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# An overview of caecilians (Amphibia: Gymnophiona) of North East India

## Abstract

An overview of the caecilians of North East India (NEI) is presented. Two caecilian families are known from NEI, the widespread Asian family Ichthyophiidae, and the NEI-endemic and monotypic family Chikilidae. There are currently 12 species of caecilians reported from NEI, four species of *Chikila*, seven species of striped *Ichthyophis*, and one species of unstriped *Ichthyophis*. This overview provides the progress of research on NEI caecilian fauna to date, its diversity, taxonomy, systematics, biogeography, natural history, and distribution. Based on extensive direct interactions with local people in NEI for several years, it is clear that caecilians are generally despised due to a widespread misconception that they are venomous. The general public in NEI clearly needs a sustained community education about caecilians so that they can become more sympathetic towards them. The paper also discusses the general conservation scenario, or the lack of it, in NEI, and the plight of basic research, ith an appeal for the respect that scientific merit deserves.

**Key words:** *Amphibia, morphology, public awareness, review, scientific merit, Teresomata*

*Chikila fulleri* female with her litter.

## Introduction

Caecilians (Gymnophiona Müller, 1832) are completely limbless and girdleless snake-like amphibians. They are an ancient lineage, and are sister to all other extant amphibians (Zardoya & Meyer 2000).For almost a century the systematic placement of caecilians remained uncertain; they were mostly thought to be degenerate or naked reptiles, or eels (e.g., Linnaeus1758, Schneider 1801,Seba 1735, Shaw 1802). Seba (1735) in his Thesaurus, published the first account dealing with caecilian species under the name 'Caecilia'. The first definitive indications of caecilians to be amphibians were the discovery of gills in juvenile caecilians by Müller (1831, 1835) and Hogg (1841). Duméril and Bibron's (1841) report on several aspects of caecilians anatomy provided more incisive evidence to support that caecilians belong to amphibians. However, debates still continued during the 19th century, but roughly by around the 1880s most workers accepted that caecilians were amphibians. The first caecilian species to be scientifically described was *Caecilia tentaculata* by Linnaeus (1758) providing for the first time official recognition for the name '*Caecilia*', and this name became the first generic name in Gymnophiona.

Caecilians are primarily adapted to a secretive burrowing lifestyle as adults, except for a South American group—the typhlonectids—which are secondarily aquatic or semi-aquatic (Taylor 1968, Wilkinson & Nussbaum 1999). Caecilians have elongated tube-like bodies with external rings all along the length of the body, each of which is called an annulus. Caecilians may or may not have tails; a true tail is characterised by the possession of vertebrae posterior to the cloacal vent, as in the family Ichthyophiidae; the tail is absent in members of the family Chikilidae (Kamei et al. 2013). Tails are considered an ancestral feature, and absence of tails as

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derived. Adult caecilians have protractile structures called tentacles on each side of the snout, located typically between the eyes and the nostrils, that are thought to have a sensory function (Duellman & Trueb 1994, Himstedt 1996, Noble 1931, Taylor 1968). Caecilians possess a unique, dual jaw-closing mechanism consisting of an ancestral component and a unique, novel component (Nussbaum 1977, 1983). Caecilians have a remarkable diversity of reproductive strategies; they are reported to have oviparity with both direct and indirect development and at least two modes of viviparity (*sensu* Blackburn 1992, 2000; e.g., Kouete et al. 2012, Kupfer et al. 2006, Loader et al. 2003, Wilkinson & Nussbaum 2006). Unlike in anurans (exception tailed frogs, *Ascaphus*) and caudates where external fertilisation is the typical mode of fertilisation, all species of caecilians practice internal fertilisation (e.g., Taylor 1968, Wake 1977) through an intromittent organ, or phallus, in males (e.g., Gower & Wilkinson 2002).

Caecilians are currently known to occur in the tropical (and some adjacent subtropical) regions of Asia, Africa, the Seychelles islands and Central and South America. To date there are 205 nominal species (Frost 2017) classified in 34 genera (Wilkinson et al. 2011). The latest family-level classification of caecilians recognises ten distinct caecilian families (Kamei et al. 2012, Wilkinson et al. 2011), each of which has an ancient (Mesozoic) origin. Most of the families are diagnosable by small sets of characters (Kamei et al. 2012, Wilkinson et al. 2011). Caecilians remain very poorly studied, in several aspects—including their lower-level taxonomy, breeding biology, life history, conservation requirements and/or status. Gower and Wilkinson (2005) highlighted the lack of even basic information for a majority of caecilian species; detailed ontogenetic studies, sexual variation, and morphological variation within and between populations of caecilians are badly wanting (Nussbaum & Wilkinson 1989). Caecilians' secretive burrowing lifestyle and the consequent difficulty to find them, requiring physical labor [skilled and dedicated soil digging, e.g., Gower & Wilkinson (2005), Malonza & Müller (2004)], is one of the biggest challenges to the study of caecilians, and perhaps is responsible for the relative under representation of specimens in museum collections. This "rarity" of specimens has resulted in a large number of very poorly circumscribed species as early original descriptions were often based on a unique type specimen (e.g., Alcock 1904, Taylor 1968), or small sample size (two to three animals), and/or just one sex.

## History of NEI caecilian studies

North East India (NEI) is the easternmost region of India comprising the contiguous seven states (Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland and Tripura), Sikkim, and the northerndistricts (Darjiling, Kalimpong, and Jalpaiguri) of West Bengal, and shares international boundaries with Bangladesh, Bhutan, China, Myanmar and Nepal (Fig. 1).

The region is located between 29.46°–21.96°N and 97.39°–88.88°E, and forms a significant portion of two global biodiversity hotspots—the Indo-Burma and the Himalaya hotspots—ca. 8.2% of the 3,114,763 km$^2$ occupied by the two hotspots combined (Mittermeier et al. 2004) with a larger bulk of the region falling in the Indo-Burma hotspot. Aspects such as diverse physiography; vegetation diversity ranging from tropical rainforests to alpine scrubs (Mani 1974); extensive altitudinal range (from sea level to more than 85000 m asl); very heavy precipitation, being one of the highest rainfall-receiving regions in the world (Jain et al. 2013), provide unique micro-/habitats for amphibians making NEI one of India's two main hotspots (the other being the Western Ghats, Inger & Dutta [1986]) for its diversity and endemism.

Amphibians of NEI have rarely been included in regional (or global) phylogenetic and biogeography studies—e.g., on caecilians (Kamei et al. 2012), and anurans (Biju et al. 2014, 2016, Mahony et al. 2017). Prior to 2009, very little was known about NEI's caecilian diversity, taxonomy or its phylogenetic affinities. At the turn of the 20th century, the region with a geographical area of about 255,000 km$^2$ was reported to have only four poorly circumscribed caecilian species, known altogether from ten adult museum specimens, with adults

