

Conservation of Caecilians in the Eastern Himalayas Region

Project Report

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Credit Page and details

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Conservation of Caecilians in the Eastern Himalayas Region

Abstract

In this project, 33 localities were surveyed primarily in the northeast Indian states of Manipur, Nagaland and Meghalaya. The results obtained include, the most comprehensive collection of caecilians ever made in the Eastern Himalayas Region (EHR) covering 50 populations. All four currently described species were rediscovered at the type localities for the first time since their original descriptions. Approximately 20 new species have been discovered of which three has been formally described (see the appendix 1) and three in press, thus this study has resulted in the discovery of the probably largest number of new caecilian species of any single project in history. Caecilians are here reported from the states of Manipur and Nagaland for the first time. Data collected in this project will provide the first information on breeding biology and habitat niche preferences for caecilians from the EHR providing vital information allowing assessment of the true conservation status of all currently described and soon to be described new species.

Major findings and activities	
	Surveyed 33 localities in northeast Indian states of Manipur, Nagaland and Meghalaya
	Studied over 50 populations. Probably for many populations, this might be the first time they were studied. 
	Discovered about 20 new taxa and awaiting conservation assessment after formal recognition of taxa. More taxonomic discoveries point to need for more conservation work.
	Three new species described, Zootaxa , 2009; first cut of significant yields from this project. 
	Rediscovered <i>Gegeneophis fulleri</i> after 130 years after the first collection. Achievement after a century of 'invisible existence'.
	Rediscovered <i>Ichthyophis sikkimensis</i> after 100 years from type locality 
	Fact vs Myth. Educated local community that caecillians are not poisonous. Emphasised why they should be conserved.

Introduction

India has more than 240 amphibian species (including 170 national endemics), of which 28% are categorized as globally threatened species by IUCN (<http://www.iucnredlist.org/>). Unfortunately, 85 of the country's amphibians are so poorly-known that they are currently categorized as Data Deficient (DD). Many of these DD species have historically only been recorded from areas of extensive habitat loss, and it is entirely plausible that most populations are severely threatened with extinction. Further field studies are now urgently needed to document the distribution, ecological needs, threats, and conservation status of these DD species and to thereby inform national, regional and global conservation strategies.

In terms of diversity, northeast India is a very important biogeographical region as it is the point where Indian, southeast Asian and Chinese fauna meet and in some cases disperse to inhabit new biogeographical regions. Contrarily the high mountain ranges of the eastern Himalaya and Indo-Myanmar ranges form an important dispersal barrier for many species. Much information is currently known for most other higher vertebrate animals regarding their ability or disability to disperse across this geographical barrier however very little information is known for the lesser studied animals such as amphibians. In other regions and countries, research by like-minded herpetologists have revealed that most species of amphibians have very restricted elevational preferences, however even this basic information is still lacking for most northeast Indian species. Furthermore, the difficult terrain of the mountainous northeastern states have proved difficult for comprehensive surveys on this faunal group thus the current species numbers recorded here are presumed to be grossly underestimated.

Caecilians (Gymnophiona) are without question the most poorly known and understudied family of amphibians both nationally in India and internationally. In India, the Western Ghats (WG), a long narrow mountain range oriented north to south parallel to the western coast of India, has received increased attention from herpetologists in recent years to document the caecilian fauna of this globally important biodiversity hotspot. The combined result of this research has increased the number of described caecilian species by 52% since 1999 (Bhatta & Prashant, 2004; Bhatta & Srinavasa, 2004; Bhatta *et al.*, 2007a & b; Giri *et al.*, 2003; Gower & Wilkinson, 2007; Gower *et al.*, 2003; Oommen *et al.*, 2000; Pillai & Ravichandran, 1999; Ravichandran, 2003; Wilkinson *et al.*, 2007). The species diversity has not however been the only focus of research there, as several major discoveries have also focused on other aspects of caecilian biology such as biogeography (Gower *et al.*, 2002 & 2007), survey techniques (Gower *et al.*, 2006) and behaviour (Measey *et al.*, 2004).

