



First population assessment of the endemic insular Psychedelic Rock Gecko (*Cnemaspis psychedelica*) in southern Vietnam with implications for conservation

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Abstract.—The Psychedelic Rock Gecko (*Cnemaspis psychedelica*) was recently discovered on Hon Khoai Island, Ca Mau Province, South Vietnam. Its striking coloration makes the species highly desired on the international pet market. Although public access to the Island is generally prohibited, a number of specimens were already illegally captured and internationally offered for extremely high prices. In contrast, the current wild population size and the extent of human impacts on the species remain unknown. The present study provides the first population size estimation using a capture-recapture method and evaluation of potential threats to *C. psychedelica* in order to assess its conservation status. While the wild population was found to be relatively stable and actively reproducing at time, we simultaneously recorded increasing habitat destruction, which might considerably affect the population of *C. psychedelica*. Thus, we herein provide recommendations for *in situ* conservation. Furthermore, we report the first record of *C. psychedelica* from another small offshore Island in Rach Gia Bay.

Keywords. Population size, conservation status, habitat degradation, threats, *in-situ* species management, endemism

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Introduction

The colorful Psychedelic Rock Gecko (*Cnemaspis psychedelica*) was recently discovered on Hon Khoai Island in Rach Gia Bay, Ngoc Hien District, Ca Mau Province, southern Vietnam, where it was assumed to be endemic (Grismer et al. 2010). The island, which is only about eight km² in size, is one of the biggest of the total 92 islands in Rach Gia Bay. Currently, five *Cnemaspis* species are known from Vietnam, namely *C. aurantiacopes*, *C. boulengerii*, *C. caudanivea*, *C. psychedelica* and *C. tucludupensis*, whereas two (*C. boulengerii*, *C. psychedelica*) are endemic to islands in southern Vietnam (Grismer

and Ngo 2007; Grismer et al. 2010). *Cnemaspis psychedelica* is the most strikingly colored *Cnemaspis* species, which makes it even more attractive for the pet trade. Although the public access to the island, which is managed by the military, is prohibited, concrete evidence exists for the repeated appearance of the species in the international trade (Altherr 2014; Auliya et al. 2016; Nguyen et al. 2015). Island species are particularly vulnerable to extinction due to human impacts, because over-collection for the pet trade has frequently caused rapid local extirpation of lizard species (e.g., Auliya et al. 2016; Stuart et al. 2006; van Schingen et al. 2015).

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Fig. 1. Habitat of *Cnemaspis psychedelica*. **A.** Hon Khoai Island; **B.** Microhabitat on Hon Khoai; **C.** Hon Tuong Island; **D.** Deposited eggs on Hon Tuong Island. Photos H.N. Ngo.

Basic knowledge on the current population status of *C. psychedelica*, its ecology and potential threats are still lacking, as it is the case for most lizard species in the region. To better understand the threat level of a species, population size estimations provide essential baseline information and are thus crucial for wildlife management strategies and the assessment of the conservation status of populations and species (Ngo et al. 2016; Reed et al. 2003; Traill et al. 2007). The present study aims to provide the first assessment of the population size of *C. psychedelica* as well as an evaluation of potential threats, in particular human impacts, in order to assess its conservation status and develop adequate conservation strategies. We further investigated seasonal variation in population size and structure by conducting field surveys both during the wet and dry seasons. In addition, we surveyed another, smaller offshore island in proximity to Hon Khoai to investigate potential occurrence of the species to assess its distribution range.

Materials and Methods

Field surveys. Field surveys were conducted during the wet season in November 2015 as well as during the beginning of the dry season in January 2016 on Hon Khoai Island, Rach Gia Bay, Ca Mau Province, south-

