Evaluating drones as bird deterrents in industrial environments: multirotor vs fixed-wing efficacy

Imran Mohd Hornain, Nik Fadzly N Rosely
School of Biological Sciences, Universiti Sains Malaysia, Pulau Pinang, Malaysia

Article Info

Article history:

Received Aug 9, 2023
Revised Apr 1, 2024
Accepted May 17, 2024

Keywords:

Deterrents
Drones
Fixed-wing
Multirotor
Pest birds

ABSTRACT

Unmanned aerial vehicles (UAVs) or drones have been proposed as deterrent tools to mitigate pest birds' problems. Many studies have been conducted to evaluate the efficacy of drones, mainly to protect crops, fishponds and airports. Little information can be acquired on using drones in industrial areas. In this study, two types of drones, categorized as multirotor drones and fixed-wing drones, were used to evaluate their efficacy in reducing pest birds, Asian glossy starling (*Aplonis panayensis*) flocks in one of the semiconductor factories in Kulim Hi-tech Park, Kedah, Malaysia during dusk. Each drone was evaluated during its five minutes of operation time and five minutes after landing. Control data were also taken to compare drone treatment days with no drone treatment days. Our result shows a significant difference between multirotor drone treatment and control treatment but not between fixed-wing drone treatment and control treatment due to different altitudes applied, ambient light intensity and size of flight path covered. We suggest implementing biomimetic design into drones and applying other conventional ground deterrents to prolong the residual effect of post-treatment.

Corresponding Author:

Nik Fadzly N Rosely
School of Biological Sciences, Universiti Sains Malaysia
11800 Gelugor, Pulau Pinang, Malaysia
Email: nfadzly@usm.my

1. INTRODUCTION

In the context of human-wildlife conflict, unmanned aerial vehicles (UAVs), commonly known as drones, have been proposed as a nonlethal means to discourage birds [1]-[4]. Drones play a valuable role in ecological research and monitoring, finding applications in a range of wildlife management tasks, such as conducting population surveys, detecting wildlife, combating poaching, and monitoring avian nests [5]-[7]. While numerous studies have assessed the impact of drones on wildlife, only a limited number have deliberately utilized drones to provoke an escape reaction [7], [8]. The ability of drones to prompt avoidance behaviour in birds indicates their potential as nonlethal tools for hazing [9]. Drones could be integrated into pest management strategies to mitigate economic losses and safety risks associated with birds if proven effective. Wildlife response to drones can be influenced by various factors, such as the type of vehicle used, flight characteristics, and the evolutionary background of the targeted species [8].

Birds can assess the level of threat posed by different aerial predators based on visual cues [10]. This understanding can be applied to designing drones for hazing purposes. A previous study revealed that birds exhibited the highest level of disturbance when approached by a fixed-wing drone that closely resembled the shape of an aerial raptor, compared to multirotor drones [11]. Waterfowl, in particular, displayed a less noticeable disturbance response when approached by the multirotor drones. These observations indicate that the flight dynamics and physical form of both predators and flying vehicles can influence birds' perception of threat. Wildlife managers can utilize this knowledge to provoke the desired escape response by employing drone approaches.

Agricultural pests, such as birds may cause significant damage to crops and reduce growers' ability to provide agricultural commodities to the market. When this occurs, the broader economy may suffer due to reduced production and fewer commodities for processing and sale [12]. Research by Gavris [13], specifically addresses the problems of managing pest birds in Ukrainian cities, including damage to buildings, food contamination, and discomfort caused by species such as feral pigeons, house sparrows, and rooks. Feral pigeons (*Columba livia*) are typically ignored by ornithologists but can be found roosting in the thousands within cities across the world. However, killing pigeons has been unsuccessful in decreasing abundance, and chemical inhibition can be expensive and must be used throughout the year. A case study at Texas Tech University [14] has found that populations fluctuate throughout the year, making it difficult to manage numbers. In Peninsular Malaysia, many species of birds are considered pests, such as House Crows, Swiftlets and one of the most prominent species is the Asian glossy starling (*Aplonis panayensis*) [15]-[17]. The Asian glossy starling is easily recognisable due to its bright red eyes and glossy dark green plumage. Although under poor lighting conditions, it can be mistaken as blackbirds and even crows to the untrained eye. It is a medium-sized bird weighing about 50-60 g with an average body length of 20 cm [18].

