Acta Oecologica 127 (2025) 104081

Contents lists available at ScienceDirect

Acta Oecologica

journal homepage: www.elsevier.com/locate/actoec

Discovering threatened freshwater turtles by an innovative floating camera trap system

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ARTICLE INFO

Keywords:
Camera traps
Freshwater turtles
Rafetus swinhoei
Elusive species
Vietnam

ABSTRACT

Camera traps are widely used for terrestrial wildlife monitoring but remain underutilized for aquatic species due to inherent challenges in freshwater environments. Freshwater turtles, particularly the critically endangered Swinhoe's softshell turtle (*Rafetus swinhoei*), are notoriously difficult to observe in the wild. Here, we present a novel floating camera trap system specifically designed to enhance the probability of detecting this elusive species in a historical habitat. Seven floating camera traps were deployed in a lake in northern Vietnam, operating for a cumulative 420 camera-trap days and capturing 33,846 images. Among these, one image documented the head of a large softshell turtle exhibiting morphological characteristics apparently consistent with only *R. swinhoei*, providing critical evidence of its likely continued presence in the wild. Additionally, the system recorded multiple freshwater reptile species, including other threatened turtles, demonstrating its broader applicability for freshwater biodiversity assessments. Our results confirm (i) the effectiveness of floating camera traps in detecting freshwater species and (ii) the potential survival of *R. swinhoei* in northern Vietnam, a pivotal finding for global turtle conservation. The system is lightweight, cost-effective, and easily replicable, offering a scalable tool for non-invasive monitoring of freshwater ecosystems and rare aquatic taxa.

1. Introduction

Elusive and rare animal species present inherent challenges for scientific study (Kelly, 2008). Consequently, their monitoring in the wild necessitates the integration of complementary methodologies and technologies to increase the likelihood of direct observations of the target taxa (Kelly, 2008), thereby improving data collection on their presence, distribution, and ecology (Kelly, 2008). Among the most widely employed technological tools for detecting and studying rare and elusive species, camera traps have proven highly effective across diverse environmental settings and taxa, addressing a broad spectrum of ecological research questions (e.g., Nichols and Karanth, 2011; Cui et al., 2020; Smith et al., 2020). Camera traps are non-invasive, highly adaptable tools that can be tailored to the environmental constraints and behavioral characteristics of the focal species, including those that are particularly cryptic (Kelly, 2008). While these devices are extensively utilized for studying a wide array of mammalian species (and particularly those of medium and large size), their application to other taxonomic groups, such as reptiles, remains limited (Ariefiandy et al., 2013; Adams et al., 2017).

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https://doi.org/10.1016/j.actao.2025.104081
Received 12 September 2023; Received in revised form 30 January 2025; Accepted 13 April 2025

Most camera trap systems are designed to be species-specific (Bennett and Clements, 2014) and primarily developed for monitoring terrestrial fauna (Welbourne, 2013; Martin et al., 2017; McQuade et al., 2024). However, others have been useful to capture images and studying various species in a community (Axel et al., 2024; Fotsing et al., 2025). In contrast, their efficacy for studying aquatic and semi-aquatic species, including otters, is significantly lower (Lerone et al., 2015). The logistical challenges associated with deploying camera traps in freshwater environments (Doody and Georges, 2020; Lerone et al., 2015) have led to their infrequent use in studies of freshwater turtles (e.g., Bluett and Cosentino, 2013), despite the critical conservation status of these reptiles on a global scale (Stanford et al., 2020). Given that freshwater turtles are often shy and difficult to observe in natural settings, researchers have developed alternative advanced monitoring technologies, such as drones, to assess their activity patterns and estimate population sizes (Bogolin et al., 2021). However, camera trapping has not been widely adopted as a standard technique for freshwater turtle research, with only a few documented applications (but see Bluett and Cosentino, 2013).

