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Relationship between the Intensity of Nocturnal Migration Measured by Radar and the Anthropogenic Mortality of Birds

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Abstract: Between August 27th and September 30th 2014 the intensity of nocturnal bird migration was measured in the Dobrudzha Region (NE Bulgaria) using a specific bird radar. During the same time period and in the same area (part of Natura 2000 net BGSPA0002051 Kaliakra and adjacent areas), road-kills as well as collisions of birds with wind turbines were recorded. Along a 9-km-long secondary road, 95 dead birds out of 24 species belonging to six orders were found. A systematic carcass search under 52 wind turbines was examined and eight collision victims belonging to five bird species of four orders were discovered. The results did not show a relation between bird mortality due to wind turbine collisions and nocturnal migration. However, a positive correlation between night passerine migration intensity and road mortality of passerines was found. Windfarms do not appear to be more detrimental to migrating birds than other anthropogenic sources of mortality, such as automobile traffic. The recorded high number of road-kills in the designated Natura 2000 zone Kaliakra provides a basis for planning additional restrictions in this zone, in order to secure the habitats, which are important for migrating passerine birds.

Key words: bird mortality, radar study, car traffic, wind turbines

Introduction

Bird migration is an impressive natural phenomenon that has been described in many scientific publications, summarised mainly by Alerstam (1990), Berthold (2001), Bildstein (2006) and Newton (2010). Some of the papers are devoted to migration over the Balkan Peninsula, which is a territory with an intensive bird migration (Dontchev 1980, Bildstein & Zalles 1995, Michev *et al*. 2011, Shurulinkov *et al*. 2011, Zehtindjiev 2001a). Bird migration is dominated by nocturnal migrants (Bruderer & Liechti 1995, 1999) where passerine birds constitute a major part (Bloch *et al*. 1981, Rabenold 1993). Many of them are long-distance migrants wintering in sub-Saharan Africa. Large-scale distribution and dynamics of nocturnal migration particularly over the Balkans and Bulgaria were studied through a direct moon watching technique (Bolshakov *et al.* 1998, Zehtindjiev 2001a, b, Zehtindjiev & Liechti 2003).

Soaring bird migration across Bulgaria has been studied systematically in different locations by visual observations (Bildstein & Zalles 1995, Michev *et al.* 2011, 2012, Shurulinkov *et al.* 2011). In the early 1980s synchronised visual and airport radar observations were carried out for the first time in Bulgaria (Michev *et al.* 1987). The main advantages of radar observations compared to visual observations are their objectiveness due to the independence between daylight and visibility (Schmaljohann *et al.* 2008, Dokter *et al.* 2009). Unfortunately, the currently used radar systems do not provide enough information about the species composition and details about single species migration. Therefore, little is known about the spatial and temporal distribution of different species during migration on the territory of

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Bulgaria (Zehtindjiev & Whitfield 2010).

The growing demand for renewable energy has led to the development of wind industry in many parts of the world, including Bulgaria. A great amount of actual information about bird migration over the country was accumulated during the last ten years as a result of demand for long-term ornithological data from the surroundings of planned wind farms (Michev *et al*. 2012; Zehtindjiev & Whitfield 2012, 2013). With the development of wind energy around the world, the question about the potential risk of bird collisions with wind turbines and the need of related studies has been raised (Larsen & Madsen 2000, Langston & Pullan 2003, De Lucas *et al.* 2007, Barrios & Rodrígues 2007, Michev *et al.* 2012, Zehtindjiev & Whitfield 2009, 2010, 2011, 2012, 2013, 2014).

The mortality of birds during migration has never been related to the intensity of bird migration. Road infrastructure has been shown to exert many negative effects on the populations of vertebrates and ecosystems in general (Smith & Dodd 2003, Van Langevelde *et al*. 2009, Wiacek *et al.* 2015) and bird mortality due to collision with cars is the most serious of them (Erritzoe *et al*. 2003). Bird traffic casualties are not systematically studied in Bulgaria and data about the number of birds as well as the composition of species among the collision victims on the roads are scarce. The earliest study of bird road-kill dynamics in Bulgaria has been carried out by Nankinov & Todorov (1983). The recent study of Van der Grift *et al.* (2008) and Kambourova-Ivanova *et al.* (2012) has found a significant impact of road traffic on the mortality of birds, mammals, reptiles and amphibians. However, no study on the relationship between the dynamics of bird migration and bird mortality either due to collisions with cars or with wind turbines has been presented up to now.

