Distribution and abundance of the caecilian *Gegeneophis ramaswamii* (Amphibia: Gymnophiona) in southern Kerala

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In 1998 and 1999 we conducted investigations of poorly known, soil-dwelling caecilian amphibians of the southern region of the Western Ghats, a recognized biodiversity hotspot. *Gegeneophis ramaswamii* was widely encountered in varied habitats between sea-level and 600 m, south of 08°58′N and west of 77°24′E. It was the most common caecilian species found here, and in two localities densities ranged between 0.44 and 1.13 individuals, and 2.59 and 5.54 g per m^2. This indicates that, contrary to many reports, caecilians are highly abundant in some localities, and that the ecological consequences of this demand investigation.

THE Western Ghats is recognized as a world biodiversity hotspot[1,2], home to many Indian and regional endemic species. Despite extensive studies of the biodiversity of many groups of prominent organisms, such as trees, birds and butterflies[3,4], we remain far from a comprehensive understanding of the diversity, distribution and abundance of many species in this region.

The general pattern of high endemicity in the Western Ghats is well-reflected in the amphibians, with approximately 75% of all Indian endemics found only in this region[5]. This pattern appears to apply to the least well-known group of amphibians, the caecilians, as well as to the more conspicuous frogs. Of the four genera and 16 nominate species of caecilians that occur in India, two genera and 14 species are Western Ghats endemics[6,7], making the region a biodiversity hotspot for this enigmatic group. A recent survey found nine of a suggested 14 species from the region, leading to the prediction that increased searching would discover more species than are currently recognized[8].

Caecilians are elongate, limbless vertebrates of the wet tropics where they are mostly burrowing, carnivorous inhabitants of soil. They are often presumed rare and many aspects of their biology are poorly known. Although their subterranean habits make caecilians harder to study or to collect than some other vertebrates, their apparent rarity is not completely supported by the primary literature. Seshachar, whose first caecilian paper was published in the first volume of *Current Science*[9], and Ramaswami established a productive research programme on the morphology and gametogenesis of caecilians. Obtaining specimens necessitated extensive fieldwork and this revealed that several Western Ghats species are not always rare[10]. Here we present our findings regarding the distribution and abundance of the caecilian species *Gegeneophis ramaswamii*.

In 1998 and 1999 (Table 1) we conducted fieldwork in Kerala as part of a study of caecilians of the Western Ghats. Surveys were conducted in a range of cultivated habitats at various locations. Sites surveyed were either previously known to yield caecilians, or were selected on the basis of the advice of local people or our own assessment of potential site suitability. Surveys were carried out by digging the soil to a depth of approximately 0.3 m, by rolling logs, and by turning over leaf litter and compost. At some sites, air and soil temperatures and soil pH were measured. Approximate altitudes, latitudes and longitudes were determined using Global Positioning System receivers and/or maps[11].

G. ramaswamii (identifications verified by comparison with type material at the Natural History Museum, London) was encountered at 14 localities. Voucher specimens are deposited at the Department of Zoology, University of Kerala. Building on previous work, there are now 18 known localities for this species (Table 1, Figure 1). With the exception of a first record for Tamil Nadu, all known localities for *G. ramaswamii* are in Thiruvananthapuram and Kollam Districts in southern Kerala. We never encountered *G. ramaswamii* in localities further north than 08°58′N. In our fieldwork, *G. ramaswamii* was the most frequently encountered of any caecilian species in these southernmost districts, both in the number of localities and numbers of specimens. This species was found in

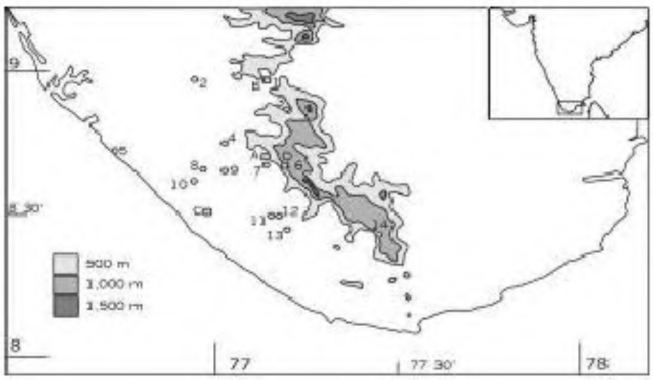

Figure 1. Map of southern peninsular India indicating the position of localities yielding *Gegeneophis ramaswamii*. Localities from the previous literature are shown as lettered squares, and those reported herein as numbered circles. Details for each locality are presented in Table 1, co-ordinates are given in degrees and minutes. Shading indicates approximate elevation in the region of the southern Western Ghats.

