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Effects of vegetation management on the composition and diversity of the insect community at Tianjin Binhai International Airport, China

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Abstract

The vegetation community affects the composition and diversity of the insect community in grasslands. To explore the effects of vegetation management on insect community abundance and diversity, regular mowing of the vegetation was conducted, and tall fescue (*Festuca arundinacea*) and ryegrass (*Lolium perenne*) were exclusively planted at Tianjin Binhai International Airport. A total of 1886 insects were collected, representing 8 orders, 23 families, and 29 species; Acrididae (Orthoptera), Coccinellidae (Coleoptera), and Chironomidae (Diptera) were the dominant taxa. The abundance and biomass of insects in the turf areas were significantly lower than those in the control area and were reduced by 45.8 and 48.5% in the ryegrass area, respectively. In all areas, insect abundance and biomass peaked in summer, and the abundance of individuals and taxa decreased as the temperature decreased. Greater diversity and richness were found in summer compared with the other two seasons, and the turf areas had lower diversity and richness indices than the control areas in spring and summer. Our results suggest that the abundance, biomass and diversity of insects can be effectively decreased by artificial regulation of grassland vegetation at the airport, the planting of a single turfgrass – specifically ryegrass had the greatest effect. The present study provides a theoretical basis for the ecological control of insects at the airport.

Introduction

Ground cover plants at airports form an ecological community with special functions and roles. They play an important role in ensuring the safe takeoff and landing of airplanes and have the potential to provide habitat for insects living in, feeding in, and moving through the area (Soldatini *et al*., 2010). Aircraft–wildlife strikes (mostly by birds, referred to as bird-strikes) occur frequently throughout the world and pose a major hazard to flight safety, resulting in the damage of aircraft and the loss of life (Servoss *et al*., 2000; Soldatini *et al*., 2011; Allan *et al*., 2016). In general, insects are regarded as an attractant for birds, which are a known hazard in aviation (Hauptfleisch and Dalton, 2015; House *et al*., 2020). Insects, as an important component of the ground cover community, form a stable food network together with vegetation and birds, and the species composition and abundance of insects are closely related to the composition and abundance of birds (Cardoso *et al*., 2014; Li *et al*., 2017).

There have been many studies on the insect communities within the different habitats of airport grasslands; however, information regarding the effects of artificial control measures on insect communities at airports is limited. Wang *et al*. (2013) investigated the insect community in seven different grassland habitats at Kunming Wujiaba International Airport and found that insect species richness was highest in the dandelion community and lowest in the *Sporobolus fertilis* community. Zhao *et al*. (2004) proposed that the diversity of grassland vegetation in the flight areas might enhance the diversity and abundance of herbivorous insects. Kutschbach-Brohl *et al*. (2010) studied arthropods at John F. Kennedy International Airport and found that the structure and composition of the vegetation community affected the richness and diversity of arthropods.

The ground cover at Tianjin Binhai International Airport and the complex surrounding habitats (many farms, ponds, bushes, etc.) provide a considerable breeding and resting habitat for insects and attract a large number of birds to forage. Therefore, from the perspective of the avian food chain, removing the food source of the birds requires controlling the diversity and abundance of insects. Plant species richness and plant composition have been reported to influence insect abundances and diversity (Haddad *et al*., 2001). The insect communities at airports can be regulated without pesticide use by management of the vegetative cover, ensuring low environmental impact. In the present study, turf vegetation (tall fescue and ryegrass), which was not present in the original habitat at the Tianjin Airport, was established and two control measures, i.e., single-species turf establishment and mowing, were adopted to reduce the species diversity, vegetation height and biomass of ground cover around the airport. The purpose of this study is to explore the effect of vegetation management on insect abundance and diversity and to provide a scientific basis for the ecological control of insects at airports.