Bulgaria has developed the National Network of Natura 2000 sites and is currently planning management programs for these territories. The rate of anthropogenic mortality of birds is of crucial significance for the adequate and efficient planning and implementation of research-grounded conservation measures and policies in such protected areas as Natura 2000 zones. The present study was partly carried out in Special Protection Area (SPA) **BG0002051** Kaliakra and the results from it could be used for better management of this SPA zone.

The aim of the present study is to link for the first time the dynamics of nocturnal bird migration and collision fatalities due to road traffic and wind turbines in the same time period and on the same territory. This will help to cast light on one of the causes of bird mortality in typical habitats in the north-eastern part of Bulgaria (South Dobrudzha).

Materials and Methods

The study was carried out between August 27th and September 30th 2014 covering a total of 35 days, including intervals of 315 hours with 3780 minutes radar scanning in the NE part of Bulgaria. The territory consists mainly of arable land with different crops (wheat, sunflower, flax), intercepted with roads and shelterbelts. The area also includes Ponto-Sarmatic steppes designated as NATURA 2000 site Kaliakra for protection of this unique habitat (Fig. 1).

Radar System

We used the Swiss BirdScan MS1 radar situated in NE Bulgaria (43°26’51.52”N 28°27’12.48”E; Fig. 1). This fixed pencil-beam radar system was developed especially for the study of bird migration by the Swiss Ornithological Institute. The radar system is based on 25 kW marine radar (Bridgemaster) with wavelength of 3 cm (X-band radar). By using a pencil-beam parabolic antenna (equivalent to the Swiss tracking radar “Superfledermaus”), the detection range is increased by about a factor of two, compared to the standard T-bar antenna. The nominal angle of the beam line is approximately 2.2° degrees. The antenna can be set in various stationary elevations (hence “fixed-beam” radar), with the following specifications:

The detection range is c. 4 km (for individual small birds, e.g. chaffinch) up to 7.5 km (for individual larger birds, e.g. goose). Radar measurements were continuously made during the night (20:00 h - 04:10 h EET) for the whole study period according to the following scanning programs:

- Four minutes at an elevation angle of 1.7° (equivalent to approximately 25-275 m elevation at 5 km distance);
- Four minutes at an elevation angle of 8.4°(equivalent to 675-825 m at 5 km distance);
- Four minutes at an elevation angle of 39.4° (equivalent to 3375-3625 m at 5 km distance);
- This cycle was repeated every hour.

We used a tailor-made software (FixBeam) to extract single echoes and distinguish (based on the echo signature) birds or non-birds automatically (Zaugg *et al.* 2008). Based on the wing beat pattern of the bird extracted from the echo signature, echoes were classified into five different flight classes according to Bruderer (1969, 1997): wader class; passerine class; swift class; large single bird class and unknown class.

Using this data, we calculated the Migration Traffic Rate (MTR = number of birds crossing a hypothetic line of 1 km perpendicular to the mean migratory direction for selected time – in our case 3 scannings x 4 minutes each hour at 3 altitude layers). This parameter was used to study the relationship between the intensity of nocturnal migration measured by radar and the anthropogenic mortality of birds caused by car traffic and wind turbines.

Monitoring of bird mortality on the roads

A daily monitoring of bird mortality between August 28th and September 30th was conducted on the 9-km-long stretch of a secondary road connecting the villages Sveti Nikola and Tyulenovo, Kavarna Municipality (Fig. 1). The monitoring was conducted by bicycle twice a day: in the morning between 7:00 and 8:00 AM EET and in the afternoon between 16:00 and 17:00 PM EET. All discovered corpses of killed birds were identified and removed immediately to avoid double count. Information about date, time, species, sex, age and location was collected.

Monitoring of collision fatalities with wind turbines

Methodology developed for bird collision monitoring at operational wind farms (Morrison 1998) was used. Plots measuring 200 x 200 m centered on a turbine were searched on transects 20 m apart. The size of these plots was based on the results of Johnson *et al.* (2000). The efficiency and the adjusted mortality were tested prior to carcass searches in the studied area as recommended by Morrison (1998).