While research on using drones on pest birds has primarily focused on safeguarding crops, plantation trees, fish farms, and preventing aircraft strikes at airports, there is limited information on deterring pest birds from man-made structures, particularly in industrial areas. The industrial areas are often overlooked due to the nature of their management and location. Most factories do not allow access to researchers, and the management of any pest (including birds) is often managed internally without any reports to the local council. In Kulim Hi-Tech Park, Kedah, Malaysia, one of the semiconductor factories is facing a significant challenge with thousands of Asian glossy starling (*Aplonis panayensis*) flocks. These pest birds would arrive in the semiconductor factory's airspace between 6.50-7.30 pm and subsequently roost on the factory structures, leading to health concerns and structural damage due to their droppings. In this rare instance, the company reached out to researchers to mitigate the problem. This is an opportunity circumstance that allowed us to study the pest bird infestation and to test the use of drones as a possible deterrence method (which has not been attempted before in an industry setting in Malaysia, to the best of our knowledge). This study aims to investigate the efficacy of using different types of drones against Asian glossy starling (*Aplonis panayensis*) flocks in industrial settings by measuring birds' activity/minute during and after drone operation time. This study also provides a rare data acquisition from an industrial setting concerning pest bird management. In the following methods section, we describe the study site, the equipment and the flight details of the drones used in this study. In the results and discussion, we analysed and discussed about the effectiveness of using drones and our future suggestions.

2. METHOD

The study was conducted at one of the semiconductor factories in Kulim Hi-Tech Park at the coordinate of 5°23'57" N 100°35'34" E. Kulim Hi-Tech Park is an industrial park dedicated to high technology enterprises in Kulim District, Kedah, Peninsular Malaysia. The semiconductor factory is surrounded by forest and human residential areas. However, one of the forest areas has turned into empty land as the company expanded its production capacity. The total area of the semiconductor factory is about 0.25 km² which is mainly comprised of its car park, office buildings (Office 1 & Office 2), fabrication buildings (FAB 1 & FAB 2), centre utility buildings (CUB 1 & CUB 2) and water tank areas (Figure 1). Based on previous observations, Asian glossy starling flocks would perch on the roof level every day at dusk before the pest birds dive into the interior middle level of buildings to roost at night after sunset. Thus, all treatments were conducted during dusk at 7 pm as conducting experiments after sunset may result in higher inaccuracy in the results obtained, as the pest birds may not return to the study plot due to their roosting behaviour. The chimney cables at FAB 1, where Asian glossy starling flocks were seen to perch, was selected as the study plot as this is the most frequent spot visited by them, and it was easier for bird counting purpose (Figure 2). The study plot size is approximately 515 m^2. About 300 Asian glossy starling individuals would perch here during dusk. The birds would usually congregate on the support wires for the large gas outlet chimneys and also on the edges of the building sides.

The method we used was based by Mohamed *et al.* [10] and Vas *et al.* [19]. Two drones were used in this study: a multirotor (DJI Phantom 4 Pro V2) and a fixed-wing drone (Skysurfer X8) (Figure 3). The diagonal length of the multirotor drone is 350 mm, and the wingspan length of the fixed-wing drone is about 1,400 mm. Both drones are white in colour. The lights on the multirotor drone were switched off in this study. Only one drone treatment was conducted in one day due to the limited timeframe where pest birds only aggregate at rooftop level from 6.50 pm until 7.30 pm approximately before diving into spaces between buildings for roosting. Each drone treatment was replicated three times to get the average value. Control data was also taken for comparison between days without drone treatment and days with drone treatment. The multirotor drone was launched from Office 1 rooftop, about 50 m from FAB 1's chimney cable. The multirotor drone was programmed to fly autonomously and randomly inside the flight barrier with an area of approximately 515 m^2 using DJI GS Pro software (Figure 4). The flight altitude for the multirotor drone was 15 m above the rooftop level, while the fixed-wing drone altitude was set to 20 m to avoid crashing into another higher chimney at the back of the study plot (Figure 5). Plus, the fixed-wing drone was programmed to fly autonomously using Mission Planner software, as shown in Figure 6. After passing through point 6, the fixed-wing UAV was programmed to do a "circle path" through points 2, 3, 4, 5, and 6 repeatedly until it reached 5 minutes; then, the aircraft was taken controlled manually by the pilot. Both of these drones would be launched at 7.00 pm and were programmed to fly for 5 minutes until 7.05 pm and then later were immediately landed on Office 1 rooftop. Although Wang *et al.* [20] suggested a rather aggressive style of flight using fixed-wing planes, we were unable to do so due to the permission restriction from the factory management team. As using drones is considered a challenge to operate in a complex industrial area, there is always a risk of crashing, and the management has discouraged such complex manoeuvres. Furthermore, fixed-wing planes are harder to control and require a large turning angle compared to quadcopters. We also did not include any artificial risk predation on both drones. Compared to the mimetic bird prey pattern employed by [20], our drone colour is completely white. We have another experiment that uses a Hawk-like fixed-wing plane, but it is currently scheduled for a separate study.