The Swinhoe's softshell turtle (*Rafetus swinhoei*) is a large softshell turtle from Vietnam and China (Pritchard, 2005, 2012; Pham et al., 2019) and is currently considered as the world's rarest turtles, with just one free ranging individual and one captive individual being known (Stanford et al., 2018, 2020). Therefore, finding new individuals in the wild is crucially needed for future conservation measures on the species. Despite the cultural importance of *R. swinhoei* in Vietnam (Bettelheim, 2012), its ecology and current distribution remains poorly understood (Le Duc et al., 2020a), although its historical distribution is relatively well known (Pritchard, 2012). During previous studies (Le Duc et al., 2020a, 2020b; Pham et al., 2020), we used standardized face-to-face interviews with fishers and former professional hunters of this species, in order to select some localities of potential presence of *R. swinhoei* in northern Vietnam. After interviewing 10 former professional hunters and 441 fishers, we selected 12 potential sites of occurrence of this species (Pham et al., 2020). Based on the information obtained by our interviewees and our own previous long-term experience with large softshell turtles, we considered that, even when present at a given site, *R. swinhoei* is so elusive that its contacts with fishers are very few as the turtle normally surfaces very briefly. Therefore, it is almost impossible for fishers to take pictures of *R. swinhoei* as evidence of presence or clear identification. Thus, if we really want to confirm the presence of this species, it is essential to develop an efficient detection system that can be used for a long time in a definite environment. Scientists have recently used eDNA but with poor success (Seimon et al., 2024). In order to do so, we developed an innovative floating camera trap system, that was set up in the same place of a Vietnamese lake where both fishers and local persons had reportedly seen huge softshell turtles, with morphological and behavioural characteristics clearly attributable to *R. swinhoei*, on multiple occasions during the years 2019 (see Le Duc et al., 2020a), 2020 (June) and 2022 (November) (Le Duc et al., unpublished). This new detection system was developed for the first time purposely for this study to minimize the difficulties related to photographing a strictly aquatic animal that does not use to frequently thermoregulate on dry substrates or on outcropping objects (tree branches etc), and of which nothing is known about its homing behavior and phenology.

Here, we describe the floating camera trap system in order to allow replication in other areas, as it can easily be transposed to the study of other rare and elusive freshwater animals, including turtles.

2. Materials and methods

2.1. Study area

Our study was carried in the Minh Quan Lake (coordinate: 21° 38.598′N 104° 54.210′E), Minh Quan Commune, Tran Yen District, Yen Bai Province (northern Vietnam). This lake, approximately 60 ha surface and characterized by the presence of a complex of islands (Appendix A), is human-made due to a dam which aimed to provide sufficient water for agriculture since 1960s. Historically, it was connected to the Red River. Recently, the area has been disturbed by the development of a golf course (Tran, 2022). This area was a historical site for *R. swinhoei* (Pritchard, 2012), but several very reliable interviews revealed that the species could be still present (Le Duc et al., 2020a). Indeed, several interviewees have provided highly detailed descriptions of the size, coloration, and even the behavior of *R. swinhoei* when surfacing. Unlike all other species in the region, it raises its head well above the water's surface to scan its surroundings, and this behavior has been independently described by several persons living at the study area.The presence of this species was also confirmed by a recent sighting that occurred in November 2022 and up to July 2023, and that was due to a fisher who worked every day on the lake.

2.2. Detection system construction and deployment

Our floating camera system is composed for the structural part with aluminum and a round composite fiber board. We used screws and wingnuts made of stainless steel for fixating each piece together (system does not rust) and three empty plastic bottles (1.5 l) as water wings (Fig. 1, Appendix B; Appendix C; Appendix D). The selected camera trap model was COOLIFE H881 – 21 MP 1080 HD (Coolife® Corporation) – 125° - 49 LEDs with a 32 GB memory micro-SD card. We defined as the best set up for the camera the following mode: photo – “capture photos with motion detection”, with photo resolution to highest quality [32 MP

