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Alert and Flight Initiation Distances of the Coot in Response to Drones

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Abstract: Alert and flight initiation distances are important elements of bird behavioral responses and indicators of their adaptation to external disturbances; therefore, they provide an important basis for bird conservation. With continual rapid advancements in drone technology, the use of drones in bird field surveys is becoming increasingly important. However, the disturbance impact of drones on birds remains controversial and needs further assessment. This study measured the distances at which coots (*Fulica atra*) tolerated drones in the Baiyangdian wetland, Northern China, over 42 days from August to November 2023 and at the end of July 2024. The results show the maximum alert distance (AD) and maximum flight initiation distance (FID) of the coot to be 44 m and 35 m, respectively. The coots showed no signs of disturbance when the drones flew at an altitude of 50 m. The AD of the coot showed a significant relationship with whether it saw the drones in advance, environmental conditions, and the drone's behavior before it approached, whereas the FID was only significantly affected by whether the coot saw the drones in advance. The sight of drones in advance considerably increased the AD and FID.

Keywords: drone; coots; alert distance; flight initiation distance

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1. Introduction

Routinely and accurately monitoring wildlife population sizes is crucial for species conservation [1]. Traditional bird survey methods typically involve monitoring the population of a target species at fixed locations. However, the vegetation of specific habitats may reduce the visibility of birds for observers on the ground, resulting in an underestimation of actual population numbers, a situation that has been confirmed in waterbird surveys [2]. While continuous and rapid advancements in drone technology have gradually prompted their use in wildlife monitoring [3], uncertainties regarding their disturbance effects in bird surveys remain.

Numerous past studies have confirmed the higher efficiency and more precise monitoring data obtained via drone-assisted surveys of bird populations in comparison to traditional methods [4–7]. Drones provide a substantial advantage in monitoring inaccessible areas [8]. However, the increasing deployment of drones in wildlife habitats has emerged as a significant source of potential animal disturbance [9], and these concerns have been amplified by the accelerating use of drones for wildlife research [10]. Given that drones share the airspace with birds, birds are particularly susceptible to drone interference, and the use of recreational drones for filming bird activities has been shown to profoundly disturb bird populations [11]. The frequent manifestation of bird disturbance responses can lead to increased energy expenditure and reduced available feeding time [12,13]. The expected increasing use of drones for avian research and monitoring has highlighted the need for the establishment of scientifically based conservation policies regulating the use of drones in this context. The establishment of such policies will require extensive data on the distances at which birds respond to drones, their behavioral reactions, and the factors influencing these interactions.

The distances at which birds tolerate drones encompass both the bird alert distance (AD) and the flight initiation distance (FID). The AD and FID are critical factors in the behavioral responses of birds, reflecting their adaptation to external disturbances [14], and they serve as vital metrics for avian conservation [15]. The AD is defined as the distance between a bird and an approaching stimulus for which the bird first shows an alert response, whereas the FID is the distance at which a bird begins to exhibit an escape response [16]. Historically, while humans have been the primary stimulus in studies of avian disturbance responses [17,18], the responses of birds to other stimuli, such as cars and boats, have also been examined [19,20]. The increasing emergence of drones in recent years has led to studies on their impacts on avian disturbance responses [10,14,21].

Research has shown that the FID is regulated by both inter- and intraspecies factors, such as bird group size and reproductive status, as well as by the method of observation and environmental elements (e.g., habitat type) [16]. The responses of birds to drones are regulated by various parameters, with past studies identifying the drone flying altitude rather than horizontal distance or vertical descent rate as being the main factor initiating a bird disturbance response [22]. The responses of waterbirds during the non-breeding season are influenced by group size and habitat type; bird sensitivity to drones is positively correlated with flock size, and waterfowl in coastal areas and arable land are more likely to respond to drones compared to those in inland freshwater bodies [11]. The angle at which a drone approaches has also been shown to have a substantial impact on bird responses, with vertical approaches triggering larger reactions [21]. The starting distance (SD), the distance at which a drone is deployed relative to the target bird, has been shown to be positively correlated with the FID, suggesting that drones launched from greater distances tend to increase the FID [14,23].

The "Flush Early and Avoid the Rush" (FEAR) hypothesis suggests that, at the initiation of a predator alarm response, animals rapidly evacuate an area to lower the cost of monitoring the predator [24]. The importance of considering this theory when analyzing the effect on the FID in the context of the predator alert has been highlighted by the validation of the theory in certain species [25–27]. These past studies have raised the question of whether the detection of a predator in the absence of a subsequent reaction may affect the AD and FID. The detection distance (DD), which relates to the distance at which a bird initially detects a stimulus but does not react [16], has been largely overlooked in previous studies. The DD can have an impact on a bird's subsequent reactions to a stimulus, potentially influencing the AD and FID.

The formulation of scientifically based policies for avian conservation management requires further data on the effects of drones on bird reaction distances, behaviors, and influencing factors. However, past related studies are scarce [9–11,14]. We hypothesize that changes in coots' response to drones may be influenced by the following factors: (a) the type of environment, (b) pre-approach behavior, and (c) whether the drone was seen in advance. To investigate this, we conducted a series of experiments flying drones over coots in different areas.

2. Methods

2.1. Study Area

Baiyangdian (38°43′ N–39°02′ N, 115°38′ E–116°07′ E, Figure 1) is the largest freshwater lake wetland in the North China Plain, encompassing 143 shallow lakes with an average depth of 2.84 m [28]. The present study selected eight research zones in the study area, including two environment types, namely lakes, and reed ponds, with each zone separated by at least 3 km. These study areas allow drones to fly, so there is interference from recreational drones, as well as other factors such as vehicle noise and boat movements.