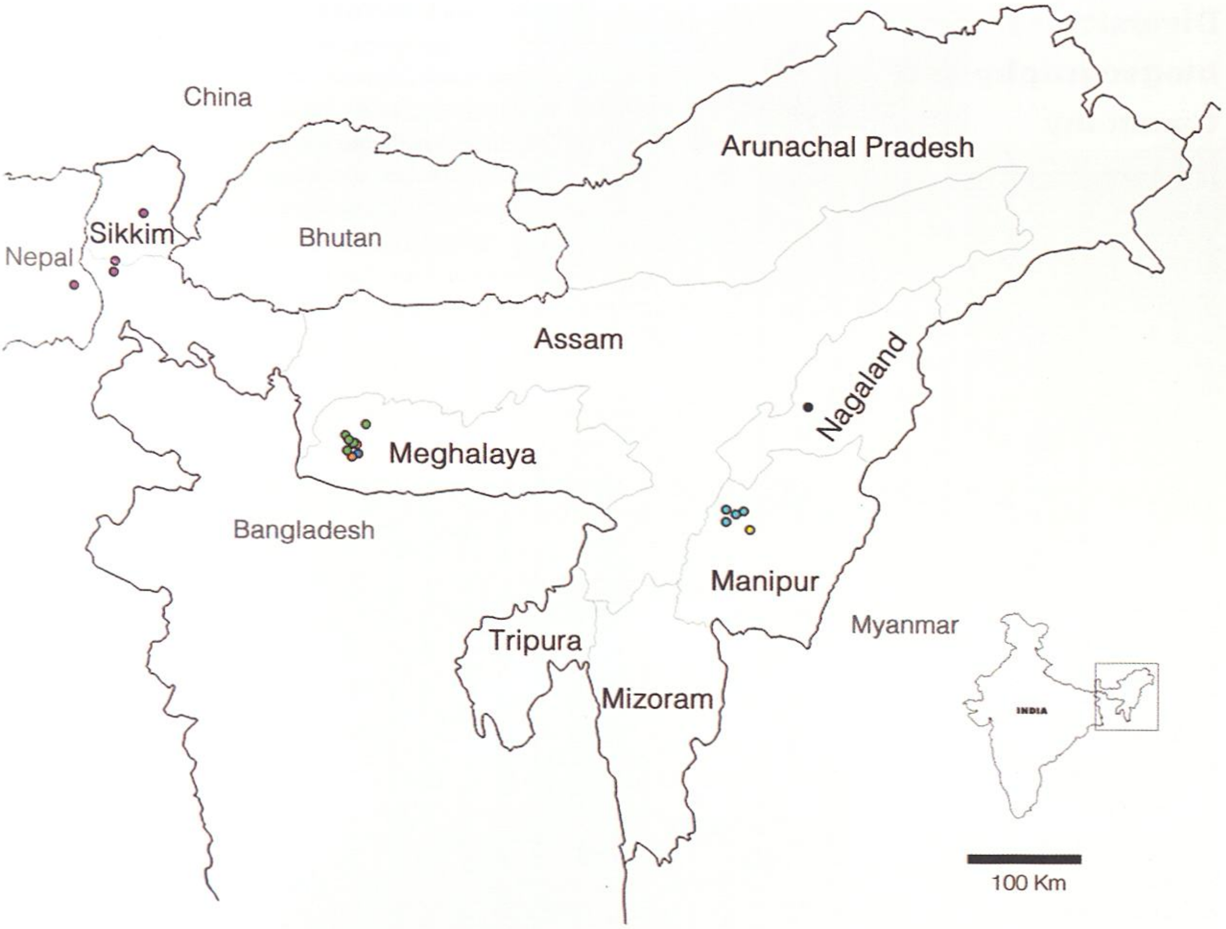


***Figure 1.*** Map of North East India (NEI) showing the distribution of Ichthyophis species in NEI. Localities of *Ichthyophis garoensis* are from Kamei & Biju (2016). Localities for all remaining species are from their original descriptions. *Ichthyophis alfredi* = blue, *I. daribokensis* and *I. nokrekensis* = orange, *I. garoensis* = green spots, *I. khumhzi* = yellow, = *I. moustakius* = turquoise, *I. sendenyu* = black, *I. sikkimensis*= pink.

and juveniles reported from less than 15 localities (Alcock 1904, Pillai & Ravichandran 1999, Taylor 1960). The first caecilian species described from NEI was *Herpele fulleri* Alcock, 1904 from Assam. After a hiatus of nearly 50 years, a second caecilian species, *Ichthyophis sikkimensis* Taylor, 1960 was described from 'Darjeeling' and 'Sikkim'. Pillai and Ravichandran (1999) in their taxonomic study and review of the Indian caecilians then known added two new species, *Ichthyophis garoensis* and *I. husaini* from Meghalaya. A few subsequent publications on NEI amphibians included reports of the occurrence of *I. garoensis* from additional localities (e.g., Choudhury et al. 2002, Mathew & Sen 2009). The original descriptions of all four of these NEI caecilians were sketchy, based on a small sample size of one to four specimens, were incomplete, and information on intraspecific variation was severely lacking. Caecilian studies based on contemporary field research remained neglected for about a decade after Pillai and Ravichandran's (1999) work.

Kamei et al. (2009) conducted the first expansive field-based caecilian research, covering all NEI states (bar Mizoram, see Kamei et al. 2013), and based on their new collections they described three new species in the family Ichthyophiidae: *Ichthyophis khumhzi, I. moustakius* and *I. sendenyu*, from Manipur and Nagaland. Shortly after, Mathew & Sen (2009) described an additional three new species in the same family from Meghalaya, *Ichthyophis alfredi, I. daribokensis* and *I. nokrekensis*. Kamei et al. (2012) discovered an ancient, endemic, and an intriguing lineage of caecilians from NEI that was described as a new genus *Chikila* in a new family Chikilidae, and Kamei et al. (2013) described three new chikilid species: *Chikila alcocki, C. darlong* and *C. gaiduwani* from several NEI states.

## Diversity, systematics biogeography and taxonomy

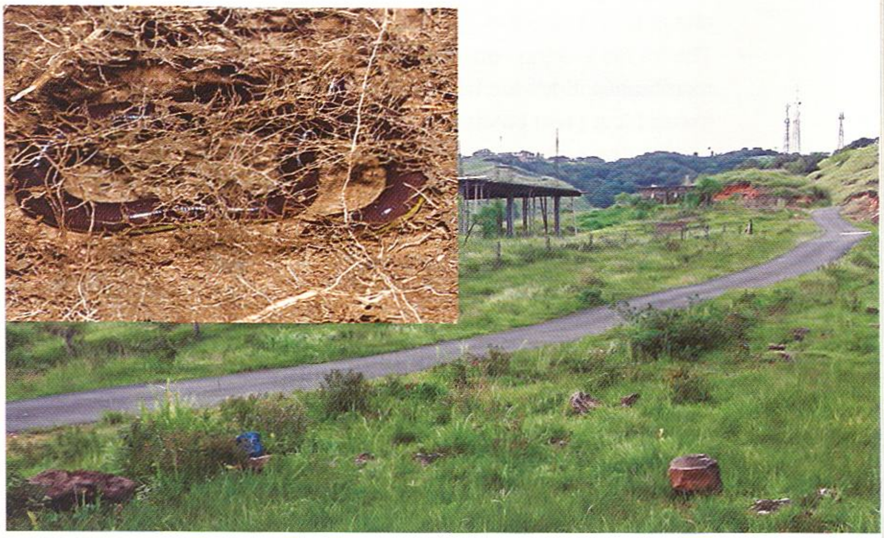
### ICHTHYOPHIIDAE

Diversity: The family currently contains two genera *Ichthyophis* Fitzinger, 1826, and *Uraeotyphlus* Peters, 1880 (Wilkinson et al. 2011). The distribution of the genus *Ichthyophis* is restricted to South and Southeast Asia, while *Uraeotyphlus* is endemic to southern peninsular India. *Ichthyophis* is the most speciose genus within the amphibian order Gymnophiona with currently 50 nominal species (Frost 2017). The species diversity of *Ichthyophis* from NEI is notable—more than 50%(eight out of 15 species) of India's *Ichthyophis* diversity is endemic to the region. The diversity is represented by one unstriped form, *Ichthyophis sikkimensis*, and seven striped forms, *I. alfredi, I. daribokensis, I. garoensis, I. khumhzi, I. moustakius, I. nokrekensis* and *I. sendenyu*. A second

***Figure 2:*** Examples of habitats where caecilians can be found. Bottom image © Systematics lab.

unstriped form, *Ichthyophis husaini*, which was known from a single and faded specimen from the West Garo Hills, Meghalaya, was recently synonimised under the striped form *I. garoensis* by Kamei & Biju (2016) based on re-examination of the holotype, and comparison with new specimens from the type localities (and their vicinities) of the two species.

(ii) Systematics and biogeography: The genus *Ichthyophis* is distributed in Sri Lanka, India, eastern Nepal and southern China,and throughout Southeast Asia as far south as the Wallace's Line. Being the only caecilian group that presently occurs substantially beyond the borders of former Gondwanan landmasses, their historical biogeography has attracted attention (e.g, Duellman & Trueb 1986, Feller & Hedges 1998). Gower et al. (2002) discovered from a limited sampling that Southeast Asian ichthyophiids are monophyletic, with Sri Lankan and Western Ghats species comprising a paraphyletic grade outside this group. Gower et al.'s (2002) result is consistent with the "Out of India" dispersal hypothesis that ichthyophiids [the genus *Ichthyophis* and its sister taxon *Uraeotyphlus* (Wilkinson et al. 2011) originated in Gondwana and dispersed from South into Southeast Asia shortly after the India-Asia collision about 65–56 million years ago (Beck et al. 1995)]. The hypothesis was further confirmed by a more recent study (Nishikawa et al. 2012) that included more comprehensive Southeast Asian sampling. However, no samples from NEI have yet been included in a molecular phylogenetic analysis. Inclusion of NEI samples might provide a clearer understanding of the timing and nature of the "Out of India" dispersal. It would also help to determine whether the South to Southeast Asian dispersal route was via NEI, and if so, when the event happened. Knowledge of the phylogenetic positions of all NEI *Ichthyophis* will also establish whether one or more radiations occur in NEI, and how long these have been evolving in the region. Until such studies are done, NEI may aptly be called a 'blind spot' in the evolution of the Asian-endemic genus *Ichthyophis*.



The inset picture shows an *Ichthyophis* among roots of grasses, which was found under a rock by the roadside.

Within India, a significant and longstanding biogeographic anomaly was recently resolved. Conflicting with the previous knowledge that *I. sikkimensis* was restricted to Sikkim and Darjeeling (northern West Bengal) (Taylor 1960, 1961, 1968),Pillai & Ravichandran (1999) assigned to this species a single specimen collected by A. F. Hutton in 1949 from Injiparai Estate, Anamalai, Kerala in the Western Ghats (see also Ravichandran 2004). Gower et al. (2017) re-examined the specimen, compared it with the type specimens of *I. sikkimensis*, and concluded based on meristic and morphometric data, and substantial differences in anterior phallodeal morphology between *I. sikkimensis* and the Western Ghats specimen, that the Western Ghats specimen is not conspecific with *I. sikkimensis*. The taxonomic conclusion that *I. sikkimensis* is absent from peninsular India has improved our understanding of biogeographical patterns in Asian caecilians.

(iii) Biology: *Ichthyophis* species in NEI have been found to be easier to locate during the heavy monsoons (beginning of June to end of July) when the animals likely migrate to near water sources such as borders of canals that feed water to paddy fields and banks of slow flowing streams for breeding (Kamei et al. 2009; Fig. 2).