Materials and methods

Study site

The study area was the flight zone with ground cover near the southwest runway of Tianjin Binhai International Airport (117° 20′48″ E, 39°07′28″ N, altitude 3 m). The area has a warm temperate semihumid continental monsoon climate with a mean annual temperature of 11.8°C, an average annual rainfall of 598 mm and 188 frost-free days. The vegetation is a wild native herb community, including *Lagopsis supina*, *Hemistepta lyrata*, *Heteropappus altaicus*, and *Chenopodium glaucum*. The area has many species of insects, and the abundance of insects varies significantly with the seasons. Insects are highly active in summer, whereas only a few arthropods such as spiders remain active in winter. The birds in this habitat mainly include *Passer montanus*, *Pica pica*, and *Hirundo rustica*. The bird community around the airport shows obvious seasonal changes – the species richness, total abundance and diversity index are highest in autumn and lowest in spring.

Experimental design

Ryegrass and tall fescue were selected as the experimental plants for single-species turf establishment. Four areas with a ground cover were randomly selected around the airport, each of which was 15 m × 20 m with a spacing of 2 m. A total of four treatments were established as follows: (1) the control area was ploughed in August 2015, no grass seed was sown, and the vegetation grew naturally without mowing; (2) the mowed area was rolled twice a year, and the vegetation was mowed once every 2 weeks; (3) the tall fescue area was ploughed with 50 trenches at a spacing of 0.3 m at the same time as the control area and then sown with 10 kg of tall fescue seeds; (4) the ryegrass area was ploughed and sown with ryegrass seeds in the same manner as the tall fescue area. During the experimental period, the four treatment areas were managed using routine measures without the application of any chemicals. In the tall fescue area and the ryegrass area, the ears of the tall fescue and ryegrass were removed 3 times, in April, May, and June of 2016.

Insect sampling

Insects were sampled twice a month in spring (March–May), summer (June–August), and autumn (September–November) of 2016. Three sample plots (1 m × 1 m each) were randomly chosen in each treatment area. The insects were sampled using a standard sweep net (Evans *et al.*, 1983; Zhu *et al.*, 2012). When using the net to capture the insects, the same person swept the net 6 times within each plot with the same strength and amplitude. The collected insects were placed in bottles containing 75% alcohol, and some large lepidopteran insects were placed in triangular bags and brought back to the laboratory for species identification and weighing. The sampled insects were identified to the species level. The collected insects were then placed in alcohol to remove the soil residue, patted dry with filter paper and weighed.

Data analysis

The insect community indices were calculated using the following formulae: Shannon–Wiener diversity, $H' = -\Sigma p_i \ln p_i$; *Margalef* richness, $D = (S-1)/\ln N$; *Berger-Parker* dominance, $C = N_{max}/N$; *Pielou* evenness, $J = H'/\ln S$, where p_i is the proportion of the ith genus, N is the total number of individuals in a community, S is the total number of genera, and N_{max} is the number of dominant species (Han *et al.*, 2013; Hauptfleisch and Dalton, 2015).

The data are presented as the mean ± standard deviation and were analyzed using SPSS 17.0 statistical software. A one-way analysis of variance followed by Duncan's multiple range test was used to compare the differences among treatments at a significance level of $P < 0.05$.

Results

Insect community composition and biomass

A total of 1886 insects representing 29 species, 23 families and 8 orders were collected in the four experimental areas (tables 1 and 2). The insect community was dominated by Lepidoptera, Coleoptera, Diptera, and Orthoptera. The main dominant species included *Acrida cinerea* and *Locusta migratoria manilensis* (Orthoptera), *Propsilocerus akamusi* (Diptera), *Cicadella viridis* and *Schizaphis graminum* (Hemiptera), and *Coccinella septempunctata* and *Opatrum subaratum* (Coleoptera). The coleopteran families (5) and species (7) accounted for the majority (21.7 and 24.1%, respectively) of the total number of families and species. Orthoptera had the highest abundance (573) among the captured insects, accounting for 30.4% of the total; of these, *A. cinerea* insects were in large numbers, which accounted for 15.2%, followed by *L. migratoria manilensis*, *Teleogryllus emma*, *Oedaleus infernalis*, and *Calliptamus abbreviatus*. Neuroptera had the lowest species richness and abundance, accounting for 3.4 and 3.6% of the total, respectively; only 68 *Chrysoperla sinica* were captured. A comparison of the four experimental areas showed that the species richness of insects captured in the control area was 30, which was highest among all the areas, and the insect species in the mowed area, the tall fescue area and the ryegrass area were 5, 6, and 8, respectively.

