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Study on the White Stork (*Ciconia ciconia*) Autumn Migration, Northeastern Bulgaria

Georgi Gerdzhikov[1], Mihail Iliev[1], Stoyan C. Nikolov[2*]

[1] Bulgarian Society for Protection of Birds / BirdLife Bulgaria, 5 Leonardo da Vinci, P.O.Box 562, 4000 Plovdiv Bulgaria; E-mails: georgi.gerdjikov@gmail.com, iliev.mihail@gmail.com
[2] Bulgarian Society for Protection of Birds / BirdLife Bulgaria, Yavorov complex, bl. 71, vh. 4, PO box 50, 1111 Sofia, Bulgaria; E-mail: stoyan.nikolov@bspb.org

Abstract: A lot of studies exist on the soaring bird migration along the Eastern Mediterranean migration route. However, most of them are focused on the avian species composition and numbers, while the migration patterns and the influence of weather conditions are still poorly investigated. The present study is focused on the migration of White Storks in northeastern Bulgaria, based on data collected for 6-year period (2004-2010) from 33 observation points. Our aim was to investigate the horizontal and vertical distribution of migrating storks, and how the dynamics of these distributions was influenced by the weather conditions. We demonstrated that the migration route of White Storks in the study area extends up to 70 km inland from the coast. The most intensive was the migration in the early afternoon, during the last 10 days of August and under north-coming winds. The majority of storks was flying above 400 m and the altitude of flight was influenced by the air temperatures and the day hour. The main driver for the flight distance from the sea was the wind direction. Considering the potential negative cumulative effects due to the high concentration of wind parks in northeastern Bulgaria, we emphasise that the prospective intentions for construction of wind farms, even located at 70 km from the coast, should be subjected to careful studies on the soaring bird migration through the area.

Keywords: Mediterranean flyway, *Via Pontica*, soaring birds, migration dynamics

Introduction

The Mediterranean/ Black Sea flyway is one of three Palaearctic-African flyways that connects Europe with Africa and part of the world's largest bird migration system (BirdLife International 2010). The Mediterranean Sea constitutes a natural barrier for birds crossing into Africa, especially for large size species, such as raptors, storks and cranes, which rely on updrafts and thermals to maintain their soaring flight. Therefore, migration through the Mediterranean basin is concentrated at a number of narrow straits and 'land bridges'. One of these sites is Bosphorus in Turkey, which has been recognised as a major migratory bottleneck, where more than 2 million storks and raptors pass in spring and autumn (BirdLife International 2010).

A significant part of the soaring birds passing through Bosphorus comes by the Western Black Sea Migratory 'stream' also known as '*Via Pontica*' (Simeonov *et al.* 1990). In Bulgaria, the first published data on bird migration along *Via Pontica* were available from the end of the 18th century (Alleon 1886) and were followed by some fragmentary data in the grey literature. More systematic studies have been conducted since the 1980s (*e.g.* Nankinov 1980, 1981, Michev, Simeonov 1981, Michev *et al.* 1987) and mainly focused of the waterfowl migration. One

*Corresponding author: stoyan.nikolov@bspb.org

of the best studied sites along *Via Pontica* is Burgas Bay that is considered as a local migration bottleneck for soaring birds. The data from a long-term monitoring (1979–2003) showed that 90% of the soaring birds migrating in autumn through Bulgaria passed through that site (Michev *et al.* 2011). The White Stork (*Ciconia ciconia*) has been recognised as the most numerous soaring migrant along *Via Pontica* in autumn (Michev *et al.* 2011) with ca. 40% of the European population passing through this flyway (Van Loon *et al.* 2011), as well in spring (Shurulinkov *et al.* 2011). Although, according to the IUCN criteria, the species is from Least Concern and its population seems to increase, it is considered as one of the key species for determining bottleneck Important Bird Areas and a lot of threats have been identified along its flyway (BirdLife International 2013). The electrocution, collision with powerlines (del Hoyo *et al.* 1992, Demerdzhiev *et al.* 2009, Gerdzhikov, Demerdzhiev 2009, Demerdzhiev 2014) and wind turbines (Manville 2005, Kostadinova, Gramatikov 2007, European Commission 2010) are amongst the most serious threats to the White Stork during migration (Hancock *et al.* 1992).

The problem with the wind turbines is of great concern for Bulgaria as a recent EU member state that is obliged to demonstrate significant progress in the development of renewable energy sector (Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources). Wind farms are known as potential factor for significant mortality in birds, with the other negative impacts being disturbance, displacement, barrier effect and habitat alterations (Drewitt *et al.* 2006, Desholm 2009, European Commission 2010). In this light, the spatial planning of the wind farms was proven to have significant effect on the degree of negative impact on birds (Noguera *et al.* 2010). However, the appropriate spatial planning is not possible without preliminary data on spatial distribution and flight features of the migrating birds. Most of the studies conducted so far on soaring bird migration along the western Black Sea coast have been focused on the dynamics in species composition and numbers, and concentrated on a rather narrow belt along the coast. Furthermore, no investigation of flight characteristics and how they are influenced by the weather conditions and distance from the sea coast has been made (but see Shurulinkov *et al.* 2011). Some evidence exists about the extension of *Via Pontica* by tens and even hundreds of kilometres towards inland (Michev *et al.* 1987, Kostadinova, Gramatikov 2007, Shurulinkov *et al.* 2011), but the picture of the westernmost limits of that migration route is not clear and most importantly, the factors influencing horizontal and vertical distribution on migrating soaring birds are poorly known. The mentioned gap in our knowledge is used by many decision-makers to conclude that there is no serious collision risk for migrating birds when the wind farms are installed a few kilometres inland from the shore. As a result, the number of wind farms in northeastern Bulgaria, and along the western Black Sea Migration route, has increased tremendously in the last several years (Fig. 1).

