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SOME ASPECTS OF THE OCCURRENCE AND BEHAVIOUR OF THE CRANE *GRUS GRUS* IN POLAND IN LIGHT OF PRE-INVESTMENT WIND-FARM MONITORING

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ABSTRACT

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Ornithological pre-investment monitoring at planned wind farm sites is a standard and obligatory procedure in Poland and other EU countries. Pre-investment wind farm monitoring has a very important 'side effect' to its main goal (the safety of bird populations), namely the collection of valuable avifaunistic data from many localities that most probably would never be studied if not for the obligation to prepare environmental reports when wind energy investments are planned. The main aim of this paper is to show what we can learn from obligatory pre-investment monitoring when the standard field monitoring procedure and unified evaluation methodology are used. As an example the Common Crane *Grus grus* was selected, as a bird listed in Annex 1 of Directive 2009/147/EC and easy to identify and count. The data were collected at 155 controlled monitoring sites all over Poland, but mainly along the Baltic coast and in the Masurian Lake District. The methodology of the data collection and evaluation of results was strictly according to a paper by Busse (2013). The presentation of the results includes the numerical distribution of cranes in all seasons and some details of their behaviour - observations of birds on the ground and those using the air space: below the future rotor swept area of the wind turbines, at the rotor swept height, and flying above it. The estimated collision rates vary depending on the area, season and local heights of movements. It was concluded that such an evaluation of data already collected could be helpful in evaluating a particular site in comparison with other, previously studied localities.

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INTRODUCTION

Ornithological pre-investment monitoring at planned wind farm sites is a standard and obligatory procedure in Poland and elsewhere. Typically it lasts for one or sometimes two years and covers all seasons of the yearly life cycle of birds. This is because the potential influence of the wind farm on birds may vary according to the changing behaviour of the birds in successive parts of their life cycle.

It is well known that during the breeding season birds stay most of the time at their breeding sites (single nests or breeding colonies), and at their breeding territories when the bird is territorial. The breeding territory must include a secure location for the nest and an area large enough for feeding, which is especially important during feeding of chicks. At that time what is most important for the breeding pair is (1) whether the wind farm occupies the optimal habitat for the nest ('occupies' means here that construction of the farm limits the area outside the species' range of intolerance; some species are not concerned with the distance of the nest from the turbine, while others may be sensitive to the distance and the wind farm may substantially limit the territory suitable for the species; (2) if the bird has chosen a good place for the nest, another problem, depending on the behaviour of the species, could be the location of the optimal feeding area of the pair settled there—if the shortest line between the nest and the optimal feeding area crosses the farm area, the problem lies in a potentially increased collision risk or in a potential loss of energy used by the birds to fly around the farm. In the first case the most important factor is species behaviour in terms of usual flight height (within or outside the wind-turbine rotor swept area). However, the problem is complicated by other behavioural properties: some local birds learn dangers inside the farm and change their flight level accordingly, or even pass the farm area only when rotors are not moving, e.g. due to a lack of wind or turbines having been stopped for service. This adaptive behaviour is also important in discussing the second aspect mentioned above, the loss of energy. This problem mainly affects species with short feeding flight ranges. Birds normally hunting far from the nest may lose very little energy when flying around small farms, in contrast with large areas with turbines. All of these problems are difficult to discuss on the basis of pre-investment monitoring results, especially when a relatively small wind farm is planned. We must be aware that bird behaviour changes when a wind farm is built and conclusions drawn from pre-investment data are only a rough estimation. Thus collecting information from post-investment monitoring is crucial for correct future interpretation of pre-investment monitoring data.

During periods outside the breeding season constraints on estimation of risks to birds connected with wind farm construction are different. Risks associated with construction of wind farms are limited; impact associated with elimination of the feeding area is lower because local birds have much greater flexibility in exploiting a wider territory, and thus considerations of energy losses are unsound. The same applies to migratory birds – they can freely choose feeding/resting locations, unless, however, unique feeding/resting places are occupied. For migrants, flying around even a large wind farm area does not pose a problem, as this is a negligible addition to their normal migration distances, numbering thousands of kilometres. At the time of migration only a wind farm located just within the migration corridor could pose a clear difficulty. Collision risk depends on two main parameters: the number of birds passing the site and, to a greater extent, behaviour in flight (local flight level habits). Thus it is believed that pre-investment observations should be focused on these parameters.

Pre-investment wind-farm monitoring has a very important 'side effect' to its main goal (the safety of bird populations), i.e. the collection of valuable avifaunistic data from many localities that would never be studied if not for the obligation to prepare environmental reports when wind energy investments are planned. This is because they are frequently not especially 'ornithologically interesting', either to professional ornithologists working on scientific problems or to amateur bird-watchers hoping to 'hunt' (with binoculars and/or cameras) as many rare birds as possible. This last aspect should be taken under consideration when evaluating wind farm monitoring, in which numbers of rare birds are usually overestimated in relation to common species. This overestimation of the value of the site results in more cautious conclusions in the evaluation and alters its actual value (e.g. when an area is concluded to be 'valuable', when actually on a broader scale it is in fact quite ordinary). It is difficult to establish what an 'average level' for the species is. It is crucial for evaluators to know what a normal level is.

The main aim of this paper is to show what we can learn from obligatory pre-investment monitoring when the standard field monitoring procedure and unified evaluation methodology are used. As an example the Common Crane *Grus grus* was selected, as a bird listed in Annex 1 of Directive 2009/147/EC and easy to identify and count. The results will not be discussed in a monographic style or in relation to other information about this species in Poland.

MATERIAL AND METHODS

The material for this evaluation was collected at 155 sites monitored all over Poland, although with very unequal space distribution, due to the unequal value of areas for placement of wind farms as well as the arbitrary nature of investors' commissions of expert reports on such sites. A 'site' here is defined as 'the area planned as the location of a wind farm or a part of larger unit to be studied'. The site area ranged from a few hundred to about 3,000 ha, while larger areas for large farms were divided into a few independent sites of this size. The distribution of the sites studied is presented in Figure 1 (the number of dots is less than the total number of sites, as adjacent sites could not be shown separately). For generalization and simplicity, sites were grouped into twelve areas designated by capital letters (Fig. 1).

The method used for field monitoring and methods of evaluation of collected data were presented and discussed in detail in a paper by Busse (2013).

The main points of methodology are as follows:

1. Field observations – usually 30-35 days over the course of a year: in spring (1 Mar.-30 Apr.), breeding period (1 May-30 June), dispersion period (post-breeding time) (1 Jul.-31 Aug.), autumn (1 Sep.-15 Nov.) and winter (16 Nov.-28 Feb.).

