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Endemic *Indirana* frogs of the Western Ghats biodiversity hotspot

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Frogs of the genus *Indirana* belong to the endemic family Ranixalidae and are found exclusively in the Western Ghats biodiversity hotspot. Since taxonomy, biology and distribution of these frogs are still poorly understood, we conducted a comprehensive literature review of what is known on the taxonomy, morphology, life history characteristics and breeding biology of these species. Furthermore, we collected information on the geographical locations mentioned in the literature, and combined this with information from our own field surveys in order to generate detailed distribution maps for each species. Apart from serving as a useful resource for future research and conservation efforts, this review also highlights the areas where future research efforts should be focussed.

Introduction

The world's biodiversity is threatened by human activities, yet the sustainable use of biodiversity is fundamental to the future development of humanity (Jenkins 2003). As financial and human resources are limited for nature conservation, it may be appropriate to focus efforts on biodiversity hotspots (Myers *et al*. 2000, Brooks *et al*. 2002, Roberts *et al*. 2002). About 34 biodiversity hotspots have been recognised, based on plant and vertebrate species richness, endemism and threat status. These 34 biodiversity hotspots contain 50% of all plant species and 42% of all vertebrate species, but these areas comprise only 2.3% of all the land surface of the globe (www.biodiversityhotspots.org), and they are under threat from growing human populations (Cincotta *et al*. 2000). Therefore, it can be argued that their protection should be of high priority, as they may represent an efficient way of preserving a large proportion of the world's biodiversity. Yet, our understanding of the diversity in these hotspots remains very poor, and is often limited to species counts of a few key groups of fauna and flora. This hampers any rational approach to conservation in biodiversity hotspots, and questions any strategy that protects these regions as a surrogate sample of total global biodiversity (Grenyer *et al*. 2006).

The Western Ghats–Sri Lanka biodiversity hotspot (Bossuyt *et al*. 2004) is one of the world's

recognized biodiversity hotspots (cf. www.biodiversityhotspots.org). The herpetofauna of southern India — an area which comprises parts of the Western and Eastern Ghats — is one of the most diverse and poorly known groups in tropical Asia (Inger 1999). Although many species of amphibians are yet to be described from India (Aggarwal 2004, Kuramoto *et al*. 2007), of the known 284 species (Dinesh *et al*. 2009), 13 species are at present critically endangered and 31 species are endangered (www.iucn.org). These facts combined with the realization that amphibians comprise a group of organisms facing particularly pronounced declines and extinction risks worldwide (Houlahan *et al*. 2000, Stuart *et al*. 2004, Mendelson *et al*. 2006), suggest that studies into the diversity and conservation biology of the Western Ghats amphibians should be well motivated.

The current knowledge of the amphibian fauna of the Western Ghats is scanty and fragmented. All that is known suggests that this fauna is unique with high degree of endemism (Inger 1999, Biju 2001). Three families, Micrixalidae, Nasikabatrachidae and Ranixalidae, and ten genera are endemic to the Western Ghats. The genus *Indirana* which is the focus of this review belongs to the endemic family Ranixalidae and comprises of 10 known species (Biju 2001; Table 1). Two of them are classified as critically endangered (*I. gundia* and *I. phrynoderma*), three as endangered (*I. brachytarsus*, *I. diplosticta*, and *I. leptodactyla*), one as vulnerable (*I. leithii*), two (*I. beddomii* and *I. semipalmata*) as least concern, and two (*I. longicrus* and *I. tenuilingua*) are data deficient (www.iucn.org). The populations of all these species are small and isolated, owing to the destruction and fragmentation of their natural habitat due to various anthropogenic activities (Nair 1991), and as a result these species may face extinctions in the near future (Daniels 1992).

Table 1. The ten currently recognized *Indirana* species with their IUCN statuses and approximate estimates of their distribution ranges (km^2). The distribution ranges were obtained by summing the 50 km^2 squares for each species (*see* Fig. 1).

Species	IUCN status	Distribution range (km^2)
Indirana beddomii	Least concern	1250
Indirana brachytarsus	Endangered	550
Indirana semipalmata	Least concern	700
Indirana leithii	Vulnerable	500
Indirana leptodactyla	Endangered	600
Indirana diplosticta	Endangered	350
*Indirana gundia**	Critically endangered	50
Indirana phrynoderma	Critically endangered	100
*Indirana longicrus**	Data deficient	50
*Indirana tenuilingua**	Data deficient	50

*Known from only one locality.

The current knowledge of the interspecific biodiversity, distribution and community structure of the Western Ghats amphibians is limited (Andrews *et al*. 2005a, 2005b, 2005c, 2005d), therefore it is hardly surprising that very few intraspecific studies on the Western Ghats amphibians have, to date, been conducted. As far as we are aware, only few population genetic studies of amphibians within India have been carried out, and most of the genetic studies made at the interspecific level have focused on taxonomic questions (e.g. Bossyut & Milinkovitch 2000, Kosuch *et al*. 2001, Wilkinson *et al*. 2002). Except for a few well studied taxa (e.g. Biju & Bossyut 2009), the evolutionary relationships, taxonomy and species-level diversity of the Western Ghats amphibian fauna are poorly resolved and nothing is known of the extent of genetic variability and differentiation among local populations of most of the species. Consequently, there is a high degree of uncertainty about the taxonomic status (cf. cryptic species) and potential genetic issues (e.g. loss of genetic diversity, inbreeding, restrictions to gene flow due to habitat fragmentation) regarding the local amphibian populations. From this, it follows that any plans for the conservation and management of amphibian biodiversity in this biodiversity hotspot currently have to be based on educated guesses, rather than on scientifically based knowledge.

The aim of this review is to provide a comprehensive and critical literature review bringing together all available information on the biology of the endemic *Indirana* frogs from the Western Ghats. By doing so, we wished to create a useful resource and reference for those interested in the biology and conservation of *Indirana* frogs, as

well as to identify knowledge gaps and future research needs. Apart from bringing together what is known about the morphology, systematics, basic ecology and biology of these frogs, we paid particular attention to what is known about the geographical distribution of different species across the Western Ghats. In order to create putative distribution maps, we used both information available from literature, and data from field-surveys conducted in different parts of the Western Ghats between 2008 and 2011.

Methods

The information presented in this review was obtained from all possible literature sources which were identified by searching the Web of Knowledge (http://apps.webofknowledge.com), Google Scholar, and the amphibian databases AmphibiaWeb (www.amphibiaweb.org) and Amphibian Species of the World 5.4 (http://research.amnh.org/vz/herpetology/amphibia/), using '*Indirana*' as a search query. In general, these searches produced very few hits (5 hits in Web of Knowledge), and most information was retrieved from books, reports and specific (typically non-refereed) herpetological or zoological journals. Each time we encountered information on *Indirana* frogs in a given source, the reference list from that article was scanned for further references. By these means, we were able to find 93 publications dealing with the systematics, biology and distribution of *Indirana* frogs.

Taxonomy and life history

We searched for information about the higher level systematics of *Indirana* species, paying particular attention to studies that examined the affinities of this genus to other genera. We also review the earlier designations of *Indirana* species to other genera, and the basis upon which the species are believed to form a genus of their own. We also examined the basis for the species delimitations within the genus by studying all the available type specimens deposited at the Natural History Museum in London (NHM; *I. beddomii*, *I. brachytarsus*, *I. leithii*, *I. semipalmata*, *I. diplosticta*, *I. leptodactyla* and *I. phrynoderma*), and the National Museum of Natural History in Paris (MNHN; *I. gundia*). In addition, we also examined specimens deposited at the Bombay Natural History Museum (BNHS), the Zoological Survey of India in Calicut (ZSI, Western Ghats Regional Centre), in order to understand how many species are recognized, and on what grounds. Information regarding the ecology, breeding biology and life history was also assimilated from the literature and from our own field studies.

Biogeography

Although some distribution maps of different *Indirana* species have been published (e.g. Stuart *et al*. 2008), it is unclear how accurate those maps are, as information is typically not given about the data upon which these maps are based. In order to gain a visual overview of the distribution of different *Indirana* species, we used a dual strategy. First, we looked for records of *Indirana* species in the literature and noted the localities as accurately as they were given. The localities of the frogs mentioned in the literature typically lack precision, and often describe only a region as opposed to a precise locality. The imprecision of the locality information has also been discussed by other authors (e.g. Biju 2001). For the purposes of this review, we created a grid of 50 × 50 km squares covering the Western Ghats (Fig. 1a), and placed the locality markers within the most appropriate squares. The original data underlying these assignments are given in Appendix 1, and the localities from which the type specimens deposited in NHM and MNHN (verified by us) originated, as well as those of other verified specimens from other museums (BNHS and ZSI) are marked onto the maps (*see* Fig. 1). Second, in 2008–2011 we conducted field surveys (mostly in May–September) in the states of Karnataka and Kerala of the southern Western Ghats, and recorded locations where *Indirana* species were found (Appendix 2). The data from these surveys were also marked on the maps (Fig. 1). Moreover, the localities which were surveyed, but no studied species were encountered were also recorded (Fig. 1). Although the fact that the species were not found does not prove that

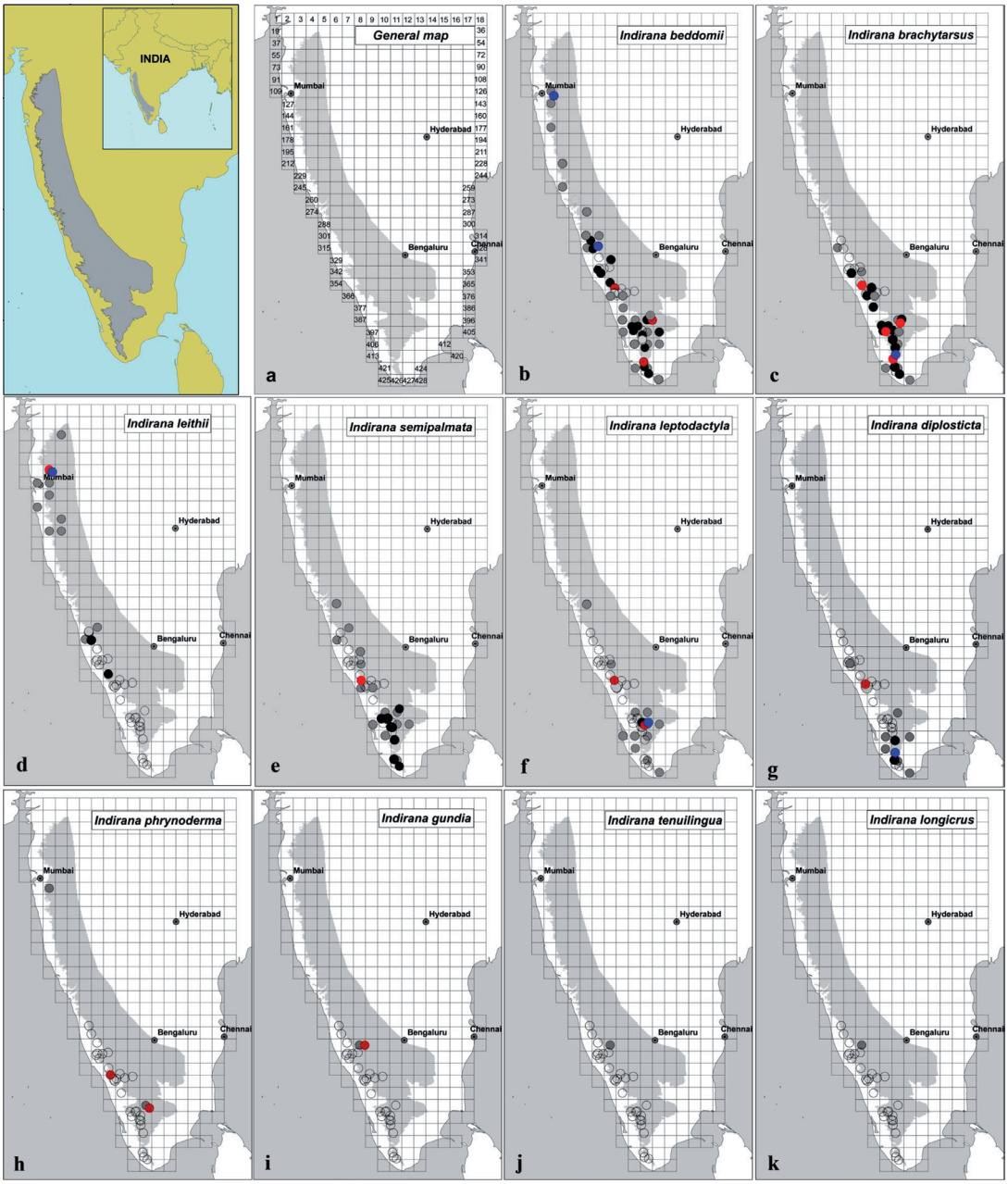

Fig. 1. The location and extent of the Western Ghats (top left), and distribution of *Indirana* species in the Western Ghats. Grey dots represent localities from literature surveys, black dots show sampling sites of our field surveys, and empty circles represent sites where species could not be observed in the field. Red and blue dots show the localities of the verified museum specimens (red = NHM, MNHN specimens; blue = BNHS, ZSI specimens, *see* Methods for abbreviations).