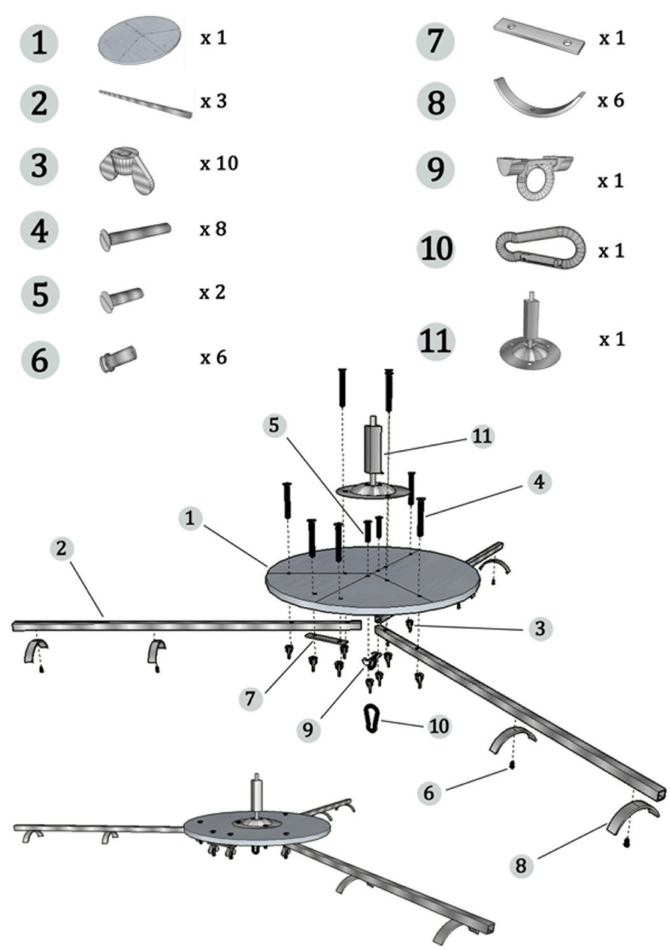


Fig. 1. The components and the detailed instructions to build the floating detection system (see Appendix B for measurements). Note that the camera trap is attached to the support 11 (see Appendix D).

(6480x4860P)], photo series – 1 photo, shot lag – 5 s, side motion sensors – ON, sensitivity motion sensors – high.

More in detail, the rationale for the optimal camera setup was determined based on the following parameters as follows:

Photo Capture Mode: The camera was set to "capture photos with motion detection," ensuring activation upon movement detection within the sensor range.

Photo Resolution: The resolution was configured to **32 MP (6480 × 4860P),** the highest setting available, to maximize image quality and facilitate detailed analysis.

Photo Series: A single-photo-per-trigger configuration was selected to minimize memory card saturation. This approach was preferred over multi-photo bursts or combined photo-video modes to ensure consistent data collection throughout the monitoring period without exceeding storage capacity.

Shot Lag: The minimum available shot lag of “5 s” was employed, allowing for sequential image capture when an animal remained within the detection field for extended durations. This setting maximized the likelihood of capturing multiple frames of the same subject while minimizing redundant storage use.

Side Motion Sensors: Enabled to extend the detection range and trigger the camera in response to lateral movements, thereby improving detection efficiency.

Motion Sensor Sensitivity: Set to “high” to increase the probability of activation, particularly for subtle or low-magnitude animal movements, enhancing overall detection rates.

This configuration was chosen to balance detection efficiency, image quality, and memory storage constraints, optimizing the camera’s performance for wildlife monitoring.

The camera trap was set up with the lens at about 25 cm above the water level and with an angle of 25° to the water surface in order to have a good view of the bait surroundings without a focus on the horizon. The system was painted green brownish for better camouflage and was covered with camouflage netting. Overall, the floating system was designed in such way that the equipment is easy to find, low-cost, light to transport in the field, easy to build and set up in the water (such as swamps, lake, ponds). The overall cost of the materials to build one single camera trap system, excluding the price of the camera trap itself, was 80 Euro.

The bait was attached to the floating system using an aluminum stick; however, the bait could be attached using bamboo stick or other materials. The bait was positioned approximately 80 cm from the floating support. This distance was selected to maintain a broad field of view, capturing both the bait and its surrounding environment, including the horizon line. A closer placement of the bait would necessitate a steeper downward camera angle, reducing the overall scene coverage and potentially limiting observational data. More precisely, the bait holder consists of a composite structure integrating two materials: a 45 cm curved aluminum arm, securely affixed to the floating support, and a 40 cm bamboo extension, which serves as the attachment point for the bait. The bait itself is positioned approximately 80 cm from the floating platform, optimizing visibility and accessibility for target species.

