

# Status and Distribution of Amphibians in the Andaman & Nicobar Island Archipelago

## Abstract

The Andaman & Nicobar Island Archipelago in the Bay of Bengal harbour a unique herpetofauna. We surveyed 23 islands across this archipelago, using a combination of methods, to estimate species richness, abundance, and distribution of amphibians. We recorded 17 species of frogs from these islands. Despite low species richness, frog densities were generally high but with high variability. Seven species were found to be endemic to the Archipelago, with five of them endemic to the Andaman Islands. Using the data on abundance, distribution, and natural history observations, we examine the conservation status of amphibians in these islands and the potential threats faced by them. We also illustrate some of the taxonomic issues that can hamper ecological studies and conservation efforts, and stress the need for taxonomic revisions for many taxa.

## Introduction

Islands have had a major role in developing our understanding of the origin of biodiversity. Small islands have low species richness of most taxa due to the combined effects of isolation from source habitats, small geographic area, relatively young age of islands, and stochastic disturbance events on habitats. These factors create relatively simpler ecosystems (compared to continents) where ecological and evolutionary phenomena are often stark. However, most islands are not considered as hotspots of amphibian biodiversity. Majority of amphibian species are dependant on fresh water at some stage of their lives, a resource that is scarce in most small islands. Immigration of organisms to islands happen through active (across land bridges, flying, or swimming) or passive (rafting on flotsam, floating islands, or wind) dispersal. Almost all amphibian species have hygroscopic skin and are highly intolerant to salinity. This makes dispersal across ocean barriers a highly unlikely event for most amphibian species. More than anything else, this could be the single most

important factor restricting the diversity of amphibians in islands. However, several recent studies have provided evidence for multiple oceanic dispersals by amphibians (Bell et al. 2015; de Queiroz 2005; Vences et al. 2003). Thus, many isolated islands harbour small but unique amphibian fauna. As the phylogenetic species concept finds widespread acceptance, it is likely that many isolated island populations of species that are currently considered as widespread species will be recognized as evolutionarily distinct lineages. Identification of such island lineages as distinct species will result in a marked increase in the number of

Higher elevation in saddle peak supports stunted wet evergreen forest.

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endemic island amphibian species. This is true in the case of the largest island archipelago system in India, the Andaman & Nicobar Islands.

### The Andaman & Nicobar Island Archipelago

The Andaman & Nicobar Islands consist of 556 islands, islets, and rocks, covering 8249 km<sup>2</sup>, situated in the eastern part of the Bay of Bengal (Anonymous 2007). These islands are part of a chain of mountains sprawling in a great arc between Cape Negrais in Myanmar and Achin Head in Sumatra about 155 km southeast of Great Nicobar Island. The length of the island chain itself is about 1126 km (Biswas & Sanyal 1980; Das 1999; Smith 1940). It is a part of the Great Alpine-Himalayan System (Karunakaran et al. 1968). The northward movement of the Indian tectonic plate, opening the Andaman Sea with its outer arc overriding the Indian plate, lead to the emergence of these islands (Lee & Lawver 1995). Thus, they are 'plate-boundary islands' and are highly tectonically active (Whittaker & Fernández-Palacios 2007). Cenozoic plate reconstructions of Southeast Asia indicate that the emergence of these islands above sea level happened only during the late Miocene (10 million years before present) and the present configuration was achieved about 5 - 10 million years ago (Lee & Lawver 1995). The Mentawai Islands off the coast of Sumatra appear to be a continuation of the Nicobar Islands (Weeks et al. 1967; Rodolfo 1969). While the Nicobar Islands appear to be truly oceanic in nature, surrounded by deep channels, the Andaman Islands at their northern tip might have been connected to mainland Asia during the Pleistocene (Ripley & Beehler 1989). The mean annual rainfall in these islands exceeds 3000 mm. The highest amount of rainfall is in southernmost islands with no distinct dry season, whereas the northern islands show greater seasonal variation (Biswas & Sanyal 1980, Das 1999).

Owing to this high precipitation and their tropical location, the predominant vegetation type in these islands is wet evergreen forest. There are 11 major forest types in these islands (Champion & Seth 1968). These are: 1) Giant evergreen forest 2) Andaman tropical evergreen forest 3)



Southern hilltop tropical evergreen forest 4) Cane brakes 5) Wet bamboo brakes 6) Andamans semi evergreen forest 7) Andamans moist deciduous forest 8) Andamans secondary moist deciduous forest 9) Littoral forest 10) Tidal swamp forest 11) Submontane hill valley swamp forest (Champion & Seth 1968). These islands form parts of two global biodiversity hotspots: the Andaman Islands are a part of the Indo-Burma hotspot and the Nicobar Islands are part of the Sundaland hotspot (Myers et al. 2000).