The present study is focused on the migration of White Storks in northeastern Bulgaria and aims to investigate the horizontal and vertical distribution of migrating storks, and how the dynamics of that distribution are influenced by the weather conditions.

Methods

Study area

The study was conducted in Dobrudzha region, northeastern Bulgaria (Fig. 2). This region is characterised mainly by lowlands, but also by hills and plateau areas. The climate is moderate continental with the most eastern parts falling under the Black Sea climate influence. The mean annual temperature is 12°C and the mean precipitation is 500-550 mm. The main wind directions are from northeast and north, with mean annual speed 3-6 m/s (Slaveykov *et al*. 2007).

Study design

For the purposes of this study we used data from monitoring of the soaring birds autumn migration for a 6-year period (2004-2010), which were collected at 33 observation points (Fig. 2) and available at the Bulgarian Society for Protection of Birds/ BirdLife Bulgaria. The fieldwork followed a standard methodology at national level (Michev *et al.* 2012). The observation points were located at sites with good visibility (at least 5 km radius) and with a minimal distance between two neighboring observation points of ca. 3 km. Bird counts were made between 1st of August till 31st of October, from 08:00 till 18:00 astronomical time, daily, except for the days with heavy and extended rains. The observations were made by means of binoculars (min 8 x) and telescopes (min 20 x) by a single observer per point. All observers were skilled and we assumed there is no observer bias in this study. Frequent communication via mobile phones between the observers on different observation points minimised the risk for double counts of the same flocks. Information for two data sets were collected: (i) Bird data (response variables) – observation features (number of observations per hour and number of individuals in a single observation) and flight features (direction, height, type of flight and distance of the flock from sea coast); (ii) Environmental data (explanatory variables) – weather conditions (temperature, power

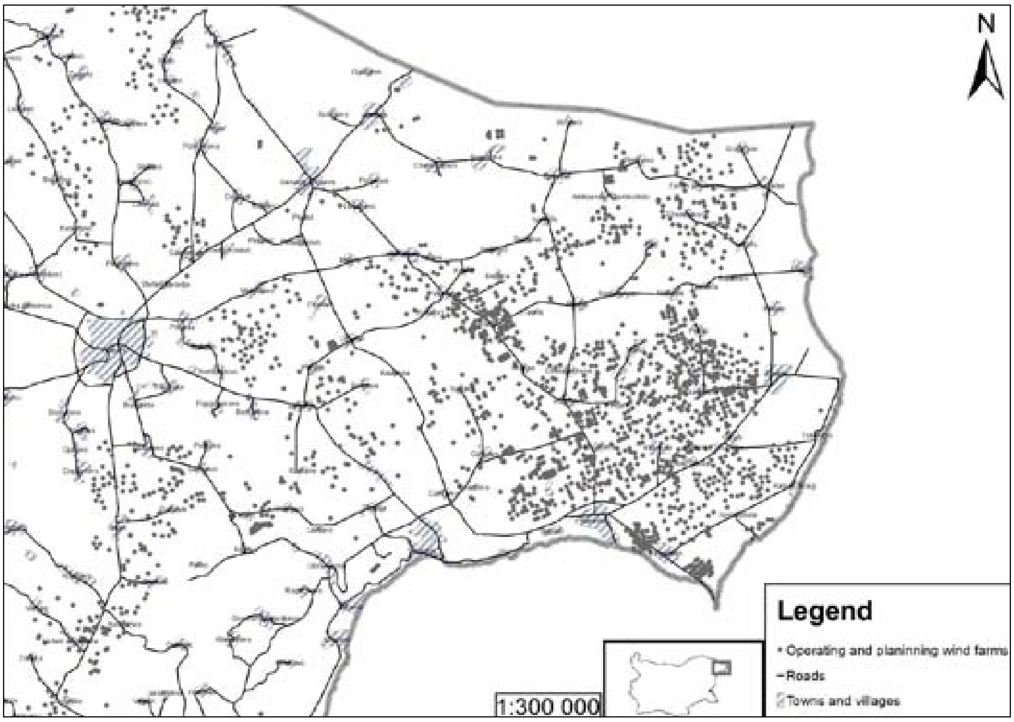


Fig. 1. Distribution of operating wind and planned farms in northeastern Bulgaria in 2011 (BSPB, *unpublished data*)

