Monitoring of wintering geese in the AES Geo Energy Wind Farm "Sveti Nikola" territory and the Kaliakra region in winter 2010/2011

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Contents

EXECUTIVE SUMMARY

Since 2009, AES Geo Energy OOD (AGE) has operated the Saint Nikola Wind Farm ("the Project" or "SNWF"). In 2008/2009 and 2009/2010 surveys of geese wintering in the region reported presence of the Red-breasted Goose (RBG), a globally threatened species. The surveys resulted in the first estimation of the number of geese flying through the wind farm territory and a Collision Risk Model predicting potential RBG mortality of colliding with operating turbine blades (see report for 2009/2010). As a result AGE proposed to have regular winter season surveys during the operation of the wind farm with the application of a radar, in line with provisions of the EMMP and requirements of Bulgarian Ministry of Environment and Waters.

The following main goals were set for the 2010/2011 survey:

1. Record winter bird activity specific to the Project area and evaluate dynamics of the activity between the three observed winter seasons;
2. Ascertain whether there is potential for the operating wind farm to have an adverse effect on the wintering birds (with a particular focus on RBG);
3. To apply mitigation measures in order to reduce mortality predicted by the collision risk model.

The wintering period of the geese in the region started in the middle of December (early January in the Project area) and ceased by the end of February in all three winter seasons including 2010/2011. Greater White-fronted Goose (GWFG) was the most common species recorded and the percentage occurrence of RBG in goose flocks was about 7 %. Greylag Goose was recorded sporadically and in small numbers and was not therefore considered at risk from the Project. Lesser White-fronted goose was not recorded in the wind farm territory for all three winter seasons. The duration of the 2010/2011 winter stay in the study area was similar for both RBG and GWFG with a concentration of over 90% of RBG being seen within 20 days (10 days in January and 10 days in February), corresponding to the coldest period of the winter. These results were similar to those from the 2008/2009 and 2009/2010 winters.

The flight altitudes of the geese from all species observed crossing the Project area were most intensive between 50 and 100 m above ground level. Flight activity of geese was greatest in the morning (7-9h) and, to a lesser extent, evening (16-18h). These findings were also similar in the 2008/2009 and 2009/2010 winters. It is also evident that an increasing propensity for geese to use the Black Sea as a roosting site over the three winters does not create an increasing risk of collision mortality from the Project. Rather, the use of the Black Sea is probably more indicative of increased hunting pressure at 'traditional' freshwater lakes forcing birds away from this vital resource. Consequently, more dispersed terrestrial sources of fresh water created by poorer land drainage and snow melt become increasingly important and, along with suitable feeding locations, explicatory of geese movements and distribution.

The monitoring of collision victims did not reveal any mortality of GWFG or RBG in the St. Nikola Wind Farm in the 2010/2011 winter. No intact carcasses or remains of any bird species was found in this period. The results strongly suggest that previous collision risk models based on precautionary measures are unrealistic and that the ability of geese to avoid collision risk is very close to 100 %. In the period Jan 10 – Jan 15 on several occasions the TSS, turbine shutdown system was applied. This may have prevented any geese colliding with turbines and may have contributed to the zero casualty rate.

INTRODUCTION

Background

AES Geo Energy OOD (AGE) have constructed the Saint Nikola Wind Farm (SNWF) consisting of 52 turbines (at 105m hub height and 150m tip height) in north-east Bulgaria, approximately 3-5 km inland from the Black Sea coast (Fig. 1). The Project area is close to the three main roosting sites of four goose species during the winter period December – February. This report presents the results of the third season's monitoring of wintering goose activity as detailed in the AGE's Environmental Monitoring and Management Plan (EMMP) for the Project. The protocol for the study aimed at recording qualitative and quantitative information about the characteristics of the wintering goose activity in the Project area concerning Collision Risk Assessment Model. The monitoring of collision victims for control of the model predictions was done in winter 2010/2011. This information was recorded to assess the possible impacts of the wind farm on wintering goose species.

Species Information

Detailed information for all species of geese as well as their behavioural characteristics was given in winter survey report 2008/2009 and 2009/2010 and is not repeated here.

Study Objectives

The Red-breasted Goose (*Branta ruficollis*) (RBG) is classed as globally endangered by the IUCN and threatened by BirdLife International (2004, 2005). The hinterland of the western Black Sea coast, including Bulgaria, is the main wintering ground of RBG, where flocks co-exist with other goose species, roosting on freshwater lakes and commuting to and from agricultural fields to feed during the day. Previous surveys have established that the area occupied by the Saint Nikola Wind Farm (SNWF) can be used by feeding RBG and this will therefore create a potential risk of mortality through goose flights leading to collision with moving rotor blades once the wind farm becomes operational (Zehtindjiev et al. 2009, hereafter termed "the 2008/09 winter report"). This risk was modelled by the 2008/09 and 2009/10 winter reports which concluded that whilst predicted mortality was not "significant" the risk was such that mitigation measures needed to be available to avoid any possibility of an adverse impact on the RBG population.

The following objectives were selected:

1. Record winter bird activity specific to the Project area and evaluate dynamics of the activity between the three observed winter seasons;
2. Ascertain whether there is potential for the operating wind farm to have an adverse effect on the wintering birds (with a particular focus on RBG);
3. To apply mitigation measures in order to reduce mortality predicted by the collision risk model.

METHODS

Study area

The Project area is located in NE Bulgaria, close to the Black Sea coast near the cape of Kaliakra. It lies between the roads from the village of Bulgarevo to St. Nikola (municipality of Kavarna), and the 1st class road E 87 Kavarna – Shabla (Fig.1). The Project area consists mainly of arable land of various crops, crossed by roads and shelter belts. The area is outside the Kaliakra NATURA 2000 site.

In order to collect comparable between the seasons information on the large scale movements of the wintering geese and their habits within the Project area, the survey and monitoring were set up to cover an area (study area) wider than but including the Project area (footprint of the wind farm) and adjacent agricultural fields in all three winter seasons including 2010/11 (Fig. 1).

Figure 1. Study area showing the monitoring area (red dashed line) and the location of the main roosting sites of geese: Durankulak, Shabla and Tuzla Lakes. The Project area is shown in blue.

Duration, personnel and equipment

The 2010/11 study repeated the same survey period as in the 2008/09 and 2009/10 winters: 10 December 2010 to 28 February 2011, covering a total of 78 days. This involved the period of the most intensive movements of wintering geese in the region of northern Bulgarian Black Sea coast (Dereliev et al. 2000, Georgiev et al. 2008).

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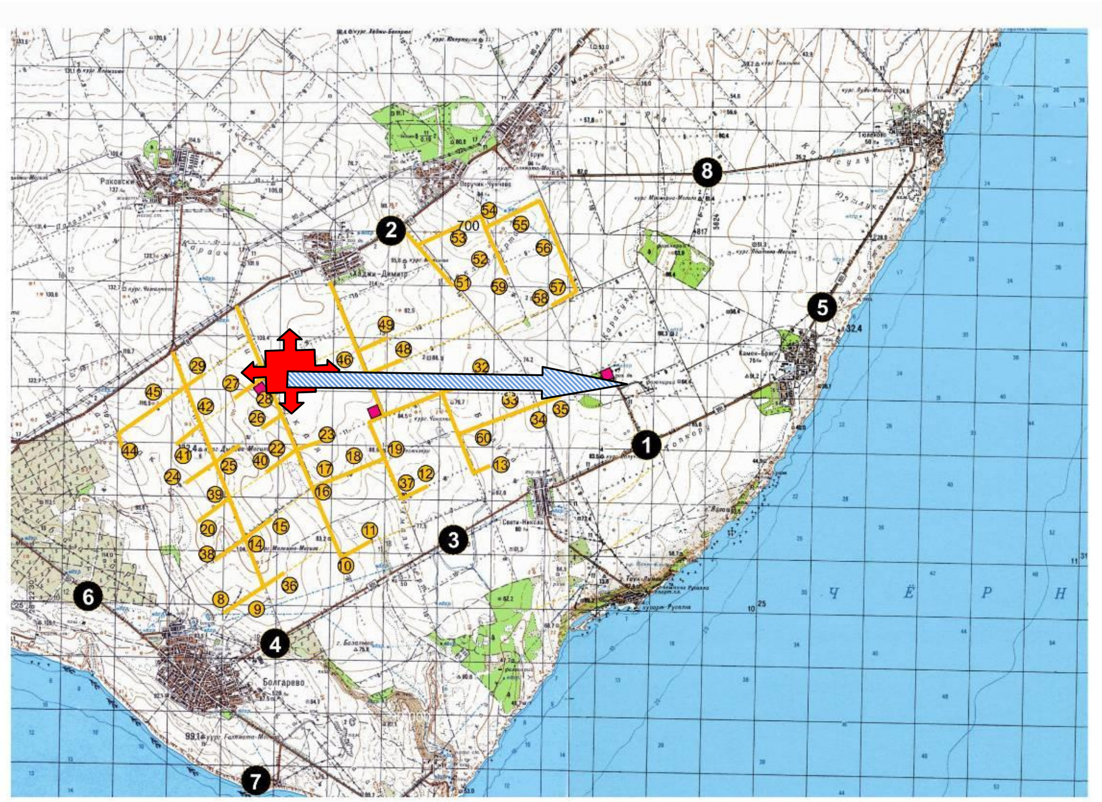

Figure 2. Location of the Project area in relation to the fixed Vantage Points (1 - 8) and the sector scanned by the radar.