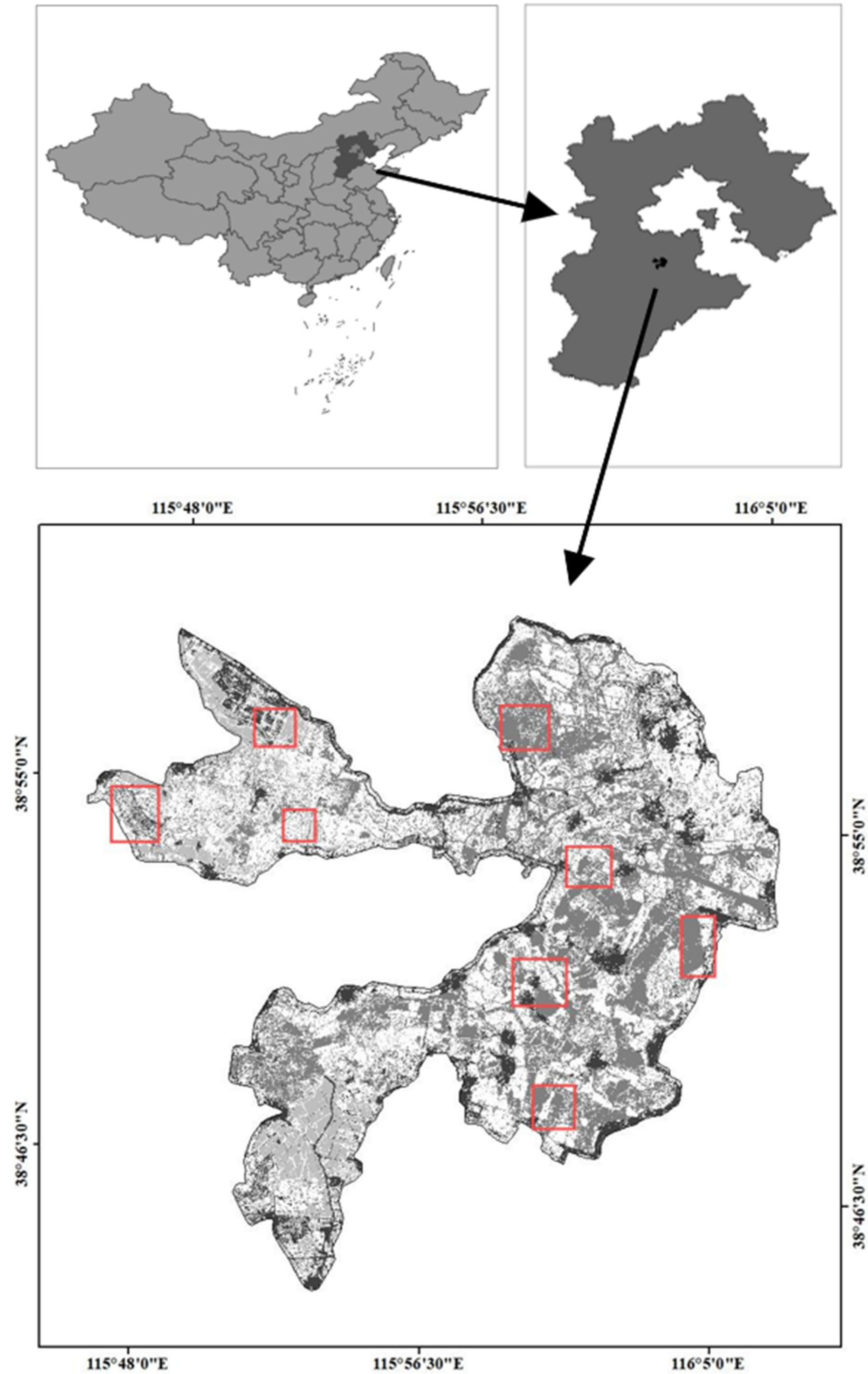

Figure 1. The geographical location of the Baiyangdian wetland. The red boxes represent the eight selected research zones.

2.2. Drone

All flight experiments were conducted using a DJI Mavic 3E drone, manufactured by DJI Technology Co., Ltd. in Shenzhen, China. The drone had a gray-black color and had a length of 35 cm (propeller to propeller), a width of 28 cm (propeller to propeller), a height of 11 cm (landing gear to propeller), and a weight of 915 g. The drone was equipped with a 7× digital zoom (56× hybrid zoom) (see Appendix A, Figure A1). The noise level of the drone ranged from 44.2 to 64.5 dB (51.3 ± 6.3 dB) (Table 1).

Table 1. Drone noise data.

H (m)	5	10	15	20	25	30	35	40	45	50
dB	64.5	57.4	54.6	53.2	51.3	48.5	47.8	46.1	45.0	44.2

2.3. Measurement of Response

Most previous related studies have shown that drones flying at altitudes of 50 m and above have little impact on birds [22,29]. Prior to the experiment, we conducted 50 drone test flights over coots at an altitude of 50 m. These initial observations indicated no disturbance to the coots at that height. Consequently, we chose a drone flight altitude of 50 m for the experiment. Furthermore, since previous research has indicated that birds are more likely to respond to a drone taking off within 100 m [21], the present study launched the drone at a distance of >100 m from the target zone. The presence of vegetation between the takeoff site and the target area also hid the experiment from the birds' view in the target area. Following takeoff, the drone's altitude was increased to 50 m before it was flown horizontally toward the target. Upon sighting the coots, the drone maintained a steady flight directly above the target bird, recording was initiated, and the drone began a controlled descent at 1 m/s to record the reactions of the target bird at various heights and distances. In outdoor conditions, the vertical fall of the drone needs to overcome the resistance generated by the horizontal wind speed, which may cause the drone fuselage to tilt or increase its noise. Although we chose mild weather for the experiment, we still could not eliminate the influence of this uncontrollable factor, which may have slightly increased the coots' response to the drone.

