



Article

Previously Unrecorded Invasive Species and the Unsatisfying Knowledge of Turtle Communities in Northern Vietnam

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Abstract: According to the IUCN, Southeast Asia is the area of the world with the highest number of threatened turtle species. The current status of chelonians is particularly catastrophic in Vietnam. However, there is still a lack of field data to unambiguously support this fact for a few species. To better understand the freshwater turtle diversity and eventually undertake efficient conservation actions, we conducted surveys with local fishers using standardized questionnaires in two independent river systems in northern Vietnam. A total of 112 questionnaires were administered to as many fishers in April and October 2022. We directly observed four sympatric freshwater species (*Pelodiscus sinensis*, *Palea steindachneri*, *Mauremys sinensis* and *Sacalia quadriocellata*) in Lao Cai and Yen Bai provinces, and two species (*Pelodiscus sinensis* and *Palea steindachneri*) in Bac Giang, Hai Duong, Thai Binh, and Hung Yen provinces. Based on the interviews, we added as possible the presence of two other species (*Rafetus swinhoei* and *Pelochelys cantorii*) in each of the two study areas. Moreover, we recorded for the first time in Vietnam, two wild individuals of an invasive alien species, the Common snapping turtle (*Chelydra serpentina*), confirming that the distribution and ecology of turtle species in Vietnam is poorly understood. Furthermore, recent photos (year 2019) of a 38 kg softshell turtle, possibly attributable to *Rafetus swinhoei*, were recorded from a restaurant in the area. In conclusion, interviews with local fishers have been found to be useful for exploring the likely presence and the local distribution of the various turtle species.

Keywords: turtle diversity; turtle communities; northern Vietnam; invasive species; field study



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1. Introduction

The Indo-Burma hotspot in tropical Asia is one of the biologically most important regions of the world [1] and includes a remarkable diversity of terrestrial and freshwater turtle species [2,3]. Despite this geographic region is recorded as a hotspot of chelonian diversity [4], the knowledge on ecology and distribution of most species remains poorly known [5], with such aspects as community ecology and sympatry being less studied in Southeast Asia than in all other tropical regions. In fact, since most data came from animals observed in trade rather than collected from the wild [5] the huge decline of turtle populations is essentially determined based on the yearly trajectories of the traded

amounts. For instance, in order to infer the declining and Critically Endangered status of *Cuora galbinifrons*, only very preliminary field population data (without any quantification based on capture-mark-recapture) were used together with “anecdotal information from interviews throughout the range” and the observations of “substantial quantities in illegal trade shipments in the 1990s and early 2000s”, whereas “only sporadic animals are observed in recent years” [6]. According to the International Union for Conservation of Nature [6], Southeast Asia is the area of the world with the highest number of Critically Endangered (CR) and Endangered (EN) species [7], with the situation being particularly critical in Vietnam [8,9]. However, the state of knowledge on the ecology and abundance of populations of these species is minimal, such that, for instance, a few species (*Cuora zhoui* Zhao, 1990 and *Mauremys nigricans* Gray, 1834) are only known from market but have doubtfully been directly observed in their natural habitat [10,11], and other species are currently known from very few free-ranging individuals (*Rafetus swinhoei* (Gray, 1873)) [6].

Indeed, to develop science-based conservation actions, it is essential to evaluate the status, abundance, ecology, distribution, and community ecology of turtle species/assemblages in Vietnam by doing systematic surveys in the field and not only in market or trade. Moreover, to undertake conservation actions, we would also need to investigate the distribution of potentially invasive turtle species. In fact, the introduction of non-indigenous species can deeply impact the ecosystem functioning, enter into interspecific competition with the native species, deplete the local biodiversity and even have remarkable social and economic costs [12]. Regarding invasive turtle species, the Red-eared slider turtle (*Trachemys scripta elegans* (Thunberg, 1792)) is listed as one of the 100 most problematic invasive species in the world [13].

In this context, we applied standardized questionnaires to fishers in two independent river systems in northern Vietnam, with the aims to: (i) understand more about the local freshwater turtle diversity; (ii) highlight local treats; (iii) uncover new potential areas of presence of *Rafetus swinhoei* and (iv) provide recommendations and future actions needed for conservation. While carrying out these surveys, we also reported direct sightings of turtle individuals of the various species, with the aim to contributing to the knowledge of the distribution and potential sympatry of freshwater chelonian species in northern Vietnam.

