Evaluation of the Use of Drones to Monitor a Diverse Crocodylian Assemblage in West Africa

Final Report for the IUCN Crocodile Specialist Group's Student Research Assistance Scheme

Clément Aubert

Under the supervision of Dr. Matthew H. Shirley

Department of Biology and Ecology
The University of Montpellier

Abstract

Context: West African crocodylian populations are declining and in need of conservation action. Surveys and other monitoring methods are critical components of crocodile conservation programs; however, surveys are often hindered by logistical, financial, and detectability constraints. Increasingly used in wildlife monitoring programs, drones can enhance monitoring and conservation efficacy.
Aims: This study aimed to determine a standard drone crocodylian survey protocol and evaluate the drones as a tool to survey the diverse crocodylian assemblage of West Africa.
Methods: We surveyed crocodile populations in Benin, Côte d'Ivoire, and Niger in 2017 and 2018 using the DJI Phantom 4 Pro drone and via traditional diurnal and nocturnal spotlight surveys. We used a series of test flights to first evaluate the impact of drones on crocodylian behavior and determine standard flight parameters that optimize detectability. We then consecutively implemented the three survey methods at 23 sites to compare the efficacy of drones against traditional crocodylian survey methods.
Key results: *Crocodylus suchus* can be closely approached (>10 m altitude) and consumer-grade drones do not cause flee responses in West African large mammals and birds at altitudes > 40-60 m. Altitude and other flight parameters did not impact detectability, because high resolution photos allowed accurate counting but observer experience significantly impacted detectability. Drone-based crocodylian surveys should be implemented from 40 m altitude in the first third of the day. Comparing survey methods, drones performed better than traditional diurnal surveys but worse than standard nocturnal spotlight counts. The latter not only detected more individuals, but also a greater size class diversity. However, drone surveys provide advantages over traditional methods, including precise size estimation, less disturbance, and the ability to cover greater and more remote areas.
Conclusions: Overall, drones offer a valuable and cost-effective alternative for surveying crocodylian populations with compelling secondary benefits, though they may not be suitable in all cases and for all species.
Implications: We propose a standardized and optimized protocol for drone-based crocodylian surveys that could be used for sustainable conservation programs of crocodylians in West Africa and globally.

Introduction

Drones are an increasingly useful and used tool in conservation science and natural resources management, and they are already revolutionizing research into wildlife and habitats (Evans *et al.* 2016). Drones have several advantages over traditional methods of observation. They can collect very high-resolution images (McEvoy *et al.* 2016), are cheaper and safer than helicopters and small bush planes (Ogden 2013; Zahawi *et al.* 2015), and they can successfully perform autonomous flights over varying distances (Floreano and Wood 2015; Ventura *et al.* 2016).

West Africa presents a unique setting in which to test the efficacy of drones as tools for crocodylian population surveys with three endemic species, the West African crocodile (*Crocodylus suchus*), the West African dwarf crocodile (*Osteolaemus sp. nov*. aff. *tetraspis*) and the West African slender-snouted crocodile (*Mecistops cataphractus*).

In the present study, we assessed the efficacy of drones as crocodile survey tools for this diverse crocodylian species assemblage in West Africa. We compared drone surveys to traditional daytime and nighttime counting methods, and investigated how flight parameters impact detectability and disturbance. We, thus, also propose a standardized and optimized protocol for drone-based crocodylian surveys.

Methods

Study Areas. We implemented this work in four different study sites in three different countries in West Africa, as follows (Fig. 1).

1) *Pendjari National Park (PNP), Benin*. We surveyed PNP from 18 March to 12 April 2017 and we surveyed crocodiles in a diversity of natural and artificial pools.

2) *Comoé National Park (CNP), Côte d'Ivoire*. We surveyed CNP from 28 July to 01 August and we surveyed a small portion of the Iringou River and a small pool "Mare aux Buffles."

3) *Azagny National Park (ANP), Côte d'Ivoire*. We surveyed ANP from 26 June to 30 June 2017and we surveyed 5 km of the Azagny canal divided into five 1 km contiguous sections.

