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Impact assessment of wind farms on birds of prey in Thrace. Annual Report August 2009-August 2010

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WWF Greece
26 Filellinon str.
GR- 105 58 ATHENS
Tel: 0030 2103314893

WWF Greece
Evros Project,
Dadia,
GR- 684 00 Soufli
Tel: 0030 2554032210,
e-mail : ecodadia@otenet.gr

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CONTENTS

0. EXECUTIVE SUMMARY

There is currently an urgent need for climate change mitigation measures. Renewable energy sources, such as wind farms, are important components of such mitigation measures. The Greek Government has set targets for generation of renewable energy. Within this framework, a large part of Thrace (northeastern Greece) has been selected as a Wind Priority Area (WPA 1).

It is known, however, that wind farm operation may have important impacts on bird populations, although effects may vary among sites and species. The primary aim of the present study was to determine the effect of wind farms on the mortality of birds of prey in Thrace.

The study area is of extreme ornithological value, as the Rhodope and Evros prefectures show the greatest diversity of birds of prey in Greece and one of the richest in Europe, including the last Black Vulture breeding colony in the Balkans. Seven areas that belong to the NATURA 2000 network are either included within or partially overlap with the WPA 1, where the carrying capacity of the area has been established at 480 standard wind turbines (960MW in total).

Carcass surveys around the wind turbines were carried out in order to estimate the mortality of birds of prey. The study area comprised 163 wind turbines in operation, 88 of which were monitored on a daily basis. The results of the surveys were corrected for the bias caused by the observers' detection ability and the scavenger removal activity. Correction factors were obtained through trials performed in previous WWF Greece's studies .

In total, 9 birds of prey as well as 73 other birds and 186 bats were found dead due to collision with a wind turbine. There were differences in bird and bat mortality between wind farms. Following two different mortality equations, estimated and adjusted mortality rates of birds of prey were 0.152 and 0.173 birds per year per turbine.

Daily searches have kept the effect of removal by scavengers and humans low. Carcass surveys, if possible on a daily basis, should be carried out at operating and future wind farms in order to monitor bird and bat mortality caused by collisions with wind turbines. It is essential to understand the effect of bird and bat wind turbine-caused mortality on their populations by conducting population viability studies.

1. INTRODUCTION

In recent years climate change has been acknowledged as a major issue and has risen as one of the biggest concerns in politics, because it represents a threat to humankind, biodiversity and life in general. It has been suggested that climate change is human induced (Hulme *et al.* 1999, Karl *et al.* 2003, IPCC report 2007*)* and thus that humanity should reduce its impact on the atmosphere or biodiversity would be led to a collapse. Therefore many countries focus their efforts on reducing the release of greenhouse gases through the implementation of renewable energy policies.

Wind energy is currently seen as one of the most promising means among others to produce clean energy and therefore the development of this industry is growing exponentially.
Nevertheless, wind farm constructions are not without negative impacts on the environment, especially when large scale industrial installations are developed. Their impacts may be a major drawback if not carefully mitigated. Among the most important consequences of wind farm operation are their negative effects on bird populations (Barrios & Rodriguez 2004, Fielding *et al. 2006*, de Lucas *et al*. 2008, Masden *et al.* 2010).

Greece has recently developed a clean energy production scheme based primarily on wind energy. Within this framework, three Wind Priority Areas (WPAs) have been selected where wind farm development is promoted, one of which is a large part of the region of Thrace, and particulalry the prefectures of Evros and Rhodope (WWF Greece 2008). To date, approximately 178 wind turbines have been installed within the boundaries of the WPA or its immediate surroundings. The carrying capacity of the area has been established at 480 standard wind turbines (960MW in total). Despite the clearly defined limitations of this capacity, applications have been submitted to the regulation authority for the construction of wind turbines escalating to more than 1800 MW (Regulatory Authority for Energy 2010, www.rae.gr).