2. Materials and Methods

2.1. Taxonomic Note

In this paper we used the taxonomy of Turtles of the World [14], but we maintained Vietnamese species of the genus *Pelodiscus* as *sinensis* and Vietnamese *Amyda* as *cartilaginea*, waiting for more investigations on these taxa.

2.2. Study Areas

The field study was carried out in two separate areas in northern Vietnam: (1) the Red River and Chay River in Lao Cai and Yen Bai provinces (named area A), and (2) Bac Giang, Hai Duong, Thai Binh, and Hung Yen provinces, (named area B) along the Luc Nam River, Thuong River, Kinh Thay River, Kinh Mon River, Thai Binh River, Luoc River and Red River (Figure 1). The Red River, with a total length of 1149 km and about 510 km in Vietnam, is part of the historical presence of *Rafetus swinhoei* [15,16]. The sector of the river course crossing through Lao Cai and Yen Bai provinces is about 200 km long and is characterized by either human settlements or forests along the banks. Chay River is parallel to the Red River and comes from China across Ha Giang, Lao Cai, and Yen Bai provinces [17]. Luc Nam River and Thuong River start from Lang Son province, about 700 m a.s.l., and run across Bac Giang province for about 200 km. After the above-mentioned sector, Thuong River meets with Cau River and Duong River in Chi Linh district, then splits to two branches called Thai Binh River and Kinh Thay River. Those rivers are under the Northern tropical monsoon climate, with the average temperature range being 23.8–26.9 °C, the average annual rainfall being 1380–1900 mm, and the rainy season occurring from May to October [18].

