Bird migration monitoring in the Saint Nikola Wind Farm, Kaliakra region, in autumn 2015, and an analysis of potential impact after six years of operation

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TERMS OF USE

CONTENTS

SUMMARY

1. This report presents the results of 90 consecutive days of monitoring and mitigation at Saint Nikola Wind Farm (SNWF) in 2015, its 6th operational year. The continued purpose is to investigate the possible impacts on migrating birds.

2. Spatial and temporal dynamics in the numbers of different species passing through the wind farm territory during autumn migration 2015 (15 August to 31 October) are presented. The data from the autumn monitoring in the years 2008 to 2015 are used to investigate the potential change in species composition, numbers, altitude or the flight direction of birds observed in these eight years at SNWF.

3. The variations in numbers of species, absolute number of birds, overall altitudes of flight and migratory direction of birds most sensitive to wind turbines do not indicate an adverse effect of the wind farm on diurnal migrating birds.

4. The Turbine Shutdown System (TSS) probably contributed to a reduced risk of collision during all years of operation within infrequent periods of intensive soaring bird migration and provided a safety mechanism to reduce collision risk for single birds and flocks of endangered bird species.

5. One juvenile Purple Heron, one Common Swift, one Common Buzzard and one Common Kestrel, were found during 725 searches under all 52 turbines for casualties at an interval of seven days or less.

6. The predicted mortality rates by species based on preconstruction data on numbers of migrating birds are not supported by the mortality observed during any of the 6 years of operation of SNWF. The levels of mortality predicted pre-construction have not been recorded during any year of operation. This is largely because 'worst case' predictions were based on BSPB (Bulgarian BirdLife partner) data that substantially exaggerated the numbers of migrants passing through SNWF.

7. The results to date indicate that mortality at SNWF does not constitute a significant obstacle or threat, either physically or demographically to any of the populations of diurnal autumn migrants observed in this study.

INTRODUCTION

AES Geo Energy OOD constructed a 156 MW wind farm consisting of 52 turbines: 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 stationary), and in the autumns of 2010 - 2015 SNWF was operational.

In previous SNWF autumn reports the major focus was assessment of potential barrier effect on birds migrating through the territory and the level of collision mortality of migrants. The analysis of the data until now showed no evidence for cumulative long term changes in the migratory bird fauna. 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 negligible collision mortality of migrating birds was found; indicating a high micro avoidance rate of the turbines by migrating bird species.

The present report updates the information on spatial distribution and temporal presence of birds in SNWF during autumn 2015 with, as in previous reports, special focus on soaring species deemed most sensitive to wind turbines.

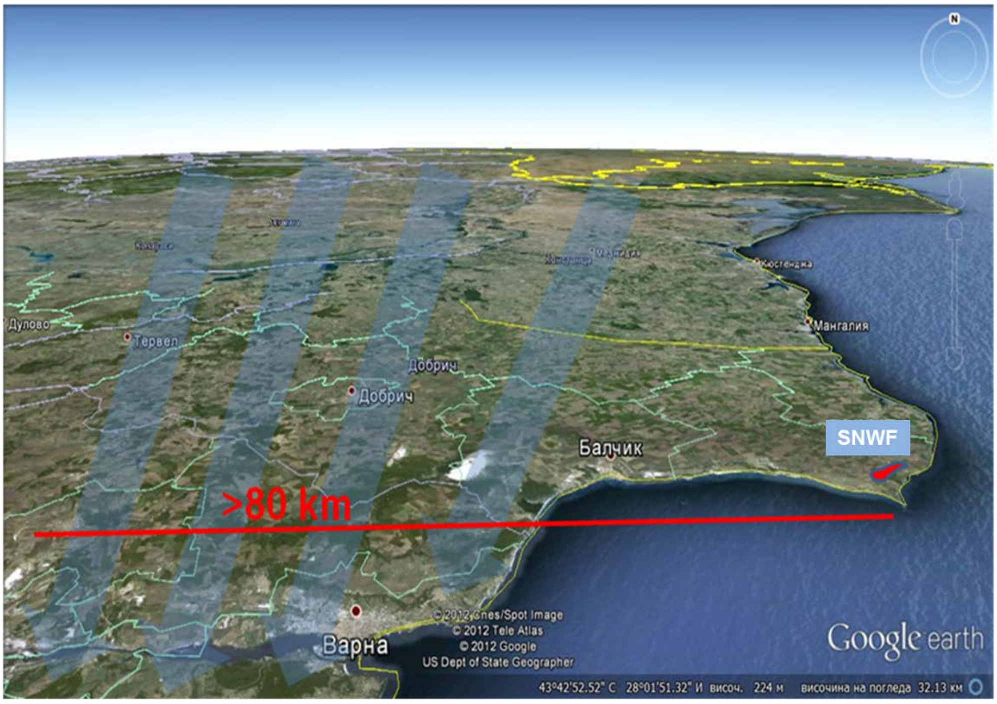

Figure 1. Schematic representation of the main autumnal migratory flyway (blue arrows) and the location of SNWF in red.

METHODS

The study area

SNWF is located in NE Bulgaria, approximately three to seven kilometers inland of the Black Sea coast and the cape of Kaliakra (Fig. 1). 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. The location of observation points is presented in Fig.2.

Study duration and equipment

The study was carried out between 15 August and 31 October 2015 using standard methods that are comparable for all eight autumn seasons since studies began in 2008, using up to six field ornithologists making visual observations. The surveys were made as in previous seasons during the day, in a standard interval of time between 8 AM and 6 PM astronomic time (for details see http://www.aesgeoenergy.com/site/Studies.html.)

Basic Visual Observation Protocol

The autumn 2015 study involved direct visual survey of all passing birds from several observation points (Fig. 2). 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 previously measured and calibrated by GPS. The surveys were carried out by means of optics, every surveyor having a pair of 10x binoculars and all observation points were equipped with 20 – 60x telescope, compass, GPS, and digital camera.

Figure 2. Map of the "SNWF" study area (red plot), and the "core study area" (brown area) covered by the autumn monitoring 2015 observations and location of the observation points (white circles).

As noted in previous reports, 2009 was exceptional in the spatial survey protocol because the observation points were moved northward to test the early warning system (TSS) for approaching flocks of birds. The northerly shift in the observation points in 2009 means that many data of migratory metrics (notably, flight direction) were likely not comparable with the years before or since. In 2009, SNWF had been constructed but was not operational. The basic temporal survey protocol was otherwise not changed in the period 2008 – 2015 (other than the temporal extension in 2013 to 2015 to cover October, additionally) in order to allow comparable data collection between years.

All details about the specific visual observation protocol are presented in a number of previous autumn reports and in the Owner Monitoring Plan (OMP) and will not be repeated here: http://www.aesgeoenergy.com/site/images/21.pdf (studies page).

All observers were qualified specialists in carrying out the surveys of bird migration for many years including previous autumn surveys at SNWF.

List of participants in the autumn observations, 2015

Dr Pavel Zehtindjiev - Senior Field Ornithologist
Institute of Biodiversity and Ecosystem Research
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Victor Metodiev Vasilev - Field ornithologist
Senior researcher in the Faculty of Biology
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Valentin Katrandjiev - Field ornithologist
BSPB (Bird Life Bulgaria) member

As described in previous reports for 2013 and 2014 the period of observation was extended in 2015 to include October, and so beyond the period of most intensive migration, August and September that was covered in years before 2013. In order to provide comparability between the three most recent seasons and previous years, however, to avoid bias associated with the extended observation period in 2013 to 2015, the data presented below are based on a comparable time period (15 August to 30 September) unless otherwise stated.

Method of 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 par. 1.6 and 2.4 of the Owners Monitoring Plan (OMP http://www.aesgeoenergy.com/site/Studies.html.). Because of established removal/disappearance rate and certain efficiency of the searches carcass numbers found during the systematic searches in 2015 has to be adjusted by the founding of trials made in previous autumns.

Statistical methods

The number of observed species, individuals as well as their average altitude of flight (by species and years) is presented in a number of tables for direct comparison across the autumn seasons of 2008 - 2015.

The altitude of migration in different autumn seasons was evaluated for significance by its mean value, standard error and standard deviation in data analysis software system STATISTICA (StatSoft, Inc. (2004, version 7. http://www.statsoft.com/). The mean flight direction as well as its significance level, for every species and group of species was calculated according to standard circular statistics (Batschelet 1981). Circular statistics was performed with Oriana (Oriana - Copyright © 1994-2009 Kovach Computing Services). This program compares two or more sets of circular distributions (directions) to determine if they differ. The tests were performed pairwise, so that each pair of samples was compared separately.

