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First record of the Cat Ba Tiger Gecko, *Goniurosaurus catbaensis*, from Ha Long Bay, Quang Ninh Province, Vietnam: microhabitat selection, potential distribution, and evidence of threats

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***Abstract.*—The Cat Ba Tiger Gecko (*Goniurosaurus catbaensis*) was described from Cat Ba Island, Hai Phong, northern Vietnam in 2008, while a presumed congener was recently spotted from another offshore island in the Ha Long Bay. During the field surveys reported here, new *Goniurosaurus* occurrences were discovered for the first time on small offshore islands in the Ha Long Bay, Quang Ninh Province. These were identified and confirmed as *G. catbaensis* based on morphological and molecular data. However, these newly found populations are very small and exposed to increasing anthropogenic pressures. Since knowledge about the species ecology remains poor, the first microhabitat characterization for *G. catbaensis* is provided herein, which is essential for conservation of the species as well as its natural habitats. Sex- and age-related differences in selection of perch height are herein presented. In addition, we present evidence for various anthropogenic threats such as regular trade in living tiger geckos (including *G. catbaensis*) on local markets in Hai Phong and Ho Chi Minh cities, Vietnam. These findings highlight the need for more stringent conservation measures to reduce human impacts on the extremely small, insular populations of the Cat Ba Tiger Gecko.**

Key words. Anthropogenic pressure, conservation, ecology, offshore islands, phylogram, trade

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Introduction

The genus *Goniurosaurus* currently comprises 19 species with a disjunct distribution in southern East Asia. Most *Goniurosaurus* species are endemic with restricted distribution ranges (Chen et al. 2014; Grismer et al. 1994, 1999; Honda and Ota 2017; Seufer et al. 2005; Yang and Chan 2015; Zhou et al. 2018; Ziegler et al. 2008). Habitat degradation and overharvesting for the pet trade were identified as major threats to wild populations of tiger geckos (Yang and Chan 2015). At present, five species of *Goniurosaurus* are known from Vietnam, namely *G. araneus*, *G. catbaensis*, *G. huuliensis*, *G. lichtenfelderi*, and *G. luii* (Nguyen et al. 2009). Among these species, the insular Cat Ba Tiger Gecko (*Goniurosaurus catbaensis*) was discovered on Cat Ba Island in Cat Hai District, Hai Phong City, northeastern Vietnam, where it was assumed to be endemic (Ziegler et al. 2008). Preliminary population assessments of *G. catbaensis* revealed that its effective population size, defined as number of mature individuals, is much smaller than the suggested threshold values for minimal viable populations to maintain a stable population in the long term (Ngo et al. 2016; Nguyen et al. 2016, 2018; Reed et al. 2003; Traill et al. 2007).

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Fig. 1. New population. **(A)** Habitat of *Goniurosaurus catbaensis* on one offshore island in Ha Long Bay, Quang Ninh Province; **(B)** Microhabitat of *G. catbaensis* in Ha Long Bay; **(C)** Adult male; and **(D)** Adult female from Ha Long Bay. *Photos: H.N. Ngo.*

Even in undisturbed habitats, *G. catbaensis* occurs at low densities (Ngo et al. 2016; Nguyen et al. 2016, 2018).

The insular Cat Ba Tiger Gecko was found to be vulnerable to anthropogenic disturbances, and of high demand in pet markets as well as on Internet platforms (Ngo et al. 2016; Nguyen et al. 2018). In addition to poaching, habitat destruction for touristic purposes has dramatically increased the pressure on the wild *G. catbaensis* population. Consequently, the need for protection of the Cat Ba Tiger Gecko has received growing attention. Based on the first international population and trade investigations, this species has recently been listed in the IUCN Red List of Threatened Species as "Endangered" (Nguyen et al. 2016). The wild population is probably in peril due to its restricted distribution range, rising anthropogenic threats, and the lack of appropriate conservation measures. For the latter, detailed information on habitat requirements and the exact distribution of this species is essential, but such data are currently lacking. Ngo et al. (2016) recently suggested the potential occurrence of *G. catbaensis* on at least one more offshore island in Ha Long Bay.

To confirm this possibility, we investigated other small offshore islands in Ha Long Bay, Quang Ninh Province to locate populations of *G. catbaensis*, and predicted the overall availability of suitable habitats for the species in northeast Vietnam. In addition, the present study aimed to provide the first data on microhabitat selection of *G. catbaensis*. We assumed that differences in habitat use would occur between age classes and sexes, as they have been observed in other lizards (Snyder et al. 2010; van Schingen et al. 2015).

Materials and Methods

Study areas: Study sites were selected based on our previous surveys on Cat Ba Island, Hai Phong City, and on photo documentation which gave evidence for the possible occurrence of *Goniurosaurus* on a small island in Ha Long Bay, Quang Ninh Province (Ngo et al. 2016). Cat Ba Island and adjacent islands comprise isolated limestone karst formations, which provide diverse habitats for a unique flora and fauna (Clements et al. 2006). Cat Ba Archipelago was recognized as the "Cat Ba Archipelago Biosphere Reserve" (CBBR) by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 2004 due to its significant ecosystem and biodiversity values (CBBR Authority 2013). Ha Long Bay was also twice recognized (in 1994 and 2000) by UNESCO as a World Heritage Site for the outstanding universal value of its landscape, geology, and geomorphology (The Management Department of Ha Long Bay 2014). Both areas are among the most popular tourist destinations in Vietnam, and face challenges from rapid tourism development.

Field surveys: Field surveys were conducted on Cat Ba Island between June and August 2014, May 2015, and during a short time in June 2016, which fell in the non-hibernation season of *Goniurosaurus* (Grismer et

al. 1999; Ngo et al. 2016). Furthermore, six offshore islands in Ha Long Bay, situated in close proximity to Cat Ba Archipelago, were surveyed in July 2016. Night excursions were conducted between 7:30 and 11:30 PM, when the lizards were found to be active (Ngo et al. 2016; Ziegler et al. 2008). To measure morphological characters, the animals were captured by hand and subsequently released at the same spot after checking and taking measurements.

Ecological analyses: Microhabitat data were recorded for each sighted *G. catbaensis*, including substrate types (classified as cliff, rock, branch, sand, or forest floor), perch height (vertical distance between captured animal and ground, in cm), percentage of vegetation or cave coverage, position (resting outside or inside cave), substrate surface condition (dry or wet), and activity (resting, feeding, or foraging). Air temperature and relative humidity were measured with a digital thermo-hygrometer (TFA Dostmann/Wertheim Kat. Nr. 30.5015), and substrate temperature and body surface temperature of animals were measured with an infrared thermometer (Measupro IRT20).

To identify intraspecific differences in microhabitat selection by *G. catbaensis*, individuals were classified into different age classes according to their snout-vent lengths (SVL): SVL < 85 mm = juvenile, SVL ≥ 85 mm and < 105 mm = sub-adult, and SVL ≥ 105 mm = adult (Ngo et al. 2016). Adults were differentiated between the sexes, as well as between gravid and non-gravid individuals. Sex of specimens was determined by the presence of the large swollen hemipenal bulges in males, while non-swollen in females.

A *t*-test, with $\alpha = 0.05$, was performed to determine differences in microhabitat parameters between age classes and sexes. Statistical analyses were performed with the program PAST, Version 2.17c (Hammer et al. 2001).

Morphological analyses: Morphometric measurements of captured individuals were taken with a digital caliper to the nearest 0.1 mm. In addition, two voucher specimens of the newly discovered populations in Ha Long Bay were collected, euthanized with ethylacetate, preserved in 70% ethanol, and deposited in the collections of the Vietnam National Museum of Nature (VNMN), Hanoi, Vietnam (VNMN 05423, VNMN 05424). Morphological characters were taken according to Ngo et al. (2016), Orlov et al. (2008), Yang and Chan (2015), and Ziegler et al. (2008).