The field work method is crucial to the discussion in this paper and therefore cited from the paper by Busse (2013): '*During the bird migration periods, when birds usually are not settled in defined places (e.g. pieces of a forest or bushes as well as fields or meadows) the best solution is to carry out observations from a fixed post that is located usually in a centre of the planned farm and it allows good visibility in all directions.*

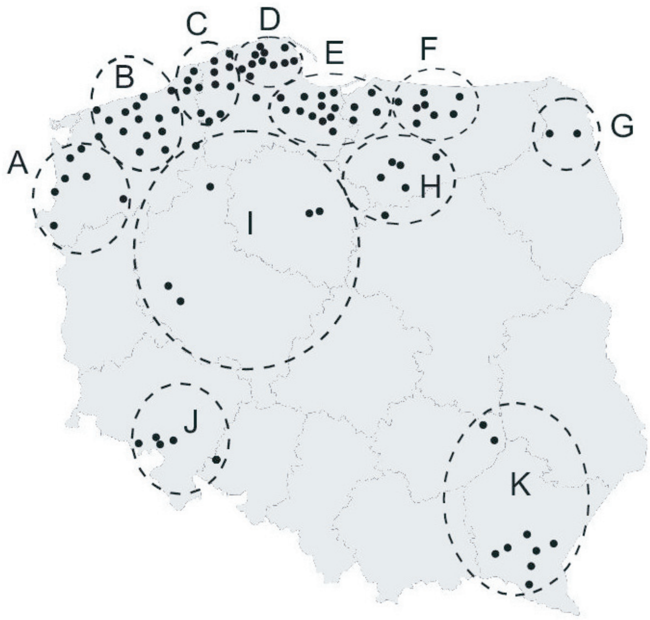

Fig. 1. Study areas with locations of planned wind farm locations

However, because of influence of current weather conditions, especially the wind force and direction, the observer can change this fixed point to another that allows to see the passage of birds better or to count individuals which landed on the site not visible from the standard post. During winter many birds are in flocks and concentrate in certain places, e.g. straw stacks, hunters' feeders etc. So, in that time observations are more effective if performed during a slow walk through the monitored area. This is so called "transect" or "moving observation point" – the procedures of noting and observation are the same as during the observations from the fixed post. The idea is the same – to learn on avifauna of the area of the future farm as accurately as possible.

In the period covering spring, breeding and post-breeding dispersion seasons the transect style of observations is the basic method as the breeding birds stay close to their nests and local feeding grounds. However, as in early spring some birds already start to breed, while others still migrate, the observer must adjust the observations to current situation and combine two methods of work.

Use of the point and transect observations with the obligatory noting the time of work is the only solution that allows combining both procedures into one set of data that are intended to answer the question: "How many birds will be exposed to the risk when the farm will be built?" *– this is the main goal of pre-investment monitoring.*

Because of the above goal of pre-investment monitoring, some methods applied to certain scientific ecological problems, even called as "monitoring" methods, are not applicable to the pre-investment monitoring.'

2. Evaluation of collision risk using an original computer program (WindRisk 7.6 by P. Busse) based on an idea presented by Band *et al.* (2007) and taking into consid-

eration the avoidance rate, which is a key factor for expectations concerning collision rates. A number of papers have discussed and further developed the idea and have updated avoidance rate values (e.g. SNH 2011). Details are presented in the paper cited above (Busse 2013). The main input from the field data is as follows: number of birds, percentage of birds flying within the turbine rotor swept area, direction of movement, and distance from the observer. The output is the species-specific estimated collision rate for 1 turbine/year. Because at the time most of the data used here were collected the standard turbine size was 2 MW with a tower of about 80 m and a rotor about 80 m in diameter, the swept area was estimated as 40-120 m above the ground. During pre-construction monitoring it is not possible to determine the height of flying birds in relation to the exact swept area level, so we must remember that estimations are subject to some variation or even observer bias.

The monitoring routine is a typical sampling procedure when observation days are distributed within a full year-round cycle. Because estimations of possible collisions must cover all days of the year, the estimation procedure includes a step to calculate both seasonal and all-year occurrence of the species. These numbers are used to describe the frequencies of the species in different parts of the area studied.

RESULTS AND DISCUSSION

Because the observers note the species of the birds, the number of individuals, direction and height of movement (if in flight), these parameters as well as estimated collision risks can be presented for any species. All of them can characterize all seasons within the bird life-cycle.

The distribution of cranes observed in different seasons is presented in Figure 2. As the crane is a migratory species and many individuals observed have arrived from outside of Poland, the numbers are clearly differentiated between seasons. The picture indicates that most potential dangers for cranes can affect migrants but not local birds. Thus the collision level should be considered with respect to the European population rather than the local population alone. This is confirmed by the calculated seasonal collision rates, presented in the Table 1. Apart from winter, when cranes are mainly at their winter quarters, the lowest expected collision rates, and thus collision frequencies, are in the breeding and post-breeding (dispersal) periods.

Variation in the intensity of observations was rather low: the number of control days in different seasons within the study areas (A-K) was slightly variable: $N = 5.1$ (dispersion time) to 8.7 (autumn migration) per site, with a coefficient of variation $V = 11\%$ to 20% within the season (Table 2); variation of numbers of observation hours was a bit higher – $N = 27.71$ to 48.49 hour, $V = 11\%$ to 37%. Variation in the results of counts was higher: number of individuals observed: $N = 41$ to 407, $V = 70\%$ to 149%; number of individuals observed per hour: $N = 0.11$ to 8.64, $V = 74\%$ to 149%; number of individuals estimated to be within observed site: $N = 1{,}752$ to 12,963, $V = 71\%$ to 191%. In contrast to the direct results, estimated collision rates within the season were quite moderate: $N = 0.0488$ to 0.0902 (only the winter value was 0.0021, due to the small number of observations), $V = 45\%$ to 83%. The expected collision frequency per turbine and season could be estimated as once per 13 to 49 years.