The logged behaviors of the coots included the following: (1) ceasing current activity and frequently gazing at the drone or displaying irregular head movements as a sign of alarm, recorded as AD, and (2) rapidly moving away, diving, or flying off, recorded as FID. Unfortunately, we could not determine whether the same birds were approached across multiple days, and recreational drone interference was present in all eight study areas, so we could not assess longer-term habituation. In this experiment, a total of 274 flight experiments were conducted over 42 days from August to November 2023 and at the end of July 2024. The coots in the experiment were in the non-breeding period or the late breeding period, and there was no brooding behavior and no coots with chicks. The experimental subjects were all adult birds.

2.4. Classification of Factors Influencing Tolerance Distance

The factors influencing the tolerance distance of coots were divided into four categories: (1) environmental, (2) pre-approach behavior, (3) number, and (4) whether the coot saw the drone in advance (See Table 2).

Table 2. Sample sizes for AD and FID obtained in different factor types.

		AD (N = 159)	FID (N = 274)
Factor	**Type**	**Sample Size**	**Sample Size**
Environment	Lake	80	153
	Reed pond	79	121
Behavior	Feeding	101	185
	Preening	25	37
	Roosting	17	25
	Loafing	16	27
See	Yes	98	127
	No	61	147

Environmental factors were further subdivided into those associated with lakes and reed ponds, defined as open expanses of water without any encircling blockages and smaller bodies of water encircled by dense reeds with a restricted field of vision, respectively.

Pre-approach behavioral factors included feeding, preening, roosting, and resting.

The number of birds was counted by reviewing the video recorded by the drone.

This study considered a coot to have seen a drone in advance if the observed coot continued its previous behavior as after seeing the drone and did not show any interference reaction, which was recorded as "Yes", and the interference reaction was recorded as "No".

2.5. Analysis

The present study constructed a generalized linear mixed model (GLMM) in R version 4.3.2 using the lme4 package [30]. The model employed a Poisson distribution and a log-link function. During the AD and FID analysis, environmental, pre-approach behavior, number (continuous variable 'N', which was log-transformed), and whether the drones were seen in advance were included as fixed effects. Location was set as a random effect to counter pseudo-replication, as some areas were repeatedly visited. Results with $p < 0.05$ were considered statistically significant. The emmeans package was used for post hoc multiple comparisons, and if $p < 0.05$, the results of the test were classified as significant.

3. Results

We obtained warning distance (AD) data for 159 coots and alarm distance (FID) data for 274 coots (Table 2). The statistical data of eight plots are shown in Table A1 of Appendix A.

The AD and FID ranged from 5 to 44 m (17.73 $\pm$ 9.00 m) and from 2 to 35 m (7.41 $\pm$ 4.12 m), respectively (Figure 2).

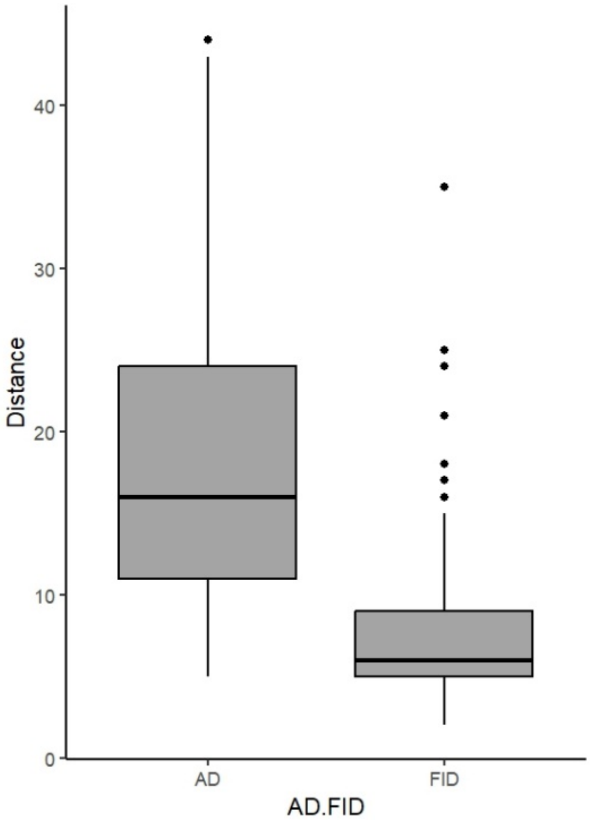

Figure 2. AD and FID data distribution.

3.1. Influences of Different Factors on Tolerance Distance

3.1.1. Influence of Related Factors on Alert Distance (AD)

Figure 3 provides a summary of the factors that significantly affected the coots' alert distance and flight initiation distance (Figure 3). The AD showed a significant correlation with habitat type, pre-approach behavior, and whether the drones were seen in advance. Coots in reed ponds (Est = 0.212, $p < 0.001$) exhibited higher alertness to drones; those engaging in preening (Est = 0.171, $p = 0.002$), roosting (Est = 0.291, $p < 0.001$), and loafing (Est = 0.290, $p < 0.001$) demonstrated lower tolerance to drones compared to those feeding; coots that detected drones earlier (Est = 0.355, $p < 0.001$) displayed alert behaviors sooner (Figure 4 and Table A2 in Appendix A).