Vegetation management regimes significantly influenced insect populations (table 3). The total numbers of insects captured in the mowed area and the turf area were significantly less than that in the control area, particularly for the ryegrass area, which had 57 individuals per m^2, which was 48 individuals per m^2 fewer than in the control area. The dominant species in all areas belonged to Orthoptera, and most of which were *A. cinerea* and *L. migratoria manilensis*. The number of orthopteran insects in the turf areas was significantly less than that in the control area, with the population in the ryegrass area decreased by 46.5% compared with the control area. In contrast, no significant effect of mowing on the numbers of orthopteran insects was observed. The smallest numbers of insects captured in all areas were neuropteran, and the numbers captured were not significantly different among the different areas.

Significant differences in insect biomass were observed between the turf area and the control area, but there was no significant difference between the mowed area and the control area

Table 1. Insects captured in the sample areas at Tianjin Binhai International Airport

Order	Families	Species
Lepidoptera	Pieridae	*Pieris rapae* (Linnaeus)
		Colias poliographus Motschulsky
	Nymphalidae	*Nymphalis xanthomelas* Denis *et* Schiffer
	Noctuidae	*Agrotis segetum* Denis *et* Schiffer
	Plutellidae	*Plutella xylostella* (Linnaeus)
Coleoptera	Coccinellidae	*Coccinella septempunctata*
		Harmonia axyridis (Pallas)
	Scarabeidae	*Popillia indgigonacea* Motsch
		Popillia quadriuttata
	Carabidae	*Harpalus sinicus*
	Tenebrionidae	*Opatrum subaratum* Faldermann
	Chrysomelidae	*Ambrostoma quadriimpressum* Motschulsky
Diptera	Chironomidae	*Propsilocerus akamusi* (Tokunaga)
	Muscidae	*Musca domestica* Linnaeus
	Sarcophagidae	*Sarcophaga naemorrhoidalis* Fallen
	Calliphoridae	*Lucilia sericata*
Hymenoptera	Apidae	*Apis cerana cerana*
	Vespidae	*Vespa tropica ducalis* Smith
	Formicidae	*Polyrhachis vicina* Roger
Odonata	Libellulidae Rambur	*Pantala flavescens* (Fabricius)
	Coenagrionidae	*Ischnura asiatica* (Brauer)
Orthoptera	Acrididae	*Locusta migratoria manilensis* (Meyen)
		Oedaleus infernalis Sauss
		Acrida cinerea Thunberg
		Calliptamus abbreviatus Ikormikov
	Gryllidae	*Teleogryllus emma*
Hemiptera	Cicadellidae	*Cicadella viridis* (Linnaeus)
	Aphididae	*Schizaphis graminum* (Rondani)
Neuroptera	Chrysopidae	*Chrysoperla sinica* Tjeder

(table 4). Compared with the control area, the insect biomasses of the tall fescue and ryegrass areas were decreased by 38.5 and 48.5% ($P < 0.05$), respectively. The taxa with the largest biomasses belonged to Orthoptera, Hymenoptera, and Odonata, particularly *A. cinerea* and *L. migratoria manilensis* (Acrididae), *Apis cerana* (Apidae), and *Pantala flavescens* (Libellulidae). The biomasses of these three orders in the ryegrass area were significantly lower than those in the control area by 39.8, 65.8 and 91.9%, respectively.