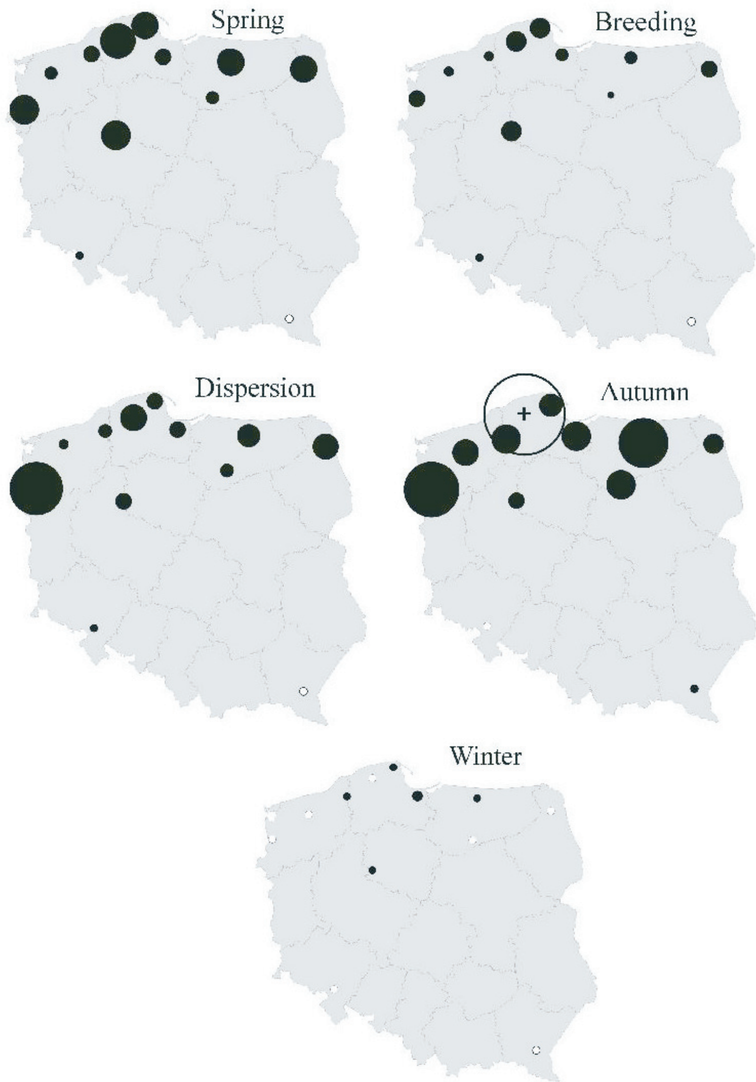

Fig. 2. Distribution of cranes observed in different seasons. Surface areas of circles are proportional to the numbers of birds estimated to be present in the season at the sites.

Details of the results for all areas studied are presented in the Table A in the *Appendix*.

In comparing results for many sites/areas, it is interesting to know which parameters of the monitoring routine influence the estimated collision rate values. In all seasons an analysis was performed of the dependencies of the collision rate on different parameters collected: number of control days, number of observation hours, number of observed individuals, number of observed individuals per hour, estimated total number of individuals per season and percentage of birds flying in the rotor swept area (Table 3). The table presents the results using Pearson's *r* values and their significance level *p*.

Table 1
Expected collision rates and significance of seasonal differences in estimated collision rates (*p* values). Average collision rate per turbine/season. Years – one collision expected per number of years given

	Collision rate	Years	Spring	Breeding	Dispersion	Autumn	Winter
Spring	0.0783	12.8	X	**<0.05**	**<0.05**	*ns*	**<0.001**
Breeding	0.0488	20.5		X	*ns*	**<0.05**	**<0.001**
Dispersion	0.0487	20.5			X	**<0.05**	**<0.001**
Autumn	0.0901	11.1				X	**<0.001**
Winter	0.0021	471					X

Table 2
Basic observations and result parameters in full year of monitoring. Controls – number of days per site, Hours – total number of hours spent in the field, *N* ind. – individuals observed, *N* est. – number of individuals estimated to visit the site during the year, Col. 1 – estimated collision rate per turbine per year, *N* years – one collision expected within *N* years.

Season		Controls	Hours	*N* ind.	*N*/hour	*N* est.	Col. 1	*N* years
Spring	***Avg***	**6.4**	**35.25**	**116**	**3.46**	**4 592**	**0.0783**	**13**
	SD	0.7	7.05	85	2.57	3 698	0.0355	4
	V %	11	20	73	74	81	45	32
Breeding	***Avg***	**5.5**	**28.75**	**41**	**1.87**	**1 752**	**0.0488**	**27**
	SD	1.1	5.24	33	1.69	1 237	0.0398	21
	V %	20	18	81	90	71	82	78
Dispersion	***Avg***	**5.1**	**27.71**	**67**	**3.02**	**4 546**	**0.0488**	**49**
	SD	0.7	2.99	82	3.83	6 618	0.0405	63
	V %	13	11	124	127	146	83	130
Autumn	***Avg***	**8.7**	**48.49**	**407**	**8.64**	**12 963**	**0.0902**	**23**
	SD	1.3	14.85	623	12.88	17 088	0.0715	32
	V %	15	31	153	149	132	79	140
Winter	***Avg***	**6.3**	**30.37**	**3**	**0.11**	**98**	**0.0021**	
	SD	0.9	11.13	4	0.13	187	0.0045	
	V %	14	37	126	120	191	214	

A bit surprisingly, the estimated collision rate is weakly but negatively correlated with the number of control days and observation hours during migration seasons (r = -0.16 to -0.20, with p 0.01 and 0.05), though not within breeding and dispersion time (very low, negative and positive r values). The question is why it is correlated negatively.

Table 3
Correlation (Pearson's *r* values) between collision rate and different parameters of number occurrence in successive seasons. Statistically significant values of *p* are given in bold.

Period:	Spring migration	Breeding	Dispersion	Autumn migration	Wintering
Collision rate	0.0783	0.0488	0.0487	0.0901	0.0021
Avg N/site:	122	50	66	457	6
Avg N/hour:	3.6	3.3	3.1	9.4	0.2
Avg N estimated:	4819	1976	4328	14 530	205
Avg % in rotor	26.7	20.1	12.1	28.9	46.3
N controls					
r	-0.16	+0.06	+0.08	-0.20	
F	3.94	0.53	0.92	6.17	
p	*ns*	*ns*	*ns*	**0.05**	
N hours					
r	-0.20	-0.03	-0.02	-0.24	
F	6.25	0.13	0.06	9.05	
p	**0.05**	*ns*	*ns*	**0.01**	
N observed					
r	+0.08	+0.07	+0.06	-0.01	
F	0.97	0.72	0.52	0.01	
p	*ns*	*ns*	*ns*	*ns*	
N obs./hour					
r	+0.15	+0.03	-0.01	+0.05	
F	3.45	0.13	0.01	0.37	
p	*ns*	*ns*	*ns*	*ns*	
N estimated					
r	+0.12	+0.25	+0.07	+0.09	
F	2.19	9.80	0.70	1.22	
p	*ns*	**0.01**	*ns*	*ns*	
% in rotor					
r	+0.80	+0.32	+0.65	+0.65	
F	149.33	12.66	81.21	81.21	
p	**0.001**	**0.01**	**0.001**	**0.001**	

The collision rate is not correlated with the number of observed birds or number of observed birds per hour – *r* values are low and both positive and negative. It could be suggested that the monitoring procedures and evaluation are efficient enough within a broad range of bird densities.

