Bird migration monitoring in the AES Geo Power Wind Park territory, Kaliakra region, in autumn 2011, and an evaluation of a potential "barrier effect" after two years of operation

Dr. Pavel Zehtindjiev

Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, 1113, Sofia, 2 Gagarin St., Bulgaria

e-mail: pavel.zehtindjiev@gmail.com

Dr. D. Philip Whitfield

Natural Research Projects Ltd, Banchory, UK

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Contents

SUMMARY

1. This report presents the comparative results of four autumn seasons' study of birds at the St Nikola Wind Farm (SNWF), with an especial focus on the possible impact of SNWF on migrating birds.
2. Spatial and temporal dynamics in the numbers of different species passing through the wind park territory during autumn migration 2011 (15 August to 30 September) are presented.
3. The data gathered from visual observations are analysed.
4. The data from the autumn monitoring in 2008, 2009, 2010 and 2011 are used to test whether, through a 'barrier effect' there has been a statistically significant change in species composition, numbers, altitude or the flight direction of passing birds in autumn, as a result of SNWF's presence.
5. There was no evidence for barrier effect of the constructed wind farm on autumn seasonal bird migration through the territory. The numbers of species, absolute number of birds, overall altitudes of flight and migratory direction varied by years with no obvious effect after the wind farm was constructed and started its operation.
6. Taking all preliminary available information into account, a system for reduction of collision risk was applied successfully through a Turbine Shutdown System, in a short period of intensive soaring bird migration through the wind park territory.
7. No victims of collision were found, despite numerous searches for casualties under the turbines.
8. The data to date indicate that SNWF does not constitute a major obstacle or threat, either physically or demographically, to important populations of diurnal autumn migrants.

INTRODUCTION

During the last century, birds have been affected by different kinds of disturbances and impacts due to man-made structures such as highways (Fajardo et al. 1998), power lines (Ferrer et al. 1991; Janss and Ferrer 1998; Penteriani 1998), radio / television towers (Stahlecker 1979; Smith 1985; Nelson and Curry 1995), wind farms (Orloff and Flannery 1992; de Lucas et al. 2007), glass windows (Klem 1990a, 1990b), and due to human activities such as poisoning (Harmata et al. 1999) or other more direct forms of persecution (Villafuerte et al.1998). The mortality of birds through collision with anthropogenic structures has generated a substantial literature evaluating the impact of these elements on bird survival rates and developing the application of protective measures (e.g. Klem 1990b; Fajardo et al. 1998; Alonso and Alonso 1999).

Studies examining the population consequences of collisions with man-made structures, although of the greatest importance, are fewer. However, recent analyses have indicated no correlation between relative collision mortality and long-term population trends for several North American species of small perching birds (passerines) (Arnold and Zink 2011). Thus, although millions of North American passerine birds are killed annually by collisions with man-made structures, this source of mortality has no discernible effect at the population level (Arnold and Zink 2011).

Arnold and Zink's (2011) study of passerines did not include collision with wind turbine blades. Nevertheless, Erickson et al. (2001) had earler concluded that the overall mortality of birds due to collision with wind turbine blades was miniscule in comparison to that created by collision rates with other anthropogenic structures. This would suggest that the conclusions of Arnold and Zink (2011) on the absence of any population-level effect would also apply to the impact of collision with wind turbine blades; at least so far as passerine species is concerned. Drewitt and Langston (2008), however, appropriately pointed out that different bird species are differentially vulnerable to collision with different types of man-made structures, and that wind turbines may be more likely to kill some species that are more vulnerable to additional mortality created by collision due to their life-history traits (e.g. low population size, low reproductive rates and high adult survival). In line with this argument, a review of numerous studies by Hötker et al. (2006) suggested that there was no indicative evidence for any possible population-level effects of wind farms on birds in Germany, with the possible exception of two large raptorial species that have intrinsic low population size, low reproductive rates and high adult survival. Several bird species have been recorded as victims of collision strike (e.g. Higgins et al. 1996; Osborn et al. 1998; Hötker et al. 2006; Drewitt and Langston 2008) but some raptors seem especially prone to collision with turbine blades, not always directly related to their abundance (e.g. Orloff and Flannery 1993; Osborn et al. 1998; Drewitt and Langston 2008; de Lucas et al. 2008).

Collision mortality is, nonetheless, only one of several potential impacts of wind farms on birds and the scientific literature on these impacts is scarce, despite the industrial capture of wind power being one of the most rapidly expanding sources of energy production facilities. In addition to mortality through collision with rotating wind turbine blades the other potential adverse impacts are:

- Direct habitat loss through land take associated with the construction of turbines and associated infrastructure, such as tracks;
- Birds may be disturbed by the presence of turbines and be displaced from habitat or airspace that they would otherwise have used. Breeding birds may abandon their territories (Pearce-Higgins et al. 2009), roosting or feeding birds may stay away from the turbine array (Leddy et al. 1999; Madsen and Boertmann 2008), or birds may enter the wind farm but avoid the immediate vicinity of the turbines (Osborn et al. 1998; Leddy et al. 1999; Whitfield and Madders 2006). If flying birds are displaced from the airspace in, around or over a wind farm then birds' movements may be prevented or increased as birds fly further to avoid the wind farm's airspace – the so-called 'barrier effect'.

A barrier, by definition is a tangible (e.g. wind facility) or an intangible (e.g. radiation or infrasound) disturbance that restricts the free movement, mingling, or interbreeding of individuals or populations of a species (Merriam-Webster Online Dictionary). The barrier effect is another consideration to address when locating and designing wind facilities.

The barrier effect has been well documented in several offshore wind projects (Desholm and Kahlert 2005, Pettersson 2005, Petersen et al. 2006, Zucco et al. 2006, Larsen and Guillemette 2007, Guarnaccia and Kerlinger 2007) where macro-avoidance behaviours by various bird species have been recorded at distances of between approximately 330 feet and 1.9 mi from turbine arrays (Tulp et al. 1999, Desholm and Kahlert 2005, Percival 2001). Some reports even show avoidance of up to 2.5 mi by several waterbirds (Kuvlesky et al. 2007). Barrier effects from land-based wind energy developments have been less frequently observed, but have been documented. In a 4-year monitoring program of six land-based wind facilities in the Beauce Region of France, preliminary results showed that 70-99% of migrating birds changed path a few hundred yards out to avoid the wind facilities, especially where turbines were densely clustered (European Commission 2010).

For avifauna, the barrier effect occurs when a bird's macro-avoidance of a wind facility results in an increase in energy use to circumvent the turbine area (Masden et al. 2009, 2010). The level of impacts from barrier effects may vary dependent on species presence, turbine layout, wind facility size, season, and the birds' ability to compensate for energetic losses (Fox et al. 2006). Analyses by Masden et al. (2009) showed that the barrier effect of a wind farm was trivial on the energy budget of migrating seaducks, largely because the extra distance birds had to travel around the wind farm were inconsequential in the context of the overall distance travelled during migration. Concern has been expressed however, that a barrier created by a wind farm between breeding and feeding areas may have significant impacts (Fox et al. 2006, Goodale and Divoll 2009, Drewitt and Langston 2006). Madsen et al. (2010) showed that potential adverse effects on breeding seabirds' energy budgets were indeed relatively far greater than for migrating seabirds, because the distance involved in avoiding a wind farm was a larger proportion of the overall distance travelled on each flight, and such flights were repeated very frequently during the course of a breeding season. Theoretical impacts varied between species due to differences in morphology and flight mode.

Long lines of turbines and large turbine arrays may be problematic as they present a larger barrier (Goodale and Divoll 2009, Drewitt and Langston 2006). Layout modification such as creating flight corridors or placing turbines closer together to reduce the project footprint have been suggested as approaches to help minimize impacts (Drewitt and Langston 2006). The combined barrier effect of multiple adjoining wind facilities is also a concern as wind development becomes more prevalent (Drewitt and Langston 2006). It is likely that this will be less of a potential issue for migrating birds than for breeding birds.

However, impacts can be site specific, and may not occur at each site (Goodale and Divoll 2009). Therefore, turbine layout and facility location should be evaluated on a site-specific basis by an experienced wildlife biologist in conjunction with available information regarding local and migratory bird and bat species in, around or passing through the proposed site to ensure that any possible barrier effects are minimized or avoided.

