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Animal behaviour

Approaching birds with drones: first experiments and ethical guidelines

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Unmanned aerial vehicles, commonly called drones, are being increasingly used in ecological research, in particular to approach sensitive wildlife in inaccessible areas. Impact studies leading to recommendations for best practices are urgently needed. We tested the impact of drone colour, speed and flight angle on the behavioural responses of mallards *Anas platyrhynchos* in a semi-captive situation, and of wild flamingos (*Phoenicopterus roseus*) and common greenshanks (*Tringa nebularia*) in a wetland area. We performed 204 approach flights with a quadricopter drone, and during 80% of those we could approach unaffected birds to within 4 m. Approach speed, drone colour and repeated flights had no measurable impact on bird behaviour, yet they reacted more to drones approaching vertically. We recommend launching drones farther than 100 m from the birds and adjusting approach distance according to species. Our study is a first step towards a sound use of drones for wildlife research. Further studies should assess the impacts of different drones on other taxa, and monitor physiological indicators of stress in animals exposed to drones according to group sizes and reproductive status.

1. Introduction

Robots are still marginal as tools in ecological research, yet they have a tremendous potential for biodiversity sampling, studies of population dynamics and ecosystem functioning, experimental biology and behavioural studies [1]. Recently, small unmanned aerial vehicles (hereafter ‘drones’) have become increasingly affordable (i.e. a few hundred to a few thousand US$), and this is currently leading to their widespread use for wildlife observations [2,3]. In ornithology, fixed-wing drones are already being widely used for census work and observations [4,5], and dozens of videos available on the Internet testify that researchers, and the general public, are keen to use drones to approach birds. In a number of countries, air traffic regulations strictly control the civil use of drones, yet no ethical guidelines exist with respect to their potential impacts on animal welfare. This policy vacuum is due to the paucity of research assessing the effect of drones on animal behaviour [6]. In this context, the aim of our study is to test the impact of approaching drones on animals, and to provide users with guidelines. We flew a small quadricopter drone, because this type of unmanned aerial vehicle is currently the most affordable, and focused on three species of waterbirds, because drones are already being extensively used for surveys within wetland/coastal areas [7].

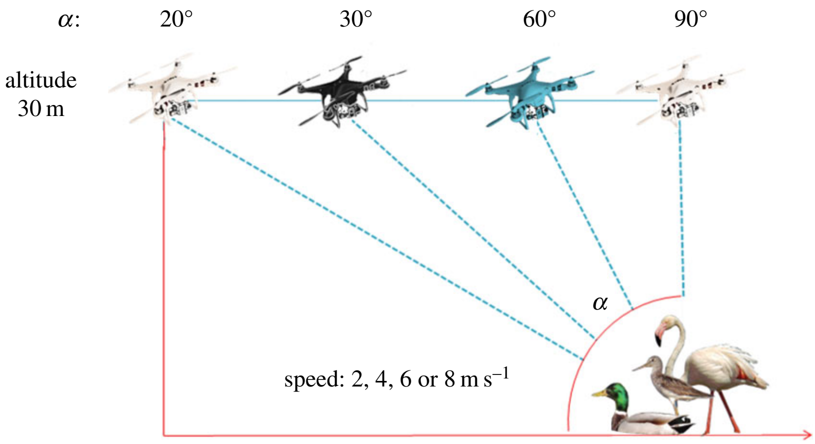

Figure 1. Flight plan for approaching birds with the Phantom drone. The drone was first ascended to 30 m, and then moved at speeds of 2–4–6 or 8 m s^{-1} towards the birds at angles α of 20°, 30°, 60° or 90°. Drones of three colours were used (white, black and blue).

2. Methods

We approached birds with drones in March and April 2014 in both semi-captive and natural settings. The semi-captive setting was located at the Zoo du Lunaret, Montpellier, France (N 43°38′30″; E 3°52′30″), and the natural area at the Cros Martin, along the brackish lagoon of the Etang de l'Or, Candillargues, France (N 43°36′18″; E 04°3′18″). In the semi-captive setting, we approached mallards (*Anas platyrhynchos*; 1.1 kg, 0.55 m length) that were living in a zoo, but capable of flying in and out of the premises. In the natural setting, we approached wild flamingos (*Phoenicopterus roseus*, 3 kg, 1.25 m length) and common greenshanks (*Tringa nebularia*, 0.2 kg, 0.35 m length). All birds were non-breeding at the time of the experiments, and were resting or feeding. They were either floating at the water surface (mallards) or standing in shallow water (flamingos and greenshanks). Bird groups included an average of 5 mallards (range 3–9), 35 flamingos (range 5–73) or 19 greenshanks (range 11–27). Birds were not individually marked, and we therefore cannot exclude that we approached some of them more than once.

