDUALS

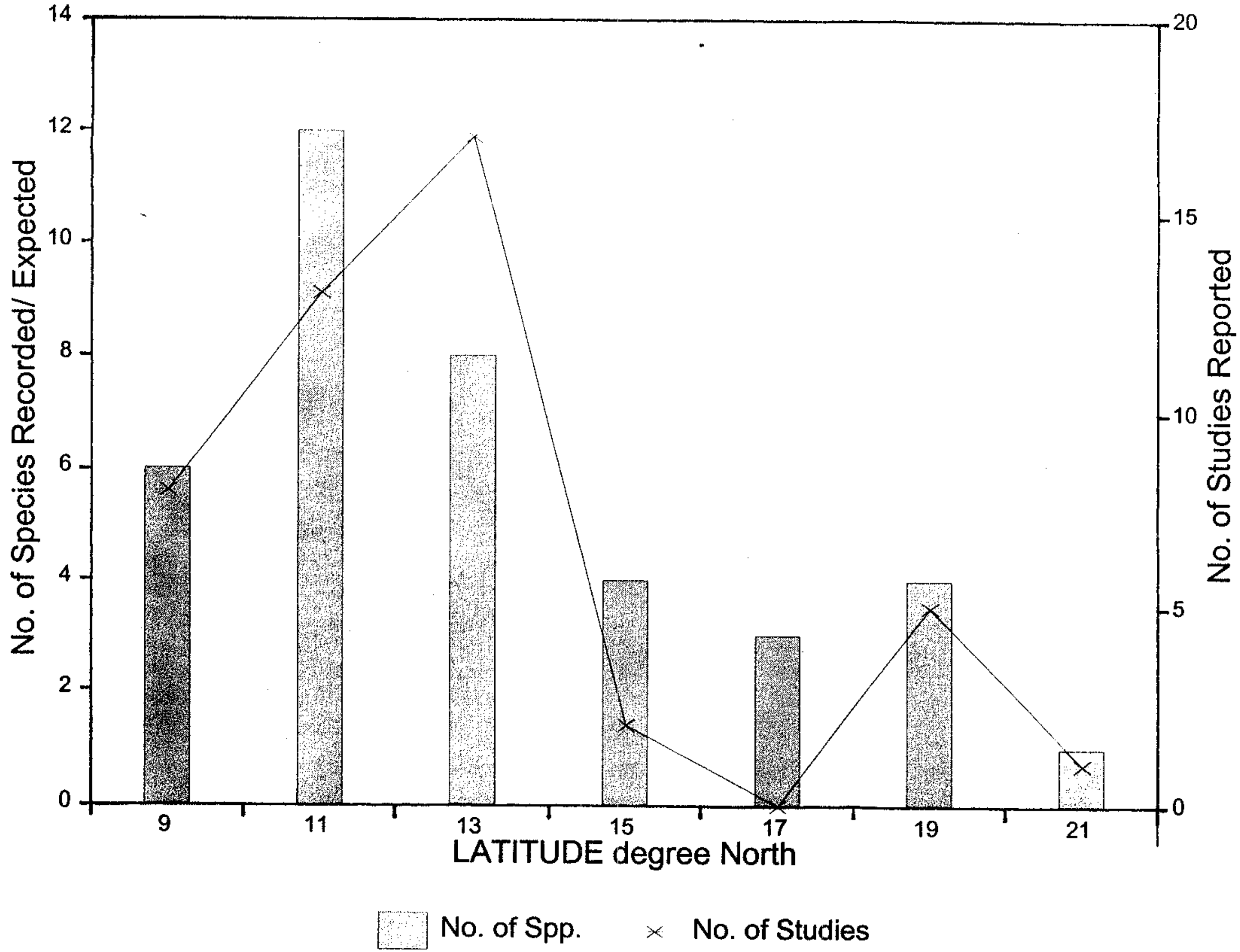

FIGURE 8. REGIONAL DISTRIBUTION PATTERN

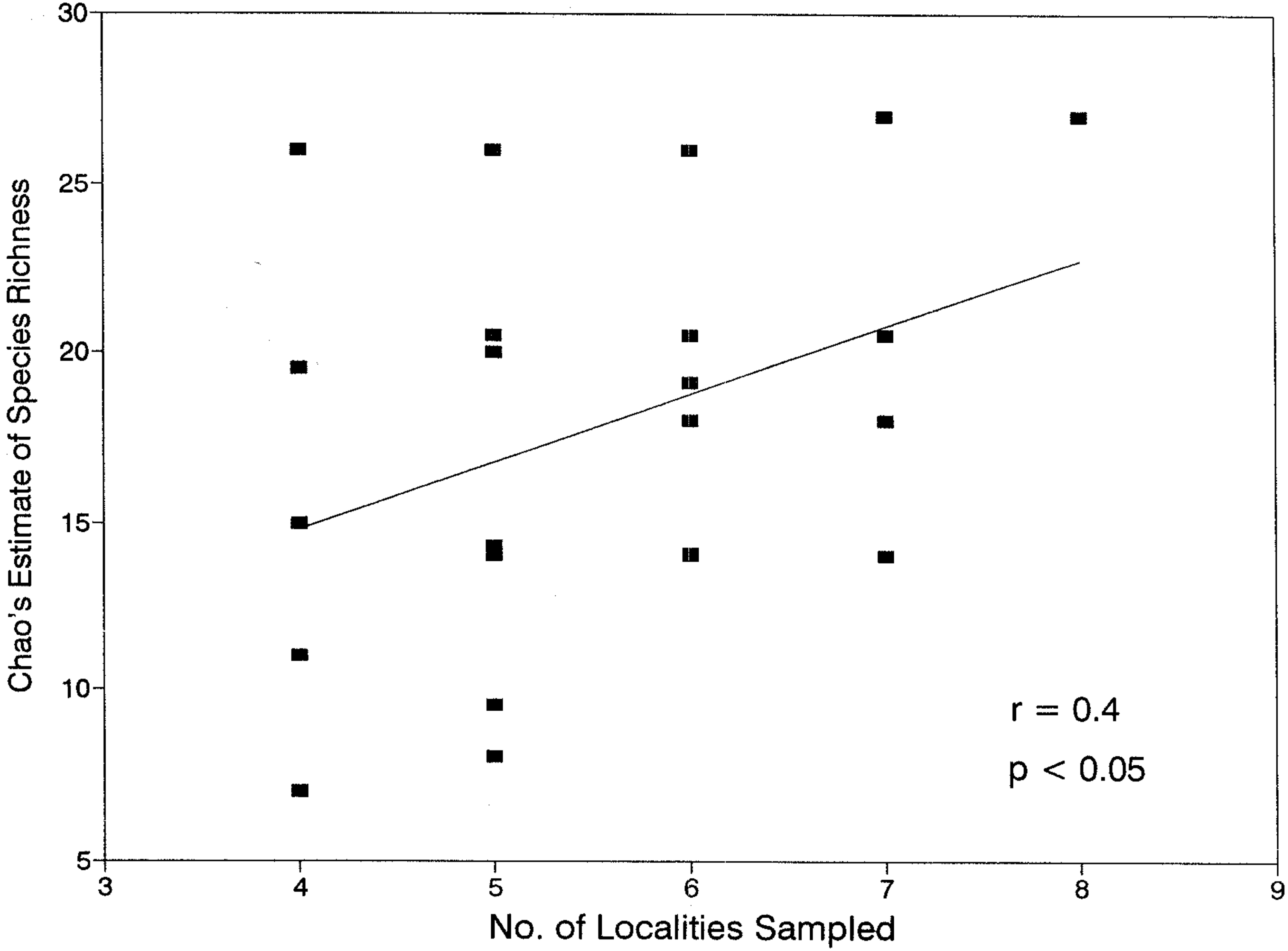

FIGURE 7. SPECIES RICHNESS EXTRAPOLATION

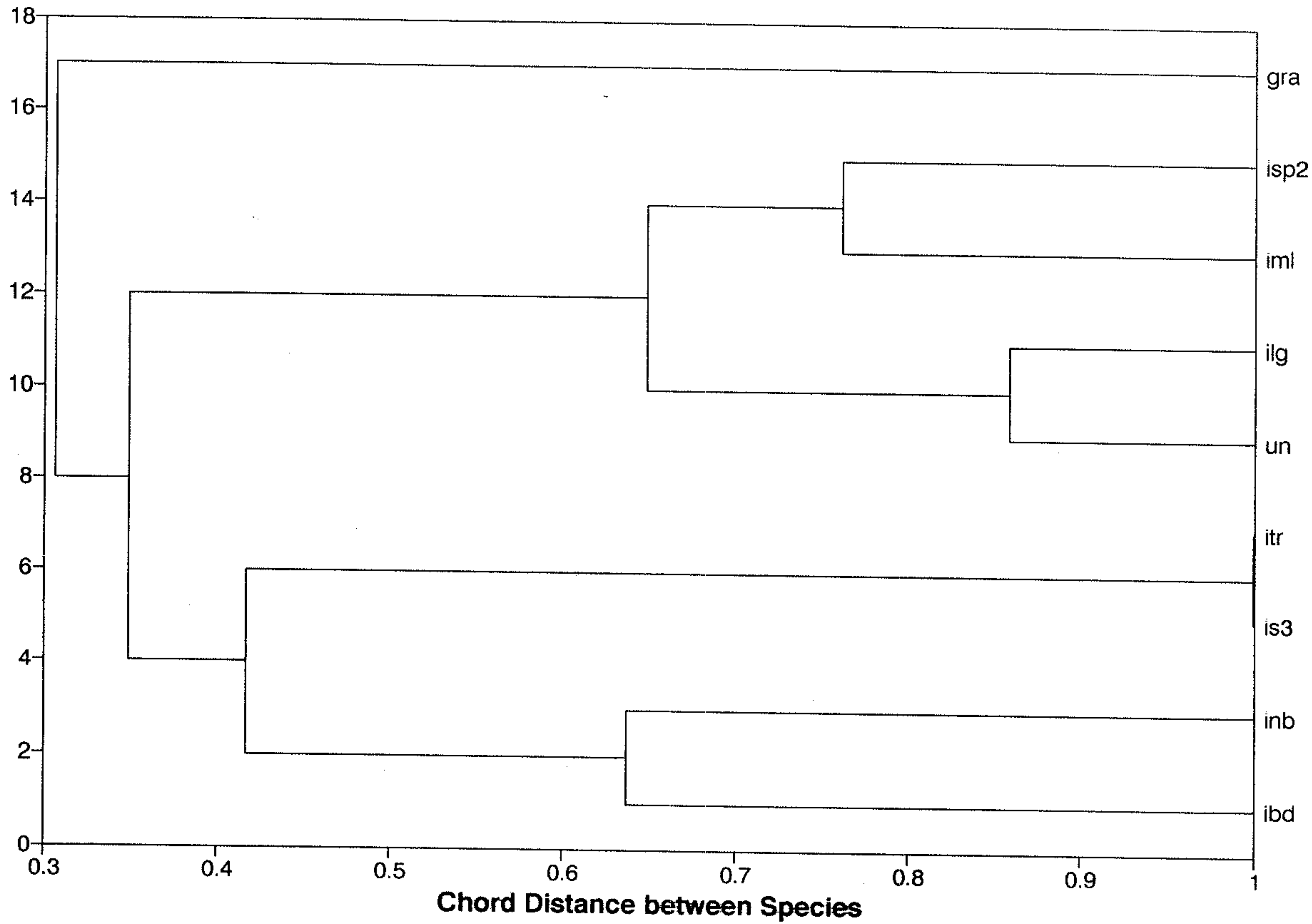

FIGURE 10. CLUSTERING OF SPECIES USING SOIL PARAMETERS

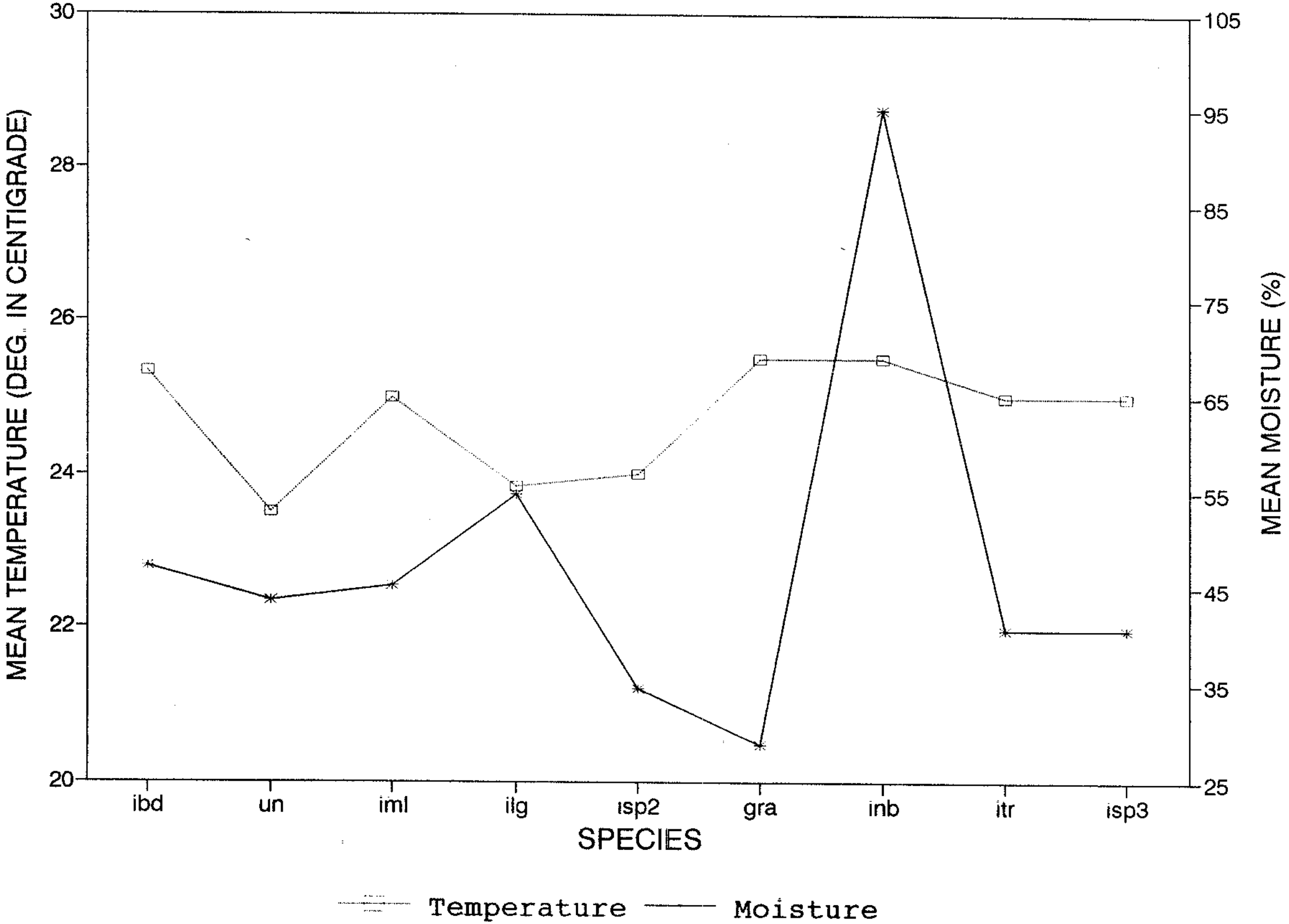

FIGURE 9. SOIL TEMPERATURE AND MOISTURE

TABLE 2

CAECILIAN DISTRIBUTION IN INDIA BASED ON THE PUBLISHED LITERATURE AND AUTHOR'S COLLECTION

Species	Localities of Collection	References cited
Ichthyophis beddomei	Kotigehar, Gersoppa, Kigga, Sringeri, Uppinangadi, Kumta, Sirsi, Mala, Neria - Karnataka Nilgiris - Tamilnadu Mundur - Kerala Supegaon - Maharashtra	Taylor 1960a, 1968 Daniels 1963 Tikader 1964 Rahman & Rajgopal 1978 Balkrishna et al 1982a, 1982b Bhatta 1986, 1997
Ichthyophis bombayensis	Waghii Surat - Bombay Province Sringeri - Karnataka	Taylor 1960a, 1968 Daniels 1963 Balakrishna et al 1982b
Ichthyophis glutinosus	Kottigehar, Somwarpet, Malige Range - Karnataka	Seshachar & Iyer 1932 Abdulali 1954 Balakrishna et al 1982b Revanasiddaiah et al 1982
Ichthyophis longicephalus	Mundur, Muttappanpuzha - Kerala Silent Valley, Mundur - Kerala	Pillai 1986 Bhatta 1997