Field observations followed census techniques according to Latta et al. (2005). Direct visual surveys of all passing birds were made daily from eight Vantage Points around the Project area (black dots: Fig. 2). (This was the same as in 2009/10 winter survey.) Point counts were performed by scanning the sky in all directions but focussed on the Project area and birds heading towards it.

The visual point surveys were supplemented by itinerant surveys throughout the Project area and surrounding agricultural fields, made as-and-when birds were seen to enter the Project area or its vicinity, and at least daily. Itinerant surveys were undertaken primarily to count and identify birds to species on the ground, thereby allowing the numbers of wintering geese feeding in the Project area and its environs to be ascertained. The overall number of birds per species was obtained by collating counts made simultaneously from at least three observation points.

All observers were qualified specialists carrying out the surveys of bird migration for many years:

Dr. Pavel Zehtindjiev
Senior Field Ornothologist
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Bulgarian Academy of Sciences

Victor Metodiev Vasilev
Senjor researcher in the Faculty of Biology
University of Shumen, Bulgaria
Member of BSPB since 1992

Dimitar Vladimirov Dimitrov
PhD student in Institute of Zoology, BAS,
Member of the BSPB since 2000

Ivailo Antonov Raykov
Museum of Natural History, Varna
PhD student,
Member of BSPB since 1999

Strahil Georgiev Peev
Student in Facultity of Biology
Sofia University

MSc Martin Petrov Marinov
Student in Facultity of Biology
Sofia University

Stefan Milenov Dimov
Student in Vartna University

The surveys were carried out using 10x binoculars and standard Admiral 20 – 60x telescopes, compass, GPS and digital camera.

Types of data collected

During all three surveys in 2008/09, 2009/10 and 2010/11 the following data were recorded:

- Species of birds
- Number of birds
- Distance of the flying birds from the observer
- Altitude of birds
- Direction of the flight
- Behaviour of the birds in relation to other existing wind farms in the region
- Other behavioural observations
- Weather conditions

Species
All geese flying in the surveyors' scope of view were identified to the level of species, if possible, and recorded. Because of the difficulty in distinguishing between similar species in harsh conditions (e.g. poor visibility, great distance, etc.), if exact identification was not possible both possible species were written down. If there was the possibility of a single RBG in a large flock of Greater White-fronted Geese then this was still recorded as an *Anser/Branta* flock. The proportions of RBG in flocks were also calculated using observations of mixed species flocks on the ground. Due to the greater precision of ground counts gathered during itinerant surveys, analytical preference was given to data collected on species composition by this method.

Numbers of geese
Surveyors counted all geese flying in their scope of view, regardless of the possibility of identification to species or higher taxonomic order (as described in the previous paragraph). For single birds or small flocks the number of birds and species composition were recorded according to units of individual birds. In larger flocks, when the counting of every single individual was impossible, numbers and composition were recorded according to units of 10 birds.

Distance from observer and flight height
The location of flying birds (distance from the observer) and their flight height were essential measures in order to determine whether flocks' flight lines and their height above ground would potentially make birds at risk of collision. The distance from the observation point was recorded for each bird or flock seen. The flight altitude of every single bird or flock was also recorded according to fixed bands of height.

Recording of both measures was facilitated by thorough familiarisation of the observers with the geography of the study area prior to observations starting. This familiarisation process included use of numerous land marks, their position and height relative to Vantage Points. The distance to land marks and their height were measured and calibrated in advance using GPS in the field and by reference to a topographic map on which they were notated.

Flight direction
The flight direction of birds was recorded according to 16 pre-defined geographic categories on which the birds were heading with respect to the observation point (each category corresponding to 22.5 degrees of the compass). These records were again facilitated by reference to land marks. The 16 categories were as follows: N (north), NNE (north-northeast), NE (northeast), ENE (east – northeast), E (east), NSE (east – southeast), SE (southeast), SSE (south – southeast), S (south), SSW (south – southwest), SW (southwest), WSW (west – southwest), W (west), WNW (west – northwest), NW (northwest), NNW (north – northwest). For the purposes of data entry and analysis, the direction of birds' flight was described in degrees.

Behaviour of birds in relation to other existing wind farms and other behavioural observations
In addition to surveys of the Project area and the vicinity, observations were also made during itinerant surveys, where possible, in relation to bird behaviour at other nearby operational wind farms, such as geese displaying avoidance behaviour in the vicinity of turbines. These

were recorded and described in detail. Additional observations concerning feeding and resting activities of birds were recorded during itinerant surveys.

Weather conditions

As weather likely affects the behaviour of the geese and thus potentially the objectivity of the surveys, the following measures were recorded:

- Wind direction
- Wind strength
- Air temperature
- Precipitation
- Visibility

Weather data were recorded at the start and end of each daily survey session as well as any time after the start when a considerable change in visibility occurred, such as created by episodes of fog or mist. Visibility was defined as the maximum distance (in metres) at which permanent land marks at known distance could be seen. Wind direction and strength as well as temperature were precisely measured by AGE through anemometer masts and kindly offered for analysis of data.

Recording and storage of data

The protocol adopted for the purposes of primary data processing was a modified version of the Protocol of Risk and Bird Mortality, used by the National Laboratory for Renewable Energy Sources of the USA (Morrison 1998). All the data were captured in a daily diary by each observer which were then processed and entered daily into an Excel database.

The diary was kept in the following manner:

1. At the start of each survey, the date and the exact hour were entered (the data were recorded by the astronomic hour, which is 1 hour behind the summer hour schedule, during the whole period of the study), as well as the name of the surveyor.
2. When detecting a bird or flock, observers first recorded the exact hour and minute, followed by the species, then the number of birds by species (see above), the horizontal distance from the watch point, flight altitude and the flight direction. After these obligatory data were recorded, additional notes on formation of flocks, landing birds with the exact location of landing etc., were also recorded. If any changes in weather or other interesting and/or important phenomena were observed, they were also entered in the diary with the exact time of the observation.
3. When finishing the daily survey, the exact time, weather conditions and the name of the surveyor were recorded again.

Collision monitoring protocol

The proposed collision monitoring methodology followed that developed in the USA for bird collision monitoring at wind farms (Morrison 1998). The detailed description of the protocol is given in the Own Ornithological Plan. Results of the monitoring are reported to the Regional Inspectorate of the Bulgarian Ministry of Environment and Waters in Varna every month. A final report will be prepared based on the results of the monitoring after a one-year operation period of the wind farm (March 2011).

It is well known that searches for victims of collision with operational wind turbines fail to find all dead birds, for several reasons, with the two principal factors being searcher efficiency (searchers fail to find all dead birds) and removal/disappearance of dead birds before the searcher can potentially find them. Accounting for these two potential biases can substantially improve estimates of collision mortality at operational wind farms derived from searches around turbine bases. Staged trials are typically undertaken in order to provide for such correction.

Such trials during winter 2009/2010 at the wind farm indicated that searches every 4 days would be appropriate during this season, in order to detect about half the numbers of any geese that may be killed. These were in contrast to comparable trials conducted during autumn 2009 and 2010 when the results suggested that searches every 7 days would detect about half of all medium to large body collision victims. All sets of trials showed that increasing search effort (i.e. increasing the interval search interval) would not generate proportionately greater confidence in documentation of mortality rates. The autumn trials were reasonably consistent across the two years as regards observer efficiency and removal of carcasses by (for example) scavengers. The winter trial showed that carcasses disappeared at a higher rate than during autumn; hence the need to search more frequently in winter to give a similar detection rate.

It is worth highlighting that the search protocol for victims of collision during the autumn migration is different to the protocol for the winter period, and that further efficiency and carcass removal trials, repeating those in 2009, were planned to be undertaken in the 2010/2011 winter. Unfortunately the winter period of 2010/2011 did not allow repetition of the trials because of increased veterinary requirements concerning risk of different pathogens distributed by the dead birds. It was therefore impossible to arrange legal conditions to use dead birds for the experiments in the wind farm territory in 2010/11. By practical necessity, the present study had to rely on those trials from the previous winter, although the search interval of individual turbines was typically less than 4 days.

Searches for collision victims were undertaken in 300 x 300 m plots centred on a turbine along transects 20 m apart, scanning with binoculars areas beyond the search plot when the searcher was at the edge of the plot. Searches were undertaken just before dark, or when no geese were present in the wind farm, in order to prevent any disturbance of geese in the wind farm. Searches were scheduled to start when geese were recorded in the wind farm area, and finish later in the winter when geese had departed the area. Searches were limited to those turbines which had presented a risk of collision, either because geese had flown or fed in their vicinity, and undertaken at a maximum of 4 days after geese had been in the vicinity. All collision victims were to be photographed, collected with notes on finding circumstances (e.g. GPS location, distance from transect, state of carcass, any tracks around carcass), and if necessary, subsequently submitted for veterinary scrutiny to clarify cause of death.

