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# Bird interactions with drones, from individuals to large colonies

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**Abstract.** Drones are rapidly becoming a key part of the toolkit for a range of scientific disciplines, as well as a range of management and commercial applications. This presents challenges in the context of how drone use might impact on nearby wildlife, especially birds as they might share the airspace. This paper presents observations (from 97 flight hours) and offers preliminary guidance for drone-monitoring exercises and future research to develop guidelines for safe and effective monitoring with drones. Our study sites spanned a range of arid, semi-arid, dunefield, floodplain, wetland, woodland, forest, coastal heath and urban environments in south-eastern and central Australia. They included a nesting colony of >200 000 Straw-necked Ibis *Threskiornis spinicollis*, the largest drone-based bird-monitoring exercise to date. We particularly focused on behavioural changes towards drones during the breeding season, interactions with raptors, and effects on birds nesting in large colonies—three areas yet to be explored in published literature. Some aggressive behaviour was encountered from solitary breeding birds, but several large breeding bird colonies were surveyed without such issues. With multi-rotor drones, we observed no incidents that posed a threat to birds, but one raptor attacked and took down a fixed-wing drone. In addition to providing observations of interactions with specific bird species, we detail our procedures for flight planning, safe flying and avoidance of birds, and highlight the need for more research into bird–drone interactions, most notably with respect to territorial breeding birds, safety around large raptors, and the effects of drones on the behaviour of birds in large breeding colonies.

## Introduction

Unmanned aerial vehicles (hereafter drones), with their varied applications and general affordability, are increasingly used in ecological research and monitoring. Surveying birds from the air has many benefits (Kingsford & Porter 2009), and drones were quickly adopted for use in this context, after becoming readily available in the last 5–10 years (Abd-Elrahman *et al*. 2005; Chabot & Francis 2016). Although application to avian research and management is relatively limited compared with other disciplines, it is gaining momentum. Current research spans a range of topics, including ethical guidelines (Vas *et al.* 2015), recreating environmental data input from bird flight-paths (Rodríguez *et al*. 2012), monitoring nesting status (Weissensteiner *et al*. 2015), and both manual and automated detection routines for groups of birds and nest counts (Trathan 2004; Descamps *et al*. 2011; Chabot & Bird 2012; Sardà-Palomera *et al.* 2012; Chabot & Francis 2016; Hodgson *et al*. 2016).

There is a range of challenges related to collection of data using drones, a major component of which is interaction with nearby wildlife (Lambertucci *et al.* 2015; Hodgson & Koh 2016), particularly birds. Research has only just begun exploring these interactions (Vas *et al*. 2015), identifying a considerable knowledge gap in the context of the diversity of bird species and how they interact with drones. In relation to drones, there is currently only ‘grey’ literature (news articles, videos etc.) on behavioural changes of birds with breeding status, interactions with raptors, and effects on birds nesting in large colonies. There is also very little information about interactions with drones by bird species in Australia (Hodgson & Koh 2016). In this paper, we provide some initial findings and guidelines to address some of these knowledge gaps, drawing observations from 97 hours of drone flight across a wide range of environments.

We particularly focus on observations of birds during the breeding season, when nesting birds are more likely to be susceptible to disruption (Lambertucci *et al.* 2015). During the breeding season, drones can be particularly hazardous for birds, given potential large congregations and territorial aggression in some species. Of particular interest are our observations while monitoring several large breeding waterbird colonies; one colony contained at least 100 000 nests. To date, the largest reported colony of birds monitored via a drone is a penguin colony of 11 000 (Trathan 2004). We report observations on raptors. and various other bird species, and also detail the drone flight characteristics, in order to help readers in their own flight preparations and planning. This paper provides the first comprehensive report of bird–drone interactions in Australia. Its primary aim is to provide a basis for further research into bird–drone interactions, and to help provide direction for development of guidelines and policy for planning and safely executing monitoring work with the use of drones.