We used a Phantom drone designed by Cyleone (Montpellier, France, http://cyleone.fr/). The device is a quadricopter with a diagonal length of 350 mm, a mass of 1030 g, a pay load of 250 g, a maximum speed of 15 m s^{-1}, a vertical and horizontal positioning accuracy of 0.8 and 2.5 m, respectively. Noise level is 60 dB at 2 m, and hence considered non-impacting [8]. The Phantom came in three colours (white, black and blue), and was equipped with a Hero3 GoPro camera (San Meteo, USA), which relayed images in real time onto a portable screen (StudioSport, France). The speed and position of the drone were determined by an onboard GPS module. The position of the birds relative to the observer and the drone was determined with a laser rangefinder (PCE-LRF 600, Strasbourg, France) held by the observer, with an accuracy of 1 m. Light intensity was 40 000 Lx on average during the trials, and never below 20 000 Lx. Visibility was at least 500 m, and wind speed (anemometer PCE-AM 81, Strasbourg, France) never exceeded 22 km h^{-1}.

The drone was launched at a minimum distance of 50 and 100 m from the birds in the semi-captive and the wild situation, respectively. These distances were chosen because pre-trials revealed that they were adequate to launch the drone without causing a reaction of the birds. While one operator was steering the drone, a second observed the birds closely with 10 × 40 binoculars and the rangefinder. From the take off point, the drone ascended vertically (at 3 m s^{-1}) to 30 m, and then approached the birds (figure 1). We varied the speed and angle of approach according to four categories each (speed: 2, 4, 6 and 8 m s^{-1}; angle: 20°, 30°, 60° and 90° from the horizontal—thus, the 90° trajectory involved the drone flying at 30 m to directly above the birds before descending). When approaching close to the ground (20°), it is challenging to fly at 8 m s^{-1}, and hence for this angle, we used only 2, 4 and 6 m s^{-1}. For all other angles (30°, 60° and 90°), we used the speed categories 2, 6 and 8 m s^{-1}. These combinations of angle and speed resulted in 12 categories, each of which was used for the three drone colours (white, black, blue). Each of these 36 approach types was performed once (66% of trials), or twice (33%) in mallards, once (33% of trials) or twice (66%) in greenshanks, and twice (33% of trials), three times (33%) or four times (33%) in flamingos. Bird reactions were classified in three categories: (type 1) no reaction; (type 2) brief head and tail movements followed by animal movements away from the drone, either walking or swimming at the water surface; (type 3) flying off. Approaches were pursued until birds reacted, or stopped when the drone was 4 m from the closest bird. We considered a bird group as 'stressed' as soon as one individual showed a type 2 or type 3 response. Owing to group dynamics, this individual reaction was always closely followed by reactions of all group members. Two-minute breaks were taken between each flight. Impacts of the different protocols on bird behaviour were tested using variance analyses conducted in R.

3. Results

We performed a total of 204 approaches in 8 days (24–36 per day), 48 on mallards in a semi-captive situation, and 156 in the wild on greenshanks (60 trials) and flamingos (96 trials). In mallards, no reaction was recorded in 35 cases (72%), type 2 reactions in nine cases, and type 3 reactions in four cases; those reactions occurred when the drone was 4–8 m from the birds. In flamingos, no reaction was recorded in 75 cases (78%), type 2 reactions in 11 cases, and type 3 reactions in 10 cases; those reactions occurred when the drone was 5–30 m from the birds. In greenshanks, no reaction was recorded in 53 cases (87%), type 2 reactions in five cases, and type 3 reactions in two cases; those reactions occurred when the drone was 4–10 m from the birds. Group size tended to influence reaction distance; with reactions at 25–30 m distance being observed only twice, for the largest flamingo groups (more than 50 individuals). Our sample size was nonetheless too limited to confirm this trend.

