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BIRD DENSITIES IN THE LOWER AIR LAYERS, A CASE STUDY ON EINDHOVEN AIRPORT 1998/99

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Abstract

Since the risk of bird strikes is the highest during take off and landing of aircrafts (i.e. the lower air layers), knowledge of bird densities, species composition and behavioural aspects in the lower air layers on and in the vicinity of an airport is needed to estimate that risk. In combination with actual bird strike data, bird strike risk can be estimated and guidelines for measures can be provided, e.g. bird control or flight restrictions. In commission of the Royal Netherlands Air Force and the City of Eindhoven we registered the number of birds aloft on Eindhoven Airport between August 1998 and July 1999 using a visual technique. Observations were conducted during four days each month and lasted the full daylight period. Observations were carried out with binoculars in a fixed position, in a fixed volume covering a part of the runway and bordering fields (fixed volume count). The most numerous species were Swift, Starling, Carrion Crow, Wood Pigeon, Skylark, Jackdaw and Stock Dove. The daily average numbers of birds aloft ranged between 50-250 birds/km^3. Due to the variation within a day, peak numbers were 5-20 times higher. In general the intensity of movements was higher in the early morning and the late afternoon, mainly due to roosting and feeding flights. In summer Swifts dominated the scene. Most birds observed seemed to be resident. In autumn and spring a minority of the total number of flight movements concerned migratory movements. The results will be discussed in relation to species composition, behavioural aspects and the frequency of bird hits.

Key Words: Visual detection, Local movements, Risk assessment, Migration, Bird density, Bird strike, Aircraft, Collision risk

Introduction

The risk of collision between birds and aircrafts is highest during take off and landing. Between 75 and 90% of these collisions take place at an altitude of less than 200 m (Blokpoel 1976, Thorpe 1992, Buurma 1995, Anonymus 1998). Therefore it is important to know how many birds are flying in the lower air layers on and in the vicinity of an airport to be able to assess collision risks. As bird strike rates differ between species also information on species composition is needed (Rochard & Horton 1980). The difference in bird strike rates between species is probably due to a difference in species density in the air, vulnerability to collision with aircraft, a difference in tendency to fly in flocks and in shape and behaviour of individual birds. Since certain types of behaviour increase the collision risk it is also important to collect information on behavioural aspects such as movements concerning feeding, roosting, resting and wandering. In combination with actual bird strike data collision risks can be estimated and guidelines for measures, e.g. bird control or flight restrictions can be provided.

In commission of the Royal Netherlands Air Force and the City of Eindhoven we registered the number of birds aloft on Eindhoven Airport between August 1998 and July 1999 by visual techniques. In this paper the following questions will be adressed:

- How many birds are flying in the lower air layers at Eindhoven Airport;
- What is the species composition of the birds;
- What is the magnitude of the day and year round variation;
- Are these data sufficient to calculate the risk of collision?

In a second paper (Poot *et al*. 2000) a second technique used will be presented and evaluated.

Methods

Measurements

Eindhoven airport is located in the south of the Netherlands, 5 km west of the city of Eindhoven, and ca. 100 km inland (5º23' E., 51º27' N.). Most of the area is characterized by a mixed arable/forest landscape. The landscape at the airbase itself is open. Fields along runways are in transition towards poor grass management (Dekker & van der Zee 1996).

To register the density of birds a standardized method was used (Lensink *et al.* 2000). In the so called fixed volume count observations were carried out from the traffic tower, 10 m above ground level. A pair of binoculars (10x40) was mounted on a tripod and directed across the runway, towards the other side of the airport. At the other side of the observation cone (at 1350 m distance) a second observer was located. Both observers were connected with an open telephone line. The tasks of the second observer were to verify observations at the end of the cone and note additional observations of birds that were missed by the first observer. The second observer also wrote down the observations of the first observer and was in control of the observation time.

Registration of the bird density took place during two successive full daylight periods, every two weeks between August 1997 and July 1998. Every clock hour two fixed volume counts of 10 minutes each were carried out, one with the horizon halfway the view (level 1) and one with the horizon at the lower edge of the glass (level 2). For every bird seen, species, number in flock, distance (in two classes), flying altitude (in four classes) and behaviour was registered. Observations in level 1 and 2 partly overlapped.

