Bird migration monitoring in the AES Geo Power Wind Park territory, Kaliakra region, in autumn 2010

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

Report to AES Geo Energy OOD,
Chervena Stena 38, 1421 Sofia,
Bulgaria

Contents

SUMMARY

This report considers the comparative results of three autumn seasons' study (2008 – 2010) within the scope of the potential impact of the Saint Nikola Wind Farm (SNWF), constructed in summer 2009, on migrating birds. Data from visual observations and radar study are analysed.

In 2010, the occurrence of autumn migrants was strongly correlated with a very short period when strong westerly winds occurred. Outwith this exceptional period, numbers of migrants were low, but rose dramatically during the short period of strong westerly winds. Spatial and temporal dynamics in the numbers of different species passing through the wind park territory during autumn migration is presented.

SNWF does not appear to lie on a regularly used part of the Via Pontica migration corridor for diurnal migrants, especially those species that rely on thermals to migrate. This is probably due to SNWF's proximity to the Black Sea and the geography of the Kaliakra Cape. The Via Pontica migration corridor is probably fairly broad in extent in Bulgaria but most of the migratory traffic is likely to the west of SNWF and Kalikra, presumably because birds try to avoid the Black Sea and the risks associated with an absence of thermals over the sea. These arguments are illustrated by analysis of data across several spatial and temporal scales regarding a common migrant, the white stork.

As a consequence, it is reasonable to conclude that few autumn migrants are typically recorded at SNWF and, when numbers are relatively high, they are strongly associated with westerly wind conditions, probably because these winds drive birds from their preferred route. Such westerly winds are unusual during autumn.

Therefore, the risk of collision mortality posed by SNWF is intrinsically low because: a) it lies away from the main Via Pontica migration corridor; and b) presence through vagrancy is further limited by the rarity of conditions that drive vagrant migrants towards SNWF (i.e. strong westerly winds).

This intrinsically low risk, through the behavioural ecology of autumn migrants, is reduced still further by the turbine shut down protocol at SNWF. This mitigation measure, to reduce collision risk, was enacted during a short spell in autumn 2010 when unusual westerly wind conditions probably pushed several migrant birds away from the their preferred migration route.

No collision victims of key migratory species were recorded during the brief period of concentrated potential vulnerability in 2010. This was likely a result of the low intrinsic risk of collision posed by SNWF and/or the turbine shutdown system that was enacted.

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

Knowledge of spatial distribution of birds is required to address many fundamental questions of evolutionary ecology and ornithology as well as for practical solutions. Bird migration is an adaptation for exploiting areas separated in space which differ in their suitability over time, with the classic example being seasonal migration of species which breed in the Northern Hemisphere but avoid the harsher conditions in winter by migrating to the Southern Hemisphere after breeding. The routes taken by migrating birds are often relatively restricted because conditions which favour migration can be geographically restricted, and such routes can be termed migration corridors.

A conditional group of soaring migrants includes pelicans, storks, birds of prey and cranes, although some raptor species and cranes fly mainly in an active manner (flapping their wings). These soaring birds primarily use the lifting warm air currents (thermals) for a special kind of flight that is energetically efficient because it uses extrinsic sources of energy (thermals) to move forwards, without active flapping of wings. Soaring bird migration consequently tends to be restricted to the land and at times when solar radiation is sufficient to generate thermals, and is often concentrated in space and time accordingly because major water bodies (e.g. the sea) and times of day (e.g. at night) are not conducive to the generation of thermals.

At the border between the ground and water bodies, such as at the Black Sea coast, in particular, there is a difference in the air temperature. This difference limits the flight abilities of the soaring migrants and can lead birds along the coastal lines. This 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. Although there are data pointing to the guiding role of the Black Sea coast creating the migration corridor known as *Via Pontica* (Zalles & Bildstein, 2000), the satellite tracking data of many soaring bird species shows deviation of over 200 km in individual migratory tracks in the autumn. For example, results suggest that white storks *Ciconia ciconia* have only a rough inherited migratory direction and therefore meteorological conditions and winds particularly must influence their direction and distribution on migration. In keeping with this, all soaring species can be observed throughout the whole of Bulgaria during autumn migration.

In NE Bulgaria, close to the Black Sea coast, AES Geo Energy OOD has constructed a wind farm, the Saint Nikola Wind Farm (SNWF), consisting of 52 turbines. SNWF is within a broader area considered to be part of the general Via Pontica migration corridor. In the last 6 years, several field studies have investigated the spatial and temporal distribution of migratory and breeding birds within this area.

With a view to providing objective possible data for evaluation of the risk for the birds this study aim at comparative analysis of the three autumn seasons concerning correlations in the numbers of birds and meteorological conditions at the wind park territory. Particular emphasis is placed on the white stork, given its abundance and conservation status, and the wealth of knowledge on this species' migration due to satellite tagging of birds of the breeding grounds. The report also updates the priority list of species with high conservation value concerning possible impact on their populations.

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 (Map 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.

METHODS

Duration and equipment

The study was carried out in the period 15 August – 30 September 2010, covering a total of 45 days, the period of the most intensive migration according to preliminary information (6 years of regular monitoring of the site). The surveys were made during the day, in standard interval of time between 8 AM and 6 PM Astronomic time. 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 according to the following scanning program:

Diurnal Radar Observations

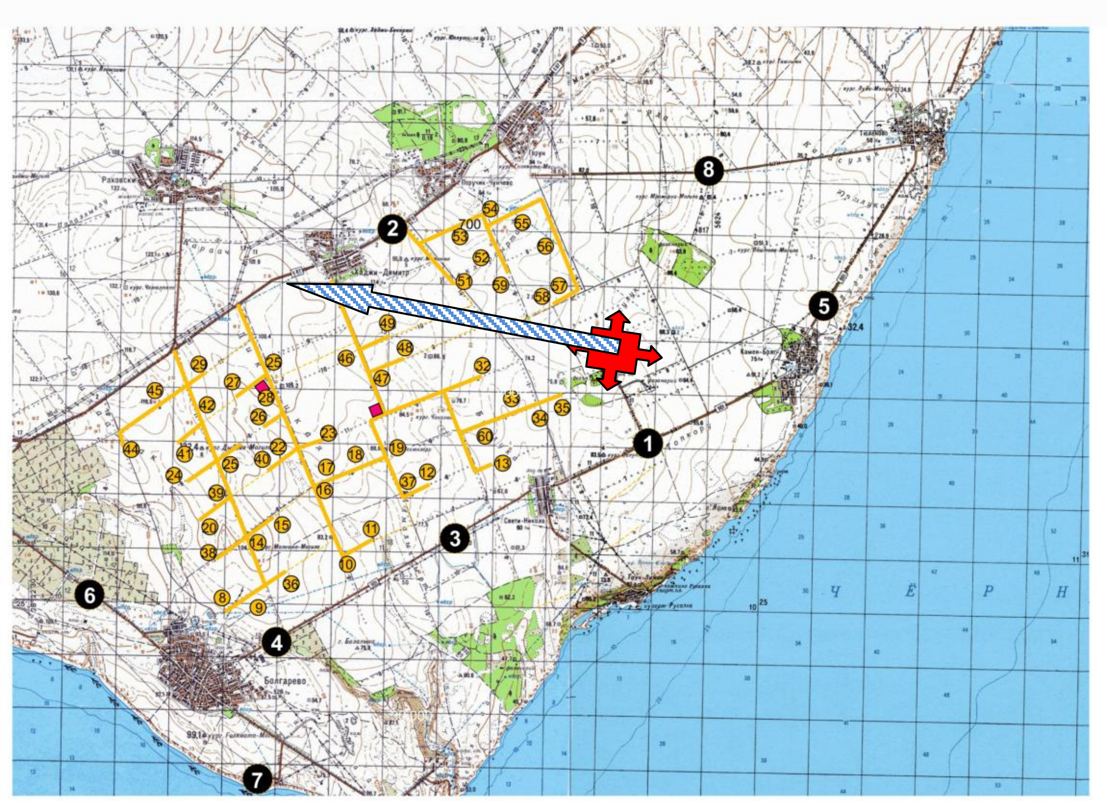
1. Four minutes at 30 mills, or as low as ground clutter permits (equivalent to approximately 25-275 m elevation at 5 km distance);
2. Four minutes at 80 mills (equivalent to275-525 m at 5 km distance);
3. Four minutes at 130 mills (equivalent to 525-775 m at 5 km distance);
4. Four minutes at 180 mills (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.

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

Map 1. Location of the plot of the wind park radar beam and the observation points (black dots). The study involved direct simultaneous visual survey of all passing birds from eight points (black dots).



This conditional division was made to allow for focusing the study mainly on the birds of conservation importance like pelicans, storks and diurnal raptors. Data about other (non-soaring) species were collected as a second priority, as specified in the text below.

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 constructions and other landmarks in the vicinity of the observation points that had previously been measured, calibrated on location by GPS, and marked on maps available to the observer. Such site familiarization is very important in ensuring that records are as accurate as possible.

All observers were qualified specialists carrying out the surveys of bird migration for many years including the last three autumns. All observers are active members of the BSPB (BirdLife Bulgaria).

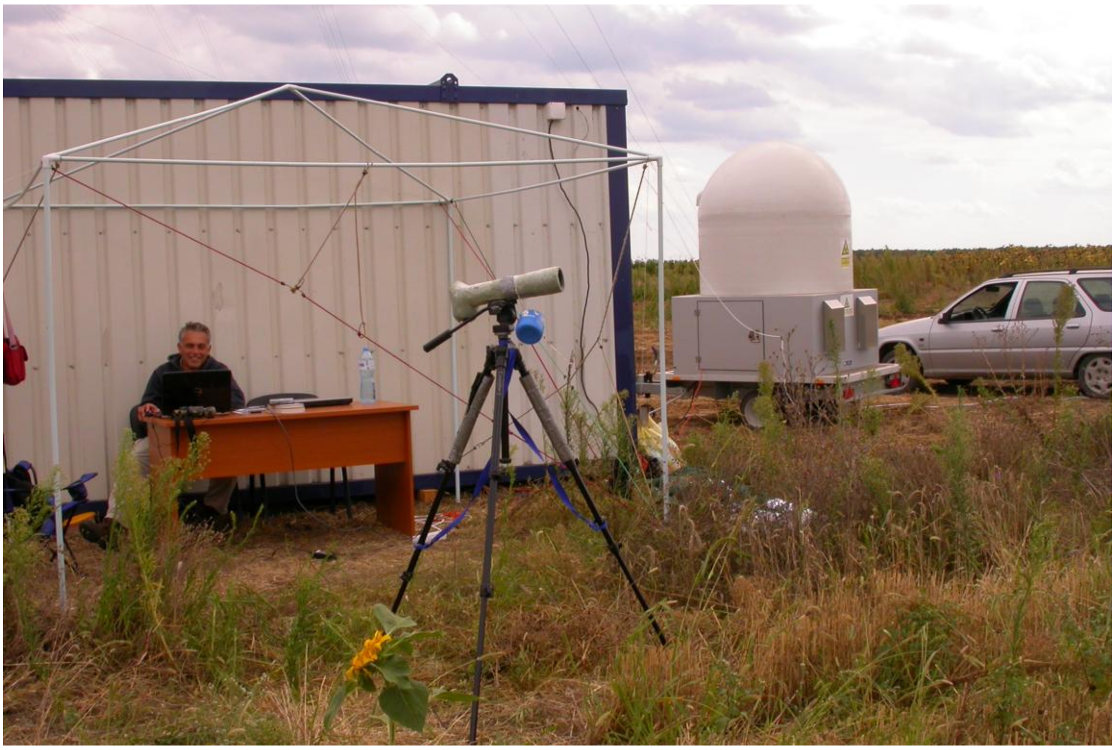


Photo 1. Coordinated combination of radar and visual observations in autumn 2010.