Results were largely consistent across all three species and the semi-captive versus natural set-up, and bird behaviour (resting/feeding) was a non-significant factor within all analyses: approach speed had no influence on bird reactions ($F_{3,203} = 2.19$, $p = 0.09$). Drone colour had no impact on bird

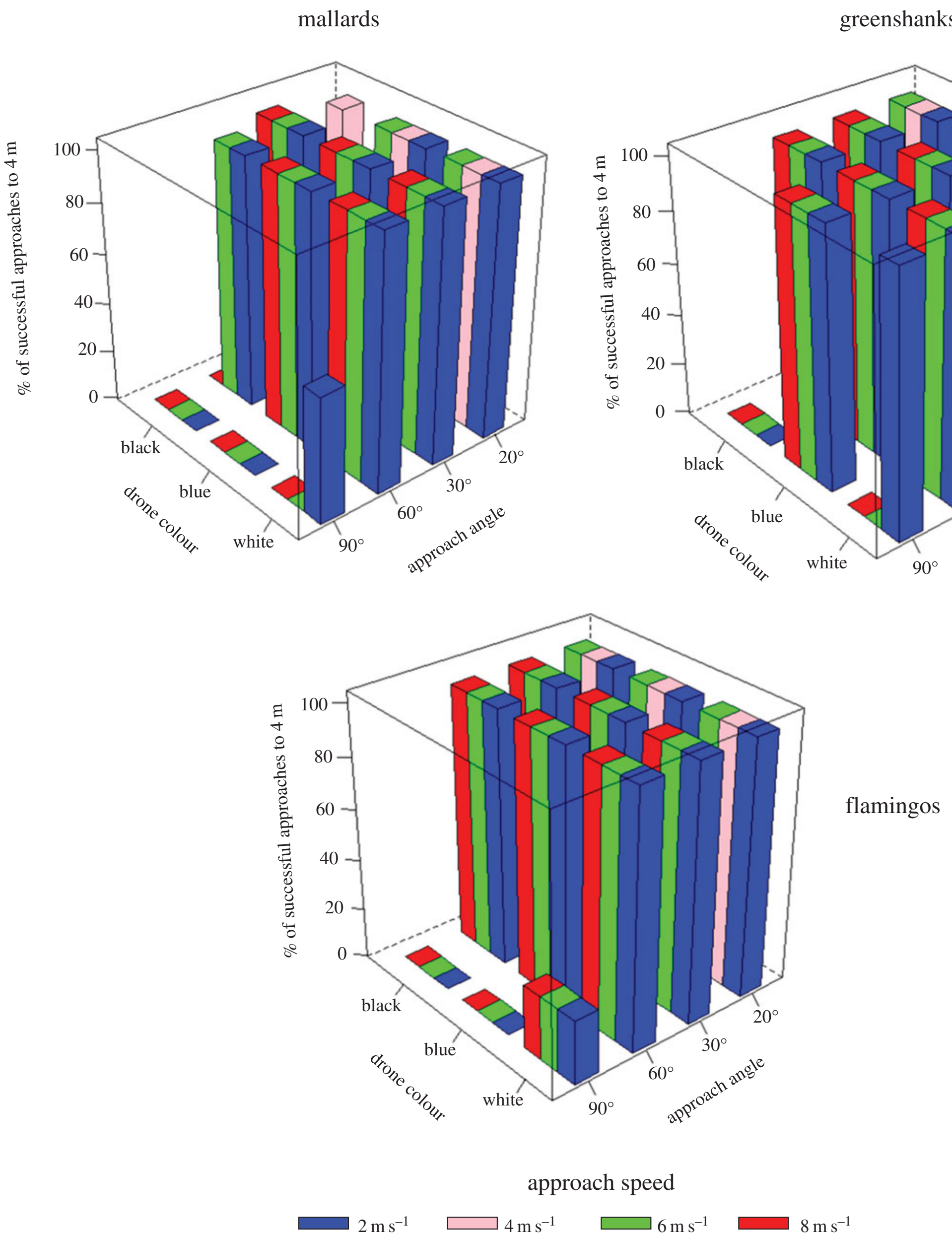

Figure 2. Impacts of drone colour (white, blue, black), approach angle (°) and flight speed (m s^{-1}) on bird behaviour across 204 approach flights conducted in three bird species. The impact is rated as the percentage of approaches to within 4 m of the birds during which animals did not show visible reactions. See Methods and Results sections for details.