Based on their origin and connectivity in the past, these islands can be divided into two major groups: the Andaman Islands in the northern part and the Nicobar Islands in the southern part. Ten Degree Channel, named so for the latitude at which it is located, separates these island groups. This channel is about 1000 m deep and approximately 140 km wide. This has ensured that the Andaman Islands and the Nicobar Islands remained separated from each other even during maximum sea level drops during the Pleistocene (Lee & Lawver 1995). The deep Andaman Sea on the east separates this island chain from Southeast Asia and The Bay of Bengal separates it from the Indian subcontinent.

Towards the north, Great Coco Island which is the northern-most island in the Andamans (geologically) is separated from Preparis Island which is located on the outer continental margin of Southeast Asia, by a channel about 76 km wide and approximately 500 m deep. The distance between Cape Negrais of Myanmar and Great Coco Island is about 215 km, although

Red-eared frog *Hylarana erythraea* from Great Nicobar island – this species is not been recorded post-tsunami survey in Nancowry group.

the sea is less than 100 m deep along most of this separation. The northernmost island in the Andamans administered by India is Landfall Island, which is about 40 km southwest of Little Coco Island. The highest peak in the Andaman and Nicobar Archipelago is Saddle Peak, which reaches 732 m above mean sea level (hereafter asl), and is in North Andaman Island.

Narcondam and Barren are the easternmost islands in the Andaman Islands, though they are volcanic in origin and have never had land connection with other islands in the Andamans. North Sentinel Island is the westernmost island in the Andamans.

Within Andamans, there are further divisions such as North Andaman, Middle Andaman, Baratang, and South Andaman, which, together with numerous adjoining islands are called Great Andamans. A major hill range occurs on the northeast part of south Andaman, comprising of several peaks such as Mt. Harriet (365 m asl), Mt. Carpenter (373 m asl), Mt. Goodridge (377 m asl), Mt. Koyob (460 m asl), Mt. Hext (424 m asl) and Mt. Warden (422 m asl) (Das 1997; Das 1999). Ritchie's Archipelago is a cluster of islands situated towards the east of Great Andamans. The southernmost island in the Andamans is Little Andaman Island, about 140 km north of Car Nicobar Island. Little Andaman is approximately 55 km south of South Andamans. Everywhere within the Andaman Islands, with the exception of Barren and Narcondam, the sea is relatively shallow (50-100 m), which means that all these islands were interconnected during major sea level changes in the Pleistocene.

The Nicobar Islands consist of 23 islands south of the Ten Degree Channel. The total land area of these islands is 1841 km<sup>2</sup>. Three clusters of islands can be identified in this group. The northern cluster consists of only two islands, Car Nicobar and Batti Malv. The central cluster is collectively known as Nancowry group consisting of ten islands. Sombrero Channel separates the Nancowry group from the southern cluster consisting of Great Nicobar, Little Nicobar, and nine much smaller islands. Great Nicobar is the southernmost island in this group and is only about 300 km northwest of Sumatra. The Great Channel between Great Nicobar and Sumatra is more than 1000 m deep, which rules out any possibility of land

connections in the recent past.

Car Nicobar is a relatively flat island with a maximum elevation of 30 m. It is also the most densely populated island and coconut plantations and orchards dominate the landscape. Patches of evergreen forests occur intermittently throughout the island. Nancowry group is hillier; Maharani Peak in Tillangchong Island reaches about 300 m asl. Islands in the Nancowry group also have evergreen forests, though in many areas, they have been replaced by secondary forest. They also support extensive grasslands on hilltops. Islands in the southern group have lower human population density and are extensively covered in wet evergreen forests. Mt. Thullier in Great Nicobar is the highest peak in the Nicobar Islands, reaching about 642 m asl.

### Amphibians of the Andaman & Nicobar Islands

Herpetological exploration in the Andaman & Nicobar Islands started in the middle of the 19th century when the Austrian 'Novara' expedition collected natural history specimens from several islands in this archipelago (Steindachner 1867). The first amphibian species recorded from these islands was the toad *Docidophryne spinipes* Fitzinger 1861 "1860" from the Nicobar Islands, currently considered as a synonym of *Duttaphrynus melanostictus* (Schneider, 1799). This was followed by the discovery of *Hylorana nicobariensis* Stoliczka, 1870 (current name *Amnirana nicobariensis* (Stoliczka 1870)). In the same paper, Stoliczka also described *Rana gracilis* var.