List of participants in the observations:

Dr Pavel Zehtindjiev
Institute of Zoology
Bulgaran Academy of Sciences
Sinior Field Ornithologist

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

Dimitar Vladimirov Dimitrov
PhD student in Institute of Biodeversity 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

Dr Mihaela Nikolova Ilieva
Institute of Biodeversity and Ecosystem Research, Bulgarian Academy of Sciences
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

The surveys were carried out by means of optics, every surveyor having a pair of binoculars with 10x magnification. Observation points were permanently equipped with standard Admiral telescopes, with magnification 20 – 60x, compass, GPS and digital camera.

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 Autumn Monitoring Reports for 2008 and 2009). 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 small 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 4), 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.

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 same method was used for calibration of the radar at both observation lines during the survey period.

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. Tendencies for species (or group of species) to fly in particular directions were tested according to standard circular statistics (Batschelet, 1981).

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.

Recording of the data

All the data of the surveys were entered in a field 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.

Colision Risk Reduction System

The general principles, which provide a procedural checklist, are listed below and were used to inform the decision making process. 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 scenarios, when considering all species and circumstances at any one time, would be too numerous to prescribe).

1. As soon as a significant number of birds were detected flying in close proximity to the wind farm (definition of 'close proximity' will vary with weather conditions and general visibility but anything sighted within 5 km should be considered), either through field observation or radar, the Senior Field Ornithologist was notified of this activity. This bird activity was tracked to determine the direction of flight.

2. Determination of what is considered a significant number should be based upon a combination of the species in the flock and their number. As a broad example, a small number of key migrant species (as defined within the Supplementary Information Report) should be considered as important as a larger number of non-key species, and vice versa. The determination of whether the number of birds is significant was the responsibility of the Senior Field Ornithologist informed by the field ornithologists and/or radar operator.

3. Where the direction flight lies close to the wind farm but appears unlikely to pass through the site then the activity was observed until such time as the birds have passed the site and out of close proximity. The Senior Field Ornithologist made the final decision of when a flock of birds, considered as significant, no longer lies in close proximity and thus when observations of that flock can cease.

4. Prevailing wind strengths and directions for the site and surrounding area have been established at the outset of each day and were considered in terms of its possible influence on flight direction of birds (particularly soaring species). It was particularly important to consider times where strong westerly winds could result in large, and potentially unexpected, migration across the site.

5. Where the direction of flight lay in close proximity and appeared to be heading towards any part of the wind farm, the activity was observed from the relevant vantage point(s). Two mobile observers were operating

along the main roads around the wind park in order to track all identified flocks.

6. The Senior Field Ornithologist made the decision of if and when to shut down the relevant turbines informed by his own observations, the observations of the field ornithologists and the radar operator in consideration of a combination of the following:

    - The species within the flock (this determines issues such as likely avoidance behaviour, speed of flight, height of flight and relative importance);
    - The height at which the flock is approaching the wind farm;
    - The speed at which the flock is approaching the wind farm (this will be a function of the type of species within the flock and prevailing wind conditions);
    - The direction of the flight (in order to inform the number of turbines that could require shut down);
    - The known typical behavioural patterns of the species in terms of turbine avoidance;
    - The weather conditions, primarily in terms of the prevailing wind directions, the possibility of changes in direction, and strength; and
    - The time lag between verbally instructing a shut down and cessation of blade rotation (see point below for further information).

7. It should be noted that the time lag between the verbal notification to shut down and cessation of blade rotation is considered to be in the order of up to 2 minutes. The decision of when to instruct a shut down will take account of this time lag.

8. Where the species identified were those key species addressed within the Project Supplementary Information Report[1], specific regard was paid to their conservation status and a precautionary approach was taken in each case of potential shut down i.e. where doubt existed as to whether the birds that may enter the wind farm were of high conservation status then a shut down was enacted.

9. Where a flock heading towards the wind farm eventually takes evasive action, avoids the wind farm, and thus a shut down is not enacted by the Senior Field Ornithologist, the principles established in bullet 3 were followed.

10. For birds observed as roosting on the site at dawn, the Senior Field Ornithologist instructed the operations office to shut down the relevant turbines that could potentially cause a risk to the birds when they take flight. Once the birds have taken flight the same procedure as detailed in bullet point 9 above was followed.

---

[1] Saint Nikola Kavarna Wind Farm Supplementary Information Report, Rev04, July 2008, AES Geo Energy

11. For birds observed as roosting close to the site at dawn, the activity was observed and the Senior Field Ornithologist made a professional judgement as to whether to shut down the relevant turbines based upon:

    - Proximity of the flock to the wind farm;
    - The species within the flock (this determines issues such as take off behaviour, speed of flight, height of flight likely avoidance behaviour, and relative importance);
    - The weather conditions, primarily in terms of the prevailing wind directions, the possibility of changes in direction, and wind strength;
    - Likely direction of flight when the birds take off, where possible (by way of illustration, if geese are observed it is possible that, once they have finished roosting, they will take flight northwards towards Shabla);
    - The time lag between verbally instructing a shut down and cessation of blade rotation (see bullet below for further information).

12. Where shut down is not enacted, observations of the birds were maintained until such time as they take flight. Once they have taken flight, if they moved away from the wind farm then the principles detailed within bullet point 3 above were to be followed. If they moved towards the wind farm then the principles detailed under bullet points 5 to 9 above were followed.

This interim protocol was followed in order to test reduction risk sytem during the period of intensive migration in autumn 2010 between 15 August and 30 September.

Statistical methods

The circular-linear correlation coefficient (Fisher, 1993: p.145; Mardia & Jupp, 2000: p.245; Zar, 1999: p. 651) was calculated between a circular variable (e.g. wind direction) and a linear variable (e.g. number of birds by species). This correlation coefficient ranges from 0 to 1, so there is no negative value. The calculation of the significance of the correlation follows Mardia & Jupp (2000) in using their approximation of the F distribution in equation 11.2.2.

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 in 2010. The study encompassed 405 astronomic hours of observations from eight observation points. Additional data from the studies of autumn migration in the wind park territory from 2008 and 2009 was used for the analysis of correlations between the number of birds and physical components of the environment.

The only new species observed in autumn 2010 was griffon vulture (*Gyps fulfus*). This species does not qualify for threatened, near threatened, or conservation dependent. It is categorized as Least Concern, but it is nevertheless a rare species in Bulgaria. Long-term decline (in some cases from 2nd half 19th century) has continued more recently in Portugal, Italy, Albania, Ukraine, Turkey, and Syria, while range expansion has been reported for France (aided by reintroduction scheme from early 1980s), Spain, and Bulgaria. Individuals of this species are currently being introduced in Bulgaria from Spain. The rest of the species showed different degrees of variation in numbers over the three autumn seasons of studies; presented in Table 1.

Table 1. Numbers of birds observed in the wind park territory during autumn migration 2008, 2009 and 2010 for soaring bird species and target species of high conservation value.

Species	**Number of birds**		
	Year		
	2008	**2009**	**2010**
A. brevipes	95	210	976
A. chrysaetos			2
A. cinerea	120	259	26
A. gentilis	10	6	5
A. heliaca	2		
A. nisus	44	44	70
A. pennata			3
A. pomarina	44	9	80
A. purpurea		59	11
B. buteo	146	390	180
B. oedicnemus		1	
B. rufinus	163	151	34
C. aeruginosus	327	268	341
C. ciconia	2998	87	25478
C. cyaneus	5	1	
C. macrourus	8	27	18
C. nigra	8	8	8
C. olor		1	3
C. pygargus	32	17	86
E. alba			1
E. garzetta		7	
F. cherrug		7	
F. eleonorae	7		
F. naumanni	1		
F. peregrinus		2	4
F. subbuteo	48	125	120
F. tinnunculus	138	357	45
F. vespertinus	11	180	800
G. fulvus			1

Species	**Number of birds**		
	Year		
	2008	**2009**	**2010**
H. pennatus	4	3	17
M. apiaster	11079	3714	5325
M. migrans	18	6	32
M. milvus			1
P. apivorus	58	76	494
P. crispus	4		
P. falcinellus	5	721	
P. haliaetus	15	13	14
P. leucorodia	117	83	56
P. onocrotalus	120	1190	252
Ph. carbo	265	354	394
Ph.pygmaeus		19	

Eleven species have been observed in one autumn but did not appear in the other two autumn seasons. Three species were present in two seasons only. The other species were observed in all three seasons, in numbers that varied between species and year. The species with relatively constant numbers passing through the territory are *Ph. carbo*, *P. leucorodia*, *P. haliaetus*, *C. nigra*, *C. aeruginosus*, *B. buteo*, *A. pomarina*, *A. nisus*, and *A. gentilis*. The most dramatic variations are observed in the numbers of soaring bird species: *P. onocrotalus*, *C. ciconia*, *P. apivorus*, *M. apiaster*, *F. vespertinus*, *F. subbuteo*, and *A. brevipes*.

Dominant wind directions in the period of autumn observations 2010 is presented in Fig. 1. Prevailing winds were as for seasons 2008 and 2009: NE and SW winds. The small proportion of westerly winds (3 days in the season) coincided with greatest number of observed birds (Fig. 2, Fig. 3).