Abbreviations of measurements are as follows: snout vent length (SVL) from tip of snout to vent; tail length (TaL) from vent to tip of tail; distance between axilla and groin (AG) from posterior edge of forelimb insertion to anterior edge of hind limb insertion; forelimb length (FoL) from axilla to tip of longest finger; hindlimb length (HiL) from groin to tip of longest finger; snout to eye distance (SE) from tip of snout to anterior-most point of eye; eye to ear distance (EE) from posterior margin of eye to posterior margin of ear; orbital diameter (OD) greatest diameter of orbit; ear diameter (ED) longest dimension of ear; internarial distance (IND) as distance between nares; anterior eye distance (AED) as distance between anterior corners of eyelids; posterior eye distance (PED) as distance between posterior corners of eyelids; maximum head width (HW); maximum head height (HH); head length (HL) from tip of snout to posterior edge of occiput; pileus length (PL) from tip of snout to posterior scale of the head; and jaw length (JL).

Abbreviations of scalation are as follows: supralabials (SPL); infralabials (IFL); nasal scales surrounding nare (N); internasals (IN); gular scales bordering the internasals (PostIN); postmentals (PM); gular scales bordering the postmentals (GP); eyelid fringe scales or ciliaria (CIL); granular scales surrounding dorsal tubercles (GST); dorsal tubercle rows at midbody (DTR); paravertebral tubercles between limb insertions (TL); scales around midbody (MB); subdigital lamellae under the first finger (LF1) and the fourth finger (LF4); subdigital lamellae under the first toe (LT1) and the fourth toe (LT4); precloacal pores (PP); and postcloacal tubercles (PAT).

Molecular analyses: To confirm the taxonomic status of the newly collected *Goniurosaurus* from Ha Long Bay, Quang Ninh Province, a fragment of the mitochondrial 16S ribosomal gene was amplified, using the primer pair 16Sar and 16Sbr (Palumbi et al. 1991), for three samples (VNMN 05424 plus two small tissue samples from two released individuals, field numbers G8 and G12). Tissue samples were taken from the tail tips, which were disinfected before immediate release of the animals at the site of capture. DNA was extracted from tissue samples using the DNeasy blood and tissue kit, Qiagen (Redwood City, CA). The extracted DNA from the fresh tissue samples were amplified by PCR, with the PCR volume (21µl) consisting of 10 µl of mastermix (Fermentas, Canada), 5 µl of water, 2 µl of each primer at 10 pmol/µl, and 2 µl of DNA. The PCR conditions were: 95 °C for five minutes to activate the taq; with 40 cycles at 95 °C for 30s, 50 °C for 45s, 72 °C for 60s; and the final extension at 72 °C for six minutes (Ngo et al. 2016).

PCR products were subjected to electrophoresis through a 1% agarose gel (UltraPure™, Invitrogen). Gels were stained for 10 minutes in 1x TBE buffer at 2 pg/ml of ethidium-bromide, and visualized under UV light. Successful amplifications were purified to eliminate PCR components using GeneJET™ PCR Purifcation Kit (Fermentas, Canada). Purified PCR products were sent to 1st Base (Selangor, Malaysia) for sequencing. Sequences were edited using the program Geneious v.7.1.8 (Kearse et al. 2012). After sequences were aligned using Clustal X v2 (Thompson et al. 1997), data were analyzed by Bayesian inference as implemented in MrBayes v3.2 (Ronquist et al. 2012). Settings for these analyses followed Le et al. (2006), except that the number of generations in the Bayesian analysis was increased to 1×10^7. The optimal model for nucleotide evolution was set to GTR+I+G as selected by Modeltest v3.7 (Posada and Crandall 1998). The cutoff point for the burn-in function was set to 13 in the Bayesian analysis, as -lnL scores reached stationarity after 13,000 generations in both runs. Nodal support was evaluated using posterior probability in MrBayes v3.2. Uncorrected pairwise divergences were calculated in PAUP*4.0b10 (Swofford 2001).

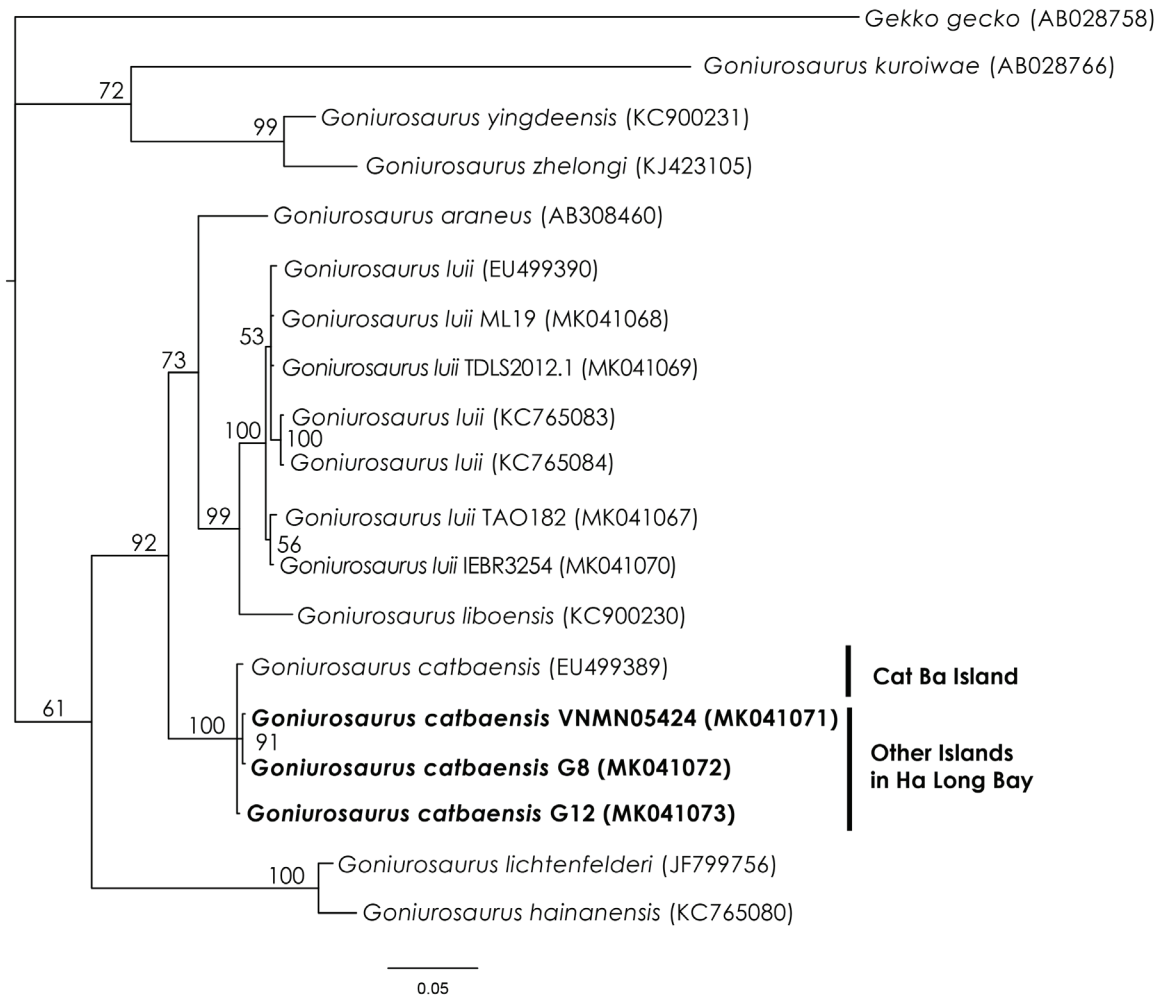

Fig. 2. Phylogram of *Goniurosaurus* based on the Bayesian analysis of a 16S ribosomal fragment. Numbers next to nodes are Bayesian posterior probabilities. Voucher numbers of new samples and GenBank accession numbers are placed after species names and in parentheses, respectively.