It is well known that searches for victims of collision with operational wind turbines fail to find all dead birds for several reasons. There are two principal factors: search efficiency (observer's fail to discover and register all dead birds) and removal/disappearance of dead birds before the observer can potentially find them. Accounting for these two potential biases, trials are typically undertaken in order to provide for such correction. Trials of hen carcass searches and assessment of its efficiency in the studied territory were done in 2009, 2010 and 2014 (Zehtindjiev & Witfield 2009, 2010, 2014). According to these reports, the efficiency of the separate searches ranged 72-88%, av. 79%. Carcass removal rate recorded in three autumn seasons indicated that hen carcasses were not removed very quickly after exposure, and several of them persisted for longer than 10-14 days.

The implication of these results for the present study is that most carcasses of collision victims and 'naturally' occurring carcasses probably persisted (and so were available during the monitoring) for longer time than the trial carcasses of hens. These data allowed estimating the optimal frequency of searches under turbines in respect to the time and energy input in the period of study. The frequency of seven days was estimated as optimal for adjusted mortality calculation after several seasons of systematic studies in this territory and after several trials in order to estimate the removal rate as well as searches efficiencies described in details in a number of re-

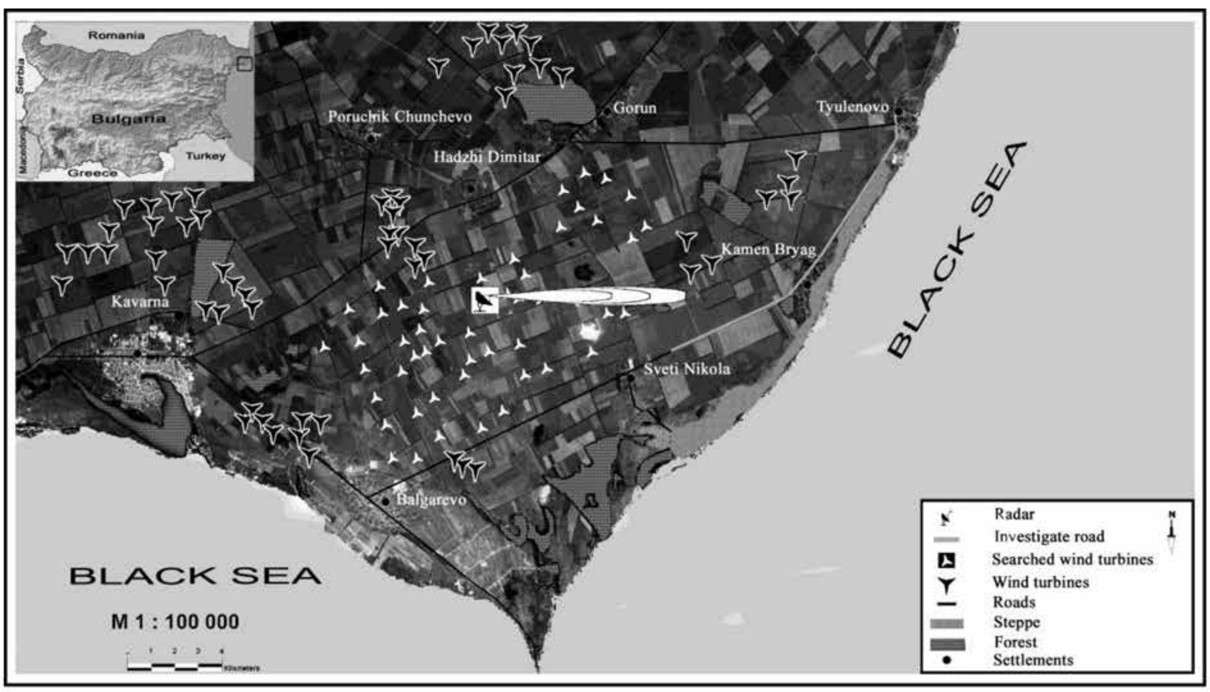

Fig.1. Map of the studied area

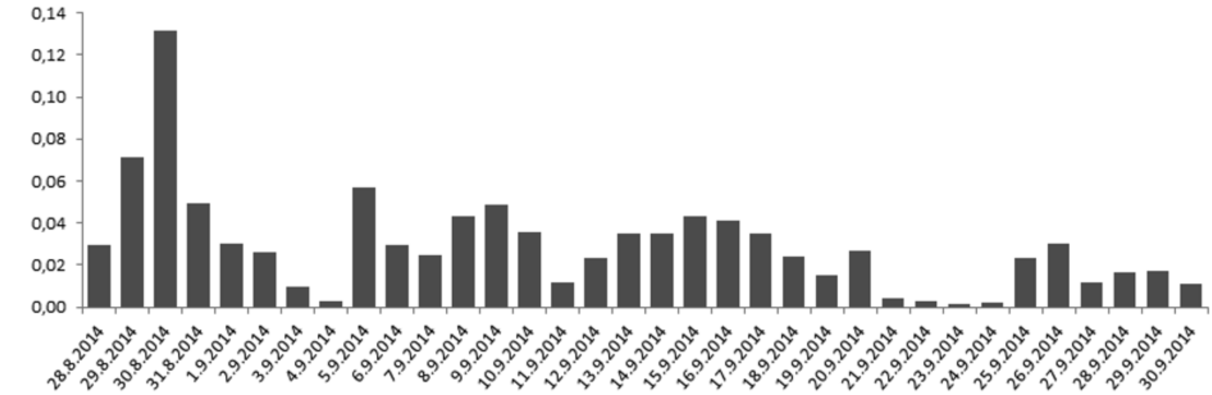

Fig. 2. Dynamics of passerine nocturnal migration, presented as proportion of all registered passerines during the studied period

ports (Zehtindjiev & Whitfield 2009, 2010, 2014).

Statistical methods