Indian bull frog *Hoplobatrachus tigerinus*, an invasive species that has established itself in north, middle and south Andaman.



*andamanensis* Stoliczka, 1870 and *Rana gracilis* var. *nicobariensis* Stoliczka, 1870, which are both currently considered as valid species under the genus *Fejervarya* Bolkay, 1915 (*Fejervarya andamanensis* & *Fejervarya nicobariensis*). Following these early discoveries, the amphibian fauna of these islands remained largely unstudied. Smith (1940) reported the presence of only four species of frogs from these islands, including *Rana doriae* (= *Limnonectes doriae*). Post 1947, there were fresh attempts at collection and exploration of biodiversity in these islands. The first Microhylid frog described from these islands, *Kaloula baleata ghoshi* Cherchi, 1954 was described from Little Andaman Island. This was followed by the description of a second species of Microhylid endemic to these islands, *Microhyla chakrapanii* Pillai, 1977 along with a single record of *Micryletta inornata* (Boulenger, 1890) (Pillai 1977). Whitaker (1978) reported the presence of nine species of frogs from these islands, including *Rana erythraea* Schlegel, 1837 (= *Hylarana erythraea*), *Rana tigerina* Daudin, 1802 (= *Hoplobatrachus tigerinus*), *Rana breviceps* Schneider, 1799 (= *Sphaerotheca breviceps*) and *Microhyla rubra* (Jerdon, 1854), though the last two species have not been recorded in the islands since and was probably based on specimens of other species. Though a new species of toad, *Bufo camortensis* Mansukhani & Sarkar, 1980 was described from Camorta in the Nicobar Islands, it is now considered a synonym of *Duttaphrynus melanostictus* (Schneider, 1799) (Crombie 1986; Mansukhani & Sarkar 1980). Das (1996a) added *Rana chalconota* (Schlegel, 1837) (= *Chalcorana chalconota*) to the amphibian fauna of Great Nicobar, while also mentioning that the population belonged to the subspecies *R. chalconota raniceps* (Peters, 1871). In the 1990s, three new species of frogs were discovered from the Andaman & Nicobar Islands. *Polypedates insularis* Das, 1995 and *Limnonectes shompenorum* Das, 1996 were described from Great Nicobar Island, while *Rana charlesdarwini* Das, 1998 (= *Ingerana charlesdarwini*) was described from Mt. Harriet National Park in South Andaman Island (Das 1995; Das 1996b; Das 1998). Das (1999) listed 19 species of anuran amphibians from these islands based on collections, and dispelled several

misidentifications. There were doubtful records of *Hoplobatrachus tigerinus*, a species thought to be introduced deliberately by humans from mainland India into the Andaman Islands as early as 1978 (Whitaker 1978). Recently, the occurrence and spread of this species was confirmed in the Andaman Islands (Harikrishnan & Vasudevan 2013). Most recently, an endemic, semi-arboreal Bufonid, *Blythophryne beryet* Chandramouli et al. 2016 was described from the Andaman Islands. This is the only amphibian genus endemic to the Andaman & Nicobar Islands (Chandramouli et al. 2016). These islands do not have any caecilian and salamander species.

