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Unexpected high forest turtle diversity in hill forests in northern Vietnam

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Abstract

Almost all Asian turtle species are considered threatened by the World Conservation Union (IUCN). We investigated the turtle fauna and their distribution in hilly forests in northern Vietnam (TamThanh commune, Quan Son district) during two consecutive periods (12th–23th May, 12th–24th August 2019). These forests are of Subtropical Moist Forest type according to WWF, and dominated by evergreen and semi-evergreen forests. We used a combination of (1) field surveys; (2) hunter interviews; (3) examination of hunter quarry, and (4) monitoring of hunting activity. We performed field surveys in bamboo and hilly secondary forests (500–1350 m), applied 103 hunter interviews, and examined the same number of hunter bags. We found a total of 124 different individuals of as many as 9 turtle

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species (representing 18% of the currently known total chelonian fauna in the Indo-Burma region). Two species were the most dominant, the Impressed tortoise (*Manouria impressa*), found mostly as shells in villages, and the Indochinese box turtle (*Cuora galbinifrons*) sighted inside bamboo forests at different elevations. *C. galbinifrons* is one of the most critically endangered turtle species in the world. Given that there are still large expanses of unexplored bamboo forests and mixed bamboo—evergreen forest (over 5 million hectares) remaining throughout northern Vietnam, if our results are typical of other similar habitats, it is likely that *C. galbinifrons* may be more common than currently assessed. We suggest that field surveys should be conducted as soon as possible to confirm whether these turtles are as seriously threatened as presently considered by the IUCN.

Keywords Chelonians · Hunting surveys · Indo-Burma region · Habitat · *Cuora galbinifrons*

Introduction

As many as 83% (88 species) of all Asian turtle taxa (Geomydidae, Testudinidae, Trionychidae, Platysternididae) are considered threatened according to the World Conservation Union (IUCN), due to overhunting and habitat loss (Rhodin et al. 2018). Most Critically Endangered (CR) and Endangered (EN) species are found in Southeastern China, Southeast Asia, Indonesia, and northern India (Rhodin et al. 2018). However, the situation is particularly critical in Vietnam (Turtle Taxonomy Working Group et al. 2017; Pham Van 2018), where there is also a taxonomically diverse turtle fauna (Bouret 1941; Stanford et al. 2018). Despite the country's importance, Vietnam's turtles remain poorly known especially in terms of their ecology (Turtle Taxonomy Working Group et al. 2017; Pham Van et al. 2019a).

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Most herpetological studies published to date in Vietnam are species lists (Nguyen et al. 2009; Nguyen and Ho 1996) or just focus on the turtle trade in the region (Cheung and Dudgeon 2006; Hendrie 2000, 2001; Hendrie and Trang 2000; Le and Broad 1995; Pham Van et al. 2019b; Tran et al. 2016; van Dijk et al. 2000; Pham Van et al. 2019a). These trade studies, which are based on market surveys only, assume catastrophic declines of Vietnamese turtles despite the fact that no field data are available to support this (Das et al. 2016; Fritz et al. 2002; Le 2007; Le et al. 2004; Ly et al. 2011; McCormack et al. 2014; Pham Van et al. 2018). Such lack of field evidence is exacerbated for some species e.g. *Cuora zhoui, Mauremys nigricans* that are only known from markets but have never been observed in the wild (Ben and John 2012; Pham Van et al. 2017). The absence of detailed information on the species' abundance, distribution and ecology makes it difficult to develop adequate conservation actions for these highly threatened reptiles; field surveys are urgently needed.

In Vietnam, turtles are likely to be less common in the lowlands than in upland forests. Typical for other animal groups in the country, most turtle species may remain relatively undisturbed in the highlands, since most of these areas have escaped habitat disturbance and destruction by humans. However, because these mountainous areas are logistically difficult to survey, few studies have been undertaken here.

In this paper, we documented the composition, habitat distribution, and abundance of turtle species in a mature secondary hilly forest area in northern Vietnam. We used field surveys as well as gathered data on hunting practices of the area's inhabitants. Over two survey periods, during the rainy season, we were able to obtain first-time records of turtle species in a little-known area of their distribution. Our study can be used as an example of the fieldwork required to advance the conservation knowledge of such a threatened group of reptiles in one of the most biodiverse countries in the world.

