

Female wanted for the world's rarest turtle: prioritizing areas where *Rafetus swinhoei* may persist in the wild

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Abstract The Yangtze giant softshell turtle *Rafetus swinhoei* is the rarest turtle species, with just two individuals known to be surviving, one male in a zoo in China and one individual recently identified as a female in the wild in Viet Nam. As the species is on the brink of extinction, it is an urgent priority to search for additional individuals in the wild, and for areas where it may still be present. Here, we analysed areas where the species may still occur, identified through interview surveys in Viet Nam. In addition, we introduced a novel system for evaluating the potential for occurrence of this rare and elusive freshwater turtle, using a conservation priority index. This index was based on three recorded variables: (1) probability of the species' presence based on interviews with local fishers, (2) degree of habitat alteration, and (3) fishing intensity, with the latter two based on experts' evaluation of the sites where the species could potentially be present. There were at least 13 independent, reliable sightings in the 2010s, seven of which were in 2018–2019, indicating that *R. swinhoei* potentially persists in the wild. Although the species was confirmed at only one site, there are at least three more sites where it is likely to be

present, and 13 sites of conservation interest. We provide a description of all sites where the species is potentially present, and a summary of relevant interviews. The Da River system has the highest number of recent sightings. We recommend that a research and conservation project be initiated urgently, and outline how such a project could be implemented.

Keywords Conservation programmes, interview surveys, potential distribution, priority index, *Rafetus swinhoei*, Viet Nam, Yangtze giant softshell turtle

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Introduction

The Yangtze giant softshell turtle *Rafetus swinhoei* (Trionychidae; Gray, 1873) is one of the largest freshwater turtles, with some males weighing > 160 kg. The species occurs exclusively in the Red River basin in China and Viet Nam, and the lower Yangtze River floodplain in China (Pritchard, 2012; Wang et al., 2013) and is of particular cultural significance in Vietnamese mythology and folklore (Bettelheim, 2012). Until recently, *R. swinhoei* has been known primarily for cultural reasons (Pritchard, 2012), with few studies describing the species' ecology and natural history (Gray, 1873; Heude, 1880; Meylan & Webb, 1988; Pritchard, 2001, 2005). Large dams have been constructed within the species' range, and potential negative effects, including impacts on the nesting habitats of the species and effects caused by isolation and overfishing, were not considered (Le Duc et al., 2020b). *Rafetus swinhoei* is categorized as Critically Endangered on the IUCN Red List (Fong et al., 2021) and is one of the most threatened turtle species globally (Stanford et al., 2020). It began to decline in the 1980s, and became rare in the 1990s as a result of habitat alteration and intensive capture for local consumption (Le Duc et al., 2020a). Currently only one male individual remains in captivity, in China, and there is one known individual in the wild in Viet Nam, which was recently identified as a female (Le Duc et al., 2020a; Stanford et al., 2020, WCS, 2020). Intensive efforts to locate more individuals in both Viet

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Nam and China have failed (Wang et al., 2013; Kuchling et al., 2014; Pham et al., 2020). Most data available on the species is in unpublished reports and documents, or has been published in unverified reports in social media. In China, *R. swinhoei* has reportedly never been observed in the wild (Stanford et al., 2018). However, the species was historically reported to occur in the Red River, c. 300 km from Yuanjiang County (Wang et al., 2013). The species is also believed to have been present along the Yangtze River until a few decades ago (Pritchard, 2012), but there is no evidence confirming its current presence in this river (Wang et al., 2013). Trapping and observation surveys have been conducted in China (Wang et al., 2013; Kuchling et al., 2014), but only limited information from the surveys has been published.