it does not exist in the given area, the information itself may be helpful for building up a broad picture about the occurrence of different species in India. Apart from marking the localities on the maps, we also summed the squares in which each species was encountered. This gave us a rough estimate of the known total distribution area of the species. These numbers should of course be

taken only as approximate species distribution areas.

Results and discussion

Current taxonomy and systematics of *Indirana* frogs

The *Indirana* frogs were intially included in the family Ranidae, and the first description of these frogs was provided by Günther (1876), who described them as ranid frogs in the genera *Polypedates* and *Ixalus*. In one of the earliest attempts to classify these frogs, Boulenger (1882) placed them in the genus *Rana* subgenus *Discodeles*, which also included some species from the Solomon Islands (Boulenger 1920). This subgenus was described based on characters including the presence of a horse-shoe shaped groove on the terminal discs of the toes or fingers, dividing them into upper and lower portions with the latter forming an adhesive pad, and the web between the toes not extending to the end of the outer metatarsals (Boulenger 1882, 1920). Most authors followed the same classification for over a century (Thurston 1888, Boulenger 1890, Inger *et al*. 1984, Daniel & Sekar 1989). However in subsequent revisions, the subgenus *Discodeles* was limited to endemic species from the Solomon Islands (Noble 1931), and a new genus, *Indirana*, was created in order to accommodate the species from southern India that were earlier placed in the subgenus *Discodeles* (Laurent 1986).

Dubois (1986) described a genus *Ranixalus*, which was characterised by the lack of intercalary bones or cartilages between the last phalanges of digits, possession of digital discs, the presence of a prominent papilla on the median part of the tongue, bilateral vocal sacs, nuptial pads and femoral glands on breeding males, and terrestrially developing tadpoles without fins that were found on wet rock cliffs. This genus initially had only one species, *Ranixalus gundia*, but later included frogs that were earlier described as *Discodeles* from southern India. He also described the tribe Ranixalini (Dubois 1987a), which included the genera *Nannophrys*, *Nyctibatrachus* and *Ranixalus*, based on the morphological similarity of *Nannophrys* and *Nyctibatrachu*s (Clarke 1981), and the similarity of the larval morphology between *Nannophrys* and *Ranixalus* — as both are semi-terrestrial (Kirtisinghe 1958). Later, the genus *Ranixalus* was considered to be synonymous with *Indirana* (Dubois 1987b), and the tribe Ranixalini was raised to the ranks of the subfamily Ranixalinae (Dubois 1992). In a subsequent classification, Blommers-Schlösser (1993) moved *Nannophrys* to the African Cacosterninae, and identified two new subfamilies, Nyctibatrachinae and Indiraninae.

The earlier classifications relied only on morphological data, but many studies have shown that identical phenotypes can be achieved by convergent evolution (e.g. Bossuyt & Milinkovitch 2000), and so such classifications can be misleading. For instance, *Nannophrys* and *Indirana* both have semi-terrestrial larvae that exhibit similar adaptive morphological features, such as a strongly developed tail with reduced fin membranes allowing them to hop long distances (Kirtisinghe 1958). These similarities had been the reason for these genera being grouped together within Ranixalinae (Dubois 1992), but studies using molecular data have revealed that these morphological features have evolved independently in Sri Lankan and Indian ranids (Bossuyt & Milinkovitch 2000). Therefore, it became necessary to incorporate changes in the earlier systematics in light of the evidence from molecular data suggesting that the many subclades within the family Ranidae might also merit family ranks (Vences & Glaw 2001).

The preliminary studies using molecular and karyological data revealed inconsistencies in the earlier classifications (Vences *et al*. 2000, Vences & Glaw 2001). The karyotypes of *Indirana* cf. *leptodactyla* (2n = 24) and another species *Indirana* sp. (2n = 24) deviate from the standard ranid karyological formula (2n = 26; Vences 2000), and *Indirana* have peculiar spermatozoa with a densely coiled head and thick tail, and both the total length and head length of the spermatozoa are nearly twice the size of those of some other ranid and rhacophorid species (Kuramoto & Joshy 2000, 2001a). These characters were early indications of the distinct phyletic lineage of the genus *Indirana* and their possible systematic misplacement. Vences *et al*.

(2000) study rejected the placement of *Nannophrys* in the African subfamily Cacosterninae, as well as its placement in the subfamily Ranixalinae. Instead, Vences *et al*. (2000) placed *Euphlyctis* (Dicroglossinae) as the sister group to Ranixalinae, which was supported by later genetic studies (Roelants *et al*. 2004). Later, Frost *et al*. (2006) reported the genus *Indirana* to be deeply imbedded in an African clade which was composed of *Conraua*, *Arthroleptides* and *Petropedetes*. Together, these were considered to be a family Petropedetidae.

Frost *et al*. (2006) pointed out the morphological similarities between *Arthroleptides* and *Indirana* larvae, which share features such as elongated tails with low caudal fins, large bulging eyes, a dorsoventrally flattened body and a laterally compressed jaw sheath with prominent lateral processes. Also, the larvae of *Petropedetes* show morphological peculiarities similar to *Arthroleptides* and *Indirana* (Frost *et al*. 2006). The adult males of *Arthroleptides*, *Indirana* and *Petropedetes* share the presence of femoral glands of variable size and the presence of spicules around the margins of the jaw and/or chin and pectoral area. They also suggested that the T-shaped terminal phalanges of *Petropedetes* and *Arthroleptides* could be synapomorphic with Y-shaped terminal phalanges (Laurent 1986) of *Indirana*. These results were inconsistent with earlier studies, as Frost *et al*. (2006) had placed *Indirana* within an African clade, whereas *Indirana* was suggested to have a sister taxon within India (Roelants *et al*. 2004, Van der Meijden *et al*. 2005).

The reliability of this has been doubtful, as it has come under severe criticism on methodological grounds, in particular due to the use of only larval characters as diagnostic traits (Weins 2007). Weins *et al*. (2009) later suggested Ceratobatrachidae (their "Ceratobrachinae") to be a sister taxa to *Indirana*, but the phylogenetic tree presented is not supported by strong bootstrap values. Although the study by Van der Meijden *et al*. (2005) indicated *Indirana* to be weakly associated as a sister taxon of Dicroglossinae, the most comprehensive work on the systematic positions of Indian endemic genera, including *Indirana*, *Micrixalus* and *Nyctibatrachus*, has been done by Roelants *et al*. (2004). Molecular dating estimates on 14 species of Ranidae *sensu lato* indicated that several lineages originated on the Indian subcontinent during its trans-Tethys drift (Bossuyt & Milinkovitch 2001).

The Indian subcontinent detached from Africa (Krause *et al*. 1999) to form the Madagascar–Seychelles–India block, and later it drifted northwards across the Tethys Sea, disconnecting from Madagascar and the Seychelles (Courtillot *et al*. 1988, Storey *et al*. 1995). The study by Roelants *et al*. (2004) indicated that four genera endemic to India (*Indirana*, *Micrixalus* and *Nyctibatrachus*) and Sri Lanka (*Lankanectes*) had diverged prior to the origin of several of the largest recognised subfamilies in Ranidae, and called for a revision of their generic status. Their analysis indicated that the endemic genera *Indirana*, *Micrixalus*, *Nyctibatrachus*, and *Lankanectes* each represents small relict clades that are remnants of a once much more diverse and widespread anuran fauna. The genus *Micrixalus* was placed as a sister taxon to *Indirana*, which is in agreement with deductions made by earlier authors, considering their morphological similarities (Inger & Dutta 1986). The subsequent studies have also supported the Indian endemic clade composed of the genera *Indirana* and *Micrixalus* (Bossuyt *et al*. 2006, Bossuyt & Roelants 2009), raising the Indian endemics to family rank: namely Ranixalidae, Micrixalidae, and Nytibatrachidae, and rejecting the nested position of *Indirana* within African clades (Bocxlaer *et al*. 2006).

Ranixalidae is now considered an endemic family of frogs in the Western Ghats biodiversity hotspot, and as it is presently known, it comprises one genera (*Indirana*) with ten species (Vitt & Caldwell 2009).

Description of species in the genus *Indirana*

Although the systematic position of the family Ranixalidae has been clarified by recent studies, the taxonomic status of the species within the genus *Indirana* is poorly known. This is also apparent from the fact that none of the studies on the systematic positioning of the genus *Indirana* have included species names (e.g., Roelants *et*

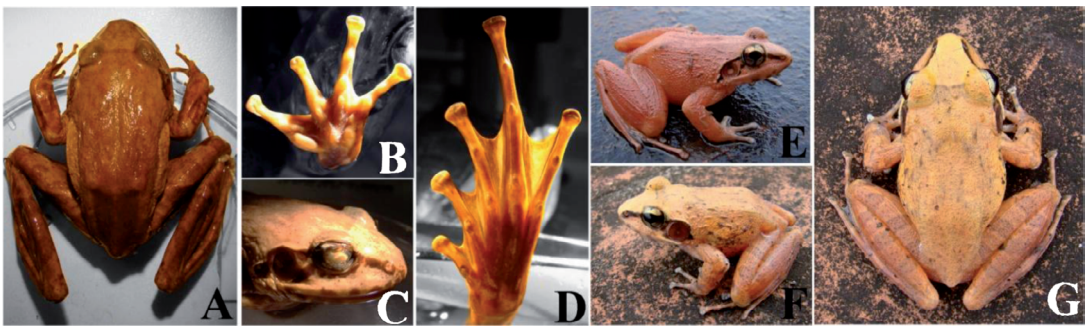

Fig. 2. *Indirana beddomii*. — **A**: dorsal view; — **B**: ventral aspects of left hand; — **C**: lateral view showing tympanum; — **D**: ventral aspects of left foot; — **E**: lateral view of adult female; — **F** and **G**: lateral and dorsal views of an adult male. (Photos: Sujith V. Gopalan).

al. 2004, Bocxlaer *et al*. 2006). Ten species are assigned to the genus *Indirana* (Table 1), but many species within the genus are data deficient, and holotypes for some species have also been lost (Biju 2001). In some cases (e.g. Dubois 1986), relevant comparisons have not been made among the type specimens before the designation of new species. The species that are currently known within the genus *Indirana* are in need of revision, as in many cases they could be composed of several species (Biju 2001). The use of morphological descriptions of species within the genus *Indirana* is an unreliable method of delimiting species, as the type specimens of many species were described on the basis of single specimens (Biju 2001). The intraspecific variation within the currently defined *Indirana* species could be large, and descriptions based on a single or a few individuals, or on individuals from single localities, may not be sufficient. Although a taxonomic key to field identification has been made available for some of the species (Daniel & Sekar 1989), there are still many taxonomic ambiguities and misidentifications reported (Boulenger 1920, Abdulali & Daniel 1954, Inger *et al*. 1984). Hereby, we provide the details of morphology, habits, distribution and conservation status of the species within this genus.