Species distribution models (SDMs): Based on occurrence records and a set of 19 environmental factors, the current overall availability of suitable habitats for *G. catbaensis* were predicted using the program Maxent Version 3.3.3.e (Beaumont et al. 2005; Phillips et al. 2006). Only the most distant occurrences of each site were included in the analyses to minimize effects of spatial autocorrelation and to ensure the independence of the records (Jennings and Veron 2011; Jennings et al. 2013). As a result, 11 records were filtered from a total of 60 localities of *G. catbaensis* on Cat Ba Island and Ha Long Bay. Nineteen bioclimatic variables that were obtained from the WorldClim global climate database (http://www.worldclim.org, accessed September 2016; Hijmans et al. 2005; Table 1) were used as environmental predictors.

Threat records: To get a first impression of trade in *Goniurosaurus* species in Vietnam, local pet markets were visited in Hai Phong and Ho Chi Minh cities, the two most important trade centers in the country, and different Internet platforms were investigated. Two local dealers from Ho Chi Minh City offering *Goniurosaurus* online were interviewed in September 2016, in order to trace the source of the traded *Goniurosaurus* species in Vietnam. Additionally, five fishermen from the Ha Long Bay were interviewed to identify caves used by tourism companies for night parties, and determine the general attitude and use of the species in Ha Long Bay. Those sites located within the World Heritage Site were subsequently surveyed in July 2016 to evaluate potential threats from tourism activities. The names of interviewees are kept anonymous to ensure data privacy rights and Internet links are not disclosed to prevent misuse. Accurate locality data, cave names, and prices are also not presented to prevent targeted poaching for the wildlife trade.

Results

New records of *Goniurosaurus catbaensis*: During the present study, new *Goniurosaurus* occurrences were discovered on four small offshore islands, including two tourism caves in Ha Long Bay, Quang Ninh Province. The distances between these islands ranged from 1.4 km to 13 km, while the shortest distance between Cat Ba Island and one surveyed island in Ha Long Bay was 1.2 km. A total of 14 individuals (eight males, four females, one juvenile, and one unsexed individual which was only photographed) were recorded on these islands, which

Table 1. Bioclimatic variables from environmental data (Source: http://www.worldclim.org, accessed September 2016).

No.	Bioclimatic variables from the WorldClim dataset
1	BIO1 = "Annual Mean Temperature"
2	BIO2 = "Mean Diurnal Range" (Mean of monthly [max temp - min temp])
3	BIO3 = "Isothermality" (P2/P7) (*100)
4	BIO4 = "Temperature Seasonality" (standard deviation *100)
5	BIO5 = "Max Temperature of Warmest Month"
6	BIO6 = "Min Temperature of Coldest Month"
7	BIO7 = "Temperature Annual Range" (P5–P6)
8	BIO8 = "Mean Temperature of Wettest Quarter"
9	BIO9 = "Mean Temperature of Driest Quarter"
10	BIO10 = "Mean Temperature of Warmest Quarter"
11	BIO11 = "Mean Temperature of Coldest Quarter"
12	BIO12 = "Annual Precipitation (year)"
13	BIO13 = "Precipitation of Wettest Month"
14	BIO14 = "Precipitation of Driest Month"
15	BIO15 = "Precipitation Seasonality" (Coefficient of Variation)
16	BIO16 = "Precipitation of Wettest Quarter"
17	BIO17 = "Precipitation of Driest Quarter"
18	BIO18 = "Precipitation of Warmest Quarter"
19	BIO19 = "Precipitation of Coldest Quarter"

ranged between 0.34 and 2.94 km^2 in size.

Molecular analysis using Bayesian inference of the obtained matrix containing 613 aligned characters showed that all samples from Cat Ba Island (n = 1) and from the most distant other islands in Ha Long Bay (n = 3) clustered in a single clade with strong statistical support (posterior probability = 100%, Fig. 2). Genetic analyses revealed that sequences of the new records from Ha Long Bay, Quang Ninh Province, were identical to each other and virtually the same (99% to 100%) as that of the holotype of *G. catbaensis* from Cat Ba Island (GenBank accession number: EU499389). The maximum genetic divergence between the samples is approximately 0.3%, whereas the lowest divergence between two species of this genus, i.e., *G. hainanensis* and *G. lichtenfelderi*, is approximately 2.3% (Table 2). These results confirmed the newly recorded *Goniurosaurus* populations in Ha Long Bay are conspecific with *G. catbaensis* from Cat Ba Island (Fig. 2).

In addition, the morphological characters of the newly recorded *G. catbaensis* from Ha Long Bay accorded well with the population from Cat Ba Island, except that three of six individuals from a single site in Ha Long Bay showed a postrostral (internasal) scale. This character is consistently lacking in individuals recorded so far from Cat Ba Island (Ziegler et al. 2008) [Fig. 3A, 3B; Table 3].

Microhabitat selection: A total of 61 sightings took place (13 from smaller islands in the Ha Long Bay, and 48 from Cat Ba Island). *Goniurosaurus catbaensis* was active in the surroundings of large limestone caves covered in part by primary forest vegetation and in the vicinity of primary shrub vegetation on limestone. Mean air temperatures were 28.1 ± 1.7 °C (21.5–31.3 °C, n =

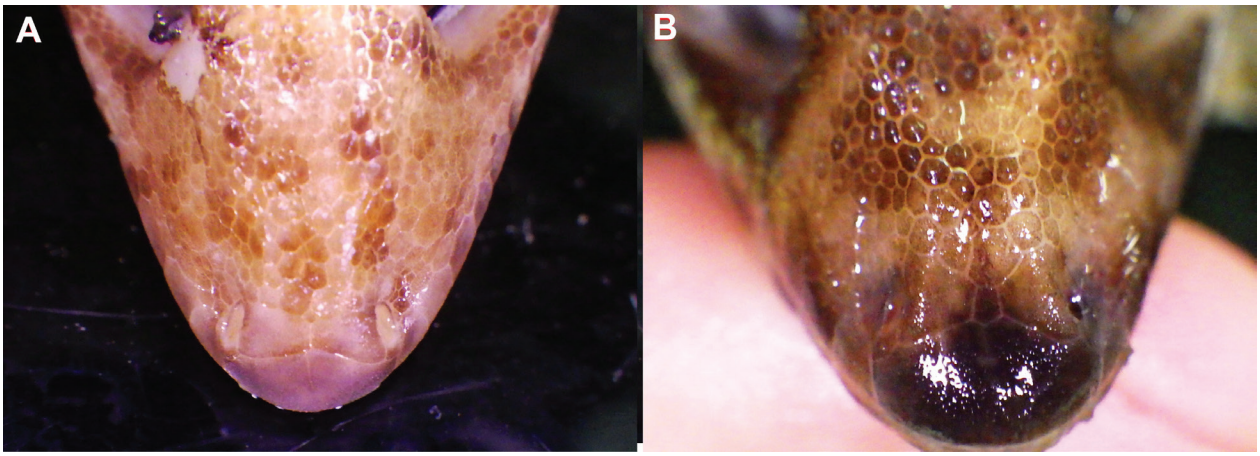

Fig. 3. Absence versus occasional presence of internasal scales of *Goniurosaurus catbaensis* from **(A)** Cat Ba Island and **(B)** Ha Long Bay. *Photos H.N. Ngo*.