Thrace hosts a rich and internationally important avifauna, including birds of prey and aquatic birds. It comprises seven areas of the Natura 2000 network, four of which are either totally or partly included in the WPA. About 50% of the WPA includes Special Protection Areas (SPAs), two of which have been declared as National Parks: The Evros Delta and the Dadia-Lefkimi-Soufli Forest, both of which are renowned for their avifauna.

The Dadia-Lefkimi-Soufli Forest National Park has been rightfully described as “the land of the birds of prey”; thirty six out of the thirty eight Western Paleartic diurnal birds of prey have been observed within its boundaries. The Black Vulture (*Aegypius monachus*) population is the last that remains of the formerly large Balkan population (Skartsi *et al*. 2008). In addition, two other vulture species, the Griffon Vulture (*Gyps fulvus*) and the Egyptian Vulture (*Neophron percnopterus*) use the area for nesting. The birds of prey in the park forage over large areas encompassing the Evros delta, the Rhodope mountains and the neighbouring parts of Bulgaria and Turkey (Vasilakis *et al*. 2008). Bird species such as the Eastern Imperial Eagle (*Aquila heliaca*), White-tailed Eagle (*Haliaeetus albicilla*), Greater Spotted Eagle (*Aquila clanga*), Golden Eagle (*Aquila chrysaetos*), Long-legged Buzzard (*Buteo rufinus*), Peregrine Falcon (*Falco peregrinus*), Booted Eagle (*Hieraaetus pennatus*), Lesser Spotted Eagle (*Aquila pomarina*), as well as Eleonora’s Falcon (*Falco eleonorae*) and Black Stork (*Ciconia nigra*), use the area for nesting, wintering or during their migration.

The diversity of the local avifauna caused the concern of WWF Greece about the impact of wind turbines on birds of prey. The organization therefore decided to focus its efforts in carrying out a research on this subject. The first monitoring study of the impact of wind farms on birds of prey in Thrace was carried out in 2004 (17/03/04 to 16/03/05) and 2005 (17/03/05 to 6/12/05) (Ruiz *et al.* 2005). A second study was implemented from June 2008 to July 2009 (Cárcamo *et al.* 2011).

The aim of this third study was to determine the number of birds of prey fatalities caused by collision with wind turbines in the study area, in a more intensive manner compared to the previous studies. Our study was implemented over the course of one year, from August 2009 to August 2010 and it is a continuation of the study undertaken by Cárcamo *et al.* (2011), during which serious concerns were raised about the potential bias of the results, originating from the activity of scavenging animals as well as deliberate human intervention. WWF Greece therefore applied more intensive methods to establish patterns of bird mortality from wind farms with higher accuracy. The new way of searching reduced the visiting interval per wind turbine from fourteen days (Cárcamo *et al.* 2011) to a single day (each WT from a total of 88 was monitored every day of the week except Saturdays).

PEOPLE INVOLVED

The following people participated in the preparation of the present report:

Baptiste Doutau: Field work, data analysis, writing and review of the technical report.
Artemis Kafkaletou- Diez: Field work, data analysis, writing and review of the technical report.
Dimitris Vasilakis: Design of the methodology, data analysis, writing and review of the technical report.
Beatriz Cárcamo: Coordination of monitoring, field work, data analysis, writing and review of the technical report.
Elzbieta Kret: Coordination of monitoring, field work, data analysis, writing and review of the technical report.
Rodoula Karampatsa, Giannis Marinos, Theodora Skartsi: Field work.
Marie Berthier, Catherine Sauvage: Field work and data entry onto database.
Javier Cordón: Field work and identification of birds' samples.
Stephen Beal: Field work and editing of the technical report.
Marion Auffray, Roberto Bruno, Ingrid Francart, Julia Gasser, Daniel Magalhaes, Elisabeth Navarrete: Field work.
Melania Desfinioti, Evdoxia Efstathiadou, Myrto Gratsea, Kostantina Karagiorga, Zinovia Karapiperi, Aggeliki Mpalampani, Fotis Nikolakopoulos, Maria Tomai, Katerina Tsiasioti, Alexandros Tzimeros: Field work.

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