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Occurrence of the lesser-known endemic *Rhinolophidae species* in the caves of the Andaman Islands, India: insights from a rapid survey

Dhanusha Kawalkar[1], Shirish S Manchi[1]*, Avimanyu J Mukherjee[1], Rima Sadhukhan[1], Pooja R Patil[1]

[1] Sálim Ali Centre for Ornithology and Natural History (South India Centre of Wildlife Institute of India), Anaikatty (P.O), Coimbatore - 641 108, Tamil Nadu, India

EDITED BY
Abhijit Das
Wildlife Institute of India, Dehradun, India.

*CORRESPONDENCE
Shirish S Manchi
ediblenest@gmail.com

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Abstract

The Andaman and Nicobar Islands host a unique diversity of cave-dwelling bat species, most of which remain understudied. We conducted a rapid assessment of the two lesser-known endemic Rhinolophidae bat species (*Rhinolophus andamanensis* and *Rhinolophus cognatus*) in 13 limestone caves in the North and Middle Andaman Islands (Baratang Island (n=5), Interview Island (n=4), and Chalis-Ek, North Andaman Island (n=4). We used passive acoustic recorders to document the occurrence of Rhinolophidae bats, sampling one cave at a time, from February 22, 2025, to March 4, 2025. After identifying the presence of each species in different caves, we performed a joint probability test followed by the chi-square test to confirm the results. Of the 13 study caves, at the three locations, five were exclusively occupied by *R. andamanensis*, two were occupied by *R. cognatus*, and both species were detected in six caves. The joint probability test indicated mutual exclusivity between both species and suggests thorough surveys for their population and distribution across the Andaman Islands. Based on the literature and the number of colonies detected, we estimate that the maximum population of *R. cognatus* can be about 400 individuals in 8 caves. It is the first focused survey, identifying caves harbouring the populations of the endemic and endangered *R. cognatus*. The study recommends prioritising the identified caves, strategising and initiating science-based conservation efforts for protecting the Threatened endemic *R. cognatus* and the subterranean cave habitats in the Andaman Islands.

Keywords: Bat conservation, cave-dwelling bats, cave prioritisation, island endemics, *Rhinolophus cognatus*

Introduction

Bats are among the most gregarious mammals, with diverse species roosting communally (Kelm *et al.*, 2021). The diurnal roosts of bats, such as tree cavities, rock crevices, abandoned buildings and caves, serve as resting places that shelter them from predation and extreme weather conditions (Kunz *et al.*, 2003). The communal roosts provide numerous benefits, including transfer of information, such as, food sources, roost sites, and other resources (Gager, 2019), interspecific social bonding, fitness benefits (Ancillotto *et al.*, 2015), and active predator deterrence (Knörnschild & Tschapka, 2012). These communal roosts are termed positive associations in cases where species pairs (or larger sets) occur at the same sites more often than expected by chance. On the other hand, negative associations or segregations or mutual exclusions occur when species tend to avoid one another (they are found at the same sites less often than expected by chance). Both these associations are collectively referred to as 'deviating', in the sense that they do not conform to random expectations (Pitta *et al.*, 2012). Several mixed-species roosts of bats are documented, deriving benefits from aggregation (Rodríguez-Durán, 1998; Korad, 2014; Barros & Bernard, 2023). Not many bat species, especially from the Rhinolophidae family, co-occur with their congenerics (Jiang *et al.*, 2008) and members of another genus, such as Hipposideridae (Struebig *et al.*, 2009). While ecologists have long focused on the coexistence of sympatric species (Jiang *et al.*, 2008), detailed information is lacking on species-specific roost selection, particularly among species in tropical communities (Kelm *et al.*, 2021). Islands in the tropics represent some of the most vulnerable ecosystems (Jones *et al.*, 2009). Given the natural fragility of these habitats, island biodiversity has been severely impacted both historically and presently by anthropogenic disturbances. According to Jones *et al.* (2009), bats form a major component of island biodiversity and are often the only native island mammals, playing critical roles in the terrestrial ecosystem for seed dispersal, pollination and also in the subterranean cave ecosystems for energy input (in the form of guano, and prey base). Despite the apparent importance of bats to island ecosystem functioning, little is known about the global distribution and status of island bat populations (IUCN, 2025).