Interview surveys have been carried out in both Viet Nam (Asian Turtle Program, 2008) and China (Kuchling et al., 2014). The results of these interviews (> 3,000 according to Timmins, 2016, unpubl. data) have not been published, the raw data are unavailable and the interview questions are unknown (Anadón et al., 2009; Turvey et al., 2015). However, information about the ecology and population biology of *R. swinhoei* has been obtained using local ecological knowledge, gathered in standardized interviews of former hunters of *R. swinhoei* in Viet Nam, raising the possibility that there may be more individuals in the wild (Le Duc et al., 2020a,b; Pham et al., 2020). Several priority sites have been identified where trapping/observational surveys are urgently needed to confirm the presence of the species (Le Duc et al., 2020a,b; Pham et al., 2020).

Here, we present the results of interview surveys with fishers on two river systems in Viet Nam where interviews have not previously been undertaken, categorize sites according to the likelihood that *R. swinhoei* is present, and recommend further research actions.

Study area

We conducted our survey in areas along the Da River (Black River), from Son La dam across the provinces of Son La, Lai Chau and Dien Bien, covering the entire 500 km of the Da River in Viet Nam (for interview data from areas along the Da River outside Viet Nam, see Le Duc et al., 2020a). The Da River (total length 910 km) originates in Yunnan province in China and flows through Viet Nam before joining the Red River in Hanoi (Dao, 2010; Vinh et al., 2014; Le Duc et al., 2020a).

Methods

We conducted 80 interviews during 13–24 November 2019, using the same questionnaire (Supplementary Material 1) and methodology as Le Duc et al. (2020a). Based on interviews with former hunters, fishers and local people during

two periods in four areas (this study and Le Duc et al., 2020a), we assigned a presence score to each site: score = 1: confirmed presence of *R. swinhoei*, based on shells, skulls or photographic evidence; score = 2: high probability of presence, where > 3 independent interviewees accurately described the species' morphological characteristics, there had been multiple sightings within the previous 10 years, the precise location of these sightings was known and the sighting was confirmed by multiple household members; score = 3: medium probability of presence, where only one interviewee described morphological characteristics accurately, and any sightings had occurred > 10 years ago; score = 4: low or no probability of presence, where interviewees did not know the species, or their comments were contradictory and/or unreliable.

We categorized the sites where *R. swinhoei* may be present according to the level of habitat modification that had occurred during the past 30 years: score = 1: no or little habitat alteration, where habitat has been modified by human activities, but still retains large patches of natural vegetation cover in the waterbody and on banks, and the size and shape of the site have not changed significantly; score = 2: moderate habitat alteration, where habitat has been modified by dams and/or land conversion, water level, area and/or shape have been changed, vegetation cover has declined, but patches of natural vegetation remain; score = 3: severe habitat alteration, where habitat has been completely modified by dams and/or land conversion, water level, shape, and/or size of the site have changed significantly, and natural vegetation has largely disappeared.

We assigned a score to estimate fishing intensity at each site: score = 1: no fishing or low fishing intensity, where < 20 fishers were active at the site; score = 2: medium fishing intensity, where 21–40 fishers were active; score = 3: high fishing intensity, with > 40 fishers. The scores for habitat alteration and fishing intensity were assigned by three authors (OLD, TVP, LL), who together had > 45 years of experience in field surveys.

Our analyses included four sites newly surveyed in this study, in addition to the sites previously described by Le Duc et al. (2020a) and Pham et al. (2020). For each site, we calculated an overall conservation priority score that combined the presence, habitat alteration and fishing intensity scores, whereby a low overall score indicates a site of high conservation priority. The conservation priority score was calculated with the formula: presence score + habitat modification score + fishing intensity score. The highest possible priority would thus be a score of 3 (1 + 1 + 1), and the lowest possible priority would be a score of 10 (4 + 3 + 3). We analysed correlations between presence, habitat alteration, fishing intensity and overall priority scores using a Spearman's rank correlation coefficient (r_s). We used PAST 3.0 (Hammer et al., 2001) for all analyses, with alpha set at 5%.