Radar Observations

The radar (Bridgemaster 65825H: Swiss BirdScan MS1) was a fixed pencil beam system, especially developed for the study of bird migration by the Swiss Ornithological Institute (http://www.vogelwarte.ch/home.php?lang=e&cap=projekte&subcap=vogelzug&file=../detail projects.php&projId=583) with the following specifications:

Transmitter Power: 25kW

Magnetron Frequency: 9410MHz, ±30MHz
Pulse Length / PRF: 0.05 µsec / 1800Hz (Short Pulse)
0.25 µsec / 1800Hz (Medium Pulse)
0.75 µsec / 785Hz (Long Pulse)
Pulse Generator: Solid state with pulse forming network
Receiver type: logarithmic with Low Noise Front End (LNFE)
Tuning: AFC / Manual
Intermediate Frequency: centred at 60MHz
Bandwith: 20MHz on short and medium pulses
3MHz on long pulse
Noise Factor: 5dB
Dynamic Range: 80dB
Weight: approx. 500 kg, excl. two wheeled trailer
Power connection standard: 1-phase 230V / approx. 1kW
Detection range: approx. 5 km (for small passerines) up to 7.5 km (for larger birds)

The radar operated continuously during daylight hours (06-21 hrs GMT) from 15 December 2010 to 28 February 2011 at a location designed to maximise coverage and minimise ground clutter confusion (Fig. 2). All radar observations were at 30 mills, as low as ground clutter permitted (equivalent to approximately 25-275 m elevation at 5 km distance). This recorded all flights of geese in the vicinity of the wind farm during the study period.

An interim Turbine Shutdown System (TSS) was discussed and synchronised with AES Geo Energy in November 2010. This TSS followed principles and experience developed during the preceding autumn 2010 migration season (see Report on that period) and was applied during the 2010/11 winter. Hence, in the 2010/11 winter when large flocks of geese approached groups of operational turbines conditions of low visibility, coordinated TSS actions with the wind farm operator, informed by measures described in the EMMP, were applied.

RESULTS

The 78 days of the study encompassed the whole period when geese were recorded in the region during 2010/11.

Total number of observed goose species and their numbers

Over 175,000 individual goose observations were recorded during the surveys (Table 1). In total, three species of goose were observed: RBG; Greater White-fronted Goose (GWFG) and Greylag Goose *Anser anser*. Additionally, two species of swans (*Cygnus* spp.) were observed (Table 1), but in such small numbers that their presence was not considered further. No Lesser White-fronted Geese were seen. Note that these records refer to visual counts of geese in the wider study area, and do not solely refer to those recorded only within the wind farm or documented by the radar.

Table 1. The number of observed birds of different species (data from visual observations).

	Species				
Date	***A. albifrons***	***A. anser***	***B. ruficollis***	***C. olor***	**Grand Total**
06.1.2011	3201	7	110		3318
07.1.2011	1121		5	137	1263
08.1.2011	3832		90		3922
09.1.2011	3545	9	11		3565
10.1.2011	18142	62	1189		19393
11.1.2011	17410		1100		18510
12.1.2011	30515		2197		32712
13.1.2011	24061		2245		26306
14.1.2011	1983	5	41		2029
15.1.2011	8445	3	1131	1	9580
16.1.2011	10935		1005		11940
17.1.2011	19169	10	1696		20875
18.1.2011	1572		20		1592
19.1.2011	253		36	5	294
03.02.2011	8200				8200
04.02.2011	6050				6050
05.02.2011	6000				6000
06.02.2011	250				250
07.02.2011	120				120
Grand Total	164804	96	10876	143	175919

The recorded numbers of all registered geese species were markedly lower than in 2008/09 and 2009/10 winter seasons.

Spatial distribution of feeding geese in the wind farm territory

The numbers of geese species observed in the wind farm territory and its vicinity in January and February are presented in Table 1. The first GWFG were recorded by observers in the territory in the beginning of January followed by an influx of RBG in the middle of the month. No geese were registered visually in the wind farm territory between 01 and 06, and 20 and 30 January. GWFG re-appeared according to visual observers within the study area from 1 – 6 February, but only small numbers of RBG were present. Observed dynamics in the number of geese and their feeding grounds between 06 and 20 of January and in early February are presented in Figures 3 -11 below. (Note that these refer only to records collected by the suite of human observers.)

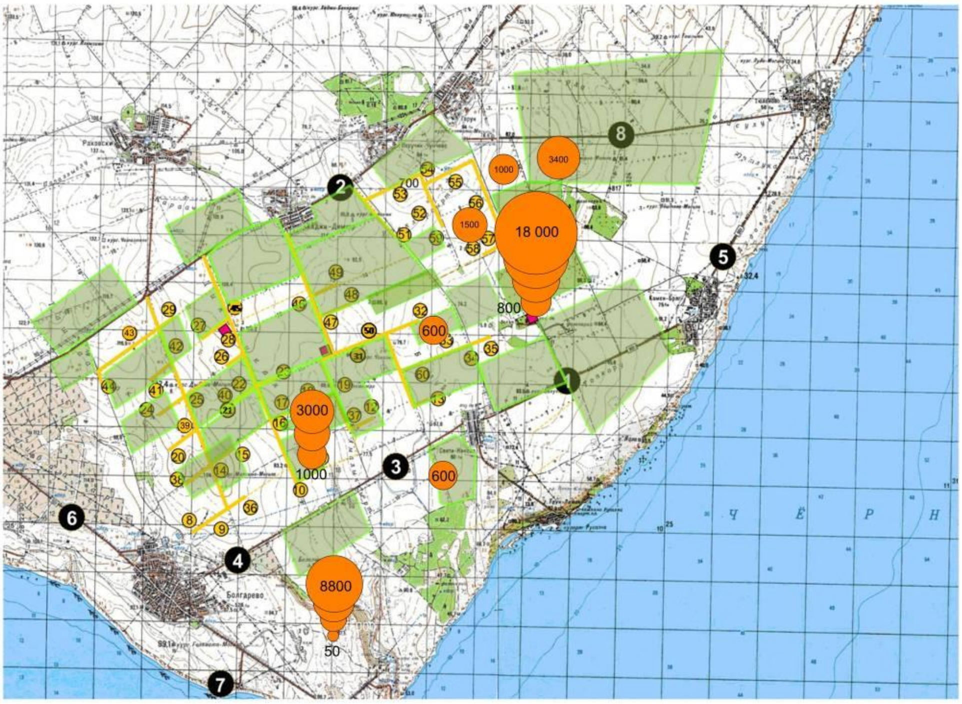

Figure 3. Distribution of feeding GWFG in the wind farm territory during the period 6 – 20 January (the maximum and minimum number is indicated and the available wheat fields are presented in green).

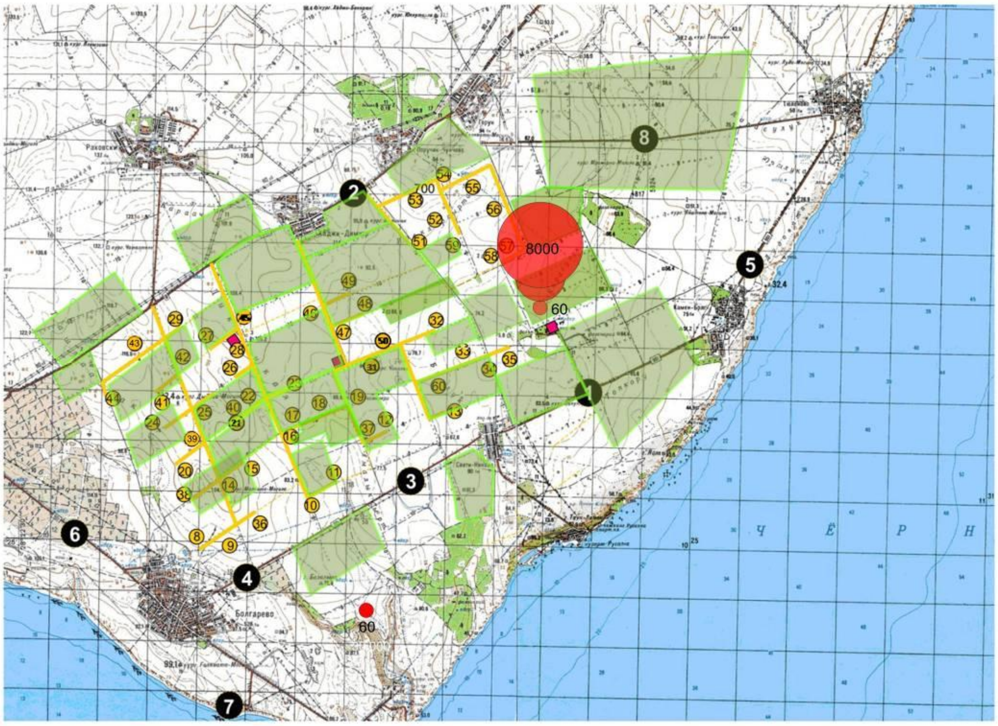

Figure 4. Distribution of feeding RBG in the wind farm territory in the period 6 – 20 January (the maximum and minimum number is indicated and the available wheat fields are presented in green).