In terms of caecilian biodiversity in the Eastern Himalayas Region (EHR), our current knowledge on this poorly studied group of fossorial amphibians is comparatively deficient. To our knowledge no caecilian specific field research

has ever been carried out in the EHR. Currently only 4 species (*Ichthyophis garoensis* Pillai & Ravichandran 1999; *I. husaini* Pillai & Ravichandran 1999; *I. sikkimensis* Taylor 1960; *Gegeneophis fulleri* (Alcock 1904)) have been described from this region based on apparently incidental collections of a small number of specimens. Two of these species *I. husaini* and *G. fulleri* are only known from a single specimen, their respective holotypes which are currently in a bad state of preservation. Despite a few additional reports of *I. garoensis* and *I. sikkimensis* from additional localities to their type locality, no further information is known on the taxonomic status of these species, morphological variation, distribution, habitat preferences and biology, thus making it impossible to assess their conservation status. Thus, it is not surprising that all four EHR caecilians are currently Data Deficient (Global Amphibian Assessment – GAA).

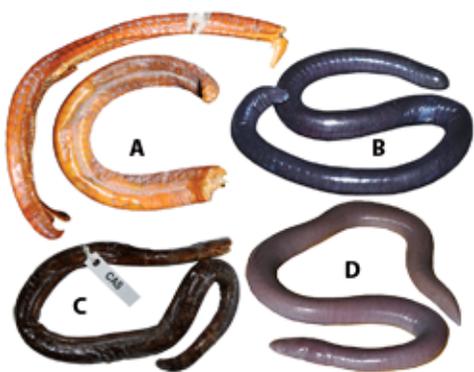


Figure 1. Rediscovery of the “lost species” during the period of this project: **a.** sole type specimen of *Gegeneophis fulleri* known before the present study, **b.** live animal which was rediscovered during the present study; **c.** type specimen of *Ichthyophis sikkimensis*, **d.** live animal which was rediscovered during the present study.

One thing that is clear from our limited knowledge of caecilian diversity in EHR, itself a globally recognised biodiversity hotspot, is that the actual diversity of caecilians is perhaps highly underestimated. Many of the above mentioned biogeographical barriers inhibiting amphibian dispersal between neighbouring countries and continents also exist within EHR itself, such as high mountain passes, deep valleys and large rivers. Such barriers limit the geographical range within EHR for most habitat specific frog species, dramatically increasing species endemism. These basic rules would also apply to the caecilian fauna further emphasising the need for extensive caecilian-specific surveys of the EHR to document the geographic range of the known species, along with discovery of undescribed species.

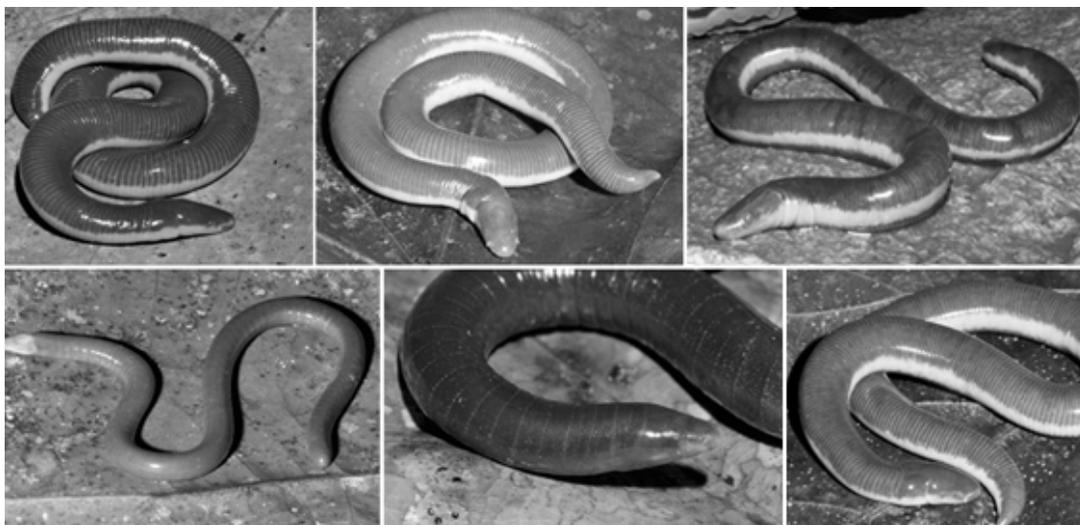


Figure 2. Six out of 20 new species discovered during the study period. First three are published- *Zootaxa*, 2267: 26–42.

An issue of grave conservation concern for the caecilian fauna of this region is the deep-rooted myth about caecilians. The local people consider these ‘slimy snakes’ as abominable beings and believe that their ‘bite’ is fatal. Locally caecilians are known as blind snake, mud snake, snake with no head or tail, back ache snake (back ache snake derives its name from the fatal backache the ‘venom’ causes). The local people in various parts/states of the Northeast has exactly the same story to tell and consequently the same instinct to kill all caecilians on sight. Such unfounded myths impose a serious conservation challenge and can only be removed with more field research and educating the local people.

