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The Effect of Airport Lawn Vehicles on the Flocking Behaviour of Barn Swallows

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ABSTRACT

The barn swallow (*Hirundo rustica*) is a common bird species in airfields and is one of the most common species involved in bird strikes. To identify the activity pattern of barn swallows within airfields, a study was conducted in August 2017 using route survey methods. The results revealed that moving vehicles easily attract barn swallows, which start following the vehicle after it has been moving for 2.250 ± 0.228 min; the number of barn swallows following the moving vehicle peaked after the vehicle had been moving for 11.750 ± 0.668 min; and the barn swallows stopped following the vehicle and quickly flew away from the lawn area 0.055 ± 0.003 minutes after the vehicle stopped moving. The number of swallows was significantly higher in lawns with moving vehicles than in lawns without moving vehicles, and there was significant vertical stratification of the number of swallows, with the highest number being observed in the 0.25–1 m layer above the ground. In addition, the density of insects in the lawn layer in areas without moving vehicles was significantly higher than that in the lawn layer after vehicles had passed through. The density of airborne insects at different heights above the lawn after vehicles had passed through was higher than that in areas without moving vehicles, with the 0.25–1 m stratum layer having the highest density of insects. There was a significant positive correlation between the number of barn swallows and the number of insects after vehicles had passed through. The results indicate that the vehicles driving on the airfield lawn disturbed the insects in the lawn layer, causing the insects inhabiting the lawn layer to fly up, resulting in a significant increase in the number of insects in the space above the lawn layer, which in turn attracted barn swallows to feed and form flocks. This study provides direct evidence for the phenomenon that airport environments attract foraging birds. Therefore, to prevent bird strikes at airports, the effect that moving vehicles on lawns has on birds should be considered in addition to efforts to reduce insect densities.

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JH designed the study. TW performed the field experiments. JW and PP carried out statistical analyses. JW and PP wrote the draft manuscript. All authors approved the final submission.

Key words
Barn swallows, Bird strikes, Vehicles, Driving, Airports

INTRODUCTION

A bird strike is defined as a collision between a bird or other flying animal such as a bat and an aircraft that is in flight or on a take-off or landing roll (Sai and Sun, 2012). The analysis of air traffic risks caused by birds is the subject of research by experts in many countries (Mackinnon, 1998; Knauer *et al*., 2000). Bird strikes at airports are a serious threat to flight safety, and available data shows that more than 80% of bird strikes occur during the take-off and landing phases of aircrafts (Allan, 2006). Therefore, the study of bird activity in low altitudes at airports is key to reduce bird strikes (Metz *et al*., 2020).

Barn swallows (*Hirundo rustica*) belong to the family Hirundinidae and are members of the order Passeriformes. They are common birds in airports, where they are numerous and widely distributed. They are also fast-flying and move in flocks, rendering them one of the main species that cause aircraft collisions (Wu and Jia, 2009; Zhao, 2016). Ridiche *et al*. (2016) found that the temporary or prolonged stay of birds in airports is due to suitable vegetation in the airports, which provide sites for birds to feed, roost, and breed. Since barn swallows breed mainly in buildings (Orlowski and Karg, 2013), the presence of feeding sites may therefore be a major factor in attracting them to roost at airports; however, there is no direct evidence of this. Therefore, further research is needed to ascertain specific behavioural patterns of barn swallows in airports.

To verify whether the vehicle itself, the movement of the vehicle or food caused the aggregation of barn swallows, we therefore surveyed the number of swallows and insects behind moving and non-moving vehicles in different areas within the airport. We hypothesised that the insects in the lawn were disturbed by the moving vehicles, thus attracting the barn swallows to come and forage. This

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paper investigates the phenomenon of swallows flocking behind moving vehicles at airports in order to provide a scientific basis for the prevention and management of bird strikes at airports.

MATERIALS AND METHODS

Overview of the study location

The airport selected is located in the south of Hebei Province. The terrain has higher elevation in the west and lower elevation in the east, with mountains, hills, and plains each accounting for approximately one-third of the geographic area. The region has a temperate continental semi-humid monsoon climate with four distinct seasons. The spring is arid with many dust storms; the summer is hot, rainy, and humid; the autumn has warm days and chilly nights, with generally cooler weather; and the winter is cold and dry, with less precipitation. The average annual temperature is 13.1°C, the average annual precipitation is 529 mm, and the average frost-free period lasts for 207 days.