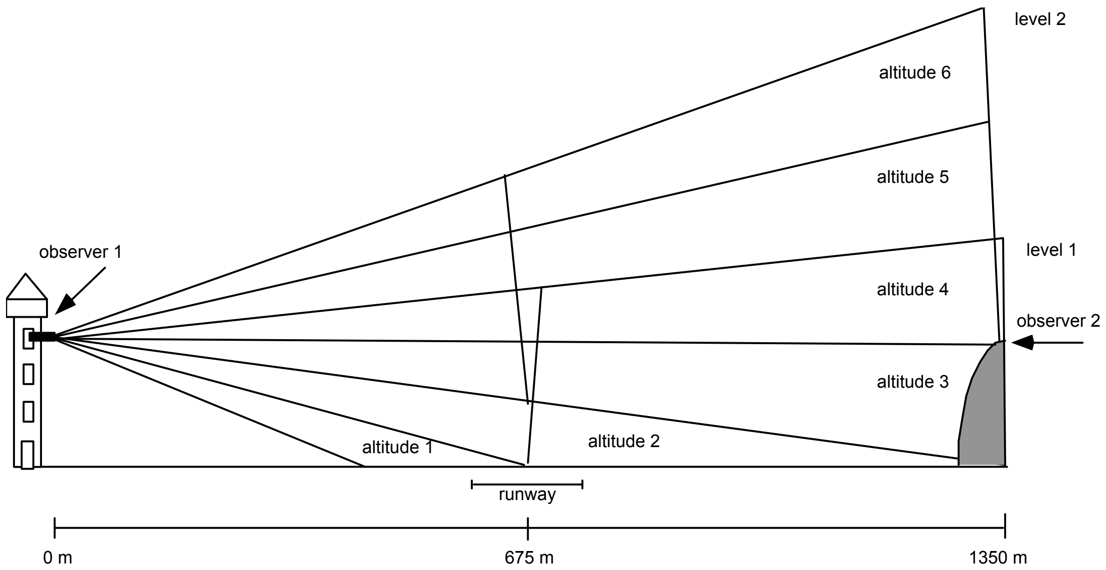

Figure 1. Schematic drawing of the fixed volume counts, observations in level 1 and 2 partly overlap.

Data analysis

Based on the field observations densities of birds were calculated using the following steps. Firstly the data set was completed by the additional observations that were made solely by the second observer. This addition was corrected for differences in the power of perception of different observers and for differences in visibility (Lensink *et al.* 2000). Secondly, the data were corrected for the time birds spent in the observation cone. For example a hovering Kestrel was observed for 25 seconds on average and a crossing Pigeon for 6 seconds. As a result the Kestrel in this case contributes > 4 times as much to the bird density as the Pigeon does (see for details Lensink *et al.* 2000). Thirdly, since the variation within and between successive observations at the same level did not differ significantly, the observations from level 1 height class 1, 2 and 3 were pooled with those from level 2 height class 2, 3 and 4, and thus getting one data set and a distribution over six height classes and two distance classes (Lensink *et al.* 2000). The resulting density for the observation cone was then expressed n birds/km^3.

Results and discussion

Densities of birds aloft

On a yearly basis the most numerous species at Eindhoven Airport were Starling, Swift, Carrion Crow, Wood Pigeon and Skylark (table 1). Peak numbers in Starlings were recorded in autumn and early winter, in Swifts between May and July, in Carrion Crow in winter, in Wood Pigeon in winter and late summer, and in Skylark in spring and early summer. Apart from these species Jackdaw (mainly spring and summer), Rock Dove (mainly summer), Lapwing (late summer), Feral Pigeon (summer) and Black–headed Gull (winter) completed the top ten of most common species. Furthermore, the following species added more than 1% to the yearly total of birds: Kestrel, Barn Swallow, Curlew, meadow Pipit, Chaffinch and Fieldfare. Buzzard, Magpie, Common Gull, Mallard, Yellow Wagtail, Black-tailed Godwit and Redwing added more than 1% to the monthly total in at least one month.

The overall density in birds was high in summer and autumn (figure 2). The high densities in summer were mainly caused by large number of Swifts foraging over the airport and in autumn by flocks of Starlings moving towards and from their roosts. In late winter and spring the density was low. Expressed as the number of flocks, the density showed a smoother pattern, also with peak numbers in summer and low numbers in winter. The even more pronounced summer peak in densities of groups is caused by small feeding flocks of Swifts that stayed within sight for a relatively long period of time.

All bird movements that were triggered by the landing or take-off of an airplane were labeled separately. Of all flocks seen (n=20,756), 1.3% was induced by an airplane (table 2). Among those, the species top ten was somewhat different compared to that of all bird movements (tables 1 & 2). Here Swift, Carrion Crow and Jackdaw were the most numerous species. Compared to the overall average of 1,3% of flocks getting away from the runway, flocks of Starling, Jackdaw, Carrion Crow, Lapwing and Buzzard were chased away relatively often (table 2).