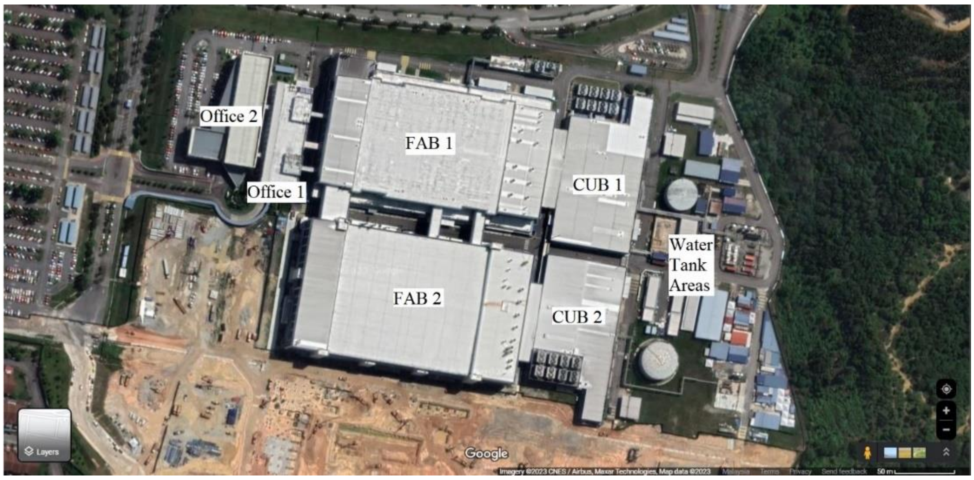

Figure 1. Map of the study site

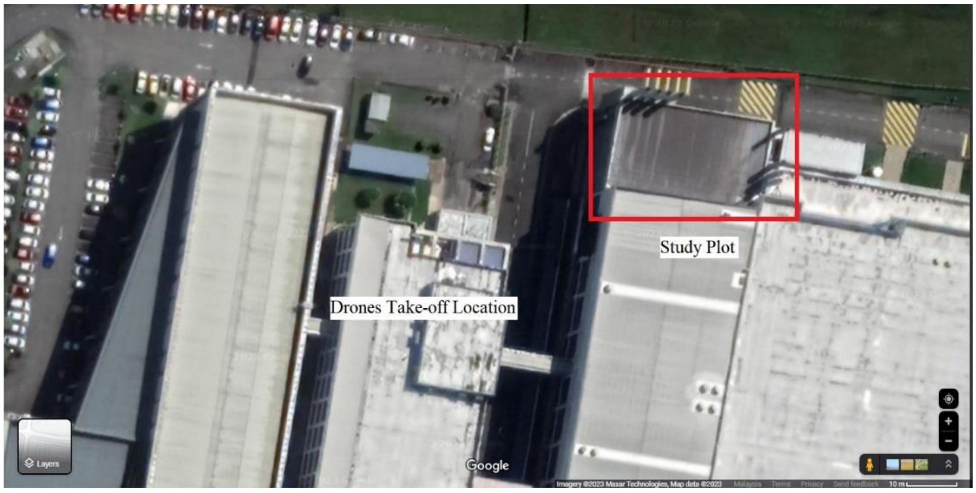

Figure 2. The location of FAB 1's chimney was selected as study plot, and the nearby drone's take-off location

Figure 3. Multirotor drone (DJI Phantom 4 Pro V2) on the left and fixed-wing drone (Skysurfer X8) on the right