We examined whether the bird-vehicle collision mortality of nocturnally migrating passerines was related to their migration rate for a period of 34 days. Only victims of order Passeriformes which migrate during the night were included in the current analysis (Table 3). We calculated the value of nocturnal migration for each particular date as a sum of the MTR measured between 8.00 PM EET on the previous date and 5.00 AM EET on the current date. We calculated the Pearson's correlation coefficient between the MTR of the passerines and the number of carcasses of nocturnally migrating passerines, pairing each value of MTR for a given date with the number of carcasses found on the same date. Prior to analysis, data were transformed using Box-Cox transformation procedure to meet assumptions of normality. Data were analysed using Statistica 8 (Statsoft Inc., Tulsa, OK, USA).

Results

Migration Traffic Rate (MTR)

Nocturnal migration during the studied period (27th August - 30th September 2014) was dominated by passerines and waders, while the other radar-classes (swifts and large single birds) were rare. The radar measurements showed up to four waves of nocturnal migration during the study period (Fig. 2). The highest peak of 14% of all passed nocturnal migrants was observed during the night of 29/30.08.2014.

Bird mortality caused by car traffic

The daily monitoring of road-kills revealed 95 dead birds of 24 species. Out of them, 89 individuals belonged to order Passeriformes and six individuals to orders Coraciiformes, Charadriiformes, Falconiformes, Gruiformes and Pelecaniformes (Table 1, Fig. 3). The Red-backed Shrike (*Lanius collurio)*, which is included in the Bird Directive (2009/147/EC), represented the largest number of dead birds. Also, more than five victims were found for House Sparrow/Spanish Sparrow *(Passer domesticus/Passer hispaniolensis)* and Whinchat *(Saxicola rubetra)***.** The temporal pattern of the road-kills is presented on Fig. 4.

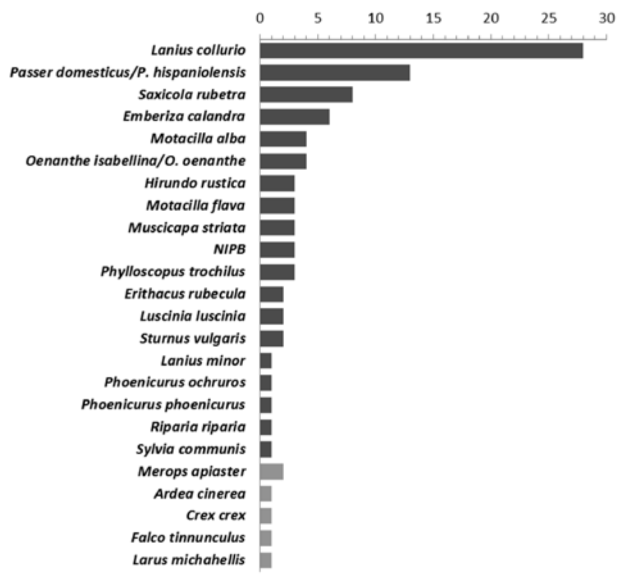

Fig. 3. Species composition and number (in ind. on the X-axis) of the registered dead birds on a secondary road in the study area. Dark grey columns – passerines, pale grey columns – non-passerines, NIPB – non-identified passerine bird

