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NOTE

Preliminary data on an affordable UAV system to survey for freshwater turtles: advantages and disadvantages of low-cost drones

Javier E. Canahuati Escobar, Mark Rollins, and Shem Unger

Abstract: Unmanned aerial vehicles (UAVs) are established, valuable tools for wildlife surveys in marine and terrestrial environments; however, they are seldom utilized in freshwater ecosystems. Therefore, baseline data on the use of UAVs in lotic environments are needed that balances flight parameters (e.g., altitude and noise level) with image quality, while minimizing disturbance to individuals. Moreover, the traditional high-cost UAVs may present challenges to researchers conducting rapid assessments on species presence with limited funding. However, emerging, affordable UAV systems can provide this preliminary data to researchers, albeit with caveats on reliability of data. We tested a low-cost UAV system to document freshwater turtle presence, species distribution, and habitat use in a small North Carolina wetland. We observed minimal instances of turtles fleeing basking sites (~0.7%), as this UAV system was only ~2.1 dB above ambient noise levels at an altitude of 20 m. Freshwater turtles were found primarily in algal mat basking habitats with highly variable numbers observed across locations and flights, likely due to image quality reliability and altitude. Our affordable UAV system was successful in providing baseline information on species presence, size distribution, and habitat preference of turtles in freshwater ecosystems.

Key words: drones, wildlife monitoring, technology, reptiles, aquatic ecology.

Résumé : Les véhicules aériens sans pilote (UAV) sont des outils très utiles pour les relevés sur la faune dans les milieux marins et terrestres, mais ils sont rarement utilisés dans les écosystèmes d'eau douce. Par conséquent, des données de référence sur l'utilisation des UAV dans des milieux lotiques sont nécessaires afin d'équilibrer les paramètres de vol (p. ex., l'altitude et le niveau de bruit) avec la qualité de l'image, tout en minimisant les perturbations pour les individus. De plus, les UAV traditionnels à coût élevé peuvent présenter des défis pour les chercheurs qui effectuent des évaluations rapides de la présence d'espèces avec un financement restreint. Cependant, des systèmes émergents et abordables d'UAV peuvent fournir ces données préliminaires aux chercheurs, bien qu'avec des mises en garde sur la fiabilité des données. Nous avons mis à l'essai un système d'UAV à faible coût afin de documenter la présence de tortues d'eau douce, la répartition des espèces et l'utilisation de l'habitat dans une petite zone humide de la Caroline du Nord. Nous avons observé des cas minimes de tortues fuyant les sites de prélassement (~0,7 %), car ce système d'UAV n'était qu'à environ 2,1 dB au-dessus des niveaux de bruit ambiant à une altitude de 20 m. Les tortues d'eau douce ont été observées principalement dans des habitats de tapis algaire, avec des nombres très variables observés à divers endroits pendant différents vols, probablement en raison de la fiabilité et de l'altitude de l'image. Notre système d'UAV abordable a fourni des renseignements de base sur la présence d'espèces, la répartition par taille et les

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préférences en matière d'habitat des tortues dans les écosystèmes d'eau douce. [Traduit par la Rédaction]

Mots-clés : drones, surveillance de la faune, technologie, reptiles, écologie aquatique.

Introduction

Worldwide, many turtle species in freshwater habitats are facing serious conservation threats and population declines (Buhlman et al. 2009; Lovich et al. 2018). Survey methods that improve detection of turtle populations while minimizing disturbance to basking turtles may help address these problems. Owing to their ability to survey noninvasively, unmanned aerial vehicles (UAVs) offer the potential to also provide presence and relative individual size data (i.e., carapace length). Although the cost of many UAVs used for wildlife surveys often exceeds US$1000, there are many emerging UAVs that allow for inexpensive surveys, making them ideal for preliminary studies or for short-term presence–absence surveys. However, to the best of our knowledge, the application of UAVs to assess freshwater turtle presence is currently unknown and limited to one preliminary study (Biserkov and Lukanov 2017). UAVs have been utilized extensively in marine habitats (Hodgson et al. 2013; Schofield et al. 2017; Aniceto et al. 2018), but only sparingly to freshwater habitats (Elsey and Trosclair 2016; Biserkov and Lukanov 2017). UAVs have provided rapid biomass estimates of smaller organisms <20 cm, i.e., jellyfish (Raoult and Gaston 2018; Schaub et al. 2018), yet they are often not considered for sampling smaller organisms utilizing large areas. A priority for research on aquatic ecosystems using UAVs is to develop guidelines that minimize wildlife disturbance (escape behavior or startle response), which may vary by taxa.