Study Area

Northeast India, comprising of the states of Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Sikkim and Darjeeling district of West Bengal, lies at the junction of Indo-Burma and Himalaya global biodiversity hotspots. The biodiversity in this region is rapidly vanishing. Habitat destruction by humans is the main cause of this rapid depletion. Significantly, the three new species discovered during this present study are from an area where there is rapid conversion of forestland into agricultural land. This discovery further highlights the need to conserve species and their habitats in the northeast India. Forests here continue to be threatened and large areas are being destroyed for agriculture and urbanization. Seemingly small disturbances in their habitat could wipe out several species. Habitats are rapidly disappearing and immediate steps are required to protect the remaining forests from human activities like Jhum cultivation.

The present study proposed only two states, Manipur and Nagaland of northeast India. The two states were selected because of complete lack of information on this group of animal; until the present study no caecilians were

reported from this area. For a wider sampling area the current project extended the study area to include Meghalaya since the two states (Manipur and Nagaland) barely represents 20 per cent of the EHR geographical area.



Figure 3. Map of northeast India (light grey) and the study area-Manipur, Nagaland, and Meghalaya (black).

Aim and Objectives

- (i) To assess the status of the four described EHR caecilian species at their type localities.
- (ii) To conduct intensive new fieldwork in two NE Indian states (Nagaland, Manipur) in order to determine caecilian diversity and distribution across protected and disturbed habitats, and latitudinal and longitudinal gradients, and use these data to extrapolate a prediction of the overall true diversity of EHR caecilians.
- (iii) To reassess the taxonomy and distribution of all EHR caecilians and incorporate this along with new ecological and reproductive data directly into the Global Amphibian Assessment.
- (iv) To educate local academics and applied conservationists in caecilian field studies and identification and promote interest and concern.
- (v) Produce and distribute (NE India, Bhutan, Nepal, Myanmar, Bangladesh) a basic (probably single-sheet), illustrated field guide to caecilians of EHR.
- (vi) Identify potential sites for future species monitoring projects.
- (vii) Generate baseline data on habitat quality (especially in relation to agricultural practices) for sites yielding and not yielding caecilians.

- (viii) Combine results from points i-vii and work them into a caecilian conservation action plan for the EHR.

Study locations

Carrying out any biological survey in northeast India is always fraught with any number of difficulties such as logistical issues, communication problems and civil unrest amongst local communities. However a major problem faced primarily in the monsoon season (i.e., our survey season) is road blocks due to landslides. The persistent heavy monsoon rains in combination with the steep and difficult terrain and to a large extent, habitat degradation, landslides are a very regular and inevitable obstacle when working in the mountainous regions of northeast India.