Indirana beddomii

Common names: Beddome's frog (Das & Dutta 1998), Beddome's Indian frog (Frank & Ramus 1995), Beddome's leaping frog (Daniels 2005).

Appearance (Fig. 2)

Medium sized frogs with adult snout-vent length (SVL) of 45.1–60.1 mm (n = 9) for females and 35.4–49.5 mm (n = 12) for males (Inger *et al*. 1984). The skin is smooth or covered with fine granulations on the dorsal side with short longitudinal glandular folds. The dorsal granulations are more pronounced around the anus and around the angle of the jaw. Ventrally, the skin is smooth with a granular area on the thighs near the anus (Inger *et al*. 1984). The inter-orbital space is as broad as the upper eyelid and the tibio-tarsal articulation reaches the tip of the snout or extends a little beyond it (Daniel & Sekar 1989). The first finger is at least as long as the second with the tips of the fingers and toes dilated into discs (Satyamurti 1967, Inger *et al*. 1984, Daniel & Sekar 1989). Males are described to have a tympanum at least as large as the eye, while that of females is at least two-thirds of the diameter of the eye, and both sexes possess a strong supra tympanic fold from the eye to the shoulder (Inger *et al*. 1984). Inger *et al*. (1984) described the toe webbing as extending to the disk on the fifth toe and on the lateral sides of toes 1, 2, and 3. Medially, webbing is said to extend to the distal subarticular tubercle on the second toe, and midway between the first and second tubercles on the third toe (Inger *et al*. 1984). The fourth toe is webbed to the second subarticular tubercle on both sides and the subarticular tubercles are well developed (Inger *et al*. 1984). The colouration is variable, with dark brown above, or with a pinkish-tan

background with an irregular speckling of dark brown. In some individuals, a pale vertebral stripe is present. A black streak along the supratympanic fold from the eye to the shoulder extends forwards up to the nostril. The lips, front and hind limbs are described to be faintly barred with dark brown. Ventrally, the colour is white with brown reticulations present on the throat and the sides of the body; the underside of the legs is described as an immaculate yellow-white (Inger *et al*. 1984).

Indirana beddomi is now believed to be a species complex consisting of more than one species, but further studies are required to validate the species status (Nair *et al*. 2012a, 2012b).

In general, sex- and age-dependent, as well as geographic variation in morphology and colouration, remain to be studied in detail. All current descriptions of the phenotypic variability are based on the examination of limited material (e.g. Boulenger 1920: $n = 13$, Inger *et al*. 1984: $n = 9–12$). The call and the sperm morphology have been described (e.g. Kadadevaru *et al*. 2000, Kuramoto & Joshy 2001a). However, nothing is known about the longevity or dispersal of these frogs.

Habits

Little known. This is a ground-dwelling species which lives on forest floors, typically among rocks close to streams and wet habitats, but it is also found among grass and dead leaves in various types of forests. Adults are agile and make fast erratic leaps when disturbed. Semi-terrestrial tadpoles live on wet rock surfaces, and possess an extremely long tail (3× body length), which is used to give thrust for skittering jumps (Veeranagoudar *et al*. 2009). Their eggs are laid in shallow (< 2 cm) pools away from streams (Veeranagoudar *et al*. 2009).

Distribution

This species is known to be widely distributed: from the Maharashtra state to the southern end of the Indian peninsula (Fig. 1b), and it is found from the sea level to 1800 m a.s.l. (Daniels 2005).

In our own surveys, we encounterd *I. beddomii* from an elevation of 51 m a.s.l. (Thattekad bird sanctuary, Idukki, Kerala 10°07´33´´N, 76°41´56´´E) to an elevation of 969 m a.s.l. (Malakapara, Thrissur, Kerala 10°17´06´´N, 76°52´17´´E). The distribution depicted in Fig. 1a should be seen as the distribution of the species complex because of the taxonomic uncertainties (Biju *et al*. 2004f, Nair *et al*. 2012a).

Conservation status

Indirana beddomii is probably the most common of the *Indirana* species; it is currently classified as 'Least Concern' in the IUCN Red list of threatened species (www.iucnredlist.org). This classification is based on its wide distribution and presumed large populations, which both are unlikely to decline fast enough to qualify it for consideration under the 'Threatened' category (Biju *et al*. 2004f). However, this view might be in need of a revision if *I. beddomii* appears to be a species complex (Biju *et al*. 2004f, Nair *et al*. 2012a).

Indirana brachytarsus

Common names: Anamallais Indian frog (Frank & Ramus 1995), leaf-hopper frog (Das & Dutta 1998), short-legged frog (Reddy *et al*. 2002), short-legged leaping frog (Daniels 2005).

Appearance (Fig. 3)

Inger *et al*. (1984) described them as small-sized frogs with SVLs of adult females and males being 28.6–44.7 and 25.1–33.7 mm, respectively; however, one of the adult female specimen studied by us had SVL of 58 mm. The skin on the dorsal surface has a series of longitudinal folds, which reach the densest concentration on the anterior part of the back. Ventrally, the skin is smooth, except for a granular patch near the anus. Fingers and toes are dilated into discs, and the discs of the toes and subarticular tubercles are less developed than in *I. beddomii*. The tympanum is two-thirds of the diameter of the eye in both males and females, with a supra tympanic fold from the eye to the shoulder (Inger *et al*.

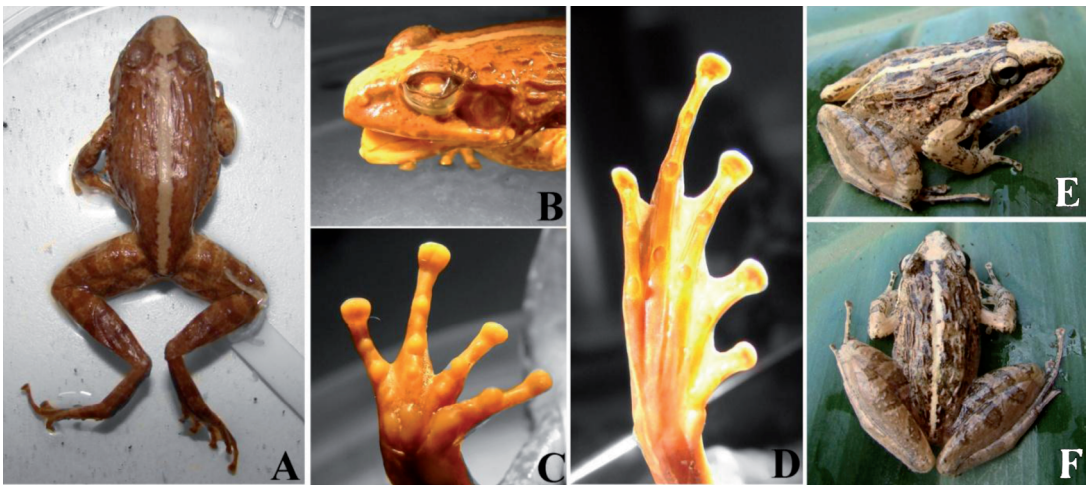

Fig. 3. *Indirana brachytarsus*. — **A**: dorsal view; — **B**: lateral view showing tympanum; — **C**: ventral aspects of right hand; — **D**: ventral aspects of right hindleg foot; — **E** and **F**: lateral and dorsal views of an adult female. (Photos: Sujith V. Gopalan).

1984). Inger *et al*. (1984) describes the toe webbing as extending to the disk on the fifth toe, and on the lateral sides of toes 1, 2 and 3. Medially, the webbing extends to the distal subarticular tubercle of the third toe, and to between the middle and the distal subarticular tubercles of the fourth toe (Inger *et al*. 1984). Typical *I. brachytarsus* individuals have tan coloured backs with a variable number of short, longitudinal brown streaks. However, some individuals are nearly completely brown, and some have a white mid-dorsal stripe extending from the eyes to the vent (Inger *et al*. 1984). A black stripe follows along the supratympanic fold from the eye to the shoulder, extending forwards up to the nostril. The lips and limbs are barred with dark brown. Ventrally, the colour is white, occasionally with a few brown spots on the throat. The undersides of the legs are yellow (Inger *et al*. 1984).

Inger *et al*. (1984) noted that *I. brachytarsus* closely resembles *I. beddomii*, and is distinguishable from it on the basis of toe webbing, colouration, dorsal skin folds, tympanic size and density of spicules in males.

Habits

Little known. This is a ground-dwelling species that is found in semi-evergreen and evergreen tropical forests that are close to hill streams. Their habits are apparently similar to those of *I. beddomii*, but they are less dependent on the proximity of water (Daniels 2005). The larvae live on wet rock surfaces close to streams (Biju *et al*. 2004a). Inger *et al*. (1987) found that *I. beddomii* and *I. brachytarsus* differ in their niche breadth, and there is little niche overlap between them as they also prefer different microhabitats.

Distribution

This species is known only from the southern Western Ghats from the states of Kerala, Tamil Nadu and Karnataka (Fig. 1c). They are found at an altitudinal range of 800–1200 m a.s.l. (Biju *et al*. 2004a, Daniels 2005). In our own surverys, we encountered *I. brachytarsus* from an elevation of 51 m a.s.l. (Thattekad bird sanctuary, Idukki, Kerala 10°07´33´´N, 76°41´56´´E) to an elevation of 1012 m a.s.l. (Sholayar Dam, Thrissur, Kerala 10°18´24´´N, 76°53´11´´E).

Conservation status

Although this species is locally common, it is currently classified as ‘Endangered’ (www.iucnredlist.org, Biju *et al*. 2004a) as its range is less

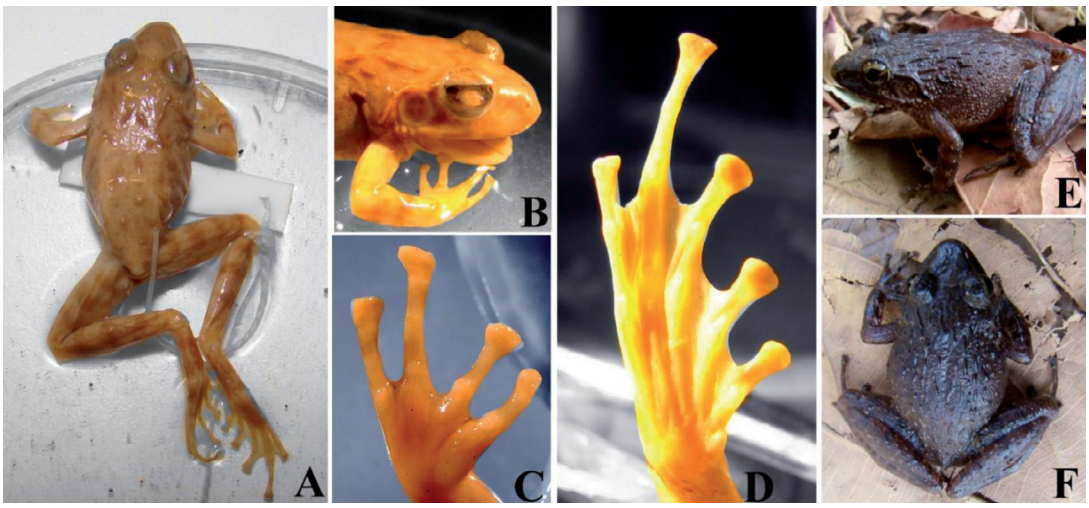

Fig. 4. *Indirana leithii*. — **A**: dorsal view; — **B**: lateral view showing tympanum; — **C**: ventral aspects of right hand; — **D**: ventral aspects of right foot; — **E** and **F**: lateral and dorsal views of an adult female specimen. (Photos: Sujith V. Gopalan).

than 5000 km^2, its distribution is severely fragmented, and the extent and quality of its habitat is declining. The major threat is thought to be the loss of forest due to habitat conversion to agricultural land (Biju *et al*. 2004a).