Materials and methods

Study area

The study was conducted during two consecutive periods (12th to 23th May, 12th to 24th August 2019) in the Tam Thanh commune (N20° 11′ 15″, E104° 50′ 29″), Quan Son district, northern Vietnam (Figs. 1 and 2). The Tam Thanh commune adjoins the southern Laos border within the northern Indochina Subtropical Moist Forests (WWF), dominated by evergreen and semi-evergreen forests. The climate of the region is subtropical montane climate, with an average temperature of 23 °C, maximum temperature of 40 °C from May to July and lowest temperature of 2.6 °C in December. Average rainfall is 1900 mm; the wet season is from May to October (>100 mm rainfall) and the dry season from December

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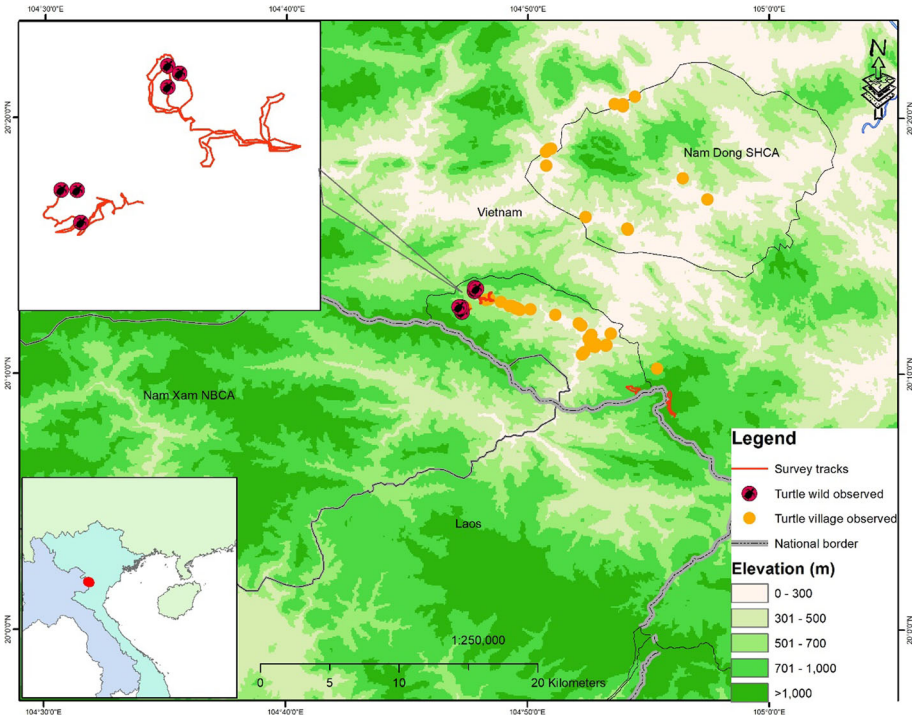

Fig. 1 Map of northern Vietnam, showing the study area, the survey tracks made by the researchers, the sites of sighting for free-ranging turtles and for individuals kept in hunters' houses

to January. Humidity averages around 84% (online dataset in http://huyenquanson.vn/gioi-thieu/dieu-kien-tu-nhien/8).

Human activities have been responsible for some habitat modification and destruction, but 80% forest cover still remains. This forest area is considered important for the conservation of biodiversity in Vietnam (Sterling and Hurley 2005). The Tam Thanh forest area (5054.2 ha) is composed of 4824.88 ha of natural forest and 85.02 ha of plantation forest. Within the natural forest, 59.3% consists of evergreen and semi-deciduous forest, 28.2% bamboo forest, and 12.5% mixed evergreen and bamboo forests (Thanh Hoa FPD 2019).

The forest in Tam Thanh commune is managed by a local board, where regulated extraction of timber and non-timber products is allowed by the local inhabitants (Regulation no. 17/2015/QĐ-TTg, 2015). The commune had a total population in 2018 of 3911 inhabitants of three main ethnicities: Thai, Muong, Kinh (Tam Thanh People Committee 2019).

Protocol

Interviews were performed in the Tam Thanh, Son Lu, Nam Dong, Trung Thuong communes in the Quan Son district. Field surveys and the hunter monitoring survey were carried out in Tam Thanh forest.

