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Status of Conservation and Decline of Amphibians: Eastern Hemisphere

Edited by

Harold Heatwole and **Indraneil Das**

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Tel: 088-233098 Fax: 088-240768
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CHAPTER 8

Status and Decline of Amphibians of India

Indraneil Das and Sushil K. Dutta

Abbreviations in text and references: asl = above sea level; CITES = Convention on International Trade in Endangered Species of Wild Fauna and Flora; GAA = Global Amphibian Assessments; IUCN = International Union for the Conservation of Nature and Natural Resources/The World Conservation Union; PA = Protected Areas.

I. INTRODUCTION

The Republic of India (Fig. 1), with a total land area of 3,387,539 km^2, of which as much as 61% is arable, is home to the world's second largest human population, after the People's Republic of China. It is a country of exceptional biotic diversity and is listed among one of the top ten countries for biodiversity (Myers 1988, 1990). It also houses two major centres of biotic diversification (or 'hotspots'), which are known areas of amphibian diversification: the Western Ghats (Biju *et al*. 2008) and northeastern India, which lies within the Eastern Himalaya (Chanda 1994; Kamei *et al*. 2012). In terms of its amphibian fauna India is the 11th most diverse country, after Brazil, Colombia, Ecuador, Peru, México, Indonesia, China, Venezuela, United States, and Papua New Guinea (IUCN 2009; see also Stuart *et al*. 2004). This diversity is attributed to the variety of ecological conditions and a complex geological history. India touches the Himalayan range and extends south to cover the entire Indian peninsula. Its political boundaries include the islands of the Bay of Bengal (Andaman and Nicobar Archipelago) and of the Arabian Sea (Lakshadweep Archipelago). The amphibian fauna of the Indian peninsula

Fig. 1. Relief map of India and adjacent countries of southern Asia, showing biogeographical regions.

also contains a number of ancient endemic lineages (Roelants *et al*. 2004), a result of its prolonged isolation from other major landmasses.

The rafting Indian plate detached from the African plate *ca*. 135 million years before present, before making contact with Eurasia, variously dated from the Early Eocene to Middle Miocene (Briggs 1987; Roelants *et al*. 2004; Li *et al*. 2013). African elements evident in the fauna include, (1) most famously, the Nasikabatrachidae, which shares affinities with the Seychellois frog family, the Sooglossidae (see Biju and Bossuyt 2003), (2) the caecilian family Chikilidae (Kamei *et al*. 2012), and perhaps (3) members of the Rhacophoridae (Frost *et al*. 2006; Li *et al*. 2013). Evidence from the pollen flora suggests the existence of rainforest refugia in the southern Western Ghats between the Late Palaeocene and Early Eocene (Prasad *et al*. 2009).

Anecdotal evidence points to a loss of vegetation in northern India since historic times (Randhawa 1945), which is tied to the desiccation of the land and, presumably, to a general loss of biodiversity. The current disjunction of wet biotas to the southwest and northeast is thus dramatic, and an alternate influential theory by Hora (1949) tried to explain it by proposing the existence of a geological causeway across what is now the flat floodplains of the Ganga. Karanth (2003) has argued for testing these, and other, hypotheses using a phylogenetic approach to separate ecological convergence from true distributional disjunction between biotas. Palynological evidence does indicate a period of intense clearance of scrub, perhaps preceding the growing of cereal crops (Misra 2000; Madella and Fuller 2006), and associated climatic change in northern India.

A. Physiographic Regions

The highly diverse biota of India is generally credited to be the result of its location (at the meeting place of the Palearctic and Oriental realms, and within the latter, the Indian, Indo-Chinese, and Indo-Malayan subregions, plus relictual elements from its association with the African-Madagascan landmasses) in addition to its present climatic conditions. Physiographic zones represented within the political boundaries of India, based on geology and vegetation (phytogeography), include several discrete units, as briefly described below:

1. The Bay Islands

The archipelagos of the Andaman and Nicobars are located between 13º40'N, 93º02'E and 06º45'N, 93º49'E, in the Bay of Bengal, and form a chain of submarine mountains that stretch like a crescent between Cape Negrais in Myanmar to Achin Head in Sumatra, Indonesia. The total land area of these islands is an estimated 8293 km^2. Average annual rainfall exceeds 3000 mm. The great variety of environments, including bays, coral reefs, mangroves, volcanoes, and rainforests on hill ranges that reach 700 m, support a species-rich herpetofauna. The fauna of the Andamans is an impoverished one derived from Myanmar during the time of its connection with the Asian mainland during the low waters of the Pleistocene glaciation, while that of the Nicobars, an oceanic group of coraline origin, is derived from the nearest land mass of Sumatra, presumably having been established by waif (overwater) dispersal.

Currently, about 90% of the land area of the Andamans (6408 km^2) are within Reserve Forests, of which about 36% are designated Tribal Reserves. All of the Nicobars have been declared as 'Tribal Areas', and about 1542 km^2 remain forested, of which *ca*. 30% are gazetted under the protected areas system. Many of the tribes of the Andamans have suffered during contact with settlers from the Indian mainland and early British civil servants, and some tribes became extinct, a result of logging, fishing, introduced diseases, and introduction of alien species (ranging from elephants and deer to fish and invertebrates) from the Indian mainland (Jayaraj and Andrews 2005).

2. The Deccan

The Deccan (the original portion of the Indian Plate) is composed of the flat peninsula, excluding the hill ranges to the east and west and south of the areas watered by the rivers arising from the Himalayan range. Palaeontological evidence points to the existence of extensive swathes of evergreen forests up to the Miocene-Pliocene (and perhaps even the Late Pleistocene). The conversion of the wet forests to deciduous forests is possibly an effect of the decline in rainfall, a result of the slight southern shift of the equator, the uplift of the Himalayas, the rise of the Western Ghats, and human activities over the past 10,000 years. Vegetation types (after Meher-Homji 1990) include *Shorea-Cleistanthus collinus-Croton oblongifolius*, in the northeast, *Shorea-Buchanania-Cleistanthus*, in central and southern areas, *Shorea-Syzygium operculatum-Toona ciliata-Symplocos spicata*, in the north, *Toona-Garuga*, in the east-central part, *Hardwickia binata*, to the south, and *Anogeissus pendula* and *Acacia senegal-Anogeissus pendula*, to the northwest. Forested areas are fragmented and threatened by logging for timber and domestic use; in addition, mining, forest fires, and damming of rivers are threats (Prasad *et al*. 2008).

3. The Eastern Ghats.

The Eastern Ghats represent a weathered relict of the peninsular plateau, marked by a series of low isolated hills that run from the Khondmal in the Baudh-Khandmal (Phulbani) District, Orissa State, southwards to central Tamil Nadu State, where they veer off towards the southwest to meet the Western Ghats in the Nilgiris. The Ghats cover an area of *ca*. 75,000 km^2, and extend *ca*. 1750 km from north to south, and reach *ca*. 220 km at its widest part. These ranges form the catchment areas of numerous east-flowing rivers of India's eastern coast, including the Mahanadi and the Godavari. The northern and southern sections of the Eastern Ghats are separated by the Godavari delta, which is *ca*. 130 km in width; other important breaks include the Mahanadi and Krishna rivers. The larger hills occur in the Dandakaranya region (Mahanadi-Godavari region), the highest peak being Arma Konda (summit at 1818 m asl). The southern sub-zone is more arid, with dry deciduous and thorn scrub, while the northern part is relatively mesic with both dry and moist deciduous forests. Over 2500 species of angiosperms have been recorded from the Eastern Ghats (Chauhan 1998), while the dominant vegetation type is dry-deciduous, with patches of moist-deciduous and semi-evergreen forests. *Shola*-type and naturally treeless zones are common only at high elevations. Major threats to the area include mining, overgrazing by cattle, logging for timber, and domestic use by the vast population along the eastern peninsula, besides overgrazing by cattle (Balaguru *et al*. 2006).

4. The Himalaya.

The Himalayan range includes some of the highest mountains on earth. Eight major Asian rivers, including the Ganga, Brahmaputra, Yangtze, Indus, and Mekong spring from these mountains. The Himalaya, including the Trans-Himalaya, cover an area of 236,300 km^2, including parts of Pakistan, India, Nepal, and Bhutan. It has a variety of forest types, from moist deciduous, through subtropical broad-leaved forests, to coniferous, mixed coniferous, and alpine scrub forests. Included in the zone are the *terai*, a swampy belt with a maximum width of 13 km, the *bhabars*, which are deep, boulder deposits, that skirt the outermost hills of the Himalaya, and the *duns,* which are broad elevated valleys at about 600 m, at the outer range of the Himalaya. The eastern Himalaya are wetter than the western part, receiving at least an annual average of 2000 mm of rainfall and often much more. The winter months (November-March), however, are relatively dry. As a result of the varied topography, both species diversity and endemism among plants are high, especially in the inner valleys of the range. Typical trees include *Michelia montana, Turpinia pomifera, Schima wallichii, Ilex godajam, Saurauja roxburghii,* and *Aporosa dioica*. Sub-alpine forests occur in the western and central Himalayas, dominant trees being *Quercus incana* and *Q. dilatata*. Thickets of *Rhododendron hyperanthum, R. leptodotum,* and *R. pumilum* occur between 3500 m and 5000 m elevation. Sub-tropical pine forests are also recorded and include *Quercus amellosa* and *Q. lineata, Rhododendron* spp., *Lyonia* spp., *Pinus roxburghii,* and *P. insularis*. At 4000–5000 m are the Alpine pastures, considered "grasslands" although there are few grasses represented, the dominant vegetation being perennial mesophytic herbs such as *Primula* spp., *Anemone* spp., *Iris* spp., and *Gentiana* spp. Human population densities at lower elevations of these mountains are high, and numerous factors threaten the ecosystems of these high mountains: grazing and trampling of vegetation by livestock, gathering wood for fuel, logging for timber, collection of medicinal plants, clearing of land for agriculture, planting of exotic tree species, construction of dams, mining, uncontrolled tourism, and wildfires, among other factors (Wikramanayake *et al*. 2001).