Indirana leithii

Common names: Matheran Indian frog (Frank & Ramus 1995), Leith's frog (Das & Dutta 1998), Boulenger's brown frog (Chanda 2002), Leith's leaping frog (Daniels 2005).

Appearance (Fig. 4)

Small sized frogs, with SVL of 32–38 mm (Daniels 2005). The skin on the back has small scattered longitudinal warts, but it is ventrally smooth. A strong glandular fold from the eye to the shoulder is present. The fingers and toes are dilated into discs, with the first finger being shorter than the second. The inter-orbital width is narrower than the upper eyelid, and the tibio tarsal articulation reaches between the eye and the tip of the snout. The tympanum is two-thirds of the diameter of the eye, with a supratympanic fold extending from the eye to the shoulder. The toes are two-thirds webbed, with subarticular tubercles that are moderately developed (Boulenger 1920, Daniel & Sekar 1989). They are brown with small, dark spots on the dorsal surface, and ventrally white with brown spots on the throat. The lips and limbs are barred with dark transverse bands (Daniel & Sekar 1989). Some individuals were reported as being dark grey, blackish, or paler, and some were reported as having golden patches (Abdulali & Daniel 1954).

Indirana leithii appears to be closely related to *I. beddomii* with respect to many taxonomic features, but differs from *I. beddomii* in having a second finger of palm longer than the first finger, whereas in *I. beddomii* the first finger is at least as long as the second. We have also noticed that toe webbing of *I. leithii* appears to be more extensive than that of *I. beddomii*.

Habits

Little known. This is a ground dwelling species which lives among ground litter, short grass and ditches on hill sides (Daniel & Sekar 1989), in moist tropical semi-evergreen forests (Biju *et al*. 2004e). The tadpoles are found on rock banks wetted by spray from hill-streams (Daniel & Shull 1964). The tadpoles are very agile, and use their long tail (2.5× body length; Daniel & Sekar 1989) for jumping. Sekar (1992) described *I.*

leithii tadpoles jumping off rocks down to water pools a distance of 2 m, and climbing back after a few minutes.

Distribution

This species is known from the state of Maharashtra located in the northern parts of the Western Ghats (Fig. 1d), and it occurs at an altitudinal range of 400–1200 m a.s.l. (Biju *et al*. 2004e). Occurrence of the species is believed to range from Surat Dangs, Gujarat to Central Kerala (Daniel & Sekar 1989, Daniels 2005). *Indirana leithii* is also reported from Madhya Pradesh (Chandra & Gajbe 2005) and from the Nallamala hills in Andhra Pradesh (Srinivasulu & Srinivasulu 2008; Srinivasulu & Das 2008). These reports of *I. leithii* from outside the Western Ghats need further validation as they could be the result of possible misidentifications. Biju *et al*. (2004e) proposed that observations of *I. leithii* outside the state of Maharashtra could in fact refer to another species requiring taxonomic verification. We have verified occurrence of *I. leithii* from an elevation of about 734 m a.s.l. (Kottencheri, Kasargode, Kerala 12°28´58´´N, 75°24´34´´E) to 859 m a.s.l. (Kudremukh National Park, Shimoga, Karnataka 13°13´07´´N, 75°10´59´´E).

Conservation status

Although locally common (Biju *et al*. 2004e), this species is currently classified as 'Vulnerable' (www.iucnredlist.org). This classification is based on the fact that the distribution is less than 20 000 km^2, and there is a decline in the extent and quality of its forest habitats. The major threats include the conversion of habitat into agricultural land (Biju *et al*. 2004e).

Indirana semipalmata

Common names: South Indian frog (Frank & Ramus 1995), Small-handed frog (Das & Dutta 1998), Brown leaping frog (Daniels 2005).

Appearance (Figs. 5 and 6)

Small sized frogs with SVL of 32–35.5 mm for females and 27.4–29.3 mm for the males (Inger *et al*. 1984). The skin on the back has short longitudinal folds, the sides are granulate with small warts, and the ventral surface is smooth. The inter-orbital width is as broad as the upper eyelid, or a little narrower. The tibio-tarsal articulation reaches the tip of the snout, or between the eye and the snout. The fingers and toes are dilated into discs with first finger being a little longer than the second (Daniel & Sekar 1989). The tympanum is equal in width to the diameter of the eye with supratympanic folds extending from the eye to the shoulder. The toes are half webbed with well developed subarticular tubercles (Daniel & Sekar 1989). Inger *et al*. (1984) described the webbing as extending to the distal subarticular tubercle on the fifth toe, on the lateral side of the third, and midway between the proximal and the second subarticular tubercle on the fourth toe. The colour is dorsally tan or light brown (Inger *et al*. 1984), with the loreal and temporal regions blackish in colour (Daniel & Sekar 1989). The limbs are cross-barred with dark bands, and the canthal stripe is absent. The ventral lower side is white, with the throat and breast mottled with brown (Daniel & Sekar 1989).

Inger *et al*. (1984) describes *I. semipalmata* to be similar in appearance to *I. brachytarsus* but can be distinguished from it on basis of less webbing and the larger size of the tympanum. The males of *I. beddomii* are known to have tympanum as large as the eye, similar to that of *I. semipalmata* (Inger *et al*. 1984), leading to a risk of misidentification in the field. Therefore, webbing of the toes should be the key identification feature of *I. semipalmata* rather than tympanum size (Gopalan *et al*. 2012).

Habits

Little known. This species is found in evergreen and moist deciduous forests, close to streams, in the forest among dead leaves, and on rocks. Males are reported to have a large vocal sac below the throat and produce a call that resem-

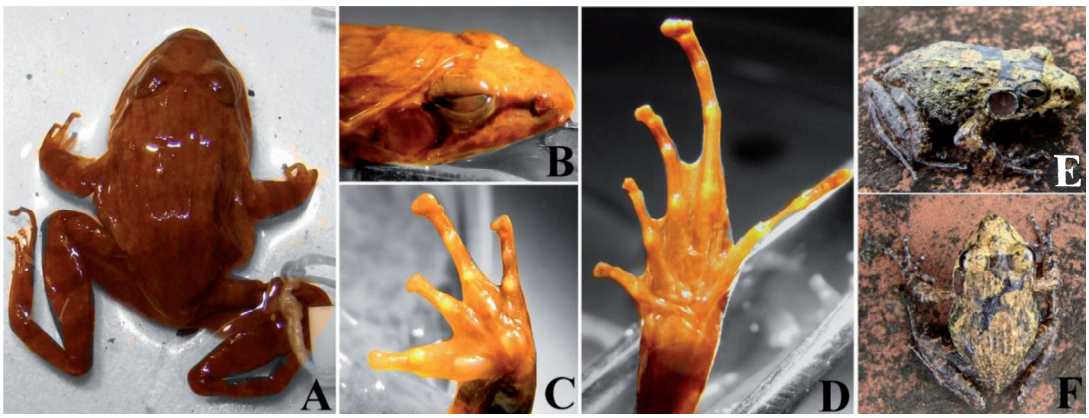

Fig. 5. *Indirana semipalmata*. — **A**: dorsal view; — **B**: lateral view showing tympanum; — **C**: ventral aspects of left hand; — **D**: ventral aspects of left foot; — **E** and **F**: lateral and dorsal views of an adult male. (Photos: Sujith V. Gopalan).

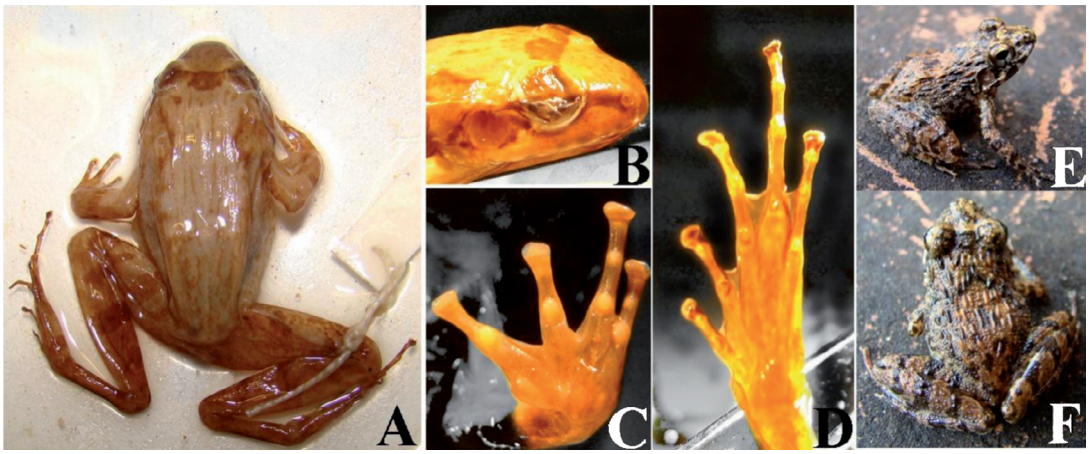

Fig. 6. *Indirana semipalmata*. — **A**: dorsal view; — **B**: lateral view showing tympanum; — **C**: ventral aspects of left hand; — **D**: ventral aspects of left foot; — **E** and **F**: lateral and dorsal views of an adult female. (Photos: Sujith V. Gopalan).

bles rapid drumming of fingernails on a thin tin plate (Fischer 1915).

Distribution

This species has a wide distribution in the southern Western Ghats (Fig. 1e), and it is found at an altitudinal range of 200–1100 m a.s.l. (Biju *et al*. 2004b). However, Daniels (2005) reported an altitudinal range up to 2000 m. We have encountered *I. semipalmata* individuals from an elevation of 78 m a.s.l. (Athirapalli, Thrissur, Kerala, 10°17´34´´N, 76°33´54´´E) to 1003 m a.s.l. (Kochupamba, Idukki, Kerala 9°25´14´´N 77°09´36´´E).

Conservation status

This species has been classified as ‘Least concern’. Although the extent of its occurrence is probably less than 20 000 km^2, it is common and unlikely to be declining fast enough to be considered under the ‘Threatened’ category (www.iucnredlist.org).