Many of the basic statistical parameters of circular distributions (directions) 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 has two properties; its direction (the mean angle, **μ**) and its length (often referred to as **r**). The length ranges from 0 to 1; a higher r value indicates that the observations are clustered more closely around the mean than a lower one. Details about the Oriana software are available at: http://www.kovcomp.com/

Turbine Shutdown System (TSS)

The principles to selectively stop specific turbines or the entire wind park to reduce risk of collisions are described in par. 1.5 of the Owners Monitoring Plan (OMP).

The TSS protocol was followed in order to reduce collision risk during the extended period of study in autumn 2015, between 15 August and 31 October. 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 AND DISCUSSION

Composition of species and number of birds passing through SNWF

The occurrence of species across all years is presented in Table 1. A total of 126 bird species have been observed in the wind farm territory during the consecutive autumn seasons of 2008 to 2015. The number of observed species varied from 48 to 82 in different years. 33 species were observed every autumn season in the period 2008 – 2015. Regular migrants through the territory included White Pelican, White Stork, Levant Sparrowhawk, Common Buzzard, Honey Buzzard and the Lesser Spotted Eagle. By contrast, another 49 species of birds were not recorded in 2008, but observed at least in one of seven post-construction autumn seasons. Among such species were, for example, many birds of prey like Golden Eagle, Saker Falcon, Black Kite; waders like Northern Lapwing, Green Sandpiper, Common Greenshank, Eurasian Stone-curlew; herons like Purple Heron, Great Egret, Little Egret; and many small passerine bird species. The occurrence of these relatively rare species after construction should be attributed to vagrancy. The only new species observed in autumn 2015 is Tawny Eagle

(*Aquila rapax*) which is a rarity for the region and cannot be typically associated with autumn migration in the region. There is no apparent substantive difference in composition of species migrating through the wind farm observed in 2008 (before the construction of the wind farm) and during the later period when the wind farm was present (2009 – 2015). No species recorded in 2008, before SNWF was constructed, has not been recorded subsequently in years after construction; and several species have been recorded in the seven years after construction that were not recorded in 2008. While this can illustrate that SNWF has not impaired the occurrence of species on migration, such differences should not be attributed to any 'beneficial' effects of SNWF but to the greater number of years of observation post-construction.

Table 1. List of species observed in SNWF during 15 August to 30 September in pre-construction (2008) and post-construction (2009 to 2015 in grey) periods of SNWF. Hatched cells represent the years when the species was registered in SNWF.

N	Species	2008	2009	2010	2011	2012	2013	2014	2015
1	*A. apus*	X	X	X	X	X	X	X	X
2	*A. arvensis*		X			X	X	X	
3	*A. brevipes*	X	X	X	X	X	X	X	X
4	*A. campestris*		X			X	X		
5	*A. cervinus*					X	X		X
6	*A. chrysaetos*			X	X	X	X	X	
7	*A. cinerea*	X	X	X	X	X	X	X	X
8	*A. gentilis*	X	X	X	X	X	X	X	X
9	*A. heliaca*	X							X
10	*A. melba*	X	X	X	X	X	X	X	X
11	*A. nisus*	X	X	X	X	X	X	X	X
12	*A. pennata*	X	X	X	X	X	X	X	X
13	*A. pomarina*	X	X	X	X	X	X	X	X
14	*A. pratensis*					X	X		
15	*A. purpurea*		X	X	X	X	X		X
16	*A.rapax*								X
17	*A. trivialis*	X			X				
18	*B. buteo*	X	X	X	X	X	X	X	X
19	*B. oedicnemus*		X		X				
20	*B. rufinus*	X	X	X	X	X	X	X	X
21	*B. vulpinus*					X	X		
22	*C. aeruginosus*	X	X	X	X	X	X	X	X
23	*C. cannabina*					X		X	
24	*C. canorus*					X	X	X	X
25	*C. carduelis*	X	X		X	X	X	X	
26	*C. chloris*	X			X				
27	*C. ciconia*	X	X	X	X	X	X	X	X
28	*C. coccothraustes*	X			X				
29	*C. corax*	X						X	X
30	*C. cornix*	X	X		X	X	X	X	X
31	*C. coturnix*	X	X		X			X	
32	*C. cyaneus*	X	X		X		X	X	
33	*C. frugilegus*	X	X			X	X	X	X
34	*C. gallicus*	X	X	X	X	X	X	X	X

N	Species	2008	2009	2010	2011	2012	2013	2014	2015
35	*C. garrulus*								
36	*C. livia domestica*								
37	*C. macrourus*								
38	*C. monedula*								
39	*C. nigra*								
40	*C. olor*								
41	*C. palumbus*								
42	*C. oenans*								
43	*C. pygargus*								
44	*D. major*								
45	*D.syriacus*								
46	*D. urbica*								
47	*E. alba*								
48	*E. calandra*								
49	*E. garzetta*								
50	*E. hortulana*								
51	*E. melanocephala*								
52	*F. cherrug*								
53	*F. coelebs*								
54	*F. eleonorae*								
55	*F. naumanni*								
56	*F. parva*								
57	*F. peregrinus*								
58	*F. subbuteo*								
59	*F. tinnunculus*								
60	*F. vespertinus*								
61	*G. fulvus*								
62	*G. glandarius*								
63	*G. grus*								
64	*G. cristata*								
65	*H. daurica*								
66	*H. icterina*								
67	*H. pallida*								
68	*H. rustica*								
69	*J. torquila*								
70	*L. cachinnans*								
71	*L. collurio*								
72	*L. megarhynchos*								
73	*L. melanocephalus*								
74	*L. minor*								
75	*L. ridibundus*								
76	*M. alba*								
77	*M. apiaster*								
78	*M. calandra*								
79	*M. cinerea*								
80	*M. flava*								
81	*M. migrans*								

N	Species	2008	2009	2010	2011	2012	2013	2014	2015
82	*M. milvus*								
83	*M. striata*								
84	*N. percnopterus*								
85	*O. hispanica*								
86	*O. isabellina*								
87	*O. oenanthe*								
88	*O. oriolus*								
89	*O. pleschanka*								
90	*P. apivorus*								
91	*P. caeruleus*								
92	*P. crispus*								
93	*P. haliaetus*								
94	*P. leucorodia*								
95	*P. major*								
96	*P. montanus*								
97	*P. onocrotalus*								
98	*P. perdix*								
99	*P. pica*								
100	*P. viridis*								
101	*Ph. carbo*								
102	*Ph. collybita*								
103	*Ph. trochilus*								
104	*Pl. falcinellus*								
105	*Ph.pygmaeus*								
106	*Ph. ochrurus*								
107	*Ph. phoenicurus*								
108	*R. riparia*								
109	*S. borin*								
110	*S. communis*								
111	*S. curruca*								
112	*S. rubetra*								
113	*S. vulgaris*								
114	*St. hirundo*								
115	*Str. decaocto*								
116	*Str. turtur*								
117	*T. nebularia*								
118	*T. glareola*								
119	*T. tadorna*								
120	*T. ochropus*								
121	*T. merula*								
122	*T.viscivorus*								
123	*Tr. ochropus*								
124	*Tr. glareola*								
125	*U. epops*								
126	*V. vanellus*								
	Number of species	77	82	48	71	79	81	79	66

The observed variations in the number of species observed in the study area is due to the vagaries of rare bird species' occurrence which in any year are present in low numbers and therefore observed sporadically in some autumns: Common Crane, Griffon Vulture, Egyptian Vulture, Imperial Eagle, Golden Eagle, Red Kite, Saker Falcon, Lesser Kestrel and Eleonora's Falcon, Eagle, Dalmatian Pelican, and Lesser Kestrel.

The 'new' species observed in autumn 2015, Tawny Eagle, breeds in Africa and Middle East and its observation in SNWF can be explained with the post breeding dispersion of juvenile birds which can lead to vagrancy in several areas around the Mediterranean Sea and beyond.

Two vulture species, registered only after the construction of SNWF are not listed in the available literature concerning the region including Standard Data Forms of the nearby NATURA 2000 zones. The Griffon Vulture was observed in autumn 2010, 2012, 2013, 2014 and 2015. In 2015 one Griffon Vulture was observed on September 7 at 500 m height crossing SNWF territory. Egyptian Vultures were observed in SNWF in 2015, twice, on 23 and 28 August, at 300 m and 500 m altitude respectively.

Absolute counts of soaring species which were most numerous, together with some additional species with high conservation value, are presented in Table 2.

Table 2. Numbers of birds recorded as passing through SNWF (primarily soaring water birds and birds of prey) in eight autumn seasons of pre-construction (2008) and post-construction years (2009 – 2015).