Table 1. Top ten of most numerous species at Eindhoven airport. For each species the relative abundance in a year is given with the maximum in bold, and the total number recorded (n).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	n
Starling	4	3	2	2	0	6	1	2	14	15	24	**28**	11477
Swift	0	0	0	0	31	20	**49**	0	0	0	0	0	10292
Carrion Crow	19	**31**	6	6	3	3	1	5	4	12	7	3	4123
Wood Pigeon	11	5	7	16	9	3	2	**23**	2	7	4	10	2374
Skylark	0	0	22	**31**	12	14	4	1	1	6	7	2	2313
Jackdaw	12	12	**21**	11	11	14	0	1	8	9	1	2	2195
Stock Dove	6	6	5	12	7	12	9	**33**	6	1	1	2	2134
Lapwing	0	3	18	3	1	2	2	10	**37**	13	7	3	1868
Black-headed Gull	**50**	7	20	1	0	1	2	4	4	5	3	2	1188
Kestrel	5	4	12	11	8	7	5	**31**	11	4	1	2	115

Table 2.Number of bird flocks which movement was induced by an airplane; expressed as relative abundance within these movements (% 1) and as proportion of the total number of flocks (% 2). Of Grey Heron, Barn Swallow, Black-headed Gull, Mistle Trush, Fieldfare, Oystercatcher, Wheatear one flock was seen (%1 = 0,4).

Species	n	% 1	% 2
Swift	49	17.8	1.3
Carrion Crow	77	27.9	2.6
Skylark	10	3.6	0.5
Wood Pigeon	12	4.3	0.5
Stock Dove	27	9.8	1.5
Kestrel	11	4.0	0.7
Starling	20	7.2	8.8
Jackdaw	29	10.5	3.0
Curlew	11	4.0	1.7
Feral Pigeon	2	0.7	0.3
Black-headed Gull	1	0.4	0.2
Lapwing	12	4.3	2.2
Buzzard	7	2.5	2.8
Magpie	2	0.7	1.3