The airport lawn is dominated by grasses, with the dominant species being *Stipa bungeana*, blady grass (*Imperata cylindrica*), and foxtail (*Setaria viridis*), with an average height of 25 cm and 85–95% grass cover (Wu *et al*., 2019). To prevent bird strikes, the airport will take a series of measures to drive birds away, such as play raptor sounds, gas cannons and shotguns (Winkler *et al*., 2017; Wu *et al*., 2019).

Sample areas and sample lines

Sample areas: The airport turf was divided into 10 sample areas, each with an area of 50,000 m^2 (500 m × 100 m), in which five survey sample areas were set up continuously on the east and west sides from south to north, for a total of ten sample areas. If the east side was selected as the experimental sample area, the west side was the control sample area, and the east and west sides were selected twice each as the experimental and control sample areas. The experimental sample area had a moving vehicle, while the control sample area was a stationary vehicle. Each experimental sample area and its corresponding control area was assigned the same letter name, thus, A, B, C, D, and E were used to represent the different areas.

Vehicle travel sample line: A vehicle travel sample line spanning 500 m in the north-south direction was set up in the middle of each sample area. Five such travel sample lines were delineated, resulting in a total length of 2500 m of vehicle travel sample lines across all samples areas.

Observation of sample lines in the control area: An observation sample line for observers was set parallel to the central line in the control sample area. Similar to the number of vehicle travel sample lines, five sample lines were delineated, resulting in a total length of 2500 m of sample lines for observation across all samples areas. The vehicle movement sample line was 80 m away from the observation sample line.

Methodology for observing the barn swallows

Distribution survey of barn swallows: From 18–26 August 2017, surveys were conducted under clear and windless weather using a simultaneous counting method, i.e. five experimental sample areas were surveyed simultaneously. For the experimental areas, we used an off-road vehicle traveling from south to north at a speed of 1.5 km/h. Observers sat at the back of the off-road vehicle and used binoculars to observe the barn swallows around the moving vehicle from the rear windscreen. The following data was recorded: the time when the vehicle started moving, the time when the barn swallows started following the vehicle, the time when the maximum number of swallows were following, and the time when the barn swallows stopped following the vehicle after it had stopped. The number of barn swallows in four different strata layers above the ground (0.25–1 m, 1–2 m, 2–3 m, and above 3 m) was recorded every two minutes. The numbers of barn swallows in the different strata were averaged across the corresponding strata in all samples. An identical off-road vehicle was parked in the control area, and since the vehicle in the control area was not driven, a researcher walked along the sample area to observe whether swallows were found. The experiments were conducted at least 1 h apart in the experimental and control areas.

In particular, the following data was collected:

(a) Time needed to start following the vehicle - the time needed for a barn swallow to first appear within 15 m of the vehicle was recorded.

(b) Time needed to reach maximum number of fofflwers - the time needed to reach the maximum number of barn swallows within 15 m of the moving vehicle was recorded.

(c) Time needed to stop following the vehicle - after the vehicle was stopped, the time needed for the last house swallow to fly beyond 15 m of the vehicle was recorded.

The experiment was repeated for four times, each on different days, in the experimental and control sample areas.

Insect survey methods

Insect surveys were conducted using the sweep net method, with white cloth trap nets 30 cm in diameter and 85 cm in depth, with poles of lengths 1 m, 2 m, and 3 m.

(1) Survey sample area: An off-road vehicle was

used to travel from south to north along the vehicle travel sample line within the survey sample area at a speed of 1.5 km/h. One person followed 1–2 m behind the off-road vehicle and captured insects using nets with different pole lengths for the following height strata: lawn layer (0–0.25 m), 0.25–1 m, 1–2 m, 2–3 m, and above 3 m. A hundred sweeps were made for each height stratum in each survey sample area.

(2) Control sample area: Sweeping with a net was carried out in the same manner at the centre of the control sample area without a moving vehicle. The experimental sample area and the control sample area were swept with a gap of at least 1 h.

One survey per sample area was considered as one replicate, and four replicates each were undertaken for the survey sample area and the control sample area. The insect survey and the swallow population survey were not conducted on the same day. The insects collected in each survey were packed in triangular bags, marked with the collection area and height, and brought back to the laboratory for identification. The species and number of insects collected were recorded.