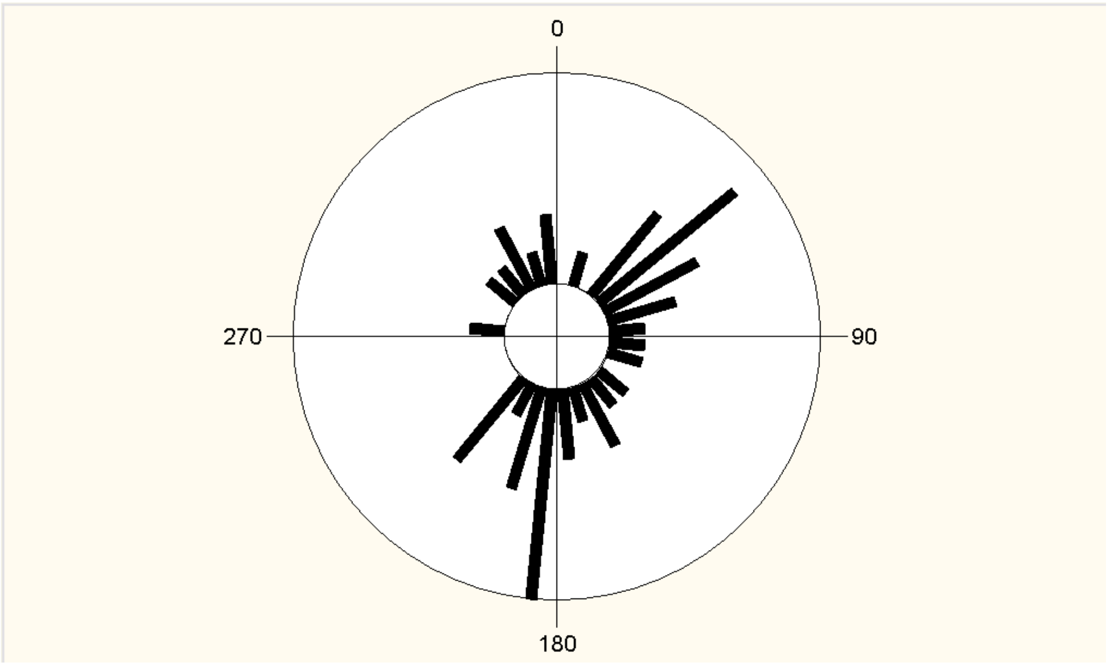


Fig. 1. Distribution of wind directions during the study period in autumn 2010.

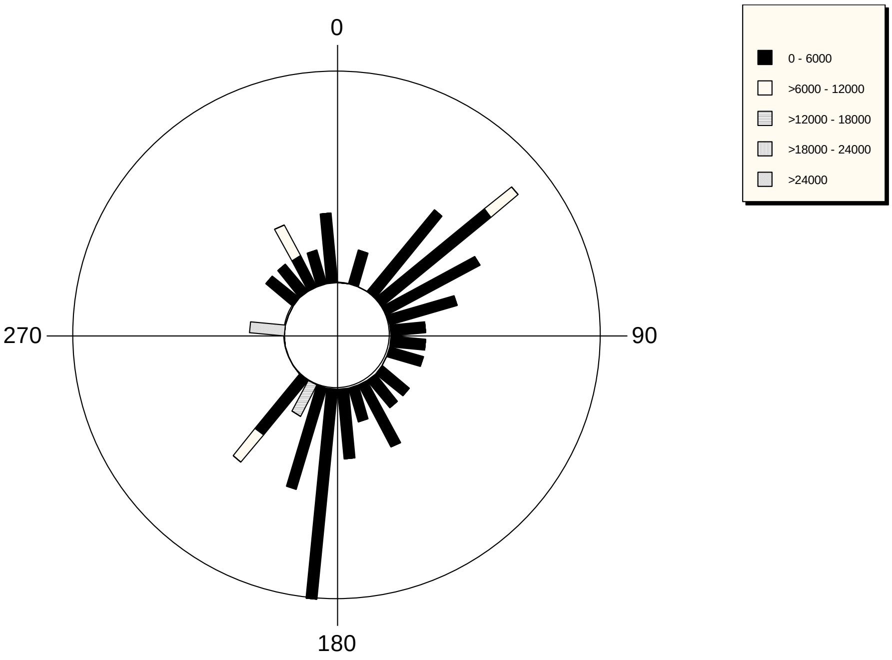


Fig. 2. Distribution of observed bird numbers in the region of the wind park according to wind directions in autumn 2010. The observed numbers include all registered birds including those that passed outside the wind park territory.

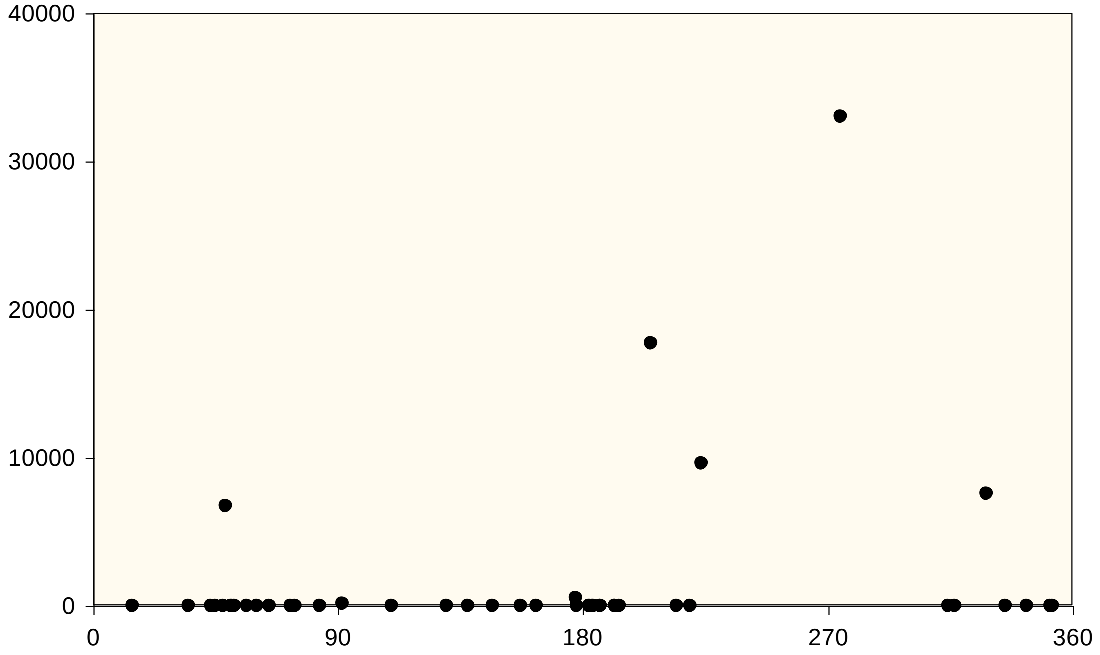


Fig. 3. Numbers of birds observed under different wind directions in the region of the wind park. Wind direction is indicated in degrees (0 – 360, where 180 is South, and 0 is North).

All these data indicated a strong relationship between number of soaring birds and wind direction. To analyse this possible relationship we used data for wind direction for the autumn 2010 (Fig. 1) and the numbers of birds by species (Table 1). The results are presented in Table 2.

Considering all birds in 2010, total counts of birds were highly significantly correlated with wind direction (Table 2), since the greatest number of soaring birds was observed in the periods with the most rare westerly wind direction (Fig. 2). For particular species, the correlation also tended to be stronger for soaring species and weaker for non-soaring species (Table 2).

The species with most significant correlation were also frequently the same as those which are most variable in numbers by autumn seasons 2008, 2009 and 2010 (Table 1). The results of the comparative analysis of the quantitative data between years clearly indicated an important role of wind conditions in the numbers of migrating birds (especially soaring migrants) passing through or over the wind park territory. These results also suggested that the constructed park did not change the migratory habits of the species crossing the territory: the numbers of these species varied by years but with no trend for a decrease after the park was constructed and started its operation.

Another potentially important component in the dynamics of the numbers by species and all birds in general in the wind farm region was wind speed. The distribution of the bird numbers observed in relation to wind speed is presented in Fig. 4.

Autumn migration in 2010 was unusual concerning numbers of some species of soaring birds like white storks (*C. ciconia*), Levant sparrowhawks (*A. brevipes*), Honey buzzards (*P. apivorus*) and Red-footed falcons (*F. vespertinus*). Th majority (over 70%) of the observed birds of these species appeared in two days of the study period when there were strong westerly winds.

Table 2. The circular-linear correlation coefficient (Fisher, 1993, p.145; Mardia & Jupp, 2000, p.245; Zar, 1999, p. 651) calculated for observed in the wind park region in autumn 2010. This correlation coefficient (*r*) ranges from 0 to 1, so there is no negative correlation. The calculation of the significance (*p*) of the correlation follows Mardia & Jupp (2000) (* indicate the most significant values).

Species	***r***	***p***
A. apus	0.207	0.167
A. brevipes	0.279	0.038
A. cinerea	0.290	0.029
A. melba	0.062	0.853
A. nisus	0.345	0.007*
A. pomarina	0.216	0.142
A. purpurea	0.193	0.21
Apus sp.	0.143	0.422
B. buteo	0.278	0.039
B. rufinus	0.078	0.775
C. aeruginosus	0.369	0.003*
C. canorus	0.241	0.086
C. ciconia	0.414	6.89E-4***
C. gallicus	0.414	6.96E-4***
C. macrourus	0.277	0.04
C. nigra	0.269	0.048
C. pygargus	0.326	0.011
D. urbicum	0.177	0.267
F. subbuteo	0.374	0.006*
F. tinnunculus	0.132	0.523
F. vespertinus	0.168	0.305
H. pennatus	0.351	0.005*
H. rustica	0.198	0.191
Hirundinidae	0.233	0.103
L. cachinnans	0.338	0.008
M. apiaster	0.167	0.318
M. migrans	0.334	0.009*
P. apivorus	0.402	0.001**
P. haliaetus	0.173	0.284
P. leucorodia	0.148	0.397
P. onocrotalus	0.328	0.011
Ph. carbo	0.361	0.004**
R. riparia	0.248	0.076
St. vulgaris	0.015	0.991
All species together	**0.429**	**4.00E-4*** **

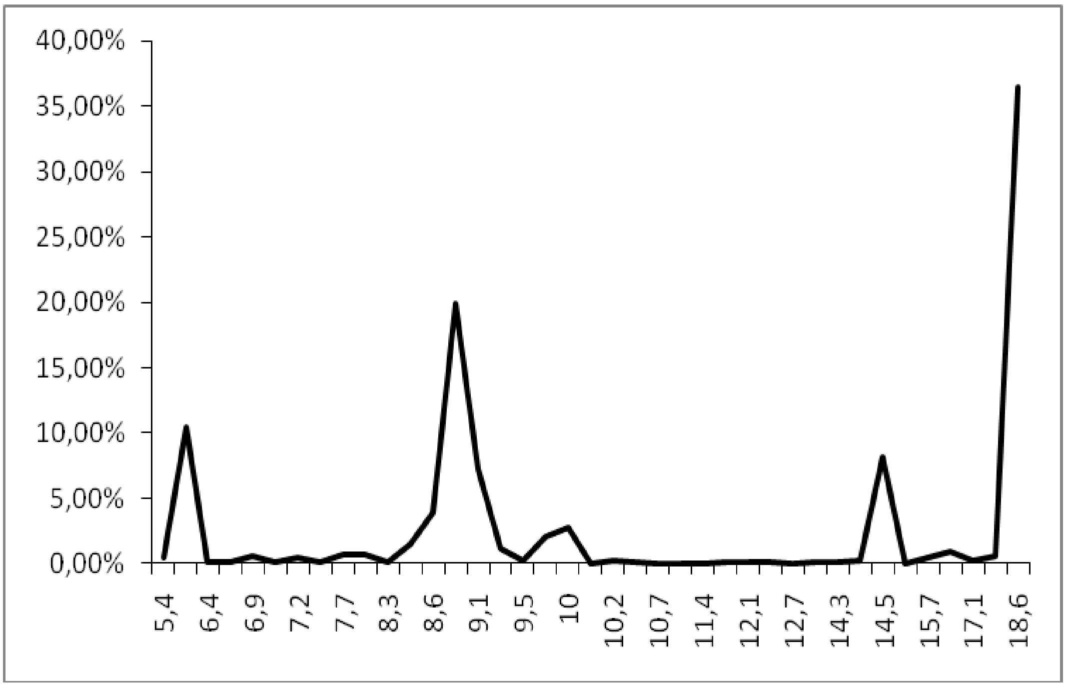


Fig. 4. Proportion of observed birds in relation to wind speed in autumn 2010.Wind speed is given in m/s.