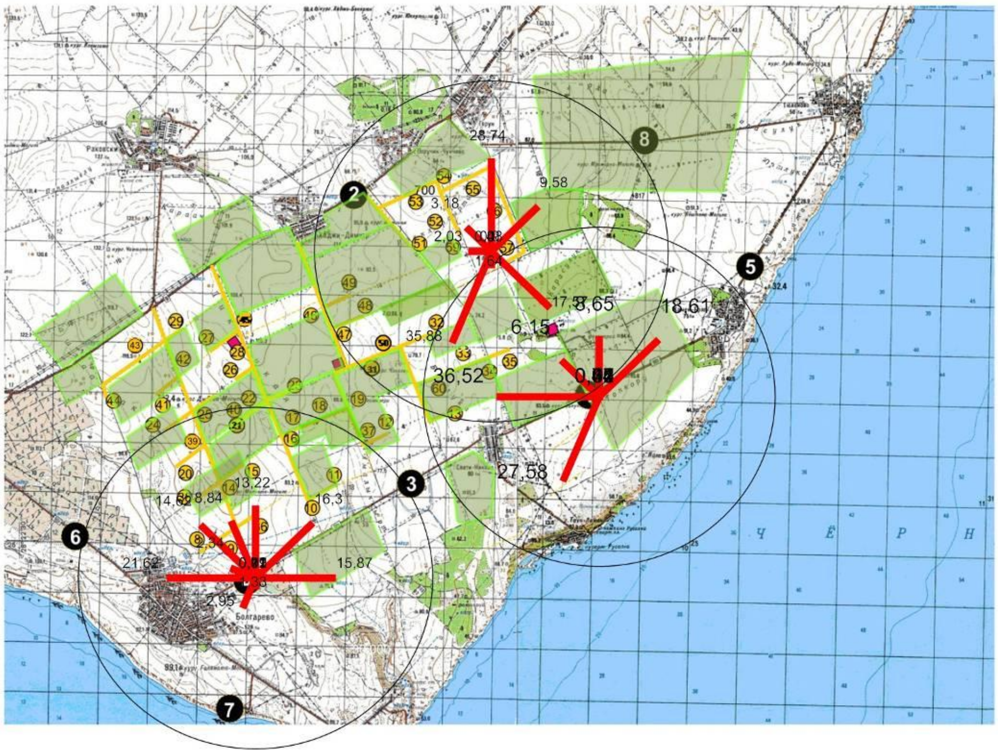

Figure 5. Proportion of the flight directions of all geese observed in morning records in the period 10 – 20 January, delineated by observation points, in the wind farm territory.