Data analysis

We used a generalised linear mixed model (GLMM) to analyse whether vehicle movement affected the flocking behaviour of barn swallows. The total number of swallows following the vehicle, the number of swallows in the 0.25–1 m, 1–2 m, 2–3 m, and above 3 m height layers; and the total number of insects, the number of insects in the 0–0.25 meter (lawn layer), 0.25–1 m, 1–2 m, 2–3 m, and above 3 m height layers were the response variables, respectively. The presence or absence of vehicle movement, different sample areas, and the interaction between vehicle movement (yes or no) and different sample areas were fixed components. The different sample areas were treated as random components and input into the model. The least significant difference (LSD) method was used for multiple comparisons. Non-parametric tests were used to verify differences between swallow counts or insect counts at different heights.

In addition, we used a correlation analysis to assess the relationship between insect numbers and the number of barn swallows. Statistical analyses were performed using SPSS 25.0 for Windows (IBM Inc., USA). All the data are presented as mean ± SD, and all statistical tests were two-tailed, with a significance level of $P < 0.05$.

RESULTS

Moving vehicles attract barn swallows

The flocks of swallows following the moving vehicles had significant vertical stratification ($P < 0.001$), with the 0.25–1 m height stratum having the highest number of swallows (11.100±1.283) and significantly higher numbers of swallows than the other height strata ($P < 0.05$). The 1–2 m and 2–3 m height strata also had higher numbers of swallows (3.850± 0.650; 2.000±0.487), and a significantly lower number of barn swallow flew above 3 m (0.250± 0.123) (Fig. 1).

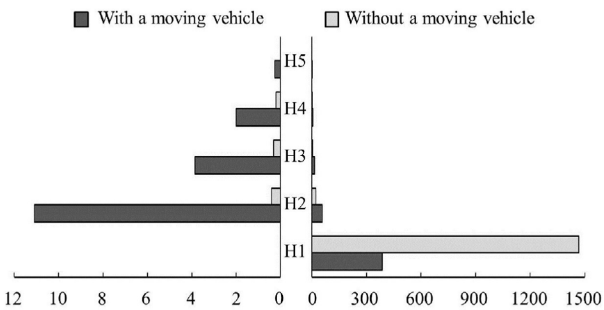

Fig. 1. Number of barn swallows (left) and insects (right) at different height strata with or without the presence of a moving vehicle (H1: 0-0.25m; H2: 0.25-1m; H3: 1-2m; H4: 2-3m; H5: More than 3 m).

Barn swallows started following the vehicle 2.250 ± 0.228 min after the vehicle started moving; the number of barn swallows behind the vehicle peaked at 11.750 ± 0.668 min after the vehicle started moving; and 0.055 ± 0.003 min after the vehicle stopped moving, barn swallows stopped following the vehicle and quickly flew away from the lawn area.

Effects of moving vehicles on barn swallows at different heights

The GLMM results showed that the presence or absence of a moving vehicle had a significant effect on the total number of barn swallows ($F_{1,30}$ = 87.302, $P <$ 0.001; Table I), with significantly higher numbers of barn swallows in the presence of vehicle passage than in the absence of vehicle passage (Fig. 1). The interaction between the presence and absence of vehicle movement and the areas also significantly affected the number of barn swallows ($F_{4,30}$ = 3.929, P = 0.011; Table I). Multiple comparisons revealed that for the different areas, except for area A, where the presence or absence of vehicle movement had no significant effect on the number of barn swallows (t = 1.154, df = 30, P = 0.258), all other areas attracted significantly higher numbers of barn swallows with vehicle movement than without (all $P < 0.01$); for the presence or absence of vehicle movement, only area A attracted significantly lower numbers of barn swallows

Table I. Effect of moving or non-moving vehicle on the number of barn swallows and insects at different heights.