Fig. 2 Main habitat types at the study area. Top left: general view of the study forest. Top right: habitat of *Geoemyda spengleri* with the dominant plant being the bamboo (*Indosasa* sp.). Bottom left: Habitat of *Cuora galbinifrons* in the bamboo forest (*Maclurochloa* ssp). Bottom right: *Geoemyda spengleri* habitat in a rocky cave. Photos by Pham Van Thong

Field surveys

In tropical and sub-tropical regions, the rainy season is the period of highest above ground activity for turtles (Luiselli 2003). Thus, in our study, we conducted random walks during the rainy season, applying a time-constrained search effort (Akani et al. 1999a, b). A team of two main researchers and seven local assistants undertook turtle searches between 0700 and 1700 Hanoi time during each survey day. The first field survey was from 11th to 23th May 2019 at an elevation range of 500–750 m a.s.l while the second was from 14th to 24th August 2019 at elevations ranging between 900 and 1350 m a.s.l (Fig. 1). We followed random transects (1 to 4.5 km long depending on the quality of the surveyed habitat) within which we searched for turtles. Recording of searching time was stopped when an animal was found and measured. Hunting dogs were not used to allow for future comparisons of the data with those from other studies that did not employ dogs.

All individual turtles found during the field surveys or caught by local hunters and available in their homes, were examined and identified to species. For each individual, we recorded straight carapace length (CL), carapace width (CW), straight carapace height (CH) and body mass (BM). Length measurements were taken with a 30 cm caliper (accuracy 0.1 cm), and turtle body mass was taken using a 5 kg scale, (accuracy 1 g). Hunters confirmed that all turtles recorded in this study came from the study area; all collected species are known to occur in the region (Stuart et al. 2001; Douglas et al. 2011). Although we could not verify the information directly, it is well known that the study area is a

starting point for the trade, and so it is very unlikely that these animals came from other, far away areas. Photographic vouchers were taken for each observed individual, as this may be important for 'difficult' genera, such as *Cyclemys* and *Pelodiscus*.

Hunter interviews

Three Vietnamese researchers applied structured interviews, in Vietnamese, from 18th to 27th December 2018 and 12th to 20th May 2019. Hunters were asked the following questions:

(i) What kind of turtles occurs in this forest? We also showed pictures of the various species for identification confirmation after their description.
(ii) Can you describe the main morphological characteristics of each species?
(iii) Do you hunt turtles by chance, or do you use specific hunting techniques?
(iv) Which months/season do you normally go to hunt for turtles?
(v) Where did you hunt for turtles?
(vi) For what purpose do you use the hunted turtles?

Hunter activity survey

To obtain more detailed information on turtle hunting activities in the study area, we monitored the movements of a hunter of Thai origin (41 years old). Using a smartphone application (Samsung Health), the hunter was able to self-record the distance travelled during each hunting trip during the hunting season (May to July 2019) as well as the number of hunting days in each month. A trained dog accompanied the hunter; although we never used dogs during our field surveys (see above), in this case, in order to make a reliable evaluation of the hunter's activity, we allowed him to use the dog as hunters normally use their dogs during hunting. During all hunting surveys, the hunter recorded the number of individuals and turtle species encountered.

Habitat description

We described the following microhabitat characteristics within a 10 m radius around each point of capture of turtles:

(i) Main habitat types: 1=stream, 2=evergreen forest, 3=bamboo forest;
(ii) Canopy cover, estimated on the basis of the percentage of sunny spots on ground;
(iii) Ground temperature (°C, collected by B61200-1300 infrared thermometer);
(iv) Ground humidity (%, by AR827 Hygrometer);
(v) Slope angle (degree, using "Angle meter", an Android app for mobile phones).

Statistical analyses

To calculate turtle searching effort, we used the following formula:

$$S = \frac{x}{a * b}$$

with S=turtle relative frequency of observation; x=number of turtles found in a given transect; a=number of people involved in the time searching along a given transect; b= total time spent for a trip along a given transect.

To determine whether the turtle taxonomic composition of the study area was adequately assessed, we performed a rarefaction analysis using the total (i.e. the field observed +the hunters' collected) turtle sample. Sample-based rarefaction (or species accumulation curve) was implemented using the analytical solution known as "Mao's tau," with Standard Deviation (Colwell et al. 2004). In the graphical plot, Standard Errors were converted to 95% confidence intervals (by $\times$ 1.96). To evaluate statistically whether the observed number of species (on the basis of the observed number of individuals) was fully assessed, we used the Chao-1 index with 95% confidence intervals, after 9999 bootstraps.

(Log-transformed) carapace length was regressed against turtle body mass using a Pearson's correlation coefficient. Alpha was set at 5%, and means are presented $\pm$ 1 Standard Deviation. All statistical analyses were performed on PASW statistical software 18.0 version.