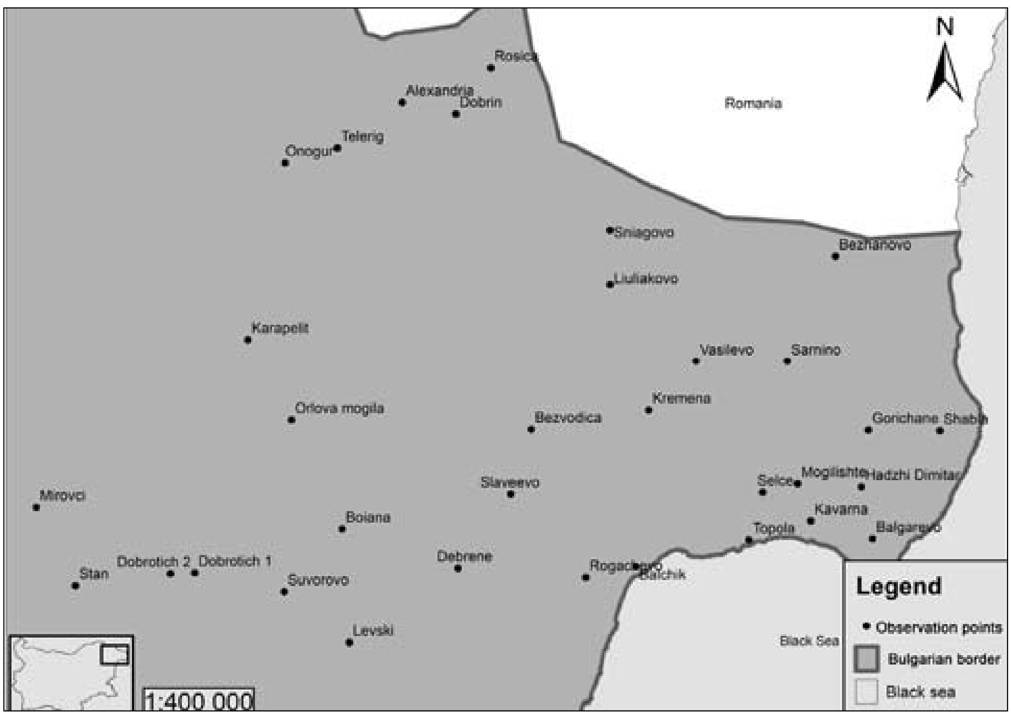


Fig. 2. Map of the study area and observation points

of wind according to Beaufort scale, wind direction, cloud cover in %, visibility in km) and hour of detection. The flight features in migrating White Storks and weather conditions were estimated and described according to Shurulinkov *et al.* (2011) and the national methodology for bird migration monitoring (Michev, Profirov 2010).

As the data were not collected specifically for the aim of this study, they were not collected in a systematic way: there was different number of observation points per year and different number of observation days per point (Appendix 1). However, considering that, on the one hand, the fieldwork followed a standard methodology, the study was long-term, and the sample size was large, and, on the other hand, the fact that the present study was focused on the effects of weather conditions on White Stork migration in general rather than on location-specific features, we assume there is not a significant methodological bias in our results.

Statistical analysis

It is known that the ability of detection decreases with the distance from the observer (Buckland *et al.* 2001). To avoid potential bias in ability of different observers to detect migrating birds we computed the effective distance radius (EDR) for White Stork detection using DISTANCE 5.2 software (Thomas *et al.* 2006). We used Uniform key function (with Cosine expansion) selected on the basis of the minimum value of the Akaike's Information Criterion. We found that the probability of detection is constantly high within 1.5 km from the observation point (EDR = 1589.3 m, CV = 0.51%, 95% CI 95%: 1573.4 – 1605.4 m). Consequently, we truncated all available data based on the EDR value and used them for further analysis. The resulting sample consists of 3231 observations of 1 052 924 individual birds.

The data were tested for normality by the Shapiro-Wilk test. Because data were not normally distributed and did not approach the normal distribution even after transformation, non-parametric tests were applied for analysis. Relations between variables were tested by the Spearman Rank Correlation. Kruskal-Wallis ANOVA was applied to test for the difference between multiple independent samples (number of migrants in different months and under different weather conditions). To avoid potential bias in the results regarding White Stork numbers due to very large but single flocks at the observation points, we analysed both the number of the individuals and the number of observations (*i.e.* flocks). Although data was not normally distributed, we checked distributions of all data visually by box-wisker plots, and as we did not found strong deviations from normality or homoscdasticity, we applied parametric test for the subsequent analyses (Quinn, Keough 2002). ANCOVA was applied to test for the effect of wind direction on the flight distance from the coast (where number of storks was response variable, the wind direction was categorical predictor and the distance from the sea was covariate) and for the effect of wind speed on the altitude of flight (where number of storks was response variable, the wind speed was categorical predictor and the altitude of flight was covariate). As significant differences in the species migration were not found from year to year, we worked with pooled data for the study period. All statistical procedures were computed in STATISTICA 7.0 (StatSoft 2004).

Results

Temporal dynamics of White Stork migration

There were 536 (SE ± 137; N = 6 years) observations of migrating White Storks per year with a mean of 155 510 (SE ± 56 096.4; N = 6 years) individual birds per year migrating over the study area (Table 1). The mean number of individuals per observation was 327 (SE ±15.03; N = 3231 observations). The month with the most intensive migration was August with an average of 398 (SE ± 116.9; N = 3 months) observations of migrating storks and 80.8% of the individuals per year observed (Table 1). However, the most intensive migration was identified from mid August to mid September when 91.9% of the migrants have been observed (Fig. 3). There was not a constant 'peak day' in White Stork numbers.