The long term impacts of barrier effects are still uncertain, nevertheless, and further research is needed to address this issue (Goodale and Divoll 2009). However, given the mounting evidence of such macro-avoidance effects resulting from both on- and offshore wind development, and the possibility of population effects over time (Drewitt and Langston 2006), wind developers need to assess the potential impacts on species prior to and following development. Knowledge of spatial distribution of birds is a source for replying many fundamental questions of the evolutionary ecology and ornithology as well as for practical solutions. In particular, the distribution of migrants through a certain territory along the Bulgarian Black Sea coast, known as *Via Pontica*, is of primary interest for the development of wind power industry in the region.

In NE Bulgaria, close to the Black Sea coast, AES Geo Energy OOD constructed a 156 MW wind farm consisting of 52 turbines in 2009: the St Nikola Wind Farm (SNWF). In autumn 2008, SNWF did not exist, in autumn 2009 the facility was built but not operational (i.e. turbine blades were not moving), and in the autumns of 2010 and 2011 SNWF was operational. In the last 8 years, several field studies have investigated the spatial and temporal distribution of the migratory and the breeding birds within this area. The main results of the autumn monitoring of bird migration in the vicinity of SNWF in previous years are published at: http://www.aesgeoenergy.com/site/Studies.html. In these studies no collision mortality of migrating birds was found indicating high avoidance rate of the turbines by migrating bird species. On the other hand, strong fluctuations in numbers of different species were correlated significantly with the wind direction especially when westerly winds occur in the peak of soaring bird migration period. It was evident that SNWF does not lie on the main migration route of the Via Pontica (likely because of its proximity to the Black Sea and that it is on a cape, at Kaliakra) and only receives major migratory 'traffic' when (unusual) westerly winds push birds from the main route.

One of the major questions addressed by this report is whether SNWF potentially has a barrier effect on birds migrating through the territory and thus could cumulatively add to long term changes in the migratory bird fauna or incur a major energetic cost should the birds have to direct their migration around the wind farm. With a view to providing objective data for evaluation of this risk for the birds this report provides a comparative analysis of the four autumn seasons concerning a possible barrier effect of the wind park.

The report also updates the information about spatial distribution of observed species in autumn 2011 in the wind park territory as well as the efficiency of the applied - for the second year - Turbine Shutdown System (TSS) for the reduction of collision risk.

METHODS

All direct observation methods used in the four autumn seasons considered by this report were identical in order to obtain comparable information concerning bird species and numbers of birds per species. All observation points were purposely kept constant during all autumn seasons. The details of the methods used in previous autumn seasons, and therefore applied during 2011, are described in a number of previous reports published at: http://www.aesgeoenergy.com/site/Studies.html. Despite consistency in observation methods across years and their descriptive availability elsewhere they are repeated here for convenience.

The study area

SNWF is located in NE Bulgaria, close to the Black Sea coast near the cape of Kaliakra. The wind farm lies between the road from the village of Bulgarevo to St. Nikola (municipality of Kavarna), and the 1st class road E 87 Kavarna – Shabla, as shown in previous reports (and in Fig. 1). SNWF consists mainly of arable land with different crops (wheat, sunflower, flax), intercepted with roads and wooded shelter belts. The development area is outside the NATURA 2000 site known as Kaliakra.

Study duration and equipment

The study was carried out in the period 15 August – 30 September 2011 in the same study period and at the same observation points as autumn seasons of 2008, 2009 and 2010, covering a total of 45 days: the period of the most intensive migration. The surveys were made during the day, in a standard interval of time between 8 AM and 6 PM Astronomic time. All methods were the same across all years.

Radar observations were made permanently during the day time and for 15 minutes per every hour of the night (20 h – 05 h) during the whole period of the survey in 2011 according to the following scanning program:

Diurnal Radar Observations

1. Four minutes at 30 mills, or as low as ground clutter permits (equivalent to approximately 25-275 m elevation at 5 km distance);
2. Four minutes at 80 mills (equivalent to 275-525 m at 5 km distance);
3. Four minutes at 130 mills (equivalent to 525-775 m at 5 km distance);
4. Four minutes at 180 mills (equivalent to 775-1025 m at 5 km distance);
5. The magnetron then rested for one minute, and then the cycle was recommenced.

Nocturnal Radar Observations

1. Four minutes at 30 mills; (equivalent to approximately 25-275 m elevation at 5 km distance);
2. Four minutes at 150 mills (equivalent to 675-825 m at 5 km distance);
3. Four minutes at 700 mills (equivalent to 3375-3625 m at 5 km distance);
4. The magnetron then rested for 48 minutes, and then the cycle was recommenced.

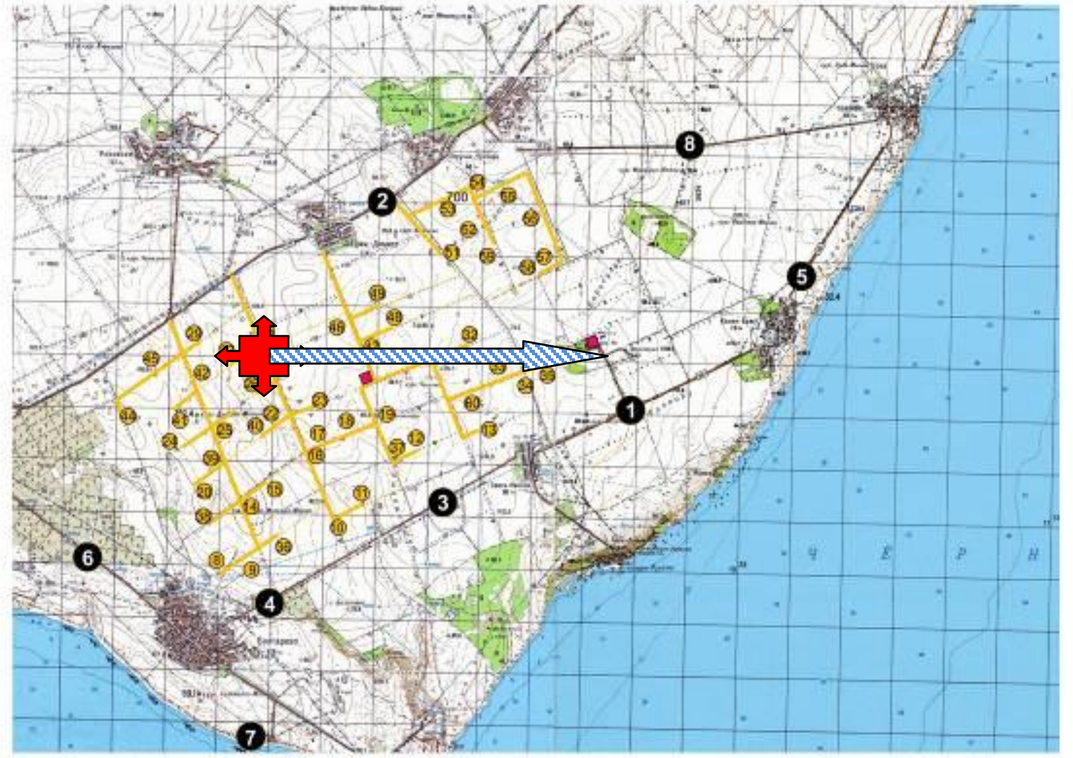
Since the radar data were available only during 2009, 2010 and 2011 only visual observations were used in the analysis and comparison of different years and changes in absolute numbers of birds, altitudes of flight and directional distributions, to maintain consistency across years of study. The radar data can, nevertheless, have a number of analytical applications as regards cross-checking of visual records and their accumulation can allow further analyses e.g. they will be analysed in respect to the nocturnal migration under request of AES Geo Energy. The radar was also applied in the collision risk reduction system for correct estimation of altitude of the flocks passing through the wind park territory.

Basic Visual Observation Protocol

The study involved direct visual survey of all passing birds from eight points (black dots in Figure 1). Field observations followed the census techniques according to Bibby et al. (1992). Point counts were performed by scanning the sky in all directions. Height estimates and distances to the birds were verified with land mark constructions around the observation points prevously measured and calibrated by GPS. The surveys were carried out by means of optics, every surveyor having a pair of binoculars with magnification (10x) and all observation points were permanently equipped with standard Admiral telescopes with magnification 20 – 60x, a compass, GPS, and digital camera.