Results

Interviewees in Son La and Lai Chau provinces reported 13 reliable sightings from 2010–2019, seven of which were in 2018–2019 (Table 1; see Supplementary Material 1 for a full summary of interview responses). Overall, we identified 13 sites where *R. swinhoei* may be present in the Da, Ma, Chu, and Red River systems, at a mean altitude of $98.6 \pm \text{SD } 80.4$ m (Table 2). One site had a presence score of 1, with one individual confirmed and possibly two others present, three sites a score of 2 (high probability of turtle presence), and nine sites a score of 3 (Fig. 1). If we combine the findings from our surveys with those from areas along the Da River and in Thanh Hoa province (Le Duc et al., 2020a), there is a total of 13 sites where *R. swinhoei* could potentially be present (Fig. 1), with sites 1 and 2 having the highest probability of presence based on the degree of habitat alteration and fishing intensity (Table 2), and sites 10, 11, 12 and 13 with multiple sightings reported over the last decade. Several of these reported sightings were in 2018 and 2019, predominantly at sites with more severe habitat alteration and higher fishing intensity (Table 1). In addition, these surveys combined provide evidence of 25 sites where *R. swinhoei* probably occurred until a few decades ago (Fig. 1). The assigned conservation priority scores for the different localities, with all variables, are shown in Table 2.

The scores for habitat alteration and fishing intensity were not significantly correlated ($r_s = 0.472$, $n = 13$, $P = 0.103$), and neither were those for fishing intensity and species presence ($r_s = 0.068$, $n = 13$, $P = 0.827$), nor for habitat alteration and species presence ($r_s = -0.058$, $n = 13$, $P = 0.851$). To protect the sites, their geographical coordinates are not reported here, but can be obtained from the authors on request. The general landscape of these sites is shown in Plate 1.

The overall conservation priority score was statistically more affected by fishing intensity ($r_s = 0.682$, $n = 13$, $P < 0.01$) than by habitat alteration ($r_s = 0.600$, $n = 13$, $P < 0.05$) and species presence ($r_s = 0.608$, $n = 13$, $P < 0.05$), but overall the three variables had a similar weight.

Discussion

Our surveys provide new information about the potential presence of *R. swinhoei* in addition to the single location where the species is currently known, supporting the evidence previously reported by Le Duc et al. (2020a) and Pham et al. (2020). At least two sites (sites 1 and 3; Table 2) appear to be potentially suitable, and there have been reliable reports of occasional, recent sightings of the species at several other sites. We therefore consider it likely that *R. swinhoei* persists in additional sites in northern Viet Nam.

Several recent sightings were at sites with a relatively high density of fishers, perhaps because the probability of sightings

TABLE 1 Recent sightings (2010–2019) of *Rafetus swinhoei* that were reported in November 2019 by fishers from Son La and Lai Chau provinces, Viet Nam, along the Da River (only reliable reports were included; see Methods for details).

Number of sightings (location ¹)	Month of observation ²	Year
29 (site 10)	Feb.	2010
77 (site 13)	Apr. & Nov.	2014–2015
79 (site 13)	Apr. & Nov.	2015
31 (site 12)	Apr. & Nov.	2018
7 (site 10)	Sep.–Oct.	2018
26 (site 10)	Feb.	2019
25 (site 11)	Feb.	2019
16 (site 12)	May	2019
17 (site 12)	June	2019
3 (site 10)	July–Aug.	2019

¹For site numbers, see Table 2.

²A dash between two months (e.g. July–Aug.) indicates that the interviewee was unable to remember exactly the month of their observation, whereas an ampersand between two months (e.g. Apr. & Nov.) indicates that the interviewee reported distinct observations in different months.

increases when there are more observers. Sightings reported from sites with highly altered habitat cannot, however, be explained by collinearity effects between habitat alteration and density of fishers, as these two variables were not significantly correlated. The most likely interpretation is that *R. swinhoei* is an elusive, shy species that is rarely detected in the wild. It is therefore possible that the population of *R. swinhoei* is larger than believed and that the species can persist in remote areas where habitat alteration is low and fishing intensity moderate.