Herein, we assessed the use of an affordable UAV system (~US$300) to obtain baseline data on freshwater turtle species presence following existing guidelines at two flight altitudes, 10 and 20 m. We further report on the potential to identify species and obtain size data and monitor UAV disturbance in freshwater turtles. Finally, we make further recommendations on the use of UAVs in aquatic ecosystems and report on the potential for estimation errors and other considerations when using low-cost UAVs.

Materials and Methods

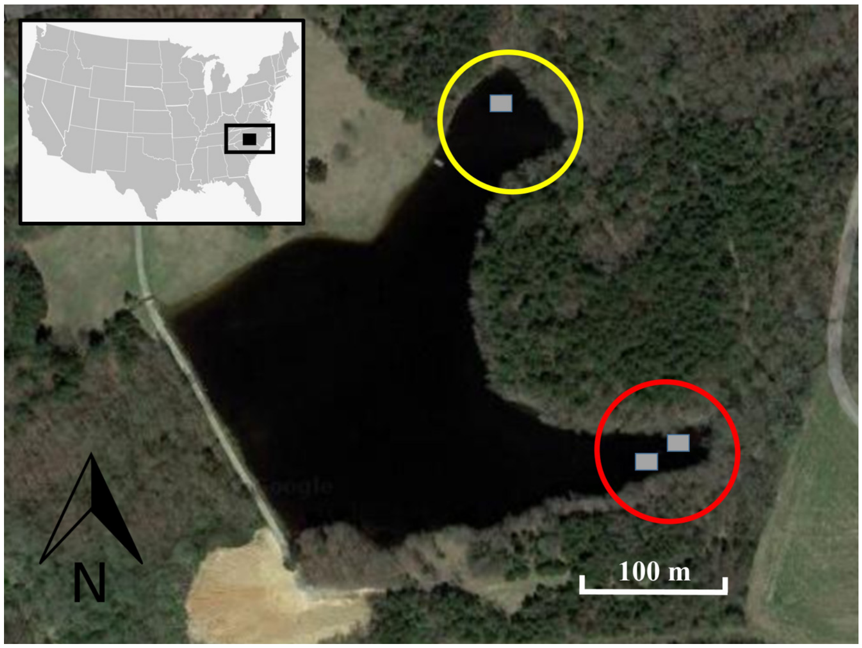
Study site

This study was conducted in the spring of 2018 at Wingate University campus lake, located at 34°59′10.12″ north latitude and 80°25′45.40″ west longitude (Fig. 1). We selected two areas of the lake for this study (Bulldog Bay and Turtle Bay) that support readily visible basking turtle species (~20–30 cm length), primarily yellow-bellied sliders (*Trachemys scripta*) and painted turtles (*Chrysemys picta*) (Escobar et al. 2018). To potentially increase detection and relative body size estimation of basking turtles, we deployed three artificial basking platforms, each measuring 122 cm × 80 cm approximately (Fig. 1).

UAV survey flights

An MJX (Guangdon Meijiaxin Innovative Technology Co., LTD, Shantou City, China) Bugs 3 Quadcopter UAV (~US$ 100), measuring 44 cm × 44 cm × 15 cm equipped with four motors and a 7.4 V 1800 mA LiPo battery was used to perform the flights. The UAV provided approximately 18–20 min of flying time and up to 500 m of control distance with a total weight of 450 g. A 128 g GoPro Hero Session 5 (GoPro Inc., San Mateo, CA, USA) with a 64 GB microSD card was attached to the underside of the UAV facing straight down using industrial strength Velcro (Velcro Ltd., Cheshire, UK). The field of view for 16:9 or wide camera setting was 69.7° vertically, 118.9° horizontally, and 149.6° diagonally. Ground sampling distance (GSD) was estimated as 1.1 cm/pixel and 0.5 cm/pixel for 20 and 10 m altitude, respectively.

Fig. 1. Map of the study area at Wingate University Lake, campus of Wingate University, North Carolina, USA (state location shown on upper left, box shows approximate location of study area). Circled areas represent Bulldog Bay (yellow) and Turtle Bay (red). Location of platforms represented by gray boxes. Image obtained from Google maps on 11/6/2018, map data ©2018 Google.