## Material and methods

### *Study locations and monitoring details*

The study locations were predominantly within eastern Australia but we focus on bird species with a continental distribution (Figure 1). The clustered sites around Sydney

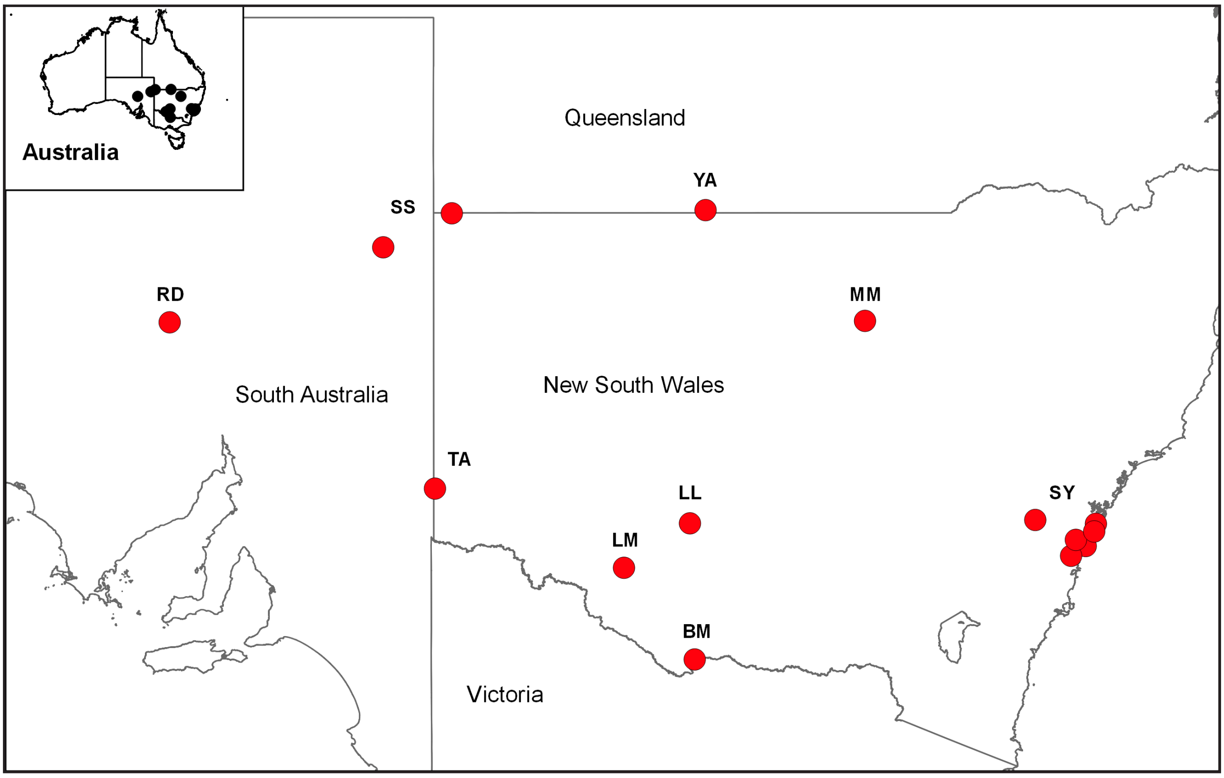


**Figure 1.** Map showing study locations for this paper. BM = Barmah–Millewa, LL = Lower Lachlan River, LM = Lower Murrumbidgee River, MM = Macquarie Marshes, RD = Roxby Downs, SS = Sturt and Strzelecki Deserts, SY = Sydney Basin/City, TA = Tarawi Nature Reserve, and YA = Yantabulla Floodplain. See Table 1 for more details.

were at various National Parks and urban greenspaces. The remaining sites were spread across a range of environments, including arid and semi-arid floodplains, shrublands and dunefields, as well as permanent wetlands. Drone use spanned a range of survey planning and environmental monitoring activities involving 97 hours of flight. Table 1 provides details of study sites, including the purpose of drone use and flight characteristics. Exact locations are not provided due to sensitivity for breeding birds, but they are available from the authors on request. Except for the ibis colonies, bird observations were incidental to normal drone operation activities. For the ibis colonies, we conducted more systematic observations, which are detailed below. The main drone used for monitoring at all sites was a DJI Phantom 3 Professional quad-copter. Additionally, a Sensefly eBee fixed-wing and a DJI S900 hexa-copter were flown at some sites.

### *General flight details*

The main purpose for drone use at most of the study sites was to acquire imagery to generate orthorectified mosaics of habitats and related three-dimensional model products. This typically involved flying parallel flight lines at speeds between 5 and 10 m/s. To acquire sufficient image overlap for processing, flight lines were typically 20–100 m apart, depending on flying height. For example, flying at 100 m above take off (ATO), flight lines were ~100 m apart, whereas at 20 m ATO, flight lines were ~20 m apart. As an example, one of the Lower Lachlan River surveys covered an approximately circular area of ~7 km$^2$, and we flew 34 individual flight transects at 100 m ATO.