Results

Field surveys

A total of 361.8 h, covering a total of 64.9 km transect length, were spent in the forest searching for turtles by the survey team (194.4 h in May and 167.4 in August). During the May surveys, three *C. galbinifrons* and two *G. spengleri* were found, but only one *G. spengleri* was observed during the second survey (Fig. 3). In May, the overall turtle encounter rate was 0.014 individuals $\times$ person $\times$ hour (altitudinal range=500–750 m a.s.l.), but 0.006 in August (altitudinal range=900–1350 m a.s.l.). The encounter frequency for *C. galbinifrons* was 0.008 individuals $\times$ person $\times$ hour and that of *G. spengleri* was 0.005

Fig. 3 Individuals of *Cuora galbinifrons* (above) and *Geoemyda spengleri* (below) observed in the wild at the study area. Photos by Pham Van Thong

individuals × person × hour. The observed density for *C. galbinifrons* was 0.057 individuals per km and 0.031 individuals per km for *G. spengleri*.

Microhabitat characteristics for each individual turtle observed are given in Appendix 1, body size measurements in Appendix 2. *C. galbinifrons* individuals were found at lower elevations (mean=657.2±36 m a.s.l.) than *G. spengleri* (mean=772.3±170.6 m a.s.l.), but sample sizes were too small for any statistical evaluation. Three *C. galbinifrons* were found in bamboo forest but all three *G. spengleri* individuals were observed in mixed bamboo-evergreen forest. No animals were found in surroundings of streams or water bodies, and only one *G. spengleri* individual was discovered in a rocky area of the forest with numerous crevices. Percentage forest cover was similar for both species (*C. galbinifrons*: 70.0±15.8%; *G. spengleri*: 73.3±7.6%) as well as the slope of the sighting site (*C. galbinifrons*: 21.2±14.4°; *G. spengleri*: 26.3±11.8°). Only one of six individuals (a *G. spengleri*) was observed nearby a forest trail, but all other individuals were in more remote sites.

Mean carapace length of *Manouria impressa* (n=36) was 212.2±47.1 mm (range 124–310 mm) and the mean body mass (only shells) was 429.8±304.7 g (range 80–1800 g). Carapace length and body mass were positively correlated (r=0.868, P<0.0001). Mean carapace length of *C. galbinifrons* was 156.3±26.4 mm (range 67.2–187.5 mm; n=16) and mean body mass was 619.2±218.6 g (range 31–960 g; n=16); as expected, (log-transformed) carapace length and body mass were significantly positively correlated (r=0.871, P<0.0001; slope=1809.4, Y-intercept=− 3352.7; see Appendix 3). In *C. mouhotii,* mean carapace length was 161.4±12.9 mm (range 147–176 mm; n=5) and mean body mass was 506.6±187.7 g (range 247–693 g; n=5); in *G. spengleri*, mean carapace length was 102.8

Fig. 4 Some turtle individuals observed in the hunters' houses at the study area. Left: *Platysternon megacephalum* in Pa village (photo by Nguyen Van Tai). Right: a group of seven *Cuora galbinifrons* and three *Manouria impressa* (photo by Lo Van Ngoi)

±7.7 mm (range 91–112 mm; n=7) and mean body mass was 149.6±30.2 g (range 120–211 g; n=7). Sample sizes were too small in the latter two species to apply any correlation analysis between carapace length and body mass.

In hunter houses in the Tam Thanh commune and Nam Dong SHCA we examined directly and identified a total of 118 turtles (Fig. 4) of the two species found in the field as well as another seven species (Table 1); the turtle fauna in the study area being 9 species, 89% of them listed as threatened by IUCN Red List (CR, EN and VU; see IUCN 2019).

The resulting individual rarefaction curve showed that the species' taxonomic diversity was adequately represented by our data (Fig. 5), with the Chao-1 index indicating that the theoretically predicted number of species (n=9) was the same as the number of species actually observed in our surveys. *M. impressa* and *C. galbinifrons* were the two dominant species in hunter houses, where there was one singleton (*Cyclemys oldhamii*) and three doubletons (Table 1). Individuals of *M. impressa* were observed in villages as shells of dead animals that had been consumed by local people and then kept as decoration. On the other hand, all *C. galbinifrons* were found alive, recently caught individuals that hunters would sell to market traders.