5. The Northeast.

The northeastern region of India is composed of three major physiographic subunits, the Karbi-Meghalaya plateau and associated plains, the eastern ranges of the Himalaya, and the plains of the Brahmaputra, Barak Manipur, and Tripura (Bora 2000); collectively these cover an area of *ca*. 255,168 km^2. With rainfall exceeding 2000 mm and a wide physiognomic range, and with some elevations >7000 m asl, the Northeast supports a rich tropical to temperate vegetation, growing on rich alluvial soils in the plains or on lateritic and red soils in the hills. The major precipitation locally is brought by the Southwest Monsoons, between June and September, causing extensive rainfall and annually, great loss to life and property through flooding of the major rivers. The main vegetation types represented include moist deciduous, semi-evergreen and temperate montane forests, including *Lagerstroemia, Tetrameles, Shorea robusta, Quercus, Juglans,* and *Magnolia*. Tropical evergreen forests in the region have a three-tiered structure, the highest of which reach about 46 m above the forest floor. Climatic fluctuations during the year are minimal, temperatures on average ranging from 20°C to 30ºC in the plains. Forests of the northeast are threatened by logging for timber (including bamboo), as well as by *jhum* (slash-and-burn agriculture), and collection of medicinal plants and other forest produce. Scarcity of knowledge of the contents and distribution of the region's herpetofauna presents challenges for its conservation and management (see Pawar *et al*. 2007).

6. The Northwest.

The Northwest includes the extreme western parts of India (and ecologically also, the eastern districts of Pakistan) and is bounded by the Indus and Nara Valleys in the west, the Aravalis in the east, and the Kachchh to the south. To the north lie the Indian states of Haryana and Punjab, comprising the plains of the Sutlej and Chambal Rivers. The Northwest is chiefly composed of hills, stony plateaus, and peneplains. Included here is the Thar or Great Indian Desert, which occupies more than 200,000 km^2. It comprises sandy plains and lies at elevations up to *ca*. 100 m asl. Severe winters characterize the zone, which is outside the influence of the monsoons. Annual rainfall is 250–500 mm and the mean maximum temperature, is greater than 45ºC. The flora, while not diverse, contains many unique elements, and 682 plant species have been recorded (Khan and Frost 2001). Thorny thickets, dominated by *Acacia senegalensis, A. catechu, Prosopis cinoraria* (introduced from North America), and *Zizyphus nummularia* are the common woody species to be seen. Dominant tree species on the desert peneplains (annual rainfall 250 mm or less) include *Prosopis cineraria*, *Zizyphus numularia,* and *Capparis decidua*. Major causes of endangerment of the fragile desert ecosystem include removal of medicinal plants and harvesting of woody plants for fuel, fodder, fencing, and other uses, by the relatively sparse population (22 million) of humans (Khan 1996).

7. The Trans-Himalayas.

Zanskar, Ladakh, and Karakorum dominate the landscape of the Trans-Himalayas (outer Himalayas). To the east, Zanskar and Ladakh reach down to the Tibetan plateau, where the region is marked with brackish marshes and bogs. The region is composed of mountains that are up to 6600 m high and sandy valleys are drained by the Indus. The sedimentary deposits are mostly of marine origin and are up to Late Tertiary in age. The dry landscape is due in part to the extremely low temperatures (below 0°C) that inhibit the absorption of water by roots of plants during the winter and early spring when occasional showers take place. Vegetation includes coniferous forests as well as alpine steppe. In general, the rainfall increases along a west-east gradient, reaching 1000 mm in the Kumaon, Uttar Pradesh. At higher elevations, the vegetation is xerophytic, dominated by *Salix denticulata, Juniperus communis, Mertensia tibetica,* and *Potentilla desertorum*. The alpine steppe vegetation shows high endemism. Pressures on the land come from uncontrolled tourism, grazing by livestock, and logging (Pandit *et al*. 2007).

8. The Western Ghats.

The Western Ghats lie between 8° and 21° north for *ca*. 1,600 km along the western coast of peninsular India, *ca*. 50–100 km inland. They are a series of hill ranges that are often isolated from each other by low-lying savannahs. The zone extends from the centre of Maharashtra to the southern extremes of Tamil Nadu and Kerala, including the Nilgiris, Anaimalais, and the Palnis, where ranges of hills reach elevations of 450–2800 m and receive average annual rainfall in excess of 2000 mm. About 5500 species of flowering plants have been recorded from the Western Ghats. Typical flora includes *Lagerstroemia lanceolata, Dalbergia latifolia, Toona ciliat,* and *Chukrassia tabularis*, and forest types have been classified as evergreen, semiclosed evergreen, stunted evergreen, semievergreen, moist deciduous, dry deciduous, and scrub/savannah (Utkarsh *et al*. 1998). The high turnover of species is an important aspect of the diversity of amphibian fauna of the Western Ghats; many lineages are drainage specific (Vasudevan *et al*. 2006). In addition, lowlands and midhills (0–1000 m asl) in the southern Western Ghats have higher species diversity and endemicity compared to the higher, northern hills (Daniels 1992). The forests of the Western Ghats are threatened by fragmentation caused by logging and by the harvesting of minor forest produce, in addition to other factors such as the widespread use of organochlorine pesticides associated with plantations that have replaced the original tree cover (Vasudevan 1996; Biju *et al*. 2008). These pesticides are known to disrupt thyroid activity, retinoid pathways, and sexual differentiation (Mann *et al*. 2009).

B. Lineage Composition and Regional Distribution

Nomenclature follows that of Frost (2010), and includes a number of recently described species by Mathew and Sen (2009), whose taxonomic status requires further evaluation. At present, 328 species of amphibians are known from the Republic of India (Table 1), belonging to 14 families and 56 genera, a majority of which are members of the Order Anura (Figs. 2–3). The Gymnophiona, long considered depauperate, is now receiving attention, and a number of species have been described in recent years. A single species of the Caudata is represented. The families Bufonidae (29 species), Discroglossidae (58 species), Ranidae (31 species), Microhylidae (23 species), and especially, Rhacophoridae (95 species) are speciose. The Western Ghats, a narrow sliver of mountain range on the western coast of the Indian Peninsula, are the home of four endemic anuran families, including Micrixalidae (11 species), Nasikabatrachidae (one species), Nyctibatrachidae (28 species), and Ranixalidae (10 species). Caecilians known from India belong to two long-known families — the Caeciliidae (10 species) and Ichthyophiidae (22 species) — and a recently described family, Chikilidae (one species).

The amphibian fauna of continental India exhibits four major distributional patterns: (1) restricted to specific physiographic regions (or regional endemics), (2) widespread within the country and occurring in more than one

Table 1. Checklist of amphibians of India. Current as of 31 August 2013.

ORDER ANURA

Family Bufonidae

Bufoides meghalayanus (Yazdani and Chanda 1971)
Bufotes latastii (Boulenger 1882)
Bufotes pseudoraddei (Mertens 1971)
Duttaphrynus beddomii Günther 1876
Duttaphrynus brevirostris Rao 1937
Duttaphrynus chandai Das, Chotia Dutta and Sengupta 2013
Duttaphrynus cyphosus (Ye 1977)
Duttaphrynus himalayanus (Günther 1864)
Duttaphrynus hololius Günther 1876
Duttaphrynus kiphirensis Mathew and Sen 2009
Duttaphrynus mamitensis Mathew and Sen 2009
Duttaphrynus manipurensis Mathew and Sen 2009
Duttaphrynus melanostictus (Schneider 1799)
Duttaphrynus microtympanum (Boulenger 1882)
Duttaphrynus mizoramensis Mathew and Sen 2009
Duttaphrynus nagalandensis Mathew and Sen 2009
Duttaphrynus olivaceus Blanford 1874
Duttaphrynus parietalis Boulenger 1882
Duttaphrynus scaber Schneider 1799
Duttaphrynus silentvalleyensis Pillai 1981
Duttaphrynus stomaticus Lütken 1864
Duttaphrynus stuarti Smith 1929
Ghatophryne ornata (Günther 1876)
Ghatophryne rubigina (Pillai and Pattabiraman 1981)
Ingerophrynus macrotis (Boulenger 1887)
Pedostibes kempi (Boulenger 1919)
Pedostibes tuberculosus (Günther 1876)
Xanthophryne koynayensis (Soman 1963)
Xanthophryne tigerina Biju, Van Bocxlaer, Giri, Loader and Bossuyt 2009

Family Dicroglossidae

Allopaa barmoachensis (Khan and Tasnim 1989)
Allopaa hazarensis (Dubois and Khan 1979)
Chrysopaa sternosignata (Murray 1885)
Euphlyctis aloysii Joshy, Alam, Kurabayashi, Sumida and Kuramoto 2009
Euphlyctis cyanophlyctis (Schneider 1799)
Euphlyctis ghoshi (Chanda 1991)
Euphlyctis hexadactylus (Lesson 1834)
Euphlyctis mudigere Joshy, Alam, Kurabayashi, Sumida and Kuramoto 2009
Fejervarya andamanensis (Stoliczka 1870)
Fejervarya brevipalmata (Peters 1871)
Fejervarya cancrivora (Gravenhorst 1829)
Fejervarya caperata Kuramoto, Joshy, Kurabayashi and Sumida 2007