The Andaman and Nicobar Islands (A&N Is) are rich in biodiversity, with 32 endemic mammal species and subspecies (Department of Environment & Forests, Andaman & Nicobar Administration 2026). Aul *et al.* (2014) documented 25 bat species across 13 genera in the A&N Is. Recently, Srinivasulu *et al.* (2017) reported a similar number of species along with the newly identified species Nicobar leaf-nosed bat (*Hipposideros ater*, Douangboubpha *et al.*, 2011) and Guillen's tube-nosed bat (*Murina guilleni*; Soisook *et al.*, 2013). Many of these species are cave-dwelling, occupying a vital ecological niche within island ecosystems. Additionally, the island flying fox (*Pteropus hypomelanus*) is widespread across the Andaman and Nicobar Islands, and several other regions of South-east Asia (Indonesia, Malaysia, Thailand, Vietnam); the Andaman Horseshoe Bat (*Rhinolophus cognatus*), and Homfray's Horseshoe Bat (*Rhinolophus andamanensis*) are endemic to the Andaman Islands. The Nicobar flying fox (*Pteropus faunulus*) and Nicobar leaf-nosed bat (*Hipposideros nicobarule*) are endemic to the Nicobar Islands (Chaturvedi, 1979; Menon, 2023). Given the high endemism and ecological sensitivity of island systems, cave-dwelling bats are crucial for the overall health of both island and cave ecosystems (Tanalgo *et al.*, 2022).

The only Rhinolophid bats known from the Andaman Islands are the endemic *Rhinolophus andamanensis* and *Rhinolophus cognatus*. *R. cognatus* is an Endangered species (IUCN, 2016) and is known to occur at a few locations in the Andaman Islands (Bates & Harrison, 1997; Aul, 2014). Based on surveys by Srinivasulu *et al.* (2017), their population ranges between 50 -200 individuals and is currently declining (Aul & Chakravarty, 2016). The *R. andamanensis* was misidentified as intermediate horseshoe bat (*R. affinis*) because of the morphological similarities. However, recently Srinivasulu *et al.* (2019), based on its taxonomic distinctiveness, recognised *R. andamanensis* as a separate species.

In the islands, *R. andamanensis* occurs with *R. cognatus*, diadem leaf-nosed bat (*Hipposideros diadema masoni*), Andersen's leaf-nosed bat (*H. gentilis*), grand roundleaf bat (*H. grandis*), and Horsfield's bat (*Myotis horsfieldii*). While the distribution of these species across the islands is documented to some extent (Aul *et al.*, 2014; Srinivasulu *et al.*, 2017), no studies have focused on identifying species-specific colony sites. Since *R. cognatus*, being an endemic and Endangered, is a priority species as part of the ongoing efforts to understand and conserve the lesser-known, overlooked subterranean cave habitats. Hence, we attempted to understand the occurrence of bats in the caves of the North and Middle Andaman Islands, with special emphasis on the endemic species. As both the Rhinolophidae members are endemic and only broad distribution information is available (Srinivasulu *et al.*, 2019), the present document is focused on discussing the initial findings regarding earlier unknown cave-wise occurrence of these species in our study area. The findings also contribute to identifying caves for conservation prioritisation.

Materials and methods

We conducted this rapid survey at three sites: Baratang Island, Chalis-Ek on North Andaman Island, and Interview Island in the North and Middle Andaman Islands district of the A&N Is (06° 45′ 9" N; 13° 41′ 9" N; 92° 12′ 9" E; 93° 57′ 9" E; Fig. 1). Baratang Island (12° 05′ N, 92° 45′ E), which has more than 175 caves within 0.77 km^2 between Wraffter's Creek (also mentioned as Rafter's Creek) and Naya Dera, possesses the largest known cave complex of the A&N Is. (Sankaran, 2001; Manchi & Sankaran, 2014; Mane *et al.*, 2019). Chalis-Ek, in North Andaman, as the vernacular name suggests, is believed to have 41 caves; however, only 30 caves have been explored on this limestone hillock (Manchi & Sankaran, 2009). Interview Island, the only identified simple carbonate island in the Andaman and Nicobar Islands (Kawalkar & Manchi, 2020), comprises 34 known caves (Manchi & Sankaran, 2014). Most caves at all three sites are protected between January and June to conserve the edible-nest swiftlet (*Aerodramus fuciphagus*).