Like *Ichthyophis* spp. from other regions (Breckenridge & Jayasinghe 1979, Dunker et al. 2000), those from NEI are indirect developers with an intermediate free-swimming larval stage. *Ichthyophis moustakius* is reported to lay 9-19 eggs per clutch (n = 4 clutches, [Kamei et al. 2009]). The fragile-looking eggs are enclosed in membranes. Eggs are laid in a string (resembling pearl beads of a necklace), with consecutive eggs connected to each other by thread-like gelatinous extensions of the egg membranes. Freshly laid eggs are creamy-white and opaque (Fig. 3D).

As the embryos develop, the egg membranes turn translucent allowing one a view of the early ontogenetic development. Females are found attending their egg-clutches in underground burrows close to (seasonal or perennial) streams; marshy areas surrounding agricultural fields especially wet paddy fields; occasionally females with clutches have been found in drier habitats away from water such as under roots of herbaceous plants or near roots of banana trees. Larvae have been encountered under pebbles and leaf litter in shallow puddles of stream water. Apart from these field observations, nothing else is known about the biology of the *Ichthyophis* spp. of NEI. Although the surveys of Kamei et al. (2009) have been biased towards unprotected areas, they have been mostly found in disturbed habitats such as around wet paddy fields.

(iv) Taxonomy: The following brief taxonomic accounts of species and their distribution (Figs. 1, 4), except for Kamei et al's. [2012, 2013] species and *Ichthyophis garoensis*), are directly reproduced from the species original descriptions, and additional published localities when available.

Abbreviations used: AG = annular groove, CM = corner of the mouth, C1 = first collar, C2 = second collar, IM = inner mandibular (= 'splenial') tooth, L/H = total length divided by head length (the latter = distance between snout tip and nuchal groove1 directly behind CM), OM = outer mandibular (i.e., dentary) tooth, TA = tentacular aperture, TN/TE = ratio of the distances between the TA and the eye and naris, W/S = width at midbody divided by maximum width of stripe at midbody (Kamei et al. 2009,2013; Kotharambath et al. 2012a).

Other abbreviations are: RGK (Rachunliu G Kamei), SDB (Sathyabhama Das Biju).

In the following taxonomic sections, specimens from Mathew & Sen's (2009) were collected by Mathew & Sen and party; Kamei et al.'s (2009, 2012, 2013) specimens were collected by RGK and SDB.For historical specimens, collectors for specimens are mentioned when available.

**(a) *Ichthyophis alfredi* Mathew and Sen, 2009:** This species was described based on a type series of five specimens--holotype (sex undetermined [Mathew & Sen 2009]) collected from "Meghalaya, East Garo Hills, Nokrek Biosphere Reserve, Daribokgre IB compound" and four paratypes (two adults, sexes undetermined, [Mathew & Sen 2009];two metamorphosed juveniles)--three collected along with the holotype, one from Rongbang, 1.5 km away from Chinapat, Nokrek Biosphere Reserve (NBR), West Garo Hills.

Species diagnosis: "A fairly large species (Total length 176-330 mm) with 269-299 dorsal annuli and 262-295 ventral annuli; 5-7 annuli broken by vent, 5-7 post vent annuli; 1 dorsal transverse groove on 2nd collar; head long, depressed; tentacular aperture closer to eye than to nostril. Premaxillary-maxillary teeth c. 34-40; Prevomero-palatine teeth c. 32-40; Dentary teeth c. 32-38; Splenial teeth c. 32-40. Scales present on all annuli; lateral stripe distinct, broad, expands on collar and extend on to the lower jaw giving a clear pattern of an 'arrow shape' to gular region; body bulky, supple." (Mathew & Sen2009).

Distribution: This species is currently known only from the type locality "Meghalaya, East Garo Hills, Nokrek Biosphere Reserve, Daribokgre IB compound" and from its vicinity in Rongbang (Mathew & Sen 2009, Fig. 1). The elevational range of *I. alfredi* is 416-1119 meters asl (Mathew & Sen 2009). See Mathew & Sen (2009) for GPS coordinates for localities.

At the type locality, *Ichthyophis alfredi* occurs in sympatry with *I. daribokensis* and *I. nokrekensis*. (Mathew & Sen 2009).

**(b) *Ichthyophis daribokensis* Mathew and Sen, 2009:** This species was described based on a type series of 15 specimens--holotype (sex undetermined [Mathew & Sen 2009]) collected from "Meghalaya, West Garo Hills, Nokrek Biosphere Reserve, Rengsangre, Rongram river side" and 14 paratypes (nine adults, sexes undetermined [Mathew & Sen 2009]; five metamorphed juveniles)--one collected along with the holotype, and one from Rengsangre, NBR, West Garo Hills; from NBR in East Garo Hills--one from Mondal Nokrat, three each from Kiwang and Sasatgre, five from Daribokgre IB compound.

Species diagnosis: "A fairly large species (Total length 155-315 mm) with 264-310 dorsal annuli and 263-304 ventral annuli; 4-7 annuli broken by vent, 4-7 post vent annuli; 1-2 dorsal transverse groove on 2nd collar; head moderately long ; nuchal region moderately arched; tentacular aperture closer to eye than to nostrils. Premaxillary-maxillary teeth c. 34-40; Prevomero-palatine teeth c. 26-36; Dentary teeth c. 36-40; Splenial teeth c. 30-36. Scales present on all annuli; lateral stripe distinct, medium to broad, expand on collar, faintly extending lower jaw."(Mathew & Sen 2009).

Distribution: This species is known from multiple localities in Nokrek Biosphere Reserve (NBR) in Meghalaya--Daribokgre IB compound, East Garo Hills; Kiwang, 1 km from Daribokgre IB, East Garo Hills; Mondal Nokrat, East Garo Hills; Rengsangre, West Garo Hills; Rengsangre, Rongram river side, West Garo Hills; Sasatgre, East Garo Hills (Fig. 1). The elevational range of *I. daribokensis* is 341-1131 meters asl (Mathew & Sen 2009). See Mathew & Sen (2009) for GPS coordinates of localities.

*Ichthyophis daribokensis* occurs in sympatry with *I. nokrekensis* at all of the specific localities above, except Oragitok, NBR, East Garo Hills, Meghalaya, India (Mathew & Sen 2009; Fig. 1). *Ichthyophis daribokensis* occurs in sympatry with *I. alfredi* in Daribokgre IB compound, NBR, East Garo Hills, Meghalaya, India (Mathew & Sen 2009).

**(c) *Ichthyophis garoensis* Pillai and Ravichandran, 1999 (Fig. 3A):** This species was described based ona holotype (an adult male, Kamei & Biju 2016) collected from "Anogiri Lake, Garo Hills, Meghalaya", India by Dr. Akhlaq Hussain, and one referred specimen (sex undetermined [Pillai & Ravichandran 1999]) collected from "Tura Garo Hills, Meghalaya", India.

Remarks: After the original description of *I. garoensis*, the species was recorded from a few other localities (Ahmed et al. 2009, Choudhury et al. 2002, Mathew & Sen 2009). However, these subsequent publications were lacking in vital information such as, measurements or meristic data for the specimen(s), basis of determining the taxonomic identity (Ahmed et al. 2009, Choudhury et al. 2002), specific locality data (e.g., Ahmed et al. 2009), comparison with the type material (e.g., Mathew & Sen 2009), and hence did not improve the knowledge of the species. The few other publications that mention *I. garoensis* (e.g., Chanda 2002, Ravichandran 2004) provided only information directly reproduced, or based on the species' original description (Kamei & Biju 2016).

Kamei & Biju (2016) re-examined the holotype of *I. garoensis* and compared it with the holotype of a poorly circumscribed and inadequately known "unstriped" form, *I. husaini*. *Ichthyophis husaini* was described on the basis of a single badly faded (Kamei & Biju 2016) specimen that was also collected by Dr. Akhlaq Husain, only 20 km away ("The bronggiri Coffee Garden, Rongram, Garo Hills, Meghalaya") from the type locality of *I. garoensis*. The presence or absence of a lateral stripe has been used as a major taxonomic character in *Ichthyophis* taxonomy (e.g., Wilkinson et al. 2007). Pillai & Ravichandran (1999) clearly overlooked the presence of the stripe on their specimen, and thus believing it was unstriped, they named *I. husaini* without comparison with the sympatric striped *I. garoensis* (Kamei & Biju 2016). Kamei & Biju (2016), on a close re-examination of the holotype of *I. husaini* summarised that a partial stripe is unmistakable on the posterior part of the right side of the badly faded and poorly preserved specimen. Kamei & Biju (2016) revisited the differences reported by Pillai & Ravichandran (1999) between *I. garoensis* and *I. husaini* based on the holotypes and also compared their 12 newly collected specimens from nearby the two type localities. They concluded that the differences between the two types and the new specimens in the measurements, ratios, counts, or any other character are minor and can be attributed to intraspecific variation. Kamei & Biju (2016) therefore regarded *I. husaini* to represent a junior subjective synonym of *I. garoensis*. Their taxonomic decision not only removed the uncertainty surrounding the validity of *I. husaini*, but also improved the knowledge of the species *I. garoensis* in terms of morphological variation (15 specimens) and distribution (eight localities/sites).

Species diagnosis: The species is diagnosed by having broad (W/S < 4) and a fairly regular, mostly solid, lateral yellow stripe extending on each side. It is not known to attain lengths greater than 325 mm. The number of AGs is fewer than 310; AGs are paler than adjacent skin. The head is somewhat more U-than V-shaped and fairly short (26 > L/H > 21). TAs are about twice as far from the nares than from the eyes, and are variable (1.9 < TN/TE < 2.3). Collars are of similar length. The numbers of IMs and OMs are similar (Kamei & Biju 2016).