ern Vietnam. In 2015, six transects (0.3 km to 1.1 km in length) along granitic cliffs and boulders were repeatedly surveyed three times each. In 2016, a further site was studied in addition to previous sites. Furthermore, another small island (Hon Tuong), situated in proximity to Hon Khoai island was surveyed. Hon Tuong is about 250 m² in size and situated in about 2.3 km distance from the ranger station on Hon Khoai Island. The access to another small Island (Hon Sao), which is used to breed monkeys, was not authorized. Surveys took place after sunset from 19:30 to 23:30 h. Animals were captured by hand and measured with a digital caliper to the nearest 0.1 mm. Lizards were individually marked with a permanent pen and released on the same spot after taking measurements (for details see Ngo et al. 2016, Fig. 2). This marking technique has the advantage of being non-invasive and inexpensive. Each spot was marked by a label made of waterproof paper to identify exact positions of captured and recaptured animals. Based on direct observations during the field surveys on Hon Khoai, the extent of habitat degradation and anthropogenic pressures on the island was assessed. Local forest rangers and workers of the military were interviewed during random oral conversations to determine the general cognizance, perception, and use of the species in Vietnam. Due to privacy rights, interviewees were kept anonymous.

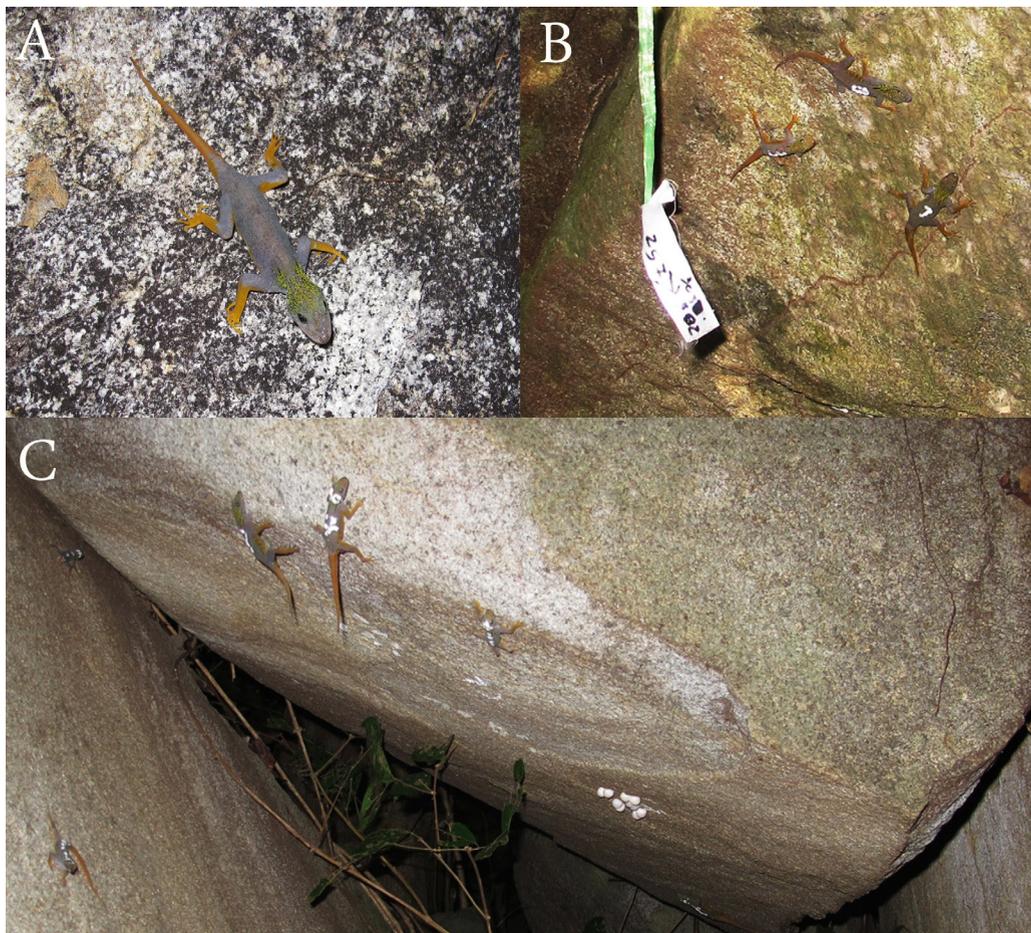


Fig. 2. A. *Cnemaspis psychedelica* on Hon Khoai Island; B. Marked *C. psychedelica* on likewise marked occurrence site; C. Group of *C. psychedelica* at egg deposition site. Photos H.N. Ngo.