Observed bird species were conditionally grouped in “soaring” and “non-soaring” categories. The first “soaring” group, according to generally acknowledged practice, included pelicans, storks, cranes and all the diurnal raptors, although some of these often migrate with active powered flight. The second group of the “non-soaring” birds included most of the other species.

Figure 1. Location of the plot of the wind farm turbines (numbered yellow dots) radar beam (the arrows, centred on the red cross) and the visual observation points (numbered black dots).



This conditional division was to allow for focusing the study mainly on birds of conservation importance like pelicans, storks and diurnal raptors (large species that are potentially most vulnerable to the risks of collision wth turbine blades). Data collection (as specified in the text below) on the other “non-soaring” species was a secondary priority as these are predominantly small species that are generally considered to be at low risk to any impacts of wind farms.

This prioritisation on basic protocol is unlikely to have made a major difference in the records collected between years because the observation effort was capable of coping with the volume of avian migratory traffic, and no observer was ‘swamped’ in time under the circumstances outlined by Madders and Whitfield (2006). This was, in large part, due to the fact that SNWF is apparently not on a major migratory route (see Autumn 2010 report) and so bird activity was not unusually intensive across a lengthy time.

All observers were qualified specialists in carrying out the surveys of bird migration for many years including previous autumn surveys at SNWF. Some of the observers are active members of the BSPB (BirdLife Bulgaria).

List of participants in the observations, 2011:

Dr Pavel Zehtindjiev
Institute of Zoology
Bulgarian Academy of Sciences
Senior Field Ornithologist

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

Dr Dimitar Vladimirov Dimitrov
Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences,
Member of the BSPB since 2000

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

Strahil Georgiev Peev
Student in Faculty of Biology
Sofia University

Karina Ivanova
Student in Faculty of Biology
Sofia University

MSc Martin Petrov Marinov

PhD student in Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences

Specific Visual Observation Protocol

During the visual surveys the following records of flying birds were noted by observers:

- Species and (if possible) gender and/or age;
- Number;
- Distance from observer;
- Direction from the observation point;
- Altitude;
- Direction of flight (flight path);
- Behaviour (notably flight behaviour) concerning existing wind farm constructions;
- Supplementary behavioural observations;
- Weather conditions;
- Precise position of birds simultaneously registered at the radar screen and by observers birds were recorded in order to ascribe specific echo signatures of target species (i.e. Pelicans, Storks and Raptors) to known species.

Species

All soaring birds, flying in the surveyors' scope of view were identified to the level of species, if possible, and recorded. The characteristics of gender (male or female) and age (adult, subadult, immature, juvenile) were also recorded for certain species when conditions allowed. Because of the difficulty in distinguishing between similar species in harsh conditions (e.g. bad visibility, great distance, etc.), if exact identification was not possible both possible species were recorded (e.g. *Aquila pomarina / clanga* or *Aquila clanga / pomarina*, depending on which of the two species was more probable). In certain cases when it was not possible to identify the bird of prey species, the bird was recorded to the lowest possible taxonomic category (e.g. genus, e.g. *Circus sp*.). When conditions did not allow identification of a bird of prey to a lower taxonomic category it was recorded as NBP (non-identified bird of prey).

Number (abundance)

The surveyors counted all migrating soaring birds, flying in their scope of view, regardless of the possibility to distinguish their species or higher taxonomic category (as described in the previous point). When the data were recorded, single birds (or pairs), as well as discrete flocks, were noted along with their number and species composition. In the case of larger flocks (e.g. white stork), when the counting of every single individual was impossible, birds were counted in groups of 5 or 10 birds after the flock started planing to the next thermal.

Although reasonably cost-effective in terms of results and expenses, the visual method on its own can seldom record every part of a migration over a certain region (Kerlinger, 1989). Consequently, as visual coverage was not complete over the entire study area, the raw results (counts) were extrapolated according to the maximum distance at which the species have been recorded during the period of the observations (see also previous Autumn Monitoring Reports). The overall number of birds per species was obtained by multiplying the number of individuals to the number of points theoretically needed, for certain species, to cover the whole territory. Obtained density of migrants was used in the further analysis. Extrapolated numbers of passerine birds and soaring birds which are visible at a maximum distance that is less than the distance between the observation points were obtained by the following formula:

$$N = (Nt/Np) * (10000/Dmax)$$

Where N = extrapolated total number, Nt = recorded total number of birds, Np = number of observation points (in the case of our study it is 8), Dmax = maximum distance at which the species has been recorded (m); 10000 (m) – is the extent of horizontal front of SNWF which birds should theoretically cross when following the main migratory direction.

Small passerine birds were not included in the analysis because the method applied does not quantify the number of passing mainly at night birds of this group.

Distance (horizontal and vertical) of the flying flocks and single birds' trajectories

Along with counting migrant soaring birds, recording the spatial location and flight trajectories of migrants was among the most important tasks of the study. The distance from the observation point and flight altitude was noted for each bird or flock.

Recording flight height estimates and distances to birds was assisted by reference to land marks near the observation points which had been previously measured and calibrated using GPS. Additionally, all human visual observers and radar observations were tested before observations commenced in a series of trials using a GPS device attached to a kite, flown at various heights and distances (Photo 1 in Autumn Monitoring Report for 2009). In each trial, the kite was independently observed (i.e. the kite controller and observer were independent) with height and distance recorded by the observer. These records were then compared with data on height and distance from the GPS device attached to the kite during the same trial. Differences between the 'observed' (human) records and the 'true' (GPS) records were then used to calibrate subsequent estimates for any consistent biases in records of birds observed during migration. The radar data, with precise measurements of distances and altitudes, were also used for the calibration of visually estimated altitudes of soaring migrants.

Flight direction

Flight direction was recorded as the geographic direction on which the bird or flock was heading relative to the observation point. To facilitate definition of the flight direction a geographic compass and GPS device was provided for every observation point. Direction was defined as one of 16 possible sectors of the geographic compass (every sector being limited to 22.5 degrees), as follows: N (north), NNE (north-northeast), NE (northeast), ENE (east – northeast), E (east), ESE (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). In the database flight direction of the bird was transcribed in degrees as a mean angle of the sector.

Weather conditions

Weather is an obvious potential influence on bird migration and the capacity to record birds visually. Hence, the following measures were recorded:

- Wind direction;
- Wind strength;
- Air temperature;
- Cloud cover;
- Rainfall;
- Visibility.

The direction and strength of the wind as well as temperature were precisely measured by the AES Geo Energy meteorological masts and kindly offered for analysis. Cloud cover was recorded as the relative cover (in %) of the visible part of the sky. Visibility was taken as the maximum distance at which permanent geographic landmarks could be seen, defined and recorded in metres

Weather records were made every morning at the start of the surveys, at every full hour subsequently, and when surveys stopped in the evening, as well as at any time when a considerable change in visibility occurred due to factors like fog or mist. The presence of factors, like fog, mist and other phenomena deteriorating the visibility was also taken into account in analysis.

Recording of the data

All the data of the surveys were entered in a diary. The data were processed daily and transcribed to a *database* designed in an Excel workbook. The protocol of primary data processing is 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).

The diary was kept in the following manner:

1. In the morning, with the start of the surveys, the date and the exact time 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 values of the physical factors of the environment (weather conditions, as described above) and the names of the surveyors.
2. When observing a migrating bird or flock, first the exact time was taken down, the species, genus or family Latin name, (gender and age, if possible), then the numbers, the vertical and horizontal distance from the watch point, the flight direction. After these obligatory data, additional ones, like soaring, "chimney" formation of flocks, landing birds with the exact location of landing, etc., were also recorded.

   Meanwhile, if changes in the weather or other interesting and/or important phenomena should be registered, they were also entered in the diary with the exact time of the observation.
3. In the evening, when finishing the surveys, the exact time, weather conditions and the names of the surveyors were taken down again.

Collision Victim Monitoring

The 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 Owners Ornithological Plan. Results of the monitoring were reported to the Regional Inspectorate of the Bulgarian Ministry of Environment and Waters in Varna every month during the first year of the operation. A final report has been prepared based on the results of the monitoring after one year operation period of the wind park (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 were undertaken in order to provide for such correction (see details in own ornithological plan at: http://www.aesgeoenergy.com/site/Studies.html.)