Distribution: This species is known from multiple localities in Tura, West Garo Hills district, Meghalaya--"Anogiri Lake, Garo Hills, Meghalaya" (Pillai & Ravichandran 1999), "The bronggiri Coffee Garden, Rongram" (type locality of the *I. husaini* synonimised by Kamei & Biju [2016]), and Asanang, Barkha forest fringe, Chitoktak, Tebronggre village (Kamei & Biju 2016; Fig. 1). The elevational range of *I. garoensis* is 410-530meters asl (Kamei & Biju2017). See Kamei & Biju (2017) for GPS coordinates of localities. Localities for *I. garoensis* that are not yet verified are not included in this work.

**(d) *Ichthyophis khumhzi* Kamei, Wilkinson, Gower, and Biju, 2009 (Fig. 3C):** This species was described based on three specimens all collected from the type locality--holotype (an adult male) and two paratypes (both adult male) collected from "Khumhzi village (24°51'46"N, 93°37'23"E; 320 m asl), Tamenglong district, Manipur, India." (Kamei et al. 2009).

Species diagnosis: *Ichthyophis khumhzi* attains the greatest total length (greater than 400 mm) among all caecilian species described from NEI. The species is diagnosed by having narrow (W/S > 6) and an irregular yellow stripe laterally on each side that extends from close to CMs anteriorly to the level of vent posteriorly, not contacting the cloacal disc, and barely or not visible on collars ventrally. The number of AGs is more than 300; AGs are darker than adjacent skin. The head is V-shaped and short (L/H > 25). TAs are more than twice as far from the nares than from the eyes (TN/TE > 2). C1 is noticeably shorter than C2. Scales are present on collars; four or five rows posteriorly on dorsum. The numbers of IMs and OMs are similar (Kamei et al. 2009).

Distribution: This species is known only the type locality in Khumhzi village, Tamenglong district, Manipur, India. (Kamei et al. 2009; Fig. 1).

**(e) *Ichthyophis moustakius* Kamei, Wilkinson, Gower, and Biju, 2009 (Fig. 3B):** This species was described based on a series of eight specimens--holotype (an adult female), from "Aziuram duikhun (duikhun = a pond) (25°01'43"N, 93°24'51"E; 990 m asl), Aziuram village, Tamenglong district, Manipur, India.", four paratypes (three adult females; one adult male) collected along with the holotype, and three referred specimens (two adult females, one adult male), one each from Guigailuang, Nriangluang namdaih (namdaih = a large village), Nswanram village, and Duidip Chaengluan, Bamgaizaeng village in Tamenglong district (Kamei et al. 2009).

Species diagnosis: The species is diagnosed by having broad (W/S < 4) and a fairly regular, mostly solid, lateral yellow stripe extending on each side from the anterior of the tail to at least the CM; the stripes are broad along mandibles with a narrow anterior gap, expanded and visible ventrally on collars, and connected to the cloacal disc by spurs. The nares and the TAs are connected by arched yellow stripes, broader at the former and narrower at the latter; the species name is derived from this character--from the Greek word *moustakius* (=moustache), referring to this distinctive (but see Kamei & Biju 2016 for variability of the 'moustache'-shaped marking) yellow, arched stripes between the TAs and nares. The species is not known to attain lengths greater than 300 mm. The number of AGs is fewer than 300; AGs are paler than adjacent skin. The head is somewhat more U-than V-shaped and fairly short (25 > L/H > 19). TAs are about twice as far from the nares than from the eyes, and are variable (1.9 <

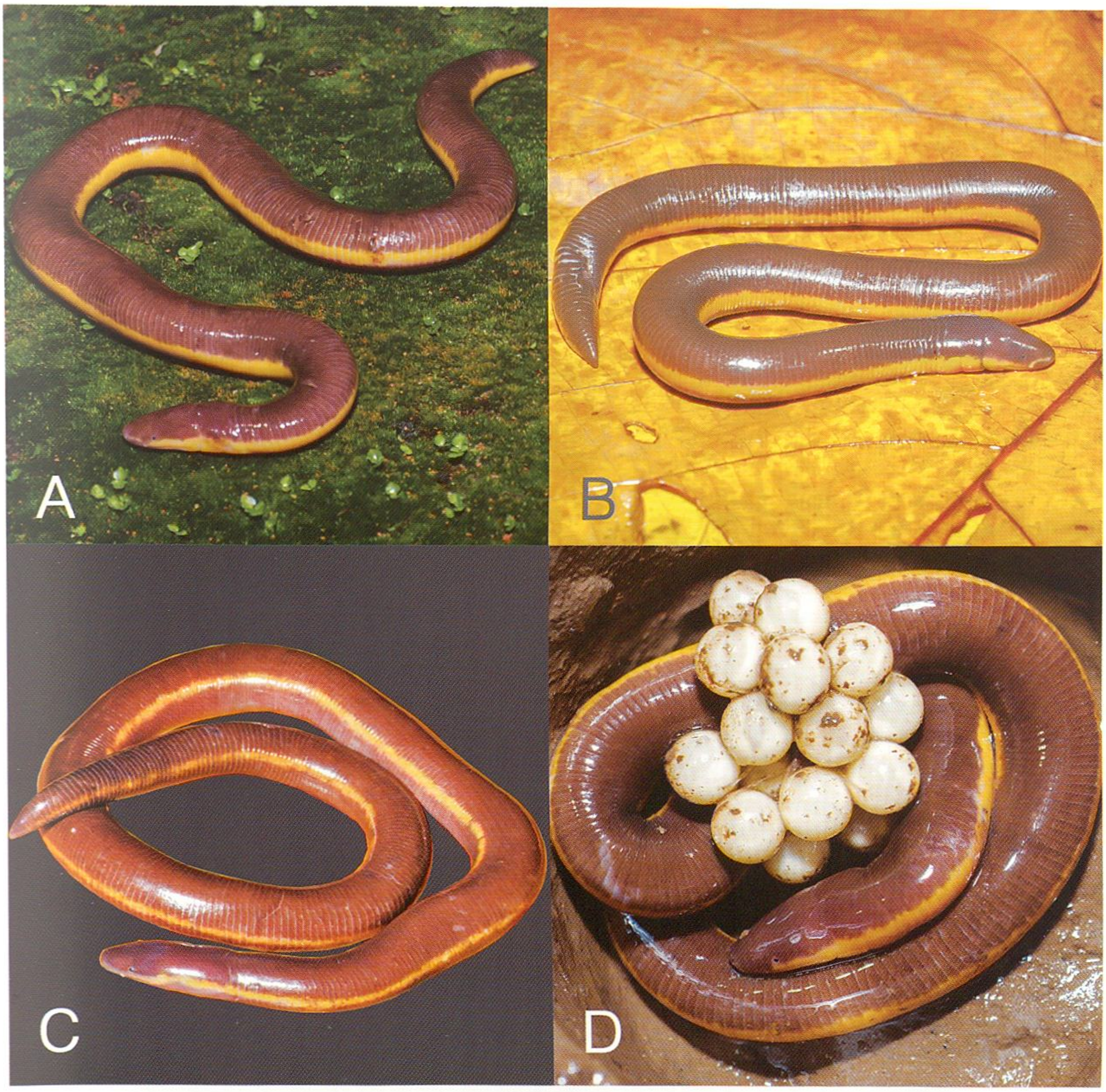
TN/TE < 2.3). Collars are of similar lengths. Scales are absent on collars; they occur from about the fourth or fifth anterior most annulus, with five rows posteriorly on the dorsum. The numbers of IMs and OMs are similar (Kamei et al. 2009).

Distribution: This species is known only the type locality in Aziuram village, Tamenglong district, Manipur, India (Kamei et al. 2009, Fig. 1). The elevational range of *I. moustakius* is 306-1107meters asl (Kamei et al. 2009). See Kamei et al. (2009) for GPS coordinates of localities.

**(f) *Ichthyophis nokrekensis* Mathew and Sen, 2009:** This species was described based on a type series of 12 specimens--holotype (sex undetermined [Mathew & Sen 2009]) from "Meghalaya, West Garo Hills, Nokrek Biosphere Reserve, Sasatgre", and11paratypes(eight adults,sexes undetermined [Mathew & Sen 2009]; three juveniles), one collected along with the holotype, one from Rengsangre, Rongram river side, NBR, West Garo Hills; from NBR in East Garo Hills--six from Daribokgre, Forest IB compound, one each from Oragitok, Kiwang, and Mondal Nokrat.

Species diagnosis: "A fairly large species (Total length 206-325 mm) with 269-300 dorsal annuli and 266-302 ventral annuli; 4-6 annuli broken by vent, 5-7 post vent annuli; 1-2 dorsal transverse groove on 2nd collar; head moderately long; nuchal region arched; tentacular aperture closer to eye

**Figure 3:** *Ichthyophis species* in life. A. *Ichthyophis garoensis*, B. *I. moustakius*, C. *I. khumhzi*, D. *I. sendenyu*, a female with egg-clutch in captivity. Image 4C © Systematics Lab.



than to nostril. Premaxillary-maxillary teeth c. 38; Prevomero-palatine teeth c. 36; Dentary teeth c. 40; Splenial teeth c. 34. Scales present on all annuli; a distinct, narrow lateral stripe separates upper and lower surface from collar region to tail." (Mathew & Sen 2009).