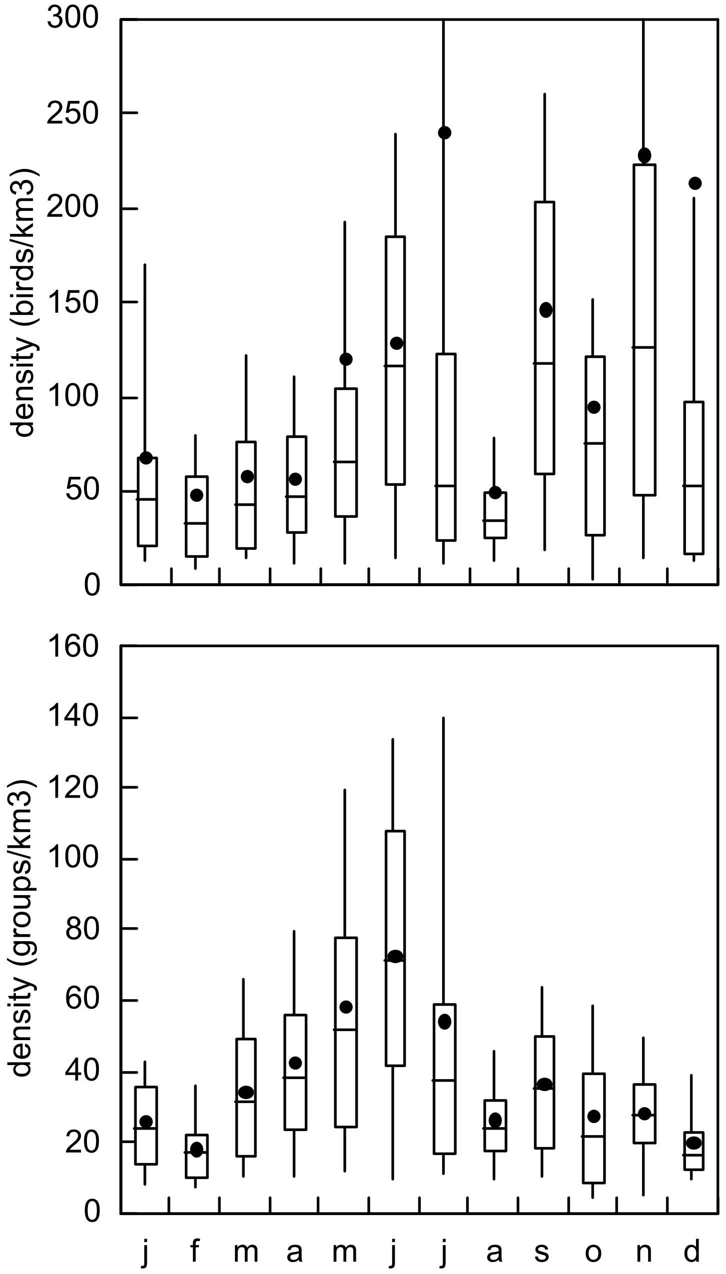

Figure 2. The density of birds for every month in the lower air layers over Eindhoven Airport, expressed as the number of birds/km^3 (upper panel) and the number of flocks/km^3 (lower panel, box-plots: dot = average, line = 10-90% interval, box = 25-75% interval and bar = median).

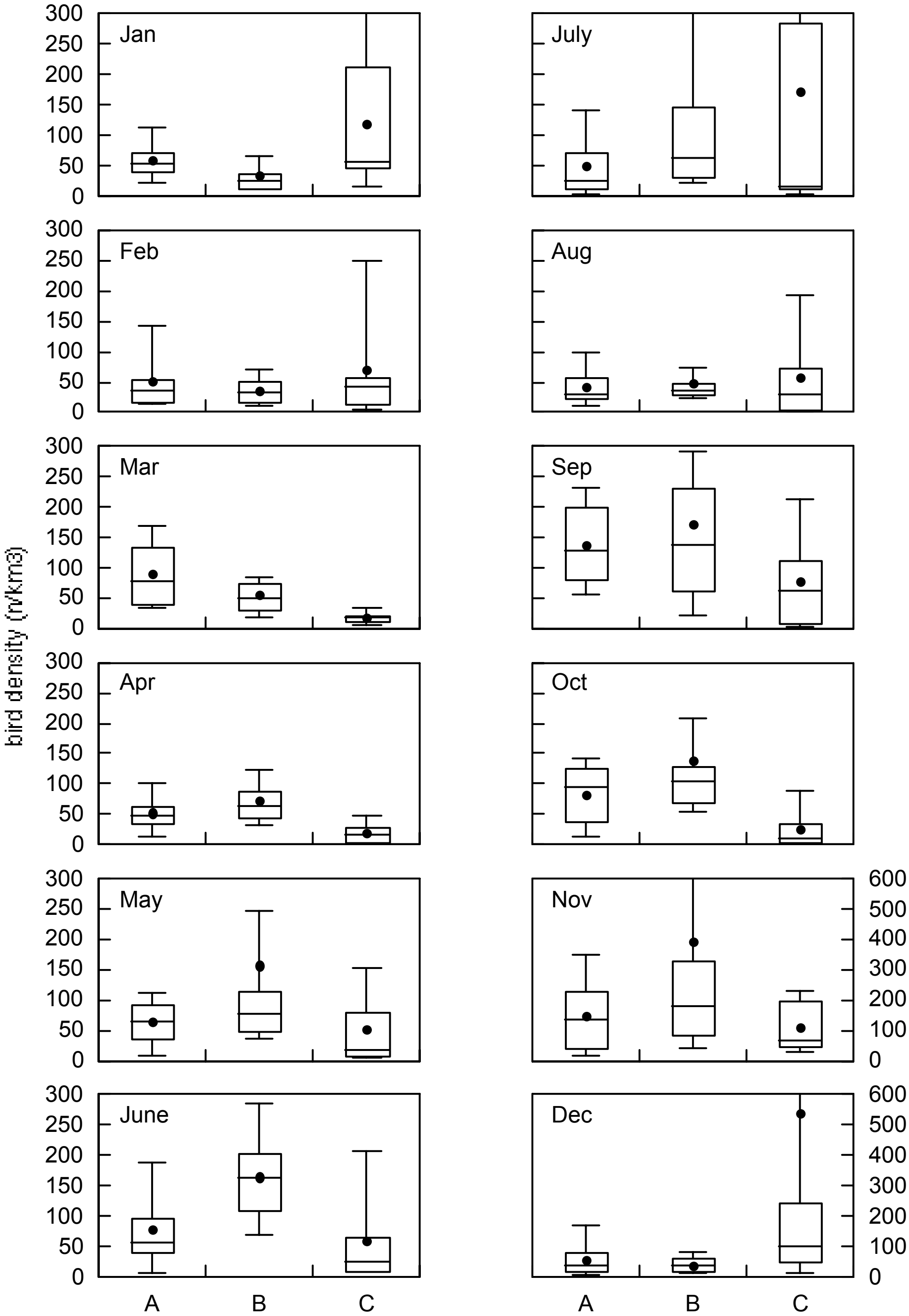

Figure 3. The density of birds (n birds/km^3) in course of the day in the lower air layers over Eindhoven Airport. The daylight period consists of three parts, a, b and c, with the separations two hours after sunrise and two hours before sunset. For further explanation see figure 1.