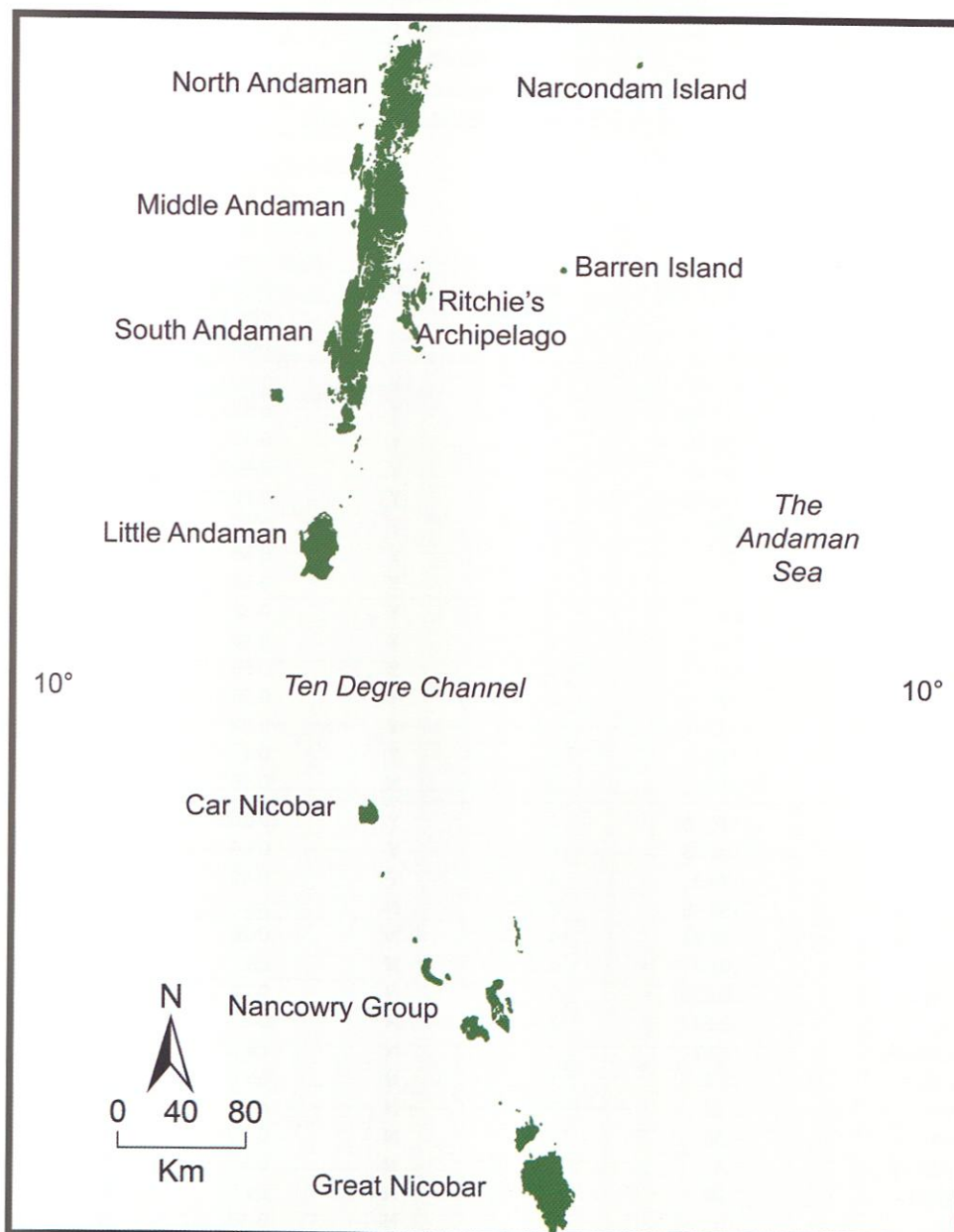
Most studies of amphibians in these islands have been rapid surveys or anecdotal records of species. So far, there is little information on abundance, distribution, and status of these species. At least one species, *Ingerana charlesdarwini*, is listed as a Critically Endangered species by IUCN, based on its supposed restricted distribution in Mt. Harriet and Saddle Peak National Parks. In this study, we surveyed 23 islands in the Andaman & Nicobar Islands for presence and abundance of amphibian species.

## Methods

Geographic distribution of amphibian and reptile species in Andaman & Nicobar Archipelago was assessed through both field surveys and secondary sources (museum specimens and literature). Field surveys were carried from October to June, avoiding peak monsoon. This is a weakness of studies in these islands due to extreme logistical difficulties in small islands during the monsoon season. To assess the presence of species in each island quadrat surveys (see below), visual encounter surveys (VES) and pitfall traps with drift fences were used. Each VES was one hour long, where we walked the forests at a slow pace looking for amphibians after sunset (between 6 p.m. and 9 p.m.). Pitfall traps with drift fences were only attempted in four islands due to logistic constraints. These were 25 cm × 30 cm buckets buried in the ground with the rim flush with the ground, and a 30 cm high plastic sheet erected vertically above them to act as a drift fence. A few holes, small

enough to prevent animals escaping but large enough for the passage of water, were put at the bottom of the buckets to drain rainwater. A 20 m long plastic sheet was used as drift fence with buckets placed at 5 m intervals. The bottom of the fence was buried in the soil to prevent animals slipping under it. These were checked twice a day and any animal found in the buckets was captured, identified, and released slightly away from the fence. Pitfall traps were not attempted in all islands as they were labour intensive and provided very few unique records. Any species found opportunistically was also recorded. We also