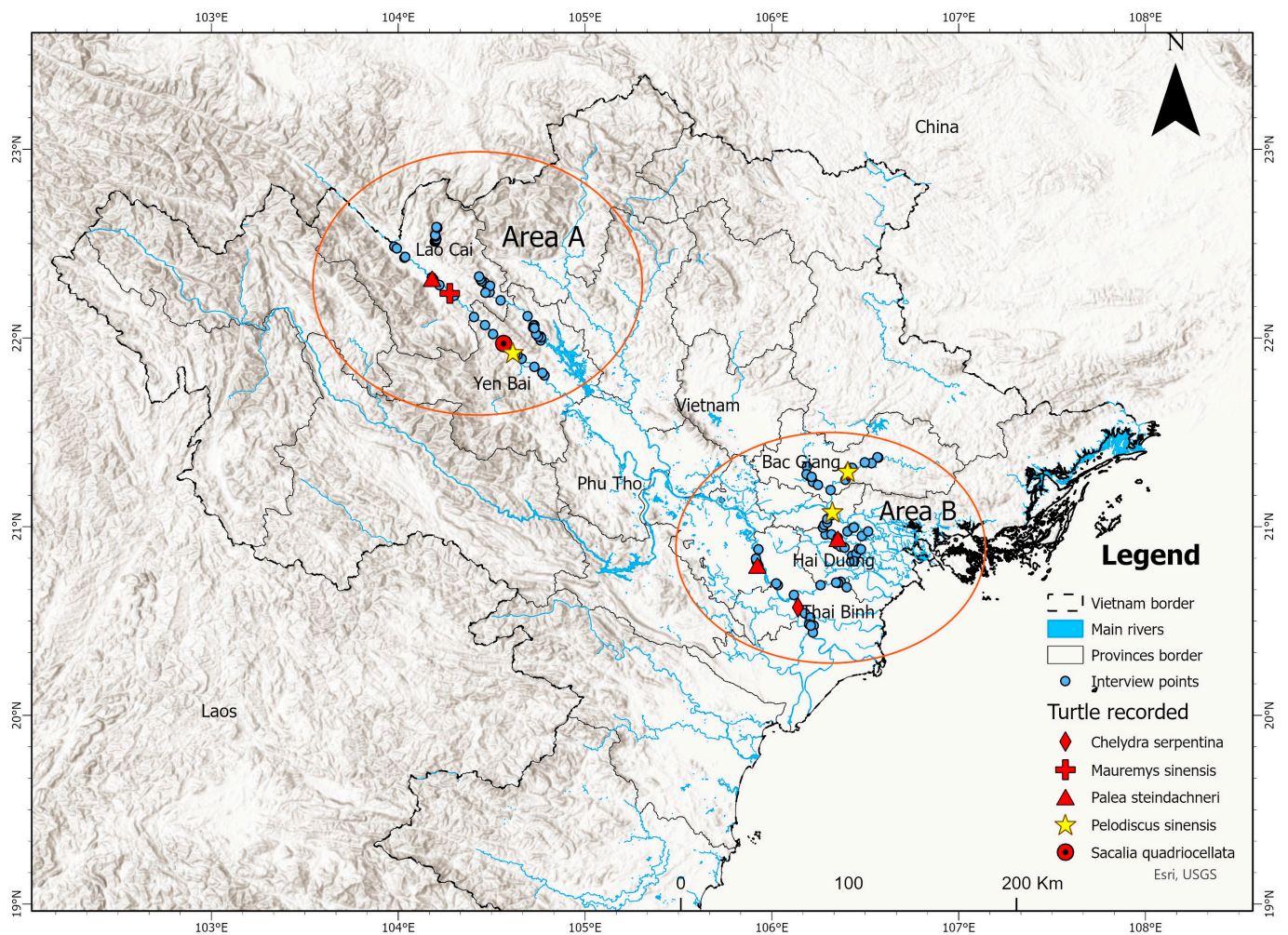


Figure 1. Map of northern Vietnam showing (i) the sites where interviews with local fishers were carried out during our survey (blue spot), and (ii) the sites of sighting of the various turtle species recorded during the interviews, in the two study areas. Area (A) includes the Red River and Chay River in Lao Cai and Yen Bai provinces, and area (B) includes Bac Giang, Hai Duong, Thai Binh, and Hung Yen provinces, along the Luc Nam River, Thuong River, Kinh Thay River, Kinh Mon River, Thai Binh River, Luoc River and Red River.

2.3. Protocol

In order to locate the potential interviewees, the “fisher camps” and the relevant villages were selected after “Google Maps” inspection of the study areas. In the relevant maps, we searched for the presence of fishing boats, floating houses with fish storages, and square dipping nets along the rivers. Then, the sites of potential interest were reached by motorbike or by boat. The travelled distance by motorbike was 856 km and by boat was 50 km in area (A), and 970 km by motorbike in area (B). At each relevant site, we randomly selected the various interviewees. A “snow-ball” procedure was employed only when a fisher specifically directed us to a colleague or member of his/her family who had direct experience, recent or past, with the capture or observation of turtles.

In area (A), the interview survey was carried out from 1 to 10 October 2022. Overall, we conducted a total of 50 interviews with fishers encountered in villages and fishers’ camps along the riverine courses in Lao Cai and Yen Bai provinces. In area (B), the interviews were conducted from 13 to 22 April 2022, on 62 fishers from Bac Giang, Hai Duong, Thai Binh, and Hung Yen provinces (Figure 1).

Surveys were conducted by two interviewers in both areas (A) (TLN and OLD) and area (B) (PTH and OLD). Interview methods followed the British Sociological Society’s

guidelines for ensuring appropriate ethical standards in projects involving data collection for research purposes. Respondents' identity was kept anonymous; interviews were only conducted with persons of at least 18 years age in Vietnamese, and after having obtained the verbal consent of the participants. The questionnaire structure, interview methodology, and associated data collection techniques were identical to those given in [19]. We used a standard set of 31 questions (see Appendix A), which took about 30 min to complete (see also [19]).

Each interview started by recording the location, date, geographic coordinates, and name, gender, age class, and mobile phone contact (if available) of the interviewee (Appendix A). We also asked whether the interviewees had any turtle individual (alive for being sold, shells and/or photographic materials) to be shown, and, when it was the case, these specimens were examined and identified to species, sex and eventually measured (carapace length and weight). We considered as reliable a given information if the respondent was able (i) to associate the local name with the photo of the correct species, (ii) to describe the typical defensive behavior that each turtle species shows when captured, and (iii) to provide the details of some clear morphological characteristics of the various species. Since the criteria used to select the reliable information were stringent, we believe that the provided answers that passed these criteria were extremely reliable and gave remarkable support to the knowledge of the turtles of the two study areas.

2.4. Statistical Analysis

Statistical differences in the frequency of respondents between the study areas in terms of gender, marital status and level of education were assessed by contingency table χ^2 test. Similarly, χ^2 tests were used to explore inter-site frequency variation of the answers given to our questions. All tests were performed with Past 3.0 statistical software [20].