Fejervarya granosa Kuramoto, Joshy, Kurabayashi and Sumida 2007
Fejervarya keralensis (Dubois 1981)
Fejervarya kudremukhensis Kuramoto, Joshy, Kurabayashi and Sumida 2007
Fejervarya limnocharis (Gravenhorst 1829)
Fejervarya modestus (Rao 1920)
Fejervarya mudduraja Kuramoto, Joshy, Kurabayashi and Sumida 2007
Fejervarya murthii (Pillai 1979)
Fejervarya mysorensis (Rao 1922)
Fejervarya nepalensis (Dubois 1975)
Fejervarya nicobariensis (Stoliczka 1870)
Fejervarya nilagirica (Jerdon 1854)
Fejervarya orissaensis (Dutta 1997)
Fejervarya parambikulamana (Rao 1937)
Fejervarya pierrei (Dubois 1975)
Fejervarya rufescens (Jerdon 1854)
Fejervarya sauriceps (Rao 1937)
Fejervarya sengupti Purkayastha and Matsui 2012
Fejervarya syhadrensis (Annandale 1919)
Fejervarya teraiensis (Dubois 1984)
Hoplobatrachus crassus (Jerdon 1854)
Hoplobatrachus tigerinus (Daudin 1802)
Limnonectes doriae (Boulenger 1887)
Limnonectes hascheanus (Stoliczka 1870)
Limnonectes khasianus (Anderson 1871)
Limnonectes mawlyndipi (Chanda 1990)
Limnonectes shompenorum Das 1996
Minervarya chilapata Ohler, Deuti, Grosjean, Paul, Ayyaswamy, Ahmed and Dutta 2009
Minervarya sahyadris Dubois, Ohler and Biju 2001
Nanorana annandalii (Boulenger 1920)
Nanorana arnoldi (Dubois 1975)
Nanorana blanfordii (Boulenger 1882)
Nanorana chayuensis (Ye 1977)
Nanorana gammii Anderson 1871
Nanorana liebigii (Günther 1860)
Nanorana minica (Dubois 1975)
Nanorana mokokchungensis (Das and Chanda 2000)
Nanorana parkeri (Stejneger 1927)
Nanorana vicina (Stoliczka 1872)
Ombrana sikimensis (Jerdon 1870)
Sphaerotheca breviceps (Schneider 1799)
Sphaerotheca dobsonii (Boulenger 1882)
Sphaerotheca leucorhynchus (Rao 1937)
Sphaerotheca rolandae (Dubois 1983)
Ingerana borealis (Annandale 1912)
Ingerana charlesdarwini (Das 1998)
Occidozyga lima (Gravenhorst 1829)

Family Hylidae
Hyla annectans (Jerdon 1870)

Family Megophryidae
Leptobrachium bompu Sondhi and Ohler 2011
Leptobrachium smithi Matsui, Nabhitabhata and Panha 1999
Leptolalax lateralis (Anderson 1871)
Leptolalax khasiorum Das, Lyngdoh, Rangad and Hooroo 2010
Leptolalax nokrekensis (Mathew and Sen 2010)
Leptolalax tamdil Sengupta, Sailo, Lalremsanga, Das and Das 2010
Scutiger nyingchiensis Fei 1977
Scutiger sikimmensis (Blyth 1855)
Xenophrys boettgeri (Boulenger 1899)
Xenophrys glandulosa (Fei, Ye and Huang 1990)
Xenophrys major (Boulenger 1908)
Xenophrys megacephala (Mahony, Sengupta, Kamei and Biju 2011)
Xenophrys parva (Boulenger 1893)
Xenophrys robusta (Boulenger 1908)
Xenophrys serchhipii (Mathew and Sen 2007)
Xenophrys wuliangshanensis (Ye and Fei 1995)
Xenophrys zunhebotoensis (Mathew and Sen 2007)

Family Micrixalidae
Micrixalus elegans (Rao 1937)
Micrixalus fuscus (Boulenger 1882)
Micrixalus gadgili Pillai and Pattabiraman 1990
Micrixalus kottigeharensis (Rao 1937)
Micrixalus narainensis (Rao 1937)
Micrixalus nudis Pillai 1978
Micrixalus phyllophilus (Jerdon 1854)
Micrixalus saxicola (Jerdon 1854)
Micrixalus silvaticus (Boulenger 1882)
Micrixalus swamianus (Rao 1937)
Micrixalus thampii Pillai 1981

Family Microhylidae
Kalophrynus interlineatus Blyth 1855
Kaloula assamensis Das, Sengupta, Ahmed and Dutta 2005
Kaloula baleata (Müller in Van Oort and Müller 1833)
Kaloula pulchra Gray 1831
Kaloula taprobanica Parker 1934
Melanobatrachus indicus Beddome 1878
Microhyla berdmorei (Blyth 1856)
Microhyla butleri Boulenger 1900
Microhyla chakrapanii Pillai 1977
Microhyla heymonsi Vogt 1911
Microhyla ornata (Duméril and Bibron 1841)
Microhyla pulchra (Hallowell 1861)
Microhyla rubra (Jerdon 1854)
Microhyla sholigari Dutta and Ray 2000

Micryletta inornata (Boulenger 1890)
Ramanella anamalaiensis Rao 1937
Ramanella minor Rao 1937
Ramanella montana (Jerdon 1854)
Ramanella mormorata Rao 1937
Ramanella triangularis (Günther 1876)
Ramanella variegata (Stoliczka 1872)
Uperodon globulosus (Günther 1864)
Uperodon systoma (Schneider 1799)

Family Nasikabatrachidae
Nasikabatrachus sahyadrensis Biju and Bossuyt 2003

Family Nyctibatrachidae
Nyctibatrachus acanthodermis Biju, Van Bocxlaer, Mahony, Dinesh, Radhakrishnan, Zachariah, Giri and Bossuyt 2011
Nyctibatrachus aliciae Inger, Shaffer, Koshy and Bakde 1984
Nyctibatrachus anamallaiensis (Myers 1942)
Nyctibatrachus beddomii (Boulenger 1882)
Nyctibatrachus danieli Biju, Van Bocxlaer, Mahony, Dinesh, Radhakrishnan, Zachariah, Giri and Bossuyt 2011
Nyctibatrachus dattatreyaensis Dinesh, Radhakrishnan and Bhatta 2008
Nyctibatrachus deccanensis Dubois 1984
Nyctibatrachus deveni Biju, Van Bocxlaer, Mahony, Dinesh, Radhakrishnan, Zachariah, Giri and Bossuyt 2011
Nyctibatrachus gavi Biju, Van Bocxlaer, Mahony, Dinesh, Radhakrishnan, Zachariah, Giri and Bossuyt 2011
Nyctibatrachus grandis Biju, Van Bocxlaer, Mahony, Dinesh, Radhakrishnan, Zachariah, Giri and Bossuyt 2011
Nyctibatrachus humayuni Bhaduri and Kripalani 1955
Nyctibatrachus indraneili Biju, Van Bocxlaer, Mahony, Dinesh, Radhakrishnan, Zachariah, Giri and Bossuyt 2011
Nyctibatrachus jog Biju, Van Bocxlaer, Mahony, Dinesh, Radhakrishnan, Zachariah, Giri and Bossuyt 2011
Nyctibatrachus karnatakaensis Dinesh, Radhakrishnan, Manjunatha Reddy and Gururaja 2007
Nyctibatrachus kempholeyensis (Rao 1937)
Nyctibatrachus major Boulenger 1882
Nyctibatrachus minimus Biju, Van Bocxlaer, Giri, Roelants, Nagaraju and Bossuyt 2007
Nyctibatrachus minor Inger, Shaffer, Koshy and Bakde 1984
Nyctibatrachus periyar Biju, Van Bocxlaer, Mahony, Dinesh, Radhakrishnan, Zachariah, Giri and Bossuyt 2011
Nyctibatrachus petraeus Das and Kunte 2005
Nyctibatrachus pillaii Biju, Van Bocxlaer, Mahony, Dinesh, Radhakrishnan, Zachariah, Giri and Bossuyt 2011
Nyctibatrachus poocha Biju, Van Bocxlaer, Mahony, Dinesh, Radhakrishnan, Zachariah, Giri and Bossuyt 2011
Nyctibatrachus sanctipalustris Rao 1920
Nyctibatrachus sholai Radhakrishnan, Dinesh and Ravichandran 2007
Nyctibatrachus shiradi Biju, Van Bocxlaer, Mahony, Dinesh, Radhakrishnan, Zachariah, Giri and Bossuyt 2011
Nyctibatrachus sylvaticus Rao 1937
Nyctibatrachus vasanthi Ravichandran 1997
Nyctibatrachus vrijeuni Biju, Van Bocxlaer, Mahony, Dinesh, Radhakrishnan, Zachariah, Giri and Bossuyt 2011