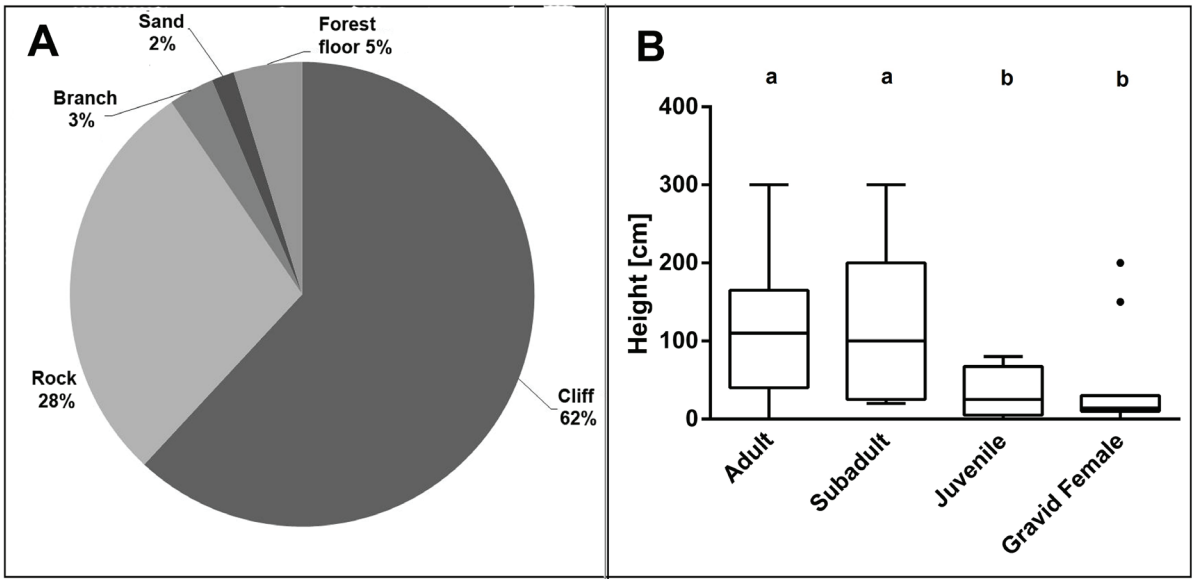

Fig. 4. (A) Substrate selection of *Goniurosaurus catbaensis*. **(B)** Box plots of perch heights of different age classes and sexes.

59) slightly higher than mean substrate temperatures of 26.02 ± 1.5 °C (22.2–28.2 °C, n = 28, Table 4). Recorded relative humidity at microsites ranged between 70–99% (mean 84.9 ± 6.99%, n = 52).

A vast majority of lizards was found on limestone cliffs (62%), followed by rocks (28%), while only a few specimens were found on the forest floor (5%), branches (3%), or sand (2%) [Fig. 4A]. A significantly lower number of lizards was encountered inside compared to outside of limestone caves (26.9% vs. 73.1%, respectively). *Goniurosaurus catbaensis* selected spots with a mean canopy coverage of 95.2 ± 9.6% (n = 63, Table 4). Adult specimens (non-gravid) were found at average heights of 1.15 m (n = 38), while juveniles and gravid females resided at significantly lower heights of 0.28 m (n = 4) and 0.41 m (n = 12), respectively ($t = 2.82$, df = 48, $P < 0.05$; $t = 2.06$, df = 40, $P < 0.05$, Fig. 4B). A majority (about 77.4%, n = 48) of lizards was resting during the surveys, while only a few individuals (n = 14) were found actively foraging.

Suitable habitats for *G. catbaensis* were predicted to encompass a majority of small islands belonging to Cat Ba Island and Ha Long Bay, and include a wider area on the coastal mainland of Quang Ninh Province, where no surveys have been conducted so far (Fig. 5).

Trade: Trade in living tiger geckos has been frequently recorded by our team in local pet markets from Hai Phong and Ho Chi Minh cities, as well as on Facebook since 2015. Interviews with two local traders in Ho Chi Minh City revealed that they pay for local villagers living within the species' distribution range to collect live tiger geckos during the non-hibernation season, confirming the wild (rather than captive-bred) source of traded animals. The dealers reportedly received individuals of three tiger gecko species, namely *G. huuliensis*, *G. luii*, and *G. catbaensis,* collected in April 2015. Among those, three individuals of *G. huuliensis* (one male and two females) were allegedly collected by a local hunter from Huu Lien Nature Reserve, Lang Son Province. Two local collectors from Cao Bang Province reportedly collected six individuals (three males and three females) of *G. luii* in northern Vietnam and another local hunter collected two couples of *G. catbaensis*. These 13 wild caught tiger geckos were transferred to pet markets in Ho Chi Minh City, southern Vietnam, in April 2015.

Human impacts on the habitat: Tourism activities in the region have dramatically increased in the past, and likely exerted enormous pressure on wild *G. catbaensis* populations. Events organized by tourism companies

Table 2. Uncorrected ("p") distance matrix showing percentage pairwise genetic divergence (16S) between members of *Goniurosaurus.*

Species name	1	2	3	4	5	6	7	8	9
1. *G. araneus*	–								
2. *G. catbaensis*	6.4–6.7	–							
3. *G. hainanensis*	13.7	12.4–12.8	–						
4. *G. kuroiwae*	20.4	19.5–19.8	19.3	–					
5. *G. liboensis*	6.3	6.6-6.8	12.8	21.9	–				
6. *G. lichtenfelderi*	12.9	11.2–11.6	2.3	18.8	13.3	–			
7. *G. luii*	5.6–6.2	6.2–7.1	12.2–12.9	20.0–20.4	3.4–3.8	11.5–13.5	–		
8. *G. yingdeensis*	14.8	13.4–13.5	15.2	18.8	13.0	15.2	13.3–13.5	–	
9. *G. zhelongi*	15.3	14.2–14.4	16.9	21.4	13.4	16.2	14.8–15.4	4.8	–

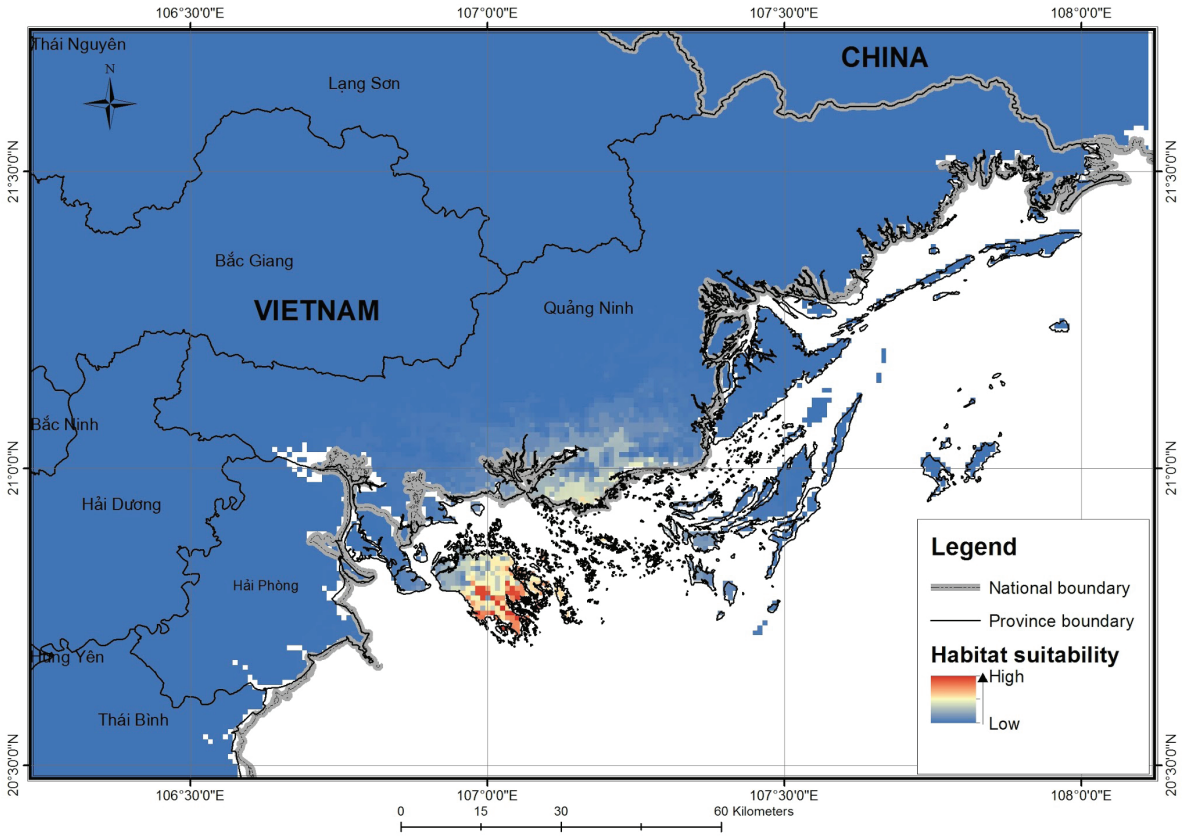

Fig. 5. Predicted habitat suitability for *Goniurosaurus catbaensis* in Vietnam.

regularly took place in at least two caves located within the UNESCO World Heritage Site. According to interviews with fishermen, daily excursions to the caves are scheduled to start at 7:30 PM and end around 11:00 PM. On these occasions, tourists dine in brightly lit caves before returning to their tour boats (Fig. 6B). As a consequence, wildlife is likely to be disturbed by the candle light, noisy sounds, and waste left by the tourists.