3. Results

3.1. Socio-Economic Profile of the Fishers

All respondents were active fishers, mainly males (respectively, 90% and 79% in the two study areas) and ranged in age 18–72 in area (A) and 30–76 in area (B), with a great preponderance of married persons (94% and 96.8%). The two most frequent education categories were secondary school (42%) and non-scholarized (36%) in area (A) and primary school (38.7%) and secondary school (33.9%) in area (B). Despite a very similar demographic structure, the socio-economic profile of fishers differed remarkably between the two areas ($\chi^2 = 48.7$, $df = 4$, $p < 0.0001$): in (A) the majority of persons were professionally fishing since less than 5 years, whereas in (B) the dominant category fished since at least 30 to 40 years. In both areas, (i) over 90% of the interviewees started fishing in the same area where they are working now, and (ii) the great majority (respectively, 61% and 75.8%) were full-time fishers.

3.2. Habitat Protection and Conservation

In (A), 58.7% of the respondents considered the fishery stock of their area as fully exploited, whereas just 3.2% of the fishers did so in (B). This difference between areas was statistically significant (χ^2 test, $p < 0.01$). In addition, the percentage of fishers thinking that their area was unexploited was also considerably higher in the area (B) (12.9% versus 2.2%), thus revealing that (B) was likely in much better ecological conditions than area (A). However, 79% of the respondents suggested that area (B) was also depleted with loss of species. Overall, the difference between the two areas was statistically significant ($\chi^2 = 88.1$, $df = 4$, $p < 0.0001$). According to the several interviewees, the main species that were depleted in (A) were the fishes *Squaliobarbus curriculus* (Richardson, 1846), *Labeo rohita* (Hamilton, 1822), *Chanos chanos* (Forsskål, 1775), *Hemiculter leucisculus* (Basilewsky, 1855), *Hemibagrus guttatus* (Lacepède, 1803), *Cranoglanis sinensis* Peters, 1881, *Onychostoma laticeps* (Günther, 1896) and *Chanodichthys* sp. In (B), the species reported as the most depleted

were the fishes *Pisodonophis* sp., *Bagarius yarrelli* (Sykes, 1839), *Tenualosa* sp., and the turtle *Pelodiscus sinensis* Wiegmann, 1835.

According to our interviewees, the use of illegal gear was the prominent reason for the decline of fishery stocks at both study sites (54.4% of answers in (A) and 86.7% in (B)). In (A), 82.6% of fishermen claimed that many places in the area where once productive fishing grounds, however, are now depleted. On the other hand, in (B), the feeling was completely opposite with only 34.4% of persons claiming that the fisheries are in worse condition than before.

3.3. Fishers and Turtles

More than half of the fishers were aware of the presence of very big turtles in both their sites (51.1% of the answers in (A) and 51.6% in (B)). Turtles were caught primarily using stationary gill nets in both sites (49% in (A) and 69.5% in (B)), however cast nets were significantly more used in (B) (88.1%) than in (A) (only 2%). Hooks and long lines were more frequently used in (A) (26.5%) than in (B) (1.7%). Overall, the difference between the two areas was statistically significant (χ^2 , $p < 0.001$).

In (B), 41% of the fishers claimed that they were not able to capture turtles every month, while 52.5% captured less than one turtle per month, 1.6% one turtle, 4.9% two turtles, 0% three or more turtles per month. Regarding (A), 34.7% of the fishers claimed to being unable to capture turtles every month, 6.1% less than one turtle per month, 14.3% one turtle, 6.1% two turtles, 8.2% three turtles, 6.1% four turtle and 24.5% more than five turtle per month. Overall, the frequency of the answers differed significantly between the two areas ($\chi^2 = 86.8$, $df = 6$, $p < 0.0001$).

3.4. Turtle Diversity

In area (A), we directly recorded the presence of four sympatric species: *Pelodiscus sinensis*, *Palea steindachneri* (Siebenrock, 1906), *Mauremys sinensis* (Gray, 1834) and *Sacalia quadriocellata* (Siebenrock, 1903), which were caught by local fishermen (Figures 1 and 2). Another species, *Amyda cartilaginea* (Boddaert, 1770) was observed in the hands of a trader, but it did not come from the study area (Figure 2).

Concerning the species potentially present in area (A), five interviewees apparently mentioned the presence of very large (over 100 kg weight) turtles and/or identified the photos of *Rafetus swinhoei*, suggesting that this species might still occur in the area (the last “contact” was reported for the year 2020). Obviously, there is no firm evidence that these sightings are reliable. Moreover, the possible presence of *Pelochelys cantorii* was also recorded along the Chay River as nine independent fishers insisted on the local presence of a large species that they named Đăm Đăm (meaning “punching softshell turtle”, because of the typical defensive behavior of this species).