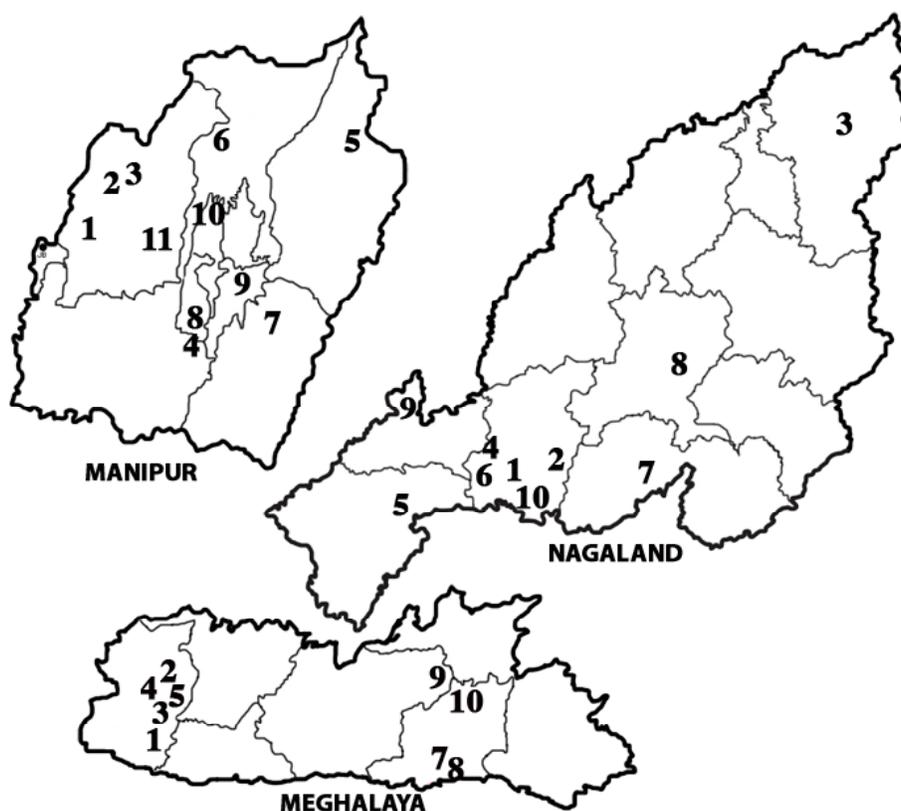


Figure 4. Study area in three states of northeast India. Numbers correspond to the study site in table 1.

Table 1. The study localities – proposed, and surveyed during this study.

Sl.no	Proposed survey localities	Habitat
Manipur		
1	Bamgaizaeng	Secondary forest and banana plantations
2	Tamenglong	Secondary forest and orange and plantation
3	Aziuram	Primary forest and orange plantation
4	Raengzaeng	Primary forest and plantation
5	Ukhrul	Primary forest and plantations
6	Maram	Secondary forest and plantation
7	Chandel	Forest and paddy fields
8	Bishnupur	Forest and paddy fields
9	Thoubal	Forest and plantations
10	Imphal	Paddy field with scrub forest
11	Luangmai	Primary forest and plantations
Nagaland		
1	Aradurah Hills, Kohima	Primary forest
2	Dzulakie, Kohima	Secondary forest and plantations
3	Mon	Primary forests and paddy fields
4	Jalukie	Paddy fields on forest fringes
5	Peren	Secondary forest
6	Jotsoma (Puliebadzie)	Secondary forest
7	Phek	Primary forest and paddy field
8	Zunhebuto	Forest and plantations
9	Dimapur	Paddy fields
10	Dzuku	Shola forest and open grassland
Additional localities surveyed		
Meghalaya		
1	Anogiri Lake, Garo Hills	Plantation and recreational area
2	Rongram, Garo Hills	Secondary forest and paddy fields
3	Tura peak, Garo Hills	Primary forest
4	Chitoktak, Garo Hills	Bettel plantation and rural gardens
5	Asanang, Garo Hills	Secondary forest and paddy fields
6	Nokrek N.P., Garo Hills	Primary forest
7	Cherrapunji, East Khasi	Secondary forest and open grassland
8	Laithyra, East Khasi Hills	Primary and secondary forest
9	Shillong, East Khasi Hills	Secondary pine forest
10	Mawphlang, East Khasi	Mature secondary forest and open grassland

All of the originally proposed study localities were surveyed during this project except for one, viz., locality no. 11 in Manipur. Some areas in the proposed localities were simply not accessible during the short window of opportunity that the survey team had to visit them. In these cases, extra time was allocated to working in those areas that were accessible in order to maximise our obtainable

results. In addition to the above listed localities in Nagaland and Manipur, we also surveyed the type localities of the four currently described northeast Indian caecilian species, *Ichthyophis garoensis* (type locality: Anogiri Lake, Garo Hills, Meghalaya, India); *I. husaini* (type locality: Thebronggiri Coffee Garden, Rongram, Garo Hills, Meghalaya, India); *I. sikkimensis* (type locality: Darjeeling, West Bengal, India); *Gegeneophis fulleri* (type locality: Kuttal, 6 km south-west of Silchar in Cachar, Assam, India). As two of the type localities were in the state of Meghalaya, it was economically viable to extend the study area to include the additional localities listed in table 1 for Meghalaya. The study localities all varied considerably in their habitat types depending primarily on location, altitude and degree of anthropogenic degradation.

Survey techniques

Areas assumed suitable for surveying, such as marshy depressions, seeps, banks of various sized streams, both fast and slow flowing, ponds, fringes of plantations (banana, tea, orange, and cardamom etc.), and paddy fields were dug by the field team and assistants in search of the elusive caecilians. Such is that case when attempting to specifically find any entirely fossorial species for the first time in a region, many factors affect whether efforts will provide successful results. Factors include, whether or not caecilians are present in the survey area at all, if so, what specific habitat niche preference the extant species has e.g., under rocks/leaf litter/humus/soil/clay, waterlogged/wet/moist substrate, under full canopy/no canopy, with/without dense vegetation etc. What was found in this study was that there is no trial and error factor that can be applied as a habitat may appear to be identical to that which caecilians were collected in one locality, but yield not result at another. In some cases apparently intact and undisturbed habitats produced no results but caecilians could be found to be plentiful in a nearby rice paddy. In essence, finding caecilians at any locality is often a matter of simple luck and more importantly persistent digging. To help increase our "luck", photographs were shown to many local villagers, especially those who would regularly dig for their livelihood, i.e., farmers and road workers, for local information on areas where these animals had been sighted previously. This technique had only limited usefulness as understandably these animals are clearly confused with earthworms, blind snakes (Typhlopidae) and eels depending on the individual person interviewed and only rarely would a reported sighting result in the desired caecilians. Despite all of the above mentioned hurdles, this study did produce several unexpected and very exciting results.