Source	Barn swallows				Insects			
	F	df1	df2	P	F	df1	df2	P
Model for total number								
With or without a moving vehicle	87.302	1	30	< 0.001***	26.893	1	30	< 0.001***
Area	0.728	4	30	0.580	0.093	4	30	0.984
With or without a moving vehicle * area	3.929	4	30	0.011*	2.074	4	30	0.109
Model for 0–0.25m								
With or without a moving vehicle	—	—	—	—	32.981	1	30	< 0.001***
Area	—	—	—	—	0.105	4	30	0.980
With or without a moving vehicle * area	—	—	—	—	2.179	4	30	0.095
Model for 0.25–1m								
With or without a moving vehicle	119.676	1	30	< 0.001***	6.303	1	30	0.018*
Area	0.813	4	30	0.527	0.051	4	30	0.995
With or without a moving vehicle * area	4.092	4	30	0.009**	0.675	4	30	0.615
Model for 1–2 m								
With or without a moving vehicle	41.433	1	30	< 0.001***	7.973	1	30	0.008**
Area	0.538	4	30	0.709	0.096	4	30	0.983
With or without a moving vehicle * area	2.905	4	30	0.038*	0.213	4	30	0.929
Model for 2–3 m								
With or without a moving vehicle	16.759	1	30	< 0.001***	3.972	1	30	0.055
Area	0.355	4	30	0.838	0.106	4	30	0.979
With or without a moving vehicle * area	2.373	4	30	0.075	0.418	4	30	0.795
Model for 3 m+								
With or without a moving vehicle	5.000	1	30	0.033*	5.538	1	30	0.025*
Area	0.326	4	30	0.858	0.041	4	30	0.997
With or without a moving vehicle * area	2.000	4	30	0.120	0.250	4	30	0.907

$^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$.

with vehicle movement than area D (t = −2.477, *df* = 30, *P* = 0.019) and area E (t = −2.646, *df* = 30, *P* = 0.013), while the number of swallows in the other areas was not significantly different (all *P* > 0.05). The number of swallows in all areas without a moving vehicle was also not significantly different (all *P* > 0.05).

We also analysed the number of barn swallows at different strata, and GLMM results showed that the presence or absence of a moving vehicle had a significant effect on the number of barn swallows in the 0.25–1 m stratum ($F_{1,30}$ = 119.676, *P* < 0.001) and 1–2 m stratum ($F_{1,30}$ = 41.433, *P* < 0.001; Table I). In addition, the number of barn swallows was significantly higher with a moving vehicle than without (Fig. 1). The interaction between the presence and absence of vehicle movement and the areas also significantly affected the number of barn swallows in the 0.25–1 m stratum ($F_{4,30}$ = 4.092, *P* = 0.011) and 1–2 m stratum ($F_{4,30}$ = 2.905, *P* = 0.038; Table I). The results of multiple comparisons were similar to those obtained when the total number of swallows was the target.

Contrasting this, for both the 2–3 m stratum and the stratum above 3 m, only the movement of the vehicle affected the number of swallows (Table I), the number of barn swallows was significantly higher with a moving vehicle than without (Fig. 1).

Effects of vehicle movement on insects at different height strata

The presence or absence of a moving vehicle had a significant effect on the number of insects at the 0.25–1 m stratum ($F_{1,30}$ = 6.303, *P* = 0.018; Table I), 1–2 m stratum ($F_{1,30}$ = 7.973, *P* = 0.008; Table I), and the stratum above 3 m ($F_{1,30}$ = 5.538, *P* = 0.025; Table I), all of which were significantly higher with a moving vehicle present than without (Fig. 2). In contrast, the number of insects at the 2–3 m stratum was not affected by the presence or absence of a moving vehicle. Furthermore, the number of insects in the lawn layer after vehicle movement ($F_{1,30}$ = 32.981, $P <$ 0.001; Table I; Fig. 2) and the total number of insects ($F_{1,30}$ = 26.893, $P <$ 0.001; Table I) were significantly lower than the number of insects in areas without vehicle movement.

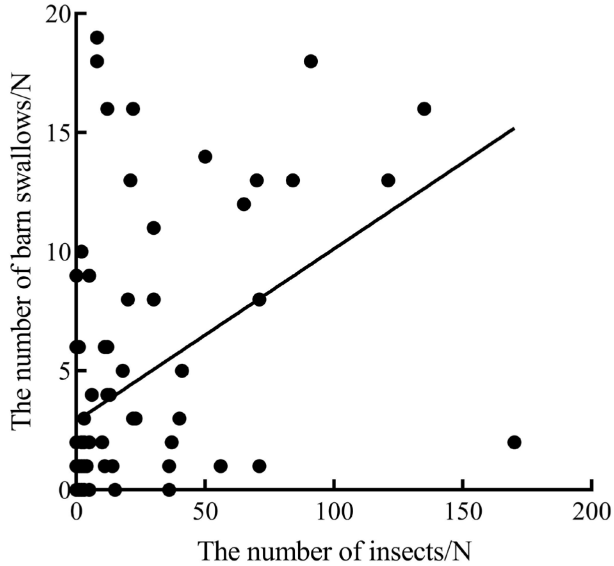

Fig. 2. Correlation between the number of barn swallows and the number of insects.