### *Ibis breeding colonies*

Drones were used to collect data on nesting habitat and bird numbers at five ibis breeding colonies with very large numbers of birds (predominantly Straw-necked Ibis *Threskiornis spinicollis*, with some Australian White Ibis *T. moluccus* and Glossy Ibis *Plegadis falcinellus*). One of the Lower Lachlan colonies had at least 200 000 adults (100 000 nests) at the time of flying, presenting particular challenges. The other colonies had between 10 000 and 50 000 adults. Ibis usually nest on inundated vegetation including lignum *Duma florulenta* and Common Reed *Phragmites australis*. Nests are typically between 20 cm and 2 m above ground level. At two of the colonies (Lower Lachlan and Lower Murrumbidgee), we collected additional information about disturbance as part of a longer-term study on the impact of field observations during active breeding events. This involved capturing video of nests from fixed video cameras before and after drone flights were conducted. This included five–six systematic ascents and descents (speed ~1 m/s) between 120 m (maximum legal height) and 10 m (minimum comfortable flight with bird traffic) ATO over the filmed nests, to observe the height at which birds flushed and the time/conditions required for them to return. We do not go into detail on the behavioural observations, but we do provide some raw imagery and video for readers. Other studies (e.g. Vas *et al.* 2015) involved multiple repeated experiments and, although this is ideal from an experimental design perspective, we considered any additional disturbance to the birds unnecessary as the subsequent monitoring involved systematic flight lines over the entire colony.

**Table 1.** Location of study sites, and dates and details of drone flights. Flight characteristics include flight heights above take off (m); drone details include type of drone used and total flight time (h) at each site. NP = National Park, NSW = New South Wales, SA = South Australia.

| *Location* | *Date(s)* | *Purpose and flight characteristics* |
|---|---|---|
| Lower Lachlan River, NSW | Oct. 2016, Sept. 2017 | Ibis colony monitoring (~100 000 nests)<br>Flight: Parallel lines, 60–100 m<br>Drone: Quad-copter, 8 h |
| Lower Murrumbidgee River, NSW | Nov. 2016 | Ibis colony monitoring (~15 000 nests)<br>Flight: Parallel lines, ~100 m<br>Drone: Quad-copter, 3 h |
| Macquarie Marshes, NSW | Nov. 2016 | Ibis colony monitoring (~20 000 nests)<br>Flight: Parallel lines, ~100 m<br>Drone: Quad-copter, 5 h |
| Barmah–Millewa forest, NSW | Dec. 2016 | Ibis colony monitoring (~20 000 nests)<br>Flight: Parallel lines, 60–100 m<br>Drone: Quad-copter, 4 h |
| Tarawi Nature Reserve, NSW | Oct. 2017 | Vegetation monitoring<br>Flight: Parallel lines & sporadic, 10–120 m<br>Drone: Quad-copter & fixed-wing, 8 h |
| Yantabulla Floodplain, NSW | 2015–2017 | Ground surveys & bird colony monitoring<br>Flight: Parallel lines & sporadic, 10–100 m<br>Drone: Quad-copter & fixed-wing, 23 h |
| Sturt NP, NSW, & Strzelecki Regional Reserve, SA | Jun. 2016, Mar. 2017 | Vegetation monitoring & ground survey<br>Flight: Parallel lines & sporadic, 10–120 m<br>Drone: Quad-copter, 8 h |
| Roxby Downs, SA | Apr. 2016, Aug. 2016 | Vegetation monitoring<br>Flight: Sporadic, 10–100 m<br>Drone: Quad-copter, 5 h |
| Sydney Basin, NSW | 2015–2017 | Vegetation monitoring<br>Flight: Parallel lines, sporadic & circular, 10–100 m<br>Drone: Quad-copter & fixed-wing, 18 h |
| Sydney city, NSW | 2015–2017 | Training & vegetation/greenspace monitoring<br>Flight: Parallel lines & sporadic, 10–120 m<br>Drone: Quad-/hexa-copter & fixed-wing, 15 h |

### *Animal welfare*

Our ethics approvals covered the types of flight patterns for testing interaction with birds, to ensure safe monitoring practices. They explicitly prohibited any experimental designs that repeatedly induced interactions with wildlife (e.g. Vas *et al.* 2015), as that was deemed to cause unnecessary potential risk. This is the primary reason for our relatively *ad hoc* observations.