4) *W National Park (WNP), Niger*. We surveyed WNP from 12 February to 17 April 2018 and wesurveyed 2.5 km of the Tapoa River divided into five 500 m contiguous sections.

Testing Flight Plans and Data Collection to Minimize Disturbance and Maximize Detectability. We collected all described drone data using a DJI Phantom 4 Pro and we programmed all flight plans using Pix4D capture software (Pix4D). We ultimately assembled and ortho-rectified all images using Agisoft Photoscan Pro ver. 1.2.5.2594 and imported them into QGIS ver. 2.8.6 for analysis.

We first test the drone for disturbance effects on the crocodiles and to other species potentially encountered during surveys. To test for disturbance, we flew the drone for 28 min over Bali Pond (PNP), starting at 80 m and descending 5 m every 2 min to an altitude of 5 m.

Also prior to implementing any drone-based crocodile surveys, we wanted to test flight, ambient light, altitude and photographic parameters to optimize crocodiles detectability in the resulting images.

To establish these parameters, we flew 16 test flights over Bali Pond (PNP) at a differents altitudes replicate four times each (20, 25, 30, and 40 meters), corresponding to different photo resolutions (0.62, 0.72, 0.95 and 1.22 cm2/pixel). Five experienced, independent observers counted the number of individual crocodylians they detected in each of the 16 maps and was limited time to 10 min per map. To verify observer reliability, a sixth observer performed an *a posteriori* recount on all maps without time limit.

Comparing Drones to Traditional Crocodile Survey Methods.

1) *Drone Surveys:* Following the results of our optimal flight evaluations, we flew drone surveys 3 times in the same day (9h-11h, 13h-15h and 17h-19h) at an altitude of 40 meters and at a speed of 5 m/s with 90° camera orientation, 60% overlap (Koh and Wich 2012), autonomously following a preprogrammed flight plan from take-off to landing.

We made maps from each survey as described above and visually searched maps to identify to species (using head shape visible in photographs) and quantify the number of crocodiles detected (Fig. 2).

2) *Diurnal Surveys*: We counted crocodiles immediately following the drone count, searching for crocodiles with the aid of binoculars by foot or using a 3.5m zodiac at a constant speed 6 - 8 km/h. For each detected crocodile, we identified it to species and took a GPS point of its location.

3) *Nocturnal Spotlight Surveys:* We counted crocodiles one time each night following standard eyeshine spotlight protocol (e.g., Shirley *et al.* 2009).

Results

Testing Flight Plans and Data Collection to Minimize Disturbance and Maximize Detectability. We found that *Crocodylus suchus* were the least disturbed by the drone of all species present – where the flee altitude ranged from 1 – 10 m (Fig. 3).

There variation between observers was significant ($F4,74 = 22.44$, $p = 6.73x10^{-12}$). We found that the five independent observers counted on average 18.21 crocodiles per map, ranging from 4 - 39, where the best observer counted on average 28.38 and the worst observer 9.44. The independent, unconstrained observer counted an average of 34.94 crocodiles per map (24 - 47), and found on average 1.23 more crocodiles than the best observer and 3.7 more than the worst observer. There was a no significant difference in the number of crocodiles observed across the different altitude ($F1,70 = 3.06$, $p = 0.085$; Fig. 4)

Comparing Drones to Traditional Crocodile Survey Methods. We detected very few crocodylians in Cote d'Ivoire – 0 at all sites by all methods, except at Mare aux Buffles where we detected 0 by drone, 0 by day count, and 3 by night count. In Benin, we detected 49 crocodiles by drone, 30 by day survey, and 71 by night survey, where most of these detections were exclusively in the Bali pond in PNP (site 1) (Fig. 5). In Niger, we detected 156 crocodiles by drone, 32 by day survey, and 311 by night survey (Fig. 5). We found that night surveys detected significantly more crocodiles than either of the other two survey methods in both countries, and that drones detected significantly more crocodiles than standard day surveys (Niger: $F_{2,18} = 38.70$, $p = 3.56x10^{-6}$; Benin: $F_{2,28} = 59.39$, $p = 5.7x10^{-5}$; Fig. 5).