The data from the 2010 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 westerly winds are strong. This suggests that the predominant migratory corridor of the Via Pontica lies to the west of the wind farm territory, such that appreciable numbers of autumn migrants (especially soaring birds) only appear in SNWF when directed by westerly winds, which are unusual.

This argument can be examined further by examining information collected away from SNWF. Considering such information, the most objective results concerning species identification and numbers that reduce subjectivity and other limitations of methodology are data concerning species that are easily recognized and are organized in flocks, such as the white stork.

Hence, the dynamics of white stork autumn migration documented by visual observations simultaneously in two locations, in NE Bulgaria i.e. at the coast of the Black Sea (at SNWF) and at 60 km inland (at Krushary), were used for the comparative analysis presented below.

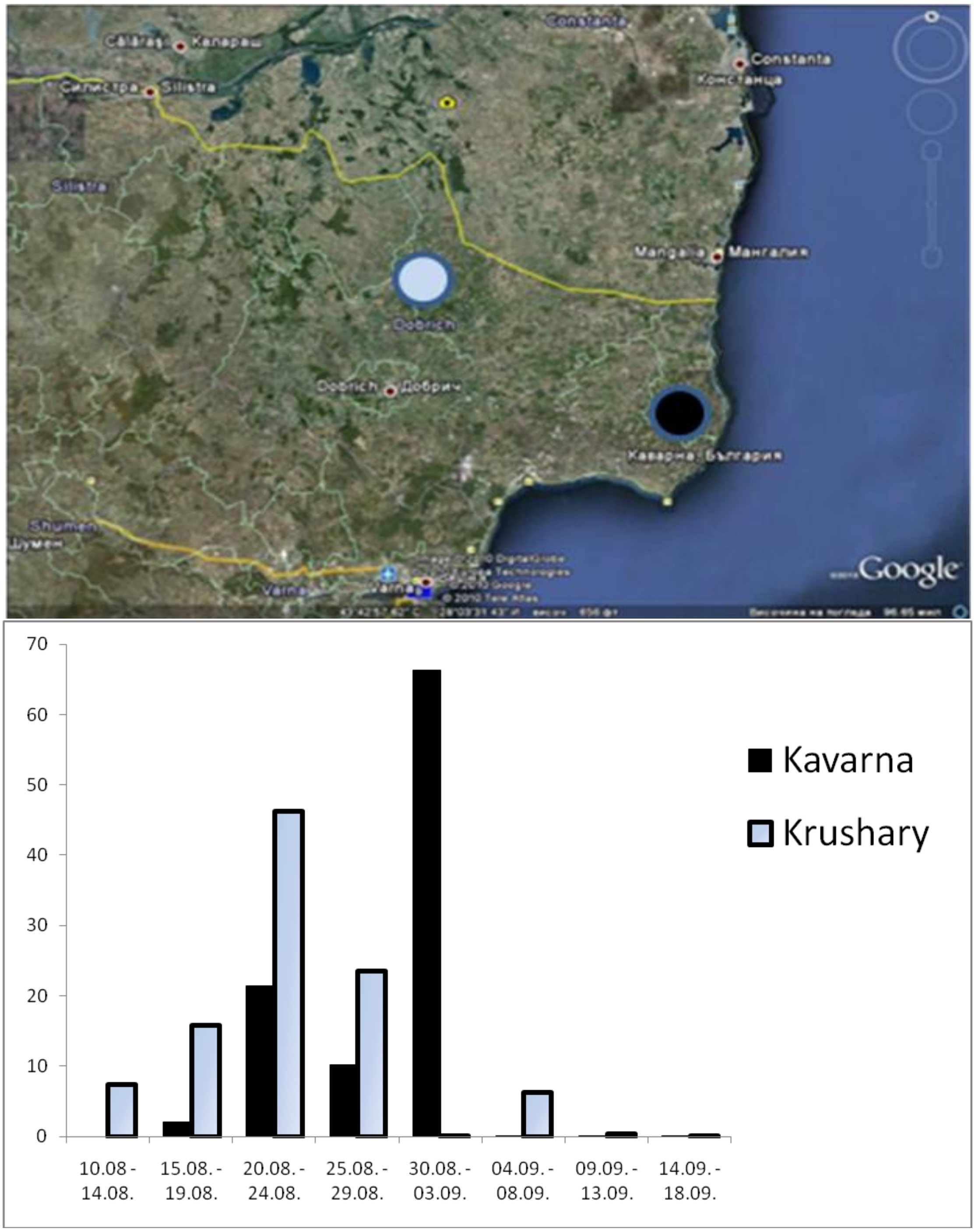


Fig. 5. Dynamics of white stork migration in two locations in autumn 2010 (% of birds by time period): the locations of the sites are given on the map above.

The observations at the inland site reflected phenology of white stork passage in Bulgaria while the SNWF data indicate smaller numbers in most time periods but an extraordinary increase in one short period. Moreover, the sudden increase in the number of White storks in Kaliakra was after the species' peak of migration observed elsewhere (Fig. 5). This result is in line with all three years of observations at in Kaliakra district (where SNWF is located) where strong fluctuations in numbers by species in different autumn seasons have been observed. For example the White stork numbers for autumn of 2008, 2009 and 2010 were 2,500, 87 and over 25,000 respectively. These results are consistent with the argument that sites like SNWF near the coast are typically peripheral for autumn migration, and are only used to any appreciable degree as a consequence of sporadic factors like rare westerly wind drifting birds into the coastal territories. A less likely explanation is that the fluctuations at SNWF reflect trends in population numbers.

For the interpretation of these possibilities larger scale information can be helpful, and data from over 10 years of satellite tracking of white storks has been recently published (Willem Van den Bossche, in collaboration with Peter Berthold, Michael Kaatz, Eugeniusz Nowak & Ulrich Querner 2002). These large scale data show obvious avoidance of large open water bodies such as Black Sea and Mediterranean Sea (Fig. 6).

☑ Flugstaffel 2006 - 2007
☑ Annamarie ☑ Prinzesschen
☑ Flugstaffel 2005 - 2006
☑ Annamarie ☑ Prinzesschen
☑ Flugstaffel 2004 - 2005
☑ Annamarie ☑ Prinzesschen
☑ Jonas
☑ Flugstaffel 2003 - 2004
☑ Felix ☑ Annamarie
☑ Prinzesschen ☑ Jonas
☑ Flugstaffel 2002 - 2003
☑ Felix ☑ Annamarie
☑ Prinzesschen ☑ Jonas
☑ Flugstaffel 2001 - 2002
☑ Felix ☑ Prinzesschen
☑ Flugstaffel 2000 - 2001
☑ Penelope ☑ ANNELIESE
☑ Flugstaffel 1999 - 2000
☑ Peterchen ☑ LOUKA
☑ Flugstaffel 1998 - 1999
☒ Animation beschleunigen
20.08.1998-19.12.2006
Zeitraum

Fig. 6. White stork migration as tracked by satellite transmitters – inter-continental view (after Willem Van den Bossche, in collaboration with Peter Berthold, Michael Kaatz, Eugeniusz Nowak & Ulrich Querner 2002)

At a finer scale these data clearly also indicate avoidance of coastal regions as typical routes for white storks on migration (Fig. 7 – 9). This is also shown by van Loon et al. (2010). At a coarse scale the gross avoidance of large water bodies is probably determined by the simple fact of total absence of thermals above the sea, and at a finer scale the tendency to avoid coastal regions whenever possible probably relates to birds trying to allow some leeway for unanticipated weather events (e.g. being blown over the sea). Thermals over land further from the sea may also in general be more frequent.

While these broad principles appear to apply, even when only considering the routes of German and Polish white storks, their distribution covers over half of Bulgaria, and so the migration corridor is not narrow (Fig. 7). Examination of flight routes used by different individuals indicates variations in individual migratory paths between seasons of over 300 km on average (Fig. 8 - 9). This suggests broadly similar routes are taken by different individuals that may be influenced by conditions encountered en route, such as wind conditions.