An important objective of the trials was to examine the frequency of the searches concerning efficiency for collision victims, calibrated for the removal rate of carcasses and check that the search interval protocol for collision victims proposed by the EMMP (7 days apart, at every turbine) was appropriate. The 2009 and 2010 trials during autumn were similar in their results and confirmed that the adopted protocol of a seven day search interval during autumn migration will detect about half of all collision victims of medium to large species (i.e. those species which are of primary conservation concern at SNWF during autumn: migrating raptors, storks, and pelicans).

Statistical methods

For comparison of the numbers as well as altitude of flight in different years the *t*-test was applied. We have used this test for comparing the means of two samples. In simple terms, the *t*-test compares the actual difference between two means in relation to the variation in the data (expressed as the standard deviation of the difference between the means). The *t*-test is a basic test that is limited to two groups. In our case we have applied *t*-test for multiple groups, comparing each pair of groups. The basic principle is to test the null hypothesis that the means of the two groups are equal. A significant problem with this is that we typically accept significance with each *t*-test of 95% ($p=0.05$). For multiple tests these accumulate and hence reduce the validity of the results.

The mean angles as well as its significance level, for every species and group of species were calculated according to standard circular statistics (Batschelet 1981). Circular statistics was performed by Oriana (Oriana - Copyright © 1994-2009 Kovach Computing Services). This program allows comparing two or more sets of circular distributions (directions) to determine if they differ. The tests were performed as pairwise, where each pair of samples is compared.

Many of the basic statistical parameters are based on the concept of the mean vector. A group of observations (or individual vectors) have a mean vector that can be calculated by combining each of the individual vectors (the calculations are explained in most books about circular statistics). The mean vector will have two properties; its direction (the mean angle, **μ**) and its length (often referred to using the letter **r**). The length will range from 0 to 1; a larger r value indicates that the observations are clustered more closely around the mean than a lower one.

Watson-Williams F-test (Fisher, 1993, p.126; Mardia & Jupp, 2000, p.129; Batschelet, 1981, p.95; Zar, 1999, p. 625) was used for comparison of the directions by years. This test compares two or more samples to determine if their mean angles differ significantly. The test was performed in a pairwise fashion and an overall test for all samples. The F-test basically proceeds by comparing the lengths of the mean vectors for each sample with that for the pooled data of the two samples. The resulting **F** statistic is the same as Fisher's variance ratio statistic which is commonly used in linear statistics, including analysis of variance. The **p** value printed for each test is the probability associated with the null hypothesis that the two mean angles are equal. If this probability is less than your chosen significance level (usually 0.05) then the null hypothesis can be rejected in favor of the hypothesis that the means are different. If the null hypothesis is not rejected (i.e. the probability is greater than 0.05) then Oriana will report the overall mean for all samples in the test, which can be used as an estimate of the overall population mean. This test assumes that the two samples are independent and drawn at random from a population with a von Mises distribution. It also assumes that the concentrations of the two samples are similar and that they are sufficiently large (>2). If the concentration is too low, a warning is printed. Finally the data may not be grouped. Each flock is treated as a single observation concerning direction even when they consisted of 1000 or more individuals. The formula for the F-test incorporates a correction factor, based on the concentration, to correct for bias. Details about the Oriana software and statistical test used are available at: http://www.kovcomp.com/

Turbine Shutdown System

The general principles, which provide a procedural checklist, were previously described in autumn report 2010 (http://www.aesgeoenergy.com/site/Studies.html). It should be noted that, due to the complexity of possible combinations of conditions that may be experienced on site, the principles are not scenario based (i.e. the potential number of scenarios, when considering all species and circumstances at any one time, would be too numerous to prescribe).

The TSS protocol was followed in order to reduce risk during the period of intensive migration in autumn 2011 between 15 August and 30 September. Turbine shutdowns are ordered by the Senior Field Ornithologist or -when delegated to- field ornithologists in case of any perceived risk, such risk as per the discretion of the ornithologist.

RESULTS

The 45 days of the study covered the main period of the autumn migration of soaring birds and part of the non-soaring bird migration. The study encompassed 405 astronomic hours of observations at 8 observation points in autumn 2011. Additional data from the studies of autumn migration in the wind park territory from 2008, 2009 and 2010 was used for the analysis of the changes in species and their numbers (barrier effect) during preconstruction and constructed/operational periods of the wind park.

Composition of species and number of birds passing through the wind park territory

The composition of species is presented in Table 1. A total of 47 bird species have been observed in the wind park territory during the four consecutive autumn seasons of 2008, 2009, 2010 and 2011. The number of species varied from 32 to 36 by different years. Most species (36) were observed in 2009, the year when the wind park had been constructed. There is no significant difference in the number of species observed in 2008 (before the construction of the wind park) and during the later period when the wind farm was present (2009 – 2011). Statistically not significant variations are mainly because of single observations of rare bird species. For example Griffon vulture (*Gyps fulvus*) was only once observed in autumn 2010. This species does not qualify for threatened, near threatened, or conservation dependent according to IUCN and is in the category as least concern; but it is a rare species in Bulgaria. A number of individuals of this species are currently being introduced to Bulgaria from Spain and local Bulgarian population is increasing in number. Dalmatian Pelican (*Pelicanus crispus*), Curlew (*Numenius arquata*), Lesser Kestrel (*Falco naumanni*), Eastern Imperial Eagle (*Aquila heliaca*) were also observed as single individuals in 2008. Two species: Little egret (*Egreta garzeta*) and Pygmy Cormorant (*Phalacrocorax pygmaeus*), were observed only in 2009. Although a common species away from SNWF, Northern Lapwing (*Vanellus vanellus*) was observed only once, in 2010, because the period of passage of these birds is later in October, and although still in small numbers, outside the study period. These single observations do not allow an estimation of any changes in the number of birds by these species and we can only say that the listed species are not typical for the region in autumn migration as they were observed only occasionally during the period of the study. As such species are uncommon in the study area then any barrier effect will clearly be immaterial in its consequences on populations, even if it occurs.

The rest of the species showed different degree of variations in the numbers for four autumn seasons of study presented in Table 1. In 24 (50%) species variations in the observed numbers by years are within the confidence interval for the sample and therefore there is no argument to discuss about the change in the numbers of these 24 species. For these 24 species there are factors outside the subject of the present analysis which can explain strong variations (like meteorological conditions and especially wind direction as presented in report of autumn 2010 at: http://www.aesgeoenergy.com/site/Studies.html. The strong variations in the number of these species seem to be a normal fluctuation at the observed territory before and after construction of the wind park. The observed fluctuations can not be correlated to the wind park operation. Even turbines were not in operation during autumn 2009 and therefore not spinning they may have an effect on behaviour, if not an effect on mortality. This is why the autumn 2009 is included in operational period of the wind park.

Of the remaining 23 species at least one of the observed values is outside the standard deviation of the sample derived from the observed number of registrations across the four autumns. These values are indicated with * in Table 1.

Table 1. Numbers of diurnal migrants by species observed in the wind park territory during period 15th August – 30th September in preconstruction (2008) and the period of commercial operation of SNWF (2009, 2010 and 2011 in grey). *Indicates statistically significant differences in respect to the Standard deviation from the average value.