Ichthyophis malabarensis	Maduvangard, Mundur - Kerala Mala, Sringeri, Sirsi, Subramanya, Kigga - Karnataka	Taylor 1960a, 1968 Daniels 1963 Seshachar et al 1982 Bhatta 1986, 1997
Ichthyophis peninsularis	Malabar, Vanjikadavu - Kerala Neria - Karnataka Alamcholai - Tamil Nadu	Taylor 1960a, 1968 Daniels 1963 Jaisingh 1978 Das & Whitaker 1990 And Author's Collection
Ichthyophis sikkimensis	Darjeeling - Sikkim	Taylor 1960a, 1968
Ichthyophis subterrestris	Kottayam, Travancore - Cochin Parambikulam - Kerala Anamalai - Kerala Alibag - Maharashtra	Taylor 1960a Daniels 1963 Taylor 1968
Ichthyophis tricolor	Maddathori, Peermade, Parambikulam, Travancore, Mundur - Kerala Nilgiris - Tamil Nadu	Taylor 1960a, 1968 Daniels 1963 Bhatta 1997

TABLE 1
CLASSIFICATION OF INDIAN CAECILIANS

FAMILY	GENUS	SPECIES
Ichthyophiidae Taylor	Ichthyophis Fitzinger	beddomei Peter*
		bombayensis Taylor*
		glutinosus (Linnaeus)
		longicephalus sp.nov.*
		malabarensis Taylor*
		peninsularis Taylor*
		sikkimensis Taylor
		subterrestris Taylor*
		tricolor Annandale*
Uraeotyphlidae Nussbaum	Uraeotyphlus Peters$	malabaricus (Beddome)*
		menoni Annandale*
		narayani Seshachar*
		oxyurus (Dumiril & Bibron)*