We used different types of food that we thought were smelly enough to attract freshwater turtles, such as large edible frogs (*Hoplobatrachus rugulosus*), shrimps, squids, crabs, snails, fishes, bananas, and jack fruits (Fig. 2). We also tried different combinations of bait mixtures to increase attraction power (Ernst, 1965; Voorhees et al., 1991; Jensen, 1998; Thomas et al., 2008; Mali et al., 2012). The bait was inserted into nylon mesh packets to allow the scent dispersal while avoiding the

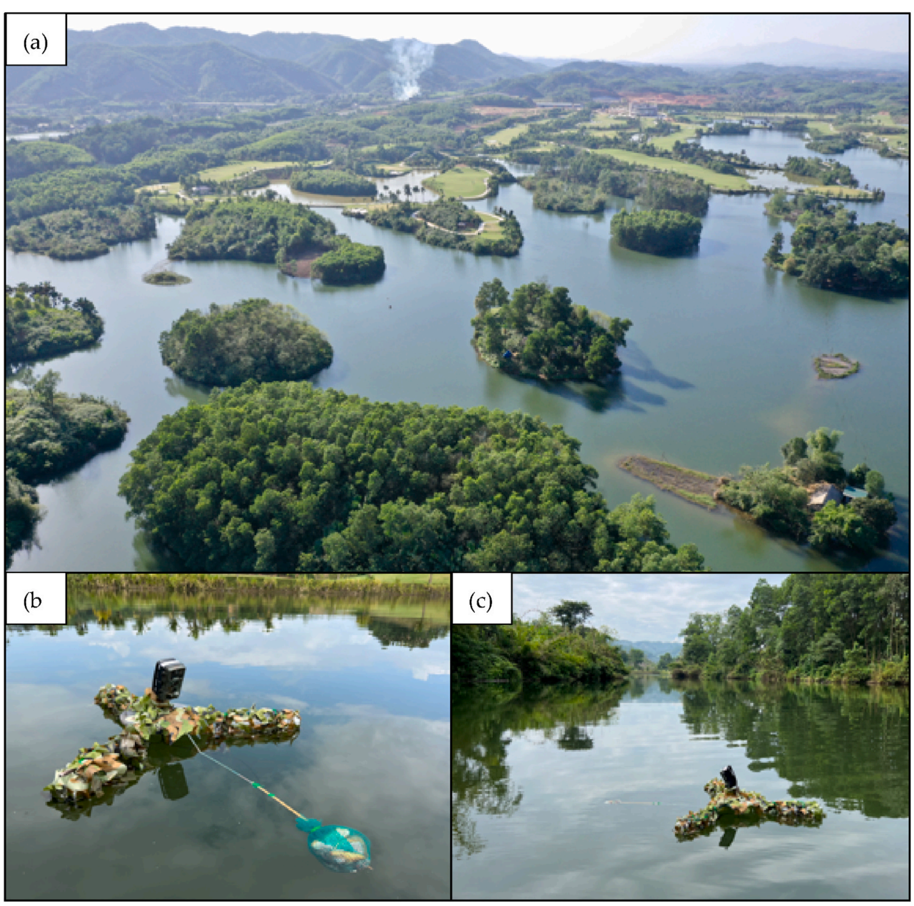


Fig. 2. Image of the landscape of the Minh Quan Lake, northern Vietnam: (**a**) from a drone; (**b**) with detail of a floating camera system with the bait package; (**c**) with the camouflage of the floating system.

consumption of the bait by the targeted or other species (Lagler, 1943; Nall and Thomas, 2009).

For this pilot study, we built seven floating detection systems, each one with one camera trap. We set them up in appropriate points within the Minh Quan Lake from 25th September until November 24, 2022, using local boats (Fig. 2). The points chosen for the traps coincided with the points of recent observation of the very large turtles (reportedly >100 kg weight) and with the apparently optimal points for the observation of these reptiles. For each camera, we used a brick as anchor to prevent any drift of the floating system. We renewed the bait weekly, and the contents of the micro-SD card were unloaded on average every two weeks, with the batteries of the camera also being changed.

3. Results

During our study, the seven floating traps took 33,846 photos in 460 camera trap-days (one camera trap day is here defined as one camera operating for one day). The quantity of images captured by camera traps is documented in Online Supplementary Materials Table S1. The proportion of images containing freshwater fauna exhibited a mean of 12.9 % ± 28.5 (S.D.), a median of 10 %, and a range spanning from 5 % to 90 %. The primary cause of null images was solar reflection (>50 %), followed by wave interference (>22 %).

Camera traps captured the images of several freshwater species, including the Endangered freshwater turtle *Mauremys sinensis* (Fig. 3). In one of these photos, the head of a large softshell turtle while being about to surface near the bait, was visible (Fig. 4). There is no possible alternative identification of this animal than a very large softshell turtle, as there are no big fishes in the lake and the head and the nose of the animal are clearly seen (Fig. 4). The photo also showed a couple of fish of undetermined species nearby the turtle head.