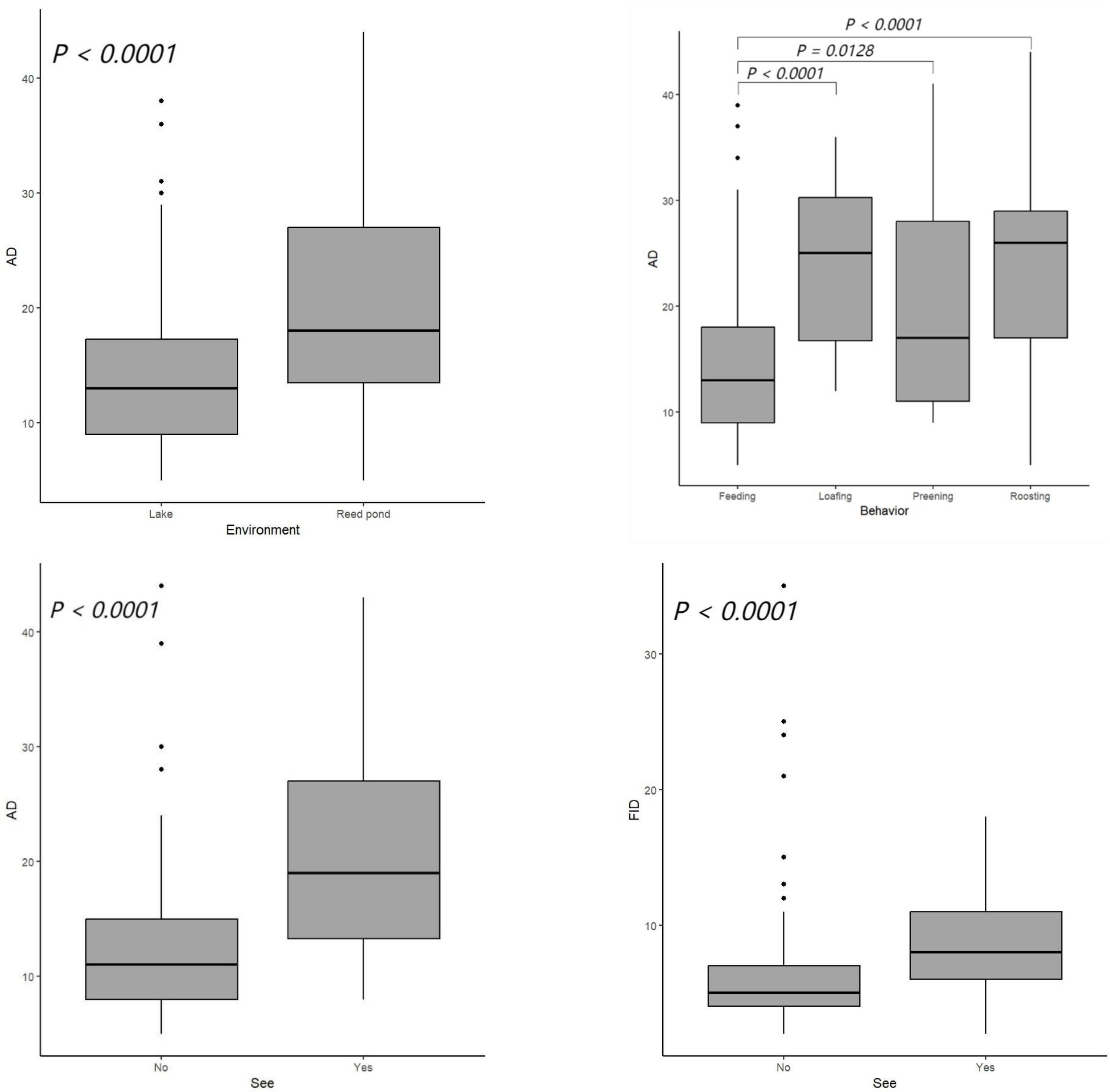

Figure 3. Box plot of the factors that significantly influence coot response to drone interference. The emmeans package was used for post hoc multiple comparisons, and the results with significant differences ($p < 0.05$) were marked in the graph.