Data analyses. We estimated the population size of *C. psychedelica* by applying a non-invasive “capture-recapture” approach after Schlüpmann and Kupfer (2009). Estimated population sizes refer to investigated sites and might not encompass the entire population of the species on Hon Khoai and the surrounding small islands. Based on snout-vent length (SVL) animals were categorized into two age classes (SVL \geq 58 mm = adult and SVL $<$ 58 mm = subadult or juvenile), sexes, and in case of females, into gravid and non-gravid specimens to assess the population structure. To test for seasonal differences in population structure a Chi² test with $\alpha = 0.05$ was applied with GraphPad Prism version 5.0 for Windows, GraphPad Software, La Jolla, California, USA, www.graphpad.com.

Results

New record. During the present study, *C. psychedelica* was recorded for the first time from the small offshore island Hon Tuong, in the vicinity of Hon Khoai Island (Fig. 1C). In total 11 individuals were observed on this island, of which two were juveniles. Animals were exclusively found within the center of the island, which was covered by vegetation. In addition, some deposited eggs

were recorded, demonstrating a reproducing population on Hon Tuong Island.

Population status. During the present study, individuals of *C. psychedelica* were found along seven transects on Hon Khoai Island as well as on the small offshore island of Hon Tuong. A total of 267 different animals were captured during the wet season, of which 196 were adults, and 526 individuals (378 adults) were observed during the dry season (Table 1). Based on four investigated sites, population size estimates revealed about 365 animals during the wet season and 576 estimated individuals in the dry season. Including two further sites (viz. six sites), we recorded a total population size of 732 individuals during the dry season on Hon Khoai Island. The effective population size (considering only mature individuals) was estimated approximately 507 animals during the dry season (Table 1).

Regarding different surveyed transects, we found higher numbers of individuals during the dry season compared to the wet season. Only at site three, we found fewer individuals during the dry season compared to the wet season (Fig. 3). Contemporarily, we observed a distinct increase in some disturbances, such as habi-

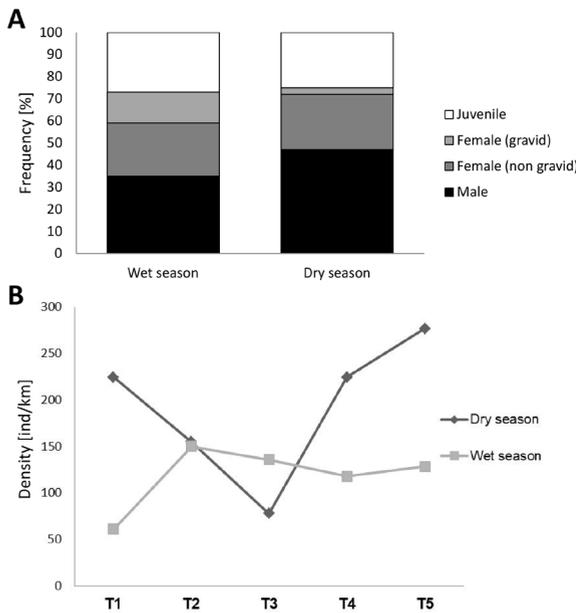


Fig. 3. Seasonal variation in the population structure of *Cnemaspis psychedelica* on Hon Khoai Island during the wet and the dry season; *n* = 154 in the wet season, 410 in the dry season, respectively; B. Seasonal variation in the densities of *C. psychedelica* on Hon Khoai Island during the wet and the dry season. T1–6 = different habitat sites.

tat destruction or waste around caves at this site, which probably had a negative impact on *C. psychedelica*. With regard to seasonal variations, the mean density of *C. psychedelica* along suitable habitat sites was estimated to be around 120 individuals per km/transect during the wet and 192 individuals per km/transect during the dry season. While densities were generally higher during the dry season, only at site three the calculated density was lower during the dry season compared to the wet season (Fig. 3). By comparing different habitat sites, the highest density of *C. psychedelica* was observed during the dry season at site five (277 individuals per km/transect; see Fig 3). This site was characterized by undisturbed dense forest, with closed canopy above the inhabited granite outcrops, relatively far from the Hon Khoai Ranger Station and areas used by the military.