Discussion

New population records: Since its discovery in 2008, the Cat Ba Tiger Gecko was thought to be endemic to Cat Ba Island (Ziegler et al. 2008). These new records of *G.* cf. *catbaensis* on further offshore islands in Ha Long Bay confirmed for the first time the occurrence of the species outside its type locality. The newly recorded specimens showed an insignificant genetic divergence from the type series from Cat Ba Island and could be assigned to *G. catbaensis* (Table 2). Accordingly, the newly collected specimens from Ha Long Bay were also almost identical to the type series of *G. catbaensis* in morphology, except for the presence of a single internasal scale (which is absent in the type series from Cat Ba, see Ziegler et al. 2008) in a few individuals from a single site in Ha Long Bay. These findings indicated a slightly broader distribution range of the species than previously expected.

According to Li et al. (2010), the islands of Ha Long Bay and Cat Ba Archipelago were shaped by the erosion of limestone karst formations within the Gulf of Tonkin at the northern east coast of Vietnam after the coastal shelf region became inundated by marine waters about 13,000 years ago. Repeated falls (> 50 m) of the sea level during glaciations periodically connected various islands and the mainland, which allowed exchanges between island and mainland populations, as well as colonization and re-colonization between island and mainland populations (Li et al. 2010; Liang et al. 2018). Thus, past recurrent gene flow is assumed to have occurred between (sub)populations, which helped to maintain a classical island-mainland metapopulation—in accordance with the high genetic similarity between *G. catbaensis* (sub)populations from different islands with identical habitats (Hanski 1991; Harrison and Taylor 1997; Levins 1969). Orlov et al. (2008) confirmed that *G. lichtenfelderi* was found from both continental mainland and islands. On the other hand, Liang et al. (2018) suggested that *G. lichtenfelderi* diverged from *G. hainanensis* of Hainan Island to Vietnam (including both mainland and island populations), which might have occurred during the glacial periods with past dispersal events. The speciation in the diversification process of *Goniurosaurus* was probably promoted by the adaption to different microhabitats. Populations of *G. lichtenfelderi* were found on granite beds of valley streams, while the closely related *G. hainaensis* is found on igneous rocks and *G. catbaensis* occurs in karst forests (Orlov et al. 2008; Liang et al. 2018; Ziegler et al. 2008; Nguyen et al. 2018).

To avoid the misuse of distribution data for targeted harvesting of the species (e.g., Lindenmayer and Scheele

Table 3. Morphological characters of *Goniurosaurus* from Ha Long Bay, Quang Ninh Province, compared with *G. catbaensis* from Cat Ba Island, Hai Phong Province. Measurements are given in mm. Note: (*) n = 6; ([a]) n = 2.

Specimens	Ha Long Bay (current study, n = 13)	Cat Ba Island (current study, n = 48)	Cat Ba Island (Ziegler et al. 2008) [n = 4]
SVL	74.54–122.7 (111.2 ± 11.9)	69.2–130.4 (108.9 ± 12.6)	84.7–111.5 (102.4 ± 14.5)
TaL	10.1–97.6 (69.9 ± 27)	28.9–104.02 (78 ± 17.7)	52.5–101.5 (68.1 ± 27.6)
AG	33.9–60.2 (52.9 ± 6.5)	43.07–58.43 (48.4 ± 5.4)*	-
HL	21.3–33.8 (30.2 ± 2.9)	17.8–34.2 (29.8 ± 3.5)	23.1–30.6 (27.7 ± 4.1)
HW	14.4–24.56 (22.1 ± 2.5)	13.9–28.2 (21.9 ± 2.5)	16.2–21.6 (19.5 ± 2.9)
HH	7.1–14.9 (12.8 ± 1.9)	8.2–16.9 (12.4 ± 1.9)	10.1–14.3 (12.2 ± 2.0)
FoL	32.2–53.8 (50.4 ± 5.6)	29.7–54 (47.8 ± 4.7)	-
HiL	42–67.47 (60.1 ± 6.2)	36.2–65 (57.9 ± 5.99)	-
SE	8.7–13.4 (11.9 ± 1.1)	10.45–13.4 (12.1 ± 1.0)*	9.8–12.6 (11.5 ± 1.6)
EE	9.4–13.2 (10.8 ± 1.5)*	9.78–12.13 (11.1 ± 0.88)*	8.5–12.3 (10.6 ± 2.1)
OD	5.6–8.3 (7.5 ± 0.7)	6.1–8.95 (7.6 ± 1.1)*	-
ED	2.8–5.3 (4.01 ± 0.8)	2.8–4.3 (3.5 ± 0.5)*	-
IND	3.39–4.33 (3.9 ± 0.34)*	2.9–4.2 (3.7 ± 0.5)*	-
IOD	6.78–8.62 (7.98 ± 0.67)*	6.9–8.47 (7.5 ± 0.6)*	-
ION	11.8–15.03 (13.9 ± 1.23)*	11.9–15.1 (13.1 ± 1.3)*	-
JL	12.3–10.8 (18.1 ± 2.1)	15.5–19.5 (17.2 ± 1.4)*	-
PL	27.6–32.5 (29.9 ± 1.7)*	26.6–32.8 (29.2 ± 2.5)*	-
SVL:HL	3.5–3.8 (3.68 ± 0.1)	3.3–4.3 (3.7 ± 0.2)	3.61–3.67 (3.7 ± 0.05)
SVL:AG	1.9–2.3 (2.1 ± 0.1)	2.04–2.45 (2.3 ± 0.14)*	-
HL:HW	1.28–1.48 (1.37 ± 0.05)	1.1–1.5 (1.36 ± 0.09)	1.43–2.11 (1.6 ± 0.4)
HL:HH	2.3–3.01 (2.35 ± 1.6)	1.79–3.3 (2.4 ± 0.4)	2.29–2.43 (2.33 ± 0.07)
SE:EE	0.9–1.2 (1.1 ± 0.1)*	1.07–1.1 (1.09 ± 1.14)*	1.02–1.15 (1.09 ± 0.07)
SPL	9–10 (9.4 ± 0.5)*	8–11 (10.08 ± 1.1)*	8–9 (8.7 ± 0.5)
IFL	8–9 (9.75 ± 0.45)*	8–10 (8.8 ± 0.7)*	6–8 (7.8 ± 0.6)
N	5–6 (5.25 ± 0.5)[a]	6–8 (7 ± 0.47)*	5–6 (5.1 ± 0.4)
IN	0–1 (0.23 ± 0.4)	0	0
PostIN	0–2 (0.4 ± 0.77)	0	0
PM	2–3 (2.5 ± 0.7) [a]	2–3 (2.83 ± 0.41)*	2–3 (2.8 ± 0.5)
GP	7[a]	6–9 (7.8 ± 1.2)*	6–7 (7.22 ± 0.6)
CIL	45–49 (46.75 ± 1.7)[a]	41–56 (47.8 ± 4.4)*	52–55 (54.0 ± 1.1)
MB	104–109 (106.5 ± 3.5)[a]	102–109 (103.8 ± 3.8)*	112–127 (119.2 ± 7.6)
GST	9–12 (10.5 ± 1.3)[a]	9–14 (10.3 ± 1.6)*	8–11 (9.8 ± 1.6)
TL	35–37 (36 ± 1.4)[a]	27–34 (31.5 ± 3.0)*	33–34 (33.7 ± 0.6)
DTR	23[a]	19–25 (22.3 ± 1.97)*	23–25 (24.0 ± 1.2)
LF1	9–12 (10.25 ± 1.3)[a]	9–11 (10 ± 0.7)*	11–12 (11.75 ± 0.5)
LF4	18–19 (18.75 ± 0.5)[a]	19–20 (19.3 ± 0.5)*	18–19 (18.1 ± 0.5)
LT1	9–10 (9.75 ± 0.5)[a]	9–10 (9.91 ± 0.3)*	11–12 (11.4 ± 0.6)
LT4	24[a]	22–24 (23.4 ± 0.8)*	22–24 (23.4 ± 0.7)
PP	20–24 (22.5 ± 1.4)*	21*	5–21 (15.3 ± 2.5)
PAT	1–3 (2.25 ± 0.6)*	2–3 (2.5 ± 0.5)*	2–3 (2.8 ± 0.5)