Distribution: See distribution for *I. daribokensis* (Fig. 1) for localities and elevational range.

**(g) *Ichthyophis sendenyu* Kamei, Wilkinson, Gower, and Biju, 2009(Fig. 3D):** This species was described based on five specimens all collected from the type locality "Dhyutere (25°54'55"N, 94°06'19"E; 782 m asl), New Sendenyu village, Tseminyu sub-division, Kohima District, Nagaland, India." (Kamei et al. 2009) -- holotype (an adult female) and four paratypes (three adult females, one adult male).

Species diagnosis: The species is diagnosed by having broad (W/S < 4) and regular, mostly solid, lateral yellow stripes, one on each side extending from approximately at the level of the posterior edge of the cloacal disc to at least the eye level on the upper jaw, and midway between the TAs and the nares on the lower jaw, a broad anterior gap expanded and may/not be visible ventrally on the collars, and connected to the cloacal disc by spurs. Arched yellow stripes extend halfway from the TAs to the nares, that taper towards the nares. The species is not known to attain lengths greater than 350 mm. The number of AGs is fewer than 315; AGs are paler than adjacent skin. The head is U-shaped, and short (L/H > 20). TAs are less than twice as far from the nares than from the eyes (TN/TE < 2). Collars are of similar lengths. Scales are present in anteriormost grooves, five to eight rows posteriorly on the dorsum. The numbers of IMs and OMs are similar (Kamei et al. 2009).

Distribution: This species is known only from the type locality in New Sendenyu village, Tseminyu sub-division, Kohima district, Nagaland, India (Kamei et al. 2009, Fig. 1).

**(h) *Ichthyophis sikkimensis* Taylor, 1960:** This species was described based on a type series of four specimens—holotype (sex undetermined [Taylor 1960]) collected from "Darjeeling, [West Bengal], India", and three paratypes (sexes undetermined [Taylor 1960]), one from "Sikkim" (collected by K. Bouk [Bauer et al. 1993]), one from "Darjeeling, Bengal, India", and one from "Rungeet Valley, British Sikkim" collected by Tom Barbour [Taylor 1960]).

Remarks: Pillai and Ravichandran (1999) identified eight additional specimens (including five larvae), of which seven are available at the Zoological Survey of India(ZSI), Kolkata and one at the Bombay Natural History Society (BNHS), Mumbai (Bombay), India. They did not examine the type specimens but relied on Taylor's (1960) description. Gower et al. (2017) re-examined the BNHS specimen and concluded that the specimen is not a congener of *I. sikkimensis*. Pending re-examination of type materials and ZSI materials, and a revision of the species, the species diagnosis below has been reproduced from the original description.

Species diagnosis: "A medium-sized species, characterized by 106-108 vertebrae; primary and secondary transverse folds 276-292; series of splenial teeth (9-9 or 10-10); tail very short, contained approximately 50 times in total length, bearing five or six folds from front of vent; tentacle near lip, closer to eye than to nostril. Scales sparse or absent in anterior half of body; two to four rows in each fold posteriorly" (Taylor, 1960).

*Ichthyophis sikkimensis* is one of the two unstriped forms of *Ichthyophis* described from India; it is a short-tailed species (distance behind vent, about 5mm [Taylor 1960]).The other unstriped form from India is the long-tailed (distance behind vent, about 15 mm [Taylor 1960]) *Ichthyophis bombayensis* Taylor, 1960, distributed in the Western, and possibly the Eastern Ghats of the Indian peninsula (Ramaswami 1947, Gower et al. 2007).

Distribution: This species is known from Darjeeling in West Bengal and Sikkim in India, and Nepal (Taylor 1960, 1961, 1968; Pillai & Ravichandran 1999, Anders et al. 2002;Fig. 1). GPS localities reported for the species by Pillai & Ravichandran (1999) are not included in this work.

## CHIKILIDAE

(i) Diversity: The family Chikilidae Kamei, San Mauro, Gower, Van Bocxlaer, Sherratt, Thomas, Babu, Bossuyt, Wilkinson, and Biju, 2012 is the most recent new family to be discovered in caecilian taxonomy and systematics. The discovery and description of a novel family was the direct result of focused and extensive soil-digging expeditions between 2006 and 2010 (Kamei et al. 2012) across NEI. The family is monogeneric, and as far as is known, Chikilidae is endemic to NEI (Kamei et al. 2012). Current taxonomy recognises four nominal *Chikila* species in the NEI states of Arunachal Pradesh, Assam, Meghalaya, Nagaland and Tripura (Kamei et al. 2012; Fig. 4)—*Chikila alcocki, C. darlong* and *C. gaiduwani* described by Kamei et al. (2012), and *Chikila fulleri* (Alcock, 1904).

(ii) Systematics and biogeography: The discovery of Chikilidae improved our knowledge of phylogenetic relationships within caecilians, and also resolved a biogeographical enigma in caecilian systematics that had persisted for over a century. *Herpele fulleri*, then placed in the catchall caecilian family Caeciliidae Rafinesque, 1814, was the first caecilian species described from NEI. The species was described by Alfred W. Alcock, a British naturalist who served as a Superintendent of the Indian Museum in Kolkata, West Bengal India in the 1890s, on the basis of a single specimen. The species was reallocated to the genus *Gegeneophis* Peters, 1880 (Indotyphlidae Lescure, Renous, and Gasc, 1986), a lineage now known to be exclusive to the Western Ghats of peninsular India (Gower et al. 2011), by Taylor (1968).

For over a century since its original description, *Gegeneophis fulleri* was accepted to represent the easternmost limit of the distribution range of the family Caeciliidae. The phylogenetic affinities of the unique teresomatan (teresomatans are the advanced [Nussbaum 1991] or higher [e.g., San Mauro et al. 2004] caecilians that lack true tails [Wilkinson & Nussbaum 2006]) specimen from NEI remained unknown; the distribution of the "lineage" remained a biogeographical conundrum, as there was no new information after the species' original description. As a result of expansive (238 localities surveyed between 2006-2010) soil-digging surveys across NEI, Kamei et al. (2012) reported finding hundreds of teresomatan caecilians. Morphological and molecular data and divergence time dating estimates indicated that NEI teresomatans were a previously overlooked, ancient lineage (ancestral divergence estimated at > 125 million years ago) with an interesting and unexpected sister-group relationship with the exclusively African herpelids, rather than to the Indian indotyphlids. The finding of an ancient endemic vertebrate lineage stimulated a novel perspective about NEI that was long-considered to be merely as a "gateway" (Mani 1995) between the Indo-Burma hotspots and Himalaya without its own distinctive and/or old endemic lineages. The discovery of Chikilidae however contested the gateway perception and showed that the region with its biotic assemblage might have a much more important role to play in understanding the global biogeography and phylogenetic affinities of caecilian fauna in particular, and biodiversity in general.

(iii) Biology: Chikila species in NEI have been found to be easier to locate during the heavy monsoons (beginning of June to end of July) when the animals likely migrate to near water sources for breeding (Kamei et al. 2013). Although not many surveys have been made outside the wet season, the few surveys made just before and after the arrival of the first few rains in May, and in January, far fewer animals were encountered in the dry seasons (pers. obs.). *Chikila* are oviparous, with direct development in the egg, i.e., no free swimming larval stage (Kamei et al. 2012). A specimen of *Chikila gaiduwani* was reported with a clutch of five eggs. The colour of eggs (freshly laid eggs and later ontogenetic developmental stages) and the manner in which eggs are laid are similar to those described for *Ichthyophis*. With the exception of drier areas of nesting sites described for *Ichthyophis*, *Chikila* females with egg clutches are also found in similar microhabitats. *Chikila* species have been found with litters of hatchlings without yolk on the bellyin the field (pers. obs.). Litter attendance could indicate some form of extended parental careas has been reported for African species (*Boulengerula taitanus*, Kupfer et al. 2006; *Geotrypetes seraphini*, O'Reillyet al. 1998). Extended parental attendance might indicate that hatchlings are altricial and are dependent on mothers for nutrition (Kupfer et al. 2006) until they can feed independently. These speculations deserve more investigation. Nothing else is known about the biology of the *Chikila* spp. of NEI. Although the surveys (Kamei et al. 2012, 2013) have been biased towards unprotected areas, they have been mostly found in disturbed habitats such as around wet paddy fields.

(iv) Taxonomy: The following are brief taxonomic accounts of species and their distribution (Figs. 2, 5). *Chikila* species are not easily identified. For example, the total number of primary annuli (PAs), how far anterior secondary AGs (SAGs) appear, and the number of PAs subdivided by SAGs are generally useful taxonomic characters used for species diagnosis in teresomatan caecilians, but these characters overlap in the four *Chikila* species. Kamei et al. (2013) distinguished the four nominal species on the basis of external (measurements and meristics) and internal morphology in concordance with mitochondrial DNA data.

Abbreviations used: AG = annular groove, PA = primary annulus, PM = premaxillary-maxillary tooth, VP = vomeropalatine tooth (Kamei et al. 2013, Kotharambath et al. 2012a, Wilkinson & Kok 2010).