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Table 1. Localities in southern India yielding *Gegeneophis ramaswamii*

	State	District	Locality	N	E	Altitude (m asl)	pH	Temp. soil (°C)	Temp. air (°C)	Habitat	Sympatric caecilians	Authority
A	Kerala	Thiruvananthapuram	Kallaar (Kallar)	08°42′*	77°07′*	152				Not stated		Ferguson[23], Daniel[24]
B	Kerala	Kollam	Thenmalai	08°58′*	77°07′*	up to 152				Forest?	Not stated	Seshachar[20], Seshachar and Ramaswami[10], Taylor[6,13]
C	Kerala	Thiruvananthapuram	Pujapura, Thiruvananthapuram	08°31′*	76°59′*	30–46				'Plantain garden'	Not stated	Ramaswami[14], Seshachar and Ramaswami[10], Taylor[6,13]
D	Kerala	Thiruvananthapuram	Vithura/Bonaccord	08°40′	77°10′	300				Not stated		Bhatta[8,25]
1	Kerala	Kollam	Nagamallay Estate, Thenmalai	08°8′*	77°07′*	140*				Rubber plantation		This paper, visited 15/09/99
2	Kerala	Kollam	near Punalur	08°58′	76°57′	70*	6.4–6.9	23.3–23.5	23.3–25.8	Rubber plantation		This paper, visited 5/08/98, 7/08/98 & 16/10/99
3	Kerala	Kollam	Kallar Valley Estate	08°52′	77°10′	550				Terraced rubber plantation	*It*	This paper, visited 06/08/98
4	Kerala	Thiruvananthapuram	TBGRI, Palode	08°45′	77°01′	160				Botanical gardens	*Ip, It*	This paper, visited 15/10/99
5	Kerala	Thiruvananthapuram	Varkala	08°45′*	76°47′*	< 50*				Flooded coconut plantation		This paper, visited 10/98
6	Kerala	Thiruvananthapuram	Bonaccord Estate	08°40′	77°10′	593	6.3–94	22.5–22.8	21.8	Tea plantation		This paper, visited 30/07/98 & 14/10/99
7	Kerala	Thiruvananthapuram	Makki	08°40′	77°07′	238				Rubber plantation	*It*	This paper, visited 30/07/98 & 14/10/99
8	Kerala	Thiruvananthapuram	Vanchuvam	08°39′	77°01′	< 100*				Small mixed plantation		This paper, visited 30/07/98
9	Kerala	Thiruvananthapuram	Cheranikara, Thekkada	08°39′	76°58′	100	7.46	24.6	22.6	Terraced mixed plantation		This paper, visited 15/07/99
10	Kerala	Thiruvananthapuram	Thekkada	08°37′	76°57′	60				Mixed smallholding	*It*	This paper, visited 08/12/98
11	Kerala	Thiruvananthapuram	Kovalathunada	08°30′	77°09′	55				Mixed plantation	*It, U*	This paper, visited 01/08/98
12	Kerala	Thiruvananthapuram	Vazhichal	08°30′	77°08′	85				Terraced rubber plantation	*It, U*	This paper, visited 15/08/98
13	Kerala	Thiruvananthapuram	Kiliyoor, Vellarada	08°27′	77°10′	< 100*				Mixed plantation	*It*	This paper, visited 15/08/98
14	Tamil Nadu	Kanyakumari	Maramalai	08°26′	77°24′	600*				Areca nut plantation	*It*	This paper, visited 26/11/98

The positions of lettered (previous literature) and numbered (this paper) localities are shown in Figure 1. pH and temperatures were all recorded in 1999 at 12:00 (± 2 hours). Soil temperatures were recorded at a depth of 0.2–0.3 m. Co-ordinates are given in degrees and minutes.

*indicates data obtained from maps[11]. Abbreviations for sympatric caecilians: *Ip* = *Ichthyophis* cf. *peninsularis*; *It* = *Ichthyophis tricolor*; *U* = *Uraeotyphlus* sp.

a wide variety of cultivated habitats (Table 1). Most specimens were found in soil, with very few found on the soil surface, under logs or litter. The animals were commonly found in moist soils in well-irrigated plantations as well as in more inundated marshy areas, but some specimens were found in relatively dry soils at some distance from running or standing water. Specimens were found in both shady and in more exposed places. We found *G. ramaswamii* at all elevations that we surveyed, from sea-level to about 600 m. Soil pH ranged from 6.30 to 7.46 and soil temperatures from 22.5 to 24.6°C.