Figure 5. "I've got a new spade, and I'm going to dig!" Caecilian researchers live this 'motto'. Caecilians are underground animals and do not leave any clues on soil surface as to where they could be. Therefore, caecilian researchers have to dig and continue to dig till they find what they are looking for!

Results in relation to original aims

- (i) **To assess the status of the four described EHR caecilian species at their type localities.** At all four type localities surveyed, caecilians representing the desired species were successfully found. Data was gathered regarding the condition and possible environmental and anthropogenic threats that the species may encounter at the type localities. This new morphological data is currently aiding in the identification of further populations of these species to allow a revised conservation status.
- (ii) **To conduct intensive new fieldwork in two NE Indian states (Nagaland, Manipur) in order to determine caecilian diversity and distribution across**

protected and disturbed habitats, and latitudinal and longitudinal gradients, and use these data to extrapolate a prediction of the overall true diversity of EHR caecilians. Surveys were carried out at all the originally proposed localities in Manipur and Nagaland except for locality number 11 in Manipur. The study area was expanded to the state of Meghalaya where an additional 10 localities were surveyed. With the combination all localities considered together, sampled altitudinal range extends from 25–2500 m a.s.l. and covers most of the important habitat types from undisturbed primary forest to heavily disturbed plantation and agricultural land. At many of these localities between one and three species were found, the identification of which is currently pending until all specimens can be thoroughly examined and compared to museum material of confirmed identity. The true overall diversity of EHR caecilians will be realised from these results.

- (iii) **To reassess the taxonomy and distribution of all EHR caecilians and incorporate this along with new ecological and reproductive data directly into the Global Amphibian Assessment.** Based on the results obtained in this study, specimens are currently under examination for definitive identification, however preliminary molecular analysis is showing extraordinary diversification in EHR caecilians, indicating numerous undescribed new species having been discovered. When reliable morphological characters can be defined for both described and undescribed species, the taxonomic status will be clarified and associated ecological and reproductive data (where obtained) will be presented to the GAA.
- (iv) **To educate local academics and applied conservationists in caecilian field studies and identification and promote interest and concern.** At all study localities, the resident people had many various misconceptions and superstitious beliefs associated with caecilians. In all cases these were addressed and clarified, regularly under circumstances where many local people had gathered to watch our work in the field. Additionally six organised public awareness campaigns were held in villages where sightings and subsequent slaughtering of these misunderstood animals were most prevalent. To the wider audience, field guide mentioned in point (v) below will be distributed to most appropriate education facilities and wildlife conservation NGOs as well as local forest departments, all major national museums, and few relevant international museum . The field guide will also be posted on the Systematics Lab web site for free open access to all interested in caecilian taxonomy. However the printing of the proposed field guide is subject to availability of fund in this project (the pending second instalment). For the scientific community, all relevant data obtained during this study will be published in internationally respected, peer reviewed journals dramatically increasing the knowledge of the concerned scientific community, thus promoting interest and concern for this usually neglected but widespread faunal group.



Figure 6. Erasing a myth! Lessons in caecilian facts for villagers were held in their village itself to emphasise that caecilians are not poisonous. Even children seemed to be convinced and handled live animals (above two images).

- (v) **Produce and distribute (NE India, Bhutan, Nepal, Myanmar, Bangladesh) a basic (probably single-sheet), illustrated field guide to caecilians of EHR.** With the pending final instalment of funding the illustrated field guide will be produced and distributed.
- (vi) **Identify potential sites for future species monitoring projects.** Surveyed localities that did not fall within the government “Protected Area” network (PA), were subject to ever increasing disturbance and encroachment by local communities. The same could be said for several areas that do fall within the PAs such as reserve forests, national parks and wildlife sanctuaries. Based on results obtained here several potential sites have been identified for future species monitoring projects. These areas were selected using the criteria of habitat encroachment threats and local species