After zooming in on the photograph and cleared it by a professional (Fig. 5), there appeared a combination of clearly visible diagnostic characters of the turtle head (yellow vermiculations on the head, absence of tubercle on the neck, shape of the nose, and overall size) identifying it almost certainly as an adult *Rafetus swinhoei*. In particular, not only all of those characteristics were consistent with the species' characteristics, but the very distinctive short shape of the nose in the camera trap photo is perfectly fitting with that of *Rafetus swinhoei*, with no possible confusions with any other softshell species of Vietnam or adjacent regions. The turtle remained on the surface of the water for a very short time, since the next image (taken 29 s later) showed a perfectly flat-water surface and nothing in evidence. Using the exact measurements of the floating system, we estimated the size of the visible anterior part of the turtle head (from the tip of the nose (nostrils) to the parietal region) to be at least 11 cm. with a predictable total head length of about 20 cm. This suggests that the photographed turtle was an averagely sized *Rafetus swinhoei,* since a measured specimen of 58.4 cm

Fig. 4. Picture of *Rafetus swinhoei* about to surface: (a) original camera trap image taken on October 15, 2022; (**b**) after zooming in, with the *Rafetus swinhoei* head, nose and eye clearly visible.

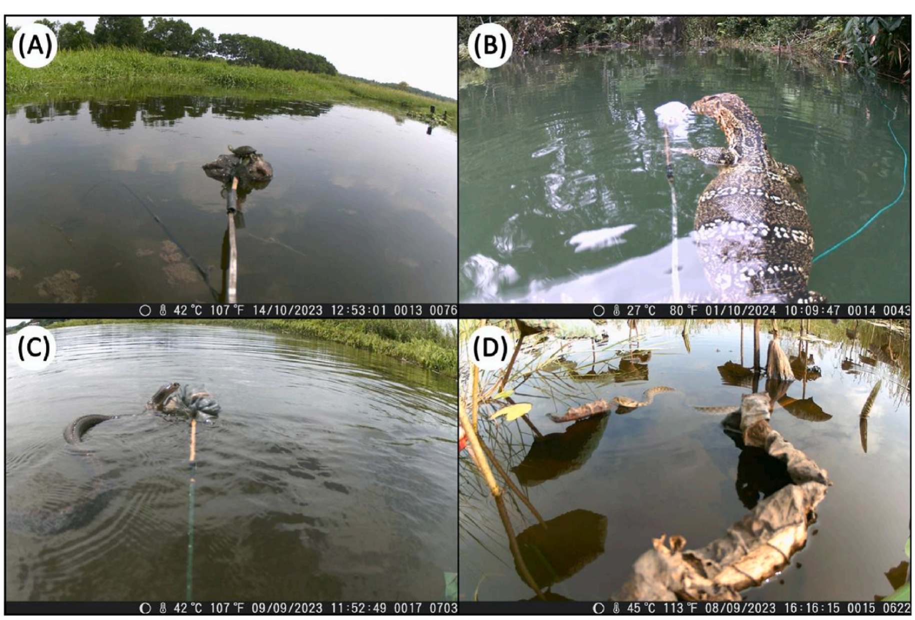


Fig. 3. Example of freshwater species "captured" by our camera tra system: A) *Mauremys sinensis*; B) *Varanus salvator macromaculatus*; C) *Naja atra*; D) *Fowlea flavipunctata*.

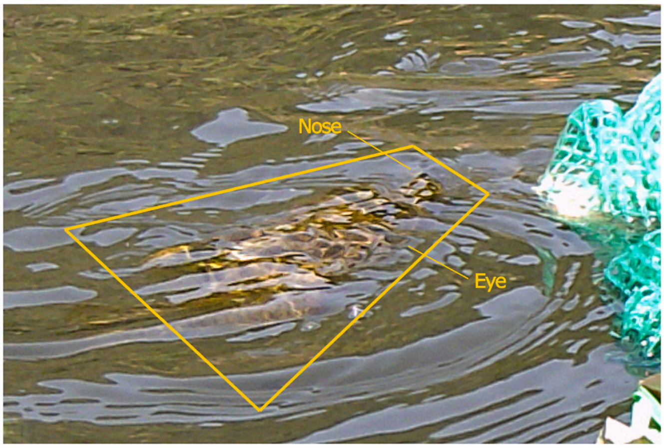


Fig. 5. Picture of *Rafetus swinhoei* cleared by a professional, with Lightroom. It was used the AI upscaling function to increase the resolution X4, so that it could then be possible to crop without losing resolution. Then with Photoshop, we simply selected the turtle's head with a brush and played slightly on the contrast, the saturation and the accentuation to make it stand out a little despite the reflections on the water.