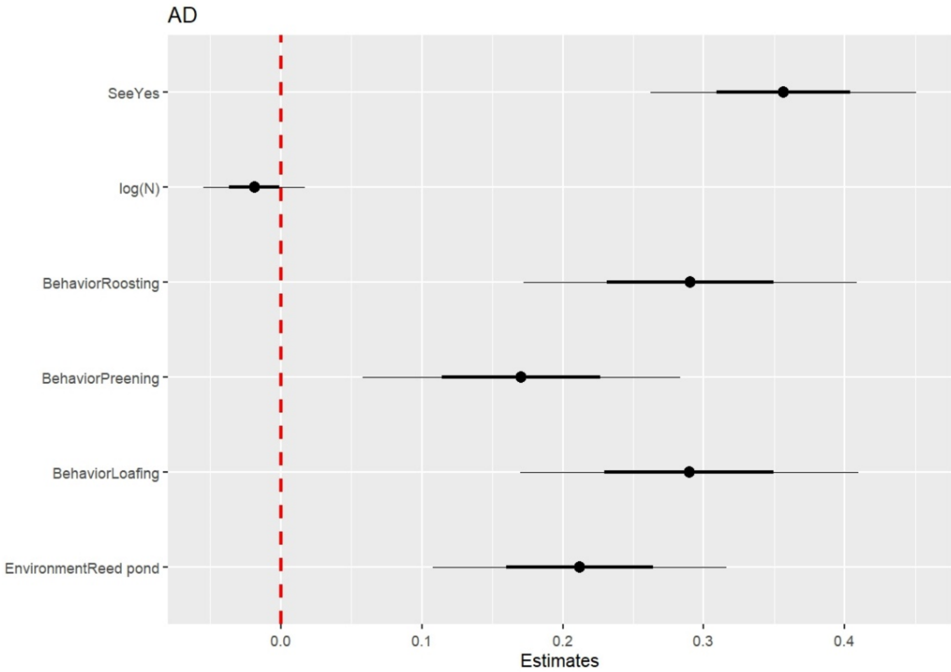

Figure 4. Variables influencing the alert distance (AD) disturbance behavior of coots within a 95% confidence interval encompassing whether the drones are seen in advance (See) ("Yes" and "No"); behavior (resting, roosting, feeding, and preening); and environment (lakes and reed ponds).

3.1.2. Influence of Related Factors on Flight Initiation Distance (FID)

The FID only showed a significant correlation with whether the drones were seen in advance, with coots detecting drones earlier (Est = 0.293, $p < 0.001$) and being more prone to flight (Figure 5 and Table A3 in Appendix A).

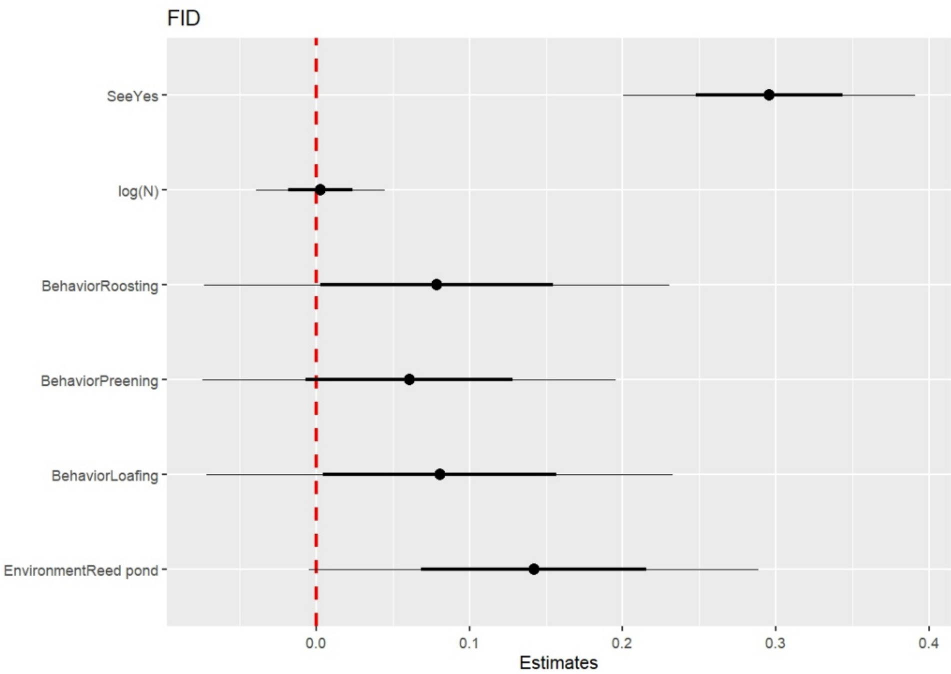

Figure 5. Variables influencing the flight initiation distance (FID) disturbance behavior of coots within a 95% confidence interval encompassing whether the drones were seen in advance ("Yes" and "No"); behavior (resting, roosting, feeding, and preening); and environment (lakes and reed ponds).

4. Discussion

The present study documented the responses of coots to drone disturbances, using AD and FID data obtained via field experiments, which involved monitoring coots' responses to a gradual and continuous vertical approach by a drone. The approach used in the present study differs from that of previous research in which the response variables were artificially segmented, including applying fixed drone heights [22,31]. The AD (17.73 ± 9.00 m) and FID (7.41 ± 4.12 m) obtained in the results were both small, which may be due to a certain habituated mechanism to drone interference. There are human activities near these study areas, with various forms of interference, such as vehicle noise or ships running, and recreational drones are used, so the coots in these areas may be less sensitive to drone interference [32].

Past related studies have shown that the tolerance distance of birds is influenced by multiple intra- and interspecies factors, such as species type, environmental type, group size, and survey method [10,11,16,23,33]. However, these studies generally did not consider whether researchers were detected by the target birds in advance, which would affect the tolerance distance results. Coots that detect drones early exhibit alert responses at greater distances, and the intensity of these responses increase with the decreasing drone distance. In contrast, coots that failed to detect the drone in advance displayed strong alert or flight responses with the decreasing drone distance, which may include a "stress response" [16]. Therefore, the disturbance responses of coots when the drone was detected in advance represent their natural AD and FID. Therefore, the results of the present study suggest that only data collected in scenarios in which the coot detected the drone early should be considered for estimating the AD and FID. Future animal tolerance distance studies should consider whether the animal detected the observer beforehand to ensure genuine experimental data.