In addition to different numbers of encountered animals during the wet and dry seasons, we further found a significant seasonal difference in population structure ($\text{Chi}^2 = 7.98, \text{df} = 3, p < 0.05$). Adult males accounted for the highest portion of observed animals during the wet season (47%), while adult females were most abundant during the dry season (38%, see Fig. 3). Furthermore, about one half of the observed females were found to be gravid during the dry season, in contrast to only 13% during the wet season (Fig. 3).

Threats. A clear increase in habitat destruction was observed within only two months from November 2015 to January 2016. A large road around the whole island is being constructed, which already led to accelerated erosion within the adjacent forest (Fig. 4A–C). To flatten the area for the road construction, granitic formations, which provide the preferred habitat for *C. psychedelica*, were blasted with dynamite (Fig. 4B). During daytime, field surveys could not be conducted, because of frequent bursting activities. For example, we observed deer killed by these activities (Fig. 5C). Besides road construction, three artificial ponds were being built for farming fish as food resources and local use (Fig. 4D). Therefore, the circumjacent forest was cleared. According to our interviews, some ecotourism programs are planned on Hon Khoai Island in the near future as well, which include the alteration and deterioration of rock habitats for *C. psychedelica*. Furthermore, fishermen are temporarily living on the island, and exclusively consume local resources (Fig. 4E). For example, they set up traps to catch monitor lizards, which we observed on both Hon Khoai and Hon Tuong islands (Fig. 4F). The fishermen set up their camps within the preferred microhabitat by *C. psychedelica*, under granite karst or within caves, consigning a lot of waste in the surrounding forest. The recently introduced Long-tailed Macaques (*Macaca fascicularis*)—known to feed on gekkonids—might represent another potential threat to *C. psychedelica* (Fig. 5A); however, the impacts are not yet fully understood so far (Grismer et al. 2010). In addition, *C. psychedelica* recently occurred in the international pet trade, even though public access

Table 1. Estimated population sizes and total numbers of observed *Cnemaspis psychedelica* on Hon Khoai and Hon Tuong islands; Est._{tot} = estimated total individuals, Est._c = estimated effective size (mature individuals), Obs._{tot} = totally observed individuals, Obs._c = number of observed mature individuals.

Site	Wet Season		Dry Season	
	Est. _{tot} (Est. _c)	Obs. _{tot} (Obs. _c)	Est. _{tot} (Est. _c)	Obs. _{tot} (Obs. _c)
1 (Hon Khoai)		6 (5)	97 (68)	74 (56)
2 (Hon Khoai)	98 (64)	63 (31)	157 (101)	124 (78)
3 (Hon Khoai)	99 (94)	68 (66)	72 (49)	39 (27)
4 (Hon Khoai)	69 (45)	53 (35)	117 (77)	101 (69)
5 (Hon Khoai)	99 (72)	77 (59)	133 (82)	83 (58)
6 (Hon Khoai)	—	—	156 (130)	94 (81)
7 (Hon Tuong)	—	—	—	11 (9)
Total	365 (275)	267 (196)	732 (507)	526 (378)



Fig. 4. Potential threats to *Cnemaspis psychedelica*. **A.** Erosion caused by opening of new ways; **B.** Forest opening and blasting of granite karst formations; **C.** Building of new roads; **D.** Building of artificial ponds to store freshwater; **E.** Camp of a fisherman living on the island; **F.** Trap for Monitor lizards. Photos H.N. Ngo.

to the island is generally prohibited (e.g., Altherr 2014; Auliya et al. 2016; Nguyen et al. 2015).

Discussion

The colorful Psychedelic Rock Gecko was thought to be endemic to Hon Khoai, one of the biggest islands in Rach Gia Bay, while our new record from Hon Tuong Island indicates a slightly wider distribution range and for the first time its existence also on very small islands. Ngo et al. (2016) also reported the occurrence of another insular gecko from Vietnam, *Goniurosaurus catbaensis*, originally thought to be endemic for Cat Ba Island, on very

small nearby offshore islands in the Ha Long Bay. These findings highlight the importance of such small islands for gekkonids, which have long been overlooked. We assume that *C. psychedelica* probably occurs on other similar small islands in the Rach Gia Archipelago (e.g., Hon Sao, Hon Doi Moi, Hon Da Le), but still endemic to Rach Gia Bay. Due to the small sizes of the islands and the limited exchange between populations the genetic variability and thus the effective population size is assumed to be quite low (Charlesworth 2009). We thus recommend future studies on population genetics of *C. psychedelica*, which can shed more light into island ecology of tropical lizards in general.