The abundance and biomass of insects in different seasons

The abundance and biomass of insects in different areas showed differential seasonal dynamics (fig. 1). The abundance and biomass of insects were significantly higher in summer compared with those in the other two seasons and accounted for 66.2% of the total insect abundance and 77.3% of the total insect biomass. Insect abundance was lowest in autumn. The numbers of *O. subaratum, Harpalus sinicus, P. akamusi,* and *S. graminum* were high in spring, but their biomasses were very small. In the fall, with the decrease in temperature, the abundance and species richness of insects were greatly reduced; in particular, *Popillia indgigonacea* (Coleoptera), *Apis cerana* (Hymenoptera), and *C. sinica* (Neuroptera) were sharply reduced in abundance or were absent. Only a small number of orthopteran insects of large body size and biomass remained.

In spring, the abundance and biomass of the insects in the turf areas were significantly lower than those in the control area, whereas the differences between the mowed area and the control area were not significant. In summer, mowing and turf establishment significantly decreased insect numbers; in particular, the ryegrass area had 38 individuals per m^2, which was 32 individuals per m^2 fewer than that of the control area. Moreover, the insect biomasses of the tall fescue and ryegrass areas decreased by 38.0 and 48.2% ($P < 0.05$), respectively, compared with the control area. In autumn, the abundance of insects in the ryegrass area was significantly lower than that in the control area. However, no significant differences were found between the other two treated areas and the control area, and insect biomass was not influenced by mowing and turf establishment in autumn.

The insect community indices

The richness (*D*) and diversity (*H'*) indices fluctuated across all seasons in the different areas (table 5). Except for the mowed area, a higher richness was observed in summer than in the other two seasons ($P < 0.05$). In spring, the richness index of the turf area was significantly lower than that of the control area, whereas no significant differences were found between the mowed area and the control area. In summer, significant decreases in richness index were observed between the three managed areas and the control area. In autumn, there were no distinct differences in the richness index among the four areas.

In all areas, the diversity index was highest in summer, followed by spring and autumn. In spring, the turf areas had a lower diversity index than the control and the mowed areas, but the difference between the mowed area and the control area was not significant. In summer, mowing and turf establishment significantly decreased diversity compared with the control area. In autumn, no significant differences in diversity index were observed among the four areas.

Discussion

The insect community in the experimental area of Tianjin Binhai International Airport was mainly composed of members of Orthoptera, Lepidoptera, Diptera, and Coleoptera. Orthoptera and Coleoptera were dominant in abundance, whereas Orthoptera and Hymenoptera were dominant in biomass. The abundance and biomass of insects changed with the seasons, and both were significantly higher in summer, mainly due to

Table 2. The insect community composition in the sample areas at Tianjin Binhai International Airport

Orders	Number of families	Percent (%)	Species number	Percent (%)	Individual number	Percent (%)
Lepidoptera	4	17.4	5	17.2	183	9.7
Coleoptera	5	21.7	7	24.1	346	18.3
Diptera	4	17.4	4	13.8	226	12.0
Hymenoptera	3	13.0	3	10.3	160	8.5
Odonata	2	8.7	2	6.9	105	5.6
Orthoptera	2	8.7	5	17.2	573	30.4
Hemiptera	2	8.7	2	6.9	225	11.9
Neuroptera	1	4.3	1	3.4	68	3.6
Total	23	100.0	29	100.0	1886	100.0

Table 3. Abundance of insects in different areas at Tianjin Binhai International Airport