Caeciliidae Rafinesque	Gegeneophis Peters$	carnosus (Beddome)*
		fulleri (Alcock)
		ramaswamii Taylor*
	Indotyphlus Taylor$	battersbyi Taylor*

$ - Endemic to India

* - Endemic to Western Ghats

TABLE 3

KEY FOR THE IDENTIFICATION OF DIFFERENT GENERA OF CAECILIANS IN INDIA

	Ichthyophis	Uraeotyphlus	Gegeneophis	Indotyphlus
Colour (in life)	Unicoloured forms are sober coloured with brown or greyish shade. Yellow lateral striped torms are violet brown on dorsal surface and light shaded on the ventral surface	Olive violet, a steel grey on the dorsal and lavender on the ventral surface	Greyish on the dorsal surface and light grey shaded on the ventral surface	Pale flesh coloured on both dorsal and ventral surfaces
Mouth	Terminal	Recessed below the snout	Recessed below the snout	Recessed below the snout
Eyes	Visible	Visible	Not visible	Visible through the skin
Tentacles	Conical, long, near edge of mouth, much closer to eye than to nostrils	Flap like, short, anterior to and below nostril, much closer to nostril than to eye	Cone shaped, very short, close behind and below the nostril, nearer to tip of snout than to eye	Cone shaped, short on a line between eye and nostril, closer to eye than to nostril