Family Ranidae
Amolops assamensis Sengupta, Hussain, Choudhury, Gogoi, Ahmed and Choudhury 2008
Amolops chakrataensis Ray 1992
Amolops formosus (Günther 1876)
Amolops gerbillus (Annandale 1912)
Amolops himalayanus (Boulenger 1888)
Amolops jaunsari Ray 1992
Amolops kaulbacki (Smith 1940)
Amolops kohimaensis Biju Mahony and Kamei 2010
Amolops marmoratus (Blyth 1855)
Amolops monticola (Anderson 1871)
Amolops nidorbellus Biju Mahony and Kamei 2010
Amolops viridimaculatus (Jiang 1983)
Clinotarsus alticola (Boulenger 1882)
Clinotarsus curtipes (Jerdon 1854)
Humerana humeralis (Boulenger 1887)
Hylarana aurantiaca (Boulenger 1904)
Hylarana danieli (Pillai and Chanda 1977)
Hylarana erythraea (Schlegel 1837)
Hylarana garoensis (Boulenger 1920)
Hylarana labialis (Boulenger 1887)
Hylarana leptoglossa (Cope 1868)
Hylarana malabarica (Tschudi 1838)
Hylarana nicobariensis (Stoliczka 1870)
Hylarana nigrovittata (Blyth 1856)
Hylarana taipehensis (Van Denburgh 1909)
Hylarana temporalis (Günther 1864)
Hylarana tytleri Theobald 1868
Odorrana andersonii (Boulenger 1882)
Odorrana chloronota (Günther 1876)

Odorrana mawphlangensis (Pillai and Chanda 1977)
Pterorana khare Kiyasetuo and Khare 1986

Family Ranixalidae
Indirana beddomii (Günther 1876)
Indirana brachytarsus (Günther 1876)
Indirana diplosticta (Günther 1876)
Indirana gundia (Dubois 1986)
Indirana leithii (Boulenger 1888)
Indirana leptodactyla (Boulenger 1882)
Indirana longicrus (Rao 1937)
Indirana phrynoderma (Boulenger 1882)
Indirana semipalmata (Boulenger 1882)
Indirana tenuilingua Rao 1937

Family Rhacophoridae
Beddomixalus bijui Abraham, Pyron, Ansil, Zachariah and Zachariah 2011
Chiromantis cherrapunjiae (Roonwal and Kripalani 1966)
Chiromantis doriae (Boulenger 1893)
Chiromantis dudhwaensis (Ray 1992)
Chiromantis senapatiensis (Mathew and Sen 2009)
Chiromantis shyamrupus (Chanda and Ghosh 1989)
Chiromantis simus (Annandale 1915)
Chiromantis vittatus (Boulenger 1887)
Ghatixalus asterops (Biju, Roelants and Bossuyt 2008)
Ghatixalus variabilis (Jerdon 1854)
Kurixalus naso (Annandale 1912)
Mercurana myristicapalustris Abraham, Pyron, Ansil, Zachariah and Zachariah 2011
Philautus dubius (Boulenger 1882)
Philautus garo (Boulenger 1919)
Philautus jerdonii (Günther 1876)
Philautus kempiae (Boulenger 1919)
Philautus kempii (Annandale 1912)
Philautus microdiscus (Annandale 1912)
Philautus namdaphaensis Sarkar and Sanyal 1985
Philautus sanctisilvaticus Das and Chanda 1997
Philautus similipalensis Dutta 2003
Polypedates assamensis Mathew and Sen 2009
Polypedates insularis Das 1995
Polypedates maculatus (Gray 1830)
Polypedates megacephalus Hallowell 1861
Polypedates occidentalis Das and Dutta 2006
Polypedates pseudocruciger Das and Ravichandran 1998
Polypedates subansiriensis Mathew and Sen 2009
Polypedates taeniatus (Boulenger 1906)
Polypedates teraiensis (Dubois 1987)
Pseudophilautus amboli (Biju and Bossuyt 2009)
Pseudophilautus kani (Biju and Bossuyt 2009)
Pseudophilautus wynaadensis (Jerdon 1854)
Raorchestes agasthyaensis Zachariah, Dinesh, Kunhikrishnan, Das, Raju, Radhakrishnan, Palot and Kalesh 2011
Raorchestes akroparallagi (Biju and Bossuyt 2009)
Raorchestes anili (Biju and Bossuyt 2006)
Raorchestes annandalii (Boulenger 1906)
Raorchestes beddomii (Günther 1876)
Raorchestes bobingeri (Biju and Bossuyt 2005)
Raorchestes bombayensis (Annandale 1919)
Raorchestes chalazodes (Günther 1876)
Raorchestes charius (Rao 1937)
Raorchestes chlorosomma (Biju and Bossuyt 2009)
Raorchestes chotta (Biju and Bossuyt 2009)
Raorchestes chromasynchysi (Biju and Bossuyt 2009)
Raorchestes coonoorensis (Biju and Bossuyt 2009)
Raorchestes crustai Zachariah Dinesh Kunhikrishnan, Das, Raju, Radhakrishnan, Palot and Kalesh 2011
Raorchestes dubois (Biju and Bossuyt 2006)
Raorchestes flaviventris (Boulenger 1882)
Raorchestes glandulosus (Jerdon 1854)
Raorchestes graminirupes (Biju and Bossuyt 2005)
Raorchestes griet (Bossuyt 2002)
Raorchestes kadalarensis Zachariah, Dinesh, Kunhikrishnan, Das, Raju, Radhakrishnan, Palot and Kalesh 2011
Raorchestes kakachi (Seshadri, Gururaja and Aravind 2012)
Raorchestes jayarami (Biju and Bossuyt 2009)
Raorchestes johnceei Zachariah, Dinesh, Kunhikrishnan, Das, Raju, Radhakrishnan, Palot and Kalesh 2011
Raorchestes kaikatti (Biju and Bossuyt 2009)
Raorchestes luteolus (Kuramoto and Joshy 2003)
Raorchestes manipurensis (Mathew and Sen 2009)
Raorchestes manohari Zachariah, Dinesh, Kunhikrishnan, Das, Raju, Radhakrishnan, Palot and Kalesh 2011
Raorchestes marki (Biju and Bossuyt 2009)
Raorchestes munnarensis (Biju and Bossuyt 2009)
Raorchestes nerostagona (Biju and Bossuyt 2005)
Raorchestes ochlandrae (Gururaja Dinesh Palot Radhakrishnan and Ramachandra 2007)
Raorchestes ponmudi (Biju and Bossuyt 2005)
Raorchestes ravii Zachariah, Dinesh, Kunhikrishnan, Das, Raju, Radhakrishnan, Palot and Kalesh 2011
Raorchestes resplendens (Biju, Shouche, Dubois, Dutta and Bossuyt 2010)
Raorchestes sahai (Sarkar and Ray 2006)
Raorchestes shillongensis (Pillai and Chanda 1973)
Raorchestes signatus (Boulenger 1882)

Raorchestes sushili (Biju and Bossuyt 2009)
Raorchestes terebrans (Das and Chanda 1998)
Raorchestes theuerkaufi Zachariah, Dinesh, Kunhikrishnan, Das, Raju, Radhakrishnan, Palot and Kalesh 2011
Raorchestes thodai Zachariah, Dinesh, Kunhikrishnan, Das, Raju, Radhakrishnan, Palot and Kalesh 2011
Raorchestes tinniens (Jerdon 1854)
Raorchestes travancoricus (Boulenger 1891)
Raorchestes tuberohumerus (Kuramoto and Joshy 2003)
Raorchestes uthamani Zachariah, Dinesh, Kunhikrishnan, Das, Raju, Radhakrishnan, Palot and Kalesh 2011
Rhacophorus bipunctatus Ahl 1927
Rhacophorus burmanus (Andersson 1939)
Rhacophorus calcadensis Ahl 1927
Rhacophorus kio Ohler and Delorme 2006
Rhacophorus lateralis Boulenger 1883
Rhacophorus malabaricus Jerdon 1870
Rhacophorus maximus Günther 1858
Rhacophorus pseudomalabaricus Vasudevan and Dutta 2000
Rhacophorus rhodopus Liu and Hu 1960
Rhacophorus subansiriensis Mathew and Sen 2009
Rhacophorus suffry Bordoloi Bortamuli and Ohler 2007
Rhacophorus translineatus Wu 1977
Rhacophorus tuberculatus (Anderson 1871)
Theloderma andersoni (Ahl 1927)
Theloderma asperum (Boulenger 1886)
”*Theloderma*” *moloch* (Annandale 1912)
Theloderma nagalandense Orlov Dutta Ghate and Kent 2006

ORDER CAUDATA

Family Salamandridae

Tylototriton verrucosus Anderson 1871

ORDER GYMNOPHIONA

Family Caeciliidae

Gegeneophis carnosus (Beddome 1870)
Gegeneophis danieli Giri, Wilkinson and Gower 2003
Gegeneophis goaensis Bhatta, Dinesh, Prashanth and Kulkarni 2007
Gegeneophis krishni Pillai and Ravichandran 1999
Gegeneophis madhavaorum Bhatta and Srinivasa 2004
Gegeneophis mhadeiensis Bhatta, Dinesh, Prashanth, and Kulkarni 2007
Gegeneophis ramaswamii Taylor 1964
Gegeneophis seshachari Ravichandran, Gower, and Wilkinson 2003
Indotyphlus battersbyi Taylor 1960
Indotyphlus maharashtraensis Giri, Wilkinson, and Gower 2003

Family Chikilidae

Chikila fulleri (Alcock 1904)