bony carapace length had a head length of 22.5 cm and another individual with 63.3 cm bony carapace length had a head length of 25 cm (Pritchard, 2012). These measures unambiguously indicate that this turtle individual is far larger than any other softshell turtle in the area. Apart from *R. swinhoei*, the only other softshell turtle historically recorded in the lake is *Pelodiscus sinensis (= variegatus)* (Pham et al., 2019), a small sized species of max. 35–40 cm of overall body length and with a nose shape very different from that of *R. swinhoei*. Therefore, this latter species is (i) so much smaller and (ii) with the morphology of the nose being so different that any misidentification between these two species is not possible.

The water depth at the sighting point was between 4 and 5 m, and the linear distance of the camera trap from the shores of the lake was 10 m. This photo is the first recent direct record of wild *R. swinhoei* apart from a single individual that was regularly monitored in Dong Mo Lake for several years, and that had recently died.

The bait that attracted the *R. swinhoei* individual was composed by shrimps, but the bait preferences of this species should be tested more deeply. Regarding the setting of the camera, improvements are also needed in order to avoid that the camera takes numerous unnecessary images to the movements of the water, the heavy rain, or the reflections of the sun on the surface of the water.

Our floating detection system successfully detected freshwater turtles but also other species: a lot of fishes were recorded during the daytime and nighttime, demonstrating that this system could be used to study also different species associated with aquatic environments (e.g., crocodiles, otters, fish, birds).

4. Discussion

Camera traps are essential tools for monitoring rare and/or elusive species (e.g., Karanth and Nichols, 2011). Furthermore, in challenging environmental conditions, camera trapping remains the most time-efficient and minimally invasive survey method. However, species detectability remains a critical limitation even when employing camera traps (Rovero et al., 2008; Lerone et al., 2015). Despite these constraints, our novel floating detection system successfully detected within a short timeframe what appears to be almost certainly an individual of *R. swinhoei*, thus suggesting its continued presence in Vietnam, though standard surveys may underestimate its occurrence (e.g., Le Duc et al., 2020a). Moreover, and importantly, our floating system detected a wide variety of other freshwater reptiles, including another species of globally Endangered turtle, thus showing that it can be used with success in biodiversity studies of threatened freshwater species.

The empirical presence data obtained in this study further substantiates the hypothesis—previously derived from extensive face-to-face interviews with hundreds of fishers—that *R. swinhoei* may have a broader distribution in Vietnam than currently documented (see Zuklin et al., 2021; Ducotterd et al., 2023). Additionally, a comparative analysis of the photographed individual's size with that of specimens recently reported by local fishers suggests that the surveyed lake is likely inhabited by at least two *R. swinhoei* individuals (our unpublished interview data). To enhance future monitoring efforts, targeted surveys should be conducted in the most promising *Rafetus* habitats, as identified by Le Duc et al. (2020a), utilizing our floating camera trap system. The confirmation of additional *R. swinhoei* individuals is critical for informing future conservation strategies and facilitating the implementation of measures aimed at preserving this highly imperiled species.

Despite the success of the pilot surveys, further refinement of the floating detection system is required. In particular, the camera setup necessitates additional testing in controlled environments to optimize image acquisition, as the current configuration results in an excessive number of non-informative images. Moreover, controlled trials with alternative bait combinations should be conducted in captivity using other softshell turtle species to determine the most effective attractant for large *Rafetus* specimens. These methodological advancements will be instrumental in improving detection efficiency and maximizing the effectiveness of future surveys.