2017; Stuart et al. 2006; Yang and Chan 2015), detailed locality information of the new records is being withheld. According to the SDMs *G. catbaensis* is predicted to occur on other, similar islands in the Gulf of Tonkin, but is still endemic to Ha Long Bay and Cat Ba Archipelago. According to Orlov et al. (2008) the type locality of *G. lichtenfelderi* is an offshore island in Bai Tu Long Archipelago, which is contiguous with Ha Long Bay

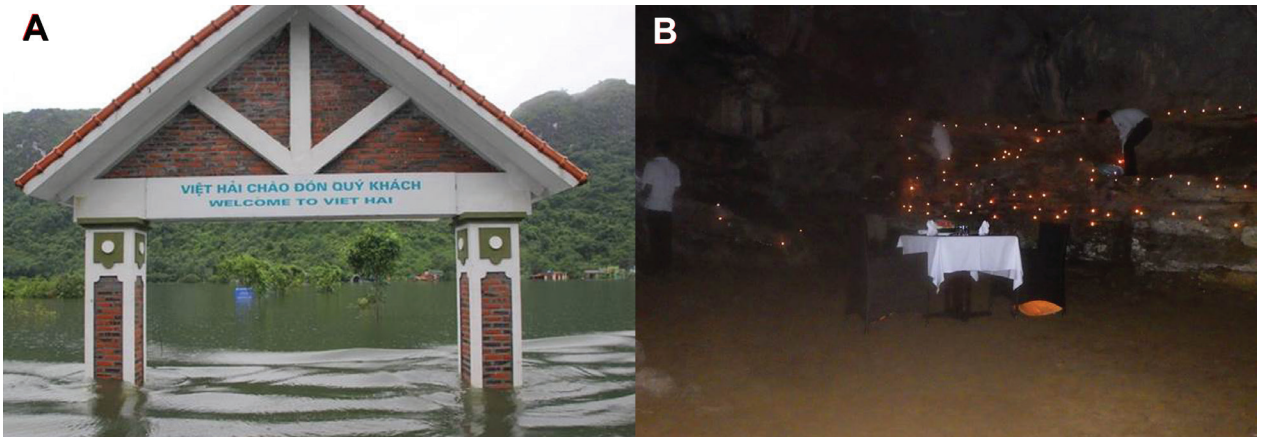

Fig. 6. Potential threats to *Goniurosaurus*. **(A)** Flooding of Viet Hai Commune in August 2015. **(B)** Tourist event in a cave within the UNESCO World Heritage Site on Ha Long Bay. *Photos H.N. Ngo*.

in the Gulf of Tonkin. However, extensive field surveys have failed to record any individual of *G. catbaensis*, occurring in syntopy with *G. lichtenfelderi* (Gawor et al. 2016; Nguyen et al. 2011; Orlov et al. 2008). The habitat of *G. lichtenfelderi* in Bai Tu Long was described as valleys of forest streams on granite rocks within mixed forests of bamboo and broad-leaved trees (Gawor et al. 2016; Nguyen et al. 2009; Nguyen et al. 2011; Orlov et al. 2008; Ziegler et al. 2008), while *G. catbaensis* was found only in limestone karst ecosystems present in Ha Long and Cat Ba archipelagos. Accordingly, our SDMs predicted the potential distribution of *G. catbaensis* to encompass Ha Long Bay and Cat Ba Archipelago, but excluding Bai Tu Long Archipelago (Fig. 5). However, the present SDMs also predicted the mainland area including limestone formations around Ha Long City to be suitable for *G. catbaensis*. Thus, it will be important to search for further occurrences at these predicted sites in order to determine the exact distribution boundaries, and to assess genetic diversity of potentially new populations.

Microhabitat selection: Both sex- and age-related perch selection were found in *G. catbaensis*, namely differences in perch heights. Specifically, juveniles and gravid females occurred at significantly lower heights than subadults and adults. Similar habitat divergences between juveniles and adult individuals have been reported for Crocodile Lizards in Vietnam (van Schingen et al. 2015), and gekkonids in New Caledonia (Snyder et al. 2010).

This study also revealed that the body surface temperature of *G. catbaensis* showed a highly positive correlation with the air temperature (r_s = 0.56; P < 0.05, n = 23) and substrate temperature (r_s = 0.66; P < 0.001, n = 26). Thus, as in other ectotherms, basic physiological functions of *G. catbaensis*, such as locomotion, growth, and reproduction are determined by the environmental temperature. Since tropical lizards are considered to have narrow temperature optima, and only few options for behavioral and physiological compensation, they are assumed to be especially vulnerable to extinction by climate warming (Deutsch et al. 2008; Doody and Moore 2010; Huey et al. 2009; Vié et al. 2009). In particular, body surface temperatures of *G. catbaensis* ranged from between 23.6 and 30.6 °C (mean = 27.2 ± 1.6 °C, n = 26) and were comparably higher than those of *G. kuroiwae* with average skin surface temperatures of 16.6 °C in the humid subtropical Oriental forest (Werner et al. 2005).

Potential threats and recommendations for conservation: Due to the restricted distribution range, low densities, and estimated global population being much lower than suggested threshold values for minimal viable populations, the Cat Ba Tiger Gecko is expected to be especially endangered to unsustainable for harvest (Ngo et al. 2016). Consequently, the species was recently assessed and ranked by the IUCN Red List of Threatened Species as "Endangered" (Nguyen et al. 2016). Other members of the genus *Goniurosaurus* from Vietnam have not been considered for inclusion on the IUCN Red List yet, as data on their population statuses are currently lacking. The findings reported here indicate that not only *G. catbaensis,* but also *G. huuliensis* and *G. luii*, are subject to intensive collection for local trade and provide concrete evidence for the wild source of the respective specimens. It is likely that the reported

Table 4. Environmental parameters characterizing the microhabitat selection of *Goniurosaurus catbaensis.*

Parameter	Number of sightings (n)	Min	Max	Mean ± SD
Canopy cover [%]	63	50	100	95.2 ± 9.6
Height [m]	54	0	3	0.97 ± 0.86
Elevation [m asl]	60	4	132	46.2 ± 32.9
Air Temperature [°C]	59	21.5	31.3	28.1 ± 1.7
Substrate Temperature [°C]	28	22.2	28.2	26.02 ± 1.5
Relative air Humidity [%]	52	70	99	84.9 ± 6.99

cases only reflect a small proportion of illegal harvesting activities. Since over-exploitation of local populations of range-restricted lizard species has been repeatedly found to rapidly cause extinction (e.g., Auliya et al. 2016; Stuart et al. 2006; Yang and Chang 2015), further research on the population status, distribution, ecology, and availability of suitable microhabitat sites is critically needed. The results of such studies may lead to the elevation or determination of the conservation status of other tiger gecko species and provide critical scientific data for future captive breeding programs. To reduce poaching and to control the trade in wild *Goniurosaurus*, we recommend continued monitoring of the scales and patterns of trade in combination with aforementioned population assessments. We also strongly advise against providing exact locality information for new *Goniurosaurus* populations in future publications, as this action might increase poaching activities at respective sites (Lindenmayer and Scheele 2017; Stuart et al. 2006; Yang and Chan 2015).