Family Ichthyophiidae

Ichthyophis alfredi Mathew and Sen 2009
Ichthyophis beddomei Peters 1880
Ichthyophis bombayensis Taylor 1960
Ichthyophis daribokensis Mathew and Sen 2009
Ichthyophis davidi Bhatta, Dinesh, Prashanth, Kulkarni and Radhakrishnan 2011
Ichthyophis garoensis Pillai and Ravichandran 1999
Ichthyophis husaini Pillai and Ravichandran 1999
Ichthyophis kodaguensis Wilkinson, Gower, Govindappa and Venkatachalaiah 2007
Ichthyophis khumhzi Kamei, Wilkinson, Gower and Biju 2009
Ichthyophis longicephalus Pillai 1986
Ichthyophis moustakius Kamei, Wilkinson, Gower and Biju 2009
Ichthyophis nokrekensis Mathew and Sen 2009
Ichthyophis sendenyu Kamei, Wilkinson, Gower and Biju 2009
Ichthyophis sikkimensis Taylor 1960
Ichthyophis tricolor Annandale 1909
Uraeotyphlus gansi Gower, Rajendran, Nussbaum and Wilkinson 2008
Uraeotyphlus interruptus Pillai and Ravichandran 1999
Uraeotyphlus malabaricus (Beddome 1870)
Uraeotyphlus menoni Annandale 1913
Uraeotyphlus narayani Seshachar 1939
Uraeotyphlus oommeni Gower and Wilkinson 2007
Uraeotyphlus oxyurus (Duméril and Bibron 1841)

Table 2. Measures of biodiversity of the physiographic zones in India (see Figure 1). Abbreviations are: AN, Andaman; DC, Deccan; EG, Eastern Ghats; HM, Himalayas; NE, Northeast; NI, Nicobar; NW, Northwest; TH, Trans-Himalayas, and WG, Western Ghats.

	AN	DC	EG	HM	NE	NI	NW	TH	WG
Species richness	10	17	21	35	129	11	12	10	171
Endemicity	3	1	3	6	50	2	0	3	159
Per cent endemicity	33.3	5.9	14.3	17.1	38.8	18.2	0.0	33.3	93.0

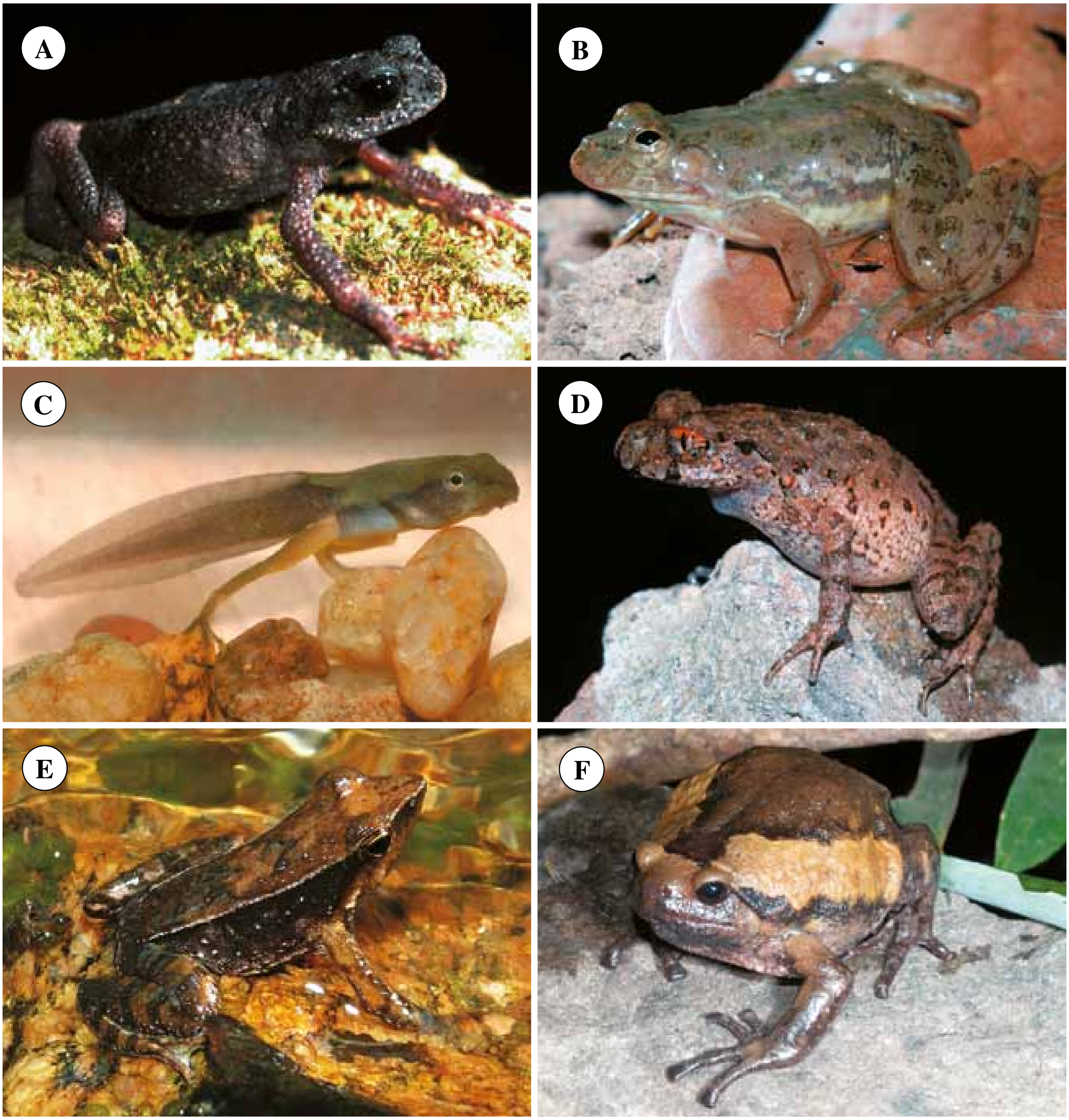

Fig. 2. Representatives of families of Indian frogs: **A.** Bufonidae: *Bufoides meghalayanus*; **B.** Dicroglossidae: *Euphlyctis cyanophlyctis*; **C.** Hylidae: *Hyla annectans*; **D.** Megophryidae: *Leptolalax khasiorum*; **E.** Micrixalidae: *Micrixalus fuscus*; **F**. Microhylidae: *Kaloula pulchra*. Photograph **E** by S. Harikrishnan; others by first author.

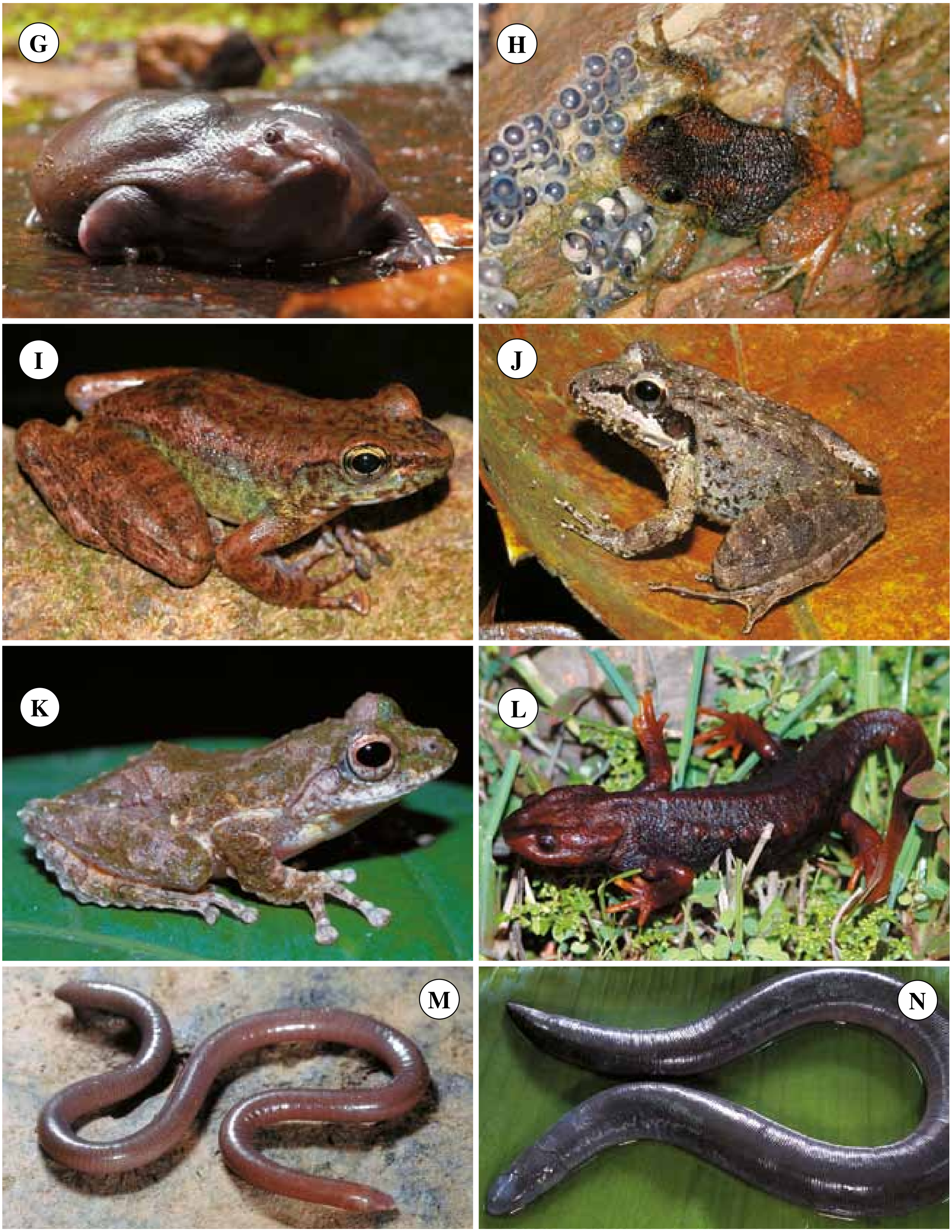

Fig. 3. Representatives of families of Indian frogs and salamander: **G.** Nasikabatrachidae: *Nasikabatrachus sahyadrensis*; **H.** Nyctibatrachidae: *Nyctibatrachus petraeus*; **I.** Ranidae: *Amolops assamensis*; **J.** Ranixalidae: *Indirana brachytarsus*; **K.** Rhacophoridae: *Chiromantis simus*; **L.** Salamandridae: *Tylototriton verrucosus*. Photographs **G** and **J** by S. Harikrishnan; **H** by K. Kunte; others by first author. Representatives of families of Indian caecilians: **M.** Caeciliidae: *Indotyphlus maharashtraensis*; **N.** Ichthyophiidae: *Ichthyophis bombayensis*. Photographs by A. Captain.

region, but still restricted to the country (country endemics), (3) widespread species whose ranges include India, and finally, (4) human commensals. The fauna of the islands of the Andamans and Nicobars also include regional endemics, in addition to widespread species, shared with adjacent landmasses. Table 2 indicates species richness and endemicity by region.