Species	2008	2009	2010	2011	Total	Average	St. deviation
A. brevipes	95	210	976*	290	1571	393	344
A. chrysaetos			2	2	4	2	0
A. cinerea	120	259*	26	40	445	111	93
A. gentilis	10	6	5	11	32	8	3
A. heliaca	2				2	2	0
A. nisus	44	44	70	73*	231	58	14
A. pennata			5	1	6	3	2
A. pomarina	44	9*	80	76	209	52	29
A. purpurea		59*	11	1	71	24	25
B. buteo	146*	390	180	459*	1175	294	134
B. oedicnemus		1		1	2	1	0
B. rufinus	163*	151	34	30*	378	95	63
C. aeruginosus	327	268*	341*	271	1207	302	33
C. ciconia	2998	87	24980*	620	28685	7171	10340
C. cyaneus	5*	1		1	7	2	2
C. gallicus	29*	19	18	25	91	23	4
C. macrourus	8	27*	18	4*	57	14	9
C. nigra	8	8	8	1*	25	6	3
C. olor		1	3		4	2	1
C. palumbus	10		1		11	6	5
C. pygargus	32	17*	111	151*	311	78	55
E. alba			1	1	2	1	0

Species	2008	2009	2010	2011	Total	Average	St. deviation
E. garzetta		7			7	7	0
F. cherrug		7		2	9	5	3
F. eleonorae	7			1	8	4	3
F. naumanni	1				1	1	0
F. peregrinus		2	4	1	7	2	1
F. subbuteo	48*	125	120	96	389	97	30
F. tinnunculus	138	357*	45*	120	660	165	116
F. vespertinus	11	180	1773*	63	2027	507	734
G. fulvus			1		1	1	0
H. pennatus	4	3	17*	4	28	7	6
M. migrans	18	6	32*	17	73	18	9
M. milvus			1	1	2	1	0
Num. arquata	1				1	1	0
P. apivorus	58	76	1549*	152	1835	459	630
P. crispus	4				4	4	0
P. haliaetus	15	13	14	12	54	14	1
P. leucorodia	117*	83	56	48*	304	76	27
P. onocrotalus	120	1190*	252	277	1839	460	426
Ph. carbo	267	354	494*	75*	1190	298	152
Ph.pygmaeus		19			19	19	0
Pl. falcinellus	5	738			743	372	367
St. hirundo		71			71	71	0
T. tadorna		94			94	94	0
Tr. ochropus		8			8	8	0
V. vanellus			1		1	1	0
Grand Total	4855	4890	31229*	2927	43901	10975	11720
Number of species	32	36	34	34	47	34	2

C. gallicus, P. leucorodia and *B. rufinus* were the only species with the highest number recorded in 2008 before construction of the wind park. In two species (*B. buteo*, *F.subbuteo*) the lowest number was recorded in 2008. The remaining 18 species had a significant increase in number in a year after the construction of the wind farm, mainly in 2010. This increase reflected the highest number of birds registered in total for the 2010 autumn season (Table 1). The species with relatively constant numbers passing through the territory annually are *Ph. carbo*, *P. leucorodia*, *P. haliaetus*, *C. nigra*, *C. aeruginosus*, *B. buteo*, *A. pomarina*, *A. nisus*, and *A. gentilis*. The highest variations are observed in the numbers of soaring bird species: *P. onocrotalus*, *C. ciconia*, *P. apivorus*, *M. apiaster*[1], *F. vespertinus*, *F. subbuteo*, and *A. brevipes*.

This result shows that the constructed wind park did not change the migratory habits of the species crossing the territory. The numbers of these species varied by years with no trend for decrease after the park was constructed and started its operation (Figure 2).

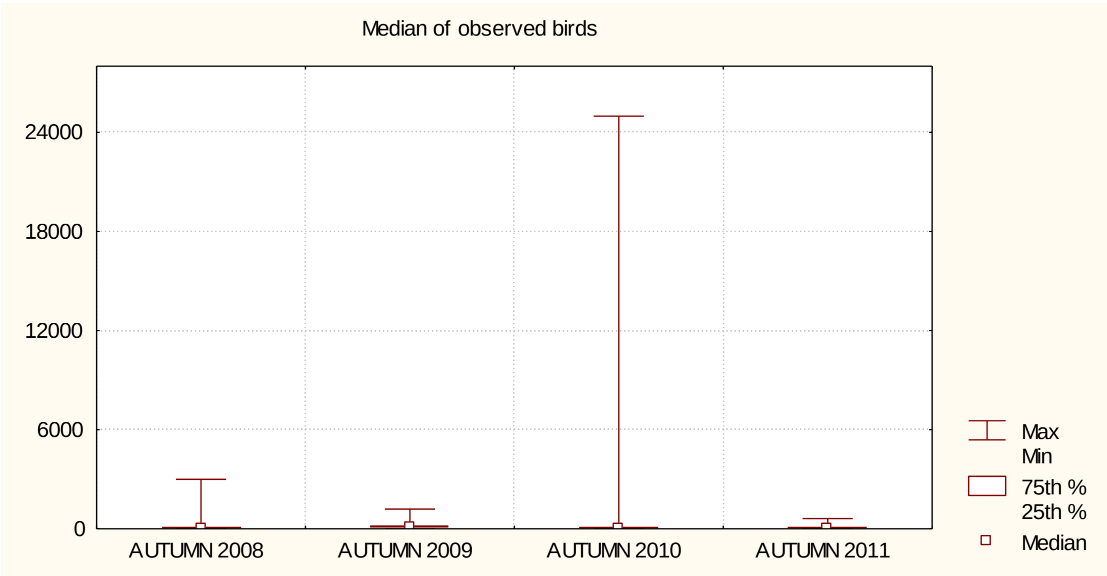


Figure 2. Average number of birds observed in autumn migration in four years (preconstruction and operational period) in the wind park territory.

All these data indicate a strong correlation of the number of soaring birds with the wind direction. For the analysis of this correlation we used data of wind direction for

[1] This species, although apparently passing through the vicinity of SNWF in substantial numbers during autumn, is not considered in the present report due to poor confidence in the counts of birds, revealed by radar work after 2008 showing that several flocks fly higher than the visual limit of observers. As the radar was not in operation before the wind farm's construction, comparable data are deemed unreliableacross the four autumn seasons of study.

the autumn 2010 and the numbers of birds by species, and these results are presented in the report for autumn 2010 at: http://www.aesgeoenergy.com/site/Studies.html.

Altitude of autumn migration

Distribution of altitudes of birds recorded during autumn migration at SNWF was reported in number of reports for 2008, 2009 and 2010 available at: http://www.aesgeoenergy.com/site/Studies.html. In order to test whether there has been change in altitude distribution of birds between the preconstruction and operational periods we have calculated average altitude per year of all species of diurnal migrants regularly passing through the wind park territory in autumn. The results are presented in Table 2.

Table 2. Average flight altitude, by species, of diurnal migrants observed in SNWF across four autumn seasons, 2008-2011: the years of commercial operation of the wind farm are highlighted in grey.

Species	2008	2009	2010	2011	Average, all years	Average for operational period
A. brevipes	132	171	171	160	161	167
A. cinerea	201	239	263	386	252	296
A. gentilis	181	176	230	199	195	202
A. nisus	150	135	162	141	148	146
A. pomarina	244	273	234	234	239	247
B. buteo	165	199	206	197	195	201
B. rufinus	109	200	230	183	163	204
C. aeruginosus	158	139	235	150	171	175
C. ciconia	199	174	434	347	354	318
C. cyaneus	136	100		10	113	55
C. gallicus	256	144	258	242	228	215
C. macrourus	251	90	240	195	176	175
C. nigra	462	325	375	350	406	350
C. pygargus	196	115	285	106	174	169
F. subbuteo	97	119	161	161	141	147

Species	2008	2009	2010	2011	Average, all years	Average for operational period
F. tinnunculus	49	96	109	70	82	92
F. vespertinus	106	106	224	289	188	206
H. pennatus	150	283	251	213	234	249
M. migrans	175	183	166	152	166	167
P. apivorus	320	175	268	283	267	242
P. haliaetus	314	208	224	433	292	288
P. leucorodia	433	285	667	317	365	423
P. onocrotalus	100	159	417	400	255	325
Ph. carbo	180	179	277	271	226	242
All species	157	154	246	179	189	193

Calculated average altitudes for most numerous species passing through the territory were statistically compared pairwise by the *t*-test. Comparison of the average altitudes of birds during autumn migration is presented in Table 3. The comparative analysis showed that the birds passed higher in 2010 than in the other three autumn seasons of our study. A statistical difference was found only in average altitudes in autumn of 2010 in respect to the average altitudes of the autumn migrations in 2008 and 2009. The observed difference between 2010 and 2011 was marginally not significant. No significant difference in altitudinal distribution of all diurnal migrants that passed through the wind park was observed betwen 2008, 2009 and 2011 (Figure 3 and Table 3). There is no statistically significant difference in the altitude of autumn migration in preconstruction and operational period when all species are considered together.

Further analyses will be undertaken, out of interest, to look at responses of individual species, especially those that typically fly low in relation to the height of wind turbine, as it apparent from the data that different species may have responded differently to the presence of turbines. But it is apparent, not least because SNWF does not lie on a major migratory route, that these will not change the essential conclusions that should be drawn from the analyses reported here; that any energetic consequences for migrants avoiding the turbines by way of a change in flight altitude will be non-existent or immaterial to overall migratory energy budgets.