The analysis shows, however, that the procedure of estimation of total bird density in a season makes the calculations closer to the actual collision rates - all *r* values are positive, but it reaches the significant level $p < 0.01$ only in the breeding time.

In contrast with the parameters discussed above, the observed share of birds using a height of flight in the rotor swept area strongly influenced the collision rate (*p* values < 0.01 to < 0.001). Hence it is very important to correctly estimate this parameter in the field.

Using the air space

All birds use the air space within the wind farm area. Apart from birds sitting on the ground (including trees, poles etc.), which at that moment cannot be killed by the turbine, there are three levels that must be taken under consideration: below the rotor swept area, the swept area and all space above. Practically, the birds can be killed by the turbine only within the rotor swept area - collisions with the solid tower, while still possible, especially at night and in fog, are clearly exceptions. Distribution of cranes observed in different seasons on the ground and at different space levels is given in Table 4. In total 33.2% of observed cranes were found on the ground, 24.4% flying below the rotor swept area, 26.5% at the rotor level and 15.4% at the passage height above the rotor. Within this general pattern there is pronounced variation between different areas during seasons (details in *Appendix* Tables B), with the highest variation noted for the share of birds observed on the ground during migration periods. During autumn migration the variance in this parameter is the highest, while the numbers of birds observed on the ground are lower. An example (Figure 3) shows the height distribution of the flying cranes during spring migration. It shows that different patterns of spatial distribution occur in different areas. In a few areas (A, B, D2, and H) most flying cranes are observed at the highest level, usually well above the swept area and thus safe from collision. These areas are mainly passage areas, while those with a large share of birds flying low, below the rotor, are close to feeding/resting/roosting places. Two large crane roosts are known along the Polish Baltic coast: Krakulice in Łeba National Park and Bielawskie Błota on the northernmost part of the coast. In contrast to the share of birds observed on the ground, variation between areas as to the level of observed movements was noted during breeding and dispersion periods. It is possible that at this time the birds' behaviour depends mainly on local landscape properties.

Table 4
Percentage shares of individuals observed on the ground and flying at different levels

	N	Ground	Below	Rotor	Above
Spring	18 618	6 223	3 534	4 978	3 877
		33.4%	19.0%	26.7%	20.8%
Breeding	7 479	2 797	2 793	1 503	301
		37.4%	37.3%	20.1%	4.0%
Dispersion	9 676	4 965	3 006	1 172	447
		51.3%	31.1%	12.1%	4.6%
Autumn	69 072	21 078	16 364	19 931	11 406
		30.5%	23.7%	28.8%	16.5%
Winter	836	79	142	387	220
		9.4%	17.0%	46.3%	26.3%
TOTAL	**105 681**	**35 142**	**25 839**	**27 971**	**16 251**
		33.2%	**24.4%**	**26.5%**	**15.4%**

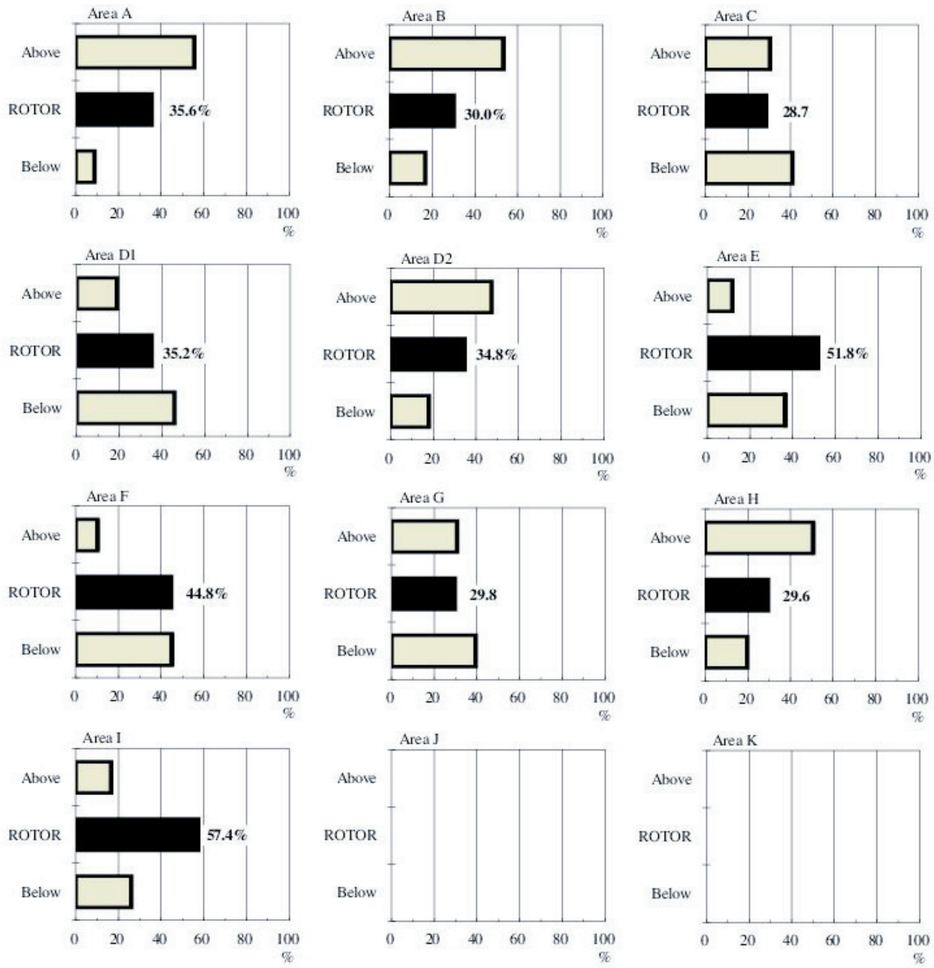

Fig. 3. Air levels used by flying cranes in different study areas

Correlations between the parameters discussed above and the number of observed birds are weak or very weak, and positive but not reaching the level of statistical significance.

Directionality of migrations

For most migrants directions of movements are not sufficiently well known. However, general papers on bird migration in Central Europe show that there is an area of variation in directions of movement due to crossing of the main European flyways: western, called 'Atlantic' – to southwestern Europe and further to western parts of Africa; 'Apennine' – guiding birds to central parts of the Mediterranean region and Central Africa; and 'Balkan', a SE-directed flyway to the Middle East and further on to East Africa. Cranes observed on migration in Poland unquestionably move mainly along the Apennine flyway, and those coming from Sweden along the SE flyway.