Regarding daytime dynamics of migration, the number of observations of migrants was the highest in the period 9:00-14:00. The numbers of individuals increased gradually after 7:00 and in the range of 9:00-11:00 there was a constant number of passing birds (Fig. 4). The highest numbers of White Storks were recorded in the period 11:00-14:00 with a peak around 12:00 by nearly 56%, after which the migration gradually decreased.

Directions and spatial distribution of White Stork migration

The main direction of White Stork migration was oriented south (in 41% of migrants), followed by southwestern (in 22% of migrants) and southeastern directions (in 13% of migrants) (Fig. 5). The numbers of migrating White Storks were not influenced by the distance from the Black Sea (Spearman Rank Correlation: r_s = - 0.04, P > 0.05; Fig. 6).

Effects of weather conditions on the White Stork migration parameters

There was a weak positive correlation of the migrating storks' number and the daily air temperature (Spearman Rank Correlation: r_s = 0.18, p < 0.05) with more intensive migration in the range between 23°C and 30°C (Fig. 7). More storks were migrating under N, NE or NW wind (Kruskal-Wallis ANOVA: H_8 = 17.04, p = 0.029; Fig. 8). The White Storks migrated at different distance from the sea coast under different wind directions (ANCOVA: F_9 = 2.24, p = 0.017). Under eastern or northeastern wind, birds were flying mainly over 30 km far from the sea coast, while under western, southwestern, northwestern, and northern wind, and in no wind conditions, they were flying mainly in a zone of up to 30 km from the coast (Fig. 9).

The mean height of the White Storks flight was 429 m (SE ± 6.2; N = 3217 observations), with the highest percentage of individuals migrating over 500

Table 1. Number of observation points per year and numbers of migrating White Storks per month and per year. Abbreviations: OP – observation points; WS – White Storks; Aug – August; Sep – September; Oct - October. Kruskal-Wallis ANOVA is applied to test for the difference in the number of storks between months per year **p<0.01, ***p<0.001

Year	Number of OP	Total number of WS per year (ind.)	Mean number of WS per OP (±SE)	Percentage of WS per month			Kruskal-Wallis ANOVA	
				Aug (%)	Sep (%)	Oct (%)	H (df=2)	N
2004	4	100 924	25 231.0±12 067.98	66.36	33.6	0.02	48.94***	364
2005	6	131 080	21 846.66±7257.3	76.02	23.96	0.02	9.57**	518
2006	5	226 133	45 226.60±11 016.34	68.03	31.97	0.0004	5.58	408
2008	2	23 797	11 898.50±9530.5	98.6	1.39	0.004	20.91***	78
2009	12	372 606	31 050.50±7679.00	87.81	12.2	0.0008	43.68***	872
2010	8	196 492	24 561.50±7063.84	88.19	11.8	0.0061	91.66***	977
Mean (±SE)		155 510±56 096.4	26 635.79±4514.82	80.8±5.21	19.2±5.21	0.009±0.00		

(a)

(b)

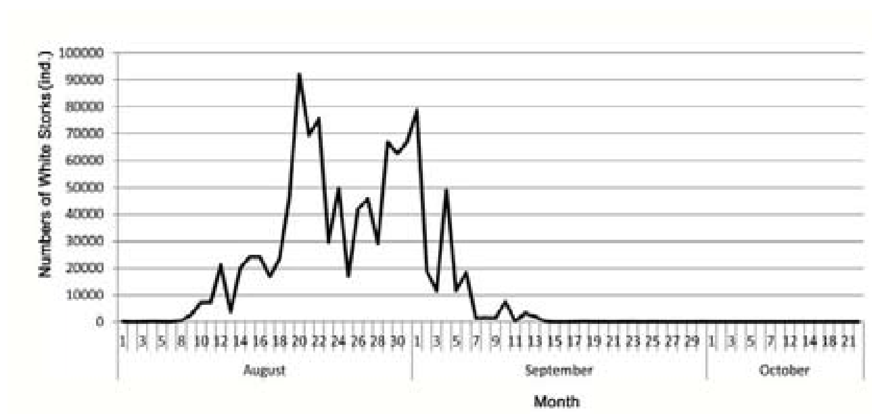


Fig. 3. Daily dynamics of observations (a) and numbers (b) of migrating White Storks in northeastern Bulgaria

m height (Fig. 10). The height of flight was positively influenced by the day hour (Spearman Rank Correlation: $r_s = 0.34$, $p < 0.05$) and by the air temperature (Spearman Rank Correlation: $r_s = 0.28$, $p < 0.05$). The White Storks were flying at higher elevations (above 2000 m a.s.l.) between 10:00 and 15:00, and in the range of 23-33 °C (Figs. 11 and 12). By increasing the wind speed, the numbers of White Storks flying at upper altitude decreased (ANCOVA: $F_8 = 6.873$, $p < 0.0001$; Fig. 13).