Tail	Short and pointed	Short, tip whitish	No tail, body ends in a blunt shield	No tail, body ends in a blunt shield
Vent	Longitudinal	Longitudinal	Transverse	Transverse

Cont...

Uraeotyphlus malabaricus	Malabar - Kerala Ootacamund - Tamil Nadu	Taylor 1968
Uraeotyphlus menoni	Koduvalli, Cochin, Kottayam, Trichur - Kerala	Daniels 1963 Taylor 1968
Uraeotyphlus narayani	Kannam, Ernakulum - Kerala Sringeri - Karnataka	Daniels 1963 Taylor 1968 Balakrishna et al 1982 Bhatta 1986, 1997
Uraeotyphlus oxyurus	Taliparamba, Wynaad, Tinnivelly Malabar, Allur, Cochin - Kerala Anamalai hills - Kerala	Taylor 1968
Gegeneophis carnosus	Peria peak, Wynaad, Ponmudi hills, Tenmalai, Trivandrum - Kerala Kotigehar, Malige Range - Karnataka	Seshachar 1942 Seshachar & Ramaswami 1943 Daniels 1963 Taylor 1968 Revanasiddaiah et al 1982
Gegeneophis fulleri	Kuttal - Cachar	Taylor 1968
Gegeneophis ramaswamii	Tenmalai, Trivandrum, Bonocord - Kerala	Taylor 1964, 1968 And Author's Collection
Indotyphlus battersbyi	Khandala, Lonavala, Supegaon - Maharashtra	Taylor 1960b, 1968, 1970 Bhatta 1997

Cont...

MORPHOLOGICAL AND MORPHOMETERICAL PARAMETER VALUES FOR THE CAECILIAN SPECIES OF WESTERN GHATS

(All the measurements are in mm.)