Discussion

Developing standard flight protocols for use of drones in crocodylian surveys. We found that image resolution using the standard camera (4K resolution) on the DJI Phantom 4 Pro were high enough that we found no effect on crocodile counts up to 40 m altitude.

Observer bias far exceeded technical flight bias as the most influential factor affecting drone-based crocodile surveys, as it has been shown for standard spotlight counts (Nichols *et al*., 2000; Shirley *et al*., 2012).

We observed *Crocodylus suchus* fled the drone at the closest approach altitude of any species at our study site, and even showed signs of being more tolerant than other crocodylian species (e.g., *Crocodylus porosus*; Bevan *et al*., 2018).

Efficacy of and uses for drones to survey crocodiles in West Africa and elsewhere. We found that nocturnal spotlight counts detected significantly more crocodiles (87%) than either of the two other methods, though we detected 231% more crocodiles by drone than during traditional diurnal surveys, congruent with previous studies counting crocodiles with drones in Africa (Ezat *et al.* 2018).

Despite detecting fewer individuals during the daytime than traditional nocturnal surveys, drone surveys likely bring several advantages in crocodylian surveys compared to standard spotlight or traditional diurnal surveys. For one, thanks to the high resolution map images (1.22 cm^2/pixel at 40m), drones allow for unbiased measurement of detected individual's size based on either *in situ* scaling or use of standard head length to total length ratios (e.g., Fukuda *et al.* 2013).

Because of the elevated point of view, drones can overcome several habitat-related visibility issues of crocodile surveys. The presence of plants and the complexity of the habitat strongly impact on-ground visibility and are a principal source of bias in estimating crocodylian populations (Shirley *et al.* 2012). In our study, we detected more crocodylians using drones than with traditional day surveys despite the shrubby vegetation cover on the banks and the presence of aquatic plants on the Tapoa River.

To conclude, drones provide an inexpensive and effective tool for assessing and monitoring crocodylian populations in some ecological contexts. They offer advantages of reduced impacts on wildlife, limiting risks for observers, easy logistics, potentially larger survey area coverage, and data security.