In addition to the illegal collection of animals, human impacts on habitats have dramatically increased by means of expanding tourism activities (see also Ngo et al. 2016). Tourism events in caves, causing disturbance by candle light, noisy sounds, and waste might result in the extirpation of *G. catbaensis* within these limestone caves. We suggest that tourism companies should hold such events only on their boats to reduce disturbances in the cave habitats of *G. catbaensis*, or at least restrict tourist access to only limited, selected islands.

Following Ngo et al. (2016), the sites in Viet Hai Village on Cat Ba Island had been recommended as a priority conservation zone for species conservation, since *G. catbaensis* was found to be most abundant at those sites. However, during the most recent survey in July 2016, no specimens of *G. catbaensis* were observed in Viet Hai Commune. We assume that an extensive flood in August 2015 might have killed a large amount of the local wildlife, including the Cat Ba Tiger Gecko, at this site. Viet Hai Commune was isolated for a week after torrential rains brought the water level up to the roofs of local houses. Since *G. catbaensis* was found to generally occur at low elevation ranges (4–132 m asl), and Viet Hai is situated only up to 36 m asl (see Fig. 6B), this species is particularly vulnerable to natural catastrophes such as storms, floods, and sea level rises, throughout its distribution range (see Dessler 2016; Saunders et al. 1991). Since local populations are extremely small, they are especially prone to extinction by catastrophic events. The devastating consequences of such natural disasters underline the importance of maintaining numerous independent subpopulations in order to compensate for such events.

In summary, the insular (sub)populations of *G. catbaensis* are threatened by harvest for the pet trade, human activities within its habitats, and natural catastrophes such as increasingly extreme floods and storms in northeastern Vietnam, probably triggered by climate change (The Governmental Committee on Flood and Storm Prevention 2016). Thus, we herewith emphasize the importance of setting aside priority conservation zones for this species, in order to establish a connected and buffered system that allows (sub) populations to recover from catastrophes. We also recommend the establishment of an assurance population, i.e., an *ex situ* conservation breeding program for the species. Although such an effort has been started at the Me Linh Station for Biodiversity (see Ziegler et al. 2016) in Northern Vietnam, more resources need to be allocated to enhance the effort to conserve the species.

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Literature Cited

Auliya M, Altherr S, Ariano-Sanchez D, Baard EH, Brown C, Cantu JC, Gentile G, Gildenhuys P, Henningheim E, Hintzmann J, et al. 2016. Trade in live reptiles and its impact on reptile diversity: the European pet market as a case study. *Biological Conservation* 204: 103–119.

Beaumont LJ, Hughes L, Poulsen M. 2005. Predicting species distributions: use of climatic parameters in BIOCLIM and its impact on predictions of species' current and future distributions. *Ecological Modelling* 186: 250–269.

Cat Ba Biosphere Reserve Authority. 2013. *Cat Ba Archipelago Biosphere Reserve*. Third edition. Hai Phong City, Vietnam. 28 p.

Chen TB, Meng YJ, Jiang K, Li PP, Wen BH, Lu W, Lazell J, Hou M. 2014. New record of the Leopard Gecko *Goniurosaurus araneus* (Squamata: Eublepharidae) for China and habitat portioning between geographically and phylogenetically close leopard geckos. *IRCF Reptiles & Amphibians* 21(1): 16–27.

Clements R, Sodhi NS, Schilthuizen M, Peter KLN-G. 2006. Limestone karsts of Southeast Asia: Imperiled arks of biodiversity. *BioScience* 56(9): 733–742.

Deutsch CA, Tewksbury JJ, Huey RB, Sheldon KS, Ghalambor CK, Haak DC, Martin PR. 2008. Impacts of climate warming on terrestrial ectotherms across

latitude. *Proceedings of the National Academy of Sciences of the United States of America* 105: 6,668–6,672.

Doody JS, Moore JA. 2010. Conceptual model for thermal limits on the distribution of reptiles. *Herpetological Conservation and Biology* 5: 283–289.

Dessler A. 2016. *Introduction to Modern Climate Change*. Second edition. Cambridge Universtiy Press, New York, New York, USA. 267 p.

Gawor A, Pham CT, Nguyen TQ, Nguyen TT, Schmitz A, Ziegler T. 2016. The herpetofauna of the Bai Tu Long National Park, northeastern Vietnam. *Salamandra* 52: 23–41.

Grismer LL, Brian, EV, Viets E, Boyle LJ. 1999. Two new continental species of *Goniurosaurus* (Squamata: Eublepharidae) with a phylogeny and evolutionary classification of the genus. *Journal of Herpetology* 33(3): 382–393.

Grismer LL, Ota H, Tanaka S. 1994. Phylogeny, classification, and biogeography of *Goniurosaurus kuroiwae* (Squamata: Eublepharidae) from the Ryukyu Archipelago, Japan, with description of a new subspecies. *Zoological Science* 11: 319–335.

Hanski I. 1991. Single-species metapopulation dynamics. Pp. 17 In: *Metapopulation Dynamics: Empirical and Theoretical Investigations*. Editors, Gilpin ME, Hanski I. Academic Press, London, United Kingdom. 340 p.

Hammer O, Harper DAT, Ryan PD. 2001. PAST: Paleontological statistics software package for education and data analysis. *Paleontologia Electronica* 4: 9.

Harrison S, Taylor AD. 1997. Empirical evidence for metapopulation dynamics. In: *Metapopulation Biology: Ecology, Genetics and Evolution*. Editors, Hanski IA, Gilpin ME. Academic Press, San Diego, California, USA. 512 p.

Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A. 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* 25: 1,965–1,978.

Honda M, Ota H. 2017. On the live coloration and partial mitochondrial DNA sequences in the topotypic population of *Goniurosaurus kuroiwae orientalis* (Squamata: Eublepharidae), with description of a new subspecies from Tokashikijima Island, Ryukyu Archipelago, Japan. *Asian Herpetological Research* 8: 96–107.

Huey RB, Deutsch CA, Tewksbury JJ, Vitt LJ, Hertz PE, Alvarez Perez HJ, Garland T. 2009. Why tropical forest lizards are vulnerable to climate warming. *Proceedings of the Royal Society B* 276: 1,939–1,948.

Jennings AP, Mathai J, Brodie J, Giordano AJ, Veron G. 2013. Predicted distributions and conservation status of two threatened small carnivores: Banded Civet and Hose's Civet. *Mammalia* 77: 261–271.

Jennings AP, Veron G. 2011. Predicted distributions and ecological niches of eight civets and mongoose species in Southeast Asia. *Journal of Mammalogy* 92: 316–327.

Kearse M, Moir R, Wilson A, Stones-Havas S, Cheung M, Sturrock S, Buxton S, Coope A, Markowitz S, Duran C, et al. 2012. Geneious Basic: an integrated and extendable desktop software platform for the organization and analysis of sequence data. *Bioinformatics* 28: 1,647–1,649.

Le M, Raxworthy CJ, McCord WP, Mertz L. 2006. A molecular phylogeny of tortoises (Testudines: Testudinidae) based on mitochondrial and nuclear genes. *Molecular Phylogenetics and Evolution* 40: 517−531.