Bird mortality caused by wind generators

We recorded eight bird individuals of five species as collision victims in the course of monitoring 52 wind generators (Table 1). Only the Corn Crake (*Crex crex)* is included in the Red Data Book of the Republic of Bulgaria as Vulnerable and in Appendix

Table 1. Species composition and numbers of birds killed by vehicles and by turbines during the study period

Order	Family	Species	Birds killed by vehicles (n)	Birds killed by turbines (n)
Apodiformes	Apodidae	*Apus apus*	0	1
Charadriiformes	Laridae	*Larus michahellis*	1	3
Coraciiformes	Meropidae	*Merops apiaster*	2	0
Falconiformes	Falconidae	*Falco tinnunculus*	1	0
Gruiformes	Rallidae	*Crex crex*	1	1
Passeriformes	Alaudidae	*Alauda arvensis*	0	2
Passeriformes	Emberizidae	*Emberiza calandra*	6	0
Passeriformes	Hirundinidae	*Hirundo rustica*	3	0
Passeriformes	Hirundinidae	*Riparia riparia*	1	0
Passeriformes	Laniidae	*Lanius collurio*	28	0
Passeriformes	Laniidae	*Lanius minor*	1	0
Passeriformes	Motacillidae	*Motacilla alba*	4	0
Passeriformes	Motacillidae	*Motacilla flava*	3	1
Passeriformes	Muscicapidae	*Erithacus rubecula*	2	0
Passeriformes	Muscicapidae	*Luscinia luscinia*	2	0
Passeriformes	Muscicapidae	*Muscicapa striata*	3	0
Passeriformes	Muscicapidae	*Oenanthe isabellina*	1	0
Passeriformes	Muscicapidae	*Oenanthe isabellina/oenanthe*	1	0
Passeriformes	Muscicapidae	*Oenanthe oenanthe*	2	0
Passeriformes	Muscicapidae	*Phoenicurus ochruros*	1	0
Passeriformes	Muscicapidae	*Phoenicurus phoenicurus*	1	0
Passeriformes	Muscicapidae	*Saxicola rubetra*	6	0
Passeriformes	Muscicapidae	*Saxicola sp.*	2	0
Passeriformes	Passeridae	*Passer domesticus*	4	0
Passeriformes	Passeridae	*Passer domesticus/hispaniolensis*	9	0
Passeriformes	Phylloscopidae	*Phylloscopus trochilus*	3	0
Passeriformes	Sturnidae	*Sturnus vulgaris*	2	0
Passeriformes	Sylviidae	*Sylvia communis*	1	0
Passeriformes		NIPB*	3	0
Pelecaniformes	Ardeidae	*Ardea cinerea*	1	0
No orders: 7	**No families: 16**	**No species: 26****	95	8

* NIPB – non-identified passerine bird.
** Bird corpses, whose species identity was not confirmed definitely, were excluded from this calculation.

1 of the Bird Directive (2009/147/EC). Taking into account the conditions and assumptions described in the methods and in accordance with the performed experiments for the removal rate and efficiency of the searches, the estimated number of victims was 16 individuals in total.

Relation between bird mortality and Migration Traffic Rate

The highest peak of passerine nocturnal migration, registered on 29.08.2014, coincided with the highest peak of passerine road mortality. During the next three days both parameters decreased simultaneously (Fig. 5). The number of nocturnally migrating passerines killed on the road correlated significantly with the intensity of nocturnal passerine migration estimated for the night preceding the road-kill monitoring ($r = 0.36$, $R^2 = 0.13$, $p = 0.037$, $n = 34$).

The scarcity and lack of variability of the data collected for migrating birds killed by collisions with wind turbines during the studied period did not allow us to find any relationship with the nocturnal migration of birds or with the road mortality (Table 2, Fig. 4).