According to the monitoring observations, crane migration in northern Poland is dominated by birds moving along the coast in W to SW directions; the coast is a clear guiding line at this stage of autumn migration (Figure 4). The same birds could be observed several times at monitoring sites located there. In spring this guiding power is even more clearly visible (Figure 5). Exceptions are visible only in the westernmost observation area A, where there is a good share of birds directed NNE, which can reach Sweden, and in the northernmost point of Poland (area D2), where many birds, which must fly over the Baltic, take the northern direction. In autumn the birds following the SE flyway are difficult to see during observations as they cross the line of the coast only once, so that the probability of seeing them more times is low. The best visibility of this direction of flights is at localities within area C, where there is an optimal landing area for different species of birds starting from Skania and Bornholm and heading southeast. The only cranes observed in area K in south-eastern Poland flew in the SE direction.

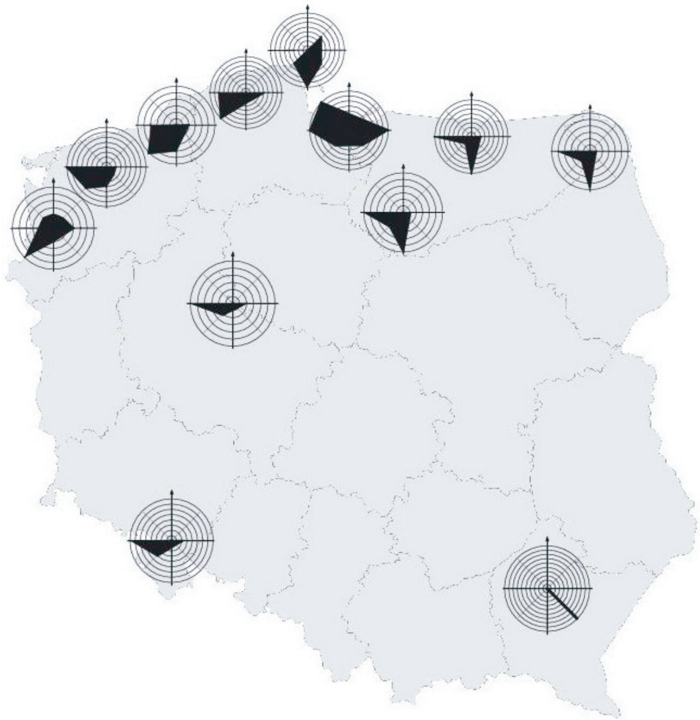

Fig. 4. Directions of observed flights of cranes in different study areas (compare Fig. 1) in autumn

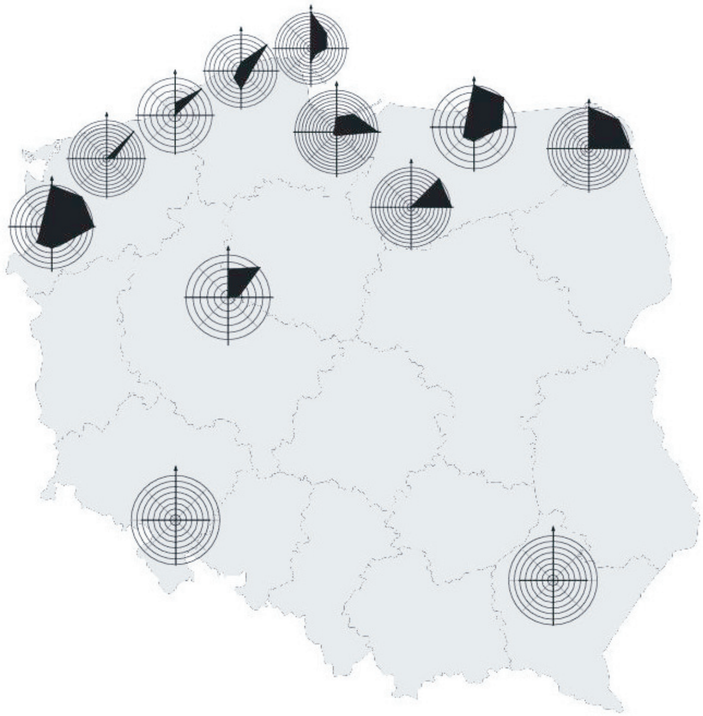

Fig. 5. Directions of observed flights of cranes in different study areas (compare Fig. 1) in spring

CONCLUSIONS

Monitoring observations at pre-investment wind farm sites, if performed and evaluated using the standardized method, can provide some valuable ornithological information on many common bird species, including those listed in Appendix 1 of the EU Directive. The most important information that could be obtained would concern the following:

1. the distribution of the species in different seasons
2. variation in expected collision rates at different sites, and thus better evaluation of the site's value as the location for the wind farm
3. migratory behaviour in terms of the height of diurnal migration and directions during spring and autumn passages

However, there is an urgent need to perform post-investment monitoring at working farms and to compare the results with those of monitoring done prior to the construction of the farm.

LITERATURE

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Appendix TA-1 – Spring

Basic observations and result parameters – spring. Areas as in Figure 1. Controls – number of days per site, Hours – total number of hours spent in the field, *N* ind. – individuals observed, *N* est. – number of individuals estimated to visit the site during the year, Col. 1 – estimated collision rate per turbine per year, *N* years – one collision expected within *N* years.