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Annex

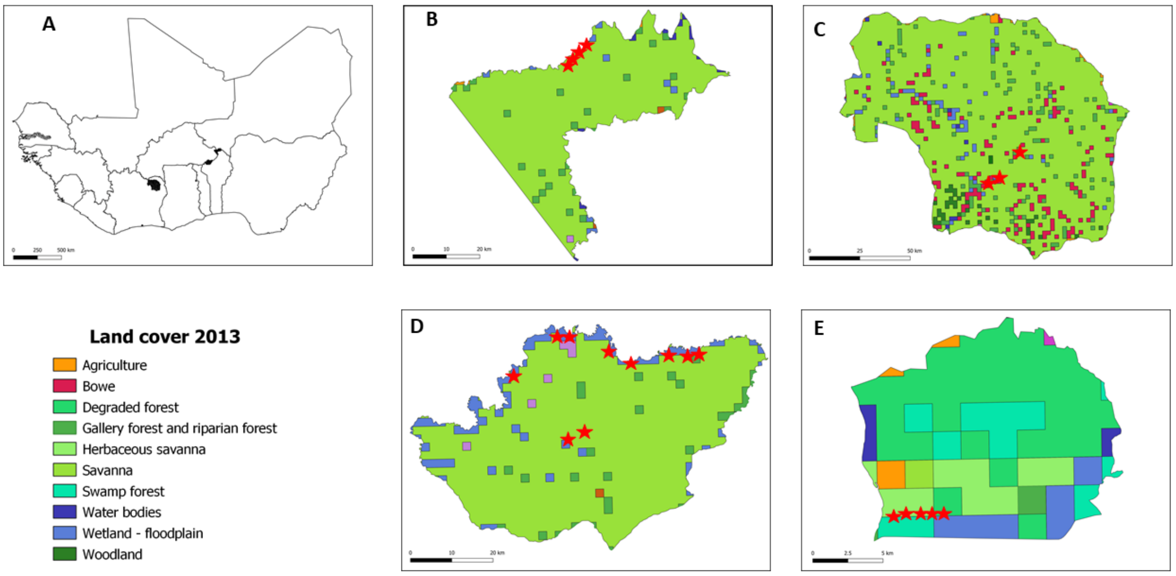

Figure 1. Distribution of study areas in West Africa (A), W National Park (WNP), Niger (B) Comoé National Park (CNP), Côte d'Ivoire (C), Pendjari National Park (PNP), Benin (D), Azagny National Park (ANP), Côte d'Ivoire(E). Study sites are ponds and river sections (red stars), the map is based on the Landscapes of West Africa atlas (2013).

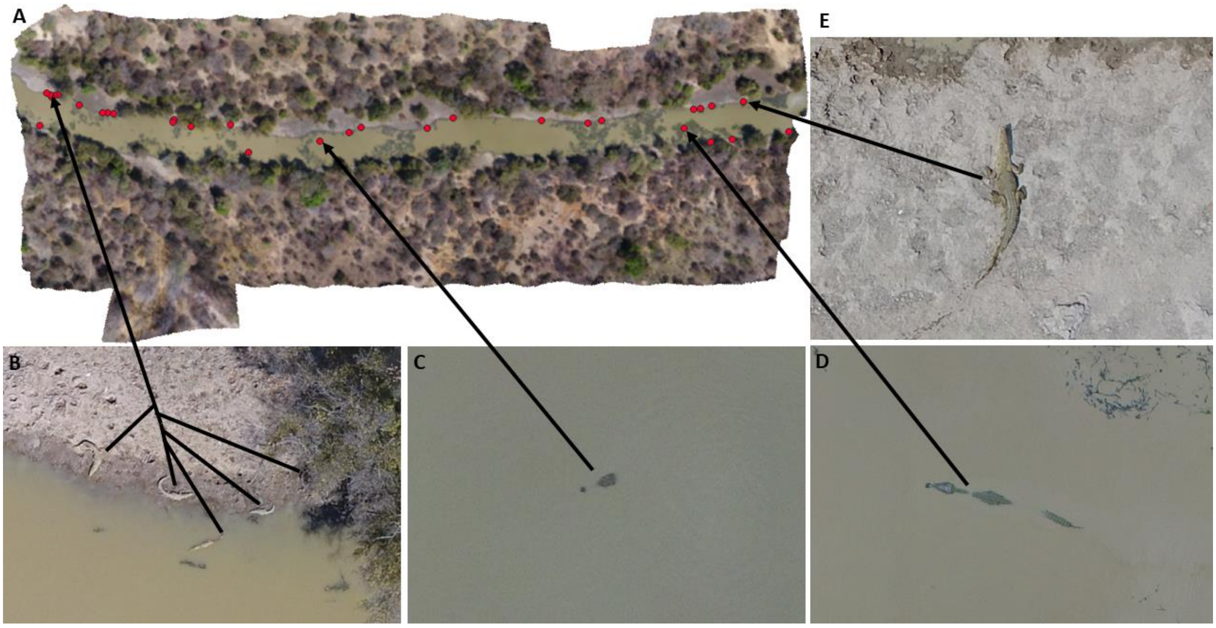

Figure 2. Crocodile counts and mapping from drone photos. The main map (A) is the aggregation of 120 orthorectified photos. The red points are for detected crocodiles, which were detected on the shore (B, E) and in the water (C, D). Flight parameters: altitude 40 meters, speed 5 m/s, overlap 60%. Tapoa river - W National Park – Niger.