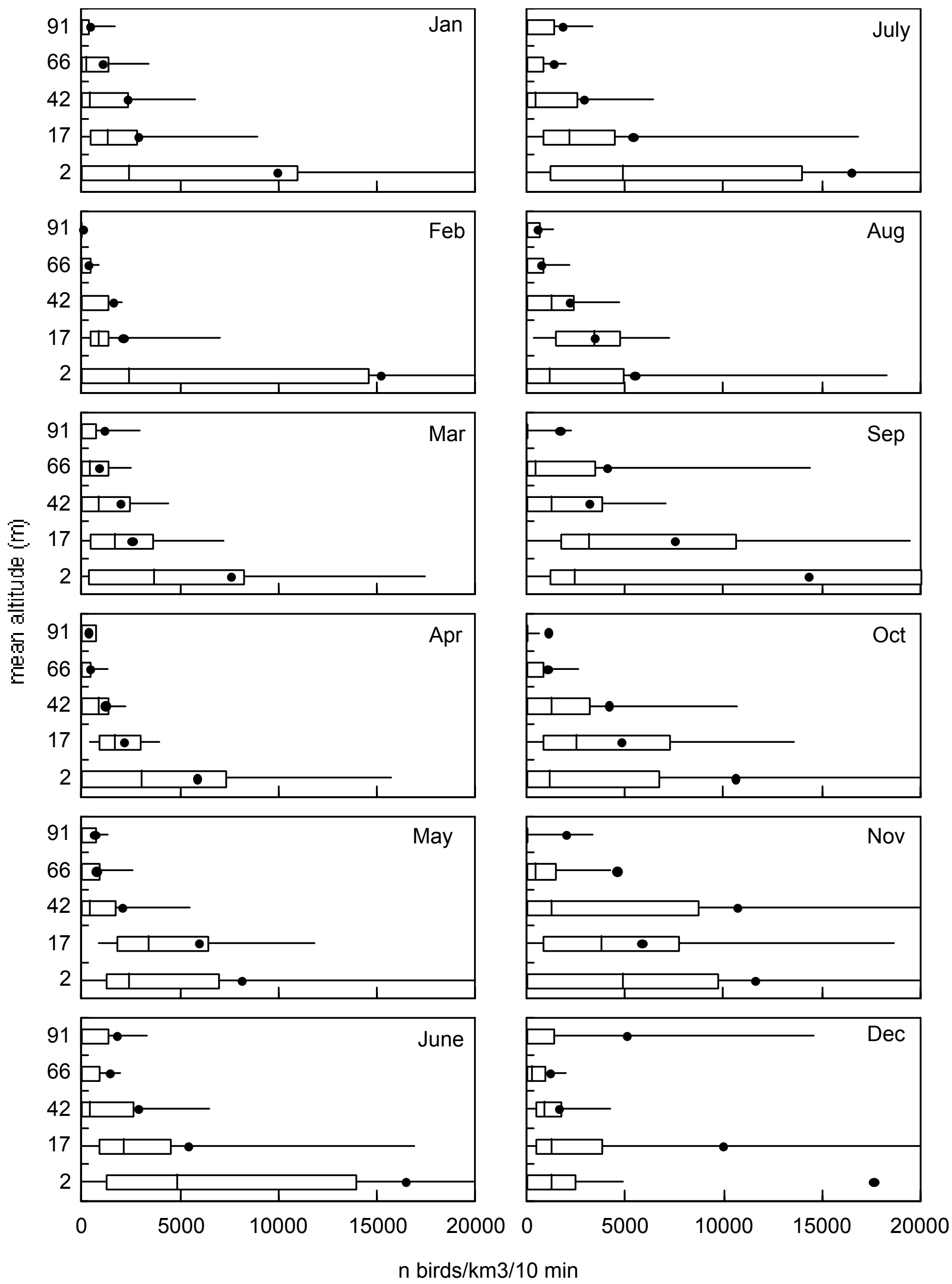

Figure 4. The density of birds over 5 height classes in the lower air layers over Eindhoven Airport, expressed as the number of birds/km^3. Note the scale of the y-axis is non-linear. For further explanation see figure 1. The numbers on the y-axis are the averages for segments in the observation cone. Because all segments have a different elevation, they partly overlap with the neighbouring segments. For instance the segment with an average height of 17 m ranges between 0 and 31 m and the segment of 42 m ranges between 4 and 74 m.