The results of this study show that coots in reed ponds displayed higher sensitivity to drones compared to those in wetland lakes, displaying earlier disturbance responses, possibly related to habitat location and concealment. Past studies have shown that the responses of non-breeding waterfowl to an approaching drone are related to bird habitat; birds in farmland showed higher sensitivity to an approaching drone due to their higher alertness triggered by vegetation blocking their view of their surroundings [11]. In the experiment conducted in the present study, the reeds encircling the pond reached a height of approximately 4 m, and the coots were positioned far from the shore. Consequently, while the coots were at no risk from predators such as weasels (*Mustela sibirica*), they were vulnerable to upland buzzards (*Buteo hemilasius*) and common buzzards (*Buteo japonicus*) in the area. These relative risks resulted in the coots devoting more attention to the skies above to avoid birds of prey. However, the insignificant effect of the type of environment on the FID can be related to coot risk response, with this behavior reducing the time available for other activities, such as feeding [34].

The responses of coots to an approaching drone depend on the activity or behavior they were displaying prior to the drone's approach. For example, a foraging coot noticed the drone at a closer distance, which could be related to the coot giving higher priority to food acquisition during foraging and responding less to the drone.

The factors responsible for the responses of birds in different colony sizes are complex, with one study finding that larger groups are more likely to respond to approaching drones at greater distances [11]. This response can be explained by the "multi-eye" hypothesis, with larger groups of individuals allowing predators to be detected earlier than in smaller groups [35]. The present study found no significant effect of group size on the AD and FID; this may be related to the size of the coot group recorded in the experiment, which were all small (up to 70 individuals), so a larger dataset may be required. In addition, one study found that the response of the mixed group was largely determined by the most sensitive species in the flock [14]. A similar situation may exist in single-species groups, wherein the response of one coot to drone interference may be influenced by other individuals in the group. This may involve more sensitive individuals responding to drones earlier or less sensitive individuals reducing their early warning of drones.

Many studies have demonstrated the feasibility of using drones as an auxiliary tool for bird surveys given their significant advantages of convenience, survey efficiency, and data accuracy over traditional methods [4,6,7]. The results of the present study showed a relatively small AD (15.85 $\pm$ 8.24 m) and FID (7.02 $\pm$ 4.13 m) for coots. In no experiment did the coots exhibit an alert or flight response to a drone flying at an altitude of 50 m, with the maximum AD recorded at 44 m. Therefore, these results suggest that drone surveys conducted at a typical flying altitude of 50 m do not disturb coots. Given improvements in drone technology, such as the increasing magnification power of cameras, the standard flight altitude for drone surveys can be further increased, thereby minimizing their impact on birds. Thus, provided that there is a thorough understanding of the minimum distance tolerance of a target bird in the survey area and the consequent use of appropriate flight altitudes, drones show significant promise in bird surveys.

The AD and FID serve as key metrics of the disturbance tolerance distances of birds and are crucial for the standardized management of drones in avian surveys. Therefore, further characterization of the AD and FID during avian drone surveys is vital for the regulatory management of drone usage in bird studies. The most recent related studies used the FID as the primary criterion for drone usage in ornithological surveys [10,14,29,36]. Under the premise of minimizing disturbances to birds as much as possible, it is unreasonable to use the FID as a threshold for drones to approach birds. Consequently, emphasis should be placed on studying the AD of birds, using it as a benchmark to set the approach distance for drone surveys to minimize inference in the regular behavior of birds. Further research on mixed populations of birds and the use of different types of drones is needed to gain more data on their impact on birds.

In conclusion, coots showed an earlier disturbance response to drone flight experiments when they had previously detected the drone. In contrast to previous studies, the present study placed more emphasis on bird AD than FID, potentially providing more reliable evidence for the management of drone use in ornithology.

Author Contributions: Z.L.: conceptualization, formal analysis, methodology, project administration, resources, validation, writing—original draft, and writing—review and editing; J.L.: conceptualization, formal analysis, methodology, resources, supervision, validation, and writing—review and editing; Z.T.: investigation, validation, and writing—review and editing; J.W.: data curation, funding acquisition, investigation, project administration, resources, validation, and writing—review and editing; and J.H.: conceptualization, data curation, funding acquisition, investigation, methodology, project administration, resources, supervision, validation, writing—original draft, and writing—review and editing. All authors gave final approval for publication and agreed to be held accountable for the work performed therein. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: This study was approved by the Ethical Evaluation Group for Animal Behavior Study (protocol code: EEGABS-007).

Data Availability Statement: The datasets used and analyzed during the current study are available from the corresponding author.

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Conflicts of Interest: We declare we have no competing interests.

Appendix A

Figure A1. DJI Mavic 3E.

Table A1. Statistics of the 8 sites.

	Site	N	Mean (m)	SD (m)	Median (m)
AD	1	12	17.92	9.67	15.5
	2	13	16.31	7.74	14.0
	3	18	20.50	7.14	22.0
	4	21	18.81	9.20	17.0
	5	22	22.77	11.75	24.5
	6	20	23.20	7.29	24.5
	7	43	11.33	5.18	10.0
	8	10	17.60	6.11	16.5
FID	1	29	7.83	3.90	6.0
	2	26	8.69	6.73	6.5
	3	25	7.16	2.87	7.0
	4	28	8.96	4.88	7.0
	5	33	7.88	3.50	7.0
	6	29	7.66	2.51	8
	7	86	5.77	3.44	5
	8	18	9.44	3.93	9.5

Table A2. Coefficients of the variables included in the prediction model of the coots' alarm distance (AD).