During our 1998 field season we formed the impression that *G. ramaswamii* was highly abundant at some sites. For example, at Bonaccord we found 55 animals in a short space of time in a strip of marshy soil (< 15 m^2) parallel to a fast flowing stream. In 1999, we obtained quantitative estimates of abundance. At two sites a series of separate plots were dug, the surface area of the soil in each plot was measured and the numbers and fresh weights of caecilians were recorded. At Bonaccord we dug five plots (of between 1.5 and 8.0 m^2) with a total surface area of 22.95 m^2 and found an average number of individuals of 1.13 per m^2 and an average mass of 3.12 g per m^2. Near Punalur we dug 30 plots (of between 0.8 and 3.7 m^2) with a total surface area of 51.45 m^2. The larger number of plots sampled here allowed estimation (using bootstrapping[12]) of 95% confidence intervals for the mean numbers of individuals and mass of *G. ramaswamii* at this site, which were 0.44–0.89 individuals per m^2 (mean = 0.64) and 2.59–5.54 g per m^2 (mean = 3.98) respectively.

G. ramaswamii was described by Taylor[13] based on a holotype and fifteen paratopotypes. He stated that this material was collected by Ramaswami from 'Tenmalai Forest', southern Kerala, at an elevation of approximately 170 m above sea level. Prior to this, both Ramaswami and Seshachar had published a number of papers utilizing material they collected from Thenmalai and from two other localities: Pujapura[14] (in the vicinity of Thiruvananthapuram, southern Kerala) at sea-level and Kottigehar[10] (in Karnataka) at approximately 950 m. Seshachar and Ramaswami[10] referred to all of this material as *G. carnosus*, which was otherwise known only from two cotypes collected and described by Beddome[15] from Peria peak (Wyanaad, northern Kerala) at a reported altitude of approximately 1500 m. Seshachar and Ramaswami[10] reported that the specimens from Kottigehar were more similar in size and colouration to Beddome's specimens and suggested that these might all be adolescents. Later, Ramaswami[16] suggested that specimens from Thenmalai and from Kottigehar might belong to two different races of *G. carnosus*. Taylor's[13] description of *G. ramaswamii* fomalized the distinction of these putative races at the specific level, with *G. ramaswamii* representing the form known from the vicinities of Thiruvanathapuram and Thenmalai in southern Kerala, and *G. carnosus* the form known from northern Kerala and Karnataka. Taylor[6] also noted that 'as far as known, *ramaswamii* is confined to low elevations and *carnosus* to elevations of 3,000 to 5,000 ft'.

Our observations indicate that *G. ramaswamii* is widespread in southern Kerala, and that it is not restricted to low elevations. *G. ramaswamii* has been previously reported from cultivated areas[10,17], and our recent fieldwork demonstrates that it is successfully exploiting a range of anthropic environments. Acidic soils have been suggested to be a possible prerequisite for caecilians[18] but this does not seem to be the case for *G. ramaswamii*.

Generally, the caecilians of the Western Ghats are thought to be rare[8,18]. However, there are several reports of plentiful collections of caecilians from the Western Ghats and elsewhere[10,17,19–21]. This suggests that, for at least some caecilian species, their apparent rarity may be a consequence of their secretive burrowing lifestyles and the infrequency with which they are encountered, rather than an accurate reflection of their abundance. Our data for *G. ramaswamii* fit this picture and indicate that this species is far more abundant than previously believed. There are very few quantitative estimates of caecilian abundances in India or elsewhere. Bhatta[8] reported finding 83 caecilians of various species in a total area of 2,221 m^2 in surveys of 24 sites at eight Western Ghats localities: a mean abundance of 0.037 individuals per m^2. This is an order of magnitude lower than our estimates for *G. ramaswamii*, but the difference is less dramatic when we consider only Bhatta's results for the two sites where he found this species (0.200 and 0.117 individuals per m^2). Our sampling strategy was not ideal in that it did not conform to a randomized block design, and the estimates of means and confidence intervals presented here should be taken as preliminary. In addition, our fieldwork was conducted in the rainy season and it remains unknown in what densities and what habitats caecilians occur at other times.