Daily patterns in the bird density varied from day tot day. In winter densities tended to be higher in the early morning and the late afternoon than during the day (figure 3). This pattern is caused by the strong contribution of movements to and from roosts to the total number of flights. The major species carrying out this type of flight were Jackdaw, Carrion Crow, Starling and Pigeons. During spring the maximum density was reached during the day. Especially in May and June Swifts, feeding over the airport in large numbers strongly effected the general pattern. In autumn the densities were higher in the morning and early afternoon than in late afternoon.

The height distribution was quite similar in all months. Generally the highest densities occurred in the layers below 54 m (figure 4). Relatively few birds were seen in the upper layer (>78 m). The height distribution varied between species. Starlings were recorded in all height classes, with the majority around 42 m. Swifts were more or less evenly distributed. The majority of Carrion Crows flew in the lower two classes, and this species was seldom seen in the upper one. Pigeons frequented the upper layers in winter and were mostly seen in the lower ones in summer. When Skylark were engaged in aerial displays they crossed all sections vertically and were therefore distributed evenly over all height classes in spring. Later in the breeding season they mostly flew in the lower layers.

Remarks on the method

With the method of standardized counts of flying birds in a fixed volume, only a small part of the airport was covered. The observation cone crossed the runway and covered the whole width of the field, so all major movements over and away from the runway were covered, but movements linked to both far ends of the runway were missed. Compared to the total surface of the airport (2.73 km^2), only 3.5% was covered in our method. Nevertheless, we have the impression that compared to other parts of the airport, our sample site was not particularly poor or rich in bird movement. Due to bird control, Starlings, gulls and Lapwings were only tolerated on the field at the far end of the runway which was not in use. Therefore these species are probably somewhat lower in our observation area as compared to the runway end.

To calculate the density of flying birds, our figures were corrected for the time birds spent in the observation cone. After this correction the effect of a slowly circling and a fast crossing bird, is the same. The length of their stay is standardized, since time is eliminated. Therefore the calculated bird density is the instantaneous density.

Remarks on densities

The calculated density is expressed as n/km^3. Since the maximum altitude of our method was 0-149 m height, the density figures are only valid for the lower air layers. Another option is to express the density in n/km^2, but this figure does not take the volume searched into account. On average the instantaneous density of birds ranged from 49 in February and August to 240 birds/km^3 in July (table 3).

Table 3.Instantaneous density of birds and biomass of birds flying over Eindhoven Airport.

	number of birds n/km^3	average bird weight gram	biomass kg/km^3
January	68.8	314.6	21.6
February	49.0	354.5	17.4
March	58.2	242.5	14.1
April	57.5	185.1	10.6
May	120.1	123.8	14,9
June	129.6	123.1	16.0
July	240.1	70.7	17.0
August	49.4	226.0	11.1
September	146.7	165.3	24.2
October	95.3	205.9	19.6
November	228.5	134.5	30.7
December	214.0	124.0	26.5

The calculated densities are averages per month, based on all counts of 10 minutes in that month. Maximum densities were recorded on 17 December 1998 (about 1900 birds/km^3, mostly Starlings) and 13 July 1999 (about 1600 birds/km^3, mostly Swifts). This was roughly 10 times higher than the average density in those months (table 3). In these cases the collision risk increases with the same factor. The biomass in the air shows a somewhat different pattern from that of the number of birds (table 3). The maximum is reached in autumn and winter and a minimum in spring and summer.
The contribution of very small species to the total number of birds varies between 1 and 50% (table 4). In March and April Skylarks are the most abundant small birds. In May, June and July the contribution of small birds is large, mainly due to Swifts. Medium-sized birds predominate in August, with a large proportion of Pigeons. The larger species are of importance in October and January-April. The contribution of the very large species is negligible in all months. Very small species never contribute much to the biomass aloft, but the small birds do (Swift, Starling, table 4). In May, July, September and November the total flying biomass is just above 10 kg/km^3 (table 2). This biomass is roughly comparable with 250 Skylarks, 250 Swifts, 30 Stock Doves or Wood Pigeons, 40 Black-headed Gulls or 20 Carrion Crows.