- diversity. These localities are Tamenglong and Ukhrul (Manipur), Mon (Nagaland) and Nokrek National Park and Tura (Meghalaya).
- (vii) **Generate baseline data on habitat quality (especially in relation to agricultural practices) for sites yielding and not yielding caecilians.** At all study localities, habitat data was acquired along with local information on general trends of shifting cultivation and other habitat clearance due to local level commercial and noncommercial tree felling. As discussed above in the “Survey techniques” section, caecilians were found only in disturbed areas at some localities and only undisturbed areas in other localities. At numerous localities no caecilians were found at all, e.g., all high altitude localities bar Darjeeling. At some lowland localities with apparently suitable habitats, again no caecilians were found in neither disturbed or undisturbed habitats.
- (viii) **Combine results from points i-vii and work them into a caecilian conservation action plan for the EHR.** The creation of a working caecilian conservation action plan based on the extensive results obtained during this project is expected to be a reality by 2010 end.

Discussion

The new collection material obtained during this study represents the most important and most comprehensive collection of caecilians ever made from the EHR. This collection will for the first time provide vital information on the inter and intra specific morphological variation of all currently described species allowing herpetological researchers to identify their own past and future collections. Each of the currently described (four) species can now be confirmed to be still extant at their type localities which previously had not been proven since their original collections. It is hoped that with further field explorations and research of collected material, additional localities can be confirmed for these species, extending their distribution range.

The several new species discovered in this project will be described when relevant specimens are studied adequately shedding light on the previously unreported high caecilian species diversity in this underexplored region. The present study has also resulted in the first confirmed records of the presence of caecilians in the states of Manipur and Nagaland. Tissue samples taken from all populations collected in this study will be sequenced to examine the inter specific relationship of all species collected in the EHR. This data will be combined with available GenBank sequences to provide important biogeographical data regarding gene flow between India and southeast Asia thus shedding new light on the dispersal routes of caecilians across the major geographical barrier, that is, the Himalayas.

The new localities in combination with the new data regarding preferred habitat niche and current habitat condition will allow an accurate reassessment to be made of the true conservation status of all northeast Indian caecilian species. Additionally, extensive data has been collected on the biology of most of the species discovered during this project. The data regarding breeding season and behaviour of EHR caecilians has never before been documented or published, thus our results will make this information available for the first time.

It is certainly unusual that the timid caecilians are such a widely persecuted animal in India, not just in the EHR but also in the Western Ghats of western India where they are equally stigmatised by many local fanatical myths (Ramachandran & Oommen, 2008). The awareness programmes involved public demonstrations of harmlessness of the animals using a hands-on approach which involved many of the audience. A presentation of photographs and basic lecture on the essential ecological role that caecilians have in the health of the environment, and thus the people who live in and depend on the environment for their livelihood, was enthusiastically attended by both young and old. Local, negative impact myths were addressed and proven wrong using easily understood demonstrations, the success of which was evident by the considerable number of people both surprised by the true facts and willing to interact directly with the demonstration animal. Though a small portion of the audience still did not particularly like the animals for their snakelike appearance and movements, all were certainly convinced of their harmless nature by the conclusion of all demonstrations and thus happy to let the animal be when encountered in future. These programmes were considered a great success, especially with the younger generation who we considered the most important candidates for changing opinions and rectifying the propagation of misconceptions to future generations. The obvious excitement created by our demonstrations amongst all age categories certainly ensured that our message was and will for some time be widely conveyed by the attending audience to friends and relatives spread throughout the region in the many village communities that could not be visited by our team. In addition to the local level success of our awareness campaigns, upon receipt of the remaining grant balance, we feel it will be exponentially beneficial to produce and distribute the proposed awareness posters to the major education centres and facilities to ensure that our conservation message will continue to educate the wider public for a long time to come.

In summary, this study has been a major breakthrough for both Asian caecilian research and conservation. The knowledge obtained during the project on this secretive and little known group of amphibians will certainly change the course of survey techniques of future herpetological expeditions in this region to ensure that this important section of the amphibian fauna is discovered and documented from the remaining states of northeast India and surrounding countries.