		Estimate	Std. Error	z-Value	*p*
AD	(Intercept)	**2.479**	**0.112**	**22.044**	**<0.001**
	Environment Reed pond	**0.212**	**0.052**	**4.064**	**<0.001**
	Behavior Preening	**0.171**	**0.056**	**3.036**	**0.002**
	Behavior Roosting	**0.291**	**0.059**	**4.922**	**<0.001**
	Behavior Loafing	**0.290**	**0.060**	**4.835**	**<0.001**
	Log (N)	−0.020	0.018	−1.089	0.276
	See (Yes)	**0.355**	**0.047**	**7.487**	**<0.001**
	Site	−0.007	0.018	−0.375	0.708

Note: Significant ($p < 0.05$) variables are shown in bold. The reference levels of the factor variables represented by the intercept are environmental: lake, behavior: feeding, and see: "No".

Table A3. Coefficients of the variables included in the prediction model of the coots' flight initiation distance (FID).

		Estimate	Std. Error	z-Value	*p*
FID	(Intercept)	**1.836**	**0.103**	**17.851**	**<0.001**
	Environment Reed pond	0.122	0.075	1.629	0.103
	Behavior Preening	0.052	0.068	0.761	0.447
	Behavior Roosting	0.073	0.076	0.957	0.339
	Behavior Loafing	0.052	0.077	0.672	0.501
	Log (N)	0.0004	0.021	0.018	0.985
	See (Yes)	**0.293**	**0.048**	**6.102**	**<0.001**
	Site	−0.009	0.016	−0.562	0.574

Note: Significant ($p < 0.05$) variables are shown in bold. The reference levels of the factor variables represented by the intercept are environmental: lake, behavior: feeding, and see: "No".

References

1. Linchant, J.; Lisein, J.; Semeki, J.; Lejeune, P.; Vermeulen, C. Are unmanned aircraft systems (UASs) the future of wildlife monitoring? A review of accomplishments and challenges. *Mammal Rev.* **2015**, *45*, 239–252. [CrossRef]
2. Pagano, A.M.; Amundson, C.L.; Pieron, M.R.; Arnold, T.W.; Kimmel, T.C. Using sightability-adjusted brood-pair ratios to estimate waterfowl productivity. *Wildl. Soc. Bull.* **2014**, *28*, 566–573. [CrossRef]
3. Christie, K.S.; Gilbert, S.L.; Brown, C.L.; Hatfield, M.; Hanson, L. Unmanned aircraft systems in wildlife research: Current and future applications of a transformative technology. *Front. Ecol. Environ.* **2016**, *14*, 241–251. [CrossRef]
4. Valle, R.G.; Scarton, F. Drones Improve Effectiveness and Reduce Disturbance of Censusing Common Redshanks *Tringa totanus* Breeding on Salt Marshes. *Ardea* **2020**, *107*, 275–282. [CrossRef]
5. Valle, R.G.; Scarton, F. Monitoring the Hatching Success of Gulls Laridae and Terns Sternidae: A Comparison of Ground and Drone Methods. *Acta Ornithol.* **2021**, *56*, 241–254. [CrossRef]
6. Scarton, F.; Valle, R.G. Comparison of drone vs. ground survey monitoring of hatching success in the black-headed gull (*Chroicocephalus ridibundus*). *Ornithol. Res.* **2022**, *30*, 271–280. [CrossRef]
7. Sikora, A.; Marchowski, D. The use of drones to study the breeding productivity of *Whooper Swan Cygnus cygnus*. *Eur. Zool. J.* **2023**, *90*, 193–200. [CrossRef]
8. Valle, R.G.; Scarton, F. Rapid Assessment of Productivity of Purple Herons Ardea purpurea by Drone Conducted Monitoring. *Ardeola-Int. J. Ornithol.* **2022**, *69*, 231–248. [CrossRef]
9. Mulero-Pázmány, M.; Jenni-Eiermann, S.; Strebel, N.; Sattler, T.; Negro, J.J.; Tablado, Z. Unmanned aircraft systems as a new source of disturbance for wildlife: A systematic review. *PLoS ONE* **2017**, *12*, e0178448. [CrossRef]
10. Weston, M.A.; O'Brien, C.; Kostoglou, K.N.; Symonds, M.R.E.; McKenzie, A. Escape responses of terrestrial and aquatic birds to drones: Towards a code of practice to minimize disturbance. *J. Appl. Ecol.* **2020**, *57*, 777–785. [CrossRef]
11. Jarrett, D.; Calladine, J.; Cotton, A.; Wilson, M.W.; Humphreys, E. Behavioural responses of non-breeding waterbirds to drone approach are associated with flock size and habitat. *Bird Study* **2020**, *67*, 190–196. [CrossRef]
12. Burton, N.H.K.; Rehfisch, M.M.; Clark, N.A. Impacts of Disturbance from Construction Work on the Densities and Feeding Behavior of Waterbirds Using the Intertidal Mudflats of Cardiff Bay, UK. *Environ. Manag.* **2002**, *30*, 865–871. [CrossRef]
13. Burton, N.H.; Rehfisch, M.M.; Clark, N.A.; Dodd, S.G. Impacts of sudden winter habitat loss on the body condition and survival of redshank *Tringa tetanus*. *J. Appl. Ecol.* **2006**, *43*, 464–473. [CrossRef]
14. Wilson, J.P.; Amano, T.; Fuller, R.A. Drone-induced flight initiation distances for shorebirds in mixed-species flocks. *J. Appl. Ecol.* **2023**, *60*, 1816–1827. [CrossRef]
15. Livezey, K.B.; Fernández-Juricic, E.; Blumstein, D.T. Database of bird flight initiation distances to assist in estimating effects from human disturbance and delineating buffer areas. *J. Fish Wildl. Manag.* **2016**, *7*, 181–191. [CrossRef]
16. Weston, M.; Mcleod, E.M.; Blumstein, D.; Guay, P.J. A review of flight-initiation distances and their application to managing disturbance to Australian birds. *Emu-Austral Ornithol.* **2012**, *112*, 269–286. [CrossRef]
17. De Villiers, M.S.; Cooper, J.; Ryan, P.J. Individual variability of behavioural responses by Wandering Albatrosses (*Diomedea exulans*) to human disturbance. *Polar Biol.* **2004**, *28*, 255–260. [CrossRef]
18. Wheeler, M.; de Villiers, M.S.; Majiedt, P.A. The effect of frequency and nature of pedestrian approaches on the behaviour of wandering albatrosses at sub-Antarctic Marion Island. *Polar Biol.* **2008**, *32*, 197–205. [CrossRef]
19. Bellefleur, D.; Lee, P.; Ronconi, R.A. The impact of recreational boat traffic on Marbled Murrelets (*Brachyramphus marmoratus*). *J. Environ. Manag.* **2009**, *90*, 531–538. [CrossRef]
20. Sueur, C.; McLeod, E.M.; Guay, P.J.; Taysom, A.J.; Robinson, R.W.; Weston, M.A. Buses, Cars, Bicycles and Walkers: The Influence of the Type of Human Transport on the Flight Responses of Waterbirds. *PLoS ONE* **2013**, *8*, e82008. [CrossRef]
21. Vas, E.; Lescroël, A.; Duriez, O.; Boguszewski, G.; Grémillet, D. Approaching birds with drones: First experiments and ethical guidelines. *Biol. Lett.* **2015**, *11*, 20140754. [CrossRef]