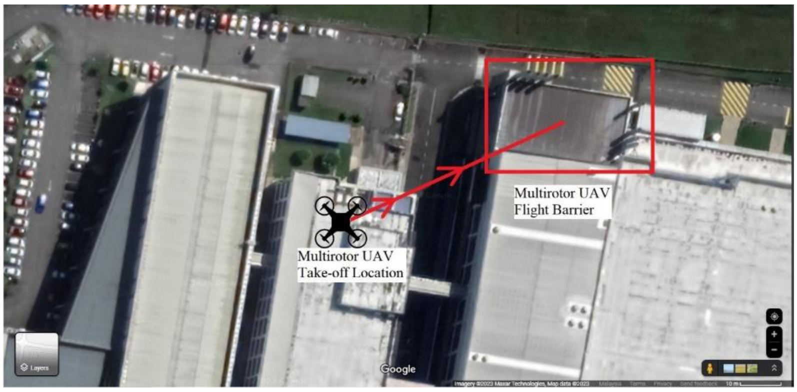

Figure 4. Red arrows represent the multirotor drone flight path, and the red rectangle represents the flight barrier

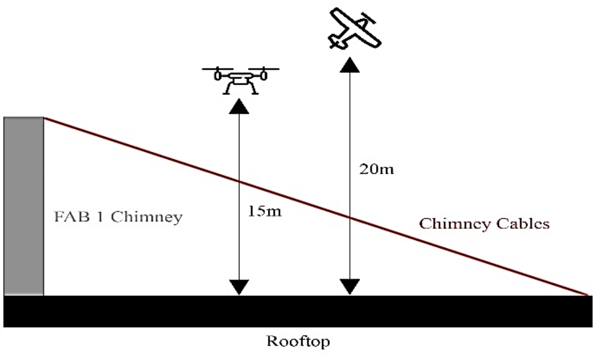

Figure 5. Flight altitude of multirotor drone at 15 m and fixed-wing drone at 20 m

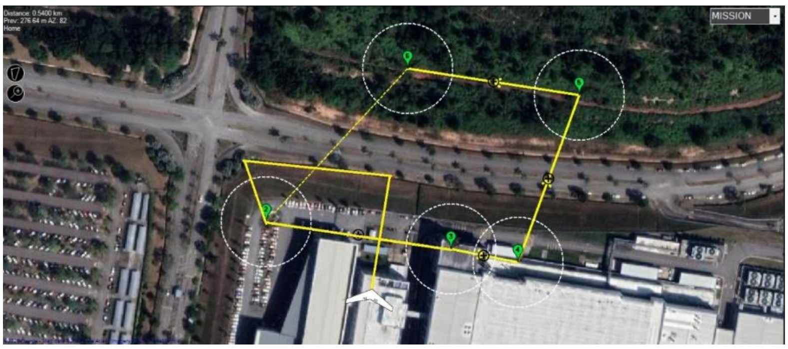

Figure 6. Yellow line represents the fixed-wing drone flight path

Data on the number of birds perched on the FAB 1 chimney cables were taken by taking photos for each minute from 7.01 pm until 7.10 pm. We define bird's activity as the number of birds that either flew or remained perched during and after the drone operation time. The first 5 minutes of data were categorized as "during drone operation time" and another 5 minutes as "after drone operation time". Kruskal Wallis tests were performed to determine the impacts of different drone platforms on the average birds' activity/minute during and after drone operation time. IBM SPSS Statistics 27 software was used for all the statistical analyses.

3. RESULT AND DISCUSSION

In this study, three replicates of each drone treatment and three replicates of the control treatment were conducted, resulting in nine sets of data during and after drone operation time, respectively. Based on these results, it appears that both types of drones had some influence on the birds' activity during their operation time. The multirotor drone seemed more effective in deterring or disturbing the birds, leading to a complete absence of activity (Table 1). On the other hand, the fixed-wing drone had a partial effect, resulting in reduced bird activity but not complete deterrence. Another point to note is that for the fixed-wing, the birds activity actually increased after the drone operation. Kruskal Wallis test was conducted to see the differences in treatments on birds' activity during and after drone operation time. There was a significant difference $\left(x^2{}_{(df=2,n=9)} = 6.161, P = 0.046\right)$ among treatments on birds' activity during drone operation time (Table 2). A pairwise comparison was conducted to see where the difference lies, and it was found that multirotor drone treatment was significantly different to control treatment ($P = 0.015$) (Table 3). There was no significant difference $\left(x^2{}_{(df=2,n=9)} = 2.222,\ P = 0.329\right)$ among treatments after drone operation time (Table 4).