All sites with multiple recent sightings (10, 11, 12 and 13) were clustered along the northern course of the Da River system, far from other sites where the species could occur (Fig. 1). This suggests that *R. swinhoei* may persist throughout the area, but has gone undetected because of the remoteness of the areas and limited survey efforts. Further research needs to focus on the northern course of the Da River system.

Our evaluation of the conservation priority of sites where this rare and elusive freshwater turtle may occur was based on an assessment of the likelihood that the species was present, the degree of habitat alteration and fishing intensity. This method could also be applied elsewhere. It requires the acquisition of interview-based data and a general inspection of habitat features and densities of fishers, variables that are relatively easy to obtain. Our approach could be applied in other areas where field surveys of chelonians are logistically difficult or time-consuming. For example, our method could be used to study species such as *Erymnochelys madagascariensis* in Madagascar, *Cyclanorbis elegans* in continental Africa (Demaya et al., 2019a,b), and *Chitra chitra*, *Chitra vandjiki*, *Chitra indica*, *Nilssonina formosa*, *Nilssonina*

TABLE 2 Details of the 13 sites with potential presence of *Rafetus swinhoei*, including the attributed scores for species presence, habitat alteration and fishing intensity (see Methods).

Site number	Site	Description	Recent sightings of large softshell turtles	Species presence score	Fishing intensity score	Habitat alteration score	Conservation priority score	Source
1	De lake, Thong Nhat plantation, Thong Nhat town, Yen Dinh district, Thanh Hoa province	40 ha, 3 m deep, dense aquatic vegetation. <i>R. swinhoei</i> abundant many decades ago, since then habitat reduced but still retaining its main characteristics. Previously undocumented skull of <i>R. swinhoei</i> from 1980s discovered in 2018 (Le Duc et al., 2020a,b).	Direct observations in 2003 & 2005, indirect signs from 2016	2	1	1	4	Pham et al., 2020; Le Duc et al., 2020a,b
2	Dap Nai dam, Buoi River, Lam Hoa commune, Lac Son, Hoa Binh province	Circa 1 km long, 50 m wide, 3–4 m deep. <i>R. swinhoei</i> was abundant in the area during 1960s–1990s. Three interviewees consistently described having recently seen a turtle with a yellow pattern on the corner of the mouth, a sign clearly distinguishing <i>R. swinhoei</i> from <i>Pelochelys cantorii</i> , a different large turtle species.	2018	3	1	1	5	Le Duc et al., 2020a,b
3	Between Dat hydro-electric dam & Hũa Na, Chu River, between Thanh Hoa province & Nghe An province	Circa 30 km long, max. 100 m deep. Six interviewees described having recently seen a turtle with a yellow or red pattern on the neck, or a yellow corner of the mouth, with white plastron & dark brown carapace.	2005, 2008/2009, 2012/2013, 2015/2016	2	2	3	7	Le Duc et al., 2020a,b
4	Suoi Bung stream, Da River, Bac Phong, Phu Yen, Son La province	10 ha, 4–5 m deep, at least 18 large softshell turtles caught during 1987–2017. Latest sighting was of a large turtle (carapace diameter 40–50 cm) in 2018.	2017, 2018	3	3	3	9	Le Duc et al., 2020a,b
5	Suoi Mu stream, Da River, Hoa Binh dam, Hoa Binh city, Hoa Binh province	10 km long, < 100 m deep. Reports of a large softshell turtle appearing in the area since 1990, latest confirmed sighting in 2018.	2018	3	3	3	9	Le Duc et al., 2020a,b
6	Dong Mo Lake, Son Tay district, Hanoi	1,200 ha, c. 15 m deep, home of the last known wild individual of <i>R. swinhoei</i> . Interviewees claimed there may be 1–2 additional individuals.	2018 (excluding the known living <i>R. swinhoei</i>)	1	3	3	7	Asian Turtle Program, 2008; Pham et al., 2020
7	Mong Hoi lake, Ao Chau lake, & Van Hoi lake, Ha Hoa district, Phu Tho province	Mong Hoi lake 20 ha, c. 9 m deep; Ao Chau lake 200 ha, c. 10 m deep; Van Hoi lake 150 ha, c. 12 m deep. Ao Chau & Van Hoi lakes have historical presence from 1980s–2000s (Pritchard, 2012), but no intensive surveys to verify current presence have been conducted (Le & Pritchard, 2009; Pritchard, 2012; Pham et al., 2020).	2010 (Mong Hoi lake)	3	3	2	8	Pham et al., 2020

Table 2 (Cont.)