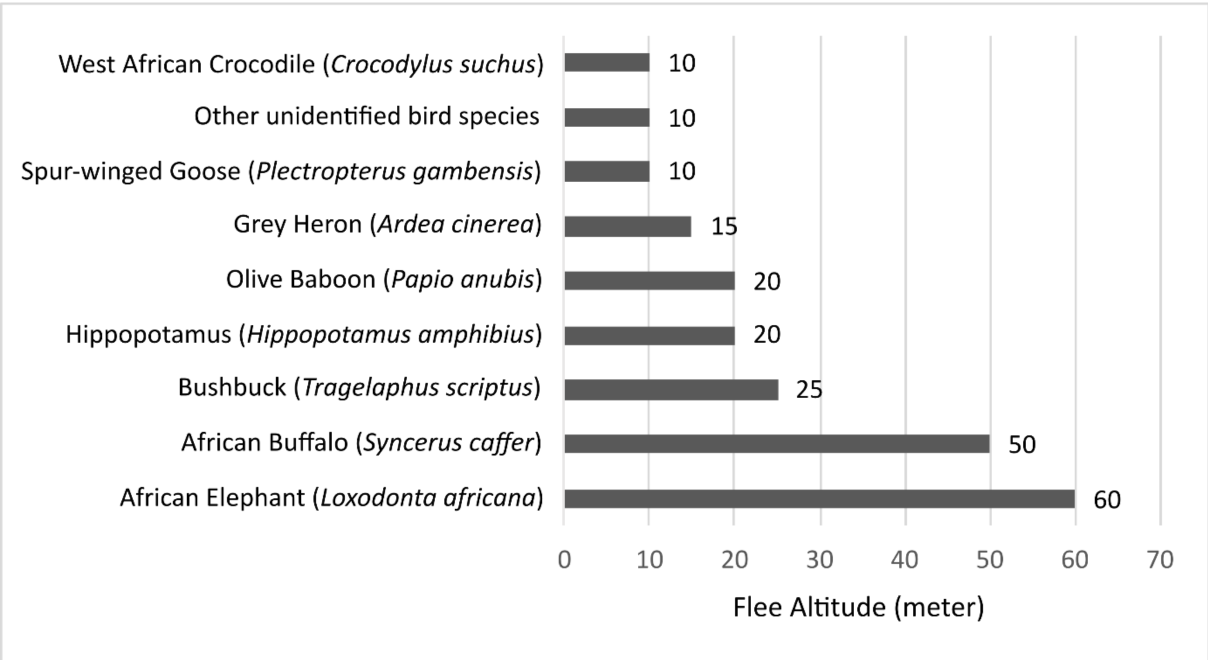

Figure 3. Drone flight altitude (meters) at which species observed at Bali Pond, Pendjari National Park, Benin fled the drone.