In area (B), we recorded for the first time in the international literature in Vietnam, two individuals of an invasive alien species, the Common snapping turtle, *Chelydra serpentina* (Linnaeus, 1758). The first individual was a subadult that was captured in Luc Nam River—Luc Nam, Bac Giang (Figure 3). The second record concerned an individual weighing 5-kg that was captured in the Red River—Hung Ha, Thai Binh (Figure 3).

Concerning the native species, we recorded sympatric *Pelodiscus sinensis* and *Palea steindachneri*. *Palea steindachneri* was observed three times in two different sites (Figure 4): (1) a 12-kg individual was caught in Thai Binh River—Ngoc Chau, Hai Duong city, Hai Duong; (2) two individuals, respectively, weighing 10-kg and 14-kg, were found in Red River, Khoai Chau, Hung Yen.

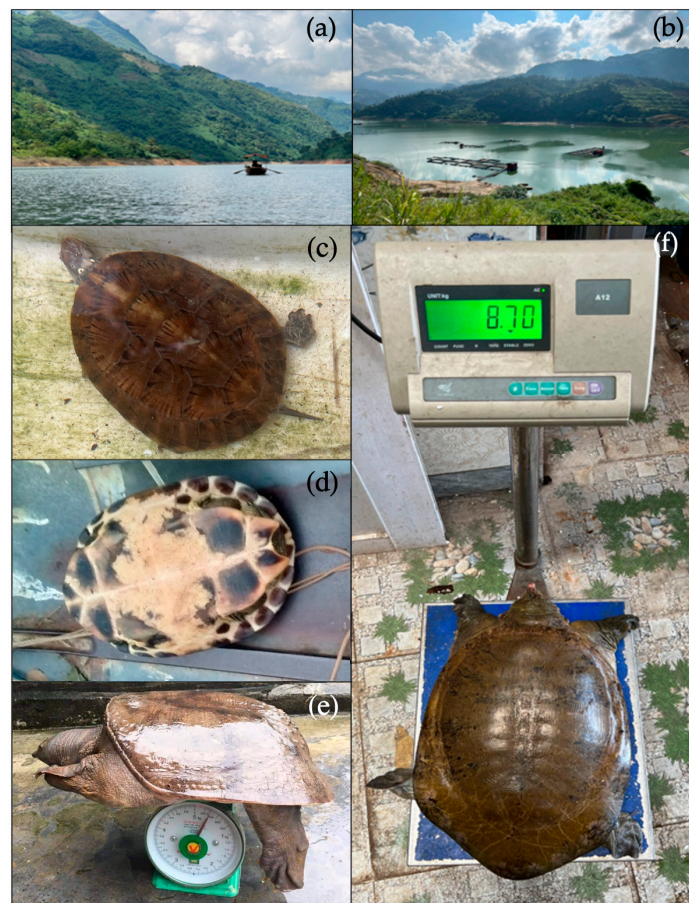


Figure 2. Turtle diversity observed during the interviews in Lao Cai and Yen Bai provinces in northern Vietnam: (a) fisherman on the Chay River; (b) water reservoir upstream of the dam (Chay River); (c) *Sacalia quadriocellata*; (d) *Mauremys sinensis*; (e) *Palea steindachneri* and (f) *Amyda cartilaginea*.