Levins R. 1969. Some demographic and genetic consequences of environmental heterogeneity for biological control. *Bulletin of the Entomological Society of America* 15: 237–240.

Li Z, Zhang Y, Li Y, Zhao J. 2010. Palynological records of Holocene monsoon change from the Gulf of Tonkin (Beibuwan), northwestern South China Sea. *Quaternary Research* 74: 8–14.

Liang B, Zhou RB, Liu YL, Chen B, Grismer LL, Wang N. 2018. Renewed classification within *Goniurosaurus* (Squamata: Eublepharidae) uncovers the dual roles of a continental island (Hainan) in species evolution. *Molecular Phylogenetics and Evolution* 127: 646–654.

Lindenmayer D, Scheele B. 2017. Do not publish. *Science* 356(6340): 800–801.

Ngo HN, Ziegler T, Nguyen TQ, Pham CT, Nguyen TT, Le MD, van Schingen M. 2016. First population assessment of two cryptic Tiger Geckos (*Goniurosaurus*) from northern Vietnam: Implications for conservation. *Amphibian & Reptile Conservation* 10(1) [General Section]: 34–45 (e120).

Nguyen TQ. 2011. Systematics, ecology, and conservation of the lizard fauna in northeastern Vietnam, with special focus on *Pseudocalotes* (Agamidae), *Goniurosaurus* (Eublepharidae), *Sphenomorphus* and *Tropidophorus* (Scincidae) from this country. Ph.D. Dissertation, University of Bonn, Bonn, Germany. 229 p.

Nguyen TQ, Ngo HN, van Schingen M, Ziegler T. 2016. *Goniurosaurus catbaensis*. *The IUCN Red List of Threatened Species*. Version 2016.2. Available: http://www.iucnredlist.org [Accessed: 5 March 2017].

Nguyen TQ, Ngo HN, Ziegler T. 2018. The reptile fauna of the Cat Ba Archipelago: a unique biological resource with high level of local endemism and important conservation significance. Pp. 48–55 In: *Workshop Proceeding of Values and Solutions to Conserve Biodiversity in Ha Long Bay and Cat Ba Archipelago: 24 August 2017, IUCN*. International Union for Conservation of Nature, Gland, Switzerland.

Nguyen VS, Ho TC, Nguyen TQ. 2009. *Herpetofauna of Vietnam*. Edition Chimaira, Frankfurt am Main, Germany. 768 p.

Orlov NL, Ryabov SA, Nguyen TT, Nguyen TQ, Ho CT. 2008. A new species of *Goniurosaurus* (Sauria: Gekkota: Eublepharidae) from north Vietnam. *Russian Journal of Herpetology* 15(3): 229–244.

Palumbi SR, Martin A, Romano S, McMillan WO, Stice L, Grabowski G. 1991. *The Simple Fool's Guide to PCR*. University of Hawaii, Department of Zoology and Kewalo Marine Laboratory, Honolulu, Hawaii,

USA. 94 p.

Phillips SJ, Anderson RP, Schapire RE. 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modelling* 190: 231–259.

Posada D, Crandall KA. 1998. MODELTEST: testing the model of DNA substitution. *Bioinformatics* 14: 817–818.

Reed DH, O'Grady JJ, Brook BW, Ballou JD, Frankham R. 2003. Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. *Biological Conservation* 113: 23–34.

Ronquist F, Teslenko M, van der Mark P, Ayres DL, Darling A, Höhna S, Larget B, Liu L, Suchard MA, Huelsenbeck JP. 2012. MrBayes 3.2: efficient Bayesian phylogenetic inference and model choice across a large model space. *Systematic Biology* 61: 539–542.

Saunders DA, Hobbs RJ, Margules CR. 1991. Biological consequences of ecosystem fragmentation: a review. *Conservation Biology* 5(1): 18–32.

Seufer H, Kaverkin Y, Kirschner A. 2005. The genus *Goniurosaurus* Barbour, 1908 (Oriental Leopard Geckos). Pp. 133–175 In: *Die Lidgeckos: Pflege, Zucht, und Lebensweise*. Kirschner & Seufer Publishing, Karlsruhe, Germany. 238 p.

Snyder J, Snyder L, Bauer AM. 2010. Ecological observations on the Gargoyle Gecko, *Rhacodactylus auriculatus* (Bavay, 1869), in southern New Caledonia. *Salamandra* 46: 37–47.

Stuart BL, Rhodin AG, Grismer LL, Hansel T. 2006. Scientific description can imperil species. *Science* 312: 1,137.

Swofford DL. 2001. *PAUP* Phylogenetic Analysis Using Parsimony (* and Other Methods), version 4*. Sinauer Associates, Sunderland, Massachusetts, USA.

The Governmental Committee on Flood and Storm Prevention. 2016. Summary the performance of projects dealing with foods and storms in Vietnam.

The Management Department of Ha Long Bay. 2014. Ha Long Bay Natural World Heritage. Second edition. Quang Ninh Province, Vietnam. 76 p.

Thompson JD, Gibson TJ, Plewniak F, Jeanmougin F, Higgins DG. 1997. The ClustalX windows interface: Xexible strategies for multiple sequence alignment aided by quality analysis tools. *Nucleic Acids Research* 25: 4,876–4,882.

Traill LW, Bradshaw CJA, Brook BW. 2007. Minimum viable population size: a meta-analysis of 30 years of published estimates. *Biological Conservation* 139: 159–166.

van Schingen M, Le MD, Ngo TH, Pham TC, Ha QQ, Nguyen TQ, Ziegler T. 2016. Is there more than one Crocodile Lizard? An integrative taxonomic approach reveals Vietnamese and Chinese *Shinisaurus crocodilurus* represent separate conservation and taxonomic units. *Der Zoologische Garten* 85: 240–260.

van Schingen M, Pham CT, An HT, Nguyen TQ, Bernardes M, Bonkowski M, Ziegler T. 2015. First ecological assessment of the endangered Crocodile Lizard *Shinisaurus crocodilurus* Ahl, 1930 in Vietnam: microhabitat characterization and habitat selection. *Herpetological Conservation and Biology* 10: 948–958.

Vié JC, Hilton-Taylor C, Stuart SN. 2009. *Wildlife in a Changing World – an Analysis of the 2008 IUCN Red List of Threatened Species*. International Union for the Conservation of Nature, Gland, Switzerland. 180 p.

Werner YL, Takahashi H, Mautz WJ, Ota H. 2005. Behavior of the terrestrial nocturnal lizards *Goniurosaurus k. kuroiwae* and *Eublepharis macularius* (Reptilia: Eublepharidae) in a thigmothermal gradient. *Journal of Thermal Biology* 30: 247–254.

Yang JH, Chan BP. 2015. Two new species of the genus *Goniurosaurus* (Squamata: Sauria: Eublepharidae) from southern China. *Zootaxa* 3980(1): 67–80.

Zhou RB, Wang N, Chen B, Liang B. 2018. Morphological evidence uncovers a new species of *Goniurosaurus* (Squamata: Eublepharidae) from the Hainan Island, China. *Zootaxa* 4369(2): 281–291.

Ziegler T, Nguyen TQ, Schmitz A, Stenke R, Rösler H. 2008. A new species of *Goniurosaurus* from Cat Ba Island, Hai Phong, northern Vietnam (Squamata: Eublepharidae). *Zootaxa* 1771: 16–30.

Ziegler T, Rauhaus A, Mutschmann F, Dang PH, Pham CT, Nguyen TQ. 2016. Building up of keeping facilities and breeding projects for frogs, newts and lizards at the Me Linh Station for Biodiversity in northern Vietnam, including improvement of housing conditions for confiscated reptiles and primates. *Der Zoologische Garten* 85: 91–120.

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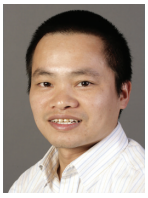

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