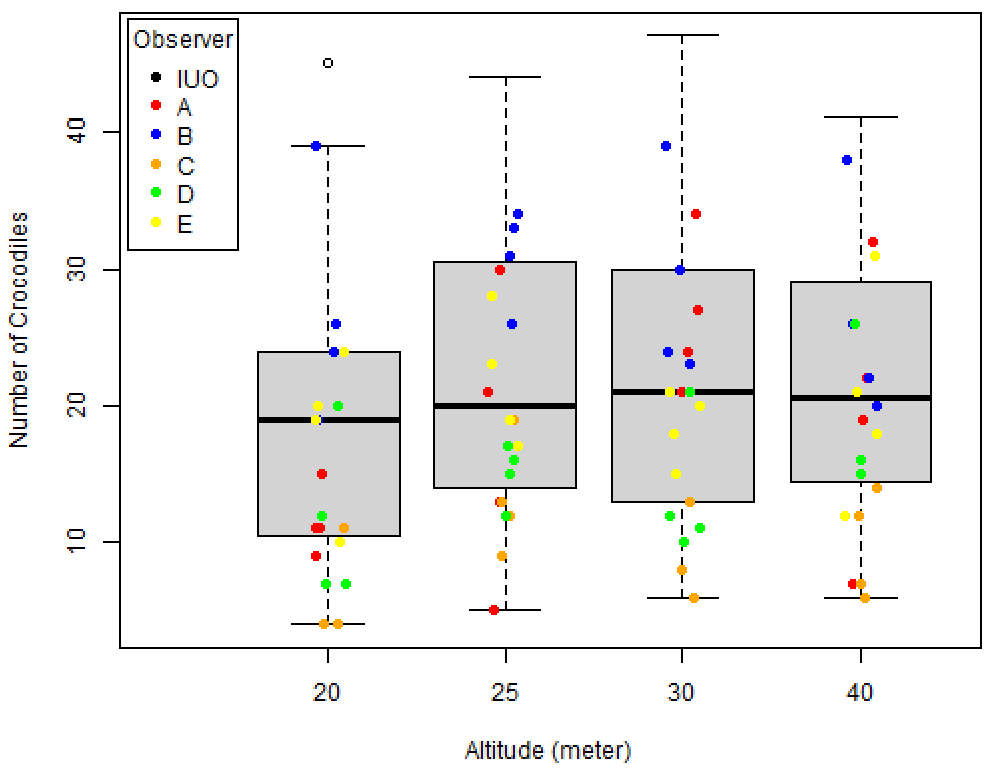

Figure 4. Observer effects on crocodile detection. Distribution of crocodile counts for each observer and flight altitude. Each observer (A to E, each with a different color) had 10 minutes to count the crocodiles on the reconstituted maps (Bali pond - Pendjari National Park - Benin), and the independent, unconstrained observer (IUO) had no time limit.

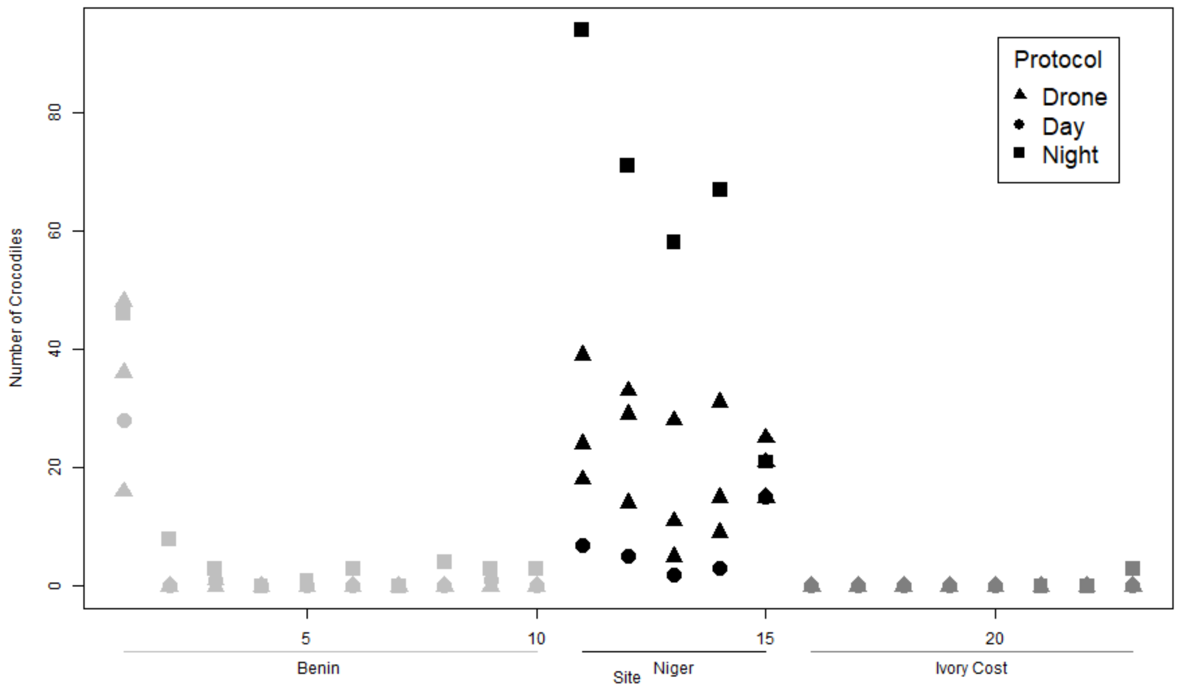

Figure 5. Number of crocodiles detected at each site by the three different survey methods. We counted crocodiles at 23 sites across Benin (blue), Niger (red), and Cote d'Ivoire (green) using three protocols: drone (triangles) and ground visual counting by day (rounds) or by night (squares).