Site number	Site	Description	Recent sightings of large softshell turtles	Species presence score	Fishing intensity score	Habitat alteration score	Conservation priority score	Source
8	Minh Quan lake, Tran Yen district, Yen Bai province	60 ha, c. 15 m deep, dense vegetation cover & complex landscape. Historical presence of <i>R. swinhoei</i> previously recorded (two skulls; Pritchard, 2012). One interviewee reported possibility of 1–2 individuals.	Unclear	3	2	2	7	Pham et al., 2020
9	Suoi Hai lake, Ba Vi district, Hanoi	1,200 ha, c. 10 m deep. An experienced hunter caught at least seven <i>R. swinhoei</i> in the 1980s & retains skull of a large individual of c. 120 kg (Le et al., 2014). He believes that at least two individuals remain.	Unclear	3	2	3	8	Pham et al., 2020
10	Suoi Mu stream, Da River, Chieng Lao, Muong La, Son La province	10 km long, 200 m wide, c. 10 m deep. Ten interviewees reported current presence of <i>R. swinhoei</i> . Two fishers reported sightings of a large softshell turtle with a head size of c. 15 cm in July–Aug. 2019. Another fisher recently observed round tracks in the sand of the river bed, where he believes <i>R. swinhoei</i> hides when hunting.	2019	2	2	3	7	This study
11	Muong Sa'i location, Da River, Quynh Nhai, Son La province	2 km long, 400 m wide, c. 15 m deep. Two interviewees reported sighting of a large softshell turtle with c. 1 m long shell in 2018, a sighting of a large black carapace in Apr. 2018 & a sighting at the same location in Nov. 2018. One report of shooting (but not killing) a softshell turtle (c. 100 kg) on the sand bank in 1992–1993, c. 3 km from the 2018 sightings.	2018	3	2	3	8	This study
12	Chieng Bang location, Da River, Quynh Nhai, Son La province	1 km long, 500 m wide, c. 10 m deep. Five interviewees reported repeatedly seeing a large softshell turtle (most recently in May 2019). Another interviewee reported a prolonged sighting of a large turtle head (c. 15 cm) in June 2019.	2019	3	2	3	8	This study
13	Nam Nhat stream, on Da River, Pa Keo, Nam Nhun town, Nam Nhun district, Lai Chau province	1 km long, 500 m wide, c. 20 m deep. Historical presence of <i>R. swinhoei</i> in 1982 (individuals hunted & sold to China), one recent sighting of a large softshell turtle with a c. 7 cm head.	2015/16	3	2	3	8	This study