Table 1. Average percentage of birds activity/minute

Treatments	Average percentage of birds activity/minute	
	During UAV operation time (7.01 pm–7.05 pm)	After UAV operation time (7.06 pm–7.10 pm)
Multirotor UAV	0.00	62.93
Fixed-wing UAV	67.13	123.67
Control Treatment	129.47	169.73

Table 2. The Kruskal Wallis test was conducted to see the treatment differences on birds' activity during drone operation

Independent-samples kruskal-wallis test summary			
Total N	Test statistic	Degree of freedom	Asymptotic Sig.(2-sided test)
9	6.161[a]	2	0.046

Table 3. Pairwise comparison was conducted to see where treatments differ during drone operation time

	DJI P4 Pro V2-skysurfer X8	DJI P4 Pro V2-control	Skysurfer X8-control
Test statistic	-3.667	5.333	1.667
Std. error	2.198	2.198	2.198
Std. test statistic	-1.668	2.426	0.758
Sig.	0.095	0.015	0.448
Adj. sig.[a]	0.286	0.046	1

Table 4. Kruskal Wallis test was conducted to see the treatment differences in birds' activity after drone operation time

Total N	Test statistic	Degree of freedom	Asymptotic Sig.(2-sided test)
9	2.222[a,b]	2	0.329

Our study showed similar results to the previous study [3], which indicated that the days with drone treatments caused birds' activity to drop during drone operation time compared to days without drone treatment (control). In the study, about 300% less were seen during drone treatment days, a huge reduction in bird activity compared to non-drone treatment days. The drone treatments in the study were equipped with onboard bird deterrence, while ours were not. Adding onboard bird deterrence may enhance the drone's efficacy in deterring pest birds. For future research, we suggest that the effect of additional bird deterrence on board and no additional bird deterrence needs to be compared.

Multirotor drone treatment effectively reduces pest birds' activity during drone operation time, probably due to the low altitude applied. A study by [4] showed that blackbirds' responses were also more pronounced at lower altitudes. This can be attributed to the UAV's increased visibility and the higher noise frequency when approaching the bird flocks at lower altitudes. Our multirotor drone treatment was programmed to fly randomly within the plot by changing direction and speed. These sudden changes might have scared the pest birds away from perching at the chimney cables. A study by [3] also found similar results. Shannon *et al.* [5], proposed that variations in noise intensity could influence animal reactions. Changes in a drone's trajectory, speed, and environmental factors like wind direction might contribute to alterations in the noise intensity produced by drones, as suggested by [6] .

Another factor that might be contributing to the weak deterrence by the drones might be related to the different body size of the birds and the available natural predatory birds. Blackbird flocks were more likely to abandon sunflower fields in response to drone approaches, but the specific drone platform did not significantly affect their behaviour [21]. Jarrett *et al.* [22] found that non-breeding waterbirds were more likely to respond to drone approaches when in larger flocks, and responses were more likely in arable and coastal habitats. Birds perceived drones with predatory characteristics as riskier than common drone models, suggesting that birds may perceive less risk from drones [21]. Vas *et al.* [19] found that drone color, speed, and flight angle had no measurable impact on bird behavior, but birds reacted more to drones approaching vertically. Overall, the findings suggest that the efficacy of large drones in deterring smaller birds may depend on factors such as flock size, habitat, and the perception of risk by the birds. In our study area, the possible predator birds are most probably raptors or eagles. These predator birds are larger than the DJI quadcopter and about the same size as the sky surfer plane.