Discussion

It is known that the Eastern Mediterranean migration flyway is very important for the migration of White Storks in Europe (BirdLife International 2010). Along that flyway, Burgas Bay is a proven bottleneck in Bulgaria, with an average of 145 177 individuals migrating per year (Michev *et al.* 2011). With the

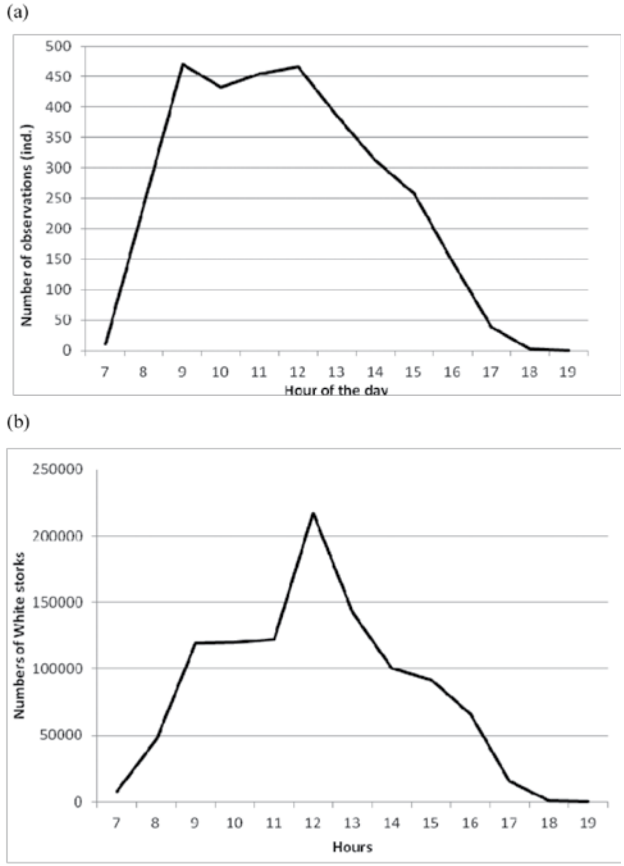


Fig. 4. Daytime dynamics of observations (a) and numbers (b) of migrating White Storks

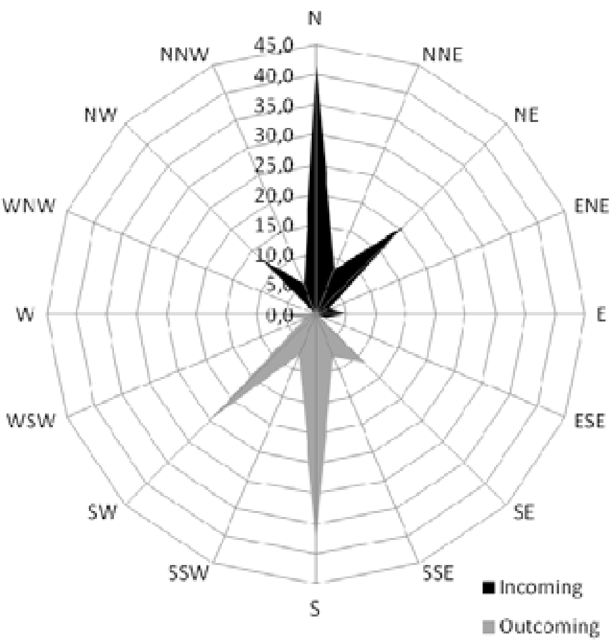


Fig. 5. Directions of the White Stork migration in northeastern Bulgaria

present study we show that similar numbers of White Storks (*i.e.* 155 510 individuals per year) migrate within 70 km from the Black Sea coast through the northeastern Bulgaria. Our results are also in accordance with the data of Michev *et al.* (2012) for a total of 188 242 White Storks per year, which fly through northeastern Bulgaria during autumn migration.

In the present study, the mean number of observations per year (536) was about twofold higher than in the bottleneck at Burgas Bay in southeastern Bulgaria (Simeonov *et al.* 1990). In accordance with the results obtained by Shurulinkov *et al.* (2012) for spring migration in southeastern Bulgaria, the present study demonstrated that the migration of the White Storks is not concentrated within the narrow zone along the coast, but extended inland. It is known that the migration of the species is influenced by landscape (Leshem *et al.* 1998): when the birds migrate over open areas, they fly at wide front, but when they reach natural barriers (*e.g.* mountain, sea, etc.) their migration concentrate over confined strip of land (along the studied migration flyway: Burgas Bay, the Bosporus, etc.). At the same line, the migration pattern in northeastern Bulgaria could be explained by the relatively flat relief of the studied area where White Storks fly at wider front but in smaller flocks (327 individuals in flock per year) compared to the bottleneck in Burgas Bay, southeastern Bulgaria (577 individuals in flock per year according to Michev *et al.* 2011). A similar migration pattern was observed also in Israel (Bossche *et al.* 2002).

Shamoun-Baranes *et al.* (2003a) found that the average duration of the autumn migration of the White Stork is 26.1 ± 4.9 days. Our results from northeastern Bulgaria support these findings and correspond to those of Michev *et al.* (2011) for southeastern Bulgaria, which show that during the autumn migration the White Stork migrate mainly between 10th of August and early October with migration peaks in late August/ early September. The main peak in the White Stork autumn migration is considered to be related mainly to birds coming from Central and Eastern Europe (Bossche *et al*. 2002). Another reason for the higher intensity of species migration in August seems to be the appropriate weather conditions: low precipitation and high air temperatures (Stanev *et al*. 1991).