	Abundance (ind m^{-2})			
Orders	Control area	Mowing area	Tall fescue area	Ryegrass area
Lepidoptera	10.2 ± 0.11a	6.3 ± 0.49b	8.3 ± 0.20ab	5.7 ± 0.15b
Coleoptera	22.7 ± 0.55a	17.8 ± 0.34b	8.7 ± 0.15c	8.5 ± 0.10c
Diptera	12.5 ± 1.09a	9.0 ± 0.54a	8.3 ± 0.99a	7.8 ± 0.43a
Hymenoptera	10.3 ± 0.11a	6.3 ± 0.24b	4.5 ± 0.52b	5.5 ± 0.26b
Odonata	5.7 ± 0.39ab	6.5 ± 0.33a	3.0 ± 0.33bc	2.3 ± 0.15c
Orthoptera	31.2 ± 0.49a	26.7 ± 0.74a	21.0 ± 0.39b	16.7 ± 0.58b
Hemiptera	9.7 ± 1.28a	9.0 ± 0.58a	10.2 ± 0.96a	8.7 ± 0.53a
Neuroptera	3.5 ± 0.17a	3.3 ± 0.29a	2.3 ± 0.20a	2.2 ± 0.06a
Total	105.8 ± 1.63a	84.9 ± 0.26b	66.3 ± 0.40c	57.4 ± 0.29d

Different lowercase letters indicate significant differences in different areas ($P < 0.05$).

Table 4. Insect biomass in different areas at Tianjin Binhai International Airport

	Insect biomass (g m^{-2})			
Orders	Control area	Mowing area	Tall fescue area	Ryegrass area
Lepidoptera	0.33 ± 0.02a	0.14 ± 0.03c	0.23 ± 0.03b	0.15 ± 0.02bc
Coleoptera	0.48 ± 0.08a	0.31 ± 0.08a	0.1 ± 0.02b	0.09 ± 0.01b
Diptera	0.02 ± 0.00a	0.01 ± 0.00b	0.01 ± 0.00b	0.01 ± 0.00b
Hymenoptera	1.96 ± 0.27a	1.02 ± 0.36b	0.44 ± 0.26b	0.67 ± 0.15b
Odonata	0.62 ± 0.15ab	0.95 ± 0.43a	0.06 ± 0.02b	0.05 ± 0.01b
Orthoptera	8.89 ± 0.30a	8.14 ± 0.51ab	6.72 ± 0.36bc	5.35 ± 0.71c
Hemiptera	0.01 ± 0.00a	0.01 ± 0.00a	0.01 ± 0.00a	0.01 ± 0.00a
Neuroptera	0.01 ± 0.00a	0.04 ± 0.03a	0.01 ± 0.00a	0.01 ± 0.00a
Total	12.32 ± 0.46a	10.62 ± 0.63a	7.58 ± 0.33b	6.34 ± 0.73b

Different lowercase letters indicate significant differences in different areas ($P < 0.05$).

the higher temperature and adequate rain in summer, which are conducive to insect reproduction and growth (Zhu *et al.*, 2014), particularly the massive reproduction and rapid increase in biomass of *A. cinerea*, *L. migratoria manilensis*, *O. infernalis*, and *C. abbreviates* (Orthoptera). The composition and dominant species of the insect communities was similar in the different areas. The dominant species in the turf areas were *A. cinerea*, *P. akamusi*, *S. graminum*, and *C. viridis*, and the dominant species in

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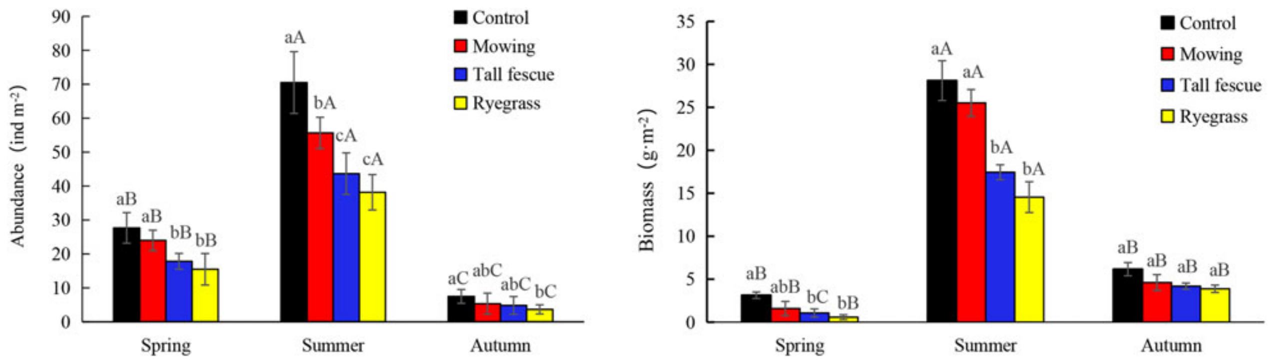