Sr. No.	ABBREVIATIONS / ATTRIBUTES	IT n = 7 min	max	mean	s.d.	IL n = 6 min	max	mea	s.d.	ISIK n = 4 min	max	mea	s.d.	ISB n = 5 min	max	mean	s.d.
1	Total length	226	330	265	33.77	192	300	253	31.9	263	276	270	4.64	149	290	218	50.57
2	Tail length	3	6	4.69	0.87	4	5	4.75	0.38	4.5	5.5	4.98	0.48	9.5	13	11.05	1.39
3	Length by tail length	49	80	58.02	9.78	42.67	75	53.8	10					19.8	34	23.86	5.15
4	Head length	9.2	13	10.89	1.48	7.6	9.3	8.3	0.57	11	11	11	0				
5	Eye to nostril	4	5.5	4.63	0.65	4.1	5	4.66	0.33								
6	Eye to tentacle	2	2.5	2.27	0.18	1.4	2.8	2.15	0.41	1.7	1.7	1.7	0	0.9	1.8	1.42	0.37
7	Eye to eye	4.5	5.7	5.14	0.38	5.1	6.4	5.72	0.41	6.1	6.1	6.1	0	4.9	7.5	6.4	1.1
8	Eye level to snout tip	4.7	6.3	5.43	0.5	4.5	5.2	5.02	0.23	5.2	5.2	5.2	0	3.9	5.5	4.92	0.72
9	Nostril to tentacle	2.5	3.7	2.93	0.49	3.1	3.7	3.28	0.2	2.9	2.9	2.9	0	2.6	4	3.15	0.52
10	Snout tip to Ist groove	11	14.6	12.46	1.03	12	12.5	12.3	0.21					8.4	13.8	11.1	2.01
11	Snout tip to 2nd groove	14.8	18	15.75	1.31	14.5	16.4	15.5	0.74					10.4	17	13.84	2.63
12	Snout tip to 3rd groove	17.2	21.7	19.21	1.54	17.3	18.8	17.9	0.54					13.8	22	17.54	3.06
13	Width of head	7.1	9.1	8.27	0.75	7.5	9.6	7.95	0.77					6.3	11	8.58	1.84
14	Width of head at eye	6.1	7.8	6.63	0.68	6.3	7.8	6.94	0.7								
15	Width of head at 1st groove	7.3	9.3	7.88	0.83	8	10.1	8.66	0.81	10	10	10	0				
16	Width of head at 2nd groove	8.2	10.1	8.68	0.82	8.5	11.4	9.26	1.1								
17	Width of body	11.2	12.8	12.04	0.7	8.5	14.1	10.6	1.71	10	12.2	11.1	1.05	7.5	14	10.04	2.64
18	Length by width	21.7	27.5	23.8	2.26	21.3	26.5	24.2	1.7	22	27	24.7	2.36	18.6	25.6	21.98	2.5
19	Width of vent	3	4.9	4.03	0.8	3.2	4.4	3.68	0.4								
20	Tail folds (in nos.)	5	10	8	1.95	7	8	8	0.47	6	6	6	0	10	18	16	3.12
21	Total folds (in nos.)	249	297	280	15.33	324	352	340	9.39	276	292	284	5.72	364	383	374	7.11
22	Premaxillary-maxillary teeth (in nos.)	31	38	34.5	3.5	35				46	46	46	0	36	48	43.8	4.4
23	Prevomeropalatine teeth (in nos.)	49	59	54	5	28				40	42	41.5	0.87	36	52	44.2	5.67
24	Dentary teeth (in nos.)	30	38	34	4	32				37	42	40.3	1.92	31	44	36.6	5
25	Splenial teeth (in nos.)	4	30	17	13	4				16	18	17.5	0.87	13	16	14.5	1.5
26	Vertebrae (in nos.)	108	108	108	0					106	107	107	0.5				

IT = Ichthyophis tricolor   IL = Ichthyophis longicephalus   ISIK = Ichthyophis sikkimensi ISB = Ichthyophis subterrestris

n = Number of specimens examined

TABLE 4

MORPHOLOGICAL AND MORPHOMETERICAL PARAMETER VALUES FOR THE CAECILIAN SPECIES OF WESTERN GHATS
(All the measurements are in mm.)