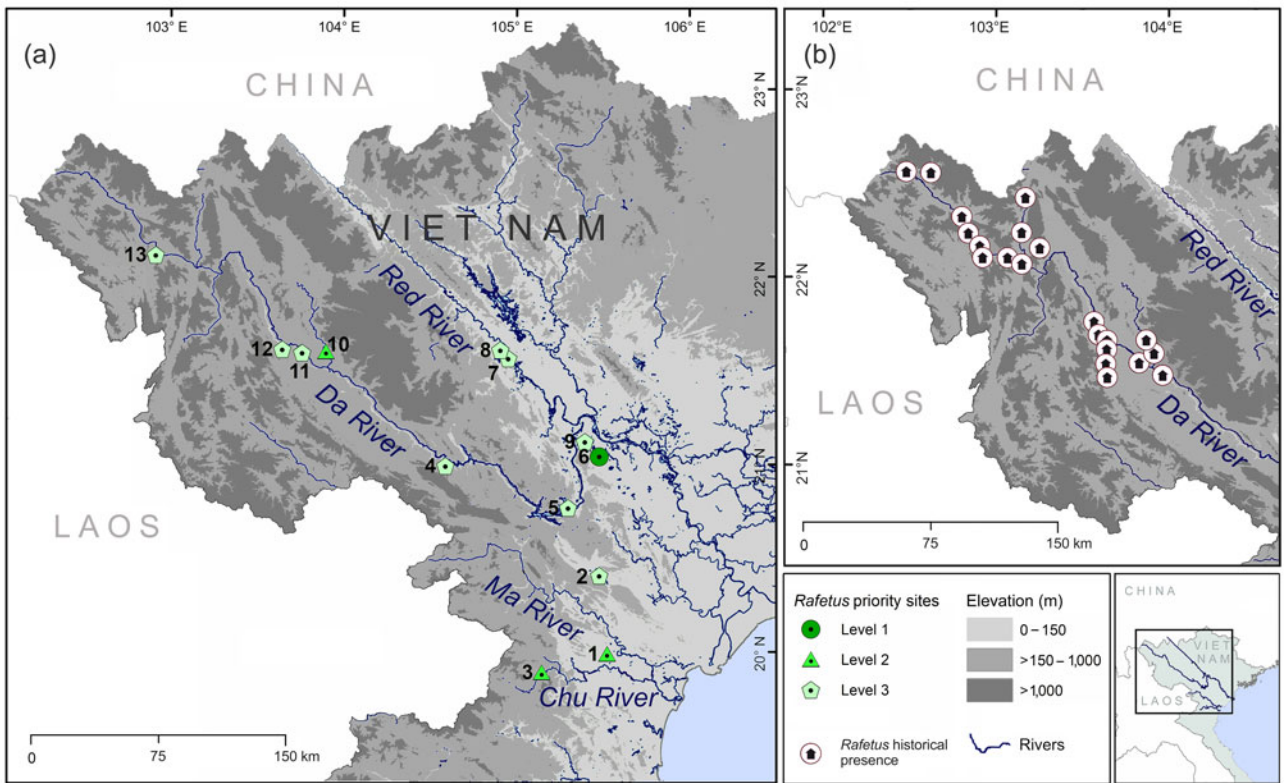


FIG. 1 Study area in northern Viet Nam, showing (a) the 13 sites where *Rafetus swinhoei* may be present, and (b) the sites where it was present before the 2000s (based on interviews with reliable descriptions of the species). For numbers of the various sites, see Table 2. To protect the sites, the precise locations are not shown; the circles indicate only the approximate locations. Scores for probability of the species' presence: 1: confirmed presence of *R. swinhoei*; 2: high probability of presence; 3: medium probability of presence (see Methods).