The study was conducted from 22nd February 2025 to 4th March 2025 in randomly selected caves (n=13) accessible at all three sites (Baratang Island = 5, Interview Island = 4, and Chalis-Ek = 4). We used passive acoustic recorders (AudioMoth; ver. 1.10) to detect the presence of various bat species in the study caves, sampling one site at a time. Based on the known acoustics characters of *R. cognatus* and *R. andamanensis* (Srinivasulu *et al.*, 2017), we configured the Audiomoth with a sample rate of 250kHz and medium gain. The calls were recorded from 1800 hours to 0600 hours, with a 5min sleep and a 10min recording cycle to maintain a balance between data resolution, battery life and storage efficiency. The use of this duty cycle allowed for adequate temporal coverage of bat activity patterns without requiring excessive battery use or data redundancy. It was also chosen for optimal conditions, such as high humidity and temperature in caves, where frequent battery replacements are impossible. Once the bat calls were recorded, we used Kaleidoscope (5.6.8) to cluster the data. Raven Pro (Ver. 1.6) was used to analyse calls, extract the robust parameters (Frequency of Maximum Energy, FMAXE Srinivasulu *et al.*, 2025), prepare spectrogram (Fig. 2) required for scientific documentation and evidence generation. Some calls were subjected to Doppler shift compensation. Following Srinivasulu *et al.* (2017), only the pulses with a good signal-to-noise ratio were selected for identification. We used the joint probability (Zohuri *et al.*, 2022) test to calculate the independent probabilities of occurrence for *R. cognatus* and *R. andamanensis*, as well as their co-occurrence at the cave level. The following formulae 1&2 were used to estimate the probability of occurrence for both Species A (*R. andamanensis*) and B (*R. cognatus*) exclusively;

$$\frac{(\text{Number of caves occupied by only species A})}{(\text{Total caves surveyed})} \quad \text{(Formula 1)}$$

$$\frac{(\text{Number of caves occupied by only species B})}{(\text{Total caves surveyed})} \quad \text{(Formula 2)}$$

Probability of occurrence of both P(A) and P(B) together;

$$P(A \cap B) = \frac{(\text{Number of caves occupied by both species})}{(\text{Total caves surveyed})} \quad \text{(Formula 3)}$$

Probability of occurrence of both P(A) and P(B) independently, then,

$$P(A) \times P(B) \quad \text{(Formula 4)}$$

We used the chi-square test to confirm the results of the probability test. All the analyses were conducted using R ver. 4.6.0 in R Studio ver. 2024 12.1 .

Results

We encountered at least one Rhinolophidae species in all 13 randomly surveyed caves (Table 1). The FMAXE and call duration were measured from high-quality calls and used as key acoustic features for species identification. For *R. cognatus*, FMAXE ranges between 85.26 to 92.35 kHz, with a mean of 89.43±1.71 kHz, and call duration varied from 40.66 to 59.06 ms (Mean±SD: 50.86±6.45 ms). For *R. andamanensis*, FMAXE varied from 56.64 to 58.74 kHz, with a mean of 57.70±0.56 kHz, and call duration varied from 35.24 to 50.40 ms (Mean±SD 43.46±5.16 ms).

Of these, five caves were exclusively occupied by *R. andamanensis* (Fig. 3a), and two were occupied by *R. cognatus* (Fig. 3b). Both species were encountered sharing six caves. We conducted the Joint Probability Test to further understand the relative occurrence of these two endemic species.

Following the formulas 1-4, the probabilities of occurrence of the species:

$P(A) = (5)/(13) = 0.38$, $P(B) = (2)/(13) = 0.15$,

$P(A \cap B) = 6/13 = 0.46$ $P(A) \times P(B) = 0.38 \times 0.15 = 0.057$

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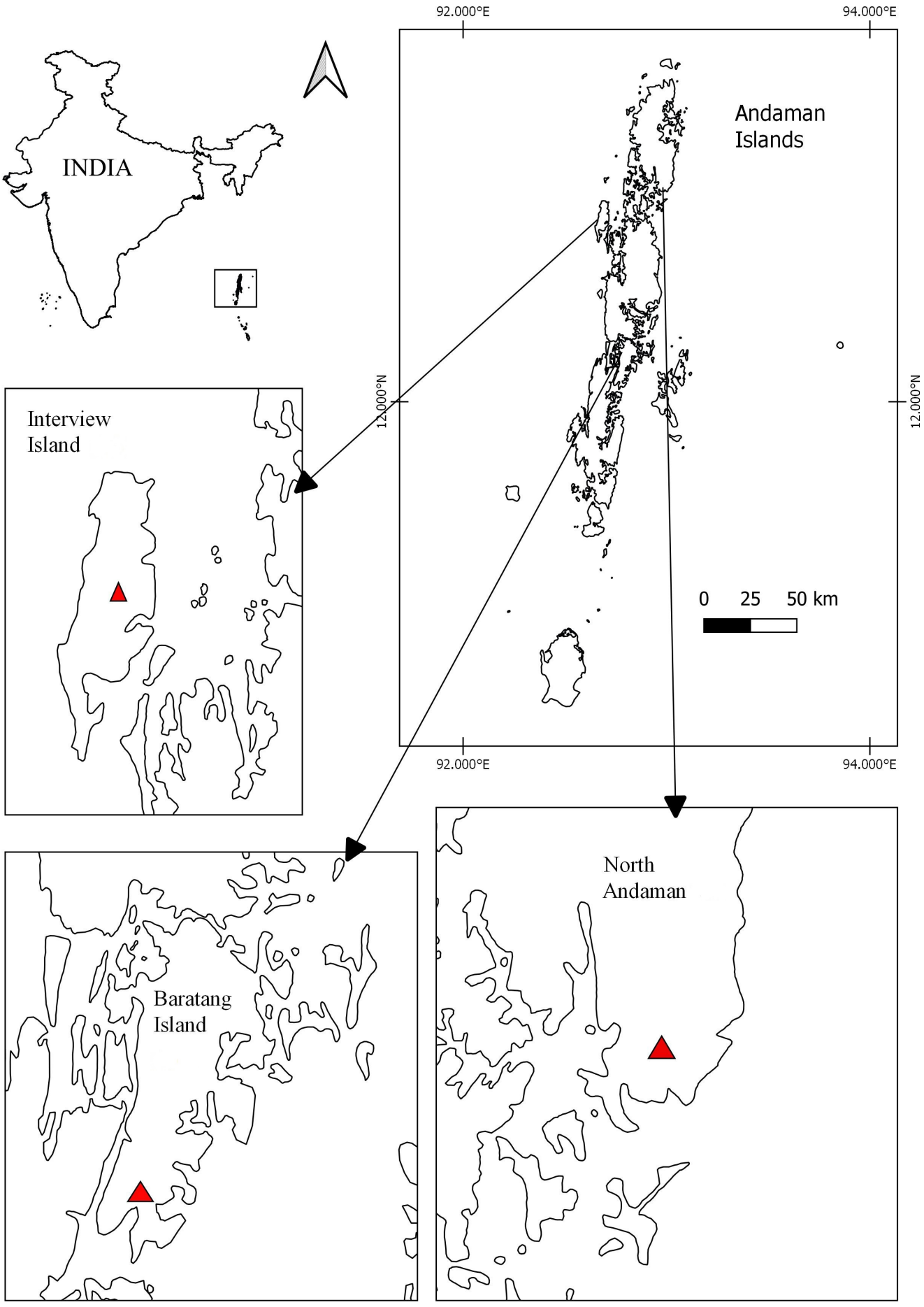


Figure 1. The geographical location of the Chalis-Ek, Interview and Baratang Islands

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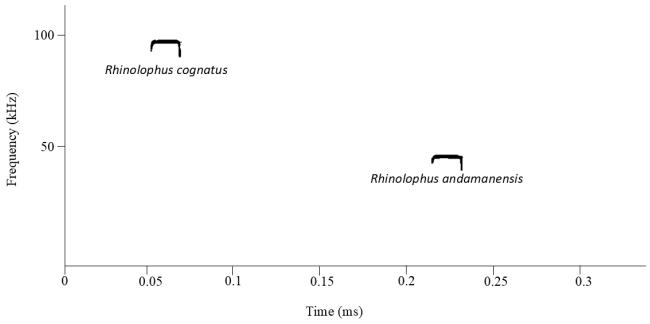


Figure 2. Spectrograms of (A) *R. andamanensis* (FMAXE range: 56.64 - 58.74 kHz, call duration- 35.24 - 50.40 ms) and (B) *R. cognatus* used for the identification of the species (FMAXE range: 85.26 - 92.35 kHz, call duration: 40.66 - 59.06 ms)

Table 1. Presence-absence data of Homfray's Horseshoe Bat (*Rhinolophus andamanensis*) and Andaman Horseshoe Bat (*Rhinolophus cognatus*) in different sampling locations in Andaman & Nicobar Islands.; the presence is denoted by ✓ and the absence is denoted by × , and the Cave IDs are given by the initials of the island names and number of the cave that is being sampled. (IN- Interview Island; CE- Chalis-EK; BT- Baratang Island)