Hunter and farmer interviews

A total of 103 independent interviews were conducted. Most interviewees belonged to the Thai ethnic group (details in Appendix 4). According to the majority of interviewees, the two most abundant species were *C. galbinifrons* and *M. impressa,* cited as the dominant

Table 1 List of the various chelonian species observed during the present study in the hands of the interviewed hunters from villages around Nam Dong SHCA and Tam Thanh commune

Family	Species	Local name	IUCN red list	No. individuals	Alive	Dead
Geomydidae	*Cuora galbinifrons*	Táu Cặp, rùa hộp	CR	36	18	18
Geomydidae	*Cuora mouhotii*	Rùa đá, rùa núi, thọ khi u, rùa gai	EN	13	10	3
Geomydidae	*Cyclemys oldhamii*	Rùa cứt trâu, táu nác	NE	1	0	1
Geomydidae	*Geoemyda spengleri*	Táu lửa, táu phay, rùa gai bé	EN	7	6	1
Geomydidae	*Sacalia quadriocellata*	Tàu khíu, cong long, rùa bốn mắt, rùa hôi	EN	2	2	0
Platysternidae	*Platysternon megacephalum*	Rùa mỏ vẹt, rùa đầu to, cạp cang	EN	6	6	0
Testudinidae	*Manouria impressa*	Táu hạc, rùa gối, tàu nam hi ng, rùa gai	VU	49	5	44
Trionychidae	*Palea steindachneri*	Pa phả nám, ba ba gai, ba ba khe	VU	2	1	1
Trionychidae	*Pelodiscus sinensis*	Pha mứn, ba ba trơn	VU	2	1	1
Total				118	49	69

IUCN (2019) red list status and local names are also given

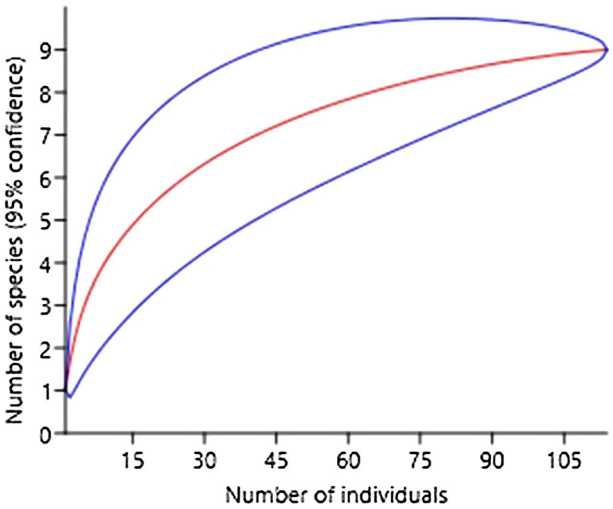

Fig. 5 Individual rarefaction curve for the total (i.e. the field observed+the hunters' collected) turtle sample recorded during the present surveys. Blue lines would indicate 95% confidence intervals after 9999 bootstraps

species by 54.4% and 64.1% of the interviewees, respectively. All hunters accurately described the main morphological characteristics of the various turtle species, using local names for each (Table 1) and, as reported above, frequently showed shells or living animals to confirm their descriptions. According to the various interviewees, there were several ways to hunt turtles, depending on the species targeted (Table 2). In general, most hunted terrestrial species such as *M. impressa, C. galbinifrons,* and *C. mouhotii*) using hunting dogs, while aquatic species (i.e. *Palea steindachneri, Sacalia quadriocellata*) were captured by hand if encountered. An individual of *C. galbinifrons* was caught in a water puddle in the village. For all species, the hunting season was between March and September (Table 2), and the main purpose for hunting was to sell to market traders or for domestic consumption when selling prices fell.

Hunter activity

During the hunting season, the hunter covered a total of 87 km in May, 108.1 km in June and 169.3 km in July; a total of 17 days in the forest in May, 19 in June and 23 in July. During this period, the hunter spent 90% of the time hunting and 10% walking. A total of 40 turtles were collected: one *P. steindachneri,* one *G. spengleri,* 15 *M. impressa* and 23 *C. galbinifrons.* The frequency of encounter was 0.002 individuals per km for *P. steindachneri* and *G. spengleri*, 0.035 for *M. impressa* and 0.053 for *C. galbinifrons*. These hunting scores confirmed that *M. impressa* and *C. galbinifrons* were clearly the two most common turtle species in the study area.