Insect densities also differed significantly ($P <$ 0.001) between height strata after vehicle movement, with the 0.25–1 m stratum having the highest insect density (56.450±10.258), followed by the 1−2 m stratum (15.050±3.342), and the 2−3 m stratum (5.900±2.407), with significantly lower insect densities in the strata above 3 m (0.600 ± 0.234). The number of insects was ranked in the following order: lawn layer > 0.25−1 m > 1−2 m > 2−3 m > area above 3 m (Fig. 1).

Correlation between the number of barn swallows and the number of insects after driving vehicles

A correlation analysis showed that there was a positive correlation between the number of barn swallows and the number of insects after vehicle movement (r = 0.445, P = 0.003; Fig. 2).

DISCUSSION

Based on an investigation of barn swallows in the airport, we found that driving vehicles on the airport lawn attracted barn swallows, with significantly higher numbers of barn swallows and insects over lawn areas with moving vehicles than over lawn areas without moving vehicles. There was a positive correlation between the number of swallows and the number of insects. Our results suggest that when vehicles drive on the lawn, they may disturb the insects inhabiting the lawn layer and cause them to fly into the air above the lawn, thus attracting flocks of barn swallows to feed by congregating in different densities at different height strata.

It is important to know the activity pattern of birds to avoid bird strikes. We studied the number of barn swallows and insects behind moving and non-moving vehicles in the airport. The results were consistent with our hypothesis that barn swallows followed moving vehicles to feed on insects. Morelli *et al*. (2014) found that roads, railways and some related buildings, although generally associated with biodiversity decline, may also have a positive impact on certain bird species, such as providing foraging habitat. Airports also have a special environment. Our results were similar to the research of Morelli *et al*. (2014), which can be proved by the following points. First, in areas without moving vehicles, the number of insects in the lawn layer was significantly higher than that in areas with moving vehicles. Second, in the air above the lawn layer, there were significantly more insects in areas with vehicles than in areas without vehicles, and the higher the stratum in question was, the lower the number of insects were in that layer. Similarly, the number of barn swallows was significantly higher over the lawn with moving vehicles than over the lawn without moving vehicles. Finally, the number of barn swallows was positively correlated with the number of insects.

The lack of significant difference in the number of barn swallows recorded with and without vehicle movement in one of our study areas may be related to the high intensity of bird-repelling activity in that subarea, which requires further study. We found that when vehicles first started to move through the lawn, barn swallows followed the vehicles in flight after about two minutes and formed significant clusters. Barn swallows may also have adapted to the airport environment, associating moving vehicles with the presence of food. However, we cannot rule out the possibility that they use scents or other cues to find food. A recent study found that the smell of grass emitted by lawn mowers can attract white storks (*Ciconia ciconia*) to forage (Wikelski *et al*., 2021). In our case, after the first swallow followed the vehicle on the lawn, more swallows joined until the vehicle left the lawn. They may also have communicated with each other by calling to their companions to come and feed (Catchpole and Slater, 2008), a hypothesis which needs to be further tested. Therefore, we need to further verify which signals are used by barn swallows to find food. For barn swallows, their flocking behaviour might have been an adaptation to improve their foraging efficiency (information center hypothesis) (Takenaka *et al*., 1994; Kasuya, 2008) and to avoid enemies (dilution effect hypothesis) (Krebs, 1973; Krebs and Davies, 1987; Sonerud *et al*., 2002). However, this flocking behaviour of barn swallows in airports has adverse effects, and inevitably leads to bird strikes. Based on the results of this study, we suggest that when bird repelling activities are carried out at airports, the attraction of birds by the movement of bird repelling vehicles should be taken into account. In addition, when bird repelling involves the cutting of grass to eliminate bird food, it is necessary to consider whether the fragrance of grass will attract the birds.

CONCLUSION

Our study shows that the flocking of barn swallows in airports is mainly influenced by moving vehicles, which agitate the insects in the grass and cause them to fly up thereby attracting barn swallows to feed, thus forming a flocking phenomenon and achieving high foraging efficiency. Therefore, along with bird control and insect management at the airport, policies should be implemented to reduce the presence of moving vehicles on the lawn, thus reducing the flocking of barn swallows and enhancing airport safety by reducing bird strikes.

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Ethical statement

This experiment did not cause any harm to the birds.

Statement of conflict of interest

The authors have declared no conflict of interest.

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