22. Irigoin-Lovera, C.; Luna, D.M.; Acosta, D.A.; Zavalaga, C.B. Response of colonial Peruvian guano birds to flying UAVs: Effects and feasibility for implementing new population monitoring methods. *PeerJ* **2019**, *7*, e8129. [CrossRef] [PubMed]
23. Tätte, K.; Møller, A.P.; Mänd, R. Towards an integrated view of escape decisions in birds: Relation between flight initiation distance and distance fled. *Anim. Behav.* **2018**, *136*, 75–86. [CrossRef]
24. Blumstein, D.T. Flush early and avoid the rush: A general rule of antipredator behavior? *Behav. Ecol.* **2010**, *21*, 440–442. [CrossRef]
25. Samia, D.S.M.; Nomura, F.; Blumstein, D.T. Do animals generally flush early and avoid the rush? A meta-analysis. *Biol. Lett.* **2013**, *9*, 20130016. [CrossRef] [PubMed]
26. Russo, D.; Samia, D.S.M.; Blumstein, D.T. Phi Index: A New Metric to Test the Flush Early and Avoid the Rush Hypothesis. *PLoS ONE* **2014**, *9*, e113134. [CrossRef]
27. Hemmi, J.M.; Samia, D.S.M.; Blumstein, D.T. Birds Flush Early and Avoid the Rush: An Interspecific Study. *PLoS ONE* **2015**, *10*, e0119906. [CrossRef]
28. Yan, S.; Wang, X.; Zhang, Y.; Liu, D.; Yi, Y.; Li, C.; Liu, Q.; Yang, Z. A hybrid PCA-GAM model for investigating the spatiotemporal impacts of water level fluctuations on the diversity of benthic macroinvertebrates in Baiyangdian Lake, North China. *Ecol. Indic.* **2020**, *116*, 106459. [CrossRef]
29. Barr, J.R.; Green, M.C.; DeMaso, S.J.; Hardy, T.B. Drone Surveys Do Not Increase Colony-wide Flight Behaviour at Waterbird Nesting Sites, But Sensitivity Varies Among Species. *Sci. Rep.* **2020**, *10*, 3781. [CrossRef]
30. R Core Team. *R: A Language and Environment for Statistical Computing*; R Foundation for Statistical Computing: Vienna, Austria, 2023.
31. Bevan, E.; Whiting, S.; Tucker, T.; Guinea, M.; Raith, A.; Douglas, R. Measuring behavioral responses of sea turtles, saltwater crocodiles, and crested terns to drone disturbance to define ethical operating thresholds. *PLoS ONE* **2018**, *13*, e0194460. [CrossRef]
32. Morelli, F.; Mikula, P.; Benedetti, Y.; Bussiere, R.; Jerzak, L.; Tryjanowski, P. Escape behaviour of birds in urban parks and cemeteries across Europe: Evidence of behavioural adaptation to human activity. *Sci. Total Environ.* **2018**, *631*, 803–810. [CrossRef]
33. Lethlean, H.; van Dongen, W.F.D.; Kostoglou, K.; Guay, P.J.; Weston, M.A. Joggers cause greater avian disturbance than walkers. *Landsc. Urban Plan.* **2017**, *159*, 42–47. [CrossRef]
34. Jiang, Y.; Møller, A.P. Escape from predators and genetic variance in birds. *J. Evol. Biol.* **2017**, *30*, 2059–2067. [CrossRef]
35. Lima, S.L.; Dill, L.M. Behavioral decisions made under the risk of predation: A review and prospectus. *Can. J. Zool.* **1990**, *68*, 619–640. [CrossRef]
36. Collins, S.A.; Giffin, G.J.; Strong, W.T. Using flight initiation distance to evaluate responses of colonial-nesting Great Egrets to the approach of an unmanned aerial vehicle. *J. Field Ornithol.* **2019**, *90*, 382–390. [CrossRef]