Endemicity is high: 227 species (69.2%) are endemic to India. The total number of genera restricted to the region is 15, of which five (*Beddomixalus*, *Melanobatrachus, Mercurana*, *Nasikabatrachus,* and *Chikila*) are monotypic. As expected, more endemic species are found in areas of high species diversity, although species-rich northeastern India has a lower endemicity (38.8%) than do the Western Ghats (93%), presumably because the former region abuts the contiguous tropical forests of Yunnan in southeastern China and northern Myanmar. Regional endemics among amphibians tend to have restricted ranges even within physiographic regions (such as within a single drainage or common to two or more drainages in close proximity to each other) and/or are habitat specific. It is predicted that many species currently thought to occur in more than a single physiographic region are part of cryptic species complexes, with each species having a restricted range. Several monotypic Indian amphibian taxa currently are suspected of harbouring unnamed lineages; these include *Nasikabatrachus* (see Dutta *et al*. 2004) and *Bufoides* (see Das *et al*. 2009).

Distinctive patterns of species radiation are shown by several amphibian lineages, including *Ramanella* (six species from the Western Ghats, two additional species from Sri Lanka), *Indirana* (nine species from the Western Ghats), *Nyctibatrachus* (15 species from the Western Ghats), *Uraeotyphlus* (seven species from the Western Ghats) and *Gegeneophis* (eight species from the Western Ghats). The four tropical moist-forest zones in the region host high species diversity of amphibians: Western Ghats (171), Northeast (129), and Himalayas (35). For its large land surface, the Deccan has relatively few species (17), but the islands of the Andamans and Nicobars in the Bay of Bengal are considered to be species rich (10 and 11 species, respectively), and additional species remain to be described. On the mainland, the Eastern Ghats (18), the Northwest (11), and the Trans-Himalayas (10) have the lowest amphibian species diversity in respect to land area, although low figures for the Eastern Ghats now appear to be the result of inadequate sampling. A small number of amphibian species are considered human commensals, their distribution being linked to habitats created by humans (Inger and Dutta 1986). These include *Duttaphrynus melanostictus*, *Microhyla ornata*, *Euphlyctis cyanophlyctis*, *Fejervarya limnocharis*, *Hoplobatrachus tigerinus*, and *Polypedates maculatus*. One species (*F. cancrivorus*) is saline tolerant; its distribution in coastal areas of eastern India is not linked to any physiographic region recognized here, although it also occurs in the Nicobar Islands, and has been counted in the faunal list of the archipelago.

Widespread species tend to be habitat generalists. Recent genetic research on a number of widespread species (e.g., Kuramoto *et al*. 2007; Inger *et al*. 2009), however, has revealed hitherto unrecognized cryptic diversity within such groups. Species-groups within the following complexes in India probably contain more than one taxonomically cryptic species, the resolution of whose identities would increase regional and national endemicity and would also have important implications for conservation: *Duttaphrynus melanostictus*, *Euphlyctis cyanophlyctis*, *Fejervarya cancrivora*, *F. limnocharis*, *F. nicobariensis*, *F. syhadrensis*, *Limnonectes kuhlii*, *L. laticeps*, *Sphaerotheca breviceps*, *Xenophrys parva*, *Kaloula baleata*, *K. pulchra, K. taprobanica*, *Microhyla berdmorei*, *M. butleri*, *Micryletta inornata*, *Amolops gerbillus*, *Clinotarsus alticola*, *Hylarana danieli*, *H. erythraea*, *H. malabarica*, *H. nicobariensis*, *H. nigrovittata*, *H. raniceps*, *Polypedates leucomystax*, *P. maculatus,* and *Theloderma asperum*. Perhaps not coincidentally, the list includes most of the species previously designated as human commensals.

II. THREATS TO AMPHIBIANS

A. Destruction and Fragmentation of Habitat

An ecological history of India can be found in a publication by Gadgil and Guha (1995). Effective protected areas in India range from sacred groves and forests maintained by the local landowners as catchment areas for the usually larger reserve forests, wildlife sanctuaries, and national parks. However, the Protected Areas (PA) system, as recognized by the government, includes only the areas under the control of the central government or state governments. The total protected area in India in 1970 was 25,000 km^2 and included 10 National Parks and 127 Wildlife Sanctuaries. The figure went up to 132,000 km^2, 66 National Parks, and 421 Wildlife Sanctuaries in 1991, and by 2004, was 156,700 km^2, or roughly 4.95% of the total surface area of the country. An increase to 5.6 per cent of the country's land area (to 183,000 km^2) has been recommended by the Wildlife Institute of India (Rodgers and Pawar 1988).

Threats to the integrity of the PA system include logging for timber or other products (Fig. 4), denotification by the State itself for timber, mineral extraction, construction of dams, industries, hotels, settlement, and aquaculture, in addition to illegal overfishing, cattle grazing, sand and coral mining, encroachment on forest land, and armed insurrection movements. Mining and quarrying, activities that tend to take place within, or in close proximity to, forested areas, are known to affect amphibian populations (Krishnamurthy and Hussain 2004).

Management problems within many reserves in India are acute for a number of reasons, including (1) the high dense human populations outside the area that had traditionally depended on the reserve for a variety of products, such as fuel-wood, thatch grass, medicinal plants, game and fish, and even leaf-litter for use as fertilizers (Daniels 1991), (2) organized poaching, and (3) removal of other valuable forest products, such as sandalwood and medicinal plants. Many reserves continue to have human settlements, even within the core area and all protective rules may be flouted. Deforestation itself is a serious problem, with 91,700 km^2 of forests being lost between 1972 and 1982. The annual deforestation rate, currently 642,041 km^2, is twice that of Indonesia, the pressures on forests arising from exploitation for fuel-wood, timber, and other forest products. Plantations established in about half of India's PA system for a variety of uses, including commercial reasons, convert primary forests to timber or pulpwood plantations of usually fast-growing, exotic tree species. These are known to adversely affect the native biotas, resulting in changes in species composition and, sometimes, in extinction. India's cattle population — the world's largest — constitutes a threat to forests through overgrazing. Cattle also compact soil through trampling, leading to reduced infiltration of rainwater, or may decrease depth of penetration of water. Deciduous forests are transformed into semi-desert scrub through the activities of cattle.

Over the past four decades, however, the destruction of forests in India has been largely due to state-sponsored subsidized supply of resources and services to organized industry and the more affluent landholders. Rapid urbanization, as the influx from rural areas to India's cities continues, and even accelerates, is another major problem, resulting in rapid changes in features of the landscape. Effects of this movement of the human population that are relevant to amphibian conservation include destruction of wetlands and other bodies of water, and development of highways through amphibian habitats; these constitute a known cause of mortality among amphibians (Seshadri *et al*. 2009).

The legal instruments for the protection of PA are the Indian Wildlife (Protection) Act of 1972 and the Indian Forest (Conservation) Act of 1980. The latter, a part of the country's constitution, restricts the powers of the states' use of land, especially in converting forestland to non-forest use. The utilization of wetlands at least seasonally adds an additional ingredient to habitat conservation of amphibians, i.e., anthropogenic pressure on seasonal wetlands and standing water that are turned into more permanent bodies of water (typically containing fishes, frequently predators of larval amphibians). Seglie *et al*. (2003) mentioned that the single most important threat to the Indian salamander, *Tylototriton verrucosus*, in eastern India is draining of its wetland habitats for conversion of land for agricultural use. Other threats to this species include extraction of water for household use or for agriculture, and perhaps also, grazing by cattle, which loosens soil, causing siltation (Dasgupta 1990).

B. Exploitation for Export of Frogs' Legs

Reported declines of Indian amphibians traditionally have been attributed to the harvesting of frogs for export of their legs to the West (Abdulali 1985; Oza 1990), a practice that was banned in 1987. During the peak of the trade, the country earned Rupees 120,000,000 (equivalent to *ca*. US$ 2.6 million at the time) by way of export of 3000–4000 tonnes of froglegs that resulted in the harvest of an estimated 6000 tonnes of frogs belonging to three species: *Hoplobatrachus crassus, H. tigerinus,* and *Euphlyctis hexadactylus* (Abdulali 1985).