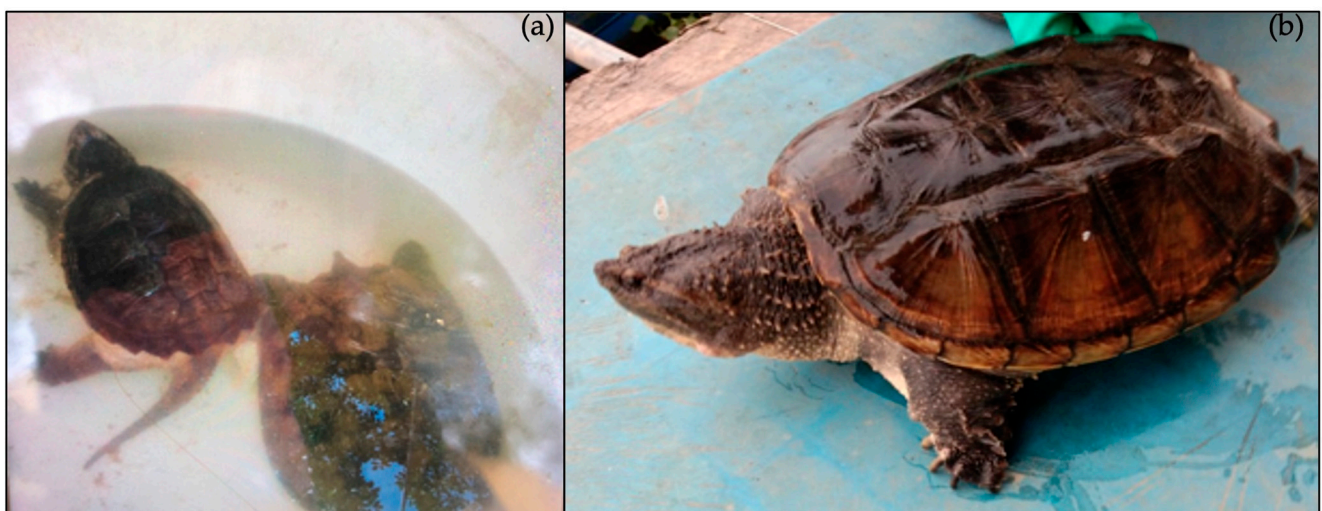


Figure 3. First record of the invasive Common snapping turtle, *Chelydra serpentina*: (a) sub-adult individual caught together with a *Pelodiscus sinensis* in Luc Nam River—Luc Nam, Bac Giang province; (b) 5-kg individual from Red River—Hung Ha, Thai Binh province.



Figure 4. Turtle diversity in Bac Giang, Hai Duong, Thai Binh, and Hung Yen provinces: (a) typical fisherman boat house on Thuong River; (b) Fish storage on Thuong River; (c,d) two different *Palea steindachneri* individuals that were caught in the Red River.

Interestingly, from a local restaurant specialized in turtle consumption in Bac Giang province, we obtained a set of digital photos showing a large softshell turtle (38 kg weight) that was consumed on 27 July 2019 (Figure 5). There were no clear diagnostic characteristics for determination of the species in the photos (Figure 5). The owner claimed that this turtle was *Rafetus swinhoei* because he regularly sells and knows very well the other species that potentially can be misidentified with (i.e., *Amyda cartilaginea*, *Palea steindachneri* and *Pelochelys cantorii*). Instead, according to his opinion, this individual very clearly did not belong to any of them. In addition, he correctly identified *Rafetus swinhoei* as the species to whom this individual belonged out of a set of photos that were shown to him by the interviewers.

In Hai Duong city, we also interviewed a trader of softshell turtles that are used for human consumption. He traded three softshell species, i.e., *Pelodiscus sinensis*, *Palea steindachneri* and *Amyda cartilaginea*. He claimed to buy all turtles from farms, with *Palea* coming from West-North Vietnam, *Amyda* from West-South Vietnam, and *Pelodiscus* from China. No turtles were bought from fishers.