Area		Controls	Hours	*N* ind.	*N*/hour	*N* est.	Col. 1	*N* years
A	*Avg*	6.4	34.45	272	6.5	8 716	0.0829	12.0
	SD	2.8	17.93	295	6.5	8 457	0.1099	
	Median	7.0	37.50	205	4.9	6 563	0.0200	
	Maximum			1 069	21.9	27 718	0.2742	
B	*Avg*	6.7	45.86	78	1.7	1 896	0.0570	17.5
	SD	1.6	20.36	73	1.4	1 590	0.1059	
	Median	7.0	42.75	60	1.2	1 712	0.0000	
	Maximum			296	5.5	7 390	0.3975	
C	*Avg*	7.2	49.98	80	1.6	2 107	0.0441	22.7
	SD	0.7	19.40	102	1.6	2 134	0.0779	
	Median	7.0	40.00	49	1.2	1 627	0.0200	
	Maximum			361	5.4	7 350	0.2717	
D1	*Avg*	7.3	40.33	242	7.9	12 246	0.0789	12.7
	SD	1.2	20.32	233	10.7	18 507	0.0995	
	Median	8.0	35.50	162	3.5	4 760	0.0300	
	Maximum			690	42.7	76 218	0.3267	
D2	*Avg*	7.0	34.97	153	4.5	6 101	0.0951	10.5
	SD	2.1	10.19	155	3.9	5 042	0.1082	
	Median	7.5	37.63	112	4.7	6 457	0.0550	
	Maximum			672	17.1	21 613	0.3753	
E	*Avg*	6.2	34.12	77	2.2	2 531	0.1182	8.5
	SD	2.4	19.49	94	1.9	2 236	0.1344	
	Median	6.0	30.00	59	1.8	1 978	0.0800	
	Maximum			458	7.4	9 000	0.4103	
F	*Avg*	5.1	24.50	115	4.4	5 268	0.1487	6.7
	SD	2.5	12.16	173	5.0	6 438	0.1765	
	Median	4.0	20.00	72	2.3	2 373	0.1110	
	Maximum			733	19.8	24 888	0.7597	
G	*Avg*	6.0	29.33	156	5.5	5 981	0.0964	10.4
	SD	0.0	0.94	108	3.9	4 073	0.0167	
	Median	6.0	30.00	96	3.2	3 480	0.0900	
	Maximum			308	11.0	11 725	0.1193	
H	*Avg*	6.0	29.56	24	0.9	1 234	0.0821	12.2
	SD	0.7	4.18	18	0.7	1 094	0.0729	
	Median	6.0	30.00	24	0.7	991	0.0650	
	Maximum			46	2.0	2 955	0.1982	
I	*Avg*	5.4	28.83	193	6.1	8 627	0.0691	14.5
	SD	1.5	13.29	302	9.7	17 046	0.1049	
	Median	6.0	30.50	68	2.5	3 255	0.0000	
	Maximum			1 147	36.4	65 085	0.3669	

Area		Controls	Hours	*N* ind.	*N*/hour	*N* est.	Col. 1	*N* years
J	*Avg*	6.7	32.83	7	0.2	402	0.0676	14.8
	SD	0.5	2.20	5	0.2	284	0.0956	
	Median	7.0	34.00	11	0.3	603	0.0000	
	Maximum			11	0.4	603	0.2099	
K	*Avg*	7.4	38.23	0	0.0	0	0.0000	
	SD	1.2	8.81	0	0.0	0	0.0000	
	Median	7.0	38.80	0	0.0	0	0.0000	
	Maximum			1	0.0	0	0.0000	

Appendix TA-2 – Breeding
Basic observations and result parameters – breeding period. Explanations as for Table TA-1.

Area		Controls	Hours	N ind.	N/hour	N est.	Col. 1	Years
A	*Avg*	5.7	29.66	55	1.3	2 267	0.0264	37.9
	SD	3.5	20.39	84	1.7	3 388	0.0302	
	Median	4.0	18.50	33	0.7	913	0.0100	
	Maximum			302	5.9	11 473	0.0700	
B	*Avg*	3.2	18.39	22	1.0	760	0.0119	83.9
	SD	2.4	12.19	49	1.4	1 696	0.0316	
	Median	2.5	13.88	8	0.5	314	0.0000	
	Maximum			209	4.5	7 158	0.1006	
C	*Avg*	4.3	23.15	31	2.1	984	0.0340	29.4
	SD	3.0	13.44	41	4.7	980	0.0664	
	Median	2.8	16.13	22	0.7	760	0.0000	
	Maximum			142	16.2	2 393	0.1884	
D1	*Avg*	4.1	21.25	124	4.9	3 151	0.0475	21.0
	SD	2.4	10.95	232	12.9	3 736	0.1145	
	Median	5.0	25.00	20	0.4	953	0.0000	
	Maximum			905	52.6	10 600	0.4291	
D2	*Avg*	5.9	29.58	71	2.3	3 550	0.1179	8.5
	SD	2.7	13.54	119	3.6	6 449	0.1463	
	Median	6.0	30.00	29	1.0	1 415	0.0700	
	Maximum			495	14.1	26 915	0.4533	
E	*Avg*	5.4	27.10	58	5.6	1 981	0.0610	16.4
	SD	2.3	13.55	201	27.5	4 007	0.1952	
	Median	5.0	25.00	6	0.3	324	0.0000	
	Maximum			1 185	163.4	19 615	1.0927	
F	*Avg*	6.7	32.54	38	2.1	1 987	0.0913	11.0
	SD	2.9	13.46	24	3.7	1 163	0.0960	
	Median	6.0	29.38	30	0.8	1 868	0.0750	
	Maximum			100	15.2	3 805	0.3114	
G	*Avg*	6.0	30.00	41	1.4	2 695	0.0438	22.8
	SD	0.0	0.00	18	0.6	1 219	0.0124	
	Median	6.0	30.00	41	1.4	2 643	0.0413	
	Maximum			63	2.1	4 213	0.0600	

Area		Controls	Hours	N ind.	N/hour	N est.	Col. 1	Years
H	*Avg*	5.5	28.69	5	0.2	375	0.1202	8.3
	SD	1.1	4.67	7	0.2	650	0.2082	
	Median	5.5	27.13	2	0.1	0	0.0000	
	Maximum			17	0.6	1 500	0.4809	
I	*Avg*	6.2	33.62	48	1.6	3 271	0.0317	31.5
	SD	2.8	17.58	61	2.4	5 274	0.0600	
	Median	6.0	26.00	45	0.8	1 060	0.0000	
	Maximum			241	9.5	20 375	0.2020	
J	*Avg*	7.3	35.25	0	0.0	0	0.0000	–
	SD	2.4	15.40	0	0.0	0	0.0000	
	Median	9.0	45.25	0	0.0	0	0.0000	
	Maximum			0	0.0	0	0.0000	
K	*Avg*	5.5	35.75	1	0.0	0	0.0000	–
	SD	1.6	13.18	1	0.0	0	0.0000	
	Median	5.0	32.00	0	0.0	0	0.0000	
	Maximum			4	0.2	0	0.0000	

Appendix TA-3 – Dispersion
Basic observations and result parameters – dispersion. Explanations as for Table TA-1.