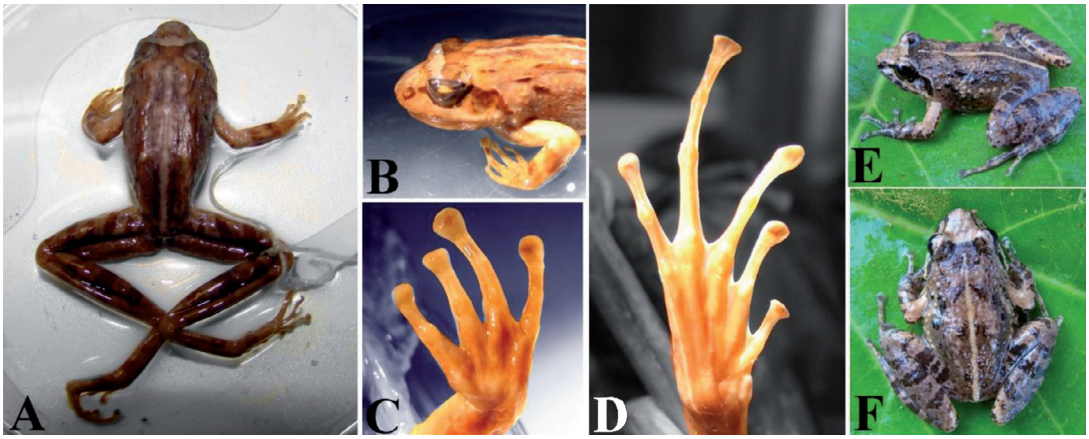

Fig. 7. *Indirana leptodactyla*. — **A**: dorsal view; — **B**: lateral view showing tympanum; — **C**: ventral aspects of left hand; — **D**: ventral aspects of right foot; — **E** and **F**: lateral and dorsal views of an adult female. (Photos: Sujith V. Gopalan).

Indirana leptodactyla

Common names: Boulenger's Indian frog (Frank & Ramus 1995), long-toed frog (Das & Dutta 1998), thin-limbed frog (Chanda 2002).

Appearance (Figs. 7 and 8)

Small sized frog with SVL of 30–45 mm for females and about 33 mm for males (Boulenger 1920). The skin of the back has short longitudinal folds, whilst the sides are granulate with flat warts. The interorbital width is as broad as, or a little narrower than the upper eyelid, and the tibio-tarsal articulation reaches the tip of the snout or beyond (Daniel & Sekar 1989). The fingers and toes are dilated into discs with the first finger shorter than the second. The tympanum is two-thirds of the diameter of the eye, and a supratympanic fold is present from the eye to the shoulder. The toes are one-fourth webbed (Daniel & Sekar 1989), and the subarticular tubercles are weakly developed (Boulenger 1920). The colouration is variable, the typical 'brown morph' (Fig. 8A and B) being olive or brownish dorsally, uniformly white or spotted with brown (or sometimes brown dotted with white) ventrally (Daniel & Sekar 1989). The other color morphs are a 'striped morph' which resembles the 'brown morph' but has white ventral stripe extending from head to anus (Fig. 8E and F), and the 'yellow-backed' morph whose head and back are yellow (Fig. 8C and D). In our unpublished genetic studies, the color morphs were verified as *I. leptodactyla* using DNA barcoding methods.

Boulenger (1882) had suggested that this species may be conspecific with *I. diplosticta*, but later treated them as separate species (Inger *et al*. 1984, Daniel & Sekar 1989). The species is larger (SVL > 36 mm, $n = 4$) than *I. diplosticta* (SVL < 30 mm, $n = 3$). Futhermore, *I. leptodactyla* has relatively slender and long forelimbs, hindlimbs, fingers and toes compared to *I. diplosticta*.

Habits

Mostly unknown. Rao (1920) reported that large eggs (4.5 mm in diameter) are laid in small clumps — typically less than 30 eggs per clump — in grassy margins of ponds. In our field work, this species was encountered in rocky-stream habitats and forest floors adjoining streams. They appear to rest underneath rocks at midday, and are more active on the forest floor at night.

Distribution

This species has been recorded from the states of Kerala, Tamil Nadu and Karnataka (Daniel & Sekar 1989). It occurs in forests at

Fig. 8. Dorsal and lateral views of colour morphs of *I. leptodactyla*. — **A** and **B**: brown morph; — **C** and **D**: yellow-backed morph; – **E** and **F**: striped morph. (Photos: Sujith V. Gopalan).

elevations above 800 m a.s.l. (Biju & Dutta 2004), and its current known distribution is shown in Fig. 1f. We observed this species from elevations of approximately 1835 m a.s.l. (10°09´02´´N, 77°01´45´´E) to an altitude of 1903 m (10°08´39´´N, 77°02´17´´E) at Eravikulaum National Park, Idukki, Kerala.

Conservation status

This species is locally uncommon (Biju & Dutta 2004) and is currently classified as 'Endangered' (www.iucnredlist.org), as its range is less than 5000 km^2 and the area of suitable habitat is also declining. The major threat is habitat conversion to agricultural land.

Indirana diplosticta

Common names: Malabar Indian frog (Frank & Ramus 1995), Rufous leaf-hopper frog (Das & Dutta 1998), Günther's frog (Chanda 2002), spotted leaping frog (Daniels 2005).

Appearance (Fig. 9)

Small sized frogs with SVL of 23.6–25.2 mm for females and about 20 mm for males (Inger *et al*. 1984). The skin on the back has a series of longitudinal folds whilst the head, sides and ventral side are all smooth. The fingers and toes are dilated into enlarged discs with the first finger shorter than the second, and the tibiotarsal articulation reaches the tip of the snout or extends beyond it (Boulenger 1920). The tympanum is well developed and it is about half the diameter of the eye (Daniel & Sekar 1989). A strong, curved supratympanic fold extends from the eye to the shoulder. The toes are less than one-fourth webbed, and the webbing extends to the proximal subarticular tubercle on medial side of third and fourth toes (Inger *et al*. 1984, Daniel & Sekar 1989). The colour is reddish-brown dorsally with a black canthal and tympanic streak. Dark brown blotches may be present on the lateral surfaces. Ventrally, the colour is light brown diffused with a fine reticulated pattern of dark brown. The limbs are cross barred with dark brown. There are large black spots on either sides of the waist and on the lateral surfaces (Inger *et al*. 1984, Daniel & Sekar 1989). This species closely resembles *I. leptodactyla* in morphology.

Habits

Little known. This is a terrestrial species that is found on the forest floor of wet, evergreen

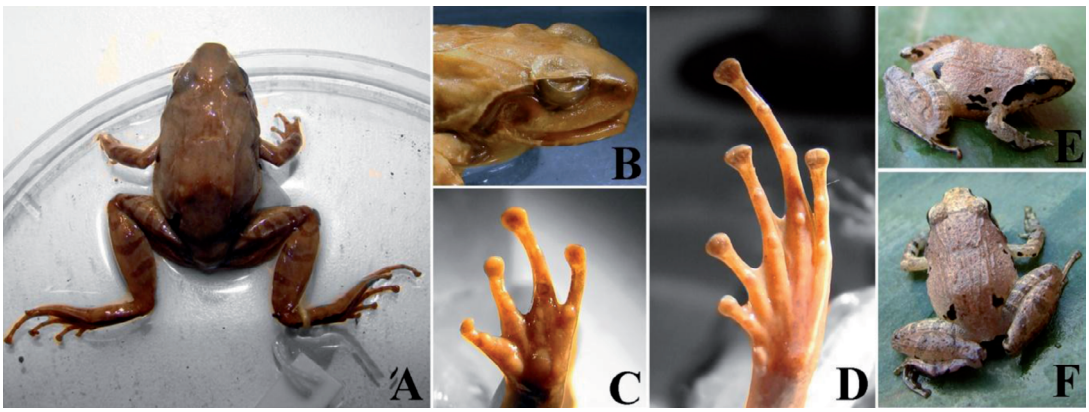

Fig. 9. *Indirana diplosticta*. — **A**: dorsal view; — **B**: lateral view showing tympanum; — **C**: ventral aspects of left hand; — **D**: ventral aspects of left foot; — **E** and **F**: lateral and dorsal views of a subadult specimen. (Photos: Sujith V. Gopalan).

and semi-evergreen forests. This species has not been found in degraded forests (Biju *et al*. 2004d). The larvae live on wet rock surfaces (Biju *et al*. 2004d). We observed this species to breed during the second monsoon showers in August and September, whereas other species from *Indirana* typically breed and lay eggs during the first showers of rain in early July.

Distribution

This species is known from the southern Western Ghats from the states of Kerala and Tamil Nadu (Fig. 1g). It has an altitudinal range of 600–1000 m a.s.l. (Biju *et al*. 2004d). We encountered the species from an altitude of 851 m a.s.l. (Ponmudi, Thiruvananthapuram, Kerala 8°45´16´´N, 77°08´33´´E) to 1003 m a.s.l. (Kochupamba, Idukki, Kerala 9°25´14´´N, 77°09´36´´E).

Conservation status

This species is locally uncommon and the populations are believed to be declining (Biju *et al*. 2004d). It is currently classified as 'Endangered' (www.iucnredlist.org), as the range is less than 5000 km^2. The major threat is habitat conversion to agricultural land.

Indirana phrynoderma

Common names: Kerala Indian frog (Frank & Ramus 1995), toad-skinned frog (Das & Dutta 1998).

Appearance (Fig. 10)

Small sized frogs with SVL of about 30 mm (Daniel & Sekar 1989). The skin on the back is covered with warts of different sizes, as well as short glandular folds. The fingers and toes are dilated into enlarged discs with the first finger shorter than the second, and the tibio-tarsal articulation reaches the tip of the snout or extends a little beyond it (Boulenger 1920). The tympanum is moderately distinct and described to be three-fifths of the diameter of the eye (Boulenger 1920). A strong glandular fold extends from the eye to the shoulder. The toe webbing is rudimentary and the subarticular tubercles are small and not prominent. The dorsal colour is dark greyish brown with obsolete dark spots, and the lower flanks are brown dotted with white (Boulenger 1920). The limbs are barred with dark crossbars. *I. phrynoderma* can be distinguished from other known congeners of the genus by having very little or no webbing between the toes. These frogs have a toad-like appearance with an irregular distribution of minute granules all over the body (Fig. 10).

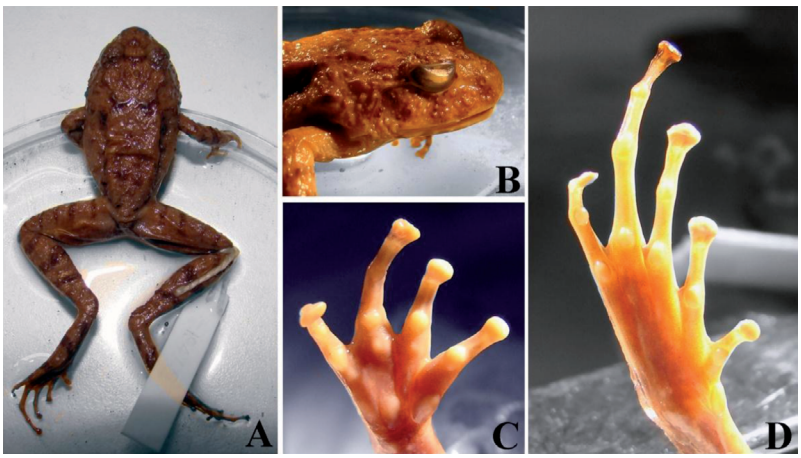

Fig. 10. *Indirana phrynoderma*. — **A**: dorsal view; — **B**: lateral view showing tympanum; — **C**: ventral aspects of right hand; — **D**: ventral aspects of right foot.

Habits

Mostly unknown. This is a ground-dwelling species which lives on the forest floor, with larvae living on wet rock surfaces (Biju *et al*. 2004g).

Distribution

This species is reported from a restricted area in the Anamalai hills in the state of Kerala and Tamil Nadu at an elevation of around 500 m a.s.l. (Biju *et al*. 2004g). This species has also been reported from the northern Western Ghats from the state of Maharashtra (Padhye & Ghate 2002). Its current known distribution is shown in Fig. 1h.