Table 2 Synthesis of the interview data concerning the turtles at the study area

Family	Species	No. mentioning interviews	%	Fishing-nets	By hand	Hunting dogs	By chance	Hunting season	Consumption	Decoration	Sell to traders	Traditional medicine	Pet
Geomydidae	*Cuora galbinifrons*	55	53.4		+	+	+	March–September		Y	Y	Y	
Geomydidae	*Cuora mouhotii*	34	33			+	+	March–September	Y		Y		
Geomydidae	*Cyclemys oldhamii*	5	4.8	+					Y				
Geomydidae	*Geoemyda spengleri*	15	14.6			+	+	March–September	Y		Y		Y
Geomydidae	*Sacalia quadriocellata*	14	13.6		+								Y
Platysternidae	*Platysternon megacephalum*	38	36.9		+			March–September					
Testudinidae	*Manouria impressa*	66	64.1			+	+	March–September	Y	Y	Y		
Trionychidae	*Palea steindachneri*	21	20.4	+	+				Y		Y		
Trionychidae	*Palea steindachneri/ Rafetus swinhoei*	3	2.9										
Trionychidae	*Pelodiscus sinensis*	20	19.4		+				Y		Y		

For the specific questions see the text

Discussion

Our results revealed that the turtle community in our study area was very diverse, with nine species from four different families (Geoemydidae, Platysternidae, Trionychidae and Testudinidae). Moreover, our saturation analyses showed that the community richness of the study area was satisfactorily captured with the performed field effort. Although our study area fell within the known range of all observed species (Stuart et al. 2001), this high species diversity was remarkable compared to overall species richness of the Indo-Burma turtle hotspot, which include southern China, Laos, Myanmar, Thailand, Vietnam, and Cambodia (Myers et al. 2000). Indeed, 18% of the species currently known in the Indo-Burma region (n=50, see Mittermeier et al. 2015) were found in our study area. The observed species' richness was even more remarkable if we take into account that considerable portions of the study forest have been altered by human activities over a long period of time. In particular, it is noteworthy that the most abundant turtle species in our area was *C. galbinifrons*, from direct observations, individuals kept by hunters in their houses, interviewees' opinion, and from information obtained from a monitored hunter. In addition, we encountered *C. galbinifrons* in the field more frequently than any other reptile, including snakes (Pham et al., unpublished observations), and our density estimates (number of individuals per km transect) gave very similar values.

Our findings for *C. galbinifrons* is in direct contrast to what has been previously published (based on essentially turtle trade inferences) which suggests that this is one of the rarest chelonian species in the world (Stanford et al. 2018). It is unlikely that our study case is unique because considerable portions of bamboo forest (over 5 million hectares) are still found in northern Vietnam (MARD 2016). These areas do not significantly differ from our study area in terms of habitat characteristics and human pressure on the natural environment. It is therefore likely that many more populations of *C. galbinifrons* are found in Vietnam since scientific exploration of these forests is minimal, and despite that hunters would normally exploit these areas even nowadays. On the other hand, the other sympatric species appeared clearly least abundant than *C. galbinifrons*. Therefore, we cannot exclude that these other species may be in more serious conservation status than currently considered. Further studies should aim to investigate in other forest areas, whether this turtle species is as threatened as supposed or whether it is just very elusive and therefore difficult to find by non-experienced researchers. There is no evidence of active quantitative field research on the demography of this species in Vietnamese forests, so we cannot say whether the hunting is having truly a heavy impact on turtle populations—for example whether they are r or k selected, despite the indirect evidences coming out from the turtle trade studies. Furthermore, the listing of the species as Critically Endangered has been extrapolated from trade data and not from field surveys is unsatisfactory (IUCN 2016). Because in our study *C. galbinifrons* was not found above 750 m elevation, it is possible that the species may be restricted to bamboo forest patches up to around 700 m a.s.l., with *G. spengleri* able to survive at higher elevations (from 650 to 1200 m a.s.l) (Blanck 2013; Pham Van et al. 2018). Further studies should be planned to evaluate whether *C. galbinifrons* is really absent from high mountain forests in northern Vietnam. However, apart from the relative altitude of the records, *C. galbinifrons* and *G. spengleri* appeared very similar in terms of microhabitat characteristics of their sites of presence, and bamboo forests seemed to be particularly important habitats for these threatened turtles (Ben-Zhi et al. 2005).

Our study also provides unique data on the morphometry of wild caught turtles since most measurements are known from captive individuals. These measurements will also be useful to enable comparative studies of the geographic variation of these species within their distribution range. In order to allow future authors to analyze the morphometric variation of these turtles across we provide the raw data in the online supplemental material for this paper.

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