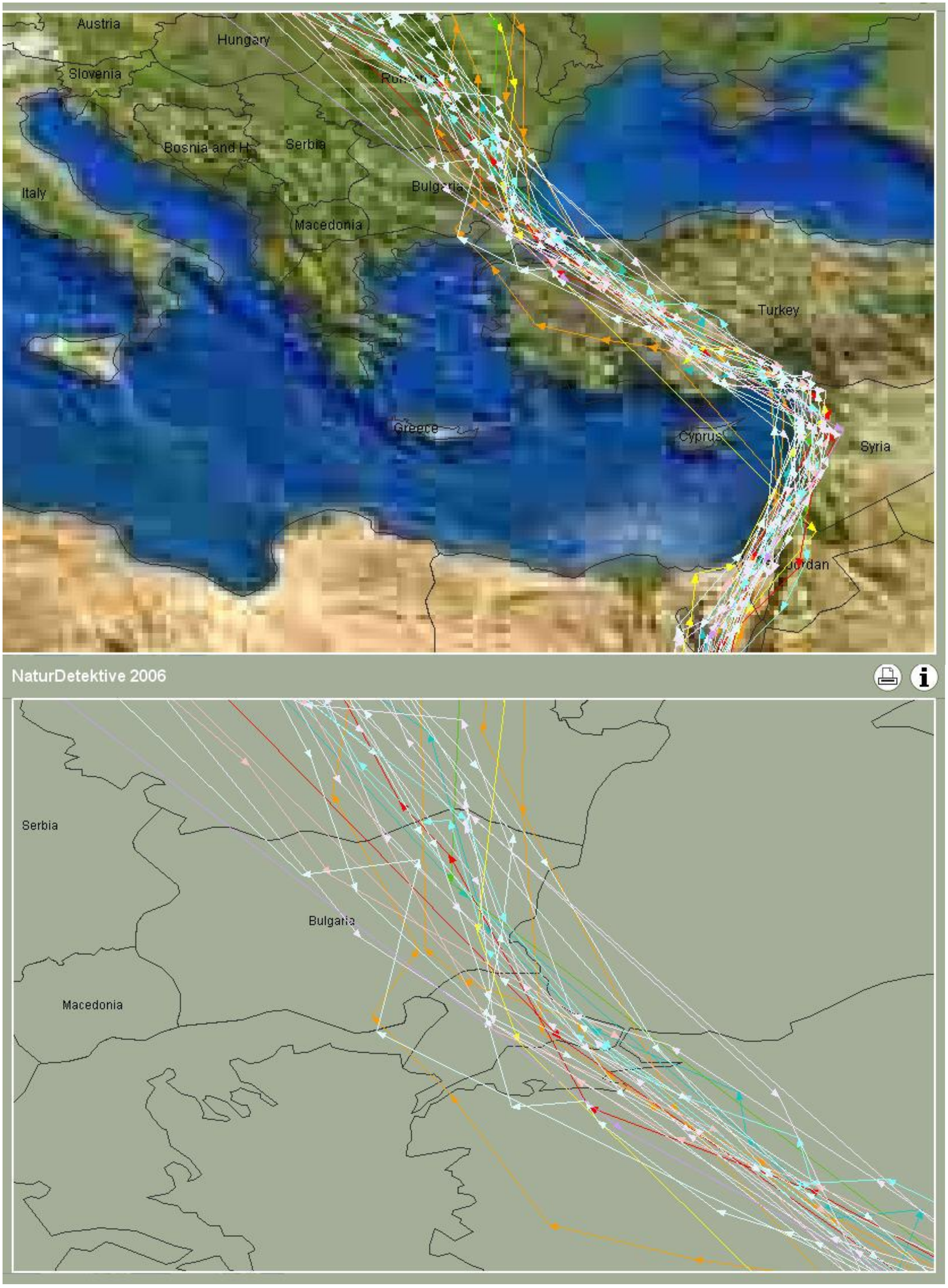
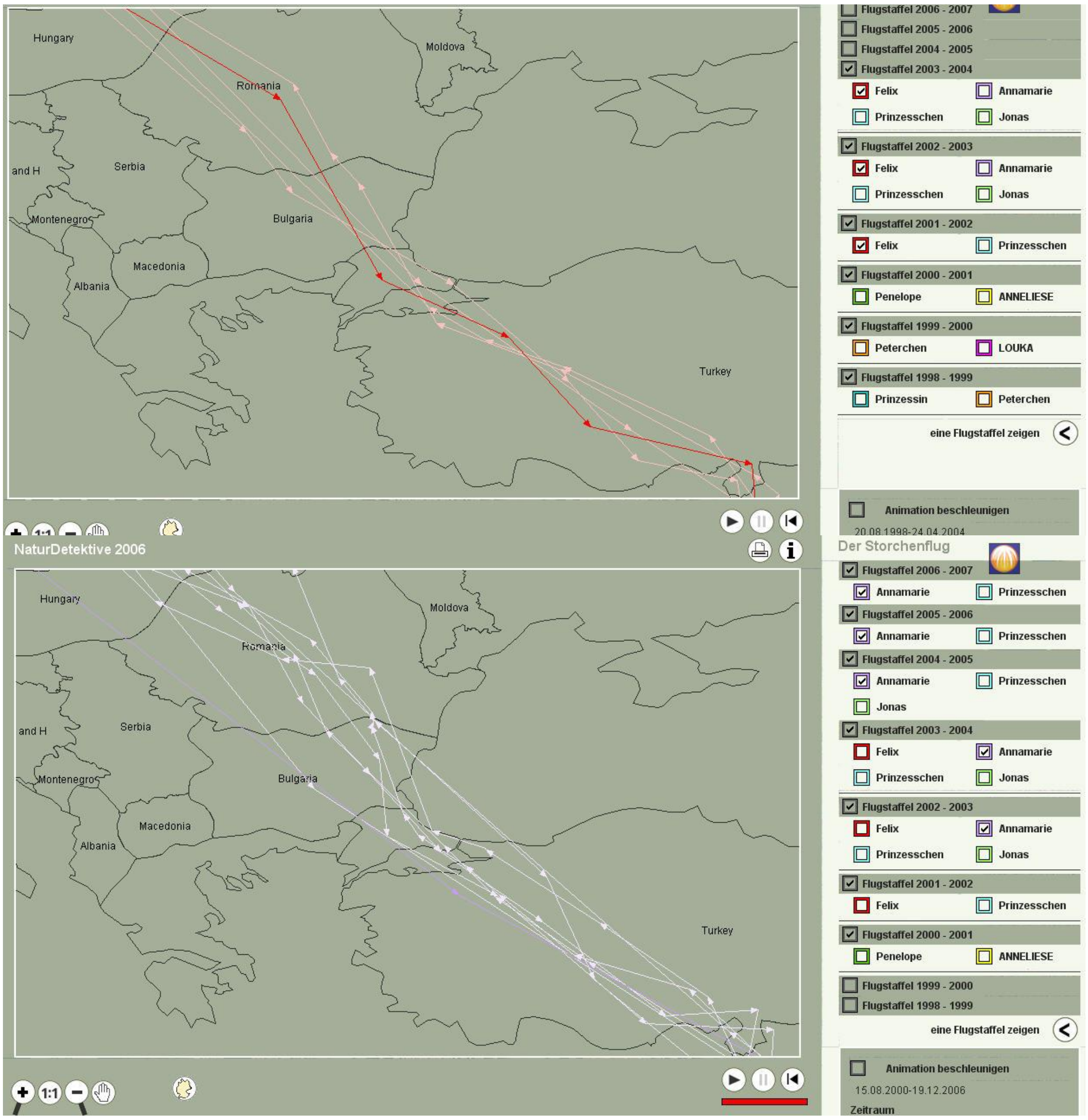


Fig. 7. Individual tracks from a 10 year study of German and Polish white storks by satellite transmitters over the countries of the Balkan Peninsula. Track on Google map (above) and the same tracks on a simplified map (below) (after Willem Van den Bossche, in collaboration with Peter Berthold, Michael Kaatz, Eugeniusz Nowak & Ulrich Querner 2002).



☐ Flugstaffel 2006 - 2007
☐ Flugstaffel 2005 - 2006
☐ Flugstaffel 2004 - 2005
☑ Flugstaffel 2003 - 2004
☑ Felix ☐ Annamarie
☐ Prinzesschen ☐ Jonas
☑ Flugstaffel 2002 - 2003
☑ Felix ☐ Annamarie
☐ Prinzesschen ☐ Jonas
☑ Flugstaffel 2001 - 2002
☑ Felix ☐ Prinzesschen
☑ Flugstaffel 2000 - 2001
☐ Penelope ☐ ANNELIESE
☑ Flugstaffel 1999 - 2000
☐ Peterchen ☐ LOUKA
☑ Flugstaffel 1998 - 1999
☐ Prinzessin ☐ Peterchen
eine Flugstaffel zeigen
☐ Animation beschleunigen
20.08.1998-24.04.2004

Der Storchenflug
☑ Flugstaffel 2006 - 2007
☑ Annamarie ☐ Prinzesschen
☑ Flugstaffel 2005 - 2006
☑ Annamarie ☐ Prinzesschen
☑ Flugstaffel 2004 - 2005
☑ Annamarie ☐ Prinzesschen
☐ Jonas
☑ Flugstaffel 2003 - 2004
☐ Felix ☑ Annamarie
☐ Prinzesschen ☐ Jonas
☑ Flugstaffel 2002 - 2003
☐ Felix ☑ Annamarie
☐ Prinzesschen ☐ Jonas
☑ Flugstaffel 2001 - 2002
☐ Felix ☐ Prinzesschen
☑ Flugstaffel 2000 - 2001
☐ Penelope ☐ ANNELIESE
☐ Flugstaffel 1999 - 2000
☐ Flugstaffel 1998 - 1999
eine Flugstaffel zeigen
☐ Animation beschleunigen
15.08.2000-19.12.2006
Zeitraum

Fig. 8. Individual tracks of two individual white storks from Gernany (after Willem Van den Bossche, in collaboration with Peter Berthold, Michael Kaatz, Eugeniusz Nowak & Ulrich Querner 2002).