The present study demonstrated that the migration of the species was more intensive under north coming winds and the White Stork migration distance from the coast was mainly determined by the wind direction. It is known that the wind speed and direction are major predictors for the features of the White Stork migration (Koistinen 2000, Liechti 2006, Chevallier *et al.* 2010). Shamoun-Baranes *et al.* (2003a) found that the speed of flight positively correlates with the average speed of the wind. By using a radar technology Koistinen (2000) demonstrated that the migration of the species under NW-N-ENE winds is the most intensive. The same author

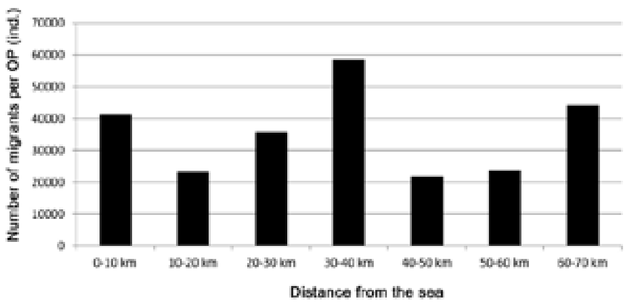
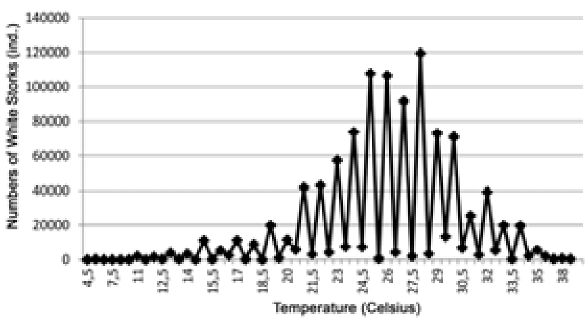


Fig. 6. Distribution of migrating White Storks in relation to the distance from the Black Sea. Abbreviation: OP – observation point

(a)



(b)

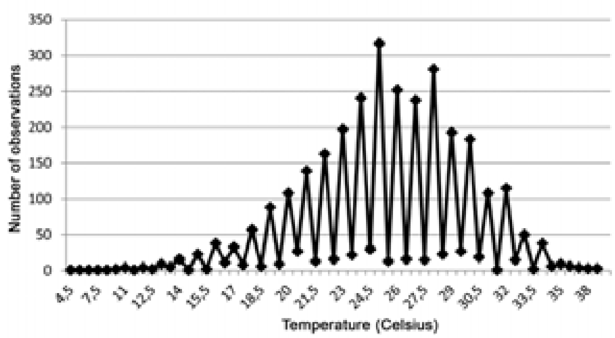


Fig. 7. Flight dynamics of migrating White Storks expressed in number of individuals (a) and number of observations (b) in relation to the daily air temperature

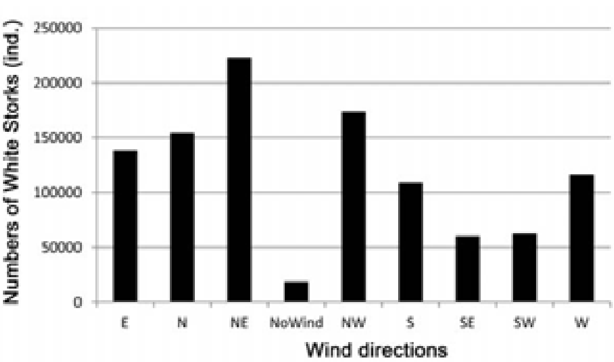


Fig. 8. Flight dynamics of migrating White Storks in relation to the wind direction

provided some evidence that, if the wind direction does not shift with the direction of the bird flight, the intensity of migration is lower.

The mean flight height of the migrating White Storks in northeastern Bulgaria (429 m) is similar to the flight height in southeastern Bulgaria (500 m), as found by Michev *et al.* (2011), but differ from the other parts of the migration flyway (*e.g*. Israel), where the main altitudinal range of flight was 670-1640 m according to Liechti *et al.* (1996) and 488-1615 m according to Shamoun-Baranes *et al*. (2003b). Moreover, we found a positive correlation between the flight height and both the hour of the day and air temperature, which reached a maximum during the early afternoon. This is in accordance with the results of Liechti *et al.* (1996) and show that the White Storks reach the maximum altitude of flight in the early afternoon, when the thermals are the most powerful. Even the air temperature is known as good predictor for altitude of bird flight, this parameter is considered as a factor with a lower significance compared with the wind speed (Koistinen 2000).

In terms of the conservation of the White Stork along the Eastern Mediterranean flyway, as the species belong to the heavy soaring birds with low maneuverability, it is often recognised among the potential common victims of wind turbines and power line wires (Bevanger 1994, Noguera *et al*. 2010, European Commission 2010). Although the White Stork is known to migrate at relatively high altitudes in comparison with other soaring birds (Shurulinkov *et al.* 2012) and the mean flight altitudes of the species in the present study were over the critical zone for collisions with the wind turbines (between 30 and 120 m above the ground; Noguera *et al.* 2010), we demonstrated that the altitude of flight could decrease in relation of the time of the day and weather conditions. Thus, the risk of collisions under specific weather conditions should not be underestimated.