Sr.	ABBREVIATIONS	IBD	n = 10			IBM	IM	n = 8			IP	n = 3		
No.	ATTRIBUTES	min	max	mean	s.d.	n = 1	min	max	mean	s.d.	min	max	mean	s.d.
1	Total length	210	270	242	21.77	390	340	540	461	64.15	260	330	292	28.96
2	Tail length	4	5	4.23	0.33	15.2	15	20	16.5	1.87	11	15.2	12.73	1.79
3	Length by tail length	50	64	58.08	4.96	25.6	21.3	32	28	3.07	22	23.8	23.13	0.81
4	Head length	7.4	7.4	7.4	0	15	9.6	22	15.29	3.75	9.5	16	12.03	2.84
5	Eye to nostril	1.8	2	1.87	0.08	5.5	5.5	7.3	6.69	0.57	4.6	5	4.77	0.17
6	Eye to tentacle	3.5	5	4.07	0.36	2.3	2.3	2.9	2.49	0.21	1.6	2.5	2.03	0.37
7	Eye to eye	3.7	4.4	4.11	0.19	8	7.5	10.6	9.36	1.02	6.3	7.1	6.6	0.36
8	Eye level to snout tip	2	2.5	2.16	0.14		7.2	10	9.17	0.99	6.1	6.4	6.25	0.15
9	Nostril to tentacle	8.6	11	9.91	0.56	4	4.2	6.2	5.2	0.54	3.3	4	3.65	0.35
10	Snout tip to Ist groove	11.7	14	12.41	0.69		14.3	24	19.29	2.74	13.1	14	13.55	0.45
11	Snout tip to 2nd groove	14	17	15.34	0.91		18.2	27.2	24.46	3	17.3	17.8	17.55	0.25
12	Snout tip to 3rd groove	6.5	9	7.77	0.95		23.3	36	30.94	4.02	21.2	21.5	21.35	0.15
13	Width of head	5.1	5.1	5.1	0	10	9.6	15.1	13.01	1.87	8.7	14.4	10.63	2.66
14	Width of head at eye	7	7	7	0		8.8	12.3	10.94	1.41	8	8.2	8.1	0.1
15	Width of head at 1st groove	7.1	7.1	7.1	0	10	9	13.8	11.89	1.76	8.2	9.1	8.65	0.45
16	Width of head at 2nd groove						9.1	14.5	12.17	1.85	9	9.6	9.3	0.3
17	Width of body	10.1	15	13.04	1.28	15	11.4	19.2	14.33	2.5	10.9	14.8	12.37	1.73
18	Length by width	16	26.7	18.78	2.86	26	26.2	41.2	32.6	4.4	22.3	25	23.73	1.11
19	Width of vent	4.1	4.1	4.1	0		4.4	9.2	7.14	1.59	5	5.3	5.15	0.15
20	Tail folds (in nos.)	9	9	9	0	14	14	19	18	1.58	18	19	18	0.47
21	Total folds (in nos.)	256	285	271	10.07	386	340	399	367	16.29	356	376	365	8.29
22	Premaxillary-maxillary teeth (in nos.)	40	49	42.67	2.98	45	67	67	67	0	49	49	49	0
23	Prevomeropalatine teeth (in nos.)	40	58	48.11	5.02	48	69	69	69	0	51	51	51	0
24	Dentary teeth (in nos.)	38	44	40.33	1.83	40	57	57	57	0	49	49	49	0
25	Splenial teeth (in nos.)	18	58	41	12.82	18	47	47	47	0	57	57	57	0
26	Vertebrae (in nos.)	102	121	108.3	7.46	111	110	110	110	0	104	104	104	0

IBD = Ichthyophis beddomei
IP = Ichthyophis peninsularis
IBM = Ichthyophis bombayensis
n = Number of specimens examined
IM = Ichthyophis malabarensis

Cont...

MORPHOLOGICAL AND MORPHOMETERICAL PARAMETER VALUES FOR THE CAECILIAN SPECIES OF WESTERN GHATS
(All the measurements are in mm.)

Sr. No.	ABBREVIATIONS ATTRIBUTES	GC n = 3 min	max	mean	s.d.	GF n = 1	GR n = 16 min	max	mea	s.d.	IBT n = 8 min	max	mean	s.d.
1	Total length	146	172	160	10.71	220	182	340	236	44.3	170	238	210	19.29
2	Tail length	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Length by tail length													
4	Head length					8.1					4.2	5.5	5.15	0.55
5	Eye to nostril													
6	Eye to tentacle										0.56	0.65	0.61	0.04
7	Eye to eye													
8	Eye level to snout tip													
9	Nostril to tentacle	1.2	1.2	1.2	0						1.3	1.3	1.3	0
10	Snout tip to Ist groove	4.8	4.8	4.8	0		7	11	8.17	1.25	4.4	5	4.8	0.24
11	Snout tip to 2nd groove	5.4	5.4	5.4	0		8.3	14	10.2	1.58	6	6.7	6.33	0.25
12	Snout tip to 3rd groove	7.7	7.7	7.7	0		11	18	13.8	1.93	7.7	8.5	8.1	0.29
13	Width of head	3	3.9	3.45	0.45		6	11	7.81	1.41	3	3.8	3.39	0.3
14	Width of head at eye													
15	Width of head at 1st groove													
16	Width of head at 2nd groove													
17	Width of body	4.2	4.9	4.57	0.29		7.9	13.6	10.3	1.5	3.7	4.9	4.27	0.41
18	Length by width	35	35	35	0		21	25	22.9	1.25	45.2	53	48.6	2.35
19	Width of vent	3.9	4	3.95	0.05	9	6.4	11	8.73	1.25				
20	Tail folds (in nos.)	0	0	0	0	0	0	0	0	0	0	0	0	0
21	Total folds (in nos.)	118	119	119	0.5	105	109	116	113	1.84	155	168	160	5.43
22	Premaxillary-maxillary teeth (in nos.)	21	25	23.67	1.89	22	29	37	32.2	2.17	18	28	22.88	2.57
23	Prevomeropalatine teeth (in nos.)	19	24	22.33	2.36	23	27	37	30	3.05	13	34	25.5	5.57
24	Dentary teeth (in nos.)	18	20	19	0.82	20	20	28	23.9	2.77	16	23	20	2.18
25	Splenial teeth (in nos.)	2	8	5	3	6	4	20	7.36	5.26	4	4	4	0
26	Vertebrae (in nos.)						106	108	107	1				

GR = Gegeneophis ramaswamii GF = Gegeneophis fulleri GC = Gegeneophis carnosus IBT = Indotyphlus battersbyi
n = Number of specimens examined

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MORPHOLOGICAL AND MORPHOMETERICAL PARAMETER VALUES FOR THE CAECILIAN SPECIES OF WESTERN GHATS
(All the measurements are in mm.)