Videos were recorded in 4K resolution, 3840 × 2160 pixels, at a rate of 30 frames per second assisted with image stabilization. To assess the potential for disturbance (escape or fleeing behavior by turtles), we used a sound meter to measure decibels (dB) above ambient while flying at both high (20 m) and low (10 m) altitudes during "calm" wind speed of ~3.1 m/s measured at the nearest weather station within ~8 km (www.wunderground.com). Specifically, at 20 m of altitude, the sound was found to be 2.1 dB above ambient (audible but barely), 4.4 dB at 10 m (increasingly audible).

Each bay was surveyed 20 times for a total of 40 flights across two bays (each bay with 10 high- and 10 low-altitude flights). Flights occurred between 13 April and 9 May 2018 during peak basking hours, e.g., between 11:00 and 14:00. Each site within the lake (Turtle and Bulldog Bay) was surveyed by flying the UAV on the same day, with a mean flight time of 2 min and 47 s. Wind speed for UAV surveys ranged from ~0.4 to ~7.5 m/s, with an average wind speed during flights of ~4.7 m/s. Surface air temperature for surveys averaged 23.1 °C and ranged from 19.4 to 26.7 °C. All survey flights involved launching from sites out of sight from animals basking (>100 m on bank) to minimize wildlife disturbance (Hodgson and Koh 2016). The UAV was flown following an east–west pattern systematically starting from the northern part of each bay for both 10 and 20 m flights. Flights were executed in manual flight mode and monitored on a smart phone using the WiFi feature on the GoPro Hero Session 5 and application (maximum camera WiFi remote signal 182 m, with application ideal at ~15 m).

Data analysis

We used the open-source VLC media player (version 3.1.2, VideoLAN, Paris, France) to review video footage and compile screenshots for enumeration of individual turtles and habitat use (turtle detected on either open water or algal mats). We recorded the number

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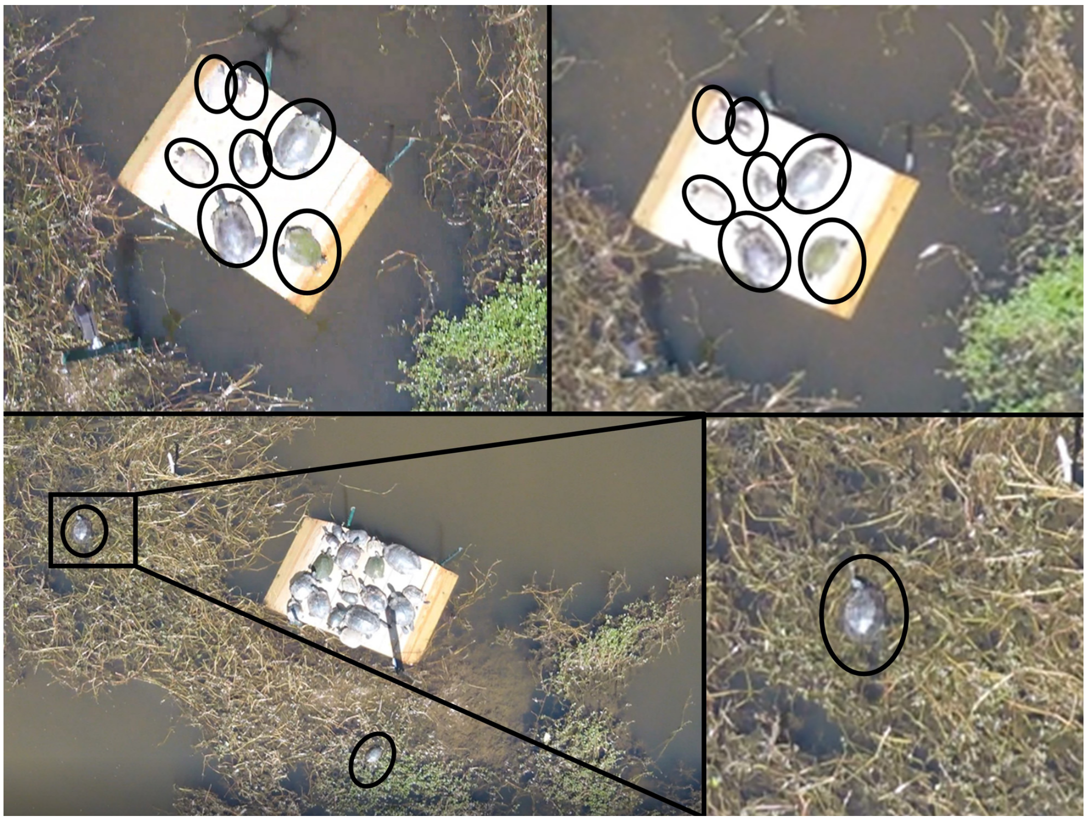
Fig. 2. Example high-altitude (20 m) flight at Turtle Bay with a zoomed area (upper right). Individual turtles enumerated circled on algal mat habitat.