Discussion

In this study, we examined two anthropogenic sources of bird mortality in relation to autumn migration. We found a significant correlation between passerine

Table 2. Total number of Road Mortality and Turbine Mortality in the same territory of South Dobrudzha measured simultaneously between 28th August and 30th September 2014

Date	Road Mortality (n)	Turbine Mortality (n)	Date	Road Mortality (n)	Turbine Mortality (n)
28.8.2014	1	1	14.9.2014	3	2
29.8.2014	5	0	15.9.2014	2	0
30.8.2014	8	0	16.9.2014	3	0
31.8.2014	3	0	17.9.2014	1	0
1.9.2014	4	0	18.9.2014	1	0
2.9.2014	1	0	19.9.2014	2	0
3.9.2014	7	0	20.9.2014	5	0
4.9.2014	3	0	21.9.2014	5	0
5.9.2014	1	0	22.9.2014	2	0
6.9.2014	1	0	23.9.2014	1	1
7.9.2014	2	1	24.9.2014	1	0
8.9.2014	1	0	25.9.2014	3	0
9.9.2014	7	0	26.9.2014	1	0
10.9.2014	4	1	27.9.2014	0	1
11.9.2014	4	0	28.9.2014	0	0
12.9.2014	2	1	29.9.2014	4	0
13.9.2014	5	0	30.9.2014	1	0
Total				95	8

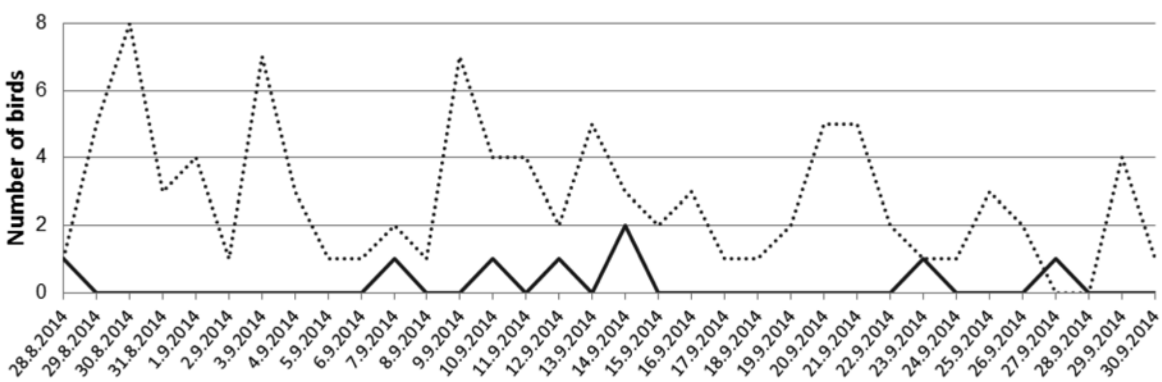

Fig. 4. Dynamics of total bird mortality (ind./day) on a 9-km-long secondary road segment (dashed line) and under 52 wind turbines (solid line) during the study period

migration rate and road-kill mortality of nocturnally migrating passerines. However, the lower rate of bird collisions with wind turbines did not allow us to find any relationship with the autumn migration. The lack of nocturnal migrants among the victims of wind turbines suggests that in the study area migrating birds are much more vulnerable to anthropogenic impacts while feeding and resting than during an active flight. Furthermore, the car traffic poses a much greater threat than the wind turbines for either migrating or non-migrating birds.

To the best of our knowledge, it is the first report of a significant correlation between migration intensities and road-kills. However, migration intensity accounted for only 13% of variation in road mortality – a result which is not surprising because car traffic rate in the study area is highly heterogeneous unlike the regular mode of the radar measurement. Many factors, such as vehicle velocity, bird behaviour and feeding preferences, vegetation proximity to the road etc., are probably linked to road fatalities (De Vault *et al.* 2015, Erritzoe *et al*. 2003, Nankinov & Todorov 1983, Santos *et al*. 2016).

The prevalence of passerines and the established MTR in our study supports the results for quantitative estimates of nocturnal migration over the entire Balkan Peninsula (Zehtindjiev & Liechti 2003). Based on the surveyed time interval, the peak of the migrating passerines is most probably in the end of August. The same dates (28-29 August) were