## Results

### *General interactions*

We encountered a diverse group of bird species across many different environments and, during 97 hours of flights, we encountered a few situations where the flights posed a presumed threat to birds. Of most concern was the Australian Magpie *Gymnorhina tibicen* in the Sydney area. During the breeding season, on two occasions (August 2015 and October 2016), individuals (sex not determined) flew towards the drone (from 30–50 m away) and chased it, although evasive action by the drone-operator was effective in avoiding collision, and the Magpies retreated. In contrast, Pied Currawongs *Strepera graculina* left their nests when a drone flew directly overhead (within ~5–10 m) and gave territorial calls, but did not attempt to physically fly towards or attack the drone. They did not immediately return to the nest, and we did not note how long they remained absent. When Currawongs were similarly approached by other birds (Channel-billed Cuckoo *Scythrops novaehollandiae*, Noisy Miner *Manorina melanocephala*, Australian Raven *Corvus coronoides*, and Common Myna *Acridotheres tristis*), they displayed both audible and physical territorial behaviour. During the non-breeding season, Australian Magpies and Pied Currawongs showed none of the same aggressive/defensive behaviour towards a drone. Masked Lapwings *Vanellus miles* also gave typical territorial calls (within ~10 m), but did not demonstrate other aggressive actions towards drones. Masked Lapwings nest on open ground, and therefore it was generally easy to minimise close proximity to the drone. On four occasions, swarms

**Table 2.** Key bird species observed in association with drone research and their associated interactions.

| *Bird species* | *Sites present* | *Interactions of note* |
|---|---|---|
| Australian White Ibis *Threskiornis moluccus*<br>Straw-necked Ibis *T. spinicollis*<br>Glossy Ibis *Plegadis falcinellus*<br>Royal Spoonbill *Platalea regia* | Lower Lachlan, Lower Murrumbidgee, Barmah–Millewa, and Macquarie Marshes | Present in large numbers (most sites 90–99% Straw-necked Ibis), but showed little interest or aversion to drones, except when approached within ~10 m. |
| Australian Magpie *Gymnorhina tibicen* | Coastal and central NSW sites | Abundant; aggressive/defensive towards drone in breeding season. |
| Masked Lapwing *Vanellus miles*<br>Pied Currawong *Strepera graculina* | Coastal and central NSW sites | Abundant and active during breeding season—vocally aggressive, but not physically. |
| Wedge-tailed Eagle *Aquila audax*<br>Brown Goshawk *Accipiter fasciatus*<br>Whistling Kite *Haliastur sphenurus*<br>Black Kite *Milvus migrans*<br>Nankeen Kestrel *Falco cenchroides*<br>Brown Falcon *Falco berigora* | All sites outside Sydney Basin | Observed to be present during many flights—no specific interest shown to multi-rotors; one falcon attacked a fixed-wing drone. |
| Waterbirds (ducks, piscivores, and waders) | Yantabulla, non-desert sites outside Sydney Basin | Birds showed no obvious reaction, but tended not to take flight while drone present. |
| Noisy Miner *Manorina melanocephala*<br>Common Myna *Acridotheres tristis* | Sydney Basin | Locally abundant; at times appear to display aggressive or defensive behaviour when close to drone (<5 m), but no contact. |
| Fairy Martin *Petrochelidon ariel*<br>Welcome Swallow *Hirundo neoxena*<br>Common Starling *Sturnus vulgaris* | Sydney Basin | Locally common; groups fly extremely close to drone (<1 m), but no obvious aggressive or defensive behaviour was observed. |

of insects were attracted to the multi-rotor drones, so thought should be given to whether insectivores might be attracted to the insects. Table 2 details additional birds that we considered might have been disturbed or put at risk at our various field sites.

### *Raptors*

Of most concern in flight planning was the presence of raptors at many of our study sites, especially given the various reports in grey literature of 'attacks' by raptors on drones. However, it is often difficult to ascertain the circumstances (e.g. breeding status, environmental conditions, drone activity etc.) around such attacks. We observed raptors on many of our flights, and often close (i.e. <100 m) to the drone, but in only one instance did a raptor physically attack the drone.

Wedge-tailed Eagles *Aquila audax* were common at many of the study sites. At Sturt National Park and Strzelecki Regional Reserve, they were present for the majority of flights and, although they commonly flew within ~100 m of the drone, they were not observed intentionally flying towards the drone. Black Kites *Milvus migrans*, and Nankeen Kestrels *Falco cenchroides* and several other falcon species were frequently observed at many of the sites outside the Sydney Basin. They often flew close (<50 m) to the drones and appeared to continue normal activities. For example, while a drone was within 15 m of a Nankeen Kestrel at one of the Lower Lachlan sites, the Kestrel appeared to continue to hunt as normal and successfully captured a prey item. These observations were true for both the multi-rotor and fixed-wing drones, excepting one incident as follows.