of turtles on video exhibiting an escape or startle response (fleeing from basking area) across flights. To enumerate turtles, we extracted video frame images from each flight which provided coverage of survey area with sufficient image sharpness showing adequate area coverage, reduced blurring, and clearly showing turtles across flight area within image. One image was selected for high-altitude surveys (Fig. 2), whereas a composite of six survey images were aligned for low-altitude surveys by creating an unrectified and nongeoreferenced mosaic in GIMP 2.10, an open-source image manipulation software (GNU Image Manipulation Program, GNOME Foundation, Orinda, CA, USA, available at www.gimp.org). Turtles were manually enumerated by circling each individual turtle for each of the 40 flights with every observer (all authors) present when reviewing the entire data set to ensure quality control and to prevent counting the same turtle twice (Fig. 3). A 500 × 500 pixel grid was added on top of the selected image to aid in enumeration of individual turtles. We used a combination of turtle shape, color, and the light reflected from a turtle carapace (dorsal shell) to count individual turtles. We ran a Kolmogorov–Smirnov test for normality to ensure data were normally distributed. A *t* test was used to compare the mean values of turtles counted in high versus low survey altitude to test if there was a statistical difference between the amount of turtles counted within the same bay surveyed, and the survey altitude of the flight.

To further evaluate utility of our UAV system for identification and size estimation of basking turtles, we used a subset of 10 images (five from Turtle bay and five from Bulldog bay) obtained from low-altitude flights of basking platforms to identify turtles down to species (painted or yellow-bellied slider) and to estimate carapace (dorsal shell) length using the known dimensions of the nearest basking platform to calculate scale. Scale was calculated for each image to account for variability across flight altitudes. Species were validated visually by authors with years of experience trapping turtles in this pond and based on morphology, size and distinguishing marks of carapace shape, size, and scute arrangement

Fig. 3. Example from Turtle Bay showing zoomed-in turtle identification images from flight 7 (upper left low altitude and upper right high altitude) for comparison image quality and flight 6 (lower left and right area magnified). Individual turtles for enumeration circled (lower left platform shown as example). Note turtles basking on algal mats near artificial platforms as well as upper left platform shows some variation in turtle position.



(Powell et al. 2016). We also further classified any *T. scripta* as juveniles if their estimated carapace length was under 11 cm (Gibbons and Greene 1990).

Results

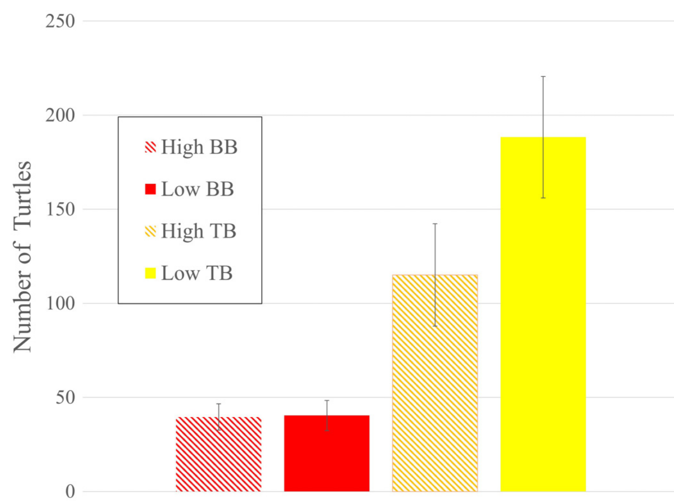
The number of turtles counted during the total 40 surveys varied and was overall greater in Turtle Bay than in Bulldog Bay (Table 1). Turtles showed a preference for basking on algal mats (83.3%), with a smaller percentage basking on open water and artificial basking platforms (7.2% and 9.0%, respectively). Data on total counts for turtles were normally distributed (Kolmogorov–Smirnov test of normality $D = 0.205$, $p = 0.059$). There was high variability but no significant difference between mean number of turtles enumerated for high- and low-altitude flight surveys for Bulldog Bay (means of 39.6 and 40.4; $t = 0.0751$, $p = 0.941$, d.f. = 18) and Turtle Bay (means of 115.1 and 188.3, $t = 1.7338$, $p = 0.100$, d.f. = 18). The number of turtles identified during the low-altitude flights was higher in Turtle Bay (Table 1, Fig. 4). We observed minimal escape or disturbance behavior (six total instances across 40 flights or ~0.7% of turtles) only from turtles basking on artificial basking structures. We identified 39 *C. picta* and 60 *T. scripta* using platforms, from a subset of 10 low-altitude flights across both bays, with mean estimated carapace (shell) length and