used the locality data of specimens in the collection of Zoological Survey of India, Kolkata and Zoological Survey of India, Port Blair. In addition, we used published literature to obtain data on distribution of species. From all such records, distribution of species across islands and species richness in each island was enumerated. Fifteen islands in the Andaman Islands were surveyed from March 2010 to December 2012. Eight islands in the Nicobar Islands were surveyed thus from March 2008 to March 2009, from December 2012 to May 2013, and from December 2013 to February 2014. For other islands, data from secondary sources were used.



**Figure 1:** The Andaman & Nicobar Islands with major islands labelled. North of Ten Degree Channel, the islands are collectively called the Andaman Islands, and south of it are the Nicobar Islands.

To estimate abundance of amphibian species, we sampled bounded quadrats of dimension 10 m × 10 m (Harikrishnan & Vasudevan 2015). These were demarcated with a 50 cm high plastic sheet erected to prevent the escape of animals during sampling. The procedure was modified from Rodda et al. (2001) and explained in detail in Harikrishnan et al. (2015). All herbaceous vegetation and leaf litter on ground was removed and examined carefully for amphibians. Quadrats were only sampled in evergreen and semi-evergreen forests and therefore did not sample species that were found in other habitats (wetlands, marshes, ponds etc).

### Results

We recorded 17 species of amphibians during our field surveys. Species were identified in the field using descriptions in published literature. Due to the lack of taxonomic clarity in many species descriptions, some species are tentatively

identified and some could only be identified to genus level. We recorded 9 species of frogs from the Andaman Islands and 10 species of frogs from the Nicobar Islands. Two species of frogs, *Duttaphrynus melanostictus* and *Fejervarya cancrivora*, occurred in both the island groups. Species richness increased with increasing island size in both the island groups ( $\text{Log } S = 0.25\text{log}A + 0.13$ ,  $R^2 = 0.59$ ,  $F = 32.33$ ,  $df = 22$ , where  $S$  is species richness and  $A$  is island area). Many small islands did not have amphibians, and there was greater variation in species richness in small islands compared to large islands (Fig. 2). Small islands had amphibians only when they were close to larger islands (e.g. Alexandra). Species richness was also influenced by the presence of human habitations in large islands, through anthropogenic introduction of species. Species richness of individual islands is summarized in Table 1.

**Table 1:** Summary of species richness of amphibians in various islands in the Andaman & Nicobar Archipelago. (\* Species occurrence data from past surveys). Abbreviations: BQ – Bounded Quadrats sampled, Y – Yes, N – No, na – Not Available (where secondary data was used).

	Island	Area (km <sup>2</sup> )	Species richness	BQ	Surveyed elevation range	Perennial fresh water
Andaman Islands	North Andaman	1375.99	7	Y	0-700	Y
	South Andaman	1350.82	11	Y	0-350	Y
	Little Andaman	734.39	6	Y	0-131	Y
	Rutland	137.17	6	Y	0-400	Y
	Havelock	113.93	4	Y	0-66	Y
	Neil Island	18.9	4	Y	0-29	Y
	Long Island	17.9	7	Y	0-56	N
	Tarmugli	11.5	1	Y	0-33	N
	Alexandra	3.6	3	Y	0-32	Y
	Hobday	3.6	1	Y	0-48	N
	Redskin	3.3	1	Y	0-53	N
	Boat	2.8	0	Y	0-30	N
	Snob	0.22	0	Y	0-33	N
	Chester	0.09	0	Y	0-7	N
	Grub	0.03	0	N	0-15	N
Nicobar Islands	Great Nicobar	1044.54	9	Y	0-203	Y
	Camorta	188.03	4	Y	0-50	Y
	Katchal	174.3	4	Y	0-53	Y
	Little Nicobar*	159.02	6	N	na	Y
	Car Nicobar	126.91	4	N	0-20	Y
	Tarasa*	101.4	4	N	na	na
	Nancowry	66.82	3	N	0-20	Y
	Trinkat	36.26	3	N	0-10	N
	Tillangchong*	16.83	3	N	na	na
	Bompoka*	13.3	1	N	na	na
	Chowra*	8.28	0	N	na	na
	Kondul	4.66	1	N	0-10	N
	Menchal	1.5	1	N	0-5	N
	Pilo Milo*	1.29	4	N	na	N
	Pigeon	0.5	0	N	0-10	N