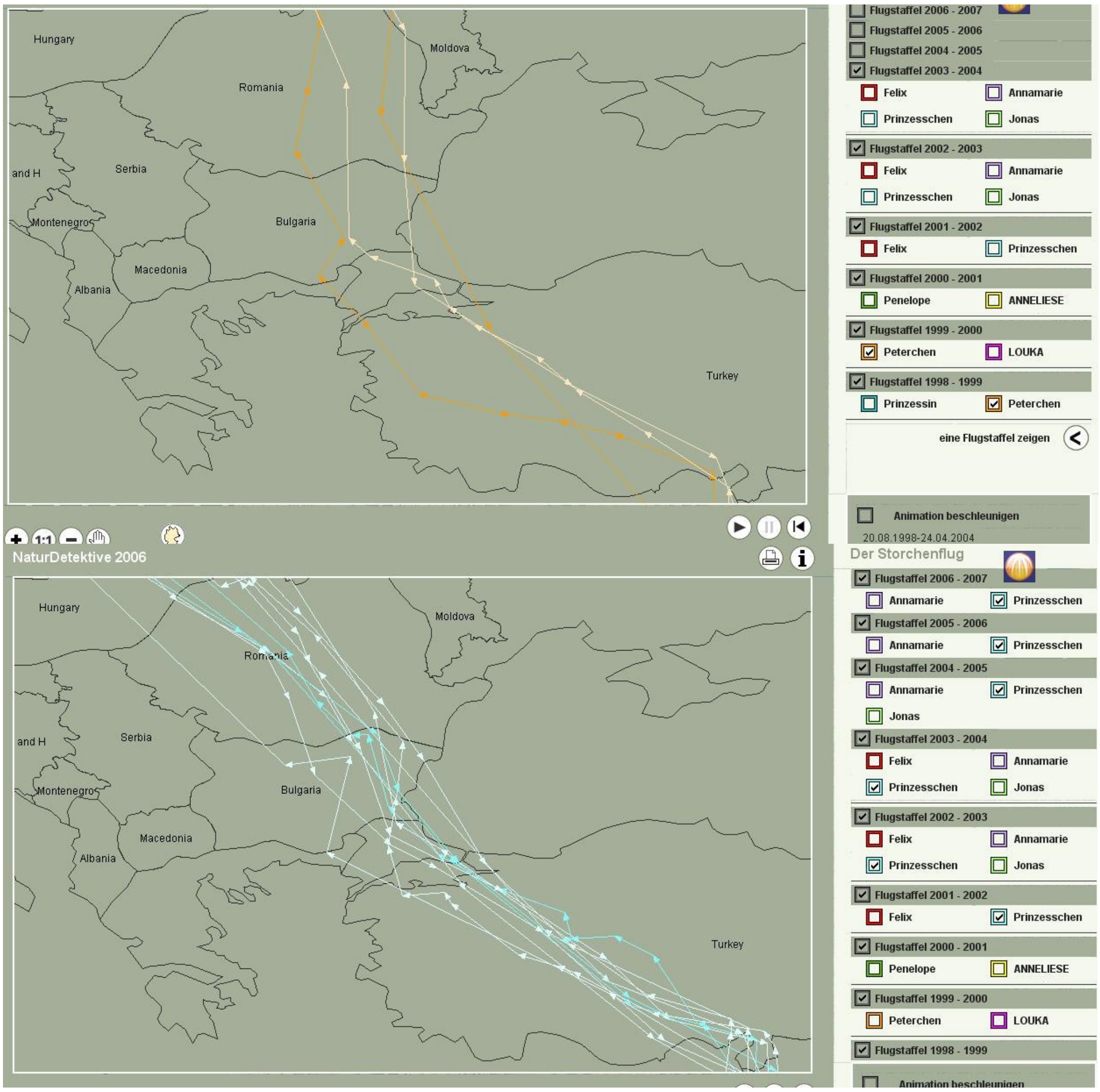


Fig. 9. Individual tracks of two individual white storks from Gernany and Poland (after Willem Van den Bossche, in collaboration with Peter Berthold, Michael Kaatz, Eugeniusz Nowak & Ulrich Querner 2002).

Behavioural observations in the wind park territory in 2010 when the number of white storks reached 25,000 for two days allow an analysis of the movement strategies of these birds in relation to the hypothesis that birds try to avoid the sea and the coast hinterland. All flocks of white storks in the region of SNWF were tracked in order to implement a turbine shutdown system under the protocol above described above, for reduction of collision risk for birds in the period of intensive migration through the wind farm territory.

The tracks and locations of the flocks observed on the 1st and 2nd of September 2010, when over 80% of the recorded white storks passed through the environs of SNWF, are presented below (Fig. 10 – 15).

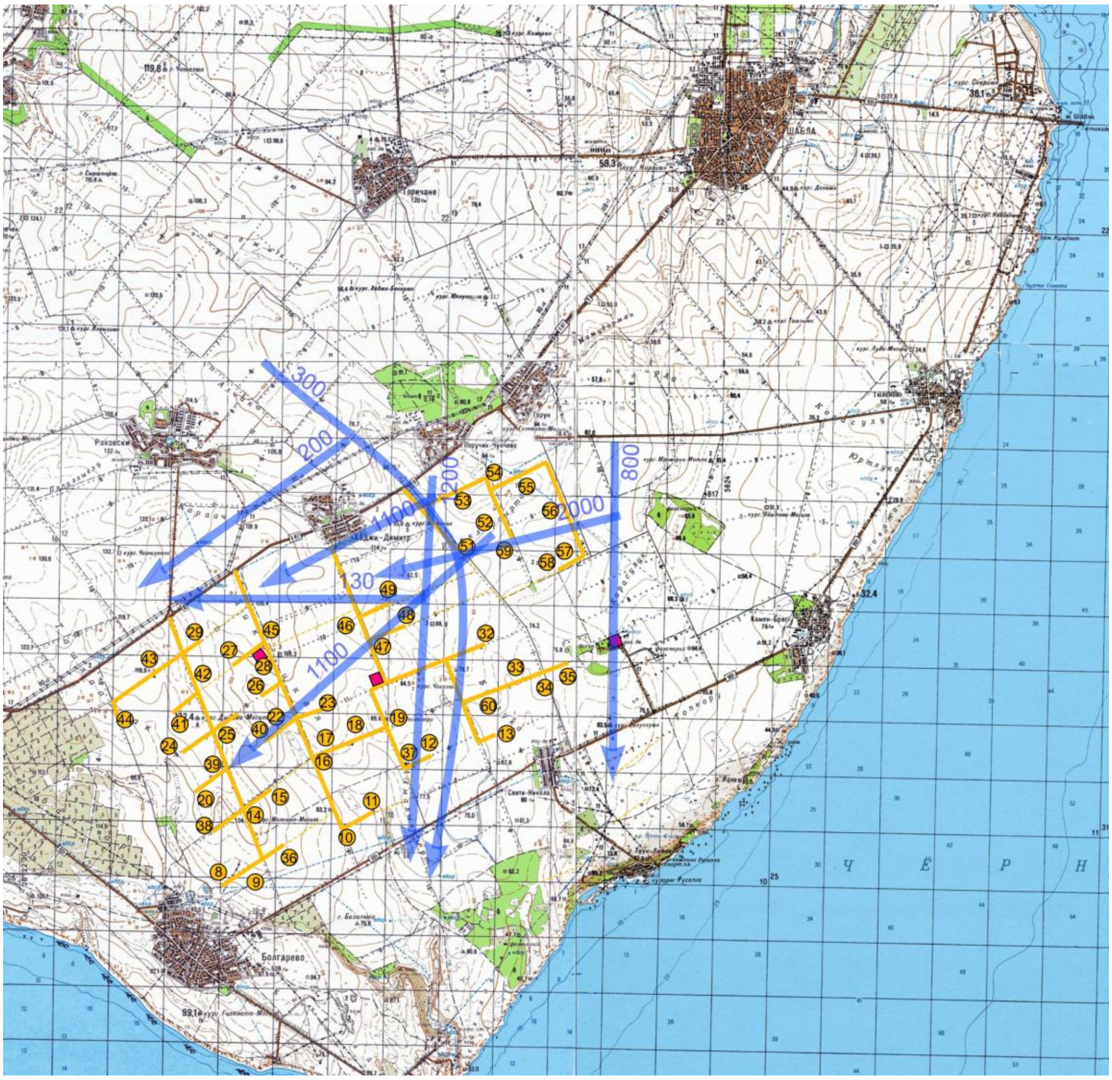


Fig. 10. Tracks of flocks of white storks observed 01.09.2010 in the vicinity of SNWF at altitudes over 200 m above ground level (i.e. at heights above risk of collision).

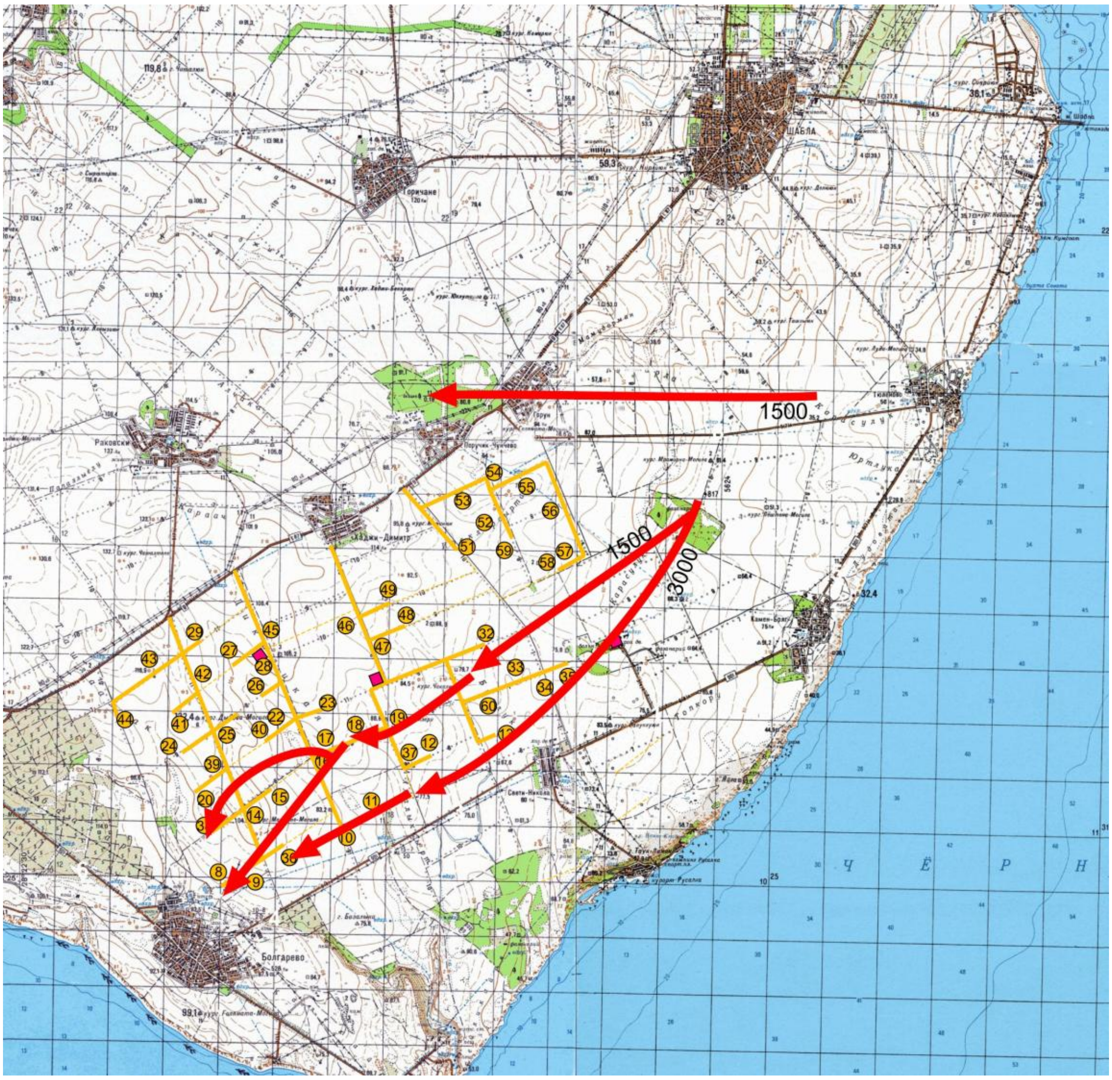


Fig. 11. Tracks of flocks of white storks observed 01.09.2010 in the vicinity of SNWF at altitudes below 200 m above ground level.