Table 1. Summary data for habitat (open water vs. algal mats) and total turtles enumerated across 10 total surveys at both high and low altitudes (20 and 10 m, respectively) for both Bulldog Bay and Turtle Bay.

	Bulldog Bay						Turtle Bay					
	High altitude			Low altitude			High altitude			Low altitude		
Flight	Water	Algae	Total	Water	Algae	Total	Water	Algae	Total	Water	Algae	Total
1	5	60	65	1	35	36	3	210	213	2	216	218
2	3	58	61	1	46	47	4	209	213	4	330	334
3	0	18	18	1	25	26	0	252	252	8	312	320
4	5	34	39	1	15	16	2	35	37	11	61	72
5	4	49	53	6	78	84	1	39	40	1	136	137
6	28	28	56	43	34	77	4	113	117	7	171	178
7	3	55	58	12	21	33	7	130	137	13	300	313
8	2	8	10	0	8	8	7	15	22	17	64	81
9	3	27	30	8	47	55	4	85	89	13	115	128
10	3	3	6	10	12	22	4	27	31	23	79	102
Total	56	340	396	83	321	404	36	1115	1151	99	1784	1883

Note: Totals included for all flights (1–10) across habitat categories (water, algae, etc.). Turtles on artificial platforms were grouped with algal mats. Note high variation across flight number, altitudes, and across bays.

Fig. 4. Mean turtle count comparison between high- and low-altitude flights at both sample areas Bulldog Bay (BB) and Turtle Bay (TB). Note similarity in Bulldog Bay with greater range of turtles enumerated between high- (20 m) and low- (10 m) altitude surveys for Turtle Bay. Standard deviations are included.