**Nicobar Islands**

	CAR	CHO	BOM	TIL	TAR	KAT	TRI	CAM	NAN	PIL	LNI	MEN	KON	PIG	GNI
<i>Duttaphrynus melanostictus</i>	+		+	+	+	+	+	+	+	+	+		+		+
<i>Microhyla heymonsi</i>												+			+
<i>Fejervarya cf. nicobariensis</i>	+				+	+	+	+	+						
<i>Fejervarya cancrivora</i>												+			+
<i>Limnonectes shompenorum</i>											+	+	+		+
<i>Limnonectes sp.</i>															+
<i>Hylarana erythraea</i>	+			+	+	+	+	+							+
<i>Amnirana nicobariensis</i>	+			+	+	+		+	+	+	+				+
<i>Chalcorana cf. chalconota</i>															+
<i>Polypedates insularis</i>											+	+			+

1 – These species were reported by earlier authors based on specimens. They were not recorded in our surveys.

2 – Introduced species, which seems to have established in the Andaman Islands.

Forty-five bounded quadrats were sampled in the Andaman Islands and 16 in the Nicobar Islands, recording 302 and 34 individuals respectively. The bounded quadrats used in the analyses are only those from islands where amphibians occurred, as inferred from quadrats, or any other methods (VES, opportunistic records, historical records etc). Average density of frogs in evergreen forests was  $720 \pm 102$

individuals/ha in the Andaman Islands, and  $210 \pm 190$  individuals/ha in the Nicobar Islands. Frogs occurred at low abundance in many small islands, but this could be an artifact of the sampling period mostly covering post-monsoon and dry seasons. There is a large variation in abundance among quadrats, indicating the possibility of patchy or clustered distribution of individuals (Table 3). Therefore, the

Stream in a rain forest in Great Nicobar island



abundance estimates reported here for individual species may not reflect the true population abundance. The most abundant species in quadrats was *Limnonectes cf. doriae* ( $455 \pm 913$  individuals/ha). This species was abundantly recorded in leaf litter in evergreen and semi evergreen forests in the Andaman Islands. In the Nicobar Islands, the most abundant species was *Amnirana nicobariensis* ( $125 \pm 161$  individuals/ha) (Table 3). Several species of frogs were not recorded in quadrats, such as the arboreal *Polypedates insularis*, even though they were encountered commonly in other habitats.

## Discussion

### Species richness & distribution of amphibians

Our survey recorded 17 species of frogs across the Andaman & Nicobar Islands. This included the new species *Blythophryne beryet* (Chandramouli et al. 2016). The two species of Microhylids that we did not encounter are known only from single specimens. During post monsoon and summer months when the surveys were conducted, they occurred in low abundances. While quadrat surveys enabled the estimation of densities of rainforest species, other methods will have to be employed to estimate population sizes of species inhabiting other habitats. *Ingerana charlesdarwini*, a species considered as Critically Endangered (IUCN, 2014), was the second most abundant species of frog in evergreen forests in Andaman Islands where it occurred, with average density of  $129 \pm 277$  individuals/ha. This species was also more widespread than previously recorded, occurring in at least ten islands. There are unsurveyed areas in Middle Andaman Island where this species could potentially occur. It should be noted that this is based on the assumption that individuals that were morphologically similar to the description of *Ingerana charlesdarwini* belonged to that species. Further taxonomic studies are necessary to determine whether all the islands harbour the same species or multiple cryptic species. In the Nicobar Islands, *Amnirana nicobariensis* was the most abundant

species in evergreen forests ( $125 \pm 161$  individuals/ha), while *Duttaphrynus melanostictus* was the most widespread species, occurring in almost all habitats. The high variability of all abundance estimates for frogs indicate a patchy distribution of amphibians in forests in the Andaman & Nicobar Islands. Therefore, improving the precision of abundance estimates might require a cluster sampling based approach.