**(a) *Chikila alcocki* Kamei, Gower, Wilkinson, and Biju, 2013 (Fig. 5A):** This species was described based on a series of 15 specimens--holotype (an adult female), from "Dhyutere (25.91528 N, 94.10528 E; 782 m asl), New Sendenyu village, Tseminyu subdivision, Kohima district, Nagaland, India.", seven paratypes (four adult females, three adult males) and seven referred specimens (three adult females, four adult males) collected from within the vicinity of the type locality (Kamei et al. 2013).

Species diagnosis: The adult colour pattern in this species is weakly bicoloured to almost unicoloured. Adult females are known to grow up to a total length of 271 mm, and males up to 255 mm. The AGs are weakly marked externally (despite strong myoseptal pigment under skin). Head is somewhat broad in dorsal view; eyes, both in life and in preservation, are not visible. The shortest distance between choanae relative to the width of each choana at that point is narrow, with a > 2.25 x gap. The number of VPs and PMs are about the same, sometimes more VPs; the shape of the anterior end of the VP series in palatal view varies from an indented arc to being weakly angulate. The cloacal disc is unpigmented, and a pale patch extends anteriorly from the disc (Kamei et al. 2013).

Distribution: This species is currently known from the type locality Dhyütere, New Sendenyu, Kohima district, Nagaland and its vicinities--Mon district in Nagaland, and Changlang district of Arunachal Pradesh (Kamei et al. 2013). See Kamei et al. (2013) for GPS coordinates of localities. The species is known from an elevational range of 320-900 meters asl, and is reported to be fairly abundant at the type locality (Kamei et al. 2012, 2013; Fig. 4).

**(b) *Chikila darlong* Kamei, Gower, Wilkinson, and Biju, 2013 (Fig. 5B):** This species was described based on a series of 16 specimens--holotype (an adult female), from "Darlong (26.93722 N, 92.99611 E; 121 m asl), Seijosa, East Kameng district, Arunachal Pradesh, India.", ten paratypes (four adult females, six adult males) and five referred specimens (three adult females, two adult males) collected from the vicinity of the type locality (Kamei et al. 2013).

Species diagnosis: The adult colour pattern in this species is moderately bicoloured (but less so than *C. fulleri*). Among *Chikila* species, *C. darlong* attains the smallest adult size; the adults are not known to grow more than 200 mm in total length; adult females are known to grow up to a total length of 164 mm, and males up to 198 mm. The AGs are moderately marked. Head is acuminate in dorsal view; eyes, both in life and in preservation are generally distinct. The shortest distance between choanae relative to the width of each choana at that point is small, with a 1.25 to 2 x gap. The numbers of VPs are fewer than PMs; the shape of the anterior end of the VP series in palatal view varies from a gentle arc to fairly angulate. Cloacal disc is unpigmented, with a pale patch extending anteriorly from the disc (Kamei et al. 2013).

Distribution: This species is currently

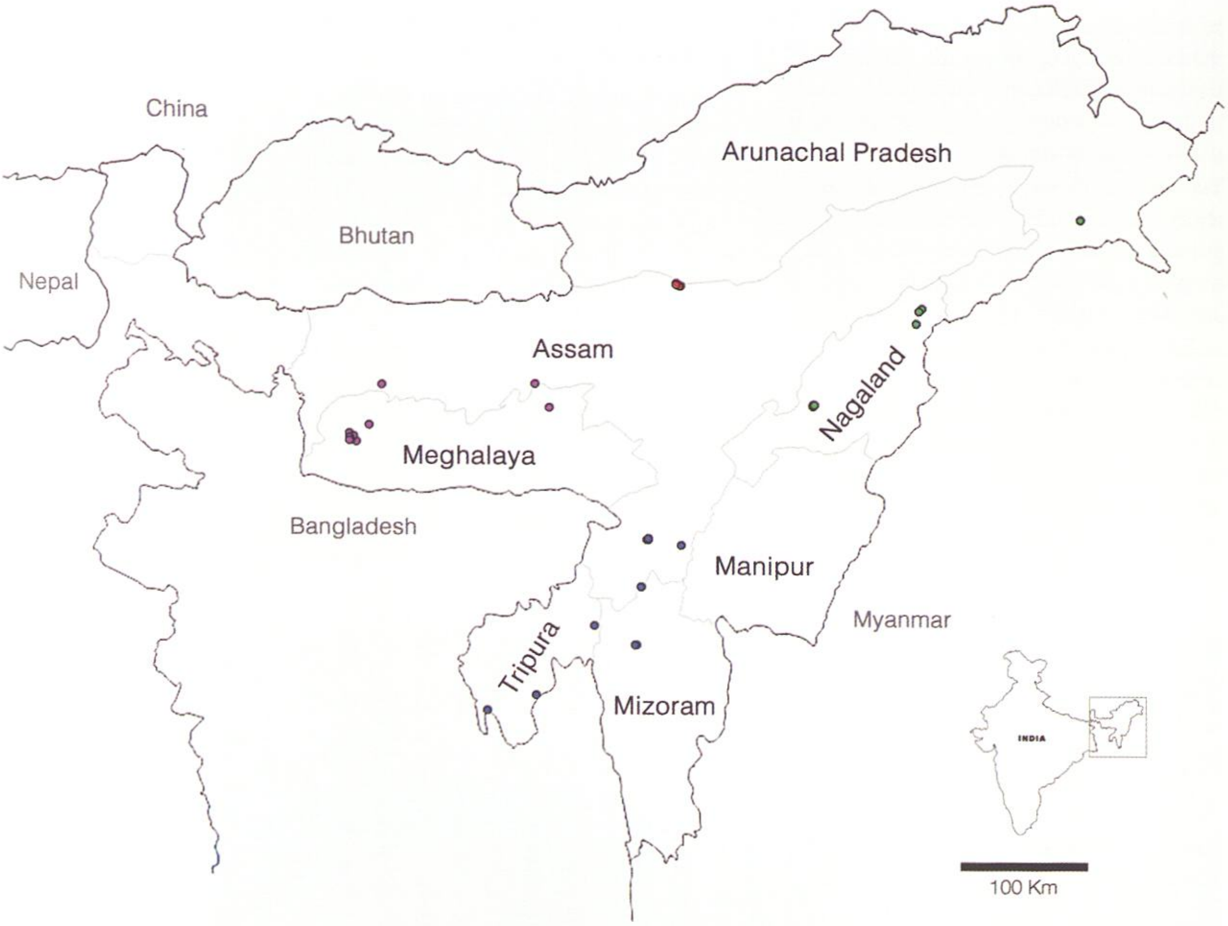


*Figure 4*: Map of North East India (NEI) showing the distribution of *Chikila* species in NEI. Localities are from (Kamei et al. 2013). *Chikila alcocki* = green spots, *C. darlong* = red, *C. gaiduwani* = pink, *C. fulleri* = dark blue.

known from the type locality in Darlong, and from Pakke Tiger Reserve (approximately 3-5 km from the type locality), East Kameng district, Arunachal Pradesh, India (Kamei et al. 2012, 2013;Fig. 4). See Kamei et al. (2013) for GPS coordinates of localities. The elevational range of this species is 120-350 m asl. *Chikila darlong* is the first, and only caecilian species endemic to Arunachal Pradesh, and is the only known chikilid species found north of the Brahmaputra River.

**(c) *Chikila fulleri* Kamei, Gower, Wilkinson, and Biju, 2013 (Fig. 5C):** This species was described by Alcock (1904) on the basis of a unique holotype specimen (a gravid female [Kamei et al. 2013]) that was "...discovered in a miscellaneous collection of snakes from Kuttal, 6 miles south-west of Silchar in Cachar", in Assam, India, purchased from Mr. C. B. Antram (Alcock 1904).

Remarks: Ordinarily, Alcock might have been expected to assign his specimen to the Asian teresomatan *Gegeneophis* but he assigned it to an African genus *Herpele*; Alcock was likely mislead by Boulenger's (1882) erroneous report that *Gegeneophis* lacked annular scales, a taxonomic error that Taylor (1961) corrected. Taylor (1968) was unable to examine the type specimen. For over a century, *C. fulleri* remained known only from the original description and the badly dehydrated and broken holotype (Kamei et al. 2013). Ahmad (2001) reported that the species was possibly extinct at the type locality. Kamei et al. (2012, 2013) reported 12 referred specimens (eight adult females and four adult males) from the type locality, and gave a revised diagnosis for the species based on the holotype and the new specimens.

Species diagnosis: The adult colour pattern in this species is moderately bicoloured (but more so than *C. darlong*). Adult females are known to grow up to a total length of 230 mm, and males up to 190 mm. The AGs are very strongly marked by distinct myoseptal pigment. Head is somewhat pointed in dorsal view; eyes, both in life and in preservation, are faint or not visible (except in the severely dehydrated holotype where they are clearly visible (Kamei et al. 2013). The shortest distance between choanae relative to the width of each choana at that point is small, with a 1.25 to 2 x gap. The number of VPs and PMs are about the same, sometimes more VPs; the shape of the anterior end of the VP series in palatal view is angulate. *Chikila fulleri* has some distinctive pigmentation patterns not seen in the other three congeners--presence of pale blotches on the chin, throat, and anterior most one to three PAs; the base of denticulations surrounding the vent are mostly pigmented; an unpigmented patch anterior to the cloacal disc (as seen in the three congeners) is absent.