Environmental factors, including ambient light intensity, can influence animals' visual acuity in distinguishing objects from their surroundings. In situations with low ambient light intensity, animals typically exhibit reduced contrast sensitivity [1], [7], leading to challenges in detecting approaching objects or predators [23]. Our fixed-wing drone treatments were conducted on cloudy days, plus with the higher altitude at 15 m, the fixed-wing drone may be less detectable to the bird flocks. For future research, we recommend conducting drone treatments under similar ambient light intensity and same flight altitude to reduce biases on investigating the efficacy of drones in deterring pest birds. Plus, our fixed-wing drone was programmed to fly further outside the boundary plot and needed to loiter across bigger distance as fixed-wing drone was not able to perform precise and direct turns like multirotor drone. If fixed-wing drone was made to loiter above the tight studied plot, it would cause the aircraft to stall and crash.

The fixed-wing drone's flight capabilities, particularly its inability to program flights below 15 m above the rooftop level, may restrict its effectiveness for deterrent purposes. It is plausible that, at altitudes of 15 m and higher, the birds perceived the fixed-wing drone as less threatening. In the review by [8] on drone-wildlife interactions, it was proposed that louder drones (e.g., fuel-powered) are more likely to trigger behavioural responses than quieter drones (e.g., electric-powered). Although both drones used in this study were electric-powered, the multirotor drone was notably louder than the fixed-wing drone.

The introduction of anthropogenic disturbances, such as drones, has been documented to potentially induce physiological or behavioural stress in wildlife. This stress could lead to changes in behaviour related to space use, a decline in survival rate and reproductive fitness, and an increase in energy expenditure [9]. However, our results showed that the average bird activity after drone operation time was not significantly different, meaning that drone treatments had no residual post-treatment effect after the drones landed. It also means that Asian glossy starling flocks would eventually return to the study plot within 5 minutes of landing the drones. Thus, Asian glossy starling flocks may perceive drones as a physical disturbance rather than a physiological disturbance. As proposed by many studies, implementing biomimetic designs on drones would prolong the residual effect of post-treatment by drones in reducing bird activity [10], [24]. Plus, applying other conventional ground deterrents such as methyl anthranilate (MA), physical barriers such as netting, and sonic treatment would further reduce birds' activity during dusk [25]-[27].

4. CONCLUSION

In conclusion, our multirotor drone treatments were shown to effectively reduce Asian glossy starling flocks' activity during drone operation time. As for fixed-wing drone treatments, it can be concluded that they were ineffective compared to multirotor drone treatments due to the higher flight altitude applied, weather conditions restrictions and requiring more extensive flight path programmed. Asian glossy starling flocks would eventually return to chimney cables within 5 minutes after drones had landed, regardless of any drone type. However, our results also suggest that overall, the drones were not a very effective deterrent method to deter the pest birds. To successfully decrease populations, it is important to have a multifaceted approach that includes removing necessary resources (e.g., nest sites and roosting areas) and adopting the integrated pest management approach in which several deterrent methods are used and interchanged to prevent the birds from adapting to the deterrents. We also would suggest that integrating biomimetic designs such as drawing of predatory birds on the fixed wings or covering the multirotor drones with colours that mimics predatory birds' colours. Future studies should also include the possibility of using artificial intelligence with the drone navigation, especially for the multirotor. Adding computer vision would enable a more active approach where the drones can recognize the pest birds and actively follow to scare them away.

ACKNOWLEDGEMENTS

This project is supported by FRGS grant, R503-KR-FRG001-0006712190-K134. Universiti Sains Malaysia financially supports this study through a grant entitled "The Feasibility of Using Autonomous Drones as Deterrence Against Swallows (*Hirundo tahitica*) at Infineon Factory, Kulim" with account no. 304.PBIOLOGI.6501144.I145. We also would like to thank Infineon Facility Management (FM) team members for their support during the fieldwork. We thank the anonymous reviewers for their helpful reviews and comments that significantly improved this manuscript.