S. No.	Cave ID	*R. andamanensis*	*R. cognatus*
1	IN 1	✓	✓
2	IN 2	×	✓
3	IN 3	✓	✓
4	IN 4	✓	✓
5	CE 1	✓	✓
6	CE 2	✓	✓
7	CE 3	✓	×
8	CE 4	✓	×
9	BT1	×	✓
10	BT2	✓	✓
11	BT3	✓	×
12	BT4	✓	×
13	BT5	✓	×

The output of the Joint Probability Test, P(A∩B) > P(A)xP(B), depicts that the congeneric species A (*R. andamanensis*) and species B (*R. cognatus*) do occur in the same caves. The Chi-square test, conducted to ratify the finding, further confirmed that the occurrence of these sympatric species is independent of each other and their occurrence in the same cave is by chance (p>0.05).

Following the estimate of Aul (2003) that *R. cognatus* colonies do not grow more than 50 individuals, we estimate the eight caves identified with the colonies can hold a maximum of 400 individuals (50×8=400) in the study caves.

Discussion

Globally, 28% of caves exhibit high bat diversity and are significantly threatened (Tanalgo *et al.*, 2022). Of the 16 cave-dwelling bats known from the Andaman Islands (Srinivasulu *et al.* 2017), the *R. cognatus* is listed in the Endangered category of the IUCN Red List due to its limited population with a declining trend (Aul & Chakravarty, 2016). The species is also among the seven most nationally important bat species listed in Schedule-I of Indian Wild Life (Protection) Amendment Act,



Figure 3. Photographic documentation of the (a) Homfray's Horseshoe Bat (*R. andamanensis*) in the Interview Island, (b) Andaman Horseshoe Bat (*R. cognatus*). The individual was found in one of the caves of the Baratang Island during the study. The photographs display distinct morphological characters. A Horse-shoe shaped nose leaf structure with three mental grooves and a pointed lancet, B Bifid structure of sella, C Pinna with a prominent antitragus in the front

2022. The roosting sites of this endemic and Endangered species and threats to this endemic species are unknown. The species is known to occur with the another endemic congeneric *R. andamanensis* which is considered relatively common compared to other cave-dwelling bat species in the Andaman Islands (Aul *et al.*, 2014). During the present study, of the 13, eight caves were identified harbouring populations of *R. cognatus*. Of these six caves, sheltering populations of *R. cognatus* were also occupied by *R. andamanensis*. The data further unveiled that the probability of occurrence of these congeneric Rhinolophus species (*R. cognatus* and *R. andamanensis*) is 46% and is mutually exclusive. This segregation indicates the randomness of their occurrence in the same cave.

Since, *R. andamanensis* is common in the islands, its presence can be attributed to its generalist characteristics (Furey *et al.*, 2020), such as roosting in available caves or caverns (Rodríguez-Durán, 2009). Species within genera often share similar roosting behaviours (Rodríguez-Durán, 2009), which may explain the co-occurrence of *R. andamanensis* and *R. cognatus* in six caves. This pattern is comparable to the concept known as "paradox of the plankton" (Hutchinson, 1978), which proposes that ecologically similar species can coexist within homogeneous environments due to temporal variation and subtle niche differentiation. In cave systems, such coexistence may be facilitated by differences in call frequencies, morphology, and roosting microhabitat, allowing both species to occupy the same caves with minimal competition. Salsamendi *et al.* (2012) documented that congeneric species coexist in the same roost, a pattern also observed in R. pearsoni and *R. affinis* by Jiang *et al.* (2008). In various studies (Jiang *et al.* 2008; Ashrafi *et al.*, 2011; Salsamendi *et al.*, 2012), it has been observed that bat species co-occur when there is low or no dietary overlap or niche separation. Detailed studies on *R. andamanensis* and *R. cognatus* can enhance our understanding of their trophic ecology and foraging habits. According to Scheffer & Van Nes (2006), various mechanisms such as predation, population dynamics, environmental

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variability, and disturbances help prevent competitive exclusion. Therefore, thorough investigations of both species, their habitat selection, and their interactions can aid in understanding the dynamics of co-occurrence or co-existence of the congeneric *R. cognatus* and *R. andamanensis*. As there have been no species-focused attempts to estimate population sizes and habitat requirements for *R. cognatus*, discussing the selection of caves or habitats by *R. cognatus* is currently challenging.