Fig. 5. A. Introduced macaque on Hon Khoai Island; B. Trapped Water Monitor Lizard for consumption; C. Deer killed by blasting of granite outcrops; D. Naturally occurring but injured *C. psychedelica*. Photos H.N. Ngo.

The present population estimation suggests a stable and actively reproducing population of *C. psychedelica* at least on Hon Khoai Island. While densities of the species at untouched sites were found to generally have increased from wet to dry season, we observed a decrease of the individual number in the areas, which were most strongly affected by habitat degradation. We assume that the current habitat destruction as well as the planned development of ecotourism will probably interfere with *C. psychedelica* natural populations, because the species was found to flee hastily in response to the presence of humans. Touristic activities and the presence of humans were already found to negatively affect other range restricted lizards such as *Shinisaurus crocodilurus* or *Goniurosaurus* species in northern Vietnam (Ngo et al. 2016; van Schingen et al. 2015). Regarding the small size of Hon Khoai Island, the availability of remaining alternative sites for *C. psychedelica* is limited. Since the species was only discovered in 2010, long-term population data is lacking and long-term consequences of habitat alteration are not yet investigated in detail.

Furthermore, the lizard's striking coloration attracts increasing interest in *C. psychedelica* in the international pet trade. Even though public access to and the export

of wild fauna for commercial purposes from Hon Khoai Island is prohibited and the collecting and caging of wild animals must be permitted by authorized state bodies, in accordance with the Law on Forest Protection and Development No. 29/2004/QH11, unsustainable international trade of *C. psychedelica* has been confirmed in recent studies (Altherr 2014; Auliya et al. 2016; Nguyen et al. 2015). *Cnemaspis psychedelica* is currently mainly traded through internet platforms, where animals fetch extremely high prices up to \$3,500/ pair (Aulyia et al. 2016).

In addition to online trading, we also observed *C. psychedelica* on the world's biggest reptile market in Hamm, Germany in November 2014. The same dealer told us in December 2015, that he was going to receive several new pairs of *C. psychedelica* in the beginning of 2016. There is already evidence for the existence of several independent traders offering *C. psychedelica* and an increasing demand for the species, especially in Europe and the US (e.g., Altherr 2014; Auliya et al. 2016; Nguyen et al. 2015). Even though the trade in the species as well as the habitat destruction only started and the wild *C. psychedelica* population still appears to remain stable, recent examples on other lizard species underline the risk of



Fig. 6. Signboard handed over to the Forest Protection Department of Ca Mau Province to point to the threats and conservation needs of the Psychedelic Rock Gecko in English and Vietnamese languages. Layout and text by Thai Do, Anna Rauhaus, Khoi Vu Nguyen, Truong Quang Nguyen, and Thomas Ziegler. Photos T.Q. Nguyen (habitat) and T. Ziegler (geckos).

local extinction in particular of range restricted and specialist species. Cases of rapid local extirpations shortly after discovery due to over-collection have been recorded for other charismatic lizard species in the region, such as *Goniurosaurus luii* and *Shinisaurus crocodilurus* (e.g., Auliya et al. 2016; Stuart et al. 2006; van Schingen et al. 2015). Learning by experience, we recommend to initiate immediate conservation actions, as long as access to the island is still limited and wild populations are still intact.

As a first measure, a Psychedelic Rock Gecko breeding facility was recently built on the mainland of southern Vietnam by Wildlife at Risk (WAR) in cooperation with the Institute of Ecology and Biological Resources (IEBR) and the Cologne Zoo, to establish an insurance population in captivity as basis for a potential future conservation breeding program (Ziegler et al. 2015; Ziegler and Nguyen 2015). In March 2015, a small breeding group of *C. psychedelica* was transferred from Hon Khoai Island with relevant permits provided by the government authorities to the Psychedelic Rock Gecko breeding facility, where breeding has been succeeded (Ziegler et al. 2016). In order to improve the conservation breeding and long-term management of the species, comprehensive research on its ecology and habitat requirements is currently being conducted by our team. This knowledge, in concert with the present first population analysis and evaluation of threats, will provide crucial baseline data for further conservation measures. Recently, based on

our first research results, *C. psychedelica* was included in the IUCN Red List of Threatened species, listed as Endangered (Nguyen et al. 2016). To further enhance the protection status and control the international trade in the species, the listing of *C. psychedelica* on the Appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is strongly recommended, since the rising international demand in the species has posed increasing pressure on wild populations.