Future plan

Northeast India is most unexplored for amphibian diversity and this project is the first ever organised, caecilian-specific research in this region. Systematics Lab is exploring the feasibility to expand caecilian research geographical area, and for further research in the areas already surveyed during the present study. The three states surveyed are part of the Indo-Burma global biodiversity hotspot. Regions of the EHR that fall in the other global biodiversity hotspot, the Himalaya, which northeast India is part of remains absolutely unexplored for caecilians except for the historical report of one caecilian species (*Ichthyophis sikkimensis* from Darjeeling and Sikkim) and this study's collection of new

samples of the species from the type locality. In a brief period of field work and a single (monsoon) season the present study tried to survey as many diverse habitats and a wide altitudinal range. However the area covered in this study is only 20 per cent (approx.) of the EHR and the remaining >80 per cent geographical area remains to be explored. Based on the interesting results of this study, we predict that there are several new taxa waiting to be uncovered. For conservation assessments to be meaningful and accurate data on the distribution range of taxa, a more complete knowledge of the biology of the animals (which is mostly not possible to realize in a single breeding season), and conditions of populations in the wild of each taxa is required. We plan to address these issues for a more complete documentation of the overall caecilian diversity in the EHR, and making available accurate conservation status of the group.

Expenditure (Amount in US dollars)

Heads	Sanctioned	Received	Spent	Balance	Remarks
Salaries for local field assistants	840	840	830.3	9.7	-
Administration costs	782.6	782.6	782.6	Nil	-
Lab and field consumables	850	Nil	Nil	Nil	Expecting the release of money before 30 October 2009
Ground travel: car hire, taxis, buses, trains, auto rickshaw	2,487.4	2142.4	2141.5	0.9	An additional 345 USD was spent by the PI to meet the financial needs in the field
Return flights for two people	1,620	1,620	1549.8	70.2	-
Field accommodation and food	3,600	3,600	3593.3	6.8	-
Printing of field guide	1000	Nil	Nil	Nil	Expecting the release of money before 30 October 2009
Total	11,180	*8985	*8915.7	87.6	*Total of 18.2 USD was deducted as commission to intermediary bank, and bank charges.
Total amount received in first instalment	9000				
Amount pending	2,180				

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- Kamei, R.G. and Biju, S.D. (in manuscript) Northeast India's soil-dwelling amphibians: insights from the rediscovery of *Gegeneophis fulleri* after more than 100 years.
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Appendix

List of publications partially or completely funded through this project.

- 1 Kamei, R.G. and Biju, S.D. (in manuscript) A remarkable new species of *Ichthyophis* (Amphibia: Gymnophiona: Ichthyophiidae) from East Khasi Hills in Indo-Burma global biodiversity hotspot.
- 2 Kamei, R.G. and Biju, S.D. (in manuscript) Northeast India's soil-dwelling amphibians: insights from the rediscovery of *Gegeneophis fulleri* after more than 100 years.
- 3 Kamei, R.G., Gower, D.J. and Biju, S.D. (in preparation) Redescription of *Ichthyophis sikkimensis*, Taylor, 1960, based on new samples with notes on current conservation status.
- 4 Kamei, R.G., Wilkinson, M., Gower, D.J. and Biju, S.D (2009) Three new species of striped *Ichthyophis* (Amphibia: Gymnophiona: Ichthyophiidae) from the northeast Indian states of Manipur and Nagaland. *Zootaxa*, 2267: 26–42.
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Three new species of striped *Ichthyophis* (Amphibia: Gymnophiona: Ichthyophiidae) from the northeast Indian states of Manipur and Nagaland

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Abstract

Three new ichthyophiid species, *Ichthyophis khumhzi* **sp. nov.**, *Ichthyophis moustakius* **sp. nov.** and *Ichthyophis sendenyu* **sp. nov.**, from the northeast Indian states of Manipur and Nagaland, are described on the basis of morphological analysis of new material. The new material (16 specimens) more than doubles the number of northeast Indian caecilian specimens reported in previous literature, and increases the caecilian fauna of the region to seven species. Two of the new species have very distinctive, moustache-like stripes between their tentacles and nares, a feature not reported in other ichthyophiids. Diagnoses, type descriptions, illustrations, data on variation, distribution, and natural history are provided for the new species. Concern for the conservation of northeast Indian caecilians is raised, given the paucity of previous work, evidence of unrecognized diversity, and ongoing habitat destruction.