Species	2008	2009	2010	2011	2012	2013	2014	2015
A. brevipes	95	210	976	290	94	650	138	190
A. chrysaetos			2	2	1	1	2	
A. cinerea	120	259	26	40	56	70	113	20
A. gentilis	10	6	5	11	22	38	9	16
A. heliaca	2							1
A. nisus	44	44	70	73	44	206	101	133
A. pennata	4	3	22	5	10	22	14	10
A. pomarina	44	9	80	76	31	1966	509	146
A. purpurea		59	11	1	7	3		2
B. buteo	146	390	180	459	238	2345	1073	499
B. oedicnemus		1		1				
B. rufinus	163	151	34	30	33	28	41	32
C. aeruginosus	327	268	341	271	179	473	298	339
C. ciconia	2998	87	24980	620	2525	11230	4639	292
C. cyaneus	5	1		1		3	18	
C. gallicus	29	19	18	25	60	88	26	38
C. macrourus	8	27	18	4	7	7	15	8
C. nigra	8	8	8	1	13	488	48	29
C. olor		1	3				2	11
C. palumbus	10		1				26	2
C. pygargus	32	17	111	151	55	82	102	161
E. alba			1	1	5			
E. garzetta		7				11	1	33
F. cherrug		7		2	1		1	
F. eleonorae	7			1	1		7	
F. naumanni	1							
F. peregrinus		2	4	1	1	5	5	2
F. subbuteo	48	125	120	96	66	88	89	135

Species	2008	2009	2010	2011	2012	2013	2014	2015
F. tinnunculus	138	357	45	120	67	103	89	108
F. vespertinus	11	180	1773	63	793	167	426	434
G. fulvus			1		1	2	1	1
G. grus						1		91
M. migrans	18	6	32	17	21	34	32	69
M. milvus			1	1		2	1	1
N.percnopterus					1			2
P. apivorus	58	76	1549	152	115	4284	113	258
P. crispus	4						5	
P. haliaetus	15	13	14	12	7	13	5	20
P. leucorodia	117	83	56	48		59		122
P. onocrotalus	120	1190	252	277	1700	3285	1679	2857
Ph. carbo	267	354	494	75	131		866	263
Ph. pygmaeus		19						
Pl. falcinellus	5	738						
St. hirundo		71						
T. tadorna		94			3			
Tr. ochropus		8			1			
Tr. glareola							3	
T. merula							80	
T. viscivorus							17	
V. vanellus			1			7		7
Total	4854	4890	31229	2927	6288	25761	10594	6332
Number of species	30	35	32	32	31	31	36	34

The number of species as well as the absolute number of birds crossing the study area (Tables 1 and 2) did not decrease after the construction of turbines. The absolute number per year of the most numerous species of soaring migrants: White Pelican, White Stork, Levant Sparrowhawk, Common Buzzard, Honey Buzzard and Lesser Spotted Eagle widely varied in the eight study seasons (Fig. 3 & 4).

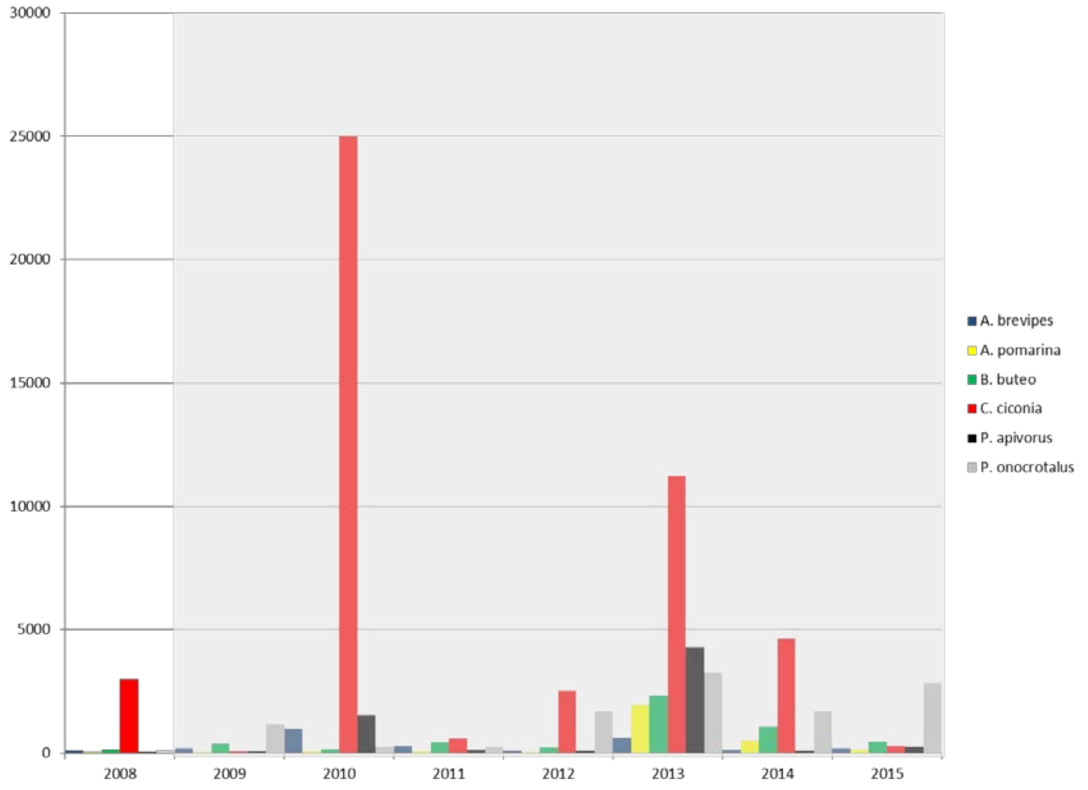


Figure 3. Variations in the total number of the most numerous soaring bird species observed during autumn migrations in eight years (pre-construction 2008 and post-construction periods- in grey) in SNWF.

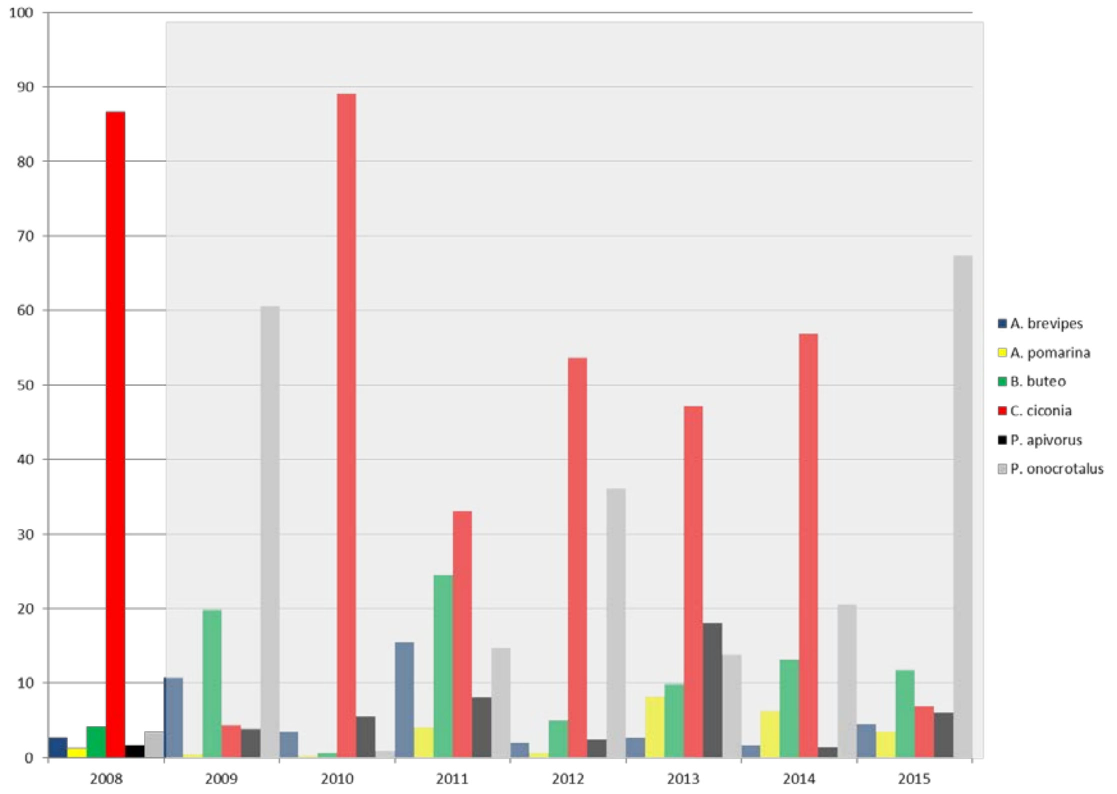


Figure 4. Proportional annual contribution of individual species (of the six most numerous soaring bird species recorded) to the total migratory traffic in and over SNWF in autumns 2008 – 2015.