### Conservation status of amphibians in islands

There are seven species of frogs that are endemic to the Andaman & Nicobar Islands (Table 3) (Fig. 3). All these species, even those occurring in multiple islands, have distribution ranges of less than 5000 km<sup>2</sup>. At least three of these, *Blythophryne beryet*, *Ingerana charlesdarwini*, and *Polypedates insularis* are primarily forest species, not recorded in human modified landscapes. *I. charlesdarwini* is the only species currently considered as Critically Endangered, though with its relatively high local abundance, it might be possible to lower the threat status classification of this species. Two species, *Fejervarya nicobariensis* and *Polypedates insularis*, are currently considered endangered based on their very small geographic distribution. The endemic *Microhyla chakrapanii* and the non-endemic *Limnonectes doriae* are data deficient species. Majority of other frog species occurring in the Andaman & Nicobar Islands are considered Least Concern (Table 3). *Hylarana erythraea*, a Least Concern species inhabiting ponds and wetlands, was recorded from southern group of islands in the Nicobars, and Car Nicobar Island, but not in the Nancowry group of islands. A survey conducted prior to the tsunami of December 2004 found these frogs in Nancowry group as well, but there have been no further records (Vijayakumar 2005; Vijayakumar & Choudhury 2006; Harikrishnan et al. 2011). We conducted surveys in the Nancowry group in October-December 2008, March-April 2013, and again in January 2014, but failed to record this species. Inundation of coastal habitats is thought to be the reason behind the decline or local extinction of this species in the Nancowry group.

Figure 3: Seven endemic amphibians of Andaman & Nicobar Islands and one potential endemic: a) *Blythophryne beryet*, b) *Kaloula baleata ghoshi*, c) *Microhyla chakrapanii*, d) *Ingerana charlesdarwini*, e) *Fejervarya cf. andamanensis*, f) *Fejervarya cf. nicobariensis*, g) *Polypedates insularis*, h) *Cholcorana cf. chalconota* (originally reported as the subspecies 'raniceps', its taxonomic status needs further study).



(a)



(b)



(c)



(d)



(e)



(f)



(g)



(h)

Species	Density/ha	Distribution in A&N	Range size	Habitat specificity	IUCN status	WPA (1972)
<i>Duttaphrynus melanostictus</i>	17.8±65.0, 6.4±3	21 (A&N)	Wide	Broad	LC	NL
<i>Blythophryne beryet</i>	51.1±127.3	5 (AND)	Narrow	Specific	NA	NL
<i>Kaloula baleata ghoshi</i>	2.2±14.9	6 (AND)	Narrow	Broad	NA	NL
<i>Microhyla chakrapanii</i>	11.1±38.3	7 (AND)	Narrow	Broad	DD	NL
<i>Microhyla ornata</i>	-	1 (AND)	Wide	-	LC	NL
<i>Micryletta inornata</i>	-	1 (AND)	Wide	-	LC	NL
<i>Microhyla heymonsi</i>	12.5±34.2	2 (NIC)	Wide	Broad	LC	NL
<i>Fejervarya cf. andamanensis</i>	2.2±14.9	3 (AND)	Narrow	Broad	LC	NL
<i>Fejervarya cf. nicobariensis</i>	31.3±87.3	6 (NIC)	Narrow	Specific	EN	NL
<i>Fejervarya cancrivora</i>	2.2±14.9	4 (A&N)	Wide	Broad	LC	NL
<i>Ingerana charlesdarwini</i>	128.9±277.7	10 (AND)	Narrow	Specific	CE	NL
<i>Limnonectes shompenorum</i>	12.5±34.2	4 (NIC)	Narrow	Specific	LC	NL
<i>Limnonectes sp.</i>	25.1±57.7	1 (NIC)	Narrow	Specific	NA	NL
<i>Hoplobatrachus tigerinus</i>	-	3 (AND)	Wide	Broad	LC	Sch IV
<i>Limnonectes doriae</i>	455.6±913.2	10 (AND)	Wide	Broad	DD	NL
<i>Hylarana erythraea</i>	-	7 (NIC)	Wide	Specific	LC	NL
<i>Amnirana nicobariensis</i>	125.1±161.3	9 (NIC)	Wide	Broad	LC	NL
<i>Chalcorana cf. chalconota</i>	-	1 (NIC)	Wide	Specific	LC	NL
<i>Polypedates insularis</i>	-	3 (NIC)	Narrow	Specific	EN	NL

Probably the most important cause of species extinctions in island habitats is invasive species. Ali (2006; 2003; 2004) first drew attention to the problem of invasive species in the Andaman Islands, by listing several such species and demonstrated the negative impact of chital (*Axis axis*) and elephants (*Elephas maximus*) on natural vegetation in those islands where they occur. During our studies, we noticed that islands that had maximum signs of chital (pellets) had lowest abundances of understorey herpetofauna, while the only major island devoid of chital, i.e. Little Andaman Island, had highest density of understorey herpetofauna (Mohanty et al. 2016). Such reduction in abundance of herpetofauna due to the presence of introduced herbivores has also been reported elsewhere (Knox et al. 2012). A recent study found that chital drastically reduced the understorey vegetation in many small islands in the Andaman Islands, reducing the habitat quality leading to reduction in abundance of forest floor herpetofauna (Mohanty et al. 2016).