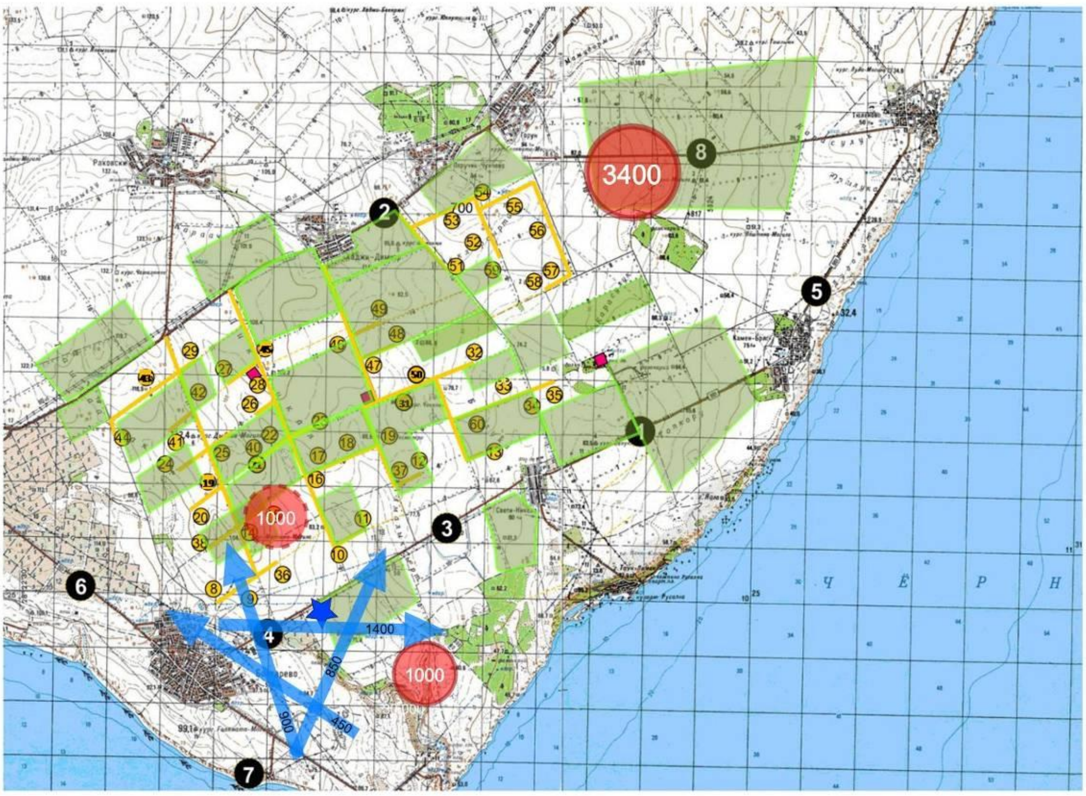

Figure 6. Number of feeding geese and observed movements 07.01.2011

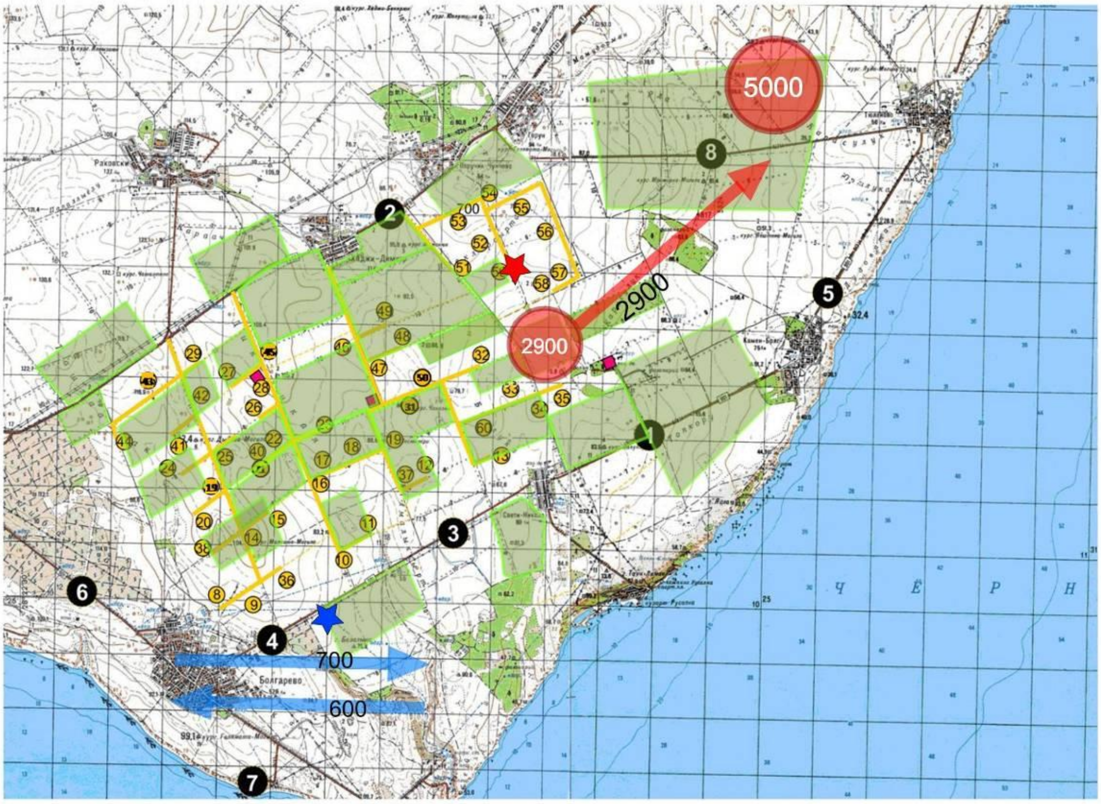

Figure 7. Numbers of feeding geese and observed movements 08.01.2011

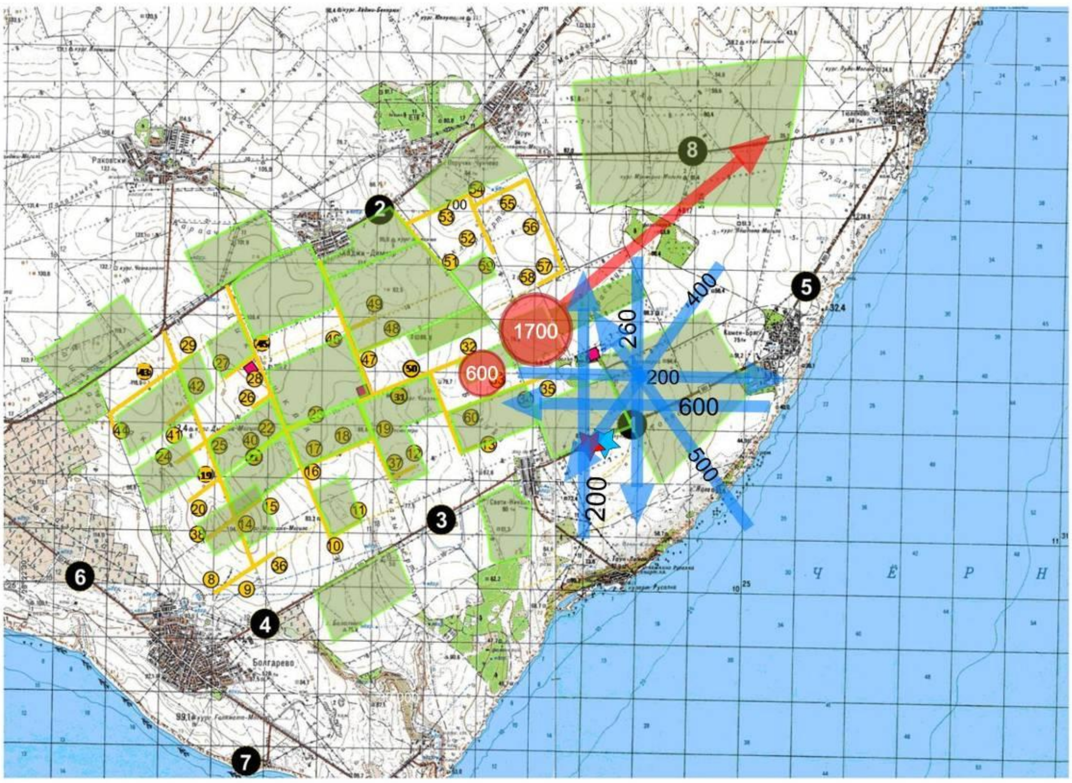

Figure 8. Numbers of feeding geese and observed movements 09.01.2011

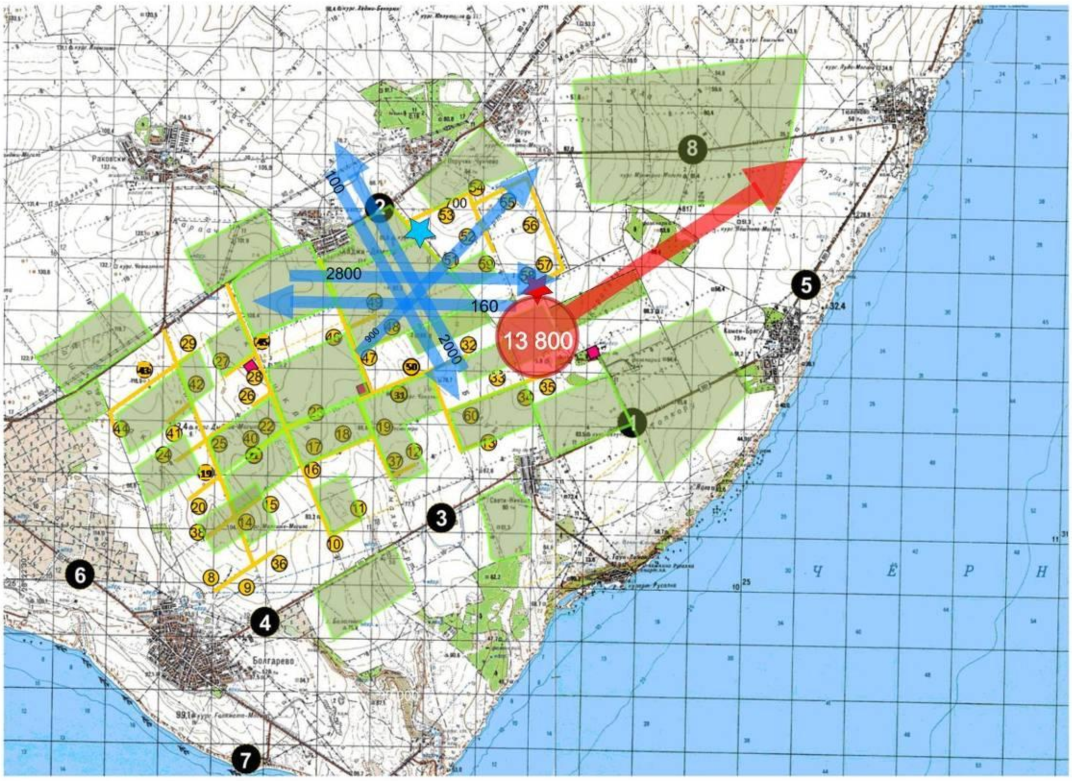

Figure 9. Numbers of feeding geese and observed movements 10.01.2011

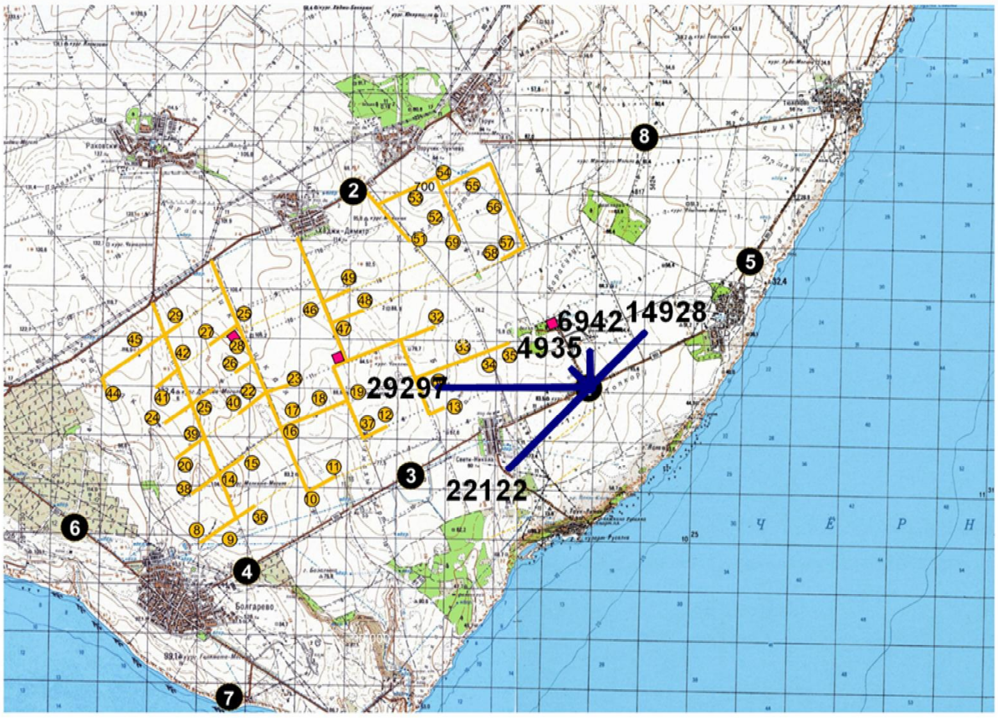

Figure 10. Summarized observed number of flights between 6 and 20 of January 2011.

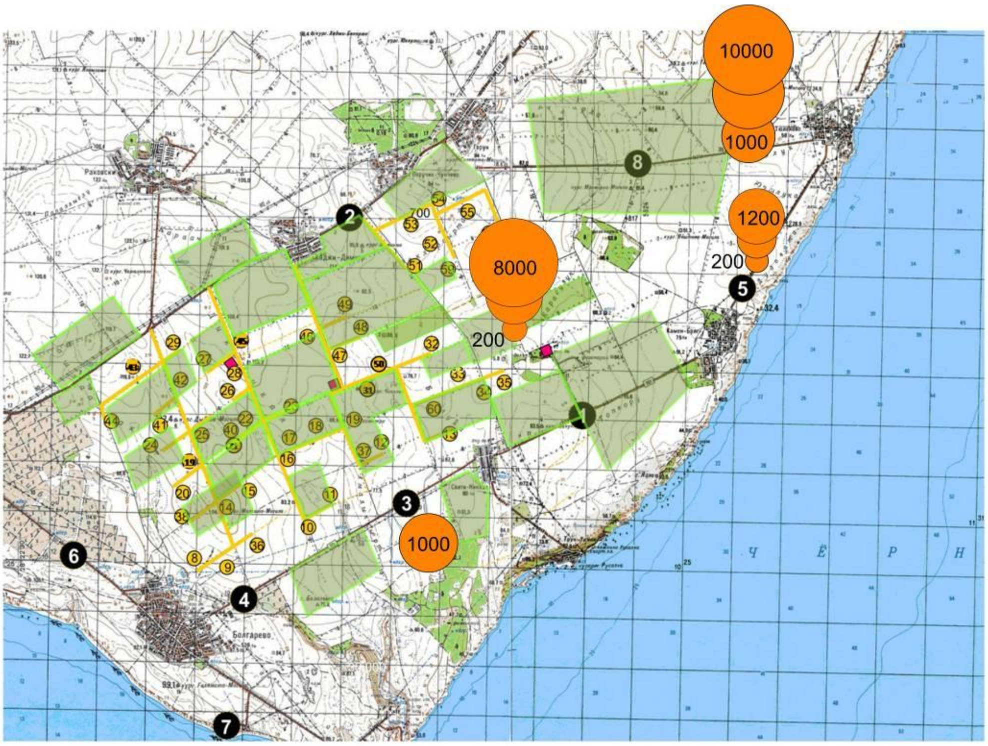

Figure 11. Distribution of feeding geese as documented by visual observation at the wind farm territory in February (the maximum and minimum number is indicated and the available wheat fields are presented in green).