Group		Controls	Hours	*N* ind.	*N*/hour	*N* est.	Col. 1	Years
A	*Avg*	5.5	30.45	304	10.8	25 499	0.0933	10.7
	SD	1.5	9.76	371	14.1	32 164	0.1457	
	Median	5.0	26.50	244	7.3	19 708	0.0076	
	Maximum			1 237	50.5	114 868	0.4651	
B	*Avg*	4.4	29.52	18	1.2	1 215	0.0060	166
	SD	1.7	15.10	27	2.3	2 832	0.0224	
	Median	5.0	27.00	8	0.4	348	0.0000	
	Maximum			116	8.9	11 930	0.0900	
C	*Avg*	5.1	29.64	28	1.0	1 844	0.0056	180
	SD	1.8	12.31	27	1.0	2 055	0.0107	
	Median	5.0	25.00	22	0.5	928	0.0000	
	Maximum			74	3.0	5 865	0.0300	
D1	*Avg*	3.9	22.70	150	11.8	5 730	0.0573	17.5
	SD	1.9	14.05	248	24.3	8 750	0.1357	
	Median	4.0	23.50	29	1.3	3 158	0.0000	
	Maximum			905	88.3	30 028	0.5248	
D2	*Avg*	5.9	29.58	39	1.4	2 563	0.1220	8.2
	SD	2.2	10.40	28	1.1	1 978	0.1579	
	Median	5.0	25.50	29	1.0	1 443	0.0300	
	Maximum			117	4.6	6 838	0.4351	

Group		Controls	Hours	*N* ind.	*N*/hour	*N* est.	Col. 1	Years
E	*Avg*	5.9	28.82	36	1.2	2 245	0.0613	16.3
	SD	1.5	7.60	65	2.1	4 192	0.1561	
	Median	6.0	30.00	7	0.3	457	0.0000	
	Maximum			293	10.7	21 595	0.7390	
F	*Avg*	5.7	27.36	69	3.2	4 540	0.0878	11.4
	SD	1.7	8.31	80	5.1	4 744	0.1193	
	Median	5.5	27.50	42	1.4	2 567	0.0300	
	Maximum			309	20.6	16 920	0.3172	
G	*Avg*	6.0	30.00	97	3.2	6 667	0.0878	11.4
	SD	0.0	0.00	32	1.1	2 265	0.1193	
	Median	6.0	30.00	95	3.2	6 555	0.0070	
	Maximum			137	4.6	9 495	0.2565	
H	*Avg*	5.5	28.31	24	0.8	1 569	0.0274	36.5
	SD	0.5	2.03	25	0.9	1 618	0.0475	
	Median	5.5	28.88	19	0.7	1 289	0.0000	
	Maximum			59	2.1	3 698	0.1096	
I	*Avg*	4.5	23.81	31	1.5	2 539	0.0367	27.3
	SD	1.3	8.32	25	1.3	2 330	0.0495	
	Median	4.0	20.00	25	1.1	1 538	0.0000	
	Maximum			73	4.2	6 520	0.1668	
J	*Avg*	4.3	21.83	2	0.1	139	0.0000	–
	SD	0.5	3.88	3	0.1	197	0,0000	
	Median	4.0	22.00	0	0.0	0	0.0000	
	Maximum			6	0.3	418	0.0000	
K	*Avg*	4.9	30.45	0	0.0	0	0.0000	–
	SD	0.8	7.88	0	0.0	0	0.0000	
	Median	5.0	27.50	0	0.0	0	0.0000	
	Maximum			0	0.0	0	0.0000	

Appendix TA-4 – Autumn

Basic observations and result parameters – autumn. Explanations as for Table TA-1.

Area		Controls	Hours	N ind.	N/hour	N est.	Col. 1	Years
A	*Avg*	10.1	53.14	1 017	23.6	28 912	0.0680	14.7
	SD	2.0	24.92	1 329	34.4	36 530	0.0814	
	Median	10.0	42.00	648	5.3	8 973	0.1740	
	Maximum			4 017	95.6	113 510	0.2331	
B	*Avg*	9.8	82.00	197	3.4	6 202	0.0693	14.4
	SD	3.1	42.29	258	5.5	9 937	0.0835	
	Median	10.0	68.38	70	1.2	2 213	0.0350	
	Maximum			1 013	19.5	33 183	0.3116	
C	*Avg*	9.9	73.13	300	3.1	7 536	0.0364	27.5
	SD	0.7	32.98	361	3.7	8 956	0.0620	
	Median	10.0	54.50	131	1.2	3 285	0.0050	
	Maximum			1 179	12.1	25 203	0.2110	

Area		Controls	Hours	N ind.	N/hour	N est.	Col. 1	Years
D1	*Avg*	9.1	52.83	2 287	45.7	62 774	0.0424	23.6
	SD	1.5	28.01	3 971	67.9	87 452	0.0624	
	Median	9.0	50.00	778	20.3	34 900	0.0100	
	Maximum			12 725	243.5	309 918	0.2273	
D2	*Avg*	9.1	43.97	123	2.6	5 295	0.2473	4.0
	SD	2.9	13.65	128	2.8	5 756	0.2374	
	Median	8.5	40.25	66	1.2	3 318	0.1773	
	Maximum			392	8.5	21 485	0.8213	
E	*Avg*	8.4	40.77	224	2.5	7 779	0.1344	7.4
	SD	3.8	19.59	826	4.2	20 542	0.1852	
	Median	8.0	35.50	20	0.5	733	0.0014	
	Maximum			4 907	14.3	117 298	0.5851	
F	*Avg*	8.1	37.05	384	13.2	21 512	0.2048	4.9
	SD	2.7	10.63	674	28.5	48 317	0.2355	
	Median	7.0	36.50	108	2.1	3 775	0.0700	
	Maximum			2 775	113.3	198 305	0.7054	
G	*Avg*	6.3	31.67	78	2.3	3 498	0.0769	13.0
	SD	0.5	2.36	92	2.6	3 983	0.0552	
	Median	6.0	30.00	15	0.5	805	0.1038	
	Maximum			208	5.9	9 128	0.1269	
H	*Avg*	7.5	35.94	184	5.0	8 728	0.0827	12.1
	SD	1.1	5.24	260	6.8	12 520	0.1432	
	Median	7.5	36.38	51	1.6	2 280	0.0000	
	Maximum			632	16.7	30 350	0.3306	
I	*Avg*	6.8	35.25	59	1.8	2 977	0.1115	9.0
	SD	1.8	10.27	67	2.1	3 718	0.1722	
	Median	7.0	36.50	26	0.7	778	0.0000	
	Maximum			178	7.0	12 750	0.4701	
J	*Avg*	11.0	53.00	0	0.0	0	0.0000	–
	SD	6.4	30.45	0	0.0	0	0.0000	
	Median	7.0	33.50	0	0.0	0	0.0000	
	Maximum			0	0.0	0	0.0000	
K	*Avg*	8.5	43.18	29	0.6	348	0.0082	122
	SD	5.0	23.61	93	1.9	1 102	0.0259	
	Median	8.0	43.25	0	0.0	0	0.0000	
	Maximum			323	6.8	3 833	0.0900	

Appendix TA-5 – Winter

Basic observations and result parameters – winter. Explanations as for Table TA-1.