Indian bullfrogs (*Hoplobatrachus tigerinus*) seem to be recently introduced into the

Andaman Islands, perhaps deliberately for consumption. We found them to be abundant in parts of Mayabunder, Middle Andaman (Harikrishnan & Vasudevan 2013). Though Whitaker (1978) listed this species in a checklist of herpetofauna from the Andaman Islands, there were no further reports and none from other areas. We also recorded this species from South Andaman and North Andaman where it seems to have spread recently. This species has the potential to become a problematic invasive in the Andaman Islands. Its large size could enable this species to competitively exclude and predate on other frog species in the Andaman Islands. It is a prolific breeder and the population could increase rapidly. This species breeds in the beginning of the monsoon and the tadpoles are carnivorous, feeding on tadpoles of other species of frogs (Khan 1996). In mainland India, it is also known to feed on small snakes, lizards and rodents, all of which have numerous endemic species in these islands (Das 1999). It is a species protected by Wildlife (Protection) Act, 1972, Schedule IV Part II.

**Table 3:** Amphibians of the Andaman & Nicobar Archipelago, with an assessment of their conservation status.

### Taxonomic problems:

Three species of frogs, which have been reported from these islands, were not recorded during our surveys. *Limnnectes hascheanus* has been reported to occur in the Andaman & Nicobar Islands (Das 1999). However, Inger & Stuart (2010) in a review of this species and of *Limnnectes limborgi*, provided evidence that the former is restricted to southern parts of Malay Peninsula and expressed doubts on its occurrence in the Andaman & Nicobar Islands. We have not yet recorded any species that matched the redescription provided by Inger & Stuart (2010). *Microhyla ornata* and *Micryletta inornata* were also not recorded during this study and their presence in these islands require further confirmation.

One of the major obstacles for conducting population and community studies of amphibians in the Andaman & Nicobar Islands is the lack of taxonomic clarity for many species, making field identifications difficult and tentative. The small Dicroglossid frogs from the Andaman & Nicobar Islands present several taxonomic issues. The status of species such as *Fejervarya andamanensis*, *Fejervarya nicobariensis*, *Limnnectes hascheanus*, and *Limnnectes doriae* require further taxonomic studies. Another example is the species identified as *Chalcorana* cf. *chalconota* from Great Nicobar Island. Recent phylogenetic studies on this group of forest frogs indicated that they contained multiple, cryptic species in southeast Asia, and several island populations were identified as valid species (Oliver et al. 2015; Inger et al. 2009; Stuart et al. 2006). Das (1996a) reported *Chalcorana chalconota* (Schlegel 1837) (as *Rana chalconota*) from Great Nicobar Island, while mentioning that the individuals had diagnostic characters of the subspecies *R. chalconota raniceps* (Peters 1871). *Chalcorana raniceps* (Peters 1871) is currently considered as a valid species, but endemic to the island of Borneo (Inger et al. 2009). In their review of the systematic of frogs previously assigned to the species *C. chalconota*, Inger et al. (2009) restricted the range of *C. chalconota* sensu stricto to Java and South Sumatra, while also describing two new species, including

*C. rufipes* (Inger et al. 2009) from Western Sumatra. Frost (2017) lists the population from Great Nicobar as *C. labialis* (Boulenger, 1887), a species occurring in peninsular Malaysia. However, the population from Great Nicobar was not part of any of the recent reviews of this group, and it is impossible to assign this population to any of the currently recognized species.

### Conclusion

The Andaman & Nicobar Islands contain a small but unique amphibian fauna, with the potential for many more species to be recognized. They are also vulnerable to extinction due to their small distributional ranges and dependency on fresh water in island systems. Since the Andaman Islands are also a major tourism destination, spread of infectious diseases, such as Chytridomycosis that is considered responsible for the greatest disease-caused loss of biodiversity in recorded history, is also a potential threat to amphibians these islands (Skerratt et al. 2007). To create effective monitoring and conservation programmes for amphibian species in these islands, it is necessary to clarify the taxonomic issues regarding the identities of species in these islands.

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