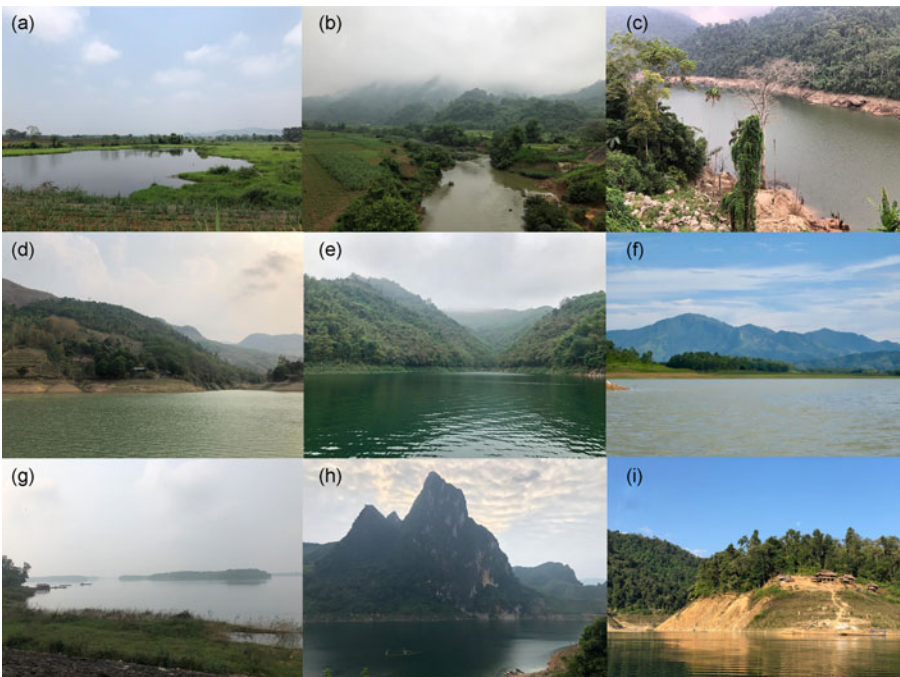


PLATE 1 Landscape of some of the sites with potential presence of *R. swinhoei* in northern Viet Nam. (a) De lake, Thanh Hoa province; (b) Dap Nai dam, Buoi River, Hoa Binh province; (c) Dat hydro dam, Chu River, Thanh Hoa province; (d) Suoi Bung stream, Da River, Son La province; (e) Suoi Mu stream, near Hoa Binh dam, Da River, Hoa Binh province; (f) Dong Mo lake, Hanoi; (g) Suoi Hai lake, Hanoi; (h) Mu stream, Da River, Son La province; (i) Muong Sai section, Da River, Son La province.

nigricans, *Pelochelys cantorii*, *Batagur affinis*, *Batagur kachuga* and *Batagur borneoensis* in Asia. The method could also be used to study other threatened freshwater animals for which habitat loss and overfishing/overhunting are drivers of population declines (e.g. freshwater dolphins and large freshwater fishes).

However, there are also potential limitations of our method. Firstly, it is based on a combination of local ecological knowledge (interviews) and expert-based assessment of scores for habitat alteration and fishing intensity. As expert-based scores are influenced by researchers' field experience, we recommend that only experts with > 5 years' experience conduct field surveys and that the cumulative number of years of field experience of the surveyors is specified when publishing results. Averaging the scores independently assigned by multiple experts (three in our case) could also increase reliability. Seasonality can have a marked effect on perceived habitat characteristics and the density of fishers, and thus for highly seasonal environments we recommend that surveys are made in both dry and wet seasons or, if it is logistically difficult to survey in both seasons, to survey only in the wet season.

Based on the current knowledge of the species' distribution and population size, *R. swinhoei* is on the brink of extinction, with just two known living individuals. Further research should focus on locating additional live individuals in the wild and developing a robust conservation strategy. With respect to the sites we surveyed, site 1 has dense aquatic vegetation, hampering observational surveys. The remaining 12 sites have clear water surfaces, but sites 6, 7, 8 and 9 present logistical difficulties for observational surveys because of their complex spatial structure, with a number of islands present within the lakes. We recommend using trapping surveys at sites 1, 6, 7, 8 and 9, and observational surveys at other sites. Drones could facilitate sightings (Oliveira-da-Costa et al., 2020) and complement riverbank transects and visual searches by boat. In addition, we recommend monitoring fishers' catches, as newborn and juvenile *R. swinhoei* that can be mistaken for *Pelodiscus sinensis* because of the morphological similarities between the two species. Environmental DNA could also be used to survey for *R. swinhoei* (Rees et al., 2014; Davy et al., 2015; Kundu et al., 2018), but the efficiency of this method to detect freshwater turtles has been questioned (Raemy & Ursenbacher, 2018), and its applicability requires further investigation.

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Conflicts of interest None.

Ethical standards This research was authorized by the Government of the Socialist Republic of Viet Nam (research permit code: 613/DHLN-HTQT and 2562/UBND-LC) and abided by the guidelines on ethical standards of *Oryx* and the British Sociological Association.

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