Conservation status

This species is very rare, and now it is known to be declining at the only known site of occurrence (Biju *et al*. 2004g). This species is currently classified as 'Critically Endangered' (www.iucnredlist.org) as its range is less than 100 km^2, and it has only been found at a single location in the Indira Gandhi National Park (www.iucnredlist.org). The major threat is believed to be habitat loss (Biju *et al*. 2004g).

Indirana gundia

Common names: Gundia Indian frog (Frank & Ramus 1995), Gundia frog (Das & Dutta 1998), Dubois's frog (Chanda, 2002).

Appearance (Fig. 11)

Based on the studied specimens, these are small frogs with male 30 mm and females from 32–33 mm in SVL. The mature adult male we examined had an enlarged tympanum, nuptial pads, and femoral glands beneath the thigh, but without visibly distinct vocal sacs. There is a discontinuous black canthal streak from the tympanum to the nostril. The tympanum is not coloured. The interorbital space bears two thick brownish bands. The legs and arms are cross-barred with brown stripes. There are longitudinal folds on the dorsal side of the body, but the ventral side is smooth. There is an inverted W-shaped marking on the dorsal side of the body. On the lateral view, the body bears black spots ventrolaterally which extends up to the shoulders. The tips of the fingers and the digits of the toes bear discs with circum marginal grooves. The tongue bears lingual papillae. Two studied museum specimens — subadults with SVLs of 24.3 mm and 25.7 mm, respectively — had a white mid-dorsal stripe. Of the five studied museum specimens of adult females, two carried pigmented ovaries, which were visible through the partially transparent, lateral body wall. The museum specimen of male had a bigger (4.2 mm) tympanum as compared with the females (n = 5, mean = 3.8 mm), and the tympanum/eye-width ratio was greater

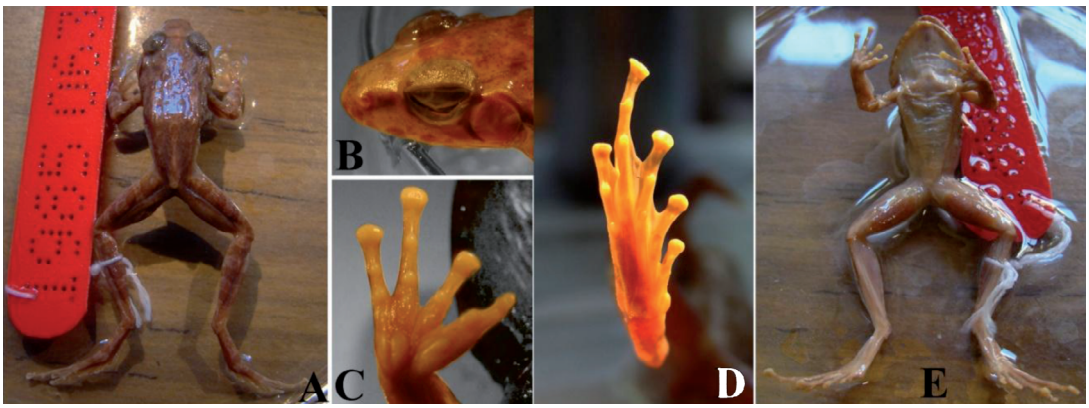

Fig. 11. *Indirana gundia*. — **A**: dorsal view; — **B**: lateral view showing tympanum; — **C**: ventral aspects of right hand; — **D**: ventral aspects of right foot; — **E**: ventral view.

in the male (0.8 mm) than in the females (mean = 0.7 mm). The webbing of *I. gundia* is similar to that of *I. brachytarsus*, extending to the disk on the fifth toe, and on the lateral sides of toes 1, 2 and 3. Medially, the webbing extends to the distal subarticular tubercle of the third toe, and in between the middle and the distal subarticular tubercles of the fourth toe. Yet another museum specimen of a female had less extensive webbing as compared with the male. In this specimen, the webbing of the third to fourth toe extended only up to penultimate subarticular tubercle. The connection of webbing between second and third toe extended only to midway between the penultimate and distal subarticular tubercles.

This species was described under the genus *Ranixalus* which had similarities to the genus *Indirana* (Laurent 1986); the former was later considered to be a synonym of the latter (Dubois 1987b). The description of this species closely resembles the morphological characters of *I. brachytarsus* (Inger *et al*. 1984), and Dubois (1987b) suggested that they could possibly be conspecifics.

Habits

Mostly unknown. This is a terrestrial species which lives in moist tropical forests. The larvae presumably live on wet rock surfaces (Biju *et al*. 2004c), but Kuramoto and Dubois (2009) reported finding tadpoles in trees and under the bark.

Distribution

This species is known only from Kempholey, Sakleshpur in Karnataka (Fig. 1i). It has been found at an altitude of 200 m a.s.l. (Biju *et al*. 2004c).

Conservation status

There is no information about the population status of this species (Biju *et al*. 2004c). It is currently classified as 'Critically Endangered' (www.iucnredlist.org) as its range is less than 100 km^2, and it is known only from a single locality. The major threats include habitat loss due to intensive livestock production, wood harvesting, and road construction (Biju *et al*. 2004c).

Indirana tenuilingua

Common names: Rao's Indian frog (Frank & Ramus 1995), slender-tongued frog (Das & Dutta 1998).

Appearance

Small sized frogs with SVL of about 23 mm (Rao 1937). The skin on the back has cutaneous folds, and the throat, chest and ventral surface of the thighs are smooth, with the abdomen finely granulated (Chanda 2002). The fingers and toes are dilated into truncated discs with the first

finger as long as, or very slightly longer than the second. The tibio-tarsal articulation reaches up to the nostril, or even to the tip of snout. The tympanum is two-thirds the diameter of the eye. The toe-webbing extends to nearly three-fourths of the first phalanx of the fourth toe, and to the second phalanx of the fifth and third toes. The toes are short with truncated discs with indistinct circummarginal grooves. The subarticular tubercle is inconspicuous, and the inner metatarsal tubercles are poorly developed (Rao 1937). Rao (1937) described the colour as "pale brown above with darker sides. Upper surface of the snout white and a dark band from the tip of the snout extending through the loreal region, and below the eyes, surrounds the tympanum; a short dark band from the tympanum to the shoulder; lower jaw with dark and white longitudinal bars; fore arm and fingers and hind limbs barred; throat pale yellow; abdomen white and under surface of thighs reddish".

This species was described by Rao (1937) on the basis of a single specimen. He noted the T-shaped phalanges and placed it under *Rana* [*Discodeles*] *tenuilingua*, but later Laurent (1986) transferred it to the genus *Indirana*. The taxonomic status of this species remains uncertain. Habits of this species are unknown.

Distribution

This species is known only from Kempholey Ghats, Hassan, Mysore, Karnataka (Rao 1937; Fig. 1j). Extensive field surveys need to be carried out in order to validate the species status and to map the distribution.

Conservation status

This species is currently classified as 'Data Deficient' as its taxonomic validity is doubtful, and information on its range and ecological requirements are unknown (www.iucnredlist.org).

Indirana longicrus

Common names: Kempholey Indian frog (Dinesh *et al.* 2009), Kempholey bubble-nest frog (Frank & Ramus 1995), Rao's bush frog (Das & Dutta 1998).

Appearance

Small sized frog with SVL of about 20 mm (Rao 1937). The dorsal surface of the skin has faint folds, but the skin is smooth ventrally (Rao 1937). The fingers and tips of the toes are dilated into prominent discs, and the first finger is shorter than the second. The tympanum is distinct and is about half the diameter of the eye. The tibio-tarsal articulation reaches far beyond the tip of the snout. The toes are half webbed, the subarticular tubercles are fairly developed and a minute elongated inner metatarsal tubercle is present. The outer metatarsals are joined at the base (Rao 1937). The colouration was described by Rao (1937) as "Upper surface of snout pale grey — a dark band between the nostril and eye, over canthas rostralis. Loreal and suborbital region yellow, extending as far behind as the angles of the mouth. A brown mark over the supra-tympanic fold. Tympanum reddish in colour. Upper and lower jaw with dark vertical bands, the upper series terminating just below the middle of the eye. Inter-orbital space with a faint transverse band. Upper surface of the body olive brown. Lower surface of body and thighs white. Thighs with cross bars on the anterior border, the posterior border is minutely marbled. Tibium also barred anteriorly, but whitish posteriorly. A dark line stretching from heel to foot".

Based on a single specimen, this species was originally described within the genus *Philautus* (Rao 1937, Dutta 1985), but later transferred to the genus *Indirana* by Bossuyt and Dubois (2001) based on morphological characters. Rao (1937) reported an absence of vomerine teeth and lingual papilla in this species, which are characteristic features of the *Indirana* genus, but Bossuyt and Dubois (2001) included this species in the genus *Indirana*, attributing the lack of these features to defects in the initial observations by Rao. Re-evaluation of the status of this species would require collection of additional specimens. Habits are unknown.

Distribution

This species is known from only one locality, Kempholey Ghats, Hassan, Mysore, Karnataka

(Fig. 1k; Rao 1937). Field surveys are needed to validate the species status and the distribution range.

Conservation status

This species is currently classified as 'Data Deficient' as its taxonomic validity is doubtful. The information on its range and ecology is lacking (www.iucnredlist.org).

Biogeography

The frogs in the genus *Indirana* are endemic to the Western Ghats Mountains in India, and are not known to occur anywhere else. The Western Ghats is a mountain chain that runs parallel to the west coast of India for over 1600 km (*see* Fig. 1 top left). The mountain chain begins in the north as low lying hills close to the river Tapti in Gujarat, and passes southwards through the states of Maharashtra, Goa, Karnataka and Kerala, ending abruptly in the Mahendragiri Hills of the Tamil Nadu state at the southernmost tip of Indian peninsula. Along its entire length, there is only one major discontinuity — the Palghat gap of Kerala — which is a low mountain pass at an elevation of only 100 m a.s.l. and about 30 km in width. *Indirana* frogs are known to occur in diverse habitats in the Western Ghats. Many species are reported from evergreen forests, moist deciduous forests and moist semi-evergreen forests (Inger *et al*. 1984). Detailed studies of the species-specific habitat preferences do not appear to have been conducted, except in a few localities (Inger *et al*. 1987, Kumar *et al*. 2002).

Although crude species distribution maps for some of the threatened species are available (Stuart *et al*. 2008), the overall distribution and abundance of these frogs are poorly understood. Some of the species are believed to have very isolated and narrow distribution ranges within the Western Ghats, but how much this reflects the true situation, and how much of it reflects the lack of detailed studies, is currently unknown. Mapping the distribution of the different species is further complicated by the taxonomic uncertainties, and possible occurrence of yet unrecognized cryptic species. Because of these issues, the distribution maps (Fig. 1) based on observations published in the literature (Appendix 1) and from our own field surveys (Appendix 2) should be viewed as tentative and subject to refinements as new information becomes available.

In his synopsis of the biogeography of the Western Ghats amphibians, Daniels (1992) noted that the highest species diversity is encountered south of the latitude 13°N. Our distribution maps reveal that the species within *Indirana* follow a similar trend, as the distribution of species in the genus *Indirana* (except *I. beddomii* and *I. leithii*) are restricted to south of latitude 13°N, indicating a possible trend in species diversity and richness of these amphibians in the Western Ghats, which could potentially be utilised in prioritising areas for the conservation of these species.

Breeding biology and life history

The breeding biology and life history of these species are largely unknown. This was pointed out also by other authors (e.g. Dinesh *et al*. 2009). Here we summarise what little information can be found from the literature.