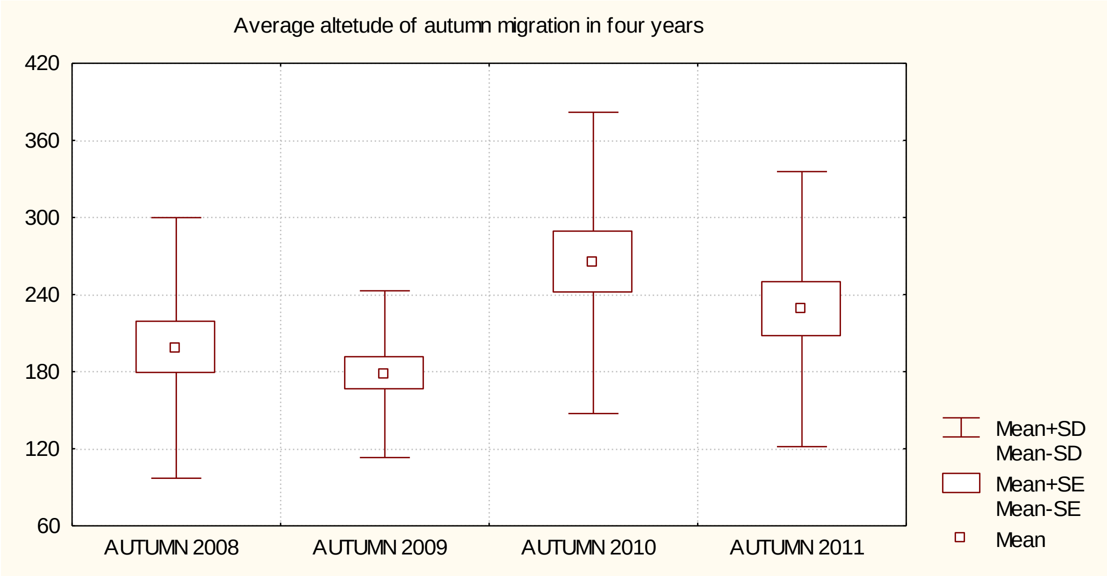


Figure 3. Mean altitude of autumn bird migration per seasons of 2008, 2009, 2010 and 2011, with variance intervals.

Table 3. Results of *t*-tests for difference in the average altitude distribution by species of diurnal migrants in four years of autumn migration in SNWF (*indicates significant differences at probability level 0.05 and calculated for compared samples value: t = 2,064).

T value	2008	2009	2010	2011	Average
2008		0,835	2,176*	1,032	0,73
2009			3,252*	2,019	1,904
2010				1,176	1,727
2011					0,439

Direction of autumn bird migration

5455 observations of 24 species which have been observed in at least three of the autumn seasons were included in the analysis of flight directions. In this analysis each flock was considered as a single observation (datum) even if it consisted of, for example, 1000 or more individuals.

The mean recorded direction, by species, of all birds observed in the study area is presented in Table 4. Superficially, it was apparent that for all species the directional distribution of recorded flocks varied to only a small degree across years.

Table 4. Mean observed direction of autumn migration by species in different years. Directions are given in degrees starting from 0 (North).

Species	2008	2009	2010	2011	Mean for the species
A. brevipes	148	149	187	179	171
A. cinerea	192	179	146	138	174
A. gentilis	186	162	171	180	176
A. nisus	207	155	189	190	186
A. pomarina	192	174	207	197	197
B. buteo	185	145	178	171	163
B. rufinus	164	157	227	176	170
C. aeruginosus	190	145	191	187	178
C. ciconia	210	161	222	207	211
C. cyaneus	180	180		225	189
C. gallicus	186	150	156	156	164
C. macrourus	155	153	180	231	170
C. nigra	203	191	248	180	207
C. pygargus	213	145	188	169	180
F. subbuteo	162	145	180	195	173
F. tinnunculus	159	147	177	153	153
F. vespertinus	142	158	177	198	172
H. pennatus	169	150	191	195	183
M. migrans	228	165	218	205	210
P. apivorus	226	175	203	198	202
P. haliaetus	187	178	185	208	189
P. leucorodia	195	167	195	195	179
P. onocrotalus	180	146	195	257	185
Ph. carbo	175	163	190	158	174
Number of birds	1049	1514	1650	1242	1364

Circular statistics of observed directional distributions of birds in four autumn seasons are presented in Table 5 and Figures 4 and 5. The calculated mean vectors per season varied between 160° in 2009 and 191° in 2010. All directional distributions of observed bird flocks/individuals across the four years of study overlapped under both

95% and 99% confidence intervals, indicating consistency in directional preferences across all four autumn seasons, and no obvious effect of the wind farm's presence.

Table 5. Circular Statistics of directional distributions in four autumn seasons

Variable	2008	2009	2010	2011	All years together
Data Type	Angles	Angles	Angles	Angles	Angles
Number of species	24	24	23	24	24
Mean Vector (μ)	185°	160°	191°	189°	181°
Length of Mean Vector (r)	0,925	0,973	0,929	0,904	0,967
Circular Variance	0,075	0,027	0,071	0,096	0,033
Circular Standard Deviation	22,5°	13,2°	21,9°	25,7°	14,8°
95% Confidence Interval (-/+) for μ	175°-193°	154°-165°	182°-200°	178°-199°	175°-187°
99% Confidence Interval (-/+) for μ	172°-196°	152°-166°	179°-202°	175°-202°	173°-189°
Rayleigh Test (Z)	20,547	22,742	19,856	19,607	22,435
Rayleigh Test (p)	3,65E-09	7,46E-10	6,57E-09	6,94E-09	9,38E-10

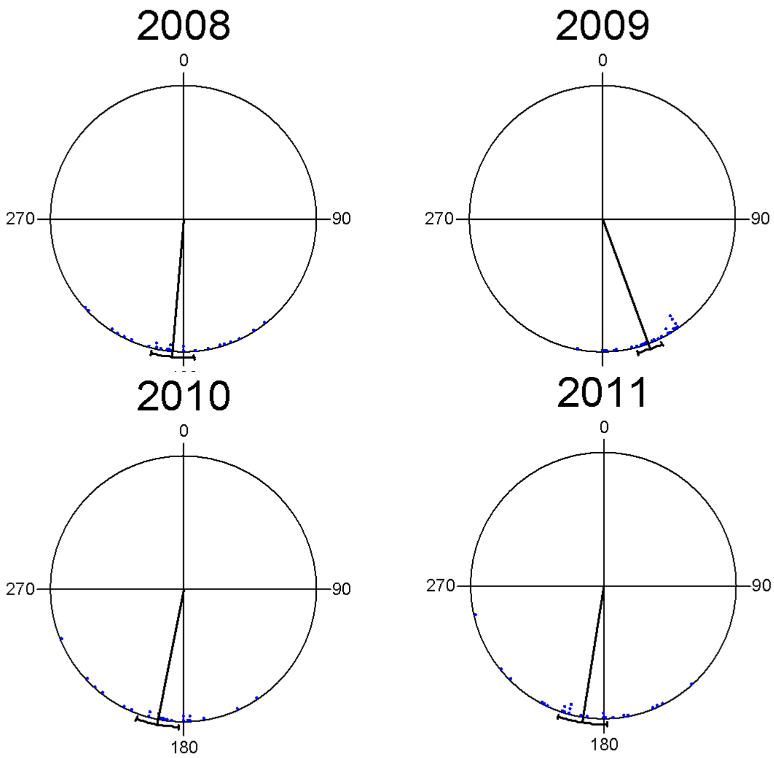


Figure 4. Mean vector and confidence interval of pooled 24 species diurnal migrants observed in the wind park in four autumn seasons. Precise values are presented in Table 5.