On 26 November 2017 at 1730 h, at Tarawi Nature Reserve (semi-arid open woodland), during the final phase of a landing (~10 m above ground), the fixed-wing drone was attacked by a falcon (either a Brown *Falco berigora* or Black Falcon *F. subniger*). The falcon was perched in a nearby tree and, when the drone was within 5–10 m, it swiftly attacked the drone. The incident lasted <10 seconds. The fixed-wing drone is mostly polypropylene foam (~700 g), so it was thrown out of flight and crashed, but the bird was observed flying away, after the incident, apparently unharmed. Local rangers have not observed Black Falcons at the Reserve, so the bird was probably a dark-plumaged Brown Falcon.

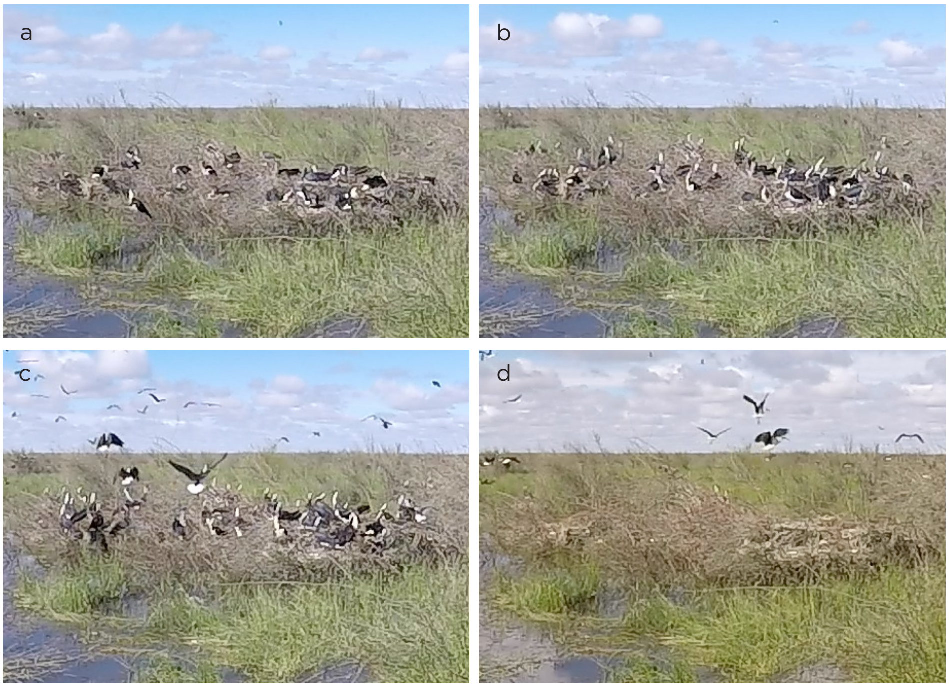


**Figure 2.** Images of a group of Straw-necked Ibis nests near the Lower Lachlan River in New South Wales. The nests shown are ~15 m away from another group of nests over which a quad-copter drone was being flown. (a) shows a typical state pre-disturbance of any kind; (b) vigilant behaviour when the drone was lowered to ~20 m above the adjacent nests, when some birds from the adjacent nests flushed; (c) more highly vigilant behaviour when the drone was lowered to ~10 m above the adjacent nests; and (d) birds flushed from nests as the camera was retrieved on foot.

*Ibis colonies*

Ibis colonies have high densities of nests and birds, meaning that adult ibis were always in close proximity to the drone. This was even true at higher flight altitudes (i.e. 100 m), as ibis were observed flying in thermals >500 m above the ground. Manual counting of individual nests from the processed drone imagery at one of the Lower Lachlan sites indicated that there were 101 360 nests. Although daunting when considering a drone-flying operation, we demonstrate that it can be done safely.

First, while approaching from above with the drone, ibis directly below the drone flushed from their nests when the drone was ~15–20 m above them (see an annotated video of the filmed nest-site: https://youtu.be/86cgvCCcNto). Ibis on adjacent nests (10–15 m away) displayed vigilant behaviour but did not flush (Figure 2). Once the drone was at least 15 m high, the birds returned to their nests within 30 seconds–1 minute. However, if the drone was left hovering at 10 m, birds did not return to their nests within 5 minutes—the maximum time that we allowed to minimise disturbance to chicks and eggs. When retrieving the fixed video cameras (i.e. walking into the colony), birds flushed at a distance of at least 30–40 m away, meaning that the number of birds flushed was much greater than that caused by the drone (Figure 2; https://youtu.be/86cgvCCcNto). Ibis occasionally flew quite close to the drone, if they did not see it when changing direction, although they quite easily avoided it. We provide a video of such an avoidance (https://youtu.be/RQGYJig5-1M).