Figure 1. Abundance and biomass of insects in different seasons. The data are reported as the means ± SE. Different lowercase letters indicate significant differences between different treatments within each season ($P < 0.05$). Different uppercase letters indicate significant differences between seasons within each treatment ($P < 0.05$).

Table 5. Community indices of insects in different seasons and areas at Tianjin Binhai International Airport

Season	Sample areas	*D*	*H'*	*C*	*J*
Spring	Control	3.65 ± 0.19aB	2.39 ± 0.10aB	0.24 ± 0.22bA	0.87 ± 0.02aA
	Mowing	3.36 ± 0.26aA	2.25 ± 0.04aB	0.28 ± 0.03abA	0.85 ± 0.01aB
	Tall fescue	2.05 ± 0.07bB	1.77 ± 0.05bB	0.37 ± 0.03aA	0.83 ± 0.01aB
	Ryegrass	1.96 ± 0.26bB	1.74 ± 0.14bB	0.30 ± 0.04abA	0.86 ± 0.02aB
Summer	Control	4.78 ± 0.28aA	2.79 ± 0.05aA	0.23 ± 0.02aA	0.87 ± 0.03cA
	Mowing	3.75 ± 0.08bA	2.61 ± 0.02bA	0.23 ± 0.02aA	0.89 ± 0.01bcAB
	Tall fescue	3.50 ± 0.17bA	2.61 ± 0.03bA	0.14 ± 0.01bB	0.93 ± 0.01abA
	Ryegrass	3.38 ± 0.20bA	2.60 ± 0.07bA	0.14 ± 0.01bB	0.95 ± 0.01aA
Autumn	Control	2.05 ± 0.19aC	1.62 ± 0.13aC	0.36 ± 0.07aA	0.86 ± 0.02bA
	Mowing	1.84 ± 0.29aB	1.56 ± 0.17aC	0.34 ± 0.08aA	0.93 ± 0.03abA
	Tall fescue	1.62 ± 0.11aC	1.42 ± 0.10aC	0.36 ± 0.01aA	0.93 ± 0.03abA
	Ryegrass	1.53 ± 0.09aB	1.33 ± 0.01aC	0.32 ± 0.03aA	0.96 ± 0.01aA

Different lowercase letters indicate significant differences between different treatments within each season ($P < 0.05$). Different uppercase letters indicate significant differences between seasons within each treatment ($P < 0.05$).

the mowed area and the control area were *A. cinerea, P. akamusi*, *P. indgigonacea*, and *C. septempunctata*. This difference may be related to the small area compared with the large range of insect activities. Spatial scale is an important feature of landscape patterns. Large-scale changes in landscape patterns around the airport can directly affect the distribution and spread of insects and can even hinder the migration of insects (Ge *et al*., 2017).

Compared with the control area, the abundances of insects in the three treated areas were significantly decreased, and species richness was also decreased. These data indicate that ground cover management was conducive to a reduction in species richness and abundance of insects in the airport ecosystem, particularly *Pieris rapae*, *P. flavescens*, *Ambrostoma quadriimpressum*, and *Popilia indgigonacea*; the abundances of these species were significantly reduced. Within the airport ecosystem, vegetation, insects, birds and their surroundings interact and restrict each other and form an ordered entity through material circulation and energy flow. Starting from this perspective, two measures – mowing and single-species turf establishment – were adopted to adjust and control the vegetation-insect-bird food chain within the ecosystem, resulting in major changes in the habitat. Some insects have poor adaptability, which can lead to a decline in their population density with habitat change. Changes in insect populations may reduce the number and species of birds and thus potentially prevent the occurrence of birdstrikes.