During 2013-14, R. Chakravarty (pers. obs.) did not encounter the *R. cognatus* around the previously known roosting locations in North Andaman, Interview Island, and Little Andaman (Aul, 2003). Furthermore, R. Chakravarty stated that this may be attributed to seasonality. Based on these observations, Aul & Chakravarty (2016) concluded that there is a declining trend in the species' subpopulations. Unlike Aul & Chakravarty (2016), the present study detected the *R. cognatus* populations in all four caves surveyed on Interview Island and in two out of four caves surveyed on North Andaman Island (*i.e.*, Chalis-Ek). These variations in population detection may be attributed to the limited survey efforts during previous studies. Considering the variations in the population detection and estimation, there is a dire need to conduct a thorough survey of the population status and distribution across the Andaman Islands to devise conservation plans for this endangered and island-endemic species.

Srinivasulu *et al.* (2017) estimated the presence of *R. cognatus* population to be 50-200 individuals. Aul (2003) studied population of *R. cognatus* in the Andaman Islands by mist-netting at cave openings. *R. cognatus* colonies generally do not exceed 50 individuals. Taking this estimation into consideration, we estimated that the population of *R. cognatus* in our study caves could not be more than 400 individuals. However, as the roosting caves of the endemic *R. cognatus* and *R. andamanensis* are known, further detailed surveys can provide clarity on the population status of these species in the study sites.

Island-dwelling bats are increasingly threatened by various stochastic events, periods of limited resource availability and increasing anthropogenic activities (Pedersen *et al.*, 2009, Willig *et al.*, 2009). According to Conenna *et al.* (2017), basic knowledge about ecological features and taxonomy is mostly lacking for Island Endemic Bats (IEBs), which in turn affects the establishment of conservation priorities (Wiles & Brooke, 2009). As Aul & Chakravarty (2016) mentioned, this is true for the *R. cognatus*. Aul (2003) suspected the disturbance from the illegal harvesting of the cave-dwelling edible-nest swiftlet's nest as the only known threat. Presently, the illegal harvesting of edible nests from more than 200 caves at all three study sites has been completely stopped since the year 2000 by protecting these caves as part of the ongoing edible-nest swiftlet conservation program (Manchi & Sankaran, 2014; Manchi *et al.*, 2022). Hence, we can conclude that the only known threat to the *R. cognatus* from the illegal harvesting of the cave-dwelling edible-nest swiftlet's nest does not exist anymore. Nevertheless, the ecological or other anthropogenic threats to the species were never identified and need to be documented and managed before the species faces any further negative change in its population status. Recognising the urgency recently, the species was included in the Schedule-I (the highest priority species list) of the Wild Life (Protection) Amendment Act, 2022. On the contrary, recently, a cave on Baratang Island was converted into a show cave, with significant modifications inside. This is a growing threat to species like *R. cognatus* and many other known and unknown cave-dwelling animals in the islands. Hence, the conservation efforts for the endemic and endangered *R. cognatus* and the island's cave habitats are critical.

Globally, subterranean habitats are overlooked (Wynne *et al.*, 2021), and the situation in India is even worse, with limited published materials on the conservation prioritization (Biswas, 2022; Saikia *et al.*, 2023; Kawalkar *et al.*, 2024; Kawalkar & Manchi, 2025). This indicates that we still lack significant knowledge regarding this least-explored priority habitat and the fauna living in it. The present study is the first focused survey to identify the colonies of the endemic Rhinolophidae species, including the endangered *R. cognatus*, in the Andaman Islands. This study is part of ongoing efforts to conserve subterranean habitats in the Andaman Islands; we will continue to identify more colonies of the species and the potential threats to it. Furthermore, it is recommended that science-based conservation efforts be strategised and initiated for the species throughout its distribution range across the Andaman Islands.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

DATA AVAILABILITY

Data is available from the corresponding author on request.

AUTHOR CONTRIBUTIONS

DK- Conceptualization, Methodology, Formal analysis, Validation, Writing – original draft, review & editing; MSS- Conceptualization, Methodology, Funding acquisition, Project administration, Resources, Investigation, Validation, Writing – original draft, review & editing; AM- Data curation, Formal analysis, Visualization, Software, Writing – original draft, review & editing; RS- Data curation, PP- Data curation.

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