Sr.	ABBREVIATIONS	UM	n = 5			UN	n = 10			UME	n = 2	UO	n = 13		
No.	ATTRIBUTES	min	max	mean	s.d.	min	max	mean	s.d.			min	max	mean	s.d.
1	Total length	145	234	190	34.87	199	245	230	13.67	245	207	82	300	237	54.91
2	Tail length	3	6	4.72	1.07	4	8	6.1	1.45	6.3	5	2	7.5	5.22	1.29
3	Length by tail length					30	55	39.73	8.81						
4	Head length					6.3	11	8.12	1.43						
5	Eye to nostril					2.3	3.6	3.29	0.37			1	1.6	1.19	0.22
6	Eye to tentacle	3	3.5	3.28	0.19	2.3	3.7	3.3	0.38	3.6	3.3	2.5	4.3	3.41	0.53
7	Eye to eye					3.5	4.5	4.03	0.27						
8	Eye level to snout tip					4	5	4.63	0.41						
9	Nostril to tentacle	1	1.2	1.1	0.07	1	1	1	0	1.2	1.1				
10	Snout tip to Ist groove	6	8.4	7.49	0.93	8.8	10	9.47	0.38	10	8				
11	Snout tip to 2nd groove					11.4	13.2	12.35	0.54	15.2	13				
12	Snout tip to 3rd groove	14	14.8	14.47	0.34	14.1	15.5	14.97	0.49						
13	Width of head					6	8.5	6.8	0.83			3.8	8.8	7.25	1.38
14	Width of head at eye	4.7	5.1	4.93	0.17	5	5.8	5.32	0.26	5.7	5.1				
15	Width of head at 1st groove	6	6.8	6.3	0.36	6	6.7	6.32	0.22	6.9	7.2				
16	Width of head at 2nd groove					6.5	7.2	6.82	0.24						
17	Width of body	6	9	7.67	0.96	9	11	9.9	0.58	12	10	4	14	10.45	2.68
18	Length by width	20	28	24.52	2.65	21	26.9	23.29	1.8	20.4	20.7	18	29	22.95	3.19
19	Width of vent					4.3	6	4.75	0.59	6.8	5				
20	Tail folds (in nos.)					3	9	7	2.3						
21	Total folds (in nos.)	206	246	234	14.81	169	184	178	3.78	176	172	187	211	200	5.91
22	Premaxillary-maxillary teeth (in nos.)	32	36	34.2	1.47	26	31	28.67	2.06	28	25	27	35	31.55	2.27
23	Prevomeropalatine teeth (in nos.)	36	43	40	2.37	36	38	37.33	0.94	36	36	31	45	36.91	4.62
24	Dentary teeth (in nos.)	30	39	35.6	3.38	30	32	31	0.82	27	28	24	36	30.5	3.75
25	Splenial teeth (in nos.)	10	17	15	2.53	10	16	13.75	2.28		15	12	52	21.1	12.27
26	Vertebrae (in nos.)					10	16	13.75	2.28			105	105	105	0

UM = Uraeotyphlus malabaricus   UN = Uraeotyphlus narayani   UMEI = Uraeotyphlus menoni   UO = Uraeotyphlus oxyurus
n = Number of specimens examined

TABLE 5

LOCALITIES, GEOGRAPHY, CLIMATE, SAMPLING EFFORTS AND SPECIES ENCOUNTERED

LOC. NO.	LOCALITY	NEARBY TOWN	Latitude (deg. N	Longitud (deg. E)	Altitude (m ASL	Rainfall (mm/yr)	Dry Months (/yr)	Dura- -tion (min)	Area Searche (sq.m)	No. of Spp.	Species Abbr.	No. of Indivi- -duals
1	Supegao	Murud	18,25'	73,45'	300	3000	7	210	175	2	inb,ibd	3
2	Mala	Karkala	13,02'	75,15'	200	6000	5	120	100	1	ibd	3
2	Mala	Karkala	13,02'	75,15'	200	6000	5	90	75	1	iml	1
3	Neggu	Sirsi	14,33'	74,39'	600	3000	6	55	45	1	ibd	4
3	Neggu	Sirsi	14,33'	74,39'	600	3000	6	60	60	1	ibd	1
3	Neggu	Sirsi	14,33'	74,39'	600	3000	6	150	125	1	iml	1
4	Badal	Kumta	14,28'	74,29'	100	4000	6	120	90	1	ibd	9
4	Badal	Kumta	14,28'	74,29'	100	4000	6	60	50	1	ibd	1
5	Kigga	Sringeri	13,26'	75,10'	800	6000	5	120	95	1	ibd	3
5	Kigga	Sringeri	13,26'	75,10'	800	6000	5	125	100	1	ibd	4
5	Kigga	Sringeri	13,26'	75,10'	800	6000	5	60	50	1	ibd	1
5	Kigga	Sringeri	13,26'	75,10'	800	6000	5	45	36	1	ibd	1
6	Karimba	Mundur	11,00'	76,32'	300	5000	4	235	192	3	isp2,itr,ibd	6
6	Karimba	Mundur	11,00'	76,32'	300	5000	4	80	80	2	iml,isp2	4
6	Karimba	Mundur	11,00'	76,32'	300	5000	4	195	180	1	iml	1
6	Karimba	Mundur	11,00'	76,32'	300	5000	4	110	85	1	isp3	1
6	Karimba	Mundur	11,00'	76,32'	300	5000	4	185	180	1	un	8
7	Thiruambadi	Calicut	11,15'	76,10'	800	4000	4	175	160	2	un,ilg	5
7	Thiruambadi	Calicut	11,15'	76,10'	800	4000	4	95	75	1	ilg	1
7	Thiruambadi	Calicut	11,15'	76,10'	800	4000	4	55	45	2	un,ilg	8
7	Thiruambadi	Calicut	11,15'	76,10'	800	4000	4	110	85	1	un	3
7	Thiruambadi	Calicut	11,15'	76,10'	800	4000	4	50	48	1	un	1
8	Vithura	Trivandrum	8,40'	77,10'	300	2000	3	65	60	1	gra	7
8	Vithura	Trivandrum	8,40'	77,10'	300	2000	3	35	30	1	gra	6
							mean	108.5	92.54	1.3		3.46
							s.d.	56.02	49.14	0.5		2.6
							total	2605	2221	9		83