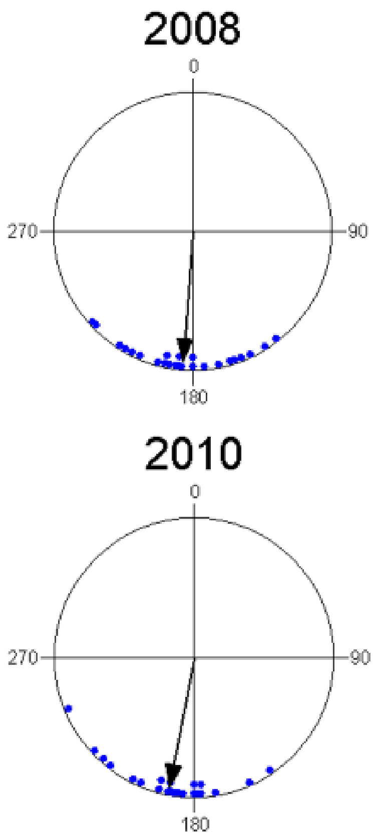


Figure 5. Distribution of directions and the mean vector (azimuth and length) of pooled 24 species diurnal migrants observed in the wind park in four autumn seasons. Precise values are presented in Table 5.

Table 6. Results of statistical analyses (Watson-Williams F-tests) comparing the directional distributions (vectors) for all bird flocks/individuals recorded across four autumn seasons. Significant differences are highlighted in grey.

F scores (lower half of matrix) and probabilities (upper half of matrix)				
Year	2008	2009	2010	2011
2008	-----	3,72E-05	0,342	0,536
2009	20,843	-----	6,11E-07	1,35E-05
2010	0,924	33,68	-----	0,787
2011	0,389	23,739	0,074	-----

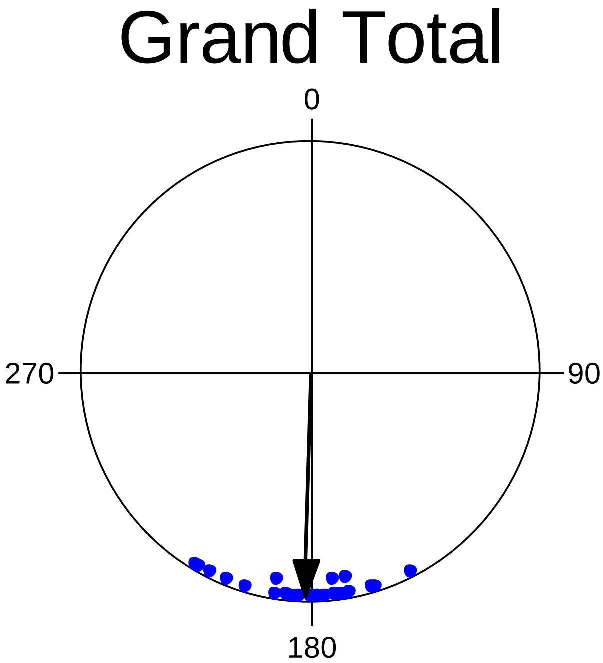


Figure 6. Distribution of directions and the mean vector (azimuth and length) of birds pooled across four autumn seasons: 24 species (blue dot per species) which were observed at least in three of the pooled seasons were included in the calculation.

Statistical comparisons of the directional distributions between the four autumn seasons are presented in Table 6. It is apparent from these comparisons that 2009 was an ‘exceptional’ year: mean direction of the autumn migration in 2009 was not only significantly different to that in 2008 (preconstruction), but also when compared to the direction in 2010 and 2011 (active operational) periods.

These differences are most likely related to climatic conditions, rather than any state of the wind farm development. In autumn 2009 there were no westerly winds and, accordingly, there was the lowest number of storks: a species whose occurrence is highly correlated with westerly winds at SNWF (see autumn 2010 report). Moreover, winds from a SSE direction were more prevalent in 2009 than in the three other autumn seasons.

The pooled direction of autumn migration (Figure 6) for all species across the four years of study does not deviate markedly from a southerly seasonal autumn migration direction (as expected in the absence of the wind farm), even though a deviational effect of the wind farm (in some form) should have been obvious, given the wind farm's presence in three of the four years of study. If the wind farm has had a major deviational influence then the major direction of migratory traffic would have been far more obviously off to the west if it is assumed that birds would naturally avoid the Black Sea (i.e. far more towards the 270^{o} vector in Fig. 6).

Overall, therefore, there is no evidence at the scale of analysis for a major directional change in the flight orientation behaviour of autumn migrants (macro-avoidance) as a result of the wind farm. At the scales considered, birds that were observed to enter the vicinity of the wind farm did not demonstrate any macro-avoidance of the turbines which could thereby be considered as a change of migratory direction and, consequently, a major change in migratory route or any detrimental effect on energy budgets.

The radar data

Location of the fixed beam Bird Scan radar in autumn 2011 is presented in Figure 1. The program for the day time operation of the radar during the autumn 2011 study period provided information for flocks and single birds in the altitudinal zone between 25 and 250 metres. All registered flocks were identified and used to inform the analysis of visual observations presented above.

The data gathered during nocturnal measurement of bird migration are archived and will be analysed in order to compare dynamics and altitudinal distributions. These results will be the subject of a special report concerning nocturnal migration in spring and autumn for the period of radar operation in the wind park territory, 2009 - 2011.

Spatial distribution of the observed flocks and the influence of wind direction

Prevailing wind directions in 2011 were as for seasons 2008, 2009 and 2010: NE and SW. The small proportion of westerly winds in 2011 (1 day in the season: 09 September 2011) coincided with the greatest number of observed storks and pelicans (Figures 7 and 8). These observations in 2011 subjectively confirmed the strong relationship between number of soaring birds and the occurrence of westerly wind direction considered objectively and in greater detail using the 2010 autumn data when the numbers of birds by species were examined according to wind direction using circular-linear correlation coefficients (for details see report for autumn 2010).

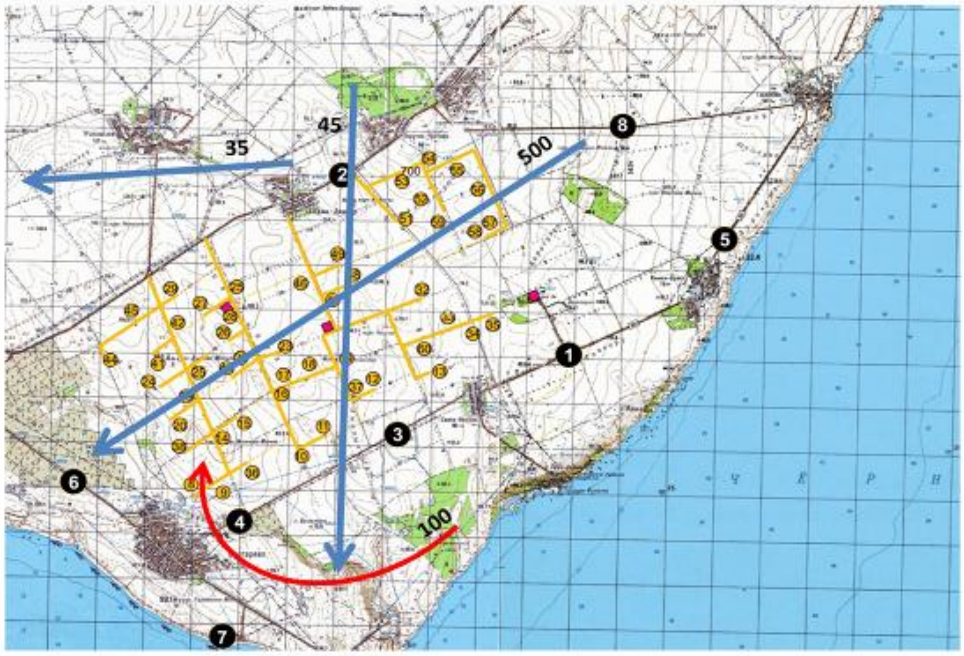


Figure 7. Tracks of flocks of white storks observed 09.09.2011 in the vicinity of SNWF at altitudes over 200 m (blue colour) below 200 m (red colour) above ground level.