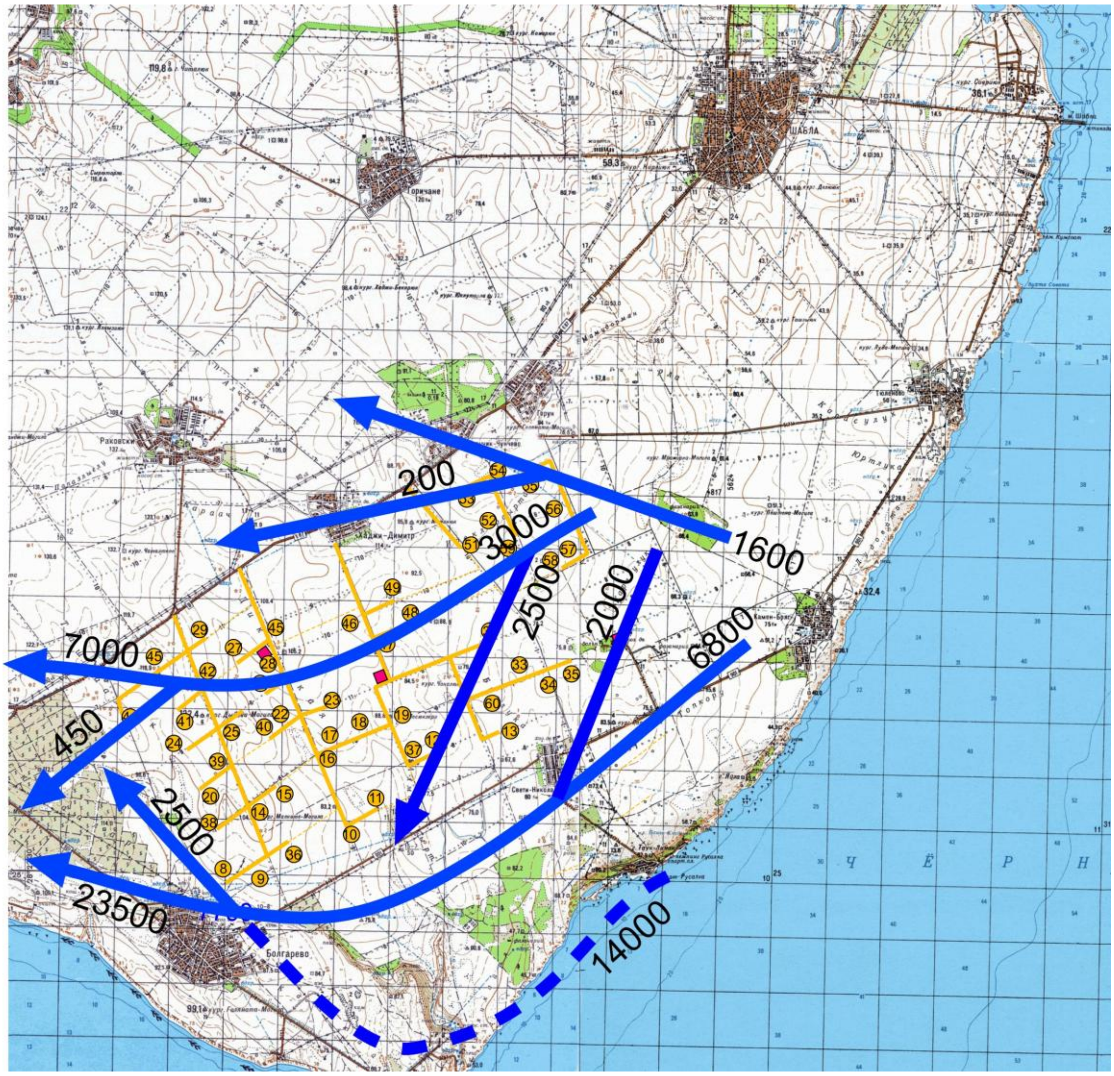


Fig. 12. Tracks of flocks of white storks observed 02.09.2010 in the vicinity of SNWF at altitudes over 200 m above ground level.

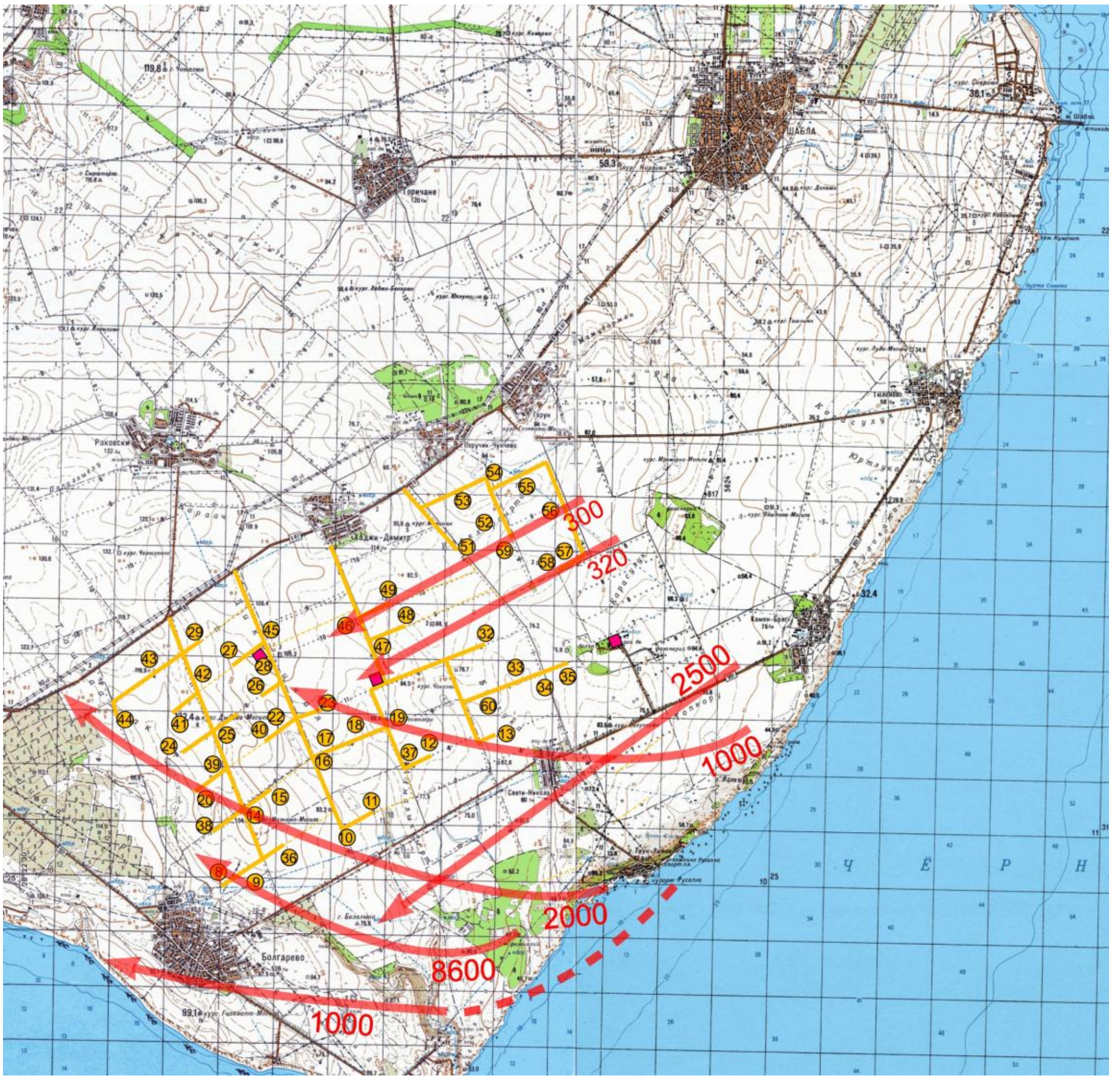


Fig. 13. Tracks of flocks of white storks observed 02.09.2010 in the vicinity of SNWF at altitudes below 200 m above ground level.

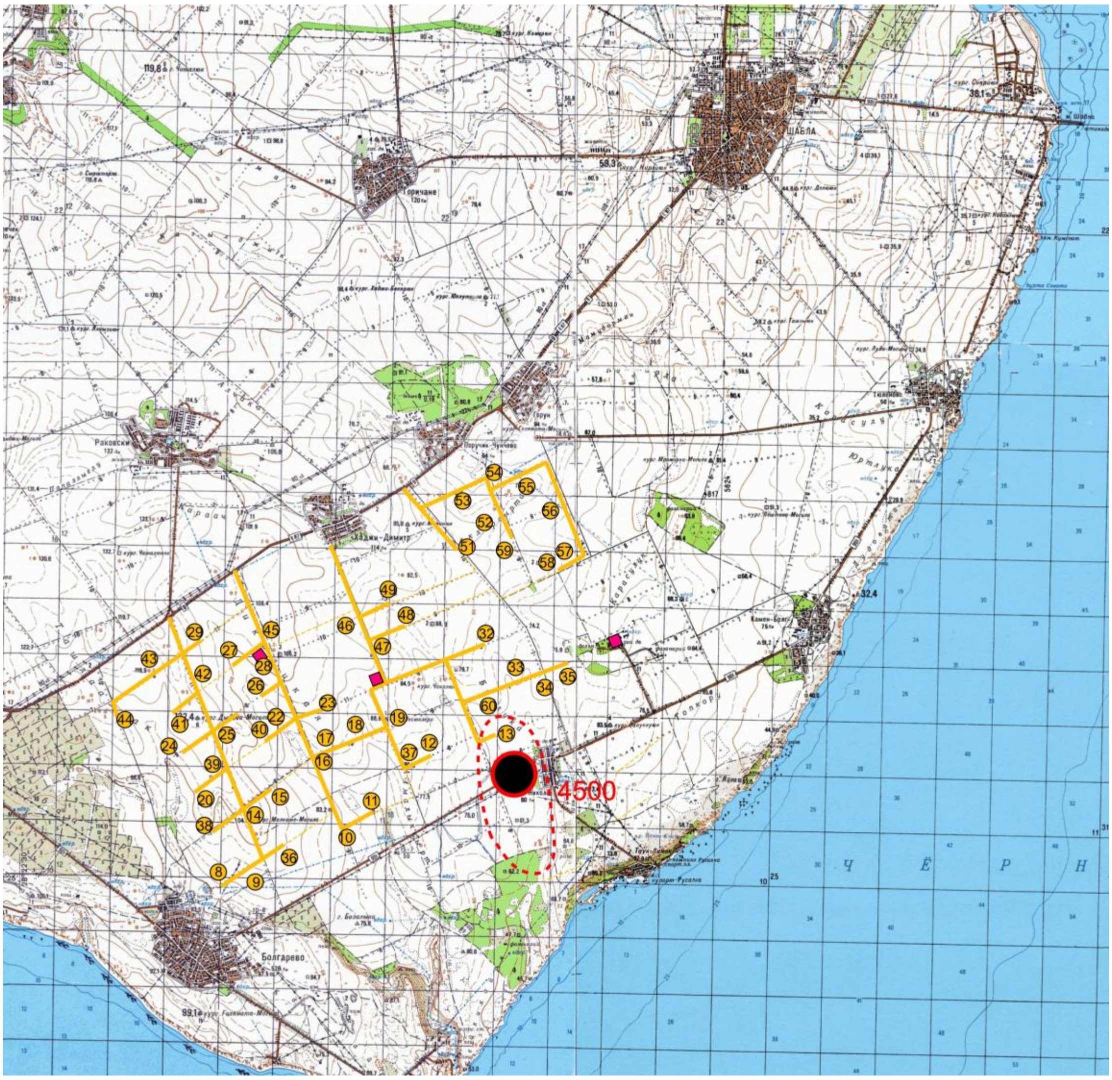


Fig. 14. Overnight locations of flocks of white storks observed 1.09.2010.