Table 4.Relative contribution of five size groups in the number of birds (per km^3) and the biomass of birds (per km^3); a = very small species 9-41 g, b = small species 42-110 g, c = medium sized species 111-400 g, d = large species 401-900 g, e = very large species >900 g.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
number of birds												
a	0.7	0.7	29.9	50.2	17.3	16.3	5.2	24.8	16.8	11.2	10.2	2.4
b	13.4	22.2	7.3	9.0	56.2	53.7	84.8	3.6	37.2	47.6	71.0	81.7
c	56.0	23.5	45.3	27.8	20.3	26.0	8.3	62.9	39.8	22.7	10.6	10.8
d	29.9	53.5	17.2	12.2	5.7	3.9	1.6	8.1	5.9	18.1	7.9	4.7
e	0.0	0.0	0.3	0.7	0.3	0.1	0.0	0.5	0.3	0.5	0.3	0.4
kilograms												
a	0.1	0.1	4.6	10.1	5.5	5.3	2.8	2.2	2.0	1.5	2.3	0.6
b	3.6	5.5	2.6	3.8	19.7	21.6	52.1	1.2	17.6	17.8	41.4	51.7
c	46.4	17.0	45.6	40.3	42.9	53.7	31.1	73.7	55.7	27.8	20.1	24.2
d	49.9	77.4	45.1	41.6	28.7	18.7	13.1	20.2	21.0	47.5	31.4	19.3
e	0.1	0.0	2.1	4.2	3.2	0.6	0.8	2.7	3.7	5.4	4.8	4.1

Remarks on strike proneness

Different bird species can react in different ways to airplanes. Movements that were caused by planes landing or taking-off relatively often involved Carrion Crow and Jackdaw (table 2). This can be expressed by dividing the percentage of bird hits involving each species by its percentage in the total number of flight movements (‘strike proneness, table 5).

Significantly more hits than expected from their relative abundance occurred in Lapwing, Wood Pigeon and Black-headed Gull, while the number of hits was significantly lower than expected in Starling and Carrion Crow. In table 5 the bird strikes at Eindhoven are compared with those from airports in the United Kingdom (Rochard & Horton 1980). The same species that have a high ‘strike proneness’ at Eindhoven also made up a large proportion of the bird strikes on the English airports. Similar patterns show up, with gulls and Lapwing reported relatively frequently among bird hits, and Crows relatively infrequently. An explanation for these differences between species could be found in behavioural aspects. Carrion Crow and Jackdaw were seen relatively frequently in movements triggered by an aircraft (table 2, figure 5). They seem to be aware of the dangers of an aircraft and therefore move away from the runway and seldom collide (table 5). On the other hand, among Lapwings these movements were seen relatively often as well. Nonetheless, this species is relatively frequently involved in bird hits (table 5).

Table 5.Average density of birds in the lower air layers above Eindhoven airport (n/km^3), the number of bird hits (1978-95, data RNLAF), and the strike proneness of species on this airport, as well as the number of bird hits in the United Kingdom (1966-76, Rochard & Horton 1980). Differences between number of observed and expected frequencies of bird hits at Eindhoven were tested with X^2 using Yates correction (df = 1).

	density in air				bird hits Ehv		strike		
					bird hits U.K.				
	n	%	n	%	proneness	X^2	p	n	%
Swift	24.2	20.0	6	8.0	0.4	1.8	ns	102	3.6
Starling	37.9	31.2	2	2.7	0.1	12.4	<0.001	86	3.0
Skylark	6.0	4.9	1	1.3	0.3	1.5	ns	71	2.5
Carrion Crow	11.6	9.6	0	0.0	0.0	5.7	<0.05	17	0.6
Lapwing	4.9	4.1	11	14.7	3.6	36.9	<0.001	428	15.0
Jackdaw	5.7	4.7	0	0.0	0.0	3.4	ns	3	0.1
Kestrel	2.8	2.3	1	1.3	0.6	0.3	ns	27	0.9
Wood Pigeon	6.6	5.4	7	9.3	1.7	5.6	<0.05	117	4.1
Stock Dove	5.2	4.2	3	4.0	1.0	0.1	ns	6	0.2
Black-headed Gull	5.5	2.9	8	10.7	3.7	26.4	<0.001	936	32.8
Barn Swallow	2.3	1.9	3	4.0	2.1	2.7	ns	20	0.7
Feral Pigeon	1.3	1.1	2	2.7	2.5	0.1	ns	87	3.1
Curlew	1.3	1.1	2	2.7	2.5	1.8	ns	8	0.3
Meadow Pipit	1.2	1.0	0	0.0	0.0	2.0	ns	7	0.2
Chaffinch	1.2	1.0	0	0.0	0.0	2.0	ns	6	0.2
Fieldfare	0.6	0.5	0	0.0	0.0	2.3	ns	5	0.2
Buzzard	0.6	0.5	1	1.3	2.6	0.3	ns	12	0.4
Common Gull	0.4	0.3	1	1.3	4.3	0.7	ns	285	10.0
Magpie	0.4	0.3	0	0.0	0.0	2.7	ns	0	0.0
Others	2.1	1.7	27	36.0				627	22.0
Total	121.4	100.0	75	100.0				2850	100.0