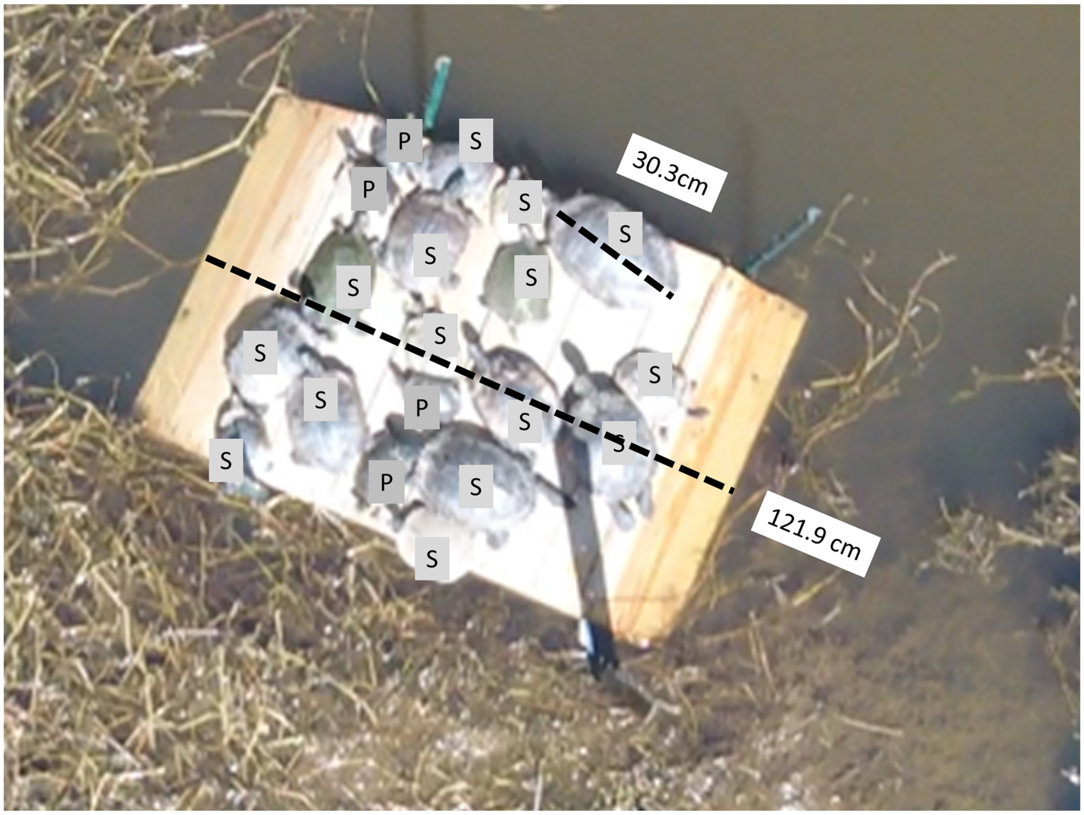


standard error (SE) measured as 11.95 ± 0.48 SE cm for *C. picta* and 17.86 ± 0.76 SE cm for *T. scripta* in GIMP 2.10 (Fig. 5). Estimated size ranges of *C. picta* and *T. scripta* were 6.9–18.4 cm and 5.8–30.3 cm, respectively. Eight of the 60 *T. scripta* were classified as juveniles based on estimated carapace length, whereas we were unable to detect any juveniles for *C. picta*.

Discussion

Our affordable UAV system provides a reliable, affordable preliminary method for detection of freshwater turtles with minimal disturbance (0.7% fleeing behavior) observed in this study. While not significant, we noted large variation in turtle counts across areas surveyed

Fig. 5. Example from Turtle Bay showing zoomed in turtle identification images from flight 6 at low altitude. Individual species shown as P (painted turtles) or S (yellow-bellied slider turtles) in boxes, with one example measurement of a turtle performed in GIMP 2.10 using measurement tool. Known distance of reference platform length show as dotted line with estimated length of turtle carapace length shown as dotted line.



and flight attitude. We recommend researchers follow published guidelines (e.g., UAV distances of 10–30 m causing no disturbance in sea turtle species; Bevan et al. 2018) or perform trial flights with any UAV system to assess the potential for wildlife disturbance that may vary by taxa. Researchers may want to consider the tradeoffs of low-cost, and thus lower-capability UAVs as use of lower resolution cameras or video may provide less than ideal images. Furthermore, low-cost UAVs may require closer flights or further validation of baseline counts in controlled environments with known numbers of individuals and species.

A caveat of low-cost UAVs includes the potential for misidentification, which may bias abundance estimates (Brack et al. 2018). As we spent a great deal of time processing and analyzing images, we suggest automated approaches to streamline counting of individuals, i.e., the use of ImageJ following Raoult and Gaston (2018). We further recommend that researchers using UAVs in freshwater ecosystems may increase reliability of data quality by incorporating photogrammetric data (i.e., size) of individuals or orthorectify images using known size reference of survey sites and available software.

We were able to successfully determine turtle carapace length using ground referenced platform size, as well as species identification in this study in addition to basking habitat use data. Most interestingly, we documented basking habitat use by turtles, as we observed freshwater turtles aggregated primarily in clusters on algal mats. Researchers should use known carapace lengths of paint-marked individuals as a fixed reference to validate UAV-derived measurements. Based on our observations, flights at 20 m are too inaccurate based on the GSD of our UAV system. Subsequently, researchers should consider using a camera with higher spatial resolution and improved focal lens along with appropriate altitude of flights to alleviate these limitations and increase reliability of counts and species identification. UAV technology and camera quality will invariably continue to both improve and become more affordable as a monitoring tool for use by wildlife managers in freshwater ecosystems. Finally, the choice of which UAV to use for wildlife surveys should balance increased image resolution across flight altitude and level of noise to further refine level of disturbance and develop guidelines for UAVs as a rapid assessment tool in aquatic ecosystems.

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