Another numerous group of migrants recorded at SNWF are species specialized in diurnal aerial foraging for insects. Not all birds of these species, bee-eaters, swifts and swallows (hirundines), crossing SNWF were detected because of their small size and methodological limitations of visual observations. The recording of these species highly depends on the distance from the observer (in both vertical and horizontal visual planes) because of their small size and, often their flight altitude) (for details see autumn report 2013). Therefore visual observations on these species are limited to a few hundred meters and cannot be considered as absolute numbers for a given area and at all altitudes.

With these caveats in mind, the results on the numbers of bee-eaters and hirundines (swallows and swifts) (hirundines not identified to the species level are not presented) registered between 2008 and 2015 are given in Table 3.

Table 3. The number of bee-eaters, swifts and swallows in SNWF in eight autumn seasons as observed in the period 15 August – 30 September.

Species	2008	2009	2010	2011	2012	2013	2014	2015
A. apus	79	10	6	8	17	12	52	39
A. melba	515	16	536	234	47	127	58	26
D. urbica	1007	697		180	3	170	109	436
H. daurica	2	8		4	1			
H. rustica	2979	4234	1735	164	5994	815	550	473
M. apiaster	4625	3355	5024	2107	2733	5906	1828	1377

Altitude of autumn migration

In order to test whether the construction of SNWF turbines has resulted in an increase of flight altitude of migrating birds we calculated the average altitude per year of all species of diurnal migrants regularly passing through SNWF in autumn, including 2015 (Table 4).

Table 4. Mean flight altitude (in meters above the ground level), by species, of diurnal migrants observed in SNWF across eight autumn seasons, 2008-2015: the years when the wind farm was constructed are highlighted in grey.

Species	2008	2009	2010	2011	2012	2013	2014	2015
A. brevipes	132	171	171	160	142	263	188	178
A. cinerea	201	239	263	386	190	344	341	133
A. gentilis	181	176	230	199	151	267	232	146
A. nisus	150	135	162	141	119	204	124	139
A. pennata	150	283	251	213	295	261	368	213
A. pomarina	244	273	234	234	241	353	279	210
B. buteo	165	199	206	197	158	278	215	187
B. rufinus	109	200	230	183	147	211	177	156
C. aeruginosus	158	139	235	150	128	222	201	113
C. ciconia	199	174	434	347	358	390	279	242
C. cyaneus	136	100		10		267	70	100
C. gallicus	256	144	258	242	218	229	269	221
C. macrourus	251	90	240	195	86	188	150	98
C. nigra	462	325	375	350	388	382	330	339
C. pygargus	196	115	285	106	79	209	144	107
F. subbuteo	97	119	161	161	127	131	181	139

Species	2008	2009	2010	2011	2012	2013	2014	2015
F. tinnunculus	49	96	109	70	79	67	85	40
F. vespertinus	106	106	224	289	121	139	156	197
M. migrans	175	183	166	152	233	243	179	213
P. apivorus	320	175	268	283	204	342	290	270
P. haliaetus	314	208	224	433		400	133	172
P. leucorodia	433	285	667	317		317		350
P. onocrotalus	100	159	417	400	265	263	271	230
Ph. carbo	180	179	277	271	254	265	285	284

No trend in the fluctuations of average altitude of the most numerous soaring bird species was registered after eight years of autumn migration monitoring at SNWF, including one pre-construction and seven post-construction seasons. The comparative analysis showed that there was no significant change in average flight altitudes of the 24 most numerous bird species regularly migrating through SNWF (Fig. 5).

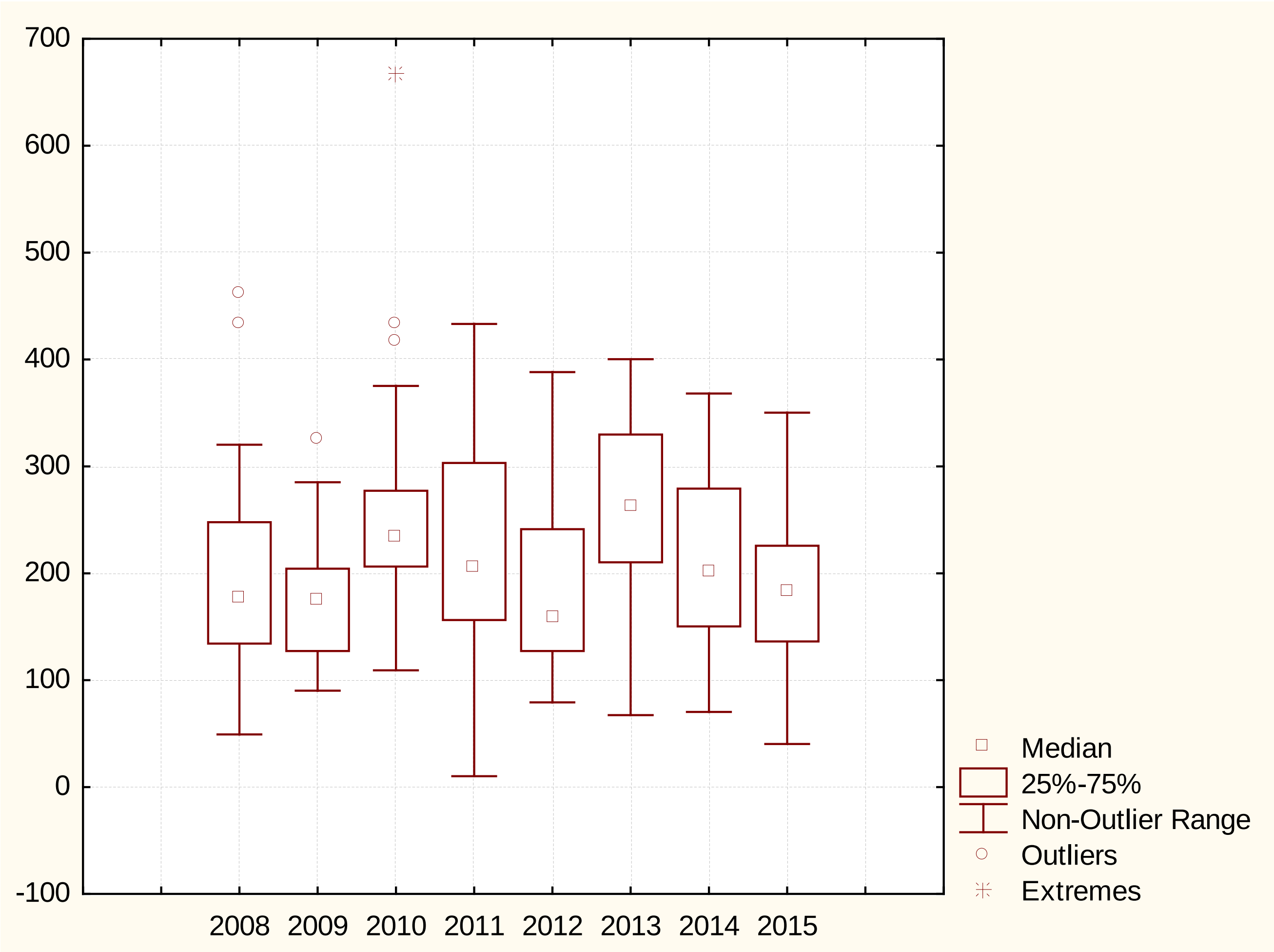


Figure 5. The median altitude of soaring bird migration observed from SNWF during autumns of 2008 to 2015, with measures of variance. The species included in the calculations are presented in Table 4.

Observed flight altitudes of bee-eaters and swallows were analyzed despite the constraints on reliability imposed by visual observation, as previously noted. Nevertheless, despite the caveats on observational constraints (which should apply more-or-less equally across study years), it appeared that while the average observed flight altitude of bee-eaters and swallows varied widely across years there was no trend that could be attributable to the presence of SNWF (Table 5).

Table 5. Mean altitude of flight during autumn migration of bee-eaters *M. apiaster* and barn swallows *H. rustica* in the period 2008 – 2015 observed in SNWF.