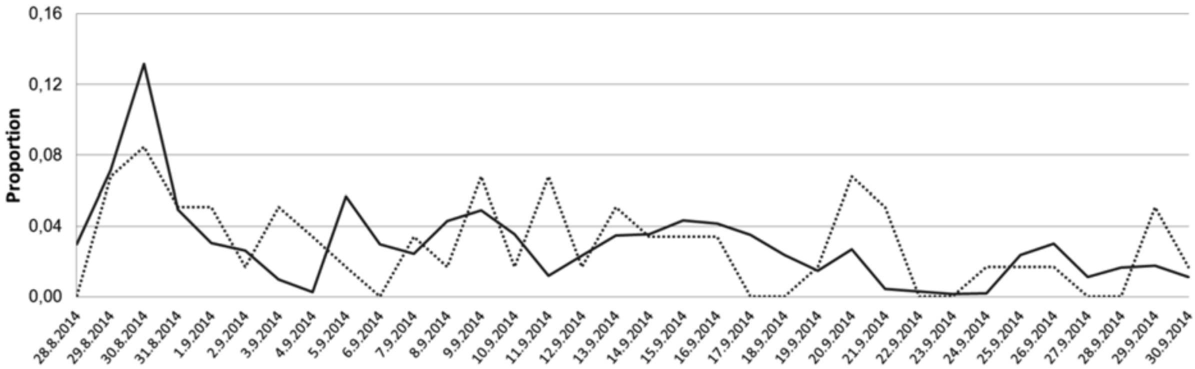

Fig. 5. Trends of nocturnal passerine Migration Traffic Rate (MTR) and Road Mortality of nocturnally migrating passerines during the studied period. Both variables are presented as proportions of the total passerine migration density and the total number of nocturnally migrating passerines killed on the road, respectively. Solid line – nocturnal passerine MTR, dashed line - Road Mortality of nocturnally migrating passerines

Table 3. Number of nocturnally migrating passerines killed on the road

Species	Number
Lanius collurio	28
Lanius minor	1
Luscinia luscinia	2
Motacilla alba	4
Motacilla flava	3
Muscicapa striata	3
Oenanthe isabellina/oenanthe	4
Phoenicurus ochruros	1
Phoenicurus phoenicurus	1
Phylloscopus trochilus	3
Saxicola rubetra	8
Sylvia communis	1
Total	59

recorded by Zehtindjiev (2001b) for the territory of Bulgaria. It is important to mention that the peak of migration of the White Stork is also on these dates (Michev *et al.* 2011).

Our results show that bird mortality caused by collisions with wind generators, adjusted by the efficiency of the searches and removal rate, is comparatively low and does not correspond to the MTR established by the radar in the same time period. However, the collisions of nocturnal migrants with cars are more frequent than wind turbine collisions and therefore pose much greater threat for migrating birds in the study area. These results are consistent with other studies from the USA, Canada and Sweden where the annual estimation of bird deaths due to collision with cars is hundreds of times higher than bird mortality caused by wind turbines (Erickson *et al.* 2001, Loss *et al*. 2015, Rydell *et al*. 2012). We suppose that the mortality rate differences in our results probably reflect the differences in location of the wind turbines and the studied road. The wind turbines have been constructed in open agricultural habitats crossed by shelterbelts (Fig. 1) while the road segment studied for mortality spreads along various habitats - agricultural fields, steppe grassland, coppices, settlements and combinations of them. Therefore, one can expect increased fatalities because of the higher diversity and abundance of bird species in close proximity to the road (Nankinov & Todorov 1983, Santos *et al*. 2016).

According to the species composition of the road-kills, the red-backed shrike (*Lanius collurio*) ranks first, which may reflect the fact that this species is one of the most numerous among all night migrants. In autumn the species migrates from the end of August to the end of October (Zehtindjiev & Whitfield 2009, Ivanov 2011). The species composition of road-kills was similar to the species composition of nocturnal migration across this region (Zehtindjiev & Whitfield 2009), an additional evidence that the number of victims reflects the general pattern of migration intensity.

The study was done in a region which covers part of the designated Natura 2000 zone Kaliakra and adjacent areas, therefore the obtained data can be used in the management plans of this important zone. The established number of birds killed by cars indicates that the traffic should be considered as the most important threat for migrating birds on this territory and provides a basis for planning additional restrictions in this zone in order to secure the habitats, which are important for migrating passerine birds. The calculated number of around two birds per day in a segment of 9 km of a secondary road reflects in 7.7 birds per day for 35 km of the secondary roads in total for the whole designated Natura 2000 zone Kaliakra. To estimate this number, one should consider at least two months of intensive bird migration, or 60 days with 462 birds killed only on the territory of one Natura 2000 zone in NE Bulgaria. The number of the victims on the road in this important bird area must be reduced by different measures, including speed limits and wild bird crossing signs on all secondary roads in the area.

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