Insects are susceptible to disturbance and vegetation conditions. The plant community is an important driving force affecting the abundance and diversity of the insect community (Kruess and Tscharntke, 2002; Zhao *et al*., 2018). In this study, the diversity of the vegetation community had a significant effect on the abundance and diversity of insects and confirmed that the greater the species richness of the vegetation, the more complex the insect community and the higher its diversity. The turf areas created a uniform vegetation community with lower vegetation coverage and diversity than the control area, and the abundance, biomass, and diversity of insects were also reduced, indicating that turf establishment had a strong inhibitory effect on insects, particularly on certain pollinating insects such as Pieridae (Lepidoptera) and Apidae (Hymenoptera). These observations are consistent with the results reported by Bronstein *et al.* (2006), who found that the species richness and abundance of insects decreased with a decrease in plant diversity. Jonas *et al.* (2002) and Haddad *et al.* (2001) studied the relationship between insects and plant diversity and found that the species richness of

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herbivorous insects was correlated with plant species richness and they believed that plant species richness determined insect species richness. Wenninger and Inouye (2008) also found that insect diversity and abundance were positively correlated with plant diversity. Mowing is a rapid and effective way to reduce plant height and biomass. As the frequency of mowing increases, competition with some tall plant species (such as *Eleusine indica*, *E. crus-galli*, and *Imperata cylindrica*) decreases, and the richness of the vegetation community decreases, resulting in an insufficient nutritional supply for insects, reduced space for insect feeding and habitation, and a decreased richness in the insect community. The present study showed that the abundance of insects in the mowed area was significantly lower than that in the control area, which was consistent with the results reported by Liu and Zhou (2004). Noordijk *et al.* (2010) showed that proper mowing reduced the diversity and richness of arthropods. Brigitte *et al.* (2009) also confirmed that mowing reduced the abundance of grasshoppers.

Studies have shown that alien plants are less susceptible to pest damage than native plants, are less attractive to insects, and can suppress insect abundance (Lau and Strauss, 2005; Kirichenko and Kenis, 2016). Around airports, the establishment of ryegrass, with its developed fibrous roots and strong tillering ability, and tall fescue, with its high cold resistance, adaptability, and disease resistance can inhibit the growth of native plants and reduce the diversity of ground cover vegetation when combined with management measures. Moreover, the establishment of non-native turf species can indirectly affect the local food network (Heard and Sax, 2013; Avanesyan and Culley, 2015). Alien turf vegetation changes the structure of trophic groups, which may reduce the attractiveness to birds that feed on grass leaves and seeds (such as *Anser fabalis serirostris*, *Anas poecilorhyncha*, and *P. montanus*). In addition, despite a small number of weeds (such as *H. altaicus*, *Conyza canadensis*, and *L. supina*) that have weak growth and are low in height and density, turf establishment makes the vegetation community less complex, which has a controlling effect on some dominant insect species with large biomasses and thereby reduces the attraction of carnivorous and omnivorous birds (such as *Lanius schach*, *Cuculus canorus*, and *Hirundinidae*). Therefore, single-species turf establishment can effectively control the vegetation and insect trophic levels in the vegetation-insect-bird food chain by affecting the normal feeding of some insects and their insect predators; in turn, the abundance and species richness of insects is reduced, thus eliminating food sources for some birds, which is conducive to reducing the appearance of birds around airports.

In summary, ground cover management at Tianjin Binhai International Airport, including mowing and single-species turf establishment, reduced the abundance, species richness, biomass, and diversity of insects and the effects were strongest in the areas where ryegrass was established. Therefore, it is recommended to plant single-species turf vegetation on a large scale around airports and to adopt appropriate management measures such as mowing or rolling to decrease the abundance and diversity of insects, thus reducing bird populations at airports.

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Ethical standards. This article does not contain any studies with human participants or animals performed by any of the authors.

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