reactions ($F_{2,203} = 1.27$, $p = 0.28$). Successive approach flights also had no significant cumulative impacts (no relation between the rank-order of the trial per day and bird response; $F_{1,203} = 0.90$, $p = 0.344$). Conversely, approach angle had a marked impact on bird reactions ($F_{3,203} = 136.33$, $p < 0.0001$; figure 2): in mallards, birds showed no reaction for all approaches conducted at angles of 20°, 30° and 60°, but showed a reaction in eight cases of nine for approaches with drones conducted at 90°. Similarly, flamingos and greenshanks never reacted for approaches at 20°, 30° and 60°, but reacted in 17 of 18 cases (flamingos) and five of nine cases (greenshanks) for approaches at 90°.

4. Discussion

Using a standardized protocol applied to three different species of waterbirds across 204 approaches, we demonstrated that in 80% of all cases one specific drone type could fly to within 4 m of the birds without visibly modifying their behaviour. We also demonstrated that approach speed, drone colour and repeated approaches did not have any significant impact on bird reaction, but that approach angles had marked impacts across all three species. A Phantom drone approaching a bird vertically was usually more disturbing, maybe because it was associated with a predator attack. To test this hypothesis, future studies should use 'neutral' quadricopters versus fixed-wing drones mimicking the shape of avian predators known to target the approached species.

It is surprising that we managed to fly so close (4 m) to seemingly undisturbed birds, as in particular wild flamingos and greenshanks are known for their extremely high sensitivity to disturbance [9]. These results suggest that, when carefully flown, drones may be used in ornithology for a wide range of population censuses, measurements of biotic and abiotic variables, and recordings of bird behaviour. Those applications could be immensely useful, especially in inaccessible areas such as mountains or large wetlands.

Nevertheless, we are calling for much caution in the use of drones for wildlife research. To take a precautionary approach, we recommend launching drones farther than 100 m from the birds, not approaching them vertically, and adjusting approaching distance according to species. We also feel that our investigations should be followed by further studies of the impacts of different types of drones (varying size and noise levels) on a larger range of bird species. Indeed, all three species investigated here feed on plants and/or invertebrates, and it seems essential to also test the reactions of omnivorous/predatory species to the presence of drones. Notably, videos available on the Internet demonstrate that birds of prey tend to attack drones, and this is also likely for corvids and larids. Further, we recorded no behavioural changes in birds during most approaches, but this does not mean that the drone presence was not stressful for the animals. Indeed, numerous studies showed that disturbance can lead to increased heart rates and/or corticosterone levels in birds that do not react behaviourally [10]. It is therefore also essential to perform studies of drone impacts in captive or wild birds for which physiological parameters can be recorded along with behaviour patterns [11]. Such stress levels should then be compared for birds censused using drones versus other techniques (e.g. walking humans). Finally, the incidence of bird group size and breeding status (non-breeding, incubating, chick-rearing) on reaction thresholds should also be thoroughly investigated.

In conclusion, our study of animal reaction to drones is important in the context of the rapid development of drone technologies for the monitoring of wild animals, particularly in protected areas [12]. It is a first step towards a code of best practices in the use of drones for ecological research, and calls for further, detailed assessments of the wildlife impacts of these new technologies.

Ethics statement. All experiments were performed under permits granted from both the French veterinary services (permit no. 34-369) and French environmental and aviation authorities (permit reference: MAP CYLEONE edition no. 04-Amendment 1).

Data accessibility. Data used for all analyses are available as electronic supplementary material. See also online video showing examples of approach flights: http://youtu.be/t_WtxX6O0JI.

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Authors' contributions. E.V., D.G., A.L. and O.D. designed the study. E.V., G.B., D.G. and A.L. performed the study. E.V. and G.B. analysed data. D.G. and E.V. wrote the manuscript, which was corrected by all authors.

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Competing interests. The authors have no competing interests.

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