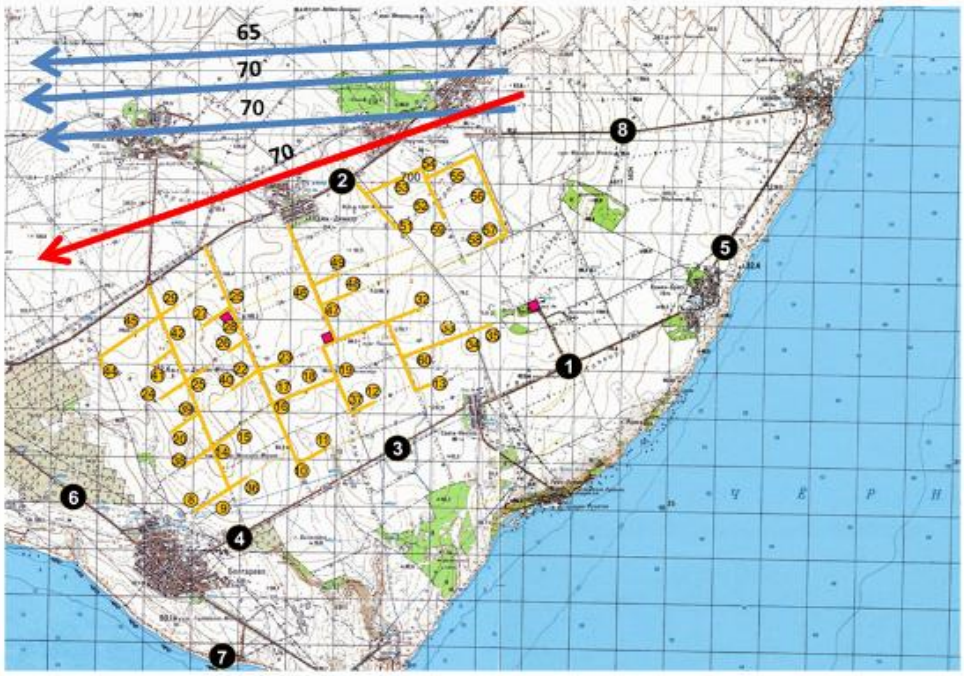


Figure 8. Tracks of flocks of white pelicans observed 09.09.2011 in the vicinity of SNWF at altitudes over 200 m (blue colour) below 200 m (red colour) above ground level.

The data from the 2011 autumn season (which reflect those from previous years) indicated that large numbers of migrants only appear in the wind farm territory when there are westerly winds, especially if these are strong. This once more suggests that the predominant migratory corridor of the *Via Pontica* lies to the west of the wind farm, such that appreciable numbers of autumn migrants (especially soaring birds) only appear in SNWF when diverted by westerly winds, which are unusual in autumn.

Turbine Shutdown System

All flocks of soaring migrants in the region of SNWF were tracked visually, and by radar, and their presence anticipated by attention to predictive weather reports, in order to ensure immediate execution of the TSS under the protocol referred to above. The TSS was applied to groups of turbines for several hours during the period around 09 September 2001 when westerly winds brought in numbers of storks and pelicans to the wind farm area (Figure 7 and 8).

Collision victim monitoring

The search frequency and number of turbines searched per day are presented in Table 3 and Figure 9 respectively. Under this search regime, no mortality attributable to collision strike with turbine blades was detected in the wind park during the autumn 2011 study period, as no carcasses which could be positively identified as collision victims were found during this period.

Table 3. Timetable of the carcass searches efforts in the period of the study.

Count of N																																																				
Date	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	29	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	Grand Tota
15.8.2011																						1	1		1	1												1			1											6
16.8.2011					1							1																1									1		1	1												6
17.8.2011		1					1	1																			1		1																							5
18.8.2011													1				1													1		1	1	1																		6
19.8.2011					1							1										1	1					1													1											6
20.8.2011						1																		1	1	1														1											1	6
21.8.2011			1	1					1	1	1					1																																				6
22.8.2011														1	1				1		1										1																					5
23.8.2011	1	1						1												1							1									1																6
25.8.2011							1						1				1	1											1	1																						6
26.8.2011																					1											1	1	1	1																	5
27.8.2011																																													1	1	1	1	1			5
29.8.2011																																										1	1	1						1		4
30.8.2011						1																	1	1	1	1																									1	6
31.8.2011																						1															1	1	1	1	1											6
06.9.2011			1	1					1	1						1																																				5
08.9.2011	1	1					1	1																			1		1																							6
10.9.2011																																													1	1	1	1	1			5
11.9.2011						1																																				1	1	1						1	1	6
12.9.2011																							1														1	1	1		1											5
13.9.2011					1							1										1						1												1												5
14.9.2011			1	1					1	1						1																																				5
15.9.2011														1	1				1												1					1																5
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17.9.2011													1				1	1											1	1																						5
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21.9.2011																																										1	1	1	1					1		5
22.9.2011					1							1										1						1													1											5
24.9.2011						1																	1	1	1	1																									1	6
25.9.2011																																					1	1	1	1												4
26.9.2011			1	1					1	1	1																																									5
27.9.2011														1	1	1															1																					4
28.9.2011	1	1																	1								1									1																5
29.9.2011							1	1					1																1																							4
30.9.2011																	1													1		1	1																			4
Grand Tota	4	5	4	4	4	4	5	5	4	4	2	4	4	3	3	4	4	2	3	1	3	5	5	3	4	4	5	4	5	4	3	3	4	3	2	3	4	4	4	5	5	3	3	3	3	3	3	3	3	3	4	186

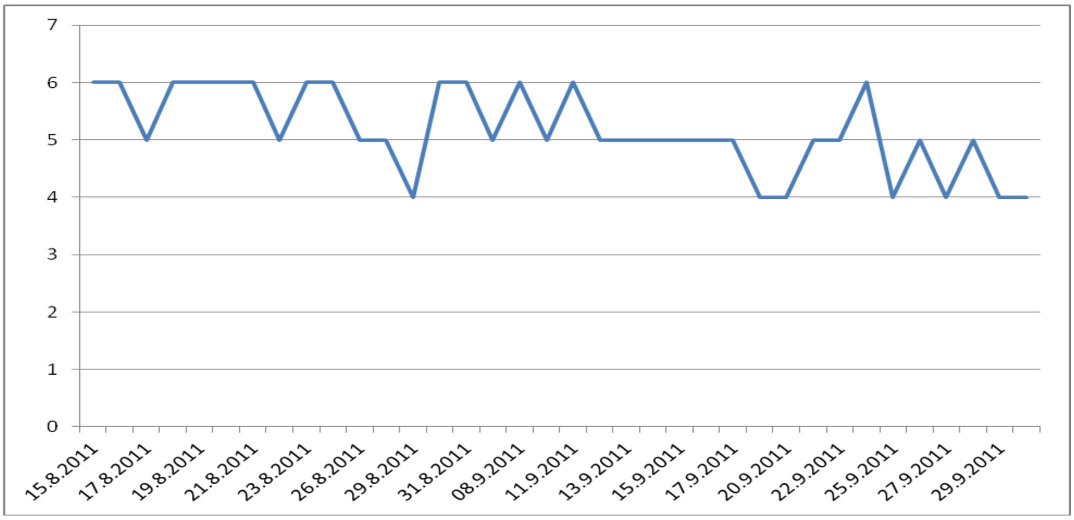

Figure 9. Number of turbines searched per day for collision victims in the period 15th August – 30th September 2011.

CONCLUSIONS

1. There is no substantial evidence for a significant barrier effect of the constructed wind park on autumn seasonal bird migration through the area influenced by SNWF.

2. The numbers of species varied across years with no trend for a decrease after SNWF was constructed and started its operation.
3. The absolute number of observed birds varied by years but with no trend for a decrease after SNWF was constructed and started its operation.
4. The altitude of flight varied by years with no overall trend for an increase after SNWF was constructed and started its operation. Some individuals of low flying species may have increased their flight altitude due to SNWF's turbines, but based on their migratory energetic budgets this will have had inconsequential effects.
5. There is no evidence for change in migratory direction (avoidance) associated with the wind park territory. At a gross scale, birds did not demonstrate macro-avoidance of the turbines that could be considered as a change of migratory direction and, thereby, a change of migratory route.
6. In 2011 the occurrence of autumn migrants was strongly correlated with a very short period of one day when strong westerly winds occurred. This confirmed previous analyses showing the strong influence of meterological conditions on the presence of birds at SNWF, which appear to massively outweigh any influence of the development's presence on the behaviour and presence of autumn migrants.
7. No collision victims were recorded during the 2011 autumn migration period, despite frequent searches under the turbines. The brief period when the TSS was applied may have contributed to this finding.
8. The substantial data collected to date indicate that the operation of SNWF does not constitute a major obstacle or threat, either physically or demographically, to populations of diurnal autumn migrants passing through its environs.

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