Morphological characters related to reproduction

Male *I. beddomii*, *I. brachytarsus* and *I. semipalmata* frogs have nuptial pads on the inner side of the first finger, and spicules distributed along the margins of the jaw, throat and along the lateral margins of the belly (Inger *et al*. 1984), whereas *I. diplosticta* have a series of large, sharp nuptial spines on medial surface of the first finger (Inger *et al*. 1984, Daniel & Sekar 1989). The males are also known to possess femoral glands, which are one of the defining characters of genus *Indirana*. The femoral gland secretions may play a role in the reproductive behaviour of these frogs, as the female mate choice in some lizards is influenced by secretions from the femoral glands (Martín & López 2010). Hence, Boulenger's (1920) statement about the lack of secondary sexual characters in *I. semipalmata* and *I. diplosticta* was

erroneous. Recent study by Gopalan *et al*. (2012) has shown that in *I. semipalmata* morphological characters differ between the sexes. Possible sexual differences in body proportions and colouration have not been systematically studied in any of the other *Indirana* species. In at least some of the species (*I. gundia*), the males possess large vocal sacs that are used in calling (Dubois 1986).

Mating calls

The call characteristics have been studied in *I. beddomii* (Kadadevaru *et al*. 2000), *I. semipalmata* (Kuramoto & Joshy 2001b) and *I. gundia* (Kuramoto & Dubois 2009). These species have similar short calls: 0.12 s in *I. beddomii*, 0.13 s in *I. semipalmata* and 0.10 s in *I. gundia*. The reported dominant frequencies are between 862–1840 Hz in *I. beddomii*, at about 1.59 kHz in *I. semipalmata*, and around 1.4 kHz in *I. gundia*. The number of pulses per call was higher for *I. beddomii* (mean = 12.3) than for *I. gundia* (mean = 6.9), whereas no clear pulse structure was observed in *I. semipalmata* (Kuramoto & Joshy 2001b). Mating calls of the other seven species in the genus are still undescribed. Males of some species have been reported to call simultaneously (e.g. Kadadevaru *et al*. 2000, Kuramoto & Dubois 2009), suggesting that they may form some sort of loose leks.

Timing of breeding

The breeding of *Indirana* frogs appears to coincide with the southwest monsoon (June–October; Daniels 2005). Individuals of *I. leithii* collected in June were reported to have mature gonads, *I. beddomii* individuals with mature gonads are reported between December and June, and *I. leptodactyla* individuals with mature gonads can be found between April and May (Daniel & Sekar 1989). In our field surveys, we observed breeding individuals of *I. diplosticta* during the second monsoon showers in August and September. For other species, no information on the timing of breeding activities is available.

Clutch sizes and information on larval stages

In *Indirana* frogs, the eggs are laid in clear pools at the base of rocks or in rock crevices, and tadpoles can be seen on wet rock faces far away from streams (Daniels 2005). This was also observed and recorded in our own field surveys. The clutch size for most of the species is unknown, with the exception of *I. leptodactyla* which is reported to deposit approximately 30 eggs in each of 6–8 batches (Rao 1920) and *I. semipalmata* which is reported to deposit 143–343 eggs (Tapley *et al*. 2011). The tadpoles of many species within the genus *Indirana* have been described by earlier authors (Annandale 1918, Noble 1927), but there have been reports of misidentifications and erroneous descriptions highlighted by later authors (Chari & Daniel 1953, Kuramoto & Joshy 2002). The tadpoles of *I. beddomii* (Kuramoto & Joshy 2002, Veeranagoudar *et al*. 2009), *I. leithii* (Chari & Daniel 1953, Sekar 1992) and *I. semipalmata* (Gopalan *et al*. 2012) have been studied extensively, and the morphological characters are well described. For example, they have elongated tails with low caudal fins which help them to hop around on rocks, a dorsoventrally flattened body, and a laterally compressed jaw sheath with prominent lateral processes that are adaptive for a semiterrestrial life. These specific adaptations have been suggested to have limited the dispersal of these species beyond the Western Ghats (Roelants *et al*. 2004). In view of the possible taxonomic misidentifications of the tadpoles in the field (e.g. Annandale 1918), it is difficult to validate how reliable the data on tadpoles and clutch sizes are. For instance, Kuramoto and Joshy (2002) identified tadpoles to be *I. beddomii* simply because they were collected from the same microhabitat as adult *I. beddomii*. Similarly, Tapley *et al*. (2011) identified eggs (and reported clutch sizes) of *I. semipalmata* on the basis that an adult male was found to be sitting close to the eggs. Only DNA barcoding techniques or direct observations of females laying eggs can be used to validate the species identity of eggs and larvae found from the wild.

Further studies

It is clear that there is a confusion regarding the taxonomy within the genus *Indirana*. Species can be difficult to tell apart based on morphology alone. Hence, the first important step is to create a molecular phylogeny of the species within this genus. This would help to clarify how many *Indirana* species there actually are, as well as to uncover any cryptic diversity. An adequate understanding of what species exist would lay the foundations for further work.

Once this information is available, and we have a way to reliably distinguish between species using barcoding techniques (Vences *et al*. 2005), systematic field studies in different parts of the Western Ghats are needed to map the distribution areas and habitats of the different species in more detail. It is likely that our current perceptions of the distribution ranges are biased: the species may well be more narrowly distributed than the current maps indicate.

Another major gap in our knowledge is regarding the life histories of all species, as this is as yet largely unstudied. For instance, nothing is known about the developmental rate from egg to adulthood, age at maturation, mating systems and longevity for any of the species. Hence, detailed autecological studies utilising capture-recapture (e.g. Campbell *et al*. 2009) and skeletochronological (e.g. Lai *et al*. 2005) methods would be illuminating. Likewise, studies focussing on mating and egg laying behaviour should be relatively easy to conduct, at least for some of the most common species. Furthermore, the peculiar sperm morphology, and unusually large sperm size of *Indirana* frogs (e.g. Kuramoto & Joshy 2000, 2001a) deserves further attention at least for two reasons. Firstly, information on sperm morphology has so far only been published for two species (*I. beddomii* and *I. semipalmata*). Secondly, the evolution of sperm morphology is driven by sperm competition, and in most species, large sperm size is typically associated with intensive sperm competition (Byrne *et al*. 2003). If so, this may suggest high degree of sperm competition in *Indirana* frogs.

Finally, in order to identify units that can be prioritised for conservation, the population structuring within each species should be investigated. This can only occur once the taxonomy has been clarified, but it would enable us to assess the level of potential genetic problems that could have been caused by the substantial habitat fragmentation, and possible associated population isolation and inbreeding. These kinds of conservation genetic studies require the development of genetic resources that are suitable for intraspecfic, population-level work, such as microsatellite markers (e.g. Nair *et al*. 2011) or single nucleotide polymorphisms (SNPs; e.g. Brumfield *et al*. 2003). The recent development of a set of microsatellite markers for *I. beddomii* (Nair *et al*. 2011) provides a basis for genetic studies at the intraspecifc level in this genus, and many of these markers may also prove to be usable for other *Indirana* species (Nair *et al*. 2012b). Recent study in *I. beddomii* using these markers has provided insights into genetic diversity and population structuring of these endemic frogs from the Western Ghats biodiversity hotspot (Nair *et al*. 2012c).

It would also be worthwhile implementing wide-spread screening for *Batrachochytrium dendrobatidis* (*Bd*) infections within populations of these frogs, as this fungus is known to be contributing to the current global amphibian declines (Crawford *et al*. 2010). Similarly, it may be worth screening for the viral pathogen, *Ranavirus*, which has recently been shown to cause population-level declines in amphibians (Teacher *et al*. 2010). A preliminary screening of *B. dendrobatidis* in *Indirana* frogs has shown that *Bd* infection is present at low levels in the southern Western Ghats, though no *Ranavirus* was detected (Nair *et al*. 2011). Hence, there is an urgent need for further extensive surveys and screening of emerging infectious diseases in this region.

In conclusion, there is a need to clarify what we know of the exceptional amphibian biota of the Western Ghats. These mountains are home to many endemic ancient lineages including Ranixalidae (Biju & Bossuyt 2003, Roelants *et al*. 2004). The fact that these lineages are concentrated in a spatially limited area emphasises the need for serious conservation efforts in the Western Ghats biodiversity hotspot. In order

to prioritise the conservation efforts for these amphibians, further research is needed into the basic biology and life history of these frogs. The frogs within Ranixalidae need taxonomic revision as it appears that taxonomic ambiguities are highly prevalent, and the status of many reported species is currently not known (categorised as data deficient by the IUCN, www.iucnredlist.org). It has been made clear that many morphologically distinct species are yet to be documented from the Western Ghats (Biju 2001), and many taxa that are considered to be common and widespread in the Western Ghats may actually represent cryptic 'species complexes'— groups of similar looking taxa that form distinct evolutionary lineages (Bickford *et al*. 2007). Without a proper understanding of the taxonomy of *Indirana* species, we cannot reliably assess the abundance or distributions, nor hope to correctly assess their conservation statuses, or to implement successful conservation interventions.

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Appendix 1. Records of *Indirana* species from literature sources.

Species/Location	Square assigned	Coordinates	Reference
I. beddomii			
Bhimashankar	111		Padhye and Ghate 2002
Mulshi	128		Padhye and Ghate 2002
Mahabaleshwar	162		Abdulali and Daniel 1955, Satyamurti 1967, Dutta 1997
Talewadi (Karnataka)	214		Daniel and Sekar 1989
Sural	246	15°40´N, 74°10´E	Veeranagoudar *et al.* 2009
Talagini	276	14°10´N, 74°50´E	Kuramoto and Joshy 2002
North Kanara	276		Boulenger 1882, Thurston 1888, Abdulali and Daniel 1955 Satyamurti 1967, Daniel and Sekar 1989, Dutta 1997, Ali *et al.* 2008, Gururaja *et al.* 2008
Agumbe	302	13°18´N, 75°04´E	Kadadevaru *et al.* 2000
Sringeri	303	13°15´–13°36´N, 75°04´–75°12´E	Krishnamurthy and Sakunthala 1993
Kudremukh	316		Krishnamurthy 2003
Bisale	331	12°15´N, 75°33´E	Krishna *et al.* 2005
Aralam Wildlife Sanctuary	367	11°50´–11°52´N, 75°49´–75°57´E	Andrews *et al.* 2005b
Wayanad Wildlife Sanctuary	368	11°35´–11°51´N, 76°02´–76°27´E	Abraham *et al.* 2001, Andrews *et al.* 2005b
Silent valley	378	11°04´–11°13´N, 76°24´–76°29´E	Dutta 1997, Andrews *et al.* 2005b
Chimmini Wildlife Sanctuary	388	10°22´–10°26´N, 76°31´–76°37´E	Andrews *et al.* 2005b
Peechi-Vazhani Wildlife Sanctuary	388	10°28´–10°38´N, 76°18´–76°28´E	Andrews *et al.* 2005b
Parambikulam	389	10°20´–10°26´N, 76°35´–76°50´E	Annandale 1918, Satyamurti 1967, Dutta 1997, Andrews *et al.* 2005b
Anamalai hills	390		Günther 1876, Boulenger 1882, Thurston 1888, Boulenger 1920, Chanda and Deuti 1997, Dutta 1997, Dinesh *et al.* 2009
Alwaye	397		Daniel and Sekar 1989
Chalakudi	397		Satyamurti 1967
Kavalai	397		Satyamurti 1967
Thattekad	397	10°07´–11°00´N, 76°40´–76°45´E	Andrews *et al.* 2005b
Munnar	399		Daniel and Sekar 1989
Palni hills	400		Daniel and Sekar 1989
Idukki Wildlife Sanctuary	407	9°45´–9°53´N, 76°55´–77°4´E	Andrews *et al.* 2005b
Periyar	408	9°18´–9°41´N, 76°55´–77°25´E	Daniel and Sekar 1989, Ravichandran and Pillai 1990, Zacharias and Bhardwaj 1996, Andrews *et al.* 2005b
Srivilliputur	409		Dutta 1997
Sivagiri	421		Günther 1876, Boulenger 1882, Thurston 1888, Boulenger 1920, Satyamurti 1967, Chanda and Deuti 1997, Dutta 1997, Dinesh *et al.* 2009
Vembayum	421		Ferguson 1904, Satyamurti 1967
Ponmudi	422		Inger *et al.* 1984, Inger *et al.* 1987,
Peppara Wildlife Sanctuary	422	8°07´–8°53´N, 76°40´–77°17´E	Andrews *et al.* 2005b
Neyyar Wildlife Sanctuary	422	8°17´–8°53´N, 76°40´–77°17´E	Andrews *et al.* 2005b
Courtallum	422		Daniel and Sekar 1989
Tenmalai	422		Annandale 1909, Satyamurti 1967
Kalakad Mundanthurai	427	8°25´–8°53´N, 77°10´–77°35´E	Satyamurti 1967, Johnsingh 2001, Vasudevan *et al.* 2001, Kumar *et al.* 2002, Vasudevan *et al.* 2006 Vasudevan *et al.* 2008
I. brachytarsus			
Kudremukh	316	13°10´–13°26´N, 75°05´–75°10´E	Reddy *et al.* 2001, Krishnamurthy 2003, Biju *et al.* 2004a
Coorg	344		Biju *et al.* 2004a

continued

Appendix 1. Continued.