5. Conclusions

Our floating detection system represents a novel and robust tool for long-term deployment in aquatic environments. Its low cost, lightweight design, and ease of construction make it a highly efficient and scalable solution for a wide range of ecological applications. This system has significant potential for broad implementation in freshwater research, facilitating species presence assessments, community structure analyses, and activity pattern monitoring. Its adaptability and cost-effectiveness position it as a valuable methodological advancement for biodiversity studies and conservation monitoring in aquatic ecosystems. Future refinements to this system may include: (i) Increasing the camera height to enhance perspective and coverage; (ii) Adjusting the bait placement relative to the floating support to optimize detection efficiency; (iii); Modifying camera settings to improve motion-triggered capture under aquatic conditions; (iv) Evaluating alternative camera models with enhanced sensitivity and detection capabilities for aquatic species.

CRediT authorship contribution statement

Olivier Le Duc: Data curation, Investigation, Methodology, Writing – review & editing. **Charlotte Ducotterd:** Investigation, Writing – original draft. **Cédric Bordes:** Investigation, Project administration. **Thong Van Pham:** Investigation. **Benjamin Leprince:** Funding acquisition, Investigation, Project administration. **An Thanh Le:** Investigation. **Vinh Quang Luu:** Investigation. **Bao Quang Tran:** Investigation. **Luca Luiselli:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Writing – original draft, Writing – review & editing.

Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of IDECC (protocol code 003 on September 11, 2020).

Funding

This research was funded by Mohamed Bin Zayed Species

Conservation Fund, grant number 212527219 and Turtle Sanctuary and Conservation Center.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We would like to thank sincerely Mr. Hoang Dinh Thien, who provided his boat to set up our floating camera traps in Minh Quan Lake and helped us to change baits during the present study, and Florian Denis for having improved the quality of the *Rafetus* photo. Andrew D. Walde (Director of Science and Conservation at Turtle Survival Alliance) examined the turtle photo, enlarged it and confirmed that there were no tubercles in the anterior part of the shell. The research was funded by Turtle Sanctuary and Conservation Center NGO, Paris. Anonymous referees helpfully commented on the submitted draft.

Appendix A

Map of Minh Quan Lake, northern Vietnam, with the exact position of each camera trap (grey points). Note that, since we changed the position of some camera traps during the pilot study; the number of camera trap points was higher than seven. This figure also shows the site where *Rafetus swinhoei* photo was taken (green point) and the sites where another individual of this species was unambiguously sighted by local persons in 2020 and 2022 (yellow points).

Appendix B

List of the materials needed for building the floating system with the item names, size and quantities.

N°	Item name	Dimensions	Quantity
1	Composite fiber board (round)	ø 300 mm/thickness 10 mm	1
2	Hollow aluminum square tube	10 mm × 10 mm x 500 mm	3
3	Wingnut stainless steel	ø 4 mm	10
4	Flat head stainless steel screws	ø 4 mm/length 30 mm	8
5	Flat head stainless steel screws	ø 4 mm/length 20 mm	2
6	Rivet aluminum	ø 2 mm/length 10 mm	6
7	Plat aluminum	10 mm × 2 mm x 50 mm	1
8	Plat aluminum	10 mm × 2 mm x 80 mm	6
9	Galvanized eyebolt 2-hole base	ø 35 mm/45 × 15 mm	1
10	Aluminum carabiner	60 × 38 × 8 mm	1

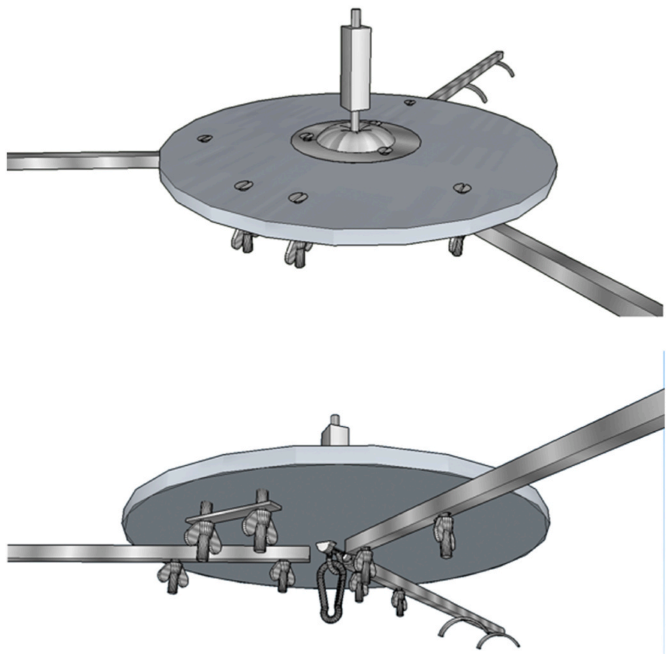
(*continued on next page*)