The apparent rarity of caecilians has led to concerns that they may be endangered. Gundappa *et al.*[18] stated that

Caecilian amphibian *Gegeneophis ramaswamii* Taylor from southern Kerala.

'It does not appear that caecilians anywhere are abundant' and concluded that: 'Denudation of the forests of the Western Ghats, which is the main home of caecilians in South India, is going on at a pace which spells the almost certain extinction of these animals within a short time. Hence, it appears imperative that their ecology and modes of life are understood before it is too late.' These are important concerns and there is certainly an urgent need for further study of caecilian ecology. However, the successful adaptation of *G. ramaswamii* to cultivated land and its abundance in some anthropic habitats suggests that this species is unlikely to be under immediate threat of extinction from deforestation alone. Hebrard *et al.*[21] suggested that agrochemicals could have an adverse effect on caecilian populations. Agrochemicals were not in use at any of the sites where we found *G. ramaswamii*, and the extent to which the survival of this species is threatened by agrochemical use, and is therefore dependent upon sympathetic agricultural practices, remains to be determined.

The abundance of *G. ramaswamii* reported here raises an important question. What is the impact of this species on soil ecosystems of the Western Ghats? There are no data on the impact of any caecilian species on the biotic and abiotic characteristics of the soils that they inhabit. Their burrowing is likely to affect soil drainage and aeration, and their skin secretions might have physicochemical effects as do those of earthworms[22]. Through predation, caecilians contribute to nutrient turnover and they must affect the population structure of earthworms and termites and the soil processes in which they are involved. The impact of caecilian ecology upon crop yields is not known. We hope to begin addressing some of the ecological issues using *G. ramaswamii* as a model system.

1. Gadgil, M., *Curr. Sci.*, 1996, **70**, 36–44.
2. Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B. and Kent, J., *Nature*, 2000, **403**, 853–858.
3. Nagedra, H. and Gadgil, M., *J. Appl. Ecol.*, 1999, **36**, 388–397.
4. Kunte, K., Joglekar, A., Utkarsh, G. and Padmanabhan, P., *Curr. Sci.*, 1999, **77**, 577–586.
5. Inger, R. F. and Dutta, S. K., *J. Bombay Nat. Hist. Soc.*, (suppl.), 1987, **83**, 135–146.
6. Taylor, E. H., *The Caecilians of the World*, University of Kansas Press, Lawrence, 1968.
7. Pillai, R. S., *Rec. Zool. Surv. India*, 1986, **84**, 229–242.
8. Bhatta, G., *Curr. Sci.*, 1997, **73**, 183–187.
9. Seshachar, B. R., *Curr. Sci.*, 1933, **1**, 311–312.
10. Seshachar, B. R. and Ramaswami, L. S., *Half-year. J., Mysore Univ.*, 1943, **4**, 111–113.
11. Maps: TCP K-8A to 8D (scale 1 : 500,000) Defense Mapping Agency, St. Louis, USA, 1983.
12. Manly, B. F. J., *Randomization and Monte Carlo Methods in Biology*, Chapman and Hall, London, 1991.
13. Taylor, E. H., *Senck. Biol.*, 1964, **45**, 227–231.
14. Ramaswami, L. S., *J. Mysore Univ.*, 1942, **3**, 205–220.
15. Beddome, R. H., *J. Med. Sci.*, 1870, **2**, 169–176.
16. Ramaswami, L. S., *Proc. Zool. Soc. London B*, 1948, **118**, 752–760.
17. Nussbaum, R. A. and Pfrender, M. E., *Misc. Publ. Mus. Zool. Michigan*, 1998, **187**, 1–32.
18. Gundappa, K. R., Balakrishna, T. A. and Shakuntala, K., *Curr. Sci.*, 1981, **50**, 480–483.
19. Loveridge, A., *Bull. Mus. Comp. Zool.*, 1936, **79**, 369–430.
20. Seshachar, B. R., *Curr. Sci.*, 1942, **11**, 439–441.
21. Hebrard, J. J., Maloiy, G. M. O. and Alliangana, D. M. I., *J. Herpetol.*, 1992, **26**, 513–515.
22. Lee, K. E., *Earthworms, their Ecology and Relationships with Soils and Land Use*, Academic Press, London, 1985.
23. Ferguson, H. S., *J. Bombay Nat. Hist. Soc.*, 1904, **15**, 499–509.
24. Daniel, J. C., *J. Bombay Nat. Hist. Soc.*, 1963, **60**, 415–438.
25. Bhatta, G., *J. Biosci.*, 1998, **23**, 73–85.

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