Species/Location	Square assigned	Coordinates	Reference
Wayanad Wildlife Sanctuary	368		Biju *et al.* 2004a
Anamalai hills	390		Günther 1876, Boulenger 1920, Chanda and Deuti 1997, Dutta 1997, Dinesh *et al.* 2009
Eravikulam National park	399	10°10´–10°20´N, 77°00´–77°10´E	Dutta 1997, Andrews *et al.* 2005b
Periyar	408		Biju *et al.* 2004a
Sivagiri	421		Günther 1876, Boulenger 1920, Chanda and Deuti 1997, Dinesh *et al.* 2009
Ponmudi	422		Inger *et al.* 1984, Inger *et al.* 1987
Kalakad Mundanthurai	427		Johnsingh 2001, Vasudevan *et al.* 2001, Kumar *et al.* 2002, Biju *et al.* 2004a, Vasudevan *et al.* 2006, Vasudevan *et al.* 2008
I. diplosticta			
Ranipuram	343		Andrews *et al.* 2005b
Anamalai hills	390		Boulenger 1920, Dutta 1997, Chanda 2002, Daniels 2005
Indira Gandhi National park	390		Biju *et al.* 2004d
Idukki wildlife sanctuary	407		Biju *et al.* 2004d, Andrews *et al.* 2005b
Srivilliputur	409		Daniel and Sekar 1989, Dutta 1997, Biju *et al.* 2004d, Daniels 2005
Athiramala	414		Biju *et al.* 2004d
Ponmudi	422		Inger *et al.* 1984, Dutta 1997, Biju *et al.* 2004d, Daniels 2005
Kalakad Mundanthurai	427		Johnsingh 2001, Vasudevan *et al.* 2001, Kumar *et al.* 2002, Biju *et al.* 2004d, Vasudevan *et al.* 2008
I. leithii			
Surat Dangs	40		Abdulali and Daniel 1954, Daniel and Shull 1964, Daniel and Sekar 1989, Sekar 1992, Dutta 1997, Daniels 2005
Kanheri caves	93		Abdulali and Daniel 1954, Daniel and Sekar 1989
Suriamal	93		Chari and Daniel 1953, Abdulali and Daniel 1954, Dutta 1997
Matheran	110		Boulenger 1888, Boulenger 1890, Boulenger 1920, McCann 1932, Abdulali and Daniel 1954, Daniel and Sekar 1989, Sekar 1992, Chanda and Deuti 1997, Padhye and Ghate 2002, Biju *et al.* 2004e, Dinesh *et al.* 2009
Bhimashankar	111		Biju *et al.* 2004e
Kalsubai Harishchandra	111		Biju *et al.* 2004e
Mulshi	128		Padhye and Ghate 2002
Karla caves	128		Abdulali and Daniel 1954, Sekar 1992
Phansad	144		Biju *et al.* 2004e
Panchgani	163		Abdulali and Daniel 1954, Daniel and Shull 1964, Sekar 1992, Dutta 1997
Koyna	163		Biju *et al.* 2004e
Khandala	179		Chari and Daniel 1953, Abdulali and Daniel 1954, Dutta 1997
Chandoli	180		Biju *et al.* 2004e
Sringeri	303		Krishnamurthy and Sakunthala 1993
Kudremukh	316		Krishnamurthy 2003
I. semipalmata			
North Kanara	276		Ali *et al.* 2008, Gururaja *et al.* 2008
Sringeri	303		Krishnamurthy and Sakunthala 1993
Kudremukh	316		Krishnamurthy 2003
Gundia	331	12°76´–12°83´N, 75°59´–75°74´E	Gururaja *et al.* 2007
Madikeri	344		Kuramoto and Joshy 2001b

continued

Appendix 1. Continued.

Species/Location	Square assigned	Coordinates	Reference
Pulloorampara	367		Daniel and Sekar 1989
Wayanad Wildlife Sanctuary	368	11°35´–11°51´N, 76°02´–76°27´E	Andrews *et al.* 2005b
Anamalai hills	390		Fischer 1915, Daniel and Sekar 1989, Dutta 1997, Daniels 2005
Cochin	397		Satyamurti 1967
Thattekad	397	10°07´–11°00´N, 76°40´–76°45´E	Andrews *et al.* 2005b
Poombarai	399		Daniel and Sekar 1989
Kodaikanal	400		Daniel and Sekar 1989
Idukki Wildlife Sanctuary	407		Andrews *et al.* 2005b
Ponmudi	422		Inger *et al.* 1984, Daniels 2005
I. leptodactyla			
Shimoga	276		Rao 1920
Coorg	344		Rao 1920, Satyamurti 1967, Daniel and Sekar 1989, Andrews *et al.* 2005b
Parambikulam	389		Satyamurti 1967, Dutta 1997, Biju and Dutta 2004, Andrews *et al.* 2005b
Anamalai hills	390		Günther 1876, Boulenger 1882, Thurston 1888, Boulenger 1890, Boulenger 1920, Daniel and Sekar 1989, Dutta 1997 Chanda 2002, Biju and Dutta 2004, Dinesh *et al.* 2009
Indira Gandhi National park	390		Biju and Dutta 2004
Vellikulam	397		Satyamurti 1967
Trichur	397		Satyamurti 1967
Devikulam	399		Boulenger 1920, Satyamurti 1967
Eravikulam National park	399	10°10´–10°20´N, 77°00´–77°10´E	Dutta 1997, Biju and Dutta 2004, Andrews *et al.* 2005b
Kodaikanal	400		Daniel and Sekar 1989, Dutta 1997
Palni hills	400		Daniel and Sekar 1989
Idukki Wildlife Sanctuary	407		Andrews *et al.* 2005b
Periyar	408		Biju and Dutta 2004
Athiramala	422		Biju and Dutta 2004
Agasthyamala hills	422		Biju and Dutta 2004
Tenmalai	422		Annandale 1909, Satyamurti 1967, Dutta 1997
Thirumala	422		Dutta 1997
Kalakad Mundanthurai	427		Johnsingh 2001, Vasudevan *et al.* 2001, Biju and Dutta 2004, Vasudevan *et al.* 2006, Vasudevan *et al.* 2008
I. gundia			
Gundia	331		Dubois 1986, Chanda and Deuti 1997, Dutta 1997, Chanda 2002, Biju *et al.* 2004c, Gururaja *et al.* 2007, Dinesh *et al.* 2009, Kuramoto and Dubois 2009
I. phrynoderma			
Mulshi	128		Padhye and Ghate 2002
Anamalai hills	390		Thurston 1888, Boulenger 1890, Boulenger 1920, Chanda and Deuti 1997, Dutta 1997, Biju 2001, Chanda 2002, Biju *et al.* 2004g, Dinesh *et al.* 2009
I. tenuilingua			
Kempholey	331		Rao 1937, Chanda and Deuti 1997, Dutta 1997, Biju 2001, Gururaja *et al.* 2007, Dinesh *et al.* 2009
I. longicrus			
Kempholey	331		Rao 1937, Dutta 1997, Biju 2001, Gururaja *et al.* 2007, Dinesh *et al.* 2009

Appendix 2. Record of *Indirana* species from field surveys. 1 = species found, 0 = species not found; *I. gundia*, *I. phrynoderma*, *I. tenuilingua*, *I. longicrus* were not found from any of the surveyed localities.

Locality	Lat. (N)	Long. (E)	*I. beddomii*	*I. brachytarsus*	*I. semipalmata*	*I. leithii*	*I. diplosticta*	*I. leptodactyla*
Ranipuram	12°25´20´´	75°21´39´´	1	0	0	0	0	0
Kottur	8°35´30´´	77°09´09´´	0	0	0	0	0	0
Ponmudi	8°45´59´´	77°06´34´´	1	1	1	0	1	0
Periyar	9°29´27´´	77°08´10´´	1	1	1	0	1	0
Vellarimala	11°26´47´´	76°04´44´´	0	1	0	0	0	0
Kaundhi	9°47´43´´	77°02´44´´	1	1	0	0	0	0
Aralam	11°55´54´´	75°50´09´´	1	0	0	0	0	0
Kannamvayal	12°17´39´´	75°29´03´´	1	1	0	0	0	0
Agumbe	13°31´22´´	75°05´20´´	1	0	0	0	0	0
Kudremukh	13°13´07´´	75°10´59´´	1	0	0	1	0	0
Mudhumalai	11°36´49´´	76°44´55´´	0	0	0	0	0	0
SulthanBatheri	11°43´02´´	76°15´37´´	0	0	0	0	0	0
Mepadi	11°31´48´´	76°08´21´´	0	1	0	0	0	0
Devarshola	11°33´29´´	76°27´16´´	0	0	0	0	0	0
Thattekad	10°07´34´´	76°41´56´´	1	1	0	0	0	0
Vazhachal	10°17´43´´	76°38´48´´	1	1	1	0	0	0
Malakapara	10°17´17´´	76°50´29´´	1	1	1	0	0	0
Sholayar	10°18´24´´	76°53´11´´	1	1	1	0	0	0
Aliyar	10°29´35´´	76°58´00´´	0	1	1	0	0	0
Wayanad	11°30´18´´	76°01´49´´	1	0	0	0	0	0
Madikeri	12°30´53´´	75°48´48´´	1	0	0	0	0	0
Coorg	12°28´22´´	75°36´09´´	0	0	0	0	0	0
Dharmasthala	12°53´16´´	75°24´13´´	0	0	0	0	0	0
Kallarkutty	9°58´39´´	76°59´59´´	0	1	1	0	0	0
Ponmudi Dam	9°57´33´´	77°02´55´´	0	1	1	0	0	0
Munnar	10°08´39´´	77°02´17´´	0	0	0	0	0	1
Kasargode	12°28´58´´	75°24´34´´	1	0	0	1	0	0
Annamalai	10°25´54´´	76°50´01´´	1	1	1	0	0	0
Peppara WLS	8°33´43´´	77°09´56´´	1	1	1	0	0	0
Silent Valley	11°05´44´´	76°26´44´´	0	1	0	0	0	0