inb= Indotyphlus battersbyi, ibd= Ichthyophis beddomei
iml= Ichthyophis malabarensis, isp2,3= Ichthyophis species 2,3
itr= Ichthyophis tricolor, un=Uraeotyphlus narayani
ilg= Ichthyophis longicephalus, gra= Gegeneophis ramaswami

TABLE 6

SOIL PARAMETERS FROM COLLECTION LOCALITIES

LOC. NO.	NEARBY TOWN	LOCALITY	SITE NO.	Soil Temp. deg. C	Relative Humidity %	pH	Elctr. Conduct. dS/m	Oganic Carbon %	Exchangeable Ca Cmol(p+)/kg	Mg	Available K2O kg/ha	P2O5 kg/ha	Total N %	Available S ppm	Exchangeable NA ppm
1	Murud	Supegao	1	25.5	95.02	6.46	1.67	7.98	14.4	4.64	1370	31.45	0.65	65.55	144.4
2	Karkala	Mala	2	26	42.95	6.47	0.53	2.76	3.33	2.63	371	69.02	0.185	36.33	140
2	Karkala	Mala	3	26	56.78	6.59	0.77	4.84	5.51	4.9	1740	27.36	0.03	29.36	157.5
3	Sirsi	Neggu	4	26	42.1	6.63	0.77	6.62	7.79	6.65	734	90.26	0.46	54.15	102
3	Sirsi	Neggu	5	26	42.1	6.64	0.2	2.21	4.55	2.01	198	30.22	0.04	29.21	76.6
3	Sirsi	Neggu	6	26	65.64	6.93	0.48	6.02	10.6	3.678	103	75.15	0.39	53.64	100.6
4	Kumta	Badal	7	26.5	34.98	6.99	0.47	4.58	6.65	5.86	296	332.89	0.11	27.07	81.9
4	Kumta	Badal	8	26	54.92	7.04	0.49	7.93	12.2	6.39	1034	111.91	0.03	65.55	111.6
5	Sringeri	Kigga	9	22.5	38.45	7.05	0.22	2.29	4.29	1.71	1223	23.28	0.15	57	146.6
5	Sringeri	Kigga	10	25.5	45.41	6.09	0.32	2.84	3.94	2.89	405	7.76	0.23	21.37	87
5	Sringeri	Kigga	11	25.5	50.59	5.89	0.42	5.13	5.69	1.92	381	31.85	0.35	47.73	111.8
5	Sringeri	Kigga	12	22.5	19.35	6.52	0.32	2.76	4.11	1.49	465	123.35	0.186	32.77	135.6
6	Mundur	Karimba	13	25	40.69	7.35	0.64	4.11	1.49	1.14	84	153.57	0.27	37.05	74.4
6	Mundur	Karimba	14	24	29.54	6.59	0.54	1.78	5.43	0.26	461	241.79	0.12	28.5	74.4
6	Mundur	Karimba	15	24	29.22	6.97	0.29	2.03	5.08	1.49	409	253.2	0.08	34.2	105
6	Mundur	Karimba	16	24	39.62	7.04	0.18	2.37	3.76	3.5	1740	46.15	0.2	29.1	111.6
6	Mundur	Karimba	17	24	29.22	6.97	0.29	2.3	5.08	1.49	409	253.2	0.08	34.2	105
7	Calicut	Thiruambadi	18	23	58.1	7.67	0.58	4.45	8.49	5.6	3528	256.5	0.06	35.62	150.9
7	Calicut	Thiruambadi	19	24	48.43	6.81	0.39	5.3	9.8	2.54	1072	144.59	0.45	59.14	157.5
7	Calicut	Thiruambadi	20	24.5	58.1	6.31	0.14	3.39	3.06	3.33	940	96.8	0.02	22.08	120.3
7	Calicut	Thiruambadi	21	24	37.5	5.46	0.08	3.9	6.65	5.16	960	8.98	0.24	26.36	144
7	Calicut	Thiruambadi	22	22	35.57	6.59	0.27	3.9	5.08	4.11	400	42.47	0.29	21.38	131.3
8	Trivandrum	Vithura	23	25.5	41.14	5.91	0.04	1.36	2.1	1.31	188	8.17	0.114	17.81	17
8	Trivandrum	Vithura	24	25.5	28.73	6.39	0.08	1.7	2.28	1.31	103	15.52	0.1	19.95	76.6
			mean	24.73	44.34	6.64	0.42	3.86	5.89	3.17	775.583	103.14	0.2	36.88	110.98
			s.d.	1.28	15.24	0.48	0.33	1.87	3.17	1.82	751.686	95.03	0.15	14.55	33.48