Currently, there is a high density of wind parks in the studied area and many new projects are underway in different stages of implementation. It is expected that, if most of them are finally accomplished, this will lead to increased mortality of the most numerous and vulnerable migratory soaring birds, such as White Storks, White Pelicans and diurnal raptors (Shurulinkov *et al*. 2012). To mitigate these potential negative effects more detailed information on the bird migration patterns is needed. Despite of the numerous papers on bird migration along *Via Pontica*, many questions on the spatial parameters of migration routes, number and dynamics of different migrant species, peak days, etc., remain open (Michev *et al.* 2012). In fact, so far most of the maps of migra-

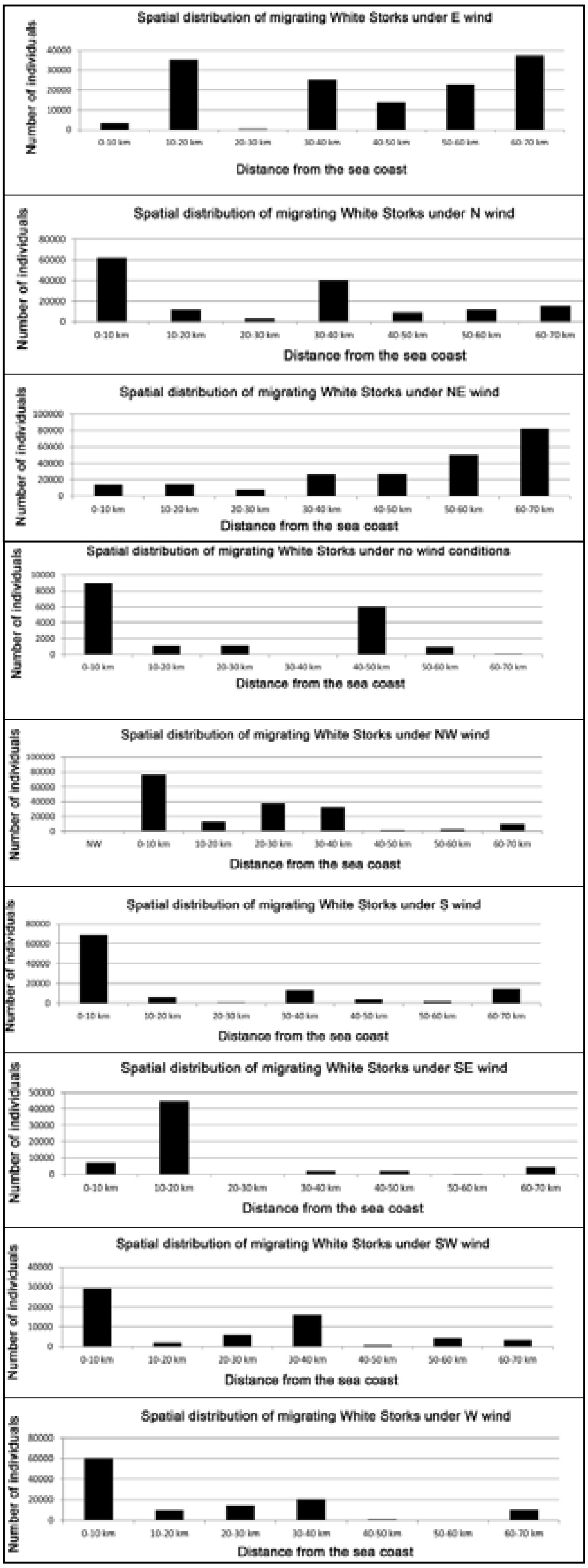


Fig. 9. Effects of wind direction on the distance of migrating White Storks from the Black Sea coast

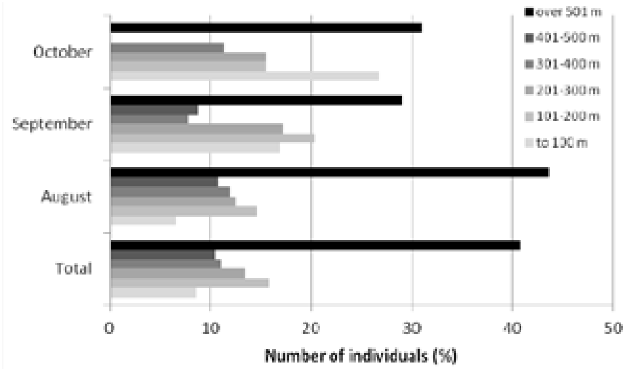


Fig. 10. Monthly distribution of the height of White Storks flight (N = 3217 observations)

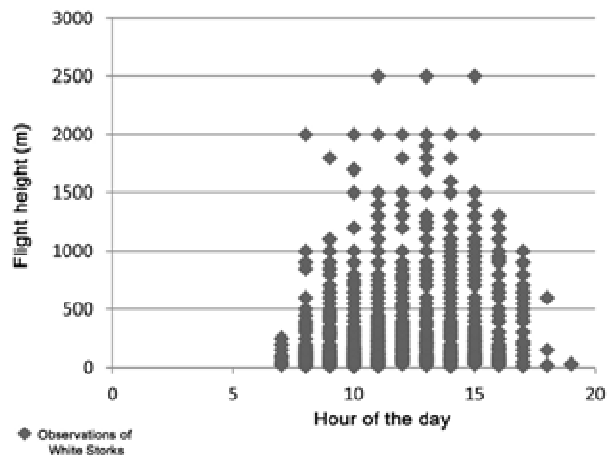


Fig. 11. Scatterplot of White Storks flight height in relation to the hour of the day