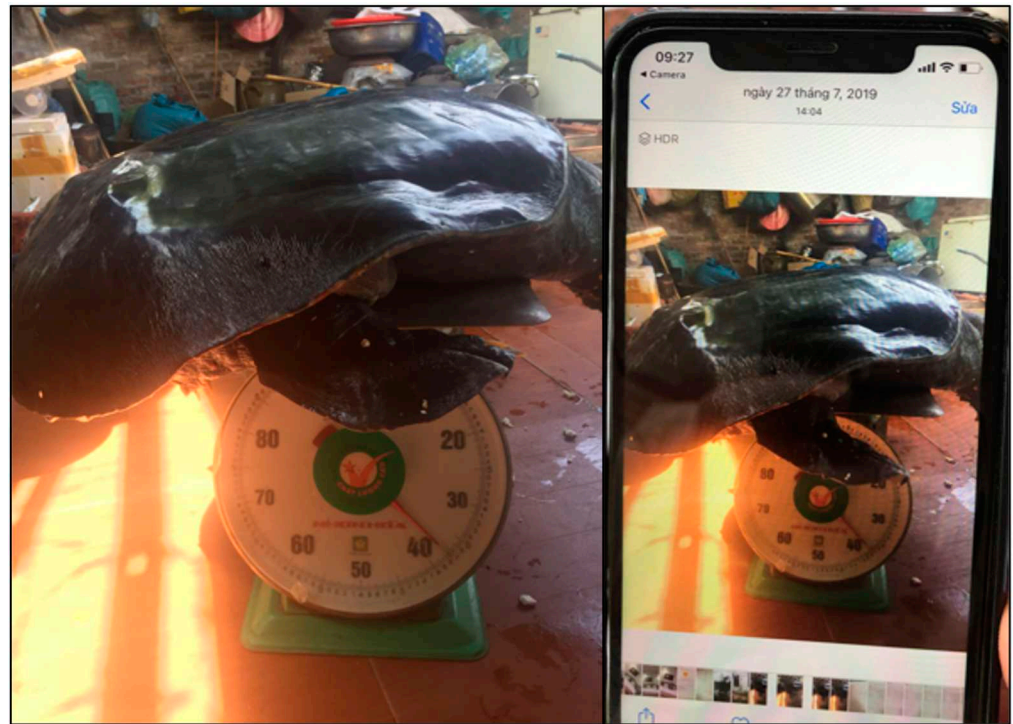


Figure 5. A 38-kg softshell turtle brought by a customer to a local restaurant on the 27 July 2019 in Bac Giang province.

4. Discussion

During our interviews, we recorded for the first time in Vietnam, two individuals of *Chelydra serpentina*. This North-American species is known to be invasive in many regions of the world [21] and has been already found in other countries in Asia [22,23]. *Chelydra serpentina* could potentially compete with native species if viable populations are established, as it has already been reported for the invasive *Trachemys scripta elegans* elsewhere [24–26]. Therefore, its impact on the native turtle species of Vietnam should be investigated more deeply.

In addition, our records are relevant because they confirmed that the knowledge of the distribution of freshwater turtle species in Vietnam is still scarce, given that even a large and morphologically very recognizable species (as *Chelydra serpentina* is) went overlooked in a logistically not-difficult area of the country. Indirectly, therefore, this fact suggests that several localities of presence of more elusive and less recognizable species may have remained unknown to the scientific world till now. On the one hand, our study therefore implies that a much more focused field effort should be taken by scientists in Vietnam in order to uncover new localities of presence of the various native species. On the other hand, our study suggests that some of the apparently very rare/threatened taxa might in fact just be insufficiently known. For example, although relatively to a terrestrial species, Pham Van et al. [27] showed that one of the supposedly most threatened turtles in south-east Asia (*Cuora galbinifrons*) was instead the most abundant species in a mountain chain of northern Vietnam, with its main natural habitat (bamboo forest) being widespread and almost untouched in wide remote and relatively un-accessible areas.

In area (A), we directly recorded four sympatric freshwater turtle species whereas just two in area (B). Interestingly, we confirmed *Palea steindachneri* to occur in large rivers and not, as usual, in small streams [28], thus showing that also for this species the ecological knowledge is certainly still inadequate. The observed number of sympatric species is consistent with the number of sympatric freshwater species from Africa, with a maximum of 4–5 [29]. Unfortunately, we were unable to find even a single published study focusing on the community ecology and the number of sympatric freshwater turtle species in single

localities of Vietnam. So, virtually nothing is known in this regard whereas such studies are essential for determining the conservation status of species and of whole communities.

Regarding the large softshell turtle that was identified as a *Rafetus swinhoei* by the restaurant's owner, we could not conclude whether this individual really belonged to that species or to *Amyda cartilaginea* because of the missing diagnostic morphological characteristics (such as the head) in the photos. However, (i) only *Rafetus* is native of the area from where the picture was taken, (ii) no tubercles can be seen on the edge of the shell, and (iii) the carapace is totally smooth. Thus, considering also the identification made by the well experienced restaurant's owner, we are led to think that this individual was possibly a *Rafetus*, in so being one of the latest observed individuals of this species. We anticipate that, based on unpublished interviews, *Rafetus swinhoei* may have a wider southwards and westwards distribution than currently known, respectively, reaching central Vietnam and north-eastern Laos. Indeed, reliable interviews reporting recent sightings of this species were collected on the Nam Xam River, that goes through northern Laos and Vietnam (where it is named Chu River) [30]. The presence of *Rafetus swinhoei* was also reported by reliable interviewees at few sites along the Vietnamese sector of this river [19]. A persistent problem when interviewing fishers is that they remember and identify as *Rafetus swinhoei* only large or huge specimens (of at least 60 or 70 kg in weight), which causes the risk of a constant underestimation of the real presence of the species in the various river axes of the area. Even the former professional *Rafetus* hunters only reported about the very large individuals, while openly declaring that juveniles and subadults were not targeted by their activities [31]. So, for instance, former hunters working in both Ba Vi Lake (Hanoi, Vietnam) and De Swamp (Thanh Hoa, Vietnam), claimed that there were still several individuals of smaller size classes in their sites until they have been searching for *Rafetus* [31]. Since no further hunting activity has been ongoing therein after their retirement [31], we are inclined to believe (i) that the number of juveniles and subadults still persisting in the wild is underestimated, and (ii) that the current available estimate (very few remaining individuals) is not strongly supported by field evidence and may be somehow pessimistic.