To raise awareness, a campaign was recently initiated by our team and signboards highlighting the conservation needs of *C. psychedelica* were provided to the provincial authorities to be shown on Hon Khoai Island (Fig. 6). Local rangers were equipped with camera and GPS devices, and funds were raised to install big waste buckets along forest paths to reduce pollution on the island. Moreover, first discussions on the potential establishment of a nature reserve on Hon Khoai Island to facilitate long-term habitat and species protection recently were held with the Forest Protection Department of Ca Mau Province and the joint planning of further activities for habitat and species protection took place in March 2016 (Ziegler and Nguyen 2016).

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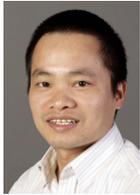
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Truong Quang Nguyen is a researcher at the Institute of Ecology and Biological Resources (IEBR), Vietnam Academy of Science and Technology (VAST) and is a member of the Biodiversity and Nature Conservation projects of the Cologne Zoo in Vietnam and Laos. He finished his doctoral degree in 2011 at the Zoological Research Museum Alexander Koenig (ZFMK) and the University of Bonn, Germany (DAAD Fellow). From 2012 to 2014 he worked as a postdoctoral researcher in the Institute of Zoology, University of Cologne (Alexander von Humboldt Fellow). He has conducted numerous field surveys and is co-author of eight books and more than 200 papers relevant to the biodiversity research and conservation in Southeast Asia. His research interests are systematics, ecology, and phylogeny of reptiles and amphibians from Southeast Asia.



Tan Van Nguyen is a young researcher at the Institute of Ecology and Biological Resources (IEBR), Vietnam Academy of Science and Technology (VAST). He has participated in numerous herpetological surveys in Vietnam and has experience in field research. He is interested in taxonomy, ecology, and conservation of reptiles and amphibians in Vietnam.



Frank Barsch is a policy officer in the Division of Species Protection in the German Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) working on national and international aspects of species conservation and trade (e.g., in the context of CITES). Between 2004 and 2007 he worked for the German Development Services (DED) in the Department for Forestry and Range Resources (Botswana) to improve the national management of natural plant resources. Between 2002 and 2004 he worked as a researcher and lecturer at the Institute for Ecology and Evolutionary Biology (University of Bremen, Germany). He has furthermore extensive working experience with environmental non-governmental organizations (e.g., WWF).



Thomas Ziegler has been the Curator of the Aquarium/Terrarium Department of the Cologne Zoo since 2003 and is the coordinator of the Cologne Zoo's Biodiversity and Nature Conservation Projects in Vietnam and Laos. Thomas studied biology at the University Bonn (Germany), and completed his diploma and doctoral thesis at the Zoological Research Museum Alexander Koenig in Bonn, with focus on zoological systematics and amphibian and reptile diversity. He has been engaged with herpetodiversity research and conservation in Vietnam since 1997. As a zoo curator and project coordinator he tries to combine *in situ* and *ex situ* approaches, viz., to link zoo biological aspects with diversity research and conservation, both in the Cologne Zoo, in rescue stations, and breeding facilities in Vietnam and in Indochina's last remaining forests. Since February 2009, he has been an Associate Professor at the Zoological Institute of Cologne University. Since 1994, Thomas has published 360 papers and books, mainly dealing with herpetodiversity.



Mona van Schingen is Ph.D. candidate at the Zoological Institute of the University of Cologne and the Cologne Zoo, Germany. Since 2011, she has been investigating the herpetofauna of Vietnam, in the working group of Thomas Ziegler and graduated in 2014 with her M.Sc. on the Crocodile lizard in Vietnam. She has conducted diverse field excursions to Vietnam and is engaged in several research, conservation, and awareness projects focusing on various species in Vietnam. Her current research focuses on ecology, population dynamics, and conservation of endangered, specialist and range restricted lizard species in Vietnam.