(*continued*)

N°	Item name	Dimensions	Quantity
11	Base of camera	ø 80 mm	1
–	Black polypropylene twine	ø 5 mm	1
–	Plastic bottle	1.5 l	3

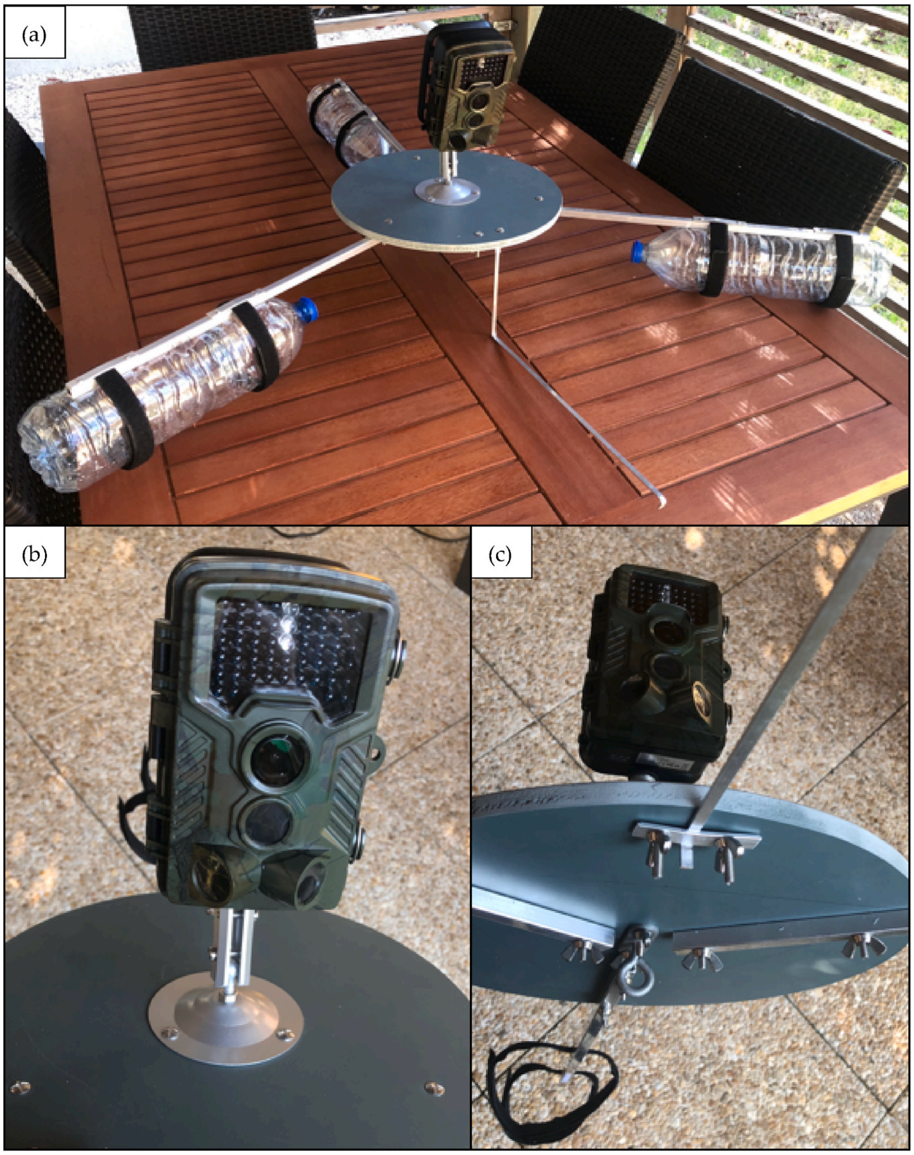
Appendix C

Detailed view of the floating system.



Appendix D

Floating system set up: (**a**) entire floating system, it is possible to attach the plastic bottle with strings or wire; (**b**) zoom of the camera trap fixation; (**c**) bottom of the floating system.



Appendix E. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.actao.2025.104081.

Data availability

Data will be made available on request.

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