Key words: caecilians, conservation, ichthyophiids, new species, northeast India, systematics

Introduction

Northeast India, comprising the states of Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Sikkim and Darjeeling district of West Bengal (Fig. 1), lies at the junction of the Indo-Burma and Himalaya global biodiversity hotspots (Mittermeier *et al.* 2004). Currently this region has 118 named amphibian species (Frost 2009) representing just over half of India's recognized amphibians. However, only four species of caecilian amphibians (Gymnophiona) are currently documented from this region, representing only 16% of the Indian caecilian fauna and very few specimens have ever been reported (e.g., Pillai & Ravichandran 1999), indicating a lack of organized basic research. One of the biggest challenges to studying terrestrial caecilians is their secretive, generally burrowing lifestyle (Gower & Wilkinson 2005). They are rarely encountered in routine herpetological surveys and excavation is generally required for their sampling (Measey *et al.* 2003; Gower & Wilkinson 2005). Although sometimes locally abundant (Oommen *et al.* 2000), even with specific effort it can sometimes prove difficult to find them, and many species are known from very small samples. However, dedicated field effort in the Western Ghats of peninsular India has resulted in a great increase in available material, and a dramatic increase in number of species new to science (Gower *et al.* 2004). Similarly extensive and dedicated surveys in northeast India might be expected to uncover taxa still unknown to science.

Based on the presence or absence of a longitudinal cream or yellow stripe on each side of the body in metamorphosed animals, the genus *Ichthyophis* can be divided for the purpose of identification into two non-monophyletic groups (Taylor 1968; Gower *et al.* 2002). Two unstriped (*I. husaini* and *I. sikkimensis*), and a single striped (*I. garoensis*) *Ichthyophis* are known from northeast India (Pillai & Ravichandran 1999). We agree with Dutta (2002) in considering a report of a specimen of *I. glutinosus* from Goalpara in Assam (Pillai

Discussion

Among many other differences, *Ichthyophis moustakius* and *I. sendenyu* are distinguished from each other and from all other caecilians by their unusual and distinctive moustache-like stripes extending forward from the TAs. Although the ‘moustache’ is distinctive in each species, the presence of this feature suggests that they are sister species. These two species are also similar in having broad stripes with spurs connecting to the disc, relatively few annuli and vertebrae, and four or five scale rows posteriorly, with minor differences in head shape and colour. *Ichthyophis moustakius* is notable for its more highly variable tentacle position than reported for other *Ichthyophis* species.

No single character serves to distinguish *I. khumhzi* from all other *Ichthyophis* but combinations of diagnostic characters serve to distinguish it from any other species. In particular, with the exception of *I. longicephalus*, all other south Asian striped *Ichthyophis* (*I. beddomei*, *I. garoensis*, *I. glutinosus*, *I. kodaguensis*, *I. pseudangularis*, *I. tricolor*) differ from *I. khumhzi* in having TAs less than twice as far as from nares than eyes ($TN/TE < 2$). All southeast Asian striped *Ichthyophis* (*I. attricularis*, *I. biangularis*, *I. bannanicus*, *I. bernisi*, *I. elongatus*, *I. humphreyi*, *I. hypocyaneus*, *I. kohtaoensis*, *I. paucisulcus*, *I. supachaii*) differ from *I. khumhzi* in having markedly fewer IMs than dentary teeth. *Ichthyophis longicephalus* differs from *I. khumhzi* in head shape and size ($L/H < 18$ versus > 25 , respectively), and in having fewer scale rows, subequal collars, and a stripe that extends onto the tail.

The three new species are known from small samples and single or few localities. One (*I. khumhzi*) is known only from adult males, and information on various life history stages of all three species is as yet minimal or absent. Although we are confident that these are distinct species, more material is required to better characterize these taxa.

The present description of three new species of *Ichthyophis* expands the poorly known caecilian diversity of northeast India to seven species – one caeciliid, two unstriped *Ichthyophis*, and four striped *Ichthyophis*. Ichthyophiidae is endemic to south and southeast Asia (Taylor 1968), and available molecular phylogenetic data support the hypothesis that ichthyophiids dispersed into southeast Asia from south Asia (Gower *et al.* 2002). Gower *et al.*'s (2002) sampling included Sri Lankan and peninsular Indian ichthyophiid samples but none from northeast India, though their inclusion in further tests of the ‘Out of India’ hypothesis would be useful considering their occurrence in a region within a possible dispersal route.

All of the four previously described caecilians of northeast India are categorized as Data Deficient in the IUCN Red List (IUCN 2009). We suggest that all three of the new species described here should also be considered Data Deficient (DD) given that we know very little about their distribution. That specimens were found in areas of human disturbance gives some hope that they are not immediately threatened, but this depends foremost on a reasonable range size. In more general terms, it is of grave concern that the region's caecilian fauna is poorly known, particularly in the light of accelerating deforestation and habitat degradation in this region (FSI 1999; Lele & Joshi 2008). Dedicated fieldwork and systematic research are priorities for a more complete inventory of the caecilian fauna of northeast India and accurate and precise assessments of conservation status.

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