In order to estimate the number of flights through the wind farm territory the flight directions of all geese in the morning were visually recorded when the birds were coming from the roosting sites. Proportions of flights in different directions through the wind farm territory for January are presented in Figure 5.

The observed flight directions in the mornings during 10 – 20 January 2011 (Fig. 5), when geese will have been coming from the roosting sites indicates a change in the behaviour of the geese, insofar as data collected during the 2008/09 and 2009/10 winters and the known ‘typical’ freshwater roost sites to the north of the Project area. Moreover, over 80% of such flights were also along a similar E-W axis in February. As for the results during January, the direction of these flights indicated a radical change in the behaviour of geese to roost in the sea along the coast (compared to records gathered in previous winters). Only around 10% of registered flights indicated movements along the coast in south or north directions that would be consistent with birds coming from the ‘traditional’ freshwater lake roost sites.

The records collected in 2011 strongly suggested that the majority of the geese were roosting on the sea, and without any of the spatial concentrations in incoming flights that would be expected if their origin was based at the locations of freshwater lakes to the north of the wind farm. Such adaptive behaviour may reflect increasing long term hunting pressure and disturbance for the last decade in the previously known main roosting sites – lakes Durankulak, Tuzla and Shabla.

In other words, the data collected in the wind farm area suggested that the geese which appeared in the vicinity of the wind farm had been roosting on the sea, and not on the freshwater lakes to the north. The most likely explanation for this shift in behaviour is increased hunting pressure (and associated disturbance) at the lakes, because geese intrinsically prefer freshwater sites to roost (e.g. to allow access to drinking water).

This use of the Black Sea as a roost site, indicated by observations in the vicinity of the wind farm, is also confirmed independently by the records of a satellite-tagged RBG satellite tagged in the 2010/11 winter (see link: http://bspb-redbreasts.org/?p=562) (Fig. 12 – 13).

It was also apparent from the distribution of geese within and in the vicinity of the wind farm that the preferred "feeding" locations were not obviously governed by the presence of turbines or the presence of sources of food in wheat fields (see reports from previous winters, and Fig. 3 and 11). Although it was not quantified, subjectively the most likely factor attracting geese to the vicinity of the wind farm was the presence of freshwater at ground level. This, in turn, was probably governed by a number of influences, such as proximity to the coast (and warming temperatures affecting snow melt), and local drainage capacity and the water table. The need for freshwater, in the absence of hunting disturbance, could become increasingly important if geese are forced away from more traditional sources of safe freshwater lake roost sites by hunting disturbance.

Figure 12. Winter range records of a satellite-tagged RBG near the Romania-Bulgaria border (see link: http://bspb-redbreasts.org/?p=562).

Figure 13. Winter range records of a satellite-tagged RBG near the Kaliakra Cape (see link: http://bspb-redbreasts.org/?p=562).

Altitudinal distribution of flying geese

155,156 observations of geese were available for the analysis of the visually observed flight altitudes. The majority of birds were observed flying at altitudes between 100 and 150 metres above ground level (Table 2). The species variations in the altitudes are not statistically significant. This distribution includes birds observed during all hours of the day. Therefore, the altitudes of the bird flights represented all kinds of functional flights and the whole spectrum of spatial trends seen during the winter season 2010/11.

Flight altitude was also recorded by the radar, and the frequency distribution of flight heights recorded by this method is illustrated in Table 3. Note that overall numbers detected by the radar are higher than those detected by observers because not all visually identified flocks were recorded to flight altitude.

Table 2. Comparative distribution of the flight altitudes of all geese species observed in the wind farm territory from the vantage points (N = 155,156 birds).

	Species			
Altitude	***A. albifrons***	***A. anser***	***B. ruficollis***	**Grand Total**
0-49	16.45%	55.21%	19.78%	16.71%
50-99	29.27%	13.54%	24.13%	28.90%
100-149	36.96%	14.58%	38.16%	37.03%
150-199	4.82%	13.54%	5.15%	4.85%
200-249	6.15%	0.00%	3.74%	5.98%
250-299	2.04%	3.13%	3.20%	2.12%
300-349	2.40%	0.00%	4.01%	2.51%
350-399	1.46%	0.00%	1.29%	1.45%
400-449	0.31%	0.00%	0.55%	0.32%
450-500	0.14%	0.00%	0.00%	0.13%

Table 3. Flight altitudes of geese registered by the radar (N = 1,123 flocks).

Altitude (m)	**Proportion**	**Number of detected geese**
0-49	1%	3700
50-99	20%	54110
100-149	44%	118930
150-199	31%	83120
200-250	5%	12350
Grand Total	100%	272210

Similar results of flight altitudes were registered in winter 2009/2010, both by visual and radar methods. It is apparent that observers and the radar were probably more likely to record particular flight heights. As in the winter survey 2009/2010, the observers tended to record more flights close to the ground (< 50 m) whereas the radar documented more flights above rotor swept height (> 150 m). This was expected since similar results were obtained in the 2009/10 winter. The observer attention was more focussed on birds coming into the wind farm to feed (at low level), whereas the radar could detect higher flying birds at greater distance, and low level flights were obscured for the radar by the influence of ground-clutter.

In the context of modelling collision risk, the two methods gave very similar results for the proportion of birds flying at risk height (crudely approximating to 50 – 149 m) in two consecutive winter seasons. This gave confidence in this important input parameter of collision risk modelling, as noted later.

Species composition of goose flocks

The radar was blind to species composition of goose flocks, even though it could reliably document gross numbers of birds and their presence entering the wind farm and its vicinity.

Species composition of goose flocks was therefore reliant on the results from visual estimates, which were concentrated during the period of greatest presence of geese during January (Table 1).

In Table 4 the visual estimates of the proportion of geese species are presented by days when the species were present in January. The proportion of RBG varied daily during the study period between 0.3% and 12%, with an average of about 7% (Table 4). Greylag Geese (*A.anser*) were comparatively low in number (96 birds, overall: Table 1), which equates to a daily proportion from 0 to 0.3% of all observed geese during January, with an overall average of 0.06%. This species can thus be considered as immaterial in any subsequent calculations.

Table 4. Average proportion of the geese species registered visually during the period of highest number of the species in January (based on numbers of birds presented in Table 1).

Date	**Species**		
	A. albifrons	*A. anser*	*B. ruficollis*
06.1.2011	96.47%	0.21%	3.32%
07.1.2011	99.56%	0.00%	0.44%
08.1.2011	97.71%	0.00%	2.29%
09.1.2011	99.44%	0.25%	0.31%
10.1.2011	93.55%	0.32%	6.13%
11.1.2011	94.06%	0.00%	5.94%
12.1.2011	93.28%	0.00%	6.72%
13.1.2011	91.47%	0.00%	8.53%
14.1.2011	97.73%	0.25%	2.02%
15.1.2011	88.16%	0.03%	11.81%
16.1.2011	91.58%	0.00%	8.42%
17.1.2011	91.83%	0.05%	8.12%
18.1.2011	98.74%	0.00%	1.26%
19.1.2011	87.54%	0.00%	12.46%
Grand Total	92.93%	0.06%	7.01%

Diurnal variation in flight activity

According to observers, the peak of flight activity occurred early in the day, as in winter 2008/9 and 2009/10 (Fig. 13). The geese arrived from their nocturnal roost sites in the first two hours after sunrise. The smaller ‘departure’ peak infers that geese took different flight routes when returning to roost and so were not detected by observers concentrating on the wind farm area.

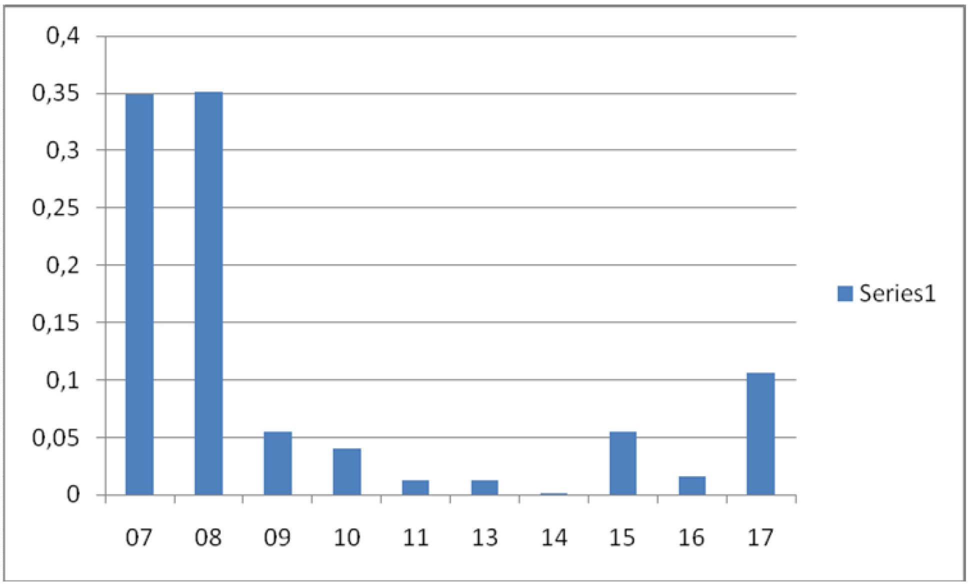

Figure 13. Circadian dynamics of flying geese through the wind farm area as registered by visual observations in the winter season of 2010/11 (x axis gives time of day (by hour), y axis gives proportion of observations).