Area		Controls	Hours	*N* ind.	*N*/hour	*N* est.	Col. 1	Years
A	*Avg*	6.8	32.16	1	0.1	0	0.0000	–
	SD	2.4	24.04	2	0.1	0	0.0000	
	Median	7.0	25.75	0	0.0	0	0.0000	
	Maximum			4	0.3	0	0.0000	

Area		Controls	Hours	*N* ind.	*N*/hour	*N* est.	Col. 1	Years
B	*Avg*	7.3	54.12	3	0.1	21	0.0000	–
	SD	2.8	37.06	5	0.1	53	0.0000	
	Median	7.0	36.00	0	0.0	0	0.0000	
	Maximum			16	0.4	155	0.0000	
C	*Avg*	8.0	51.83	5	0.1	109	0.0000	–
	SD	1.7	25.68	9	0.2	222	0.0000	
	Median	7.5	38.88	0	0.0	0	0.0000	
	Maximum			27	0.6	740	0.0000	
D1	*Avg*	7.1	34.30	0	0.0	0	0.0000	–
	SD	2.0	22.26	1	0.1	0	0.0000	
	Median	7.0	33.00	0	0.0	0	0.0000	
	Maximum			2	0.2	0	0.0000	
D2	*Avg*	6.7	31.16	5	0.3	145	0.0006	-
	SD	3.0	16.43	8	0.5	286	0.0024	
	Median	6.5	30.00	1	0.0	0	0.0000	
	Maximum			30	1.7	985	0.0100	
E	*Avg*	5.3	23.16	15	0.5	688	0.0098	102
	SD	1.8	11.07	79	2.4	3 807	0.0569	
	Median	6.0	24.25	0	0.0	0	0.0000	
	Maximum			475	14.3	22 865	0.3415	
F	*Avg*	5.1	20.77	2	0.1	58	0.0143	70.0
	SD	1.8	9.45	6	0.2	146	0.0515	
	Median	6.0	19.63	0	0.0	0	0.0000	
	Maximum			22	0.8	498	0.2000	
G	*Avg*	6.7	20.67	0	0.0	0	0.0000	–
	SD	0.9	3.77	0	0.0	0	0.0000	
	Median	6.0	18.00	0	0.0	0	0.0000	
	Maximum			0	0.0	0	0.0000	
H	*Avg*	5.8	24.19	1	0.0	0	0.0000	–
	SD	1.3	8.73	1	0.0	0	0.0000	
	Median	6.0	24.88	0	0.0	0	0.0000	
	Maximum			3	0.1	0	0.0000	
I	*Avg*	6.6	29.54	5	0.2	152	0.0008	–
	SD	1.8	17.80	11	0.4	444	0.0027	
	Median	6.0	25.00	2	0.1	0	0.0000	
	Maximum			43	1.7	1 663	0.0100	
J	*Avg*	5.3	21.75	1	0.0	0	0.0000	–
	SD	0.5	3.14	1	0.1	0	0.0000	
	Median	5.0	22.73	0	0.0	0	0.0000	
	Maximum			3	0.1	0	0.0000	
K	*Avg*	5.3	20.84	0	0.0	0	0.0000	–

Appendix TB-1 – Spring
Percentages of birds observed on the ground and shares of individuals flying at different levels

Area	Total	% of total on ground	% of birds flying		
			below	ROTOR	above
A	2 991	23.1	8.9	35.6	55.6
B	1 251	8.2	16.6	30.0	53.4
C	796	57.0	40.8	28.7	30.5
D1	3 632	50.0	45.9	35.2	18.8
D2	2 451	30.8	17.8	34.8	47.4
E	2 681	24.5	36.4	51.8	11.8
F	1 721	13.6	45.0	44.8	10.2
G	469	14.1	39.5	29.8	30.8
H	94	24.5	19.7	29.6	50.7
I	2 509	56.1	26.1	57.4	16.5
Avg		**30.19**	29.67	**37.77**	32.57
SD		**17.08**	12.73	**9.62**	17.03
V %		**57**	43	**25**	52

Appendix TB-2 – Breeding
Percentages of birds observed on the ground and shares of individuals flying at different levels

Area	Total	% of total on ground	% of birds flying		
			below	ROTOR	above
A	602	51.7	66.0	19.5	14.5
B	355	18.0	81.4	15.2	3.4
C	307	31.6	20.6	78.5	1.0
D1	1 855	30.1	79.4	10.8	9.8
D2	1 069	27.4	64.7	29.5	5.8
E	1 981	47.8	25.4	71.3	3.3
F	527	45.9	54.6	36.2	9.2
G	124	58.9	86.3	9.8	3.9
H	21	33.3	35.7	64.3	0.0
I	630	32.4	87.1	7.7	5.2
Avg		**37.71**	60.12	**34.28**	5.61
SD		**12.05**	23.85	**25.87**	4.19
V %		**32**	40	**75**	75

Appendix TB-3 – Dispersion
Percentages of birds observed on the ground and shares of individuals flying at different levels

Area	Total	% of total on ground	% of birds flying		
			below	ROTOR	above
A	3 344	74.1	34.0	62.6	3.4
B	293	13.0	77.3	11.1	11.5
C	253	56.1	73.9	6.3	19.8
D1	2 251	32.7	88.3	6.7	4.9
D2	542	58.7	55.0	36.2	8.7
E	1 230	36.3	62.3	30.3	7.4
F	969	48.0	39.4	19.9	40.8
G	291	33.7	73.6	26.4	0.0
H	97	71.1	64.3	35.7	0.0
I	400	43.0	82.1	9.2	6.6
Avg		**46.67**	65.02	**24.44**	10.311
SD		**17.90**	16.92	**16.83**	11.56
V %		**38**	26	**69**	112

Appendix TB-4 – Autumn
Percentages of birds observed on the ground and shares of individuals flying at different levels

Area	Total	% of total on ground	% of birds flying		
			below	ROTOR	above
A	11 191	77.7	17.6	45.6	36.9
B	3 151	4.0	13.2	30.8	56.1
C	3 002	17.2	3.9	54.2	41.9
D1	34 301	24.0	53.0	27.6	19.4
D2	1 970	12.8	15.9	69.8	14.3
E	7 631	32.8	12.3	66.0	21.7
F	5 765	4.6	7.8	74.1	18.2
G	235	14.0	8.0	25.0	67.0
H	734	48.4	75.7	11.1	13.2
I	769	13.3	11.9	61.0	27.1
Avg		**24.88**	21.93	**46.52**	31.58
SD		**21.71**	22.14	**20.67**	17.53
V %		**87**	101	**44**	56