Fig. 4. Deforestation on a hill slope caused by removal of native vegetation for slash-and-burn agriculture in the East Khasi Hills, Meghalaya State, northeastern India. Photograph taken by the first author in March 2009.

Fig. 5. Jorepokhri in the Darjeeling Hills, eastern India, established in 1985 as a salamander sanctuary for India's only salamander, *Tylototriton verrucosus*. Creation of a concrete embankment, introduction of exotic carp and waterbirds, and diversion of water for supply to nearby towns have contributed to the local extirpation of this species. Photograph taken in 2006 by K. Deuti.

C. Harvesting for Local Consumption

A variety of uses of frogs and salamanders in India for traditional medicine and other forms of consumptive use by indigenous people has been documented (see Das 2012). The Vedic period saw use of unspecified species of frogs that were "stripped like reeds and bound with red and blue threads to beds in which folks 'possessed by demonic force' were made to lie" (Filliozat 1943; Zysk 1985). The Indian *material medica* prescribes the flesh of *Duttaphrynus melanostictus* for treatment of gonorrhoea, tuberculosis, and leprosy (Nadkarni 1955). Unani medicine too made a number of uses of frogs for healing, including the cure of wounds, toothaches, piles, inflammation, and other ailments (Vohora and Khan 1978).

Usage by indigenous folks range from exploitation of various species for food, e.g., *D. melanostictus, Euphlyctis cyanophlyctis* (Borah *et al*. 2001), *Hoplobatrachus crassus* (Pillai 1986), *H. tigerinus* (Bodding 1940), *E. hexadactylus* (George 1995), *Fejervarya limnocharis* (Das 1998), and *Tylototriton verrucosus* (Selim 2001; Das 1997); for medicine, for example *D. melanostictus* (Chandi 2006), *E. cyanophlyctis* (Kiyasetuo 1986), and *H. tigerinus* (Negi and Palyal 2007). Tadpoles of several species are also consumed in some places, e.g., *F. limnocharis, Nanorana liebigii,* and *Hyla annectans* (Ao 1986). Froglegs are also in demand in certain urban areas, such as Kerala, where they are sold as snacks accompanying toddy (an alcoholic drink made from the sap of the palm) (Andrews and George 1998).

D. Use in Biological Experimentation and Scientific Study

Until the end of the Twentieth Century, biological supply houses all over India sold untold millions of frogs for practical classes in zoology. In southern India, it was *Euphlyctis hexadactylus* and *Hoplobatrachus tigerinus*, in the north, *H. tigerinus*. Currently, large numbers of *Duttaphrynus melanostictus* are sacrificed for biology practicals in high school science classes (Mullick *et al*. 1999). Another species in high demand is the Indian salamander, *Tylototriton verrucosus*, which is collected from the Darjeeling area for supply, especially to university and college museums throughout the country, as a representative of the Order (Dasgupta 1990).

E. Pet Trade

Adult native Indian amphibian species do not seem to feature in the domestic or international pet trade. The exception is the occasional collection of larval *Clinotarsus curtipes*, perhaps as a by-catch of the ornamental freshwater fish trade, for sale in pet shops in Singapore (K.K.P. Lim, personal observations). As a regional hub for the tropical fish trade, a number of fish species are bred in India for export. A product of this trade, the African frogs, *Hymenochirus curtipes* and *H. boettgeri*, originally from the Congo, were bred in India for export (Ballengée 2000). None of these species is protected under CITES, which lists two Indian amphibian species, *Euphlyctis hexadactylus* and *Hoplobatrachus tigerinus*, under Appendix II (CITES 2010). An Appendix-II listing included species threatened with extinction, that are, or may be, affected by trade.

F. Chemical Pollution

Amphibian populations worldwide are known to be affected by environmental contaminants, in large part due to their permeable skin, and but also through their diets and via pulmonary routes (Smith *et al*. 2007). The use of organochlorines and other pesticides has increased exponentially over the past five decades, in order to improve crop levels by controlling pests, especially in India (Mehrotra 1985), and makes the country high on a list of lower-bound estimates of annual release of toxins (Table 3). The shores of bodies of standing as well as of flowing water, and other low-lying areas that become waterlogged, generally are classified as suitable for crops like high-yield rice, and tend to require pesticides. These chemicals may be dispersed throughout an area and become absorbed by a variety of organisms. Patil and Saidapur (1989) reviewed the effects of pollution on Indian vertebrates, and concluded that heavy metals and pesticides severely reduce the reproductive potential of species, leading to, in extreme cases, their complete elimination from affected areas.

Experimental work in laboratories has demonstrated sensitivity by a number of common Indian frogs to a great variety of industrial and agricultural chemicals, including pesticides, fungicides, weedicides, and heavy

Table 3. Lower-bound estimates of annual release of toxins in India and other southern Asian countries. Source: World Resources Institute (1994).

Rank in World	Country	Aquatic organisms' risk of exposure	Year
10	India	1450.1	1986
37	Pakistan	120.2	1984
42	Bangladesh	42.4	1986
56	Sri Lanka	10.6	1987

Table 4. Pollutants and anthropogenically altered environments known to adversely affect Indian amphibians. Note that other species are likely affected. The species listed are merely those that were tested, typically the most abundant locally available frogs.

AGENT	SPECIES STUDIED AND SHOWN TO BE AFFECTED	AUTHORITY
CHEMICALS		
Aldrin	*Hoplobatrachus tigerinus*	Alka *et al*. (1988)
Cadmium	*Duttaphrynus melanostictus*	Biswas *et al*. (1976)
	Hoplobatrachus tigerinus; *Euphlyctis hexadactylus*	Ramaswami (1976); Pramoda and Saidapur (1986); Kasinathan *et al*. (1987)
Carbaryl (Sevin)	*Hoplobatrachus tigerinus*	Marian *et al*. (1983); Deshmukh and Keshhavan (1987); Sampath and Elango (1997)
Chromium	*Hoplobatrachus tigerinus*	Abbasi and Soni (1984)
Cyclophosphamide	*Duttaphrynus melanostictus*	Chakrabarti and Banerjee (2007)
Dichlorodiphenyltricloro-ethane (DDT)	*Euphlyctis hexadactylus; Hoplobatrachus tigerinus*	Chetty *et al*. (1978); Deshmukh and Keshhavan (1987)
Dimecron	*Polypedates maculatus*	Andrews and George (1994)
Dimethoate	*Duttaphrynus melanostictus*	Pandey and Tomar (1985)
Dipterex	*Euphlyctis cyanophlyctis*	Sing *et al*. (1976)
Ekalux	*Euphlyctis cyanophlyctis*	Alam (1989)
Emisan-6	*Euphlyctis hexadactylus*	Kumar (1997)
Endosulfan	*Euphlyctis hexadactylus*; *Duttaphrynus melanostictus*	Andrews and George (1991); Mathew and Andrews (2003)
Endrin	*Euphlyctis hexadactylus*	Mathur and Rane (1979)
Ethylenethiourea	*Microhyla ornata*	Ghate (1986)
Folithion	*Hoplobatrachus tigerinus*	Mohanty-Hejmadi and Dutta (1981)
Furadan	*Euphlyctis hexadactylus*	Andrews and George (1991)
Heavy metals	*Sphaerotheca breviceps*; *Microhyla ornata*; *Duttaphrynus melanostictus*	Mahajan and Juneja (1979); Rao and Madhyastha (1987); Khangarot and Ray (1987)

AGENT	SPECIES STUDIED AND SHOWN TO BE AFFECTED	AUTHORITY
Hinosan	*Polypedates maculates*; *Duttaphrynus melanostictus*	Mathew and Andrews (1999); Mathew and Andrews (2001)
Lead	*Microhyla ornata*	Ghate (1985)
Lindane	*Duttaphrynus melanostictus*	Datta and Lahiri (1986)
Malathion	*Hoplobatrachus tigerinus*; *Euphlyctis hexadactylus*; *Fejervarya limnocharis*	Mohanty-Hejmadi and Dutta (1981); Andrews and George (1991); Gurushankara *et al.* (2007)
Mercurial fungicides	*Euphlyctis cyanophlyctis*	Kanamadi and Saidapur (1992a)
Mercuric chloride	*Microhyla ornata*; *Euphlyctis cyanophlyctis*	Ghate and Mulherkar (1980); Kanamadi and Saidapur (1991, 1992b)
Methyl parathion	*Hoplobatrachus tigerinus*;	Kennedy and Sampath (2001)
Metacid	*Euphlyctis cyanophlyctis*; *Hoplobatrachus tigerinus*	Alam (1989); Mohanty-Hejmadi and Dutta (1981)
Metasystox	*Hoplobatrachus tigerinus*	Mohanty-Hejmadi and Dutta (1981)
Mitomycin	*Duttaphrynus melanostictus*	Chakrabarti and Banerjee (2007)
Organophosphate fungicides	*Duttaphrynus melanostictus*	Mathew and Andrews (2003)
Phosalone	*Hoplobatrachus tigerinus*	Anthony and Ramalingham (1990); Balasundaram *et al.* (1995)
Rogor	*Hoplobatrachus tigerinus*	Mohanty-Hejmadi and Dutta (1981)
Sumithion	*Microhyla ornata*	Pawar and Katdare (1983)
EFFLUENTS		
From dairies	"*Bufo bufo*", presumably *Duttaphrynus melanostictus*	Chockalingam and Balaji (1991)
From distilleries	*Hylarana malabarica*; *Euphlyctic hexadactylus*	Haniffa *et al.* (1985); Andrews *et al.* 1990
From dye factories	*Microhyla ornata*	Ghate *et al.* (1978)
From urban sewage	*Duttaphrynus stomaticus*; *Euphlyctis cyanophlyctis*; *Hoplobatrachus tigerinus*; *Sphaerotheca breviceps*	Sharma (1994)
Detergents	*Euphlyctis hexadactylus*	George and Andrews (1997)
ANTHROPOGENICALLY ALTERED ENVIRONMENTAL CONDITIONS		
Increased acidity, including simulated acid rain	*Hoplobatrachus tigerinus*; *Microhyla ornata*	Abbassi *et al.* (1989); Padhye and Ghate (1988)
Elevated carbon dioxide	*Nyctibatrachus major*	Gururaja *et al.* (2003)
Lowered dissolved oxygen	*Duttaphrynus stomaticus*	Mahapatro and Dash (1990)
Increased salinity	*Microhyla ornata*	Chakko (1968); Ghate *et al.* (1996)
Elevated temperature	*Euphlyctic hexadactylus*	Gunasekhar *et al.* (1988)

metals as inventoried in Table 4. These noxious chemical are pervasive and are distributed widely. It is likely that they may interact synergistically, or in other complex ways in influencing the welfare of amphibians (Heatwole 2013).