Distribution: This species is currently known from the type locality Kathal Tea Estate, Silchar, Cachar district, Assam, India as refined by Kamei et al. (2013), and in the vicinity (Chinglaeu, Bhubon Hills, Silchar) of the type locality; Joychandpur tower, Trishna Wildlife Sanctuary and Rambhadra, Gumti in South Tripura district; Vanghmun, Jampui Hills in North Tripura district (Fig. 4).The elevational range of this species is 10-600 m asl. See Kamei et al. (2013) for GPS coordinates of localities.

*Chikila fulleri*-like animals have been encountered in Mizoram (Buchangphai in Kolasib district and Lunglei in Mammit

***Figure 5:*** *Chikila* species in life. A. *Chikila alcocki* female with an egg-clutch in captivity,B. *C. darlong*, afemale with hatchlings in captivity, C. *C. fulleri*,D. *C. gaiduwani*. Image 5B © Systematics Lab.

district) (Kamei et al. 2013) but the species-level identity of the specimens could not be confirmed, as the authors could not obtain the necessary permits for collecting voucher specimens (Kamei et al. 2013).However, the distribution map (Fig. 4) has included Mizoram.

**(d) *Chikila gaiduwani* Kamei, Gower, Wilkinson, and Biju, 2013 (Fig. 5D):** This species was described based on a series of 10 specimens--holotype (an adult female), from "Diringa bisik, Silchol, Tebronggre village" (Kamei & Biju 2016) (25.61750 N, 90.23639 E; 519 m asl), Tura, West Garo Hills district, Meghalaya, India, five paratypes (four adult females, one adult male), and four referred specimens (all adult females) collected from the vicinity of the type locality.

Remarks: The original type locality "Teobronggre (Theobongiri) Coffee Garden" (Kamei et al. 2013) was subsequently corrected to Diringa bisik, Silchol, Tebronggre village (see Kamei & Biju [2016]for discussion).*Chikila gaiduwani* was named in honour of the author's father Mr Gaiduwan Gaipuizei Kammei (Kohima, Nagaland), in appreciation of him and Kamei's family who have supported immensely the author and team's research in northeast India (Kamei et al. 2013).

Species diagnosis: The adults of this species are strongly bicoloured. Adult females are known to grow up to a total length of 253 mm, and males up to 272 mm. The AGs are moderately marked. Head is broad in dorsal view; eyes, both in life and in preservation are not visible. The shortest distance between choanae relative to the width of each choana at that point is large, with a <1.25 x gap. The number of VPs and PMs are about the same, sometimes more VPs; the shape of the anterior end of VP series in palatal view forms a gentle arc (not angulate). Cloacal disc is unpigmented, and a pale patch extends anteriorly from the disc.

Distribution: This species is currently known from the type locality Teobronggre Coffee Garden, Teobronggre, Tura and surrounding areas in West Garo Hills district, and from Nongpoh, in Ri Bhoi district of Meghalaya; Dwarka, Goalpara district and Kanchiguli, Garbhanga, Kamrup district of Assam (Fig. 4). See Kamei et al. (2013) for GPS coordinates of localities. The known altitudinal range is 86-538 meters asl.

## Conservation

There is an acute lack of basic knowledge of NEI caecilians--a large majority of the general public is not aware of their existence, and this does not exclude the wildlife custodians of the region. The tiny section of the general public aware of caecilians' existence is locals in remote villages, largely the relatively uneducated farming community, living close to habitats (in and around agricultural fields, or forests) where caecilians are found. Unfortunately, a widespread misconception passed down through generations by oral traditions that caecilians are fatally venomous (Kamei, 2015 [unpublished]) have misled locals to have deep-rooted fears for caecilians, resulting infrequent intentional killing (Kamei et al. 2013, Kamei, 2015 [unpublished]; Fig.6). Animals (including eggs and hatchlings) killed in agricultural fields are frequently encountered (Kamei et al. 2013, pers. obs.; Fig. 6). Gravid females, males with enlarged testes lobes, egg clutches and / or hatchlings, of both *Ichthyophis* spp. and *Chikila* spp., have almost exclusively been reported and/or collected during the monsoon (late May to mid August) season, (Kamei et al. 2009, 2012, 2013; Mathew & Sen 2009) leading to the premise that breeding period coincides with the peak agricultural activity, especially paddy farming (Kamei et al. 20013). Due to several reasons, including an acute lack of workers in this herpetological group in the region, caecilian field research requiring long hours of skilled and dedicated soil-digging surveys, and a resource shortage, there is no published quantitative data available to infer whether persecution by uninformed locals posses a threat to the conservation of NEI caecilian species. Sharing scientific knowledge and spreading awareness to dispel the myth that caecilians are venomous to the grossly un/-misinformed general public is imperative to create a practical and sustainable conservation impact, especially in NEI where the concept of conservation exists only as a far-fetched notion, or the realm reserved almost exclusively for large charismatic mammals. Kamei (2015 [unpublished]) conducted public outreach (Fig.7) in NEI reaching out to a motley (relatively non-literate farmers and locals,

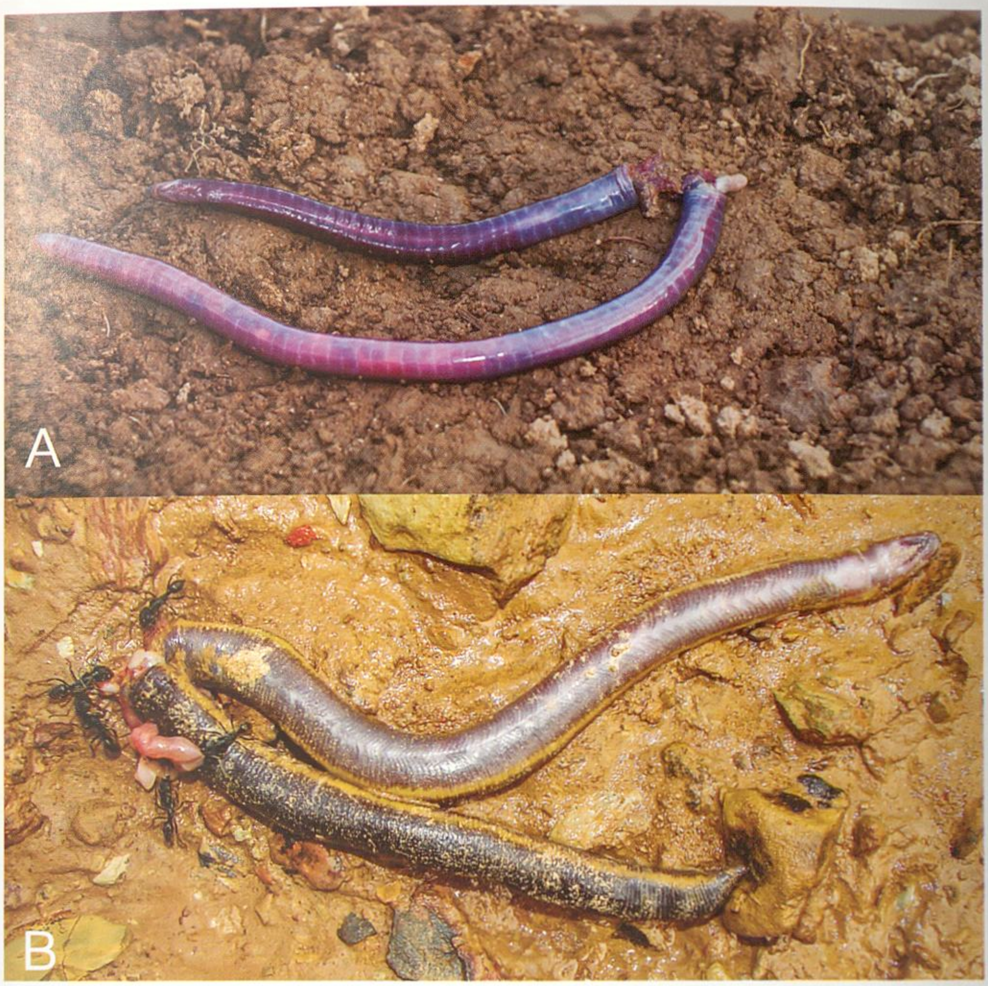


**Figure 6:** Examples of intentional killing of caecilians by local people. Image 6B © = Stephen Mahony.

school and college students, researchers, forest department staff) audience of over 6000people,educating the general public about caecilians. However, NEI is a massive geographical region beset with numerous challenges, such as, generally very poor civil infrastructure, rough terrains, ethno-civil strife, insurgency and militancy, language barriers due to the huge diversity of ethnic groups, and others. Public outreach programmes will need to be extended and supported by the state forest custodians designated to safeguard the forests and wildlife of the country, if they are to bring about a reasonably widespread awareness among the general public to contribute to a significant and lasting conservation impact. Also, given that all NEI caecilians are endemic to NEI, and are restricted to small geographical locations, the need to escalate public awareness campaigns is urgent in the face of relentless habitat destruction.

Knowledge of conservation requirements for NEI caecilian fauna are severely inadequate--all caecilian species are currently either listed as Data Deficient (DD) in the IUCN Red List (IUCN 2017) or,are yet to be evaluated against the IUCN Red List criteria. Survey of new areas for the occurrence and abundance of species particularly for those reported from only a small area (e.g., *Chikila darlong, Ichthyophis sendenyu, I. khumhzi*), or that have not been reported for several decades after the original description (i.e., *I. sikkimensis*), evaluating the presence and abundance of caecilian species in protected areas, obtaining more ecological data particularly reproduction and habitat requirements, are necessary to determine more reliable and accurate conservation assessments. Although the occurrence of species in multiple localities (e.g., Kamei et al. 2013), and their persistence in disturbed habitats (e.g., Kamei et al. 2009,2013) may provide some consolation that they might not be immediately threatened, this idea relies primarily on the assumption of a reasonable range size of the species.