## Discussion

Overall, we tended to observe reactions consistent with those reported (or implied) from various drone-monitoring studies focused on waterbirds and passerines (Descamps *et al*. 2011; Sardà-Palomera *et al.* 2012; Chabot *et al.* 2015; Vas *et al.* 2015; Hodgson *et al.* 2016). Considering this, it appears that drone flight around non-territorial birds in Australia poses relatively low risk to birds, so it should be easy to develop a set of guidelines to enable flight planning and execution that minimises risk to these birds. However, we encountered several birds that appeared to be territorial and aggressive/defensive. The Australian Magpie showed aggressive action towards a drone during the breeding season, and other breeding birds appeared to be at least disturbed. Magpies, and to a lesser extent currawongs and lapwings, readily harass and strike other birds and people, but retreat after the threat moves some distance from the nest. When Australian Magpies chased a drone, we found that an evasive action of flying the drone at full speed away, angled upwards, was sufficient to avoid contact. The Magpies retreated, as they would with other animals or people, once the drone was 50–100 m away. Operators should thus always be aware of the breeding season for birds in their study area. Further study would benefit from larger sample sizes of observations of birds both during and outside the breeding season.

There are numerous examples of raptors attacking drones in the grey literature, but these provide little detail about the flight characteristics, environmental conditions and status of the birds (breeding status, nest proximity etc.). Our more detailed observations here should thus provide a basis for further targeted research. Anecdotal evidence suggests that drones pose a serious risk to Wedge-tailed Eagles, although we did not experience this. The only case we had where a bird contacted a drone was with a fixed-wing drone, so further study on the effect of type of drones being used is warranted. Large raptors (Wedge-tailed Eagles particularly) tend to be more active in higher winds or during parts of the day when thermals have developed. We avoided those conditions in general, so that might have contributed to the minimal interactions that we encountered with raptors; we would certainly encourage others to follow similar guidelines. Nonetheless, we still do not know why one falcon attacked a drone in this study. If a raptor is observed, caution should be used when flying a multi-rotor drone, whereas we would recommend safely landing a fixed-wing drone. If a raptor surprises an operator (e.g. when landing), there is little that can be done except try to take whatever action possible to avoid injuring the bird.

Although our work was not systematically designed to test interactions, we show that relatively affordable drones have the capacity for monitoring very large groups or colonies of birds with relatively low disturbance and at fairly low risk to the birds. As far as we know, the ibis colony at the Lower Lachlan River is the largest bird colony to date to have counts derived from drone imagery. Trathan (2004), Descamps *et al.* (2011), Chabot *et al.* (2015) and Hodgson *et al.* (2016) monitored groups of birds in the order of several thousand to ~11 000. Our work in the ibis colonies is detailed here to the extent that we think will be useful for development of guidelines and policy for use of drones over large colonies. Further analysis, in the context of bird behaviour, counting strategies and accuracy, and colony monitoring success, is a focus of our current research. We shall also compare disturbance by drones and by traditional monitoring methods, i.e. on foot, by canoes, amphibious vehicles and by aerial survey. Another major focus for future research is automated processing of the drone imagery. At present, nest and bird numbers have been manually counted from the imagery, but current research is focusing on automated machine learning and statistical methods.

One important aspect that we did not measure was the impact of sound. In relatively quiet areas, drones are reasonably noisy, and can be heard 200–300 m away. We are unsure of the impact that this is likely to have, and we recommend that this deserves further research. While working in the bird colonies, the background noise of the colony was such that the drone was inaudible, to humans, once it was >30–40 m away.

In this paper we have provided a set of observations that could be useful for the development of guidelines and policy for the safe use of drones and for reducing their potential risk and impact on birds. As a general preliminary guide, we suggest that the most important consideration, after determining which birds are likely to be present, is their ecology—i.e. whether they are territorial, their breeding status, and other aspects of environmental conditions that might affect their behaviour towards drones. This paper adds to the growing literature that highlights the potential of drones for avian research, and provides important considerations for future research to ensure safe and effective monitoring.

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