Among species that were relative scarce in movements triggered by aircraft (figure 5), Black-headed Gull, Wood Pigeon and Curlew have a high strike proneness but Skylark a low one. Therefore, there is no direct relation between the movements triggered by aircraft and the strike proneness of species. The most plausible explanation is that species differ in their evasive manoeuvring relative to aircraft.

In this study we collected information on the density of birds in the lower air layers and made some links to the risk of collision of species. In order to estimate the risk of bird collision at a certain site, information on four aspects is needed: 1. the density of species on the ground, 2. the density of species in the air and the relation between 1 and 2, 3. the behaviour of species in relation to aircraft and 4. the density dependent risk of collision per species. From such a risk assessment guidelines for aircraft use, air traffic planning and bird control can be obtained.

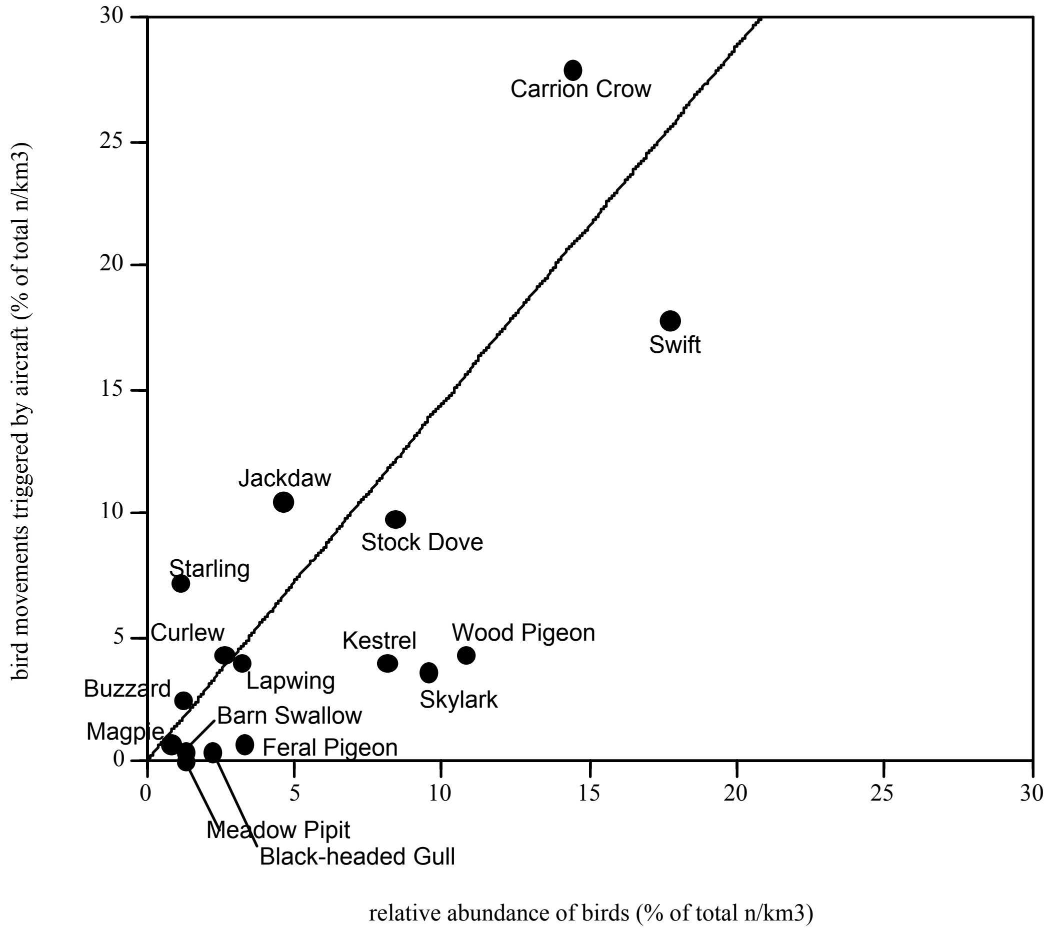

Figure 5.Relation between the relative abundance of species flocks in the air and the flocks whose movement is triggered by landing or take-off of an aircraft.

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