**Figure 7:** *Figure 7. Public outreach to different sections of society. A. Hands-on demonstration to locals that caecilians are harmless, and that they do not bite. A girl is being encouraged to hold a live caecilian in her hands to dispel her fear for caecilians. B. Sharing knowledge with locals about caecilians through pictures and informal conversation. C. The author with a batch of new recruits of forest guards in Tripura Forest Academy after field demonstration on how to search for caecilians and what kinds of habitats. D. The author with school children aged between six and fourteen after a popular talk on caecilians. Image 7C copyright = Pallab Chakraborty, 7D = Adventure Club, Tamenglong (ACT), Manipur, India.*

## Challenges

The foremost challenge to caecilian field-based research is finding specimens since NEI caecilians are generally secretive, living in concealed habitats that can only be found by digging the soil, raking through organic litter, or flipping rotting logs and rocks. On rare occasions one might have the good fortune to sight an *Ichthyophis* individual above soil surface during or after heavy downpours, but *Chikila* spp. are dedicated burrowers, and to the best of my knowledge, they have not been encountered above soil surface during the caecilian-specific surveys (Kamei et al. 2012, 2013; pers. obs.). Caecilian field work can be very labour-intensive because individuals of some species in some places can be sparsely encountered, and one may not find any individuals despite extended and intensive searching (several hours per day for several days) in habitat that appears suitable. This rarity of animal sightings and the difficulties involved in finding them are contributing factors to under representation of specimens in natural history collections and in turn account for several caecilian species known from only small sample sizes (one to a few specimens, e.g., Nussbaum & Wilkinson [1989], Wilkinson et al. [2007]).

Caecilian taxonomy has numerous limitations on several fronts. One of the fundamental difficulties is that morphologically, caecilians can be cryptic (Gower & Wilkinson 2005, Nussbaum & Wilkinson 1989, Wilkinson et al. 2007). The dearth of morphological characters due to their limbless and tubular body plan compounds this taxonomic problem—it is difficult to tell most species apart by mere "eyeballing" for subtle differences in their external morphological characters. Integrative taxonomy (Dayrat 2005, Padial et al. 2010, Wheeler 2005) is indeed the way to go but is confronted with several difficulties, e.g., scarcity of specimens for soft and / or hard (destructive) anatomical work; lack of DNA samples for historically described species; difficulty of obtaining paratopotypes, or, from near by the type localities because the recorded provenance of several of the historical species are imprecise, e.g.,the type locality of *Ichthyophis sikkimensis* is just given as“Darjeeling, [West Bengal,] India”, and it is unclear whether this referred to the town or the district of Darjeeling; there is not enough native experts to comprehensively work on this poorly studied vertebrate group, especially for India that has approximately40known native caecilian species. Type specimens are scattered in international (mostly European) natural history collections. The cost to go to examine type specimens in overseas collections is prohibitive deterring many from attempting a modern revision. International museum collections are hesitant to provide specimens (unless for destructive sampling) on loans to India, because import of biological specimens has been relatively straightforward but obtaining export permits for any biological material has been unreliable in the past. Some of the(type) specimens that are deposited in Indian natural history collections are in very poor condition (e.g., Kamei et al. 2013, Kamei & Biju 2016, Wilkinson et al 2007) reducing their value for meaningful and/or comparative taxonomic study. Although taxonomy is a fundamental basis for all biological science and its application (Sluys 2013), including conservation biology, today much of taxonomy is facing a crisis alack of prestige and resources that is crippling the continuing cataloguing of biodiversity (Godfray 2002). Securing funding for taxonomy has only become increasingly difficult.

Indian native scientists are also faced with sometimes disheartening processes of obtaining various kinds of necessary permits (e.g., Bagla 2006, Kamei et al. 2013, Madhusudan et al. 2006, Varshney 2015) that have been put in place to safeguard biodiversity. Excessive restrictions, red-tapism (e.g., Madhusudan et al. 2006, Varshney 2015), and lack of respect for scientific merit are major hindrances to biodiversity-related research, which cannot be done in isolation. Early-career scientists are also faced with the subtle form of discrimination that they are not “renowned” enough to be issued a permit despite publications in prestigious international peer-reviewed scientific journals. Often, a scientist is also faced with the conundrum “which comes first, chicken or the egg? ”—permit issuing authorities would require a signed contract for funding, while funding agencies will require permits to have been already obtained prior to funding. Basic research such as taxonomy is still considered largely irrelevant to conservation (Madhusudan et al. 2006, pers. obs.) and this knowledge deficiency seriously hinders taxonomists, which in consequence, compromises the documentation of biodiversity. A forest department initially denied issuance of permit to the author on the grounds that “taxonomy and systematics research” do not contribute to conservation, while another state forest department clearly denied collection permit for a few sample vouchers insisting that community ecology be done in situ without collection. Bureaucratic obstacles to purely academic scientific research manifested in numerous manners and forms not only work to the detriment of India's progress of understanding the diversity but also act as shackles in the strive towards fulfilling the Fundamental Duty under the Constitution of India article 51A. (j), “To strive towards excellence in all spheres of individual and collective activity, so that the nation constantly rises to higher levels of endeavour and achievement” (The Constitution of India, 1950). I hope that future academic research will be facilitated more constructively.

*Feeding habits of Caecilians are poorly known. Ichthyophis sp. feeding on earthworm*
Photo credit: Vivek Sarkar

Political volatility, guerilla warfare, and social unrest in several parts of NEI also greatly impede academic scientific work. The author's attempts to conduct public outreach programme as part of Community Education Project (Kamei, 2015[unpublished]) in schools in Imphal, Manipur, and in Tura, Meghalaya for two simultaneous (2014, 2015) years were prevented due to the sudden eruption of violence and curfews. Several regions in NEI still remain to be explored because of erratic and / or orchestrated violence that erupts all too often, or because many of the pockets of original habitat in NEI are also strongholds of the countless militias in operation. Volatilities further skyrockets the cost of logistics, if at all available. Such unsafe scenarios also put women field biologists in greater risk for personal safety.

## Conclusions

Knowledge of NEI caecilian true diversity still remains incomplete. Caecilians new to science could well be found in the remaining vast expanse of NEI that has not been covered by Kamei et al.'s (2009, 2012, 2013) and Mathew & Sen's (2009) surveys. What is known of the 12 recognised species from NEI is rather pitiable—for all of the named species, we do not know the real distribution range, presence and abundance in protected areas, breeding biology, habitat requirements, diet, how well adapted they are to human-disturbed areas, ecological requirement, captive management (whether they can be captive bred can be important for future conservation actions), genetic structure of their populations, and so forth. We do not know the phylogenetic relationships of the NEI *Ichthyophis* assemblage or, whether their DNA contains information that might help resolve more precisely an important question in Southeast Asian caecilians' biogeography (Duellman & Trueb 1986, Feller & Hedges 1998, Gower et al. 2002, Hedges et al. 1993, Nishikawa et al. 2012, Wilkinson et al. 2002,), or shed light on the roles played by biological barriers in the determining the present (and past) distributions.

Gower et al.'s (2017) recent conclusion that *I. sikkimensis* is restricted to only the Indian states of Sikkim and West Bengal (Taylor 1960) and Nepal (Anders et al.2002), and is not present in the Western Ghats as reported by Pillai & Ravichandran (1999) underscores the significance of taxonomy in defining distribution patterns, resolving biogeographic anomalies, and, consequently, for assessing the conservation status of a species (see also Gower et al. 2015, Kotharambath et al. 2012b).The taxonomic validity of a few of the striped forms of I*chthyophis* from NEI is questionable; a modern systematic review of the group is required.

Datta et al.'s (2008) "empty forests" scenario in Namdapha National Park, Arunachal Pradesh, India would not be unusual in other parts of NEI. Studies on forest depletion and habitat destruction due to different reasons are still largely unavailable for a large majority of NEI forests, but the few published studies (e.g., Kushwaha et al. 2011, Lele & Joshi 2008, Reddy et al. 2013) all indicate a forbidding scenario. The agricultural practise of slash and burn (e.g., Lele & Joshi 2008, Singh, & Borthakur 2015, Yadav et al. 2012), driven largely by the exponential human population growth, presents one of the most formidable challenges to wildlife conservation in NEI. Ethno-civil strife (e.g., Velho et al. 2014), insurgency (e.g., Reddy et al. 2013), increasing expanse of exotic vegetation (e.g., Puyravaud et al. 2010), and corruption (e.g., Laurance 2004) are other important factors that continue to threaten NEI's biodiversity unabated. Needless to say, biodiversity research is the need of the hour if our posterity is to get the privilege of relishing the diminishing nature's bounty. Increase in the scale of research in lesser-known vertebrate groups such as caecilians is clearly warranted. I hope that members of *Homo sapiens* will become more sympathetic to caecilians (and all wildlife), that the younger generation become more inspired to consider biodiversity and conservation science as viable career options, and that the bureaucracy become more compassionate towards the academic research community, to respect scientific merit, to foster global scientific collaboration, and to appreciate the benefits of international cooperation.

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