Number of goose flights through the wind farm territory

For the precise evaluation of the number of flights through the wind farm in the winter of 2010/2011 the information of visual identification of geese species and radar data were combined. In terms of documenting gross numbers of geese within the wind farm the radar data were utilised preferentially, seeing as the radar was operational over a greater time period than the deployment of observers. This greater operational deployment by the radar referred to both number of days and time of day since, respectively, geese could be recorded by the radar during observer holidays around Christmas and New Year, and in hours of darkness (when geese were still active but observers could not see them).

Whilst the radar could more accurately document the number of geese entering or flying across the wind farm it could not distinguish between different goose species. In this respect estimates of the species composition derived by the observers were utilised (Table 4). The combined estimates of numbers of goose flights (derived from radar) and the proportion of these numbers that referred to RBG (derived from visual observations) are presented in Table 5.

Table 5. Total number of goose flights through the Project area by 5 day periods (registered by the radar) and extrapolated number of RBG occurrence (see Table 4).

Period	Total number of goose flights	Number of RBG flights
14.12.2009 - 18.12.2009	0	0
19.12.2009 - 23.12.2009	0	0
24.12.2009 - 28.12.2009	0	0

Period	Total number of goose flights	Number of RBG flights
29.12.2009 - 02.1.2010	2550	179
03.1.2010 - 07.1.2010	41170	2882
08.1.2010 - 12.1.2010	3350	235
13.1.2010 - 17.1.2010	280	20
18.1.2010 - 22.1.2010	0	0
23.1.2010 - 27.1.2010	0	0
28.1.2010 - 01.2.2010	300	21
02.2.2010 - 06.2.2010	20500	1435
07.2.2010 - 11.2.2010	2050	144
12.2.2010 - 16.2.2010	250	18
17.2.2010 - 21.2.2010	0	0
22.2.2010 - 26.2.2010	0	0
27.2.2010 - 01.3.2010	0	0
Grand Total	70450	4932

CARCASS MONITORING RESULTS

Searches for collision victims in 2010/11 winter were governed by the distribution of geese (including their flight routes) within the wind farm and, therefore, the turbines which presented a risk of collision. The timing of searches was also governed by the temporal presence of geese. The first searches were undertaken on 7 January 2011, 4 days after the first major influx of geese. In total, there were 435 searches of turbines made at times when there were potential collision victims due to the presence of geese. The timing of turbine searches in relation to the numbers of GWFG recorded by radar within the wind farm is shown in Fig. 14.

As a result of trials calibrating searcher efficiency and carcass persistence conducted during the 2009/10 winter, it was estimated that if searches were conducted every 4 days then for every 10 dead birds found the adjusted (‘true’) mortality was 19.2 dead birds. In other words, if searches were conducted every 4 days then about half of all collision victims would be found. The search programme for collision victims in 2010/11 was complicated by the fact that geese were present in the wind farm area in two distinct phases and in varying numbers during those phases (Table 5, Fig. 14). During the first phase in early January the mean (± SD) search interval at individual turbines was 2.3 ± 1.3 days (N = 362). During the second phase (29 January 2010 to 09 February 2011) when the distribution and numbers of geese were more restricted, attempts were made to search under the turbines that presented a collision risk within 4 days after the presentation of risk. In this phase, therefore, the relevant search interval was less than 4 days, but has been conservatively assumed to be 4 days (i.e. about half of all collision victims should have been found in the second phase of goose presence). Further conservative measures were also enacted analytically, but these are best considered under the next section.

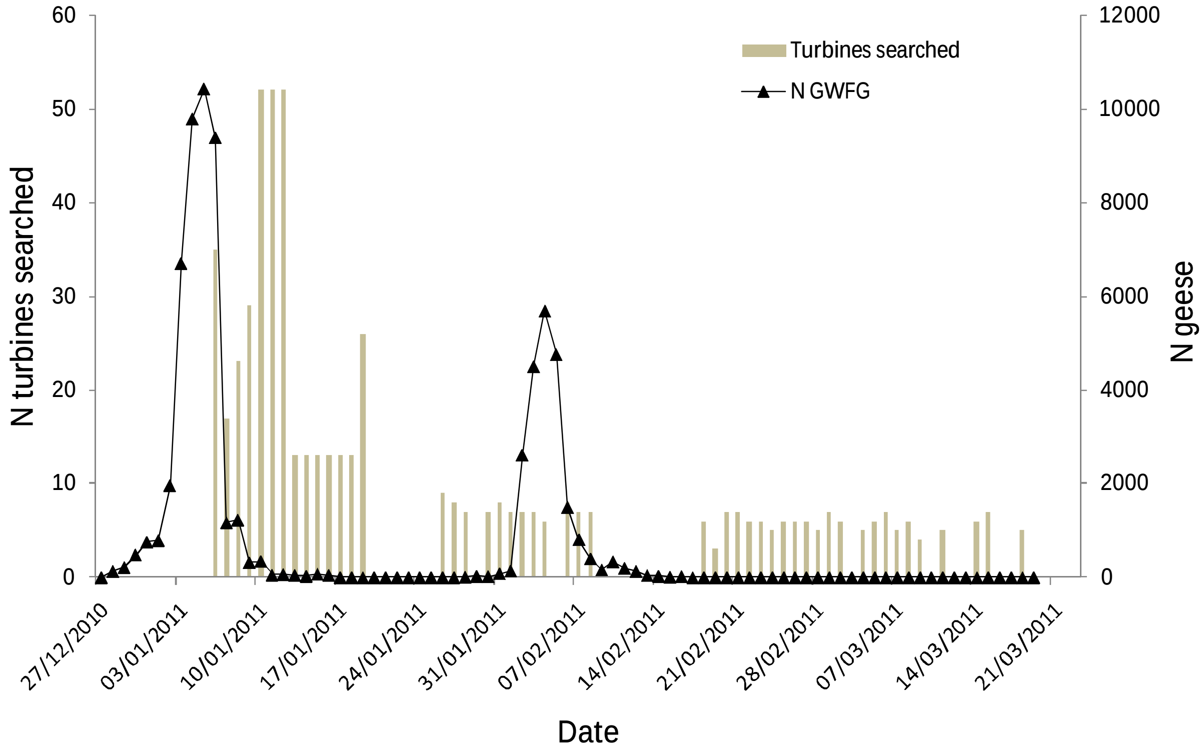

Figure 14. The timing and numbers of turbines searched for collision victims in relation to the number of GWFG recorded by radar in/over the wind farm.

No intact carcasses or remains of any bird species was found in searches under turbines in winter period of 2010/11.

COLLISION RISK ASSESSMENT

Input data

While GWFG (*A. albifrons*) is not considered to be of conservation concern, unlike RBG (*B. ruficollis*), models were run for both species as the comparison should be both instructive and helpful in the context of determining an appropriate threshold for TSS and in refining the likelihood of collisions in practice.

Bird size and flight speed

Measures of body size were taken from Cramp (1998) and flight speed from Campbell & Lack (1985) and Provan & Whitfield (2007) (Table 6).

Table 6. Measures of goose body size and flight speed used in the CRMs.

Measure	RBG	GWFG
Body length (m)	0.55	0.72
Wingspan (m)	1.26	1.49
Flight speed (m/s)	19	19

Wind farm parameters

Input values for parameters relevant to the wind farm specifications are given in Table 7. Note that the proportion of time that turbines were assumed to be operational accounts for ‘downtime’ when blades do not turn due to wind speed and turbine maintenance. The value used in the CRMs is the standard metric calculated by the wind energy industry for modern turbines such as those deployed at SNWF.

Table 7. Input values for wind farm parameters.