In contrast to laboratory studies, there appear to be few studies assembling empirical data on the negative effects of these chemicals in free-living amphibians in India. There is no reason to expect, however, that amphibians would respond less markedly to toxins in the field than they do in the laboratory and the occurrence of morphological abnormalities in amphibians from the central Western Ghats in areas where chemical fertilizers and pesticides are used, suggest that amphibians are being affected in nature (Gurushankara *et al*. 2007). Cultivation of tea not only has replaced once pristine forests, but is also known for its heavy dependence on pesticides that have been implicated in amphibian declines at one locality (Daniels 2003).

G. Other Threats

Introduced amphibian species, especially the cane toad, *Rhinella marina,* and the Taiwanese Bull Frog, *Hoplobatrachus rugulosus*, have been implicated in several amphibian declines in southeastern Asia and elsewhere (Lever 2001), via predation and competition and as carriers of the disease chytridiomycosis, caused by the chytrid fungal pathogen, *Batrachochytrium dendrobatidis*. There are no known naturalized species of frogs in India at present (and no records of introductions of *Hymenochirus*, despite its local breeding). However, a number of introduced fish species, particularly *Gambusia affinis* and *Oreochromis mossambicus,* are known predators of anurans (Ghate and Padhye 1988; 1996; Padhye and Ghate 2002) and *Cyprinus carpio* preys on India's sole salamander species, *Tylototriton verrucosus,* in the Darjeeling area (Kuzmin *et al*. 1994; Dasgupta 1997). Raghavan *et al*. (2008) reported the wide distribution of a number of introduced species within otherwise pristine areas of forest within the Western Ghats, and speculated on the negative consequences of this naturalization on the survival of indigenous species both of frogs and fishes. Introduction of exotic trees (such as *Cryptomeria japonica*) has also been associated with the decline of *T. verrucosus* in eastern India (Kuzmin *et al*. 1994).

Additional ways in which amphibians may be endangered include: loss of wetlands, effect of acid precipitation (especially in industrial areas), increased ultraviolet radiation, global climatic change, disease resulting from reduction in functioning of the immune system, and introduction of chytrid fungus into local amphibian populations. Further research on these topics is deemed critical.

III. CONSERVATION

The Indian Wildlife (Protection) Act of 1972 (amended several times, the last being 2003), which forms the legal instrument for protection of all wildlife species throughout India (except Jammu and Kashmir, which has its own laws) lists two categories of amphibians, without specifying species' names, under Schedule IV: *Rana* spp. and *Nectophrynoides* spp. Currently, the intended species within *Rana* (*sensu lato*) are distributed over the genera *Hoplobatrachus, Euphlyctis,* and others, while those within *Nectophrynoides* (currently including species restricted to Tanzania) are members of the bufonid genus *Pedostibes*. The intention of inclusion of amphibians in the Act was presumably to use legislation to stop over-harvesting of the former group, and to add importance to the conservation of the second group, which is restricted to wet forests. Nonetheless, a number of threatened species of Indian amphibians are not covered under the Act. Anecdotal reports (e.g., Padhye and Ghate 2002) indicate that the ban on froglegs and on collection for teaching has led to the revival of populations of some species, such as *H. tigerinus* in Maharashtra State.

The IUCN Red List (IUCN 2010) lists no Indian amphibian species, although the Global Amphibian Assessments, completed in 2004, have designated 63 species as threatened, representing 27% of the country's amphibian fauna (Chanson *et al.,* 2008).

Conservation activities needed for enhancing survival of India's highly diverse amphibian fauna range from improving legislation regarding its protected areas system, including stemming fragmentation and enhancing protection of areas under state control; protection of special habitats, including wetlands; and decreasing use of such areas by humans, through curtailing poaching, tree felling, grazing, and, sometimes, ecotourism. Management of forestland needs to take into account the importance of retaining primary forests, especially in areas of intensive agriculture, such as slash-and-burn cultivation and monocultures (Pawar *et al*. 2004). Outside protected areas, the use of pesticides and the disposal of other harmful chemicals need to be restricted or scientifically managed.

Given the patchiness in distribution and the differences in diversity among drainages, designation of protected areas needs to take into account the distributions of individual species/lineages in order to minimize risk of extinction. Identification of centres of high species diversity and/or endemicity is thus critical for selection and design of reserves (Das 2002). Currently, the only protected area that has been specifically established for protection of a particular species is for the Indian salamander, *Tylototriton verrucosus*, at Jorepokhri, in the Darjeeling area of eastern India; it is protected only at the state level. However, extensive development, including the use of concrete and introduction of carp and geese, have rendered the site unsuitable for salamander reproduction (see Fig. 5), and the Sanctuary is currently in the process of denotification (K. Deuti, personal communication). Networks of protected areas need to be established to protect all threatened species of Indian amphibians, with the long-term goal of maintaining viable populations of all species. This is especially true for the Western Ghats, which harbours numerous ancient and endemic lineages of amphibians.

Field guides and other resources for identification are available for some regional faunas, including the Western Ghats (Daniel 1963a,b, 1975; Daniel and Sekar 1989; Daniels 2005) and Northeast India (Chanda 1994), and one covers the national fauna (Chanda 2002). All are justifiably outdated given the rapid accretion of species and taxonomic changes at the generic and familial levels; see Abraham *et al*. (2013) for a recent example). Larval stages tend to be poorly known relative to the post-metamorphic stages, for reasons of matching tadpoles to their corresponding adult stages and the difficulties in collecting the larval stages (Das and Dutta 2007). Within Indian amphibians, caecilians remain more poorly understood as a group; the last revision of the Gymnophiona by Pillai and Ravichandran 1999 (also see Bhatta 1998) was outdated with the discovery of a number of new taxa both from the Western Ghats and Northeast India (Gower *et al*. 2004; Kamei *et al*. 2009).

Field surveys to inventory the fauna of the biodiversity hotspots and of other areas are of high priority; many important forested areas have never been visited by scientific personnel, and only partial inventories exist for some other areas. Even rapid assessments of such sites are of value, and long-term sampling has the potential to unearth rare species as well as those that are new to science (see Ao *et al*. [2003] for an example for northeastern India, and Inger *et al*. [1984] for an example from the Western Ghats). Published distributional records also need to be critically evaluated, given the frequent lack of voucher specimens and the existence of cryptic species (i.e., more than one biological species) within what is considered a single, variable, and widespread species.

There are few reported declines of amphibians from pristine areas, perhaps because of the scarcity of field investigations; no monitoring programme has been established as of the middle of 2013. Regionally coordinated monitoring of amphibian populations, using standardized methods (and hence, comparable between sites and over time) is required to address the question of whether amphibian populations in the country are stable or on the decline. Data are also required that are species-specific — including such aspects of natural history as home ranges, movement, breeding phenology, larval developmental stages, structure of natural communities, population genetics, microhabitat use, diet, and other ecological associations. Current knowledge of amphibians from other countries reveal the importance of such information relative to conservation, including the role of fragmentation and habitat loss in stochastic extinctions, importance to conservation of metapopulations, and the spread of chytrid fungus through naturalized frogs or from visitors.

Harvesting for food and other uses need to be monitored, and controlled for some populations showing decline. In such cases, alternate sources both of income and protein need to be explored. Frog farming is a possibility, as espoused by Mondal (1970) for the largely folivorous *Euphlyctis hexadactylus*.

Ramachandran and Oomen (2008) mentioned that caecilians are perceived as deadly and are killed upon encounter in parts of the Western Ghats. Nonetheless, traditional beliefs centred around amphibians are by and large positive vis-à-vis conservation, ranging from prohibition as food, including the abstinence from consumption of frog meat (Sen Gupta 1956), to the establishment of sacred groves and protection of forested landscapes (Gadgil and Vartak 1975). Numerous discoveries of new species of amphibians have been conducted in forests protected by indigenous peoples of India (see Das *et al*. 2010).

Finally, public education on the importance of amphibian conservation is deemed a necessity. Such activities can be provided near areas of frog harvest in rural areas, and also in urban areas, where decision-makers tend to reside, emphasizing the role of amphibians, including pest control (Agoramoorthy 2009) and other ecological functions. Conservation will be effective only when conservation plans draw upon the man on the street to protect India's great diversity of frogs, toads, and caecilians and its sole salamander species.

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