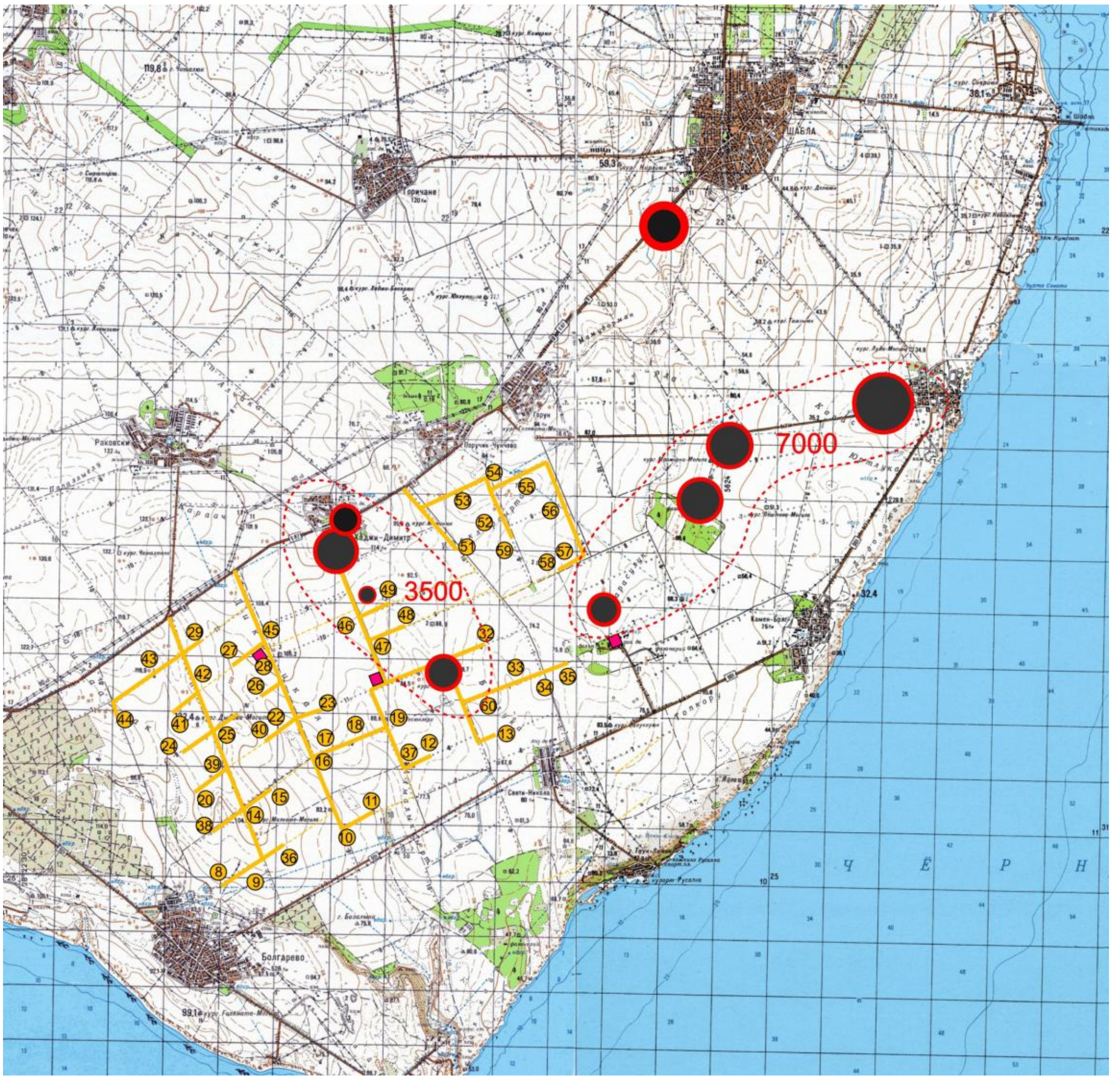


Fig. 15. Overnight locations of flocks of white storks observed 2.09.2010.

The observed behaviour of the flocks confirms the intention of the white storks to escape the coastal zone as soon as the wind conditions allowed them to continue migratory movement according to the preferred strategy.

The unusual meteorological sitiation in the two days with intensive migration of white storks allowed testing of the turbine shutdown system as a mitigation measure for reduction of collision risk for the birds. According to the above described protocol a system for coordinated actions, including six observation points, two mobile observers and radar, resulted in over 40 stops of single turbines and groups of turbines during the two days of intensive passage of white storks. No collision victims were recorded at SNWF during this potentially vulnerable period.

Radar Data

Location of the fixed beam Bird Scan radar is presented in Map 1 above. The program for the day time operation of the radar during the reported period provided information for the flocks and single birds in the risk zone between 25 and 250 m altitudes. All registered flocks are presented in Table 3.

Table 3. Flocks and single targets of birds crossing the wind park during the 2010 autumn migration identified by radar signature via a visually confirmed record.

Date	Tme		Species	N	Distance	Altitude	Direction
23.8.10	8	45	*L. cachinnans*		1500	200	SW
23.8.10	8	52	*D. urbicum*		300	30	SE
23.8.10	10	0	*L. cachinnans*	4	300	200	SE
23.8.10	10	24	*L. cachinnans*	12	450	200	SE
24.8.10	8	8	*L. cachinnans*	10	1500	50	SW
24.8.10	8	13	*D. urbicum*	5	1500	30	SW
24.8.10	8	50	*F. tinnunculus*	1	3000	100	SW
26.8.10	14	10	*L. cachinnans*	1	800	25	SW
27.8.10	12	40	*L. cachinnans*	2	1600	200	SW
27.8.10	15	20	*L. cachinnans*	4	1500	50	SW
30.8.10	15	30	*L. cachinnans*	10	2000	100	SE
31.8.10	9	15	*P. apivorus*	1	800	30	SW
31.8.10	9	53	*P. apivorus*	1	1000	40	SW
01.9.10	16	20	*C. ciconia*	1000	500	20	SW
09.9.10	9	0	*L. cachinnans*	2	1600	50	SW
09.9.10	14	45	*L. cachinnans*	3	1500	50	SW
12.9.10	8	50	*Ph. carbo*	15	4800	140	SW
12.9.10	9	26	*A. brevipes*	2	200	50	W
12.9.10	9	55	*L. cachinnans*	6	5200	150	SW
14.9.10	9	5	*L. cachinnans*	flock	3500	100	SW
16.9.10	8	45	*L. cachinnans*	13	1700	60	SW
16.9.10	9	5	*L. cachinnans*	40	2000	60	SW

In addition, all data documenting nocturnal bird migration are archived and will be analysed in order to compare spatio-temporal dynamics, including altitudinal distributions. These results will be included in a special report concerning nocturnal migration in spring and autumn of 2009 and 2010.

CONCLUSIONS

1. In 2010, the occurrence of autumn migrants was strongly correlated with a very short period when strong westerly winds occurred. Outwith this exceptional period, numbers of migrants were low, but rose dramatically during the short period of strong westerly winds.
2. SNWF does not appear to lie on a regularly used part of the Via Pontica migration corridor for diurnal migrants, especially those species that rely on thermals to migrate. This is probably due to SNWF's proximity to the Black Sea and the geography of the Kaliakra Cape.
3. The Via Pontica migration corridor is probably fairly broad in extent in Bulgaria but most of the migratory traffic is likely to the west of SNWF and Kalikra, presumably because birds try to avoid the Black Sea and the risks associated with an absence of thermals over the sea.

4. These arguments are illustrated by analysis of data across several spatial and temporal scales regarding a common migrant, the white stork.
5. As a consequence, it is reasonable to conclude that few autumn migrants are typically recorded at SNWF and, when numbers are relatively high, they are strongly associated with westerly wind conditions, probably because these winds drive birds from their preferred route. Such westerly winds are unusual during autumn.
6. Therefore, the risk of collision mortality posed by SNWF is intrinsically low because: a) it lies away from the main Via Pontica migration corridor; and b) presence through vagrancy is further limited by the rarity of conditions that drive vagrant migrants towards SNWF (i.e. strong westerly winds).
7. This intrinsically low risk, through the behavioural ecology of autumn migrants, is reduced still further by the turbine shut down protocol at SNWF. This mitigation measure, to reduce collision risk, was enacted during a short spell in autumn 2010 when unusual westerly wind conditions probably pushed several migrant birds away from the their preferred migration route.
8. No collision victims of key migratory species were recorded during the brief period of concentrated potential vulnerability. This was likely a result of the low intrinsic risk of collision posed by SNWF and/or the turbine shutdown system that was enacted.
9. Regardless, 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.

REFERENCES

BirdLife International (2004). Birds in Europe: population estimates, trends and conservation status. Cambridge, UK: BirdLife International (BirdLife Conservation Series No. 12)

BirdLife International (2005). http://www.birdlife.org/datazone/species/index.html

Laine, L. J. (1978). Autumn migration on the western coast of the Black Sea. Lintumies 13, 68-73.

Fisher, N.I. (1993). Statistical Analysis of Circular Data. Cambridge University Press, Cambridge.

Mardia, K.V. & Jupp, P.E. (2000). Directional Statistics. Wiley, Chichester.

van Loon, E.E., Shamoun-Baranes, J., Bouten, W. & Davis, S.L. (2010). Understanding soaring bird migration through interactions and decisions at the individual level. Journal of Theoretical Biology 270, 112-126.

Zar, J.H. (1999). Biostatistical Analysis. 4th Edition. Prentice Hall, New Jersey.