Interviews with local fishers are useful for exploring the potential presence, local distribution, and apparent population trend of several species [19,30,32–35]. In our study case, interviews allowed us to hypothesize that the abundance of turtles was different between the two areas, with fishermen in area (A) reporting that they capture a significantly higher number of turtles than those operating in area (B). Further studies will have to verify the correctness of the hypotheses that we have formulated on the basis of these interviews with local fishermen.

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Data Availability Statement: All data pertinent to this study are presented herein.

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Appendix A.

List of questions addressed to the various interviewees during the present study.

Appendix A.1. DEMOGRAPHY OF FISHERS

- (1) What is your marital status? (a) single (b) married (c) divorced (d) widowed;
- (2) What is your highest level of education: (a) illiterate (b) primary (c) secondary (d) university (e) other;

Appendix A.2. SOCIO-ECONOMIC GROWTH INDICATOR

- (3) When did you begin fishing in your life? (a) <5 years old, (b) 5–10 years old, (c) 10–20 years old, (d) 20–30 years old, (e) 30–40 years old.
- (4) Did you start fishing in this area? (a) Yes (b) No. If not, where did you start your fishing and when?
- (5) How did you become a fisherman? (a) trained by family members (b) motivated by friends (c) only source of income available (d) vocational training (e) traditional knowledge (f) other
- (6) How intensively do you fish? (a) full time (b) part-time (c) other
- (7) Will your children become fishers as well? (a) Yes (b) No (c) not necessarily (d) I don't know (e) Preferably not.

Appendix A.3. HABITAT PROTECTION AND CONSERVATION

- (8) How would you describe the condition of fish stocks within this area? (a) fully exploited (b) unexploited (c) depleted with loss of species (d) not depleted (e) I don't know.
- (9) Has fishing depleted stocks of any exploited species? (a) Yes (b) No (c) I don't know. If the answer is Yes, please name the species that you consider having been depleted.
- (10) By what means have fish stocks been depleted? (a) illegal gears (b) increased number of fishers (c) narrowing focus on few target species (d) increased price for fish (e) continued fishing within the same grounds (f) others;
- (11) Are your fishing grounds in a good state? (a) Yes (b) No (c) I don't know.
- (12) How would you describe the fishing grounds in this area 10 years ago/compared with now? (a) highly productive (b) moderately productive—sign of degradation observed (c) scarcely productive—degradation evident (d) non-productive—heavily degraded and depleted (e) I don't know.
- (13) Are there any places in this area that were once productive fishing grounds but are now depleted? (a) Yes (b) No (c) I don't know.
- (14) How many days in a month do you go fishing? (a) once a week (b) twice a week (c) three times a week (d) four times a week (e) five times a week (f) six times a week (g) everyday (h) zero.

Appendix A.4. FISHERS AND TURTLES

- (15) What types of fishing gear is used to catch freshwater turtle in this area? (a) stationary gill nets (b) cast nets (c) hooks and long line (d) other;
- (16) How many individual turtles do you catch every month during your fishing activities? (a) zero (b) less than one (c) one turtle (d) two turtles (e) three turtles (f) four turtles (g) more than five turtles.
- (17) How would you describe the conditions of the turtle stock in this area? (a) fully exploited (b) unexploited (c) depleted with loss of species (d) other;
- (18) To whom do you sell turtles? (a) private individuals (b) traders (c) retailers (d) others;
- (19) What is the value of in cash of different turtle species?
- (20) Are you aware that the freshwater turtles are threatened with extinction, and have been included under the IUCN Red List? (a) Yes (b) No.
- (21) Do you want to be involved in turtle protection? (a) Yes (b) No. If your answer is Yes, how do you think that it could be possible to protect/conservate threatened turtles?
- (22) What is your view concerning the creation of a community protected/gazette area in this location? Strongly disagree [a], disagree [b], indifferent [c], agree [d], strongly agree [e].