REFERENCES

[1] G. Beauchamp, "Does sun glare increase antipredator behaviour in prey?," *Journal of Avian Biology*, vol. 48, no. 4, pp. 591–595, Apr. 2017, doi: 10.1111/jav.01154.
[2] P. Luschi, G. C. Hays, C. Del Seppia, R. Marsh, and F. Papi, "The navigational feats of green sea turtles migrating from Ascension Island investigated by satellite telemetry," *Proceedings of the Royal Society of London. Series B: Biological Sciences*, vol. 265, no. 1412, pp. 2279–2284, Dec. 1998, doi: 10.1098/rspb.1998.0571.
[3] S. Bhusal, K. Khanal, S. Goel, M. Karkee, and M. E. Taylor, "Bird deterrence in a vineyard using an unmanned aerial system (UAS)," *Transactions of the ASABE*, vol. 62, no. 2, pp. 561–569, 2019, doi: 10.13031/trans.12923.
[4] L. J. Wandrie, P. E. Klug, and M. E. Clark, "Evaluation of two unmanned aircraft systems as tools for protecting crops from blackbird damage," *Crop Protection*, vol. 117, pp. 15–19, Mar. 2019, doi: 10.1016/j.cropro.2018.11.008.
[5] G. Shannon *et al.*, "A synthesis of two decades of research documenting the effects of noise on wildlife," *Biological Reviews*, vol. 91, no. 4, pp. 982–1005, Nov. 2016, doi: 10.1111/brv.12207.
[6] M. A. Ditmer *et al.*, "Bears Show a Physiological but Limited Behavioral Response to Unmanned Aerial Vehicles," *Current Biology*, vol. 25, no. 17, pp. 2278–2283, Aug. 2015, doi: 10.1016/j.cub.2015.07.024.
[7] B. F. Blackwell, T. L. DeVault, T. W. Seamans, S. L. Lima, P. Baumhardt, and E. Fernández-Juricic, "Exploiting avian vision with aircraft lighting to reduce bird strikes," *Journal of Applied Ecology*, vol. 49, no. 4, pp. 758–766, Aug. 2012, doi: 10.1111/j.1365-2664.2012.02165.x.
[8] M. Mulero-Pázmány, S. Jenni-Eiermann, N. Strebel, T. Sattler, J. J. Negro, and Z. Tablado, "Unmanned aircraft systems as a new source of disturbance for wildlife: A systematic review," *PLOS ONE*, vol. 12, no. 6, p. e0178448, Jun. 2017, doi: 10.1371/journal.pone.0178448.
[9] Z. Tablado and L. Jenni, "Determinants of uncertainty in wildlife responses to human disturbance," *Biological Reviews*, vol. 92, no. 1, pp. 216–233, Feb. 2017, doi: 10.1111/brv.12224.
[10] W. M. W. Mohamed, M. N. M. Naim, and A. Abdullah, "The Efficacy of Visual and Auditory Bird Scaring Techniques using Drone at Paddy Fields," *IOP Conference Series: Materials Science and Engineering*, vol. 834, no. 1, p. 012072, Apr. 2020, doi: 10.1088/1757-899X/834/1/012072.
[11] Z. Wang, A. S. Griffin, A. Lucas, and K. C. Wong, "Psychological warfare in vineyard: Using drones and bird psychology to control bird damage to wine grapes," *Crop Protection*, vol. 120, pp. 163–170, Jun. 2019, doi: 10.1016/j.cropro.2019.02.025.
[12] A. E.-A. S. S. Desoky, "Damage Caused By Birds and Rodent in Field Crops and Their Control," *Journal of Global Innovations in Agricultural and Social Sciences*, vol. 2, no. 4, pp. 169–170, 2014, doi: 10.17957/jgiass/2.4.515.
[13] G. Gavris, "Current situation and problems of management of pest birds in the cities of Ukraine," *8 th European Vertebrate Pest Management Conference*, 2011, doi: 10.5073/jka.2011.432.070.
[14] E. E. Stukenholtz *et al.*, "Ecology of Feral Pigeons: Population Monitoring, Resource Selection, and Management Practices," in *Wildlife Population Monitoring*, USA: IntechOpen, 2019, doi: 10.5772/intechopen.84612.
[15] S. A. N. M. Azizi, M. F. S. Ramji, W. T. Ng, N. A. Ab Razak, H. J. N. Ilan, and J. Mohd-Azlan, "Density And Nest-Site Selection Of Invasive Mynas And Starlings In Urban And Sub-Urban Areas In Western Sarawak, Malaysia," *Journal Of Sustainability Science And Management*, vol. 18, no. 4, pp. 191–201, Apr. 2023, doi: 10.46754/jssm.2023.04.014.
[16] N. E. N. Hashim, M. S. Mansor, N. A. Abdullah, and R. Ramli, "The Diet of a Roosting Population of Asian Glossy Starling Aplonis panayensis in Jelebu, Negeri Sembilan, Malaysia," *Sains Malaysiana*, vol. 50, no. 10, pp. 2885–2898, Oct. 2021, doi: 10.17576/jsm-2021-5010-04.
[17] C. A. M. Yap and N. S. Sodhi, "Southeast Asian invasive birds: ecology, impact and management," *Ornithological Science*, vol. 3, no. 1, pp. 57–67, 2004, doi: 10.2326/osj.3.57.
[18] A. Jeyarajasingam, *A Field Guide to the Birds of Peninsular Malaysia and Singapore*. Oxford University Press, 2012.
[19] E. Vas, A. Lescroël, O. Duriez, G. Boguszewski, and D. Grémillet, "Approaching birds with drones: first experiments and ethical guidelines," *Biology Letters*, vol. 11, no. 2, p. 20140754, Feb. 2015, doi: 10.1098/rsbl.2014.0754.
[20] Z. Wang, A. Lucas, G. Chamitoff, and K. Wong, "Biomimetic design for pest bird control UAVs: A survey," *17th Australian International Aerospace Congress: AIAC 2017*, pp. 26–28, 2017.
[21] C. C. Egan, B. F. Blackwell, E. Fernández-Juricic, and P. E. Klug, "Testing a key assumption of using drones as frightening devices: Do birds perceive drones as risky?," *The Condor*, vol. 122, no. 3, Sep. 2020, doi: 10.1093/condor/duaa014.
[22] D. Jarrett, J. Calladine, A. Cotton, M. W. Wilson, and E. Humphreys, "Behavioural responses of non-breeding waterbirds to drone approach are associated with flock size and habitat," *Bird Study*, vol. 67, no. 2, pp. 190–196, Apr. 2020, doi: 10.1080/00063657.2020.1808587.