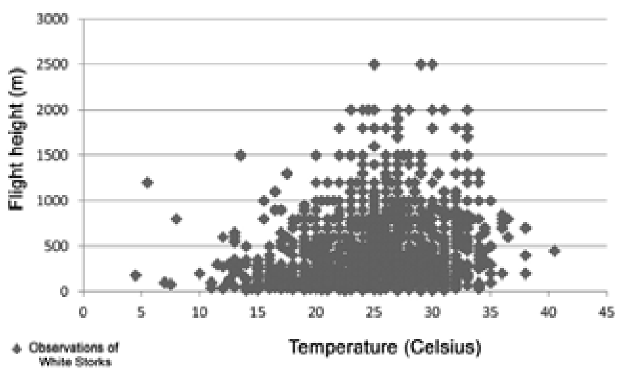


Fig. 12. Scatterplot of White Storks flight height in relation to the air temperature

tion routes across the territory of Bulgaria are based on expert assessments rather than on solid evidence (but see MICHEV *et al.* 2012). The unclear picture of the scale of the inland migration along *Via Pontica* leads many decision-makers to the conclusion that the wind farms installed some kilometres inland from the shore do not pose danger to migrants (SHURULINKOV *et al*. 2012). The results from the present study clearly show, in support of the statement of KOSTADINOVA,

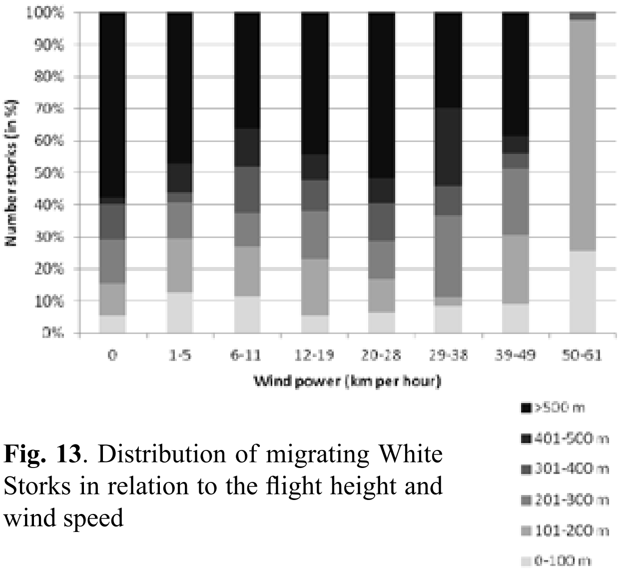


Fig. 13. Distribution of migrating White Storks in relation to the flight height and wind speed

Gramatikov (2007) and the radar investigations by Michev *et al.* (1987), that in northeastern Bulgaria the *Via Pontica* migration route extends well inland with tens of kilometres. Moreover, the spatial distribution of White Stork's migration was not consistent, but shifted under the effects of weather conditions (wind direction). The variability in migration timing and routes from year to year could also be determined on an individual basis by external factors (such as food supply), as demonstrated in the study of Berthold *et al.* (2004). Therefore, we stress out that potential intentions for construction of wind farms, even located within 70 km from the coast, should be subjected to careful studying the migration of soaring birds through the area. Considering the potential negative cumulative effects, some measures should be taken by the authorities to limit the increasing numbers of wind turbines in the area.

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Appendix 1. List of observation points, their distance to the Black Sea coast and number of observation days

No	Observation points	Distance to the sea coast (km)	Observation days per year						Total number of observation days
			2004	2005	2006	2008	2009	2010	
1	Alexandria	61.8				77	82		159
2	Balchik	0.96	72						72
3	Balgarevo	3.5	72			81			153
4	Bezhanovo	13.6			64				64
5	Bezvodica	21.2		87					87
6	Boiana	32.5						84	84
7	Debrene	19.4					77		77
8	Dobrin	57.6					38		38
9	Dobrotich	42.3					55	79	134
10	Gorichane	12.2	46						46
11	Gorichane	12.2		35					35
12	Hadzhi Dimitar	8.2			79				79
13	Karapelit	53.4					80		80
14	Kavarna	2.3			79				79
15	Kremena	16.9		87					87
16	Levski	22.5						66	66
17	Liuliakovo	32.5						83	83
18	Mirovci	62.4					80		80
19	Mogilishte	6.4			65				65
20	Onogur	63.9		88					88
21	Orlova Mogila	44.2					83		83
22	Rogachevo	4.8	72						72
23	Rosica	56.4					79		79
24	Sarnino	19.6						91	91
25	Selce	5.5			75				75
26	Shabla	4.4			75				75
27	Slaveevo	17.4					76		76
28	Sniagovo	38.7						84	84
29	Stan	54.5					79		79
30	Suvorovo	32.2		65				70	135
31	Telerig	61.5					85		85
32	Topola	0.56		92					92
33	Vasilevo	22.5					66	83	149
		Grand totals	262	454	437	158	880	640	2831