Species	2008	2009	2010	2011	2012	2013	2014	2015
H. rustica	28	51	66	19	37	32	35	35
M. apiaster	73	68	128	71	83	66	85	100

Changes in the flight altitude of soaring migrants, bee-eaters and swallows have apparently had no consistent character across years and do not indicate any impact due to SNWF. Most probably climatic factors, conditions on the breeding grounds of these species that breed away from SNWF, and local aerial insect availability at the time of passage (for those species in Table 5) are likely to be responsible for the fluctuations in average altitude of autumn migration in the eight year monitoring period. Regardless, any energetic consequences for migrants avoiding the turbines by way of a change in flight altitude will be immaterial to overall migratory energy budgets (Madsen et al. 2009, 2010) if they occur.

Direction of autumn bird migration

The mean recorded direction of the 24 species is presented in Table 6. Prevailing directions of autumn migration observed in all eight autumn seasons do not indicate changes in migratory direction through a response to SNWF in years when there was greater consistency in the location of observation points (i.e. excluding 2009 when the observation points were moved northward in order to test the TSS). The main direction in all years shows the guiding role of the coast line (see Fig. 1 and Table 7).

Table 6. Mean observed flight direction of autumn migration by species in different years. Directions are given in degrees starting from 0 (North).

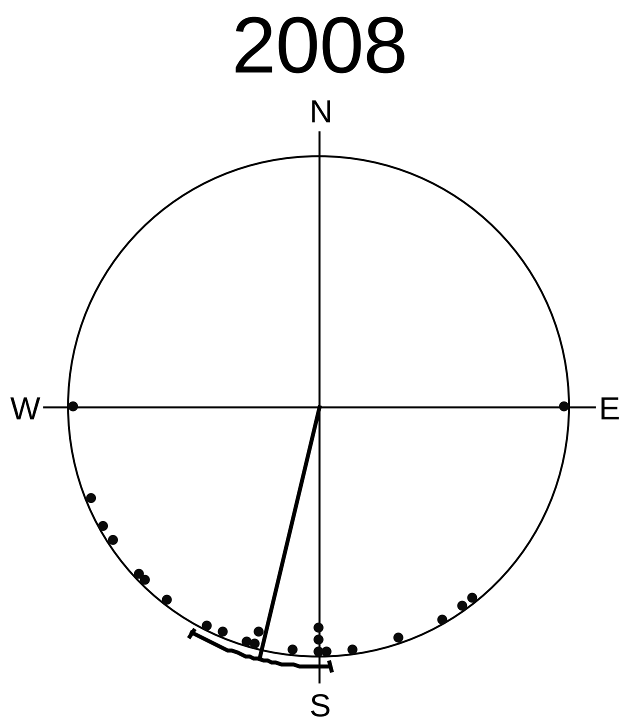
Species	2008	2009	2010	2011	2012	2013	2014	2015
A. brevipes	172	151	185	175	179	191	156	161
A. cinerea	248	178	146	138	203	167	176	101
A. gentilis	195	162	171	180	149	181	163	188
A. nisus	218	155	186	193	174	185	164	164
A. pennata	180	150	182	165	216	184	212	198
A. pomarina	225	173	204	183	193	214	180	196
B. buteo	195	150	177	179	179	198	172	165
B. rufinus	150	158	227	186	188	158	119	185
C. aeruginosus	197	150	191	188	175	199	166	166
C. ciconia	207	154	209	210	209	216	181	215
C. cyaneus	90	180		225		188	180	135
C. gallicus	203	150	144	151	129	159	142	165
C. macrourus	141	154	180	231	109	210	144	135
C. nigra	270	191	225	180	231	205	163	206
C. pygargus	237	148	182	183	174	194	154	165

Species	2008	2009	2010	2011	2012	2013	2014	2015
F. subbuteo	186	148	174	196	196	188	157	156
F. tinnunculus	144	148	177	161	191	156	153	138
F. vespertinus	180	159	177	204	218	206	169	198
M. migrans	241	153	211	207	189	192	210	179
P. apivorus	227	187	201	200	208	204	174	195
P. haliaetus	161	190	168	198	169	199	152	135
P. leucorodia	180	173	195	180		180		162
P. onocrotalus		146	195	257	232	214	180	177
Ph. carbo	178	162	192	160	121	177	155	154

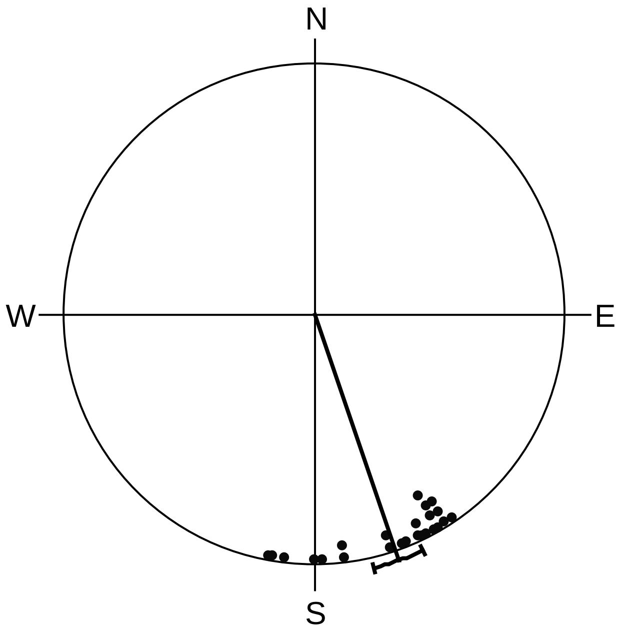
Table 7. Basic statistical parameters of empirical flight directions obtained from visual observations during eight autumn seasons in SNWF for the 24 'core' soaring bird species.

Autumn season	2008	2009	2010	2011	2012	2013	2014	2015
Number of species	23	24	23	24	22	24	23	24
Mean Vector (µ)	193°	161°	186°	188°	184°	190°	166°	168
Length of Mean Vector (r)	0,8	0,96	0,93	0,90	0,85	0,95	0,94	0,89
Concentration	2,7	16,6	8,4	5,5	3,7	11,8	8,8	5,1
Circular Variance	0,21	0,03	0,06	0,09	0,14	0,95	0,05	0,1
Circular Standard Deviation	39,3°	14,2°	20,2°	25,5°	32,3°	17,1°	19,8°	26,6

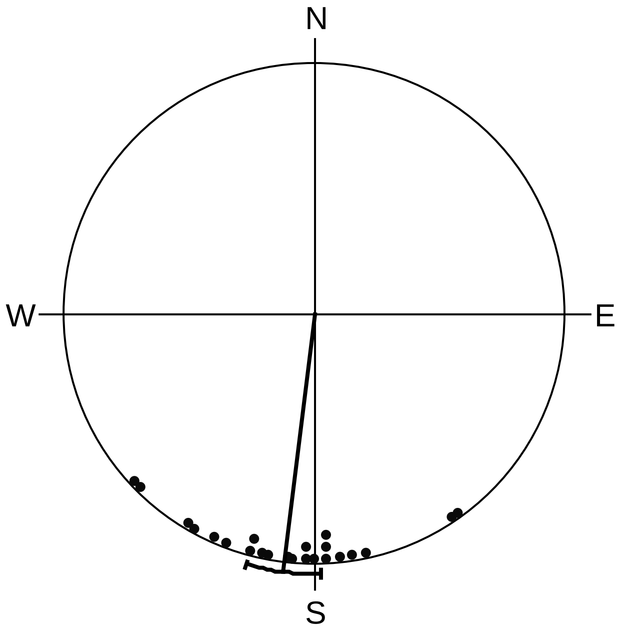
The circular (compass) distributions of flight directions of soaring birds are presented in graphs below for each year (Fig. 6).



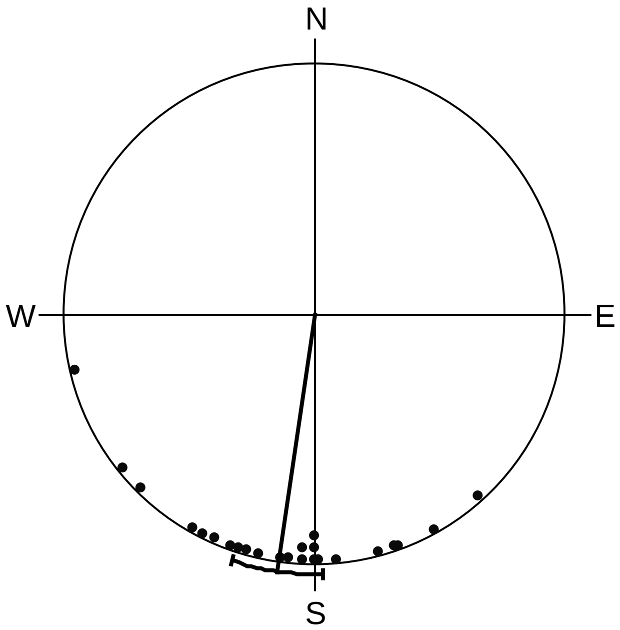
2009



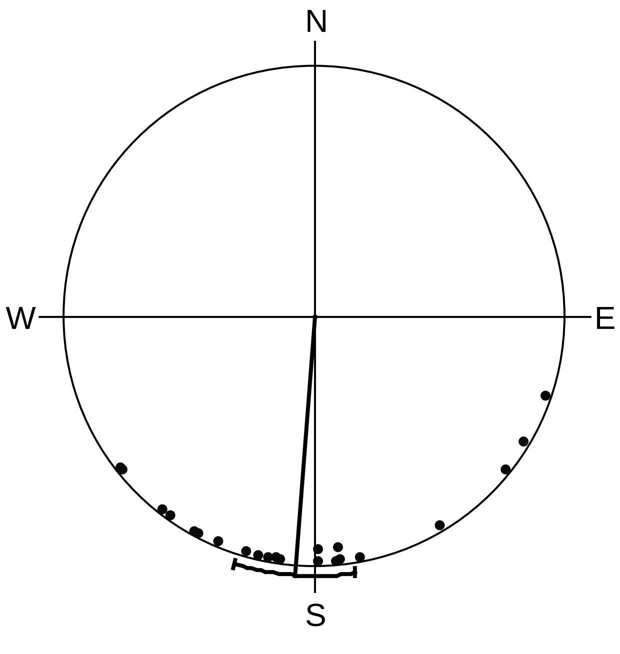
2010



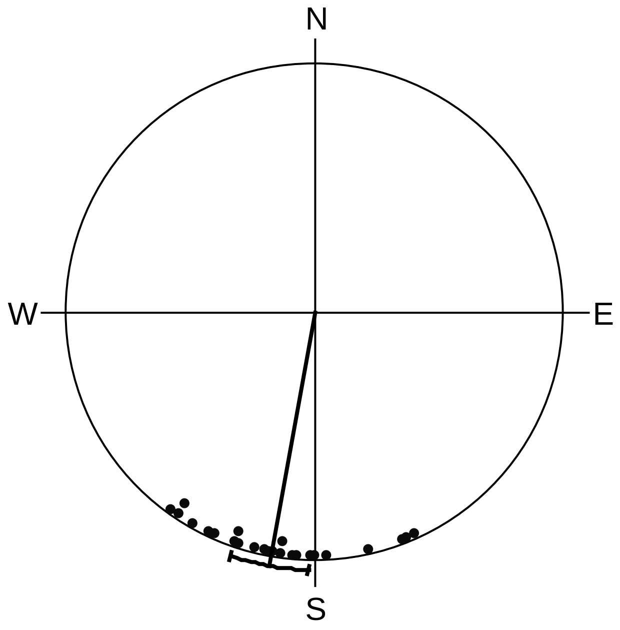
2011



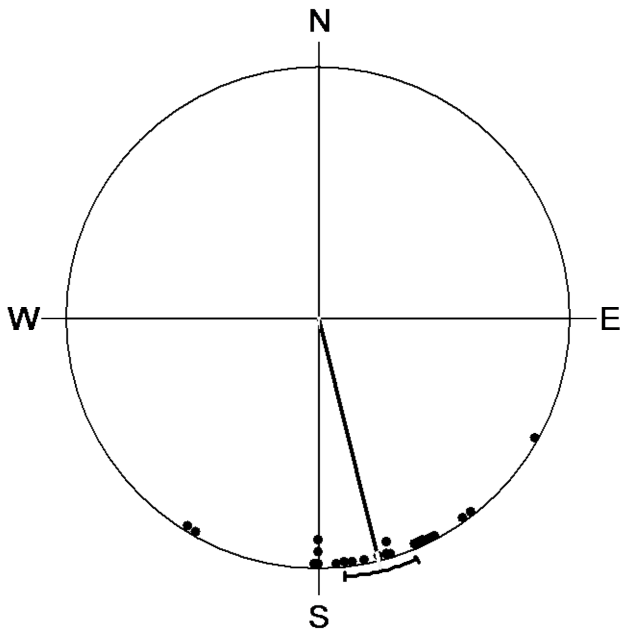
2012



2013



2014



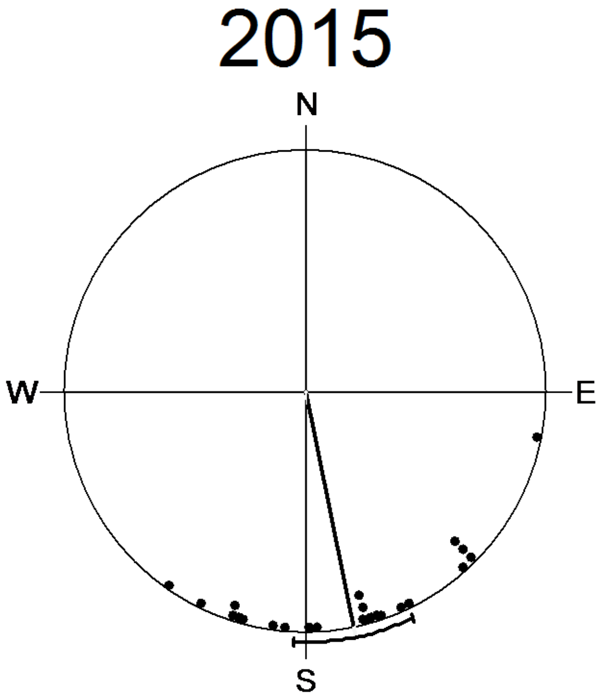


Figure 6. Graphical representations of the average flight directions of the 24 'core' soaring bird species by year: each record = 1 species (see Table 6 and 7). (In 2009, observation points were stationed further north than in other years.)

The direction of migration in 24 of most common and numerous soaring birds observed at SNWF in the last eight years does not indicate any consistent annual deviation from the seasonal migratory direction after construction of SNWF (Table 7 and Fig. 6). An expectation, if the turbines were causing birds to avoid the study area would be that there should be a major shift in migratory direction much further to the east, as birds deflect inland and away from the wind farm. This has not been recorded.

In 2014 and 2015 the mean direction of the same most numerous species of soaring birds suggested that not only the location of observation points (as in 2009) but also some other factors (conspecific flock attraction and probably specific wind directions during the season) may also explain annual deviations from the typical direction of soaring bird migration across SNWF over the eight years of study.

Bearing in mind the feeding behavior of bee-eaters and swallows which are specialized in hunting insects in the air during daytime and the detailed analysis of flight directions in previous reports it is also likely that several species' abundance may be governed by the capacity for feeding activity as well as active migratory flight through SNWF during autumn (Table 8).

Table 8. Mean flight directions of barn swallows *H. rustica* and bee-eaters *M. apiaster* as observed from SNWF across eight autumn seasons. Directions are given in degrees starting from 0 (North).

Species	2008	2009	2010	2011	2012	2013	2014	2015
H. rustica	158	144	204	169	172	150	101	68
M. apiaster	191	142	192	186	187	189	177	162

There is no evidence under the scale and form of analysis for a major directional change in the flight orientation behavior of autumn migrants (macro-avoidance) as a result of the wind farm operation. 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, contribute to a major change in migratory route or any detrimental effect on energy budgets.

Spatial and temporal distribution of observed 'major' influxes of soaring migrants and Turbine Shutdown System

In autumn 2015, intensive soaring bird migration was observed mainly in the standard monitoring period 15 August – 30 September defined in previous reports with a peak period in September (Fig. 7). Prevailing wind directions in autumn 2015 were N – NE; the same as in every previous autumn of the study. Again as in previous years, westerly winds, which bring periodic influxes of soaring migrants swept easterly from the main Via Pontica migration route (Fig. 1) were infrequent.

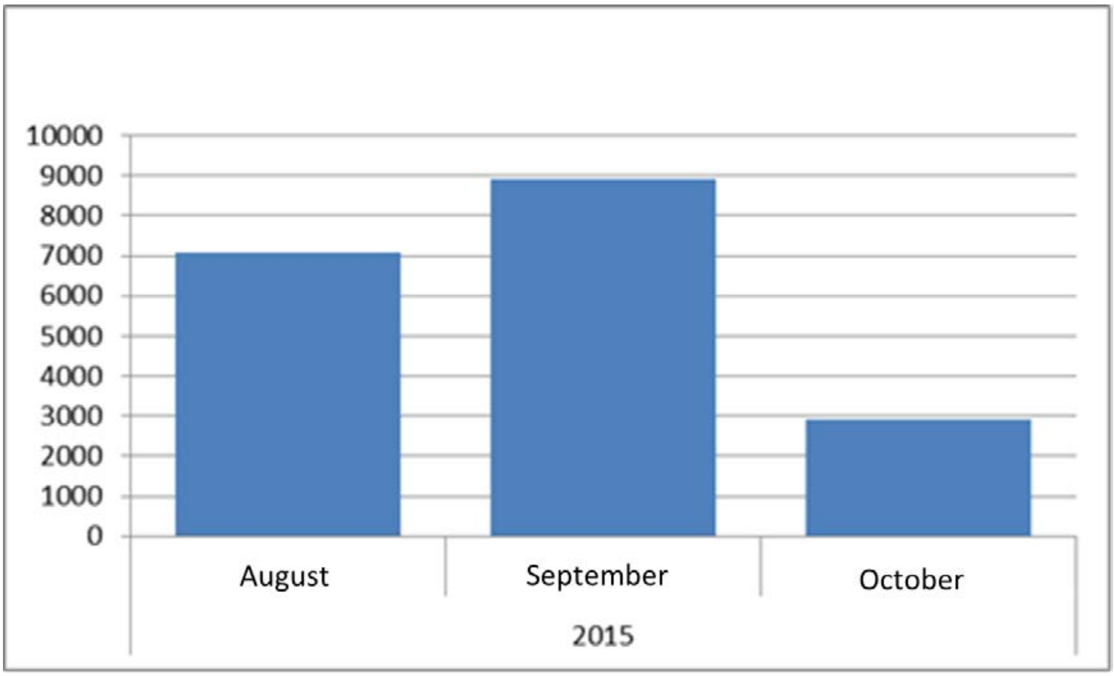


Figure 7. Distribution of all registrations of birds during the autumn season 2015.

Notable days with relatively strong migration of soaring birds was observed 22 and 23 August with 802 and 883 birds respectively and 06 and 08 September with 883 and 560 birds in total. Notable numbers are observed also in 01 October and 23 October with 201 and 130 birds respectively. For all these days there were westerly winds drifting birds from the continental part of Dobroudzha and the main Via Pontica migration route.

Specific periods with intensive migration of different species observed in SNWF during the montoring period in autumn 2015 were: 26 Lesser Spotted Eagles observed 06 September, 103 White Storks observed 23 August, 79 Honey Buzzards observed 06 September. The major influxes of White Pelicans were registered 22 and 23 August with 800 and 700 pelicans, 06 and 08 September with 664 and 558 birds, and 01 and 23 October with 200 and 130 pelicans respectively.

Interestingly in autumn 2015 an unusual number of Common Cranes passed through SNWF on 30 September and 8 October when flocks of 91 and 28 cranes respectively were observed.

In all these days with intensive bird migration the application of the Turbine Shutdown System (TSS) probably contributed to a reduced risk of collision, and provided a safety mechanism to reduce collision risk for single birds and flocks of endangered bird species. The data on the number of turbine stops under TSS in autumn 2015 with respect to the major observed flocks and single birds with conservation value are presented in Table 9.

Table 9. List of observed 'major' influxes of soaring migrants according to species, in autumn 2015 in or over SNWF, by date and the stop and start times of turbine shutdowns. See Figure 8 for locations of wind turbine groups ('WTG') and individual turbines.

Date	Stop	Start	Species	Species	No of birds	WTG/which turbines by groups	Ordered by
22.08.	13:02	13:10	*Pelecanus onocrotalus*	White pelican	120	A, B, C	M. Marinov
22.08.	14:08	14:12	*Pelecanus onocrotalus*	White pelican	280	A, B	V. Vasilev
23.08.	15:15	15:30	*Neophron percnopterus*	Egyptian vulture	1	F, E	I. Raykov
23.08.	16:23	16:36	*Pelecanus onocrotalus*	White pelican	300	T44, T43, T29, T42, E, F	I. Raykov
02.09.	13:59	14:09	*Haliaeetus albicilla*	White-tailed eagle	1	B, C	M. Marinov
03.09.	13:38	13:45	*Ciconia ciconia*	White stork	13	T55	K. Ivanova
06.09.	17:02	17:10	*Ciconia ciconia*	White stork	5	C, D	M. Marinov
07.09.	09:45	09:56	*Ciconia ciconia*	White stork	60	E, F, T45	S. Peev
08.09.	15:48	16:00	*Pelecanus onocrotalus*	White pelican	29	C, D	K. Ivanova
08.09.	15:55	16:05	*Pelecanus onocrotalus*	White pelican	29	E	S. Peev
19.09.	10:35	10:41	*Ciconia ciconia*	White stork	30	T29, T43, T44	K. Ivanova
21.09.	12:27	12:39	*Pelecanus onocrotalus*	White pelican	1	F	S. Peev
23.09.	11:03	11:27	*Pelecanus onocrotalus*	White pelican	1	A	K. Ivanova
30.09.	13:10	13:13	*Grus grus*	Common crane	8	8, 9, 38	M. Marinov
05.10.	11:25	11:36	*Pelecanus onocrotalus*	White pelican	6	A	Y.Yankov

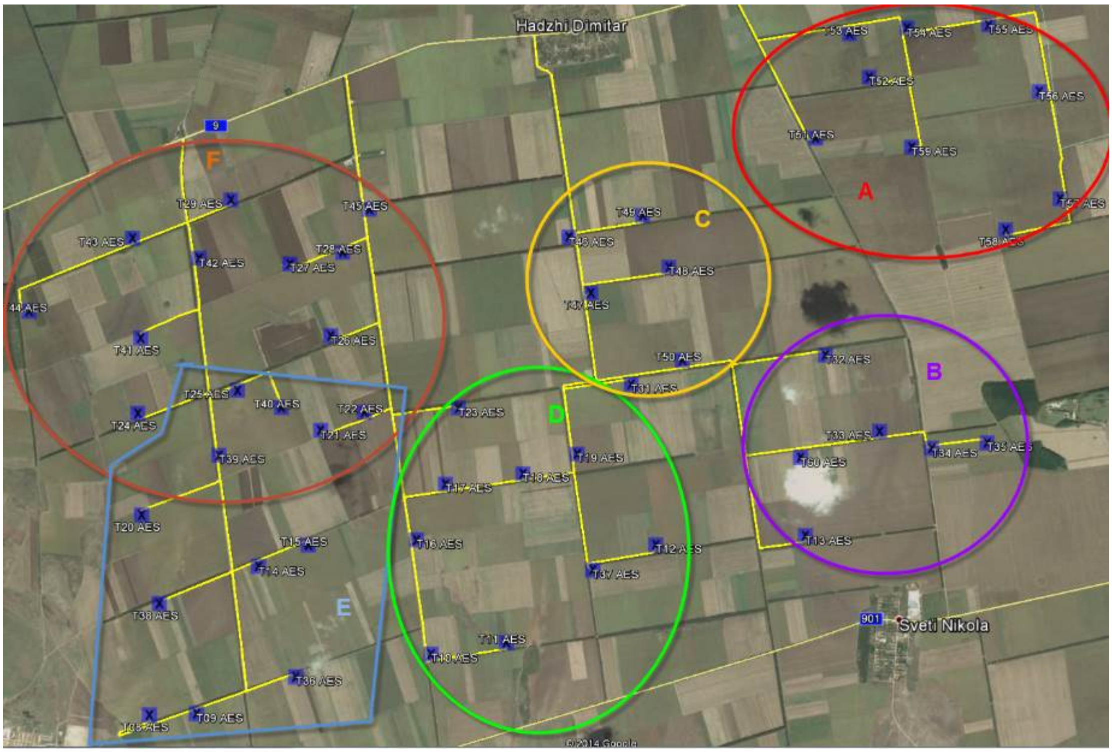


Figure 8. The groups of turbines associated with the numbers of turbine stops during autumn season of 2015 as described in Table 9, under column 'WTG/which turbines by groups' ('WTG' = Wind Turbine Groups).

The majority of flocks of soaring migrants as well as single birds of target species concerning the conditions of the TSS were observed under westerly wind conditions. This confirms previous data analyses from other years, presented in earlier reports (http://www.aesgeoenergy.com/site/Studies.html) indicating that SNWF is situated to the east of the main migratory flyway and so only occasionally hosts major numbers of migrants when -non prevailing- westerly wind conditions shift birds from the flyway. These numbers are consistently lower than stated by BSPB before SNWF was approved for operation.

Collision victim monitoring

After three trials for efficiency of the carcass searches autumn and winter seasons described in detail in the report for autumn 2014 (http://www.aesgeoenergy.com/site/tcs%20(33).html) a frequency of seven days between searches was defined as optimal to provide objective and cost-effective information about the number of bird collisions with turbines of SNWF.

The numbers of turbines searched during every autumn of operational period of the wind farm are presented in Table 10. The increase of total searches in autumn 2014 and 2015 was due to the increased monitoring period, until the end of October.

Table 10. Number of carcass searches per autumn and turbine in the operational period of SNWF.

Turbine number	Autumn 2010	Autumn 2011	Autumn 2012	Autumn 2013	Autumn 2014	Autumn 2015	Total searches
8	6	8	8	10	13	14	**59**
9	6	8	7	10	12	13	**56**
10	6	7	10	10	14	13	**60**
11	6	7	9	11	17	14	**64**
12	6	10	9	11	19	13	**68**
13	6	9	9	9	17	14	**64**
14	6	9	7	10	15	13	**60**
15	6	9	7	10	15	13	**60**
16	6	6	9	10	15	13	**59**
17	6	6	9	12	13	13	**59**
18	6	4	8	12	14	13	**57**
19	6	8	9	12	15	12	**62**
20	6	9	10	12	14	15	**66**
21	1	6	8	10	16	14	**55**
22	6	6	8	13	14	15	**62**
23	6	6	8	10	18	13	**61**
24	6	7	7	10	16	14	**60**
25	6	2	8	9	16	13	**54**
26	6	8	8	13	13	14	**62**
27	6	2	8	11	14	15	**56**
28	6	2	5	12	13	15	**53**
29	6	8	7	10	16	17	**64**
31	1	9	7	11	15	14	**57**
32	6	9	8	11	15	15	**64**
33	6	8	7	9	18	14	**62**
34	6	8	7	10	15	15	**61**
35	7	8	7	10	15	14	**61**
36	6	9	7	10	13	13	**58**
37	6	9	9	13	15	14	**66**
38	6	9	6	10	14	12	**57**
39	6	8	7	10	16	14	**61**
40	6	7	8	9	16	16	**62**
41	6	7	6	11	18	14	**62**
42	7	7	7	10	15	14	**60**
43	11	9	7	10	15	14	**66**

Turbine number	Autumn 2010	Autumn 2011	Autumn 2012	Autumn 2013	Autumn 2014	Autumn 2015	Total searches
44	11	7	7	10	15	15	**65**
45	6	8	8	10	13	14	**59**
46	6	9	8	10	14	14	**61**
47	6	9	7	10	15	16	**63**
48	6	9	7	10	14	15	**61**
49	6	10	7	13	14	13	**63**
50	6	10	7	11	15	14	**63**
51	6	9	7	9	14	13	**58**
52	6	9	5	9	15	13	**57**
53	6	9	6	10	13	13	**57**
54	6	8	7	8	15	14	**58**
55	6	9	7	10	18	14	**64**
56	6	8	7	9	14	14	**58**
57	6	9	7	8	14	14	**58**
58	6	9	7	9	14	15	**60**
59	7	9	7	9	16	14	**62**
60	6	9	7	11	15	14	**62**
Total	**315**	**404**	**389**	**537**	**777**	725	**3147**

Because of technical maintenance and consequent limited access some turbines were not searched with equal frequency, but these turbines were not operational in this time period around such maintenance and respective collision risk would be accordingly lower.

Under this search regime during the 2015 autumn migration period, four bodies have been found that could be attributed to collision with turbine blades. The number of birds found dead under turbines in 2015 and the species' conservation status according to the Bulgaria Red Data book and IUCN are presented in Table 11.

Table 11. Collision victims recorded in autumn 2015.

English name	Latin name	N	Red Data book	IUCN
Purple Heron	*Ardea purpurea*	1	Endangered	Least Concern
Common Buzzard	*Buteo buteo*	1	Not listed	Least Concern
Common Kestrel	*Falco tinnunculus*	1	Not listed	Least Concern
Common Swift	*Apus apus*	1	Not listed	Least Concern

Purple Heron is an Indo-African species breeding in the Iberian peninsula, in France, Germany, Italy, the Balkan Peninsula, southwestern Russia, Kazakhstan, Hindustan, Indochina, Indonesia, Mozambique, Angola, and Madagascar. It winters in Egypt, the

Arabian Peninsula, Africa to the south of Sahara, Madagascar, Hindustan, and southeastern Asia. According to the IUCN the total population of the species is estimated between 270,000 and 570,000 Purple Herons in the world and the population is probably decreasing slowly.

The International Union for Conservation of Nature has assessed its conservation status as being of "least concern" because the rate of decline is insufficient to justify rating it in a more threatened category. The chief threat the bird faces is drainage and disturbance of its wetland habitats.

The Bulgaria Red Data book defines the species as **Endangered** because of its limited distribution and abundance in Bulgaria: a breeding summer visitor, common only in the water basins near the Danube and the Black Sea. The bird found in SNWF could not be defined as local because of the period when it has been found – autumn migration which is outside the period when breeding birds away from SNWF are territorial. From the plumage of the victim it was clearly a juvenile, fledged in 2015 away from SNWF. It is also the first observed collision of Purple Heron at SNWF, and the species is only infrequently recorded as a migrant at SNWF (Table 2); therefore it should be considered as an accidental casualty.

Table 12. The number of carcasses attributable to collision with wind turbines found during autumn migration between 2010 and 2015 in SNWF. For details see Methods and reports on the autumn migration period in previous years.

Species	Carcasses attributable to collision	Conservation status according to IUCN (IUCN 3.1)
Alauda arvensis	3	Least Concern
Apus apus	3	Least Concern
Ardea purpurea	1	Least Concern
Acrocephalus palustris	1	Least Concern
Buteo buteo	1	Least Concern
Crex crex	1	Least Concern
Delichon urbicum	2	Least Concern
Gyps fulvus	1	Least Concern
Falco tinnunculus	1	Least Concern
Falco vespertinus	1	Near Threatened
Hirundo rustica	2	Least Concern
Lanius collurio	1	Least Concern
Larus ridibundus	1	Least Concern
Larus michahellis	5	Least Concern
Oreolus oreolus	1	Least Concern
Sylvia atricapilla	1	Least Concern
Total	**26**	

IUCN criteria were used for evaluation of bird conservation status because of the unknown origin of migratory populations in autumn when the movements of birds found dead can cover different continents. National criteria for the same species would be applicable for breeding populations of the same species in the breeding period in spring. The mortality rate at SNWF for six autumn seasons of carcass searches, typically under every turbine every week, resulted in an estimated average of 0.08 birds killed per turbine per migratory season. The adjusted mortality accounting for the removal rate as well as the efficiency of the searchers would result in about 50% additional mortality to that observed from the carcass searches, resulting in 0.16 birds per turbine per autumn season and this cannot be remotely considered influential for the populations of any of the affected species.

CONCLUSIONS

Additional data collected in the autumn 2015 by standard methods with consistent and comparable to previous years' efforts confirmed the previous results and allowed continued evaluation of the long term effect of SNWF on bird migration. The long term monitoring in the same area has allowed the following conclusions:

1. The numbers of species passing through the SNWF territory in autumn varied by year with no trend for a decrease after SNWF was constructed and started its operation (Table 1).

2. The absolute number of observed birds naturally varied by year but with no trend for a decrease after SNWF was constructed and started its operation (Table 2).

3. The altitude of flight varied by years but with no overall trend for an increase after SNWF was constructed and started its operation (Table 4 and Fig. 5).

4. There is no evidence for change in migratory direction (avoidance) associated with the wind farm 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 (Tables 6, 7, 8 and Fig. 6).

5. The occurrence of autumn migrants in all eight autumn seasons was strongly correlated with typically short periods of a few days when strong westerly winds occurred and deflected birds eastwards from the main migration corridor (Via Pontica) further to the west.

6. During six years of wind farm operation, carcass searches during the autumn periods revealed a total of 26 collision victims equal to an average of about 0.16 birds per turbine per autumn season, adjusted after several experimental studies of biases in carcass searches.

7. Records of collision mortality do not indicate any possibility of an adverse impact of SNWF on any bird population passing through the wind farm territory.

8. The application of the Turbine Shutdown System (TSS) may have made a significant contribution to the low level of direct mortality registered in the operational period of SNWF. Micro avoidance of turbine blades also appears to be very high, despite an apparent lack of macro avoidance of the wind farm. Even in the absence of TSS and micro avoidance, however, it is highly unlikely that the pre-construction predictions of mortality would have been observed, in large part because these predictions were based on inflated estimates of the numbers of migrants that occur at SNWF.

9. The substantial data collected in seven autumn seasons indicate that the operation of SNWF does not constitute an obstacle or threat, either physically or demographically, to populations of migrants passing through its environs.

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