[23] E. Fernández-Juricic, M. Deisher, A. C. Stark, and J. Randolet, "Predator Detection is Limited in Microhabitats with High Light Intensity: An Experiment with Brown-Headed Cowbirds," *Ethology*, vol. 118, no. 4, pp. 341–350, Apr. 2012, doi: 10.1111/j.1439-0310.2012.02020.x.
[24] Z. Wang, D. Fahey, A. Lucas, A. S. Griffin, G. Chamitoff, and K. C. Wong, "Bird damage management in vineyards: Comparing efficacy of a bird psychology-incorporated unmanned aerial vehicle system with netting and visual scaring," *Crop Protection*, vol. 137, p. 105260, Nov. 2020, doi: 10.1016/j.cropro.2020.105260.
[25] E. Harris, E. P. de Crom, J. Labuschagne, and A. Wilson, "Visual deterrents and physical barriers as non-lethal pigeon control on University of South Africa's Muckleneuk campus," *SpringerPlus*, vol. 5, no. 1, pp. 1–16, Dec. 2016, doi: 10.1186/s40064-016-3559-5.
[26] G. Mahjoub, M. K. Hinders, and J. P. Swaddle, "Using a 'sonic net' to deter pest bird species: Excluding European starlings from food sources by disrupting their acoustic communication," *Wildlife Society Bulletin*, vol. 39, no. 2, pp. 326–333, 2015, doi: 10.1002/wsb.529.
[27] M. L. Avery *et al.*, "Field Evaluation of Methyl Anthranilate for Deterring Birds Eating Blueberries," *The Journal of Wildlife Management*, vol. 60, no. 4, pp. 929–934, Oct. 1996, doi: 10.2307/3802395.

BIOGRAPHIES OF AUTHORS

Imran Mohd Hornain received a B.Sc. degree in Animal Science from Universiti Sains Malaysia (USM) in 2019. Currently, he is a postgraduate Master's student for M.Sc. (Zoology) in the wildlife management field. His research interest includes using conventional methods and unmanned aerial vehicles (UAVs) to mitigate pest birds in industrial settings. He can be contacted at email: imranmohd@student.usm.my.

Nik Fadzly N Rosely is an Associate Professor at the School of Biological Sciences, Universiti Sains Malaysia (USM). He received undergraduate and Master's degrees from Universiti Sains Malaysia and a Ph.D. from Victoria University of Wellington, New Zealand. His research interests are primarily in conservation areas, machine learning, mammology, ornithology, and population ecology. He can be contacted at email: nfadzly@usm.my.