Measure	Value	Notes
Number of turbines	52	
Proportion time operational	0.87	Standard industry metric
Rotor diameter (m)	90	Vestas V90 3 MW model
Rotational speed (rpm)	16.1	Variable, but 16.1 nominal speed
Maximum chord (m)	3.5	Vestas V90 3 MW model
Pitch (degrees)	15	Vestas V90 3 MW model
Corridor width (m)	6900	Mean distance across wind farm + 200 m buffer

Goose flight activity parameters

In order to reduce the risk of collision with the rotors of the wind turbines during the period of most intensive flights of geese through the wind park territory, and especially in conditions of reduced visibility, different groups of turbines (as well as single turbines) were stopped in January. The list of shutting-down events related to the TSS in January is presented below:

Days involving actual shutdown orders Jan 11-Jan 18

Total number of individual shut downs 199

Turbines most often shut down turbines T58-T35

Total lost production hours 205

The large majority of flights involving the TSS were not considered as 'risk flights' in terms of the Collision Risk Model (CRM) and as documented by the radar. This was because of the predominant circumstances when the TSS was implemented: 1) when flights did not pass through the wind farm but the TSS was implemented as a precaution in case geese were disturbed when near to the wind farm; and 2) particularly during fog when, because both observers and the radar were 'blind', there was uncertainty as to the behaviour of the geese. In both these situations, therefore, no 'at risk' flights were recorded. Consequently, the estimates of number of flights within the wind farm presented in Table 5 (and so the potential numbers of flights to be considered by a CRM) were not markedly affected by the TSS.

As noted above (Table 5) there were an estimated 4,932 flights of RBG through the Project area. From Table 5, for all geese there were an estimated 70,450 flights, and so there were an estimated 65,518 GWFG flights. With a turbine hub height of 105 m and a rotor diameter of 90 m, the rotor swept height (RSH) which presented a risk of collision was 60 – 150 m. Since there was no marked observed species difference in flight altitude (unsurprising as mixed species flocks were the norm) the proportion of flights at risk height was taken from the more precise radar records. As a conservative (precautionary) measure of flight activity at RSH from the recorded flight heights, the data for the height band 50 – 149 m was employed, giving a value of 0.64 (64 %: Table 3).

Probability of collision
As described by Band (2001) and Band et al (2007) even if birds fly through spinning rotor blades they will not always be hit by a blade due to the interaction between the movement and metrics of the blades and the movement and metrics of the bird. This ‘probability of collision’ consequently varies according to blade and bird metrics and is calculated using a standard Excel spreadsheet (Band 2001). In the present study the collision probabilities were 8.1 % (RBG) and 9.0 % (GWFG).

Avoidance rate
As noted in the 2008/09 and 2009/10 winter reports, the CRM requires the application of a substantial correction factor in order to produce realistic estimates of bird fatality rates. This factor attempts to account for the fact that birds do not simply fly towards rotating blades (as assumed by the unadjusted CRM) but take action to avoid collision, and hence is called the ‘avoidance rate’. As also noted by the previous winter reports, a precautionary avoidance rate for geese recommended by Scottish Natural Heritage (SNH) is 99 %, based on the study by Fernley et al (2006). This was the value used in the previous winter reports. However, Fernley et al (2006) recommended that a more appropriate precautionary value should be 99.6 %, and estimated that a value in excess of 99.9 % provided a more realistic empirical measure. Consequently, CRMs were run using three avoidance rates: 99 %, 99.6 % and 99.9 %.

Model outputs

Predictions based on 2010/11 flight activity
From the observed flight activity levels in the 2010/11 winter, predictions of the CRMs on the estimated number of collision strike victims varied, according to assumed avoidance rate, from about 0.1 – 1 for RBG and about 2 – 18 for GWFG (Table 8). As expected from their relative abundance, the model outputs predicted substantially more GWFG would be killed.

Table 8. Predicted annual number of geese killed by collision at SNWF based on observed flight activity in the 2010/11 winter, under three CRM avoidance rates.

Species	Avoidance rate		
	99 %	99.6 %	99.9 %
RBG	1.3	0.5	0.13
GWFG	17.5	7.0	1.7

These predictions were much higher than those predicted from the previous (2009/10) winter because numbers of geese were much higher in the 2009/10 winter (in part, probably due to the relative severity of the two winters, but also probably due to a change in geese wintering behaviour) (Table 9).

Table 9. Predicted annual number of geese killed by collision at SNWF based on observed flight activity in the 2009/10 winter, under three CRM avoidance rates.

Species	Avoidance rate		
	99 %	99.6 %	99.9 %
RBG	8.9	3.6	0.9
GWFG	86.1	34.4	8.6

Clearly, the numbers of predicted goose deaths (at least GWFG) by some of the CRMs were substantially lower in 2010/11 than those observed. The disparity can be revealing as to the 'best fit CRM' and, in particular, the most appropriate 'avoidance rate'. Hence, any revelation can help in predicting any future scenarios and to inform any need for a TSS in the future, as well as providing data to refine the generic use of the Band CRM as a predictive model for wintering geese. As noted above, however, it was difficult to estimate the expected number of collision victims (and thereby the 'actual' number of deaths) from the carcass search monitoring due to the behaviour of the geese within and over the Project and the localised nature of consequent searches for collision victims.

Under these circumstances, a highly conservative approach was adopted, namely: 1) it was assumed that during both phases of goose presence (Fig. 14) the ability to detect collision victims was based on a 4 day search interval (even though it was higher during the first phase) and; 2) it was further assumed that only searches in the periods 03 – 17 January 2011 and 29 January to 09 February 2011 would detect any dead birds under turbines. On these bases, and assuming 50 % of all victims would be detected the number of dead birds that should have been found, under the three avoidance rates, in shown in Table 10.

Table 10. The minimum number of geese collision victims that should have been found at SNWF in the 2010/11 winter, based on conservative measures of detection probability (assumed to be 0.5 under a 4 day interval search regime) and that not all periods of geese presence were covered by this detection probability, according to three CRM avoidance rates.

Species	Avoidance rate		
	99 %	99.6 %	99.9 %
RBG	0.6	0.2	0.06
GWFG	8.3	3.3	0.8

Given that no dead geese were found in the hundreds of searches under turbines, but that very few RBG were predicted to have been killed, under any CRM avoidance rate, insight into an appropriate avoidance rate is best illustrated by looking at the results for GWFG (as emphasised in the 2009/10 winter report, because this species is most common). Crudely, the clear implications of the results for GWFG are that a 99 % avoidance rate is unrealistic and that a 99.9 % avoidance rate is likely most realistic (reflecting the analysis, derived from other sources, by Fernley et al. 2006). This suggests that the 99 % avoidance rate, recommended by SNH, and taken as primacy by the 2008/09 winter report, is far too low and does not represent a realistic predictive adjustment factor in the Band CRM.

CONCLUSIONS

The methods applied to this study were similar to those in the winter seasons of 2008/2009 and 2009/2010. The comparative approach provided important information concerning the species composition of geese and their spatial and temporal distribution within the Project area in three consecutive winter seasons. Incorporation of radar into the survey protocols has provided a major advantage and increased quantification of results.

The wintering period of the geese starts in the middle of December and ceases by the end of February, as observed in all three winter seasons. Three goose species were recorded: RBG, GWFG and Greylag Goose. GWFG was the most common species recorded, and the percentage of occurrence of RBG varied between 0 % and 20 % within each winter, on average about 10 % across all winters. Greylag Goose was recorded sporadically and in small numbers and was not therefore considered at risk from the project. The duration of the winter stay in the study area was similar for both RBG and GWFG. However, there was a definite 'peak' period of activity with a concentration of over 90% of RBG being seen within 20 days; this concentration corresponds to the coldest period of the winter in all three surveyed seasons.

The flight altitudes of the geese from all species observed crossing the Project area were most intensive between 50 and 100 m above ground level in all three winter seasons. Diurnal activity of the geese generally indicates two periods of intensive flights: morning (7-9 h) and, to a lesser extent, evening (16-18 h).

The intra-seasonal patterns in number of goose flights varied across the winters of our study. This partially depended on the time period when the geese were present in the region. There was also a tendency for a decrease in the number of geese of all species registered during last three winter seasons. The difference between the 2008/09 and 2009/10 winters was probably due to the improved methods employed in the 2009/10 winter, whereas the decrease in geese numbers between the 2009/10 and 2010/11 winters was probably due to the greater severity of the 2009/10 winter. The main concentrations of geese in the vicinity of the Project over the three winters have not changed much as a result of the construction and operation of the wind farm. There is a suggestion that the distribution of geese within the wind farm is not explained by the presence of their preferred crop-type for feeding: fields used for wheat. A more likely, though more subjective (in terms of available data) explanation, is that geese are more selective of fields where fresh ground water is available, due to land drainage and snow-melt due to proximity to the coast.

A change in the behaviour of geese concerning the location of their roosting sites was apparent over the three years of study. Majority of geese of all species shifted overnight roost sites from the two fresh water lakes Durankulak and Shabla to the sea surface in a large area along the Black Sea coast in the 2010/11 winter. While this did not apparently increase the risk of geese dying through collision with turbine blades in the wind farm, it was of concern in indicating an increasing hunting pressure around the two main fresh water roosting sites of the wintering geese in the region. This will probably have an adverse effect on these wintering geese populations; far greater than any effect of SNWF.

No intact carcasses or remains of any bird species was found in winter period of 2010/11 during several hundred searches under operational turbines. The implication of predictive collision risk modelling in relation to the results of searches for collision victims is that geese have a near-perfect ability to avoid collision with wind turbines. There is no evidence of any adverse effect of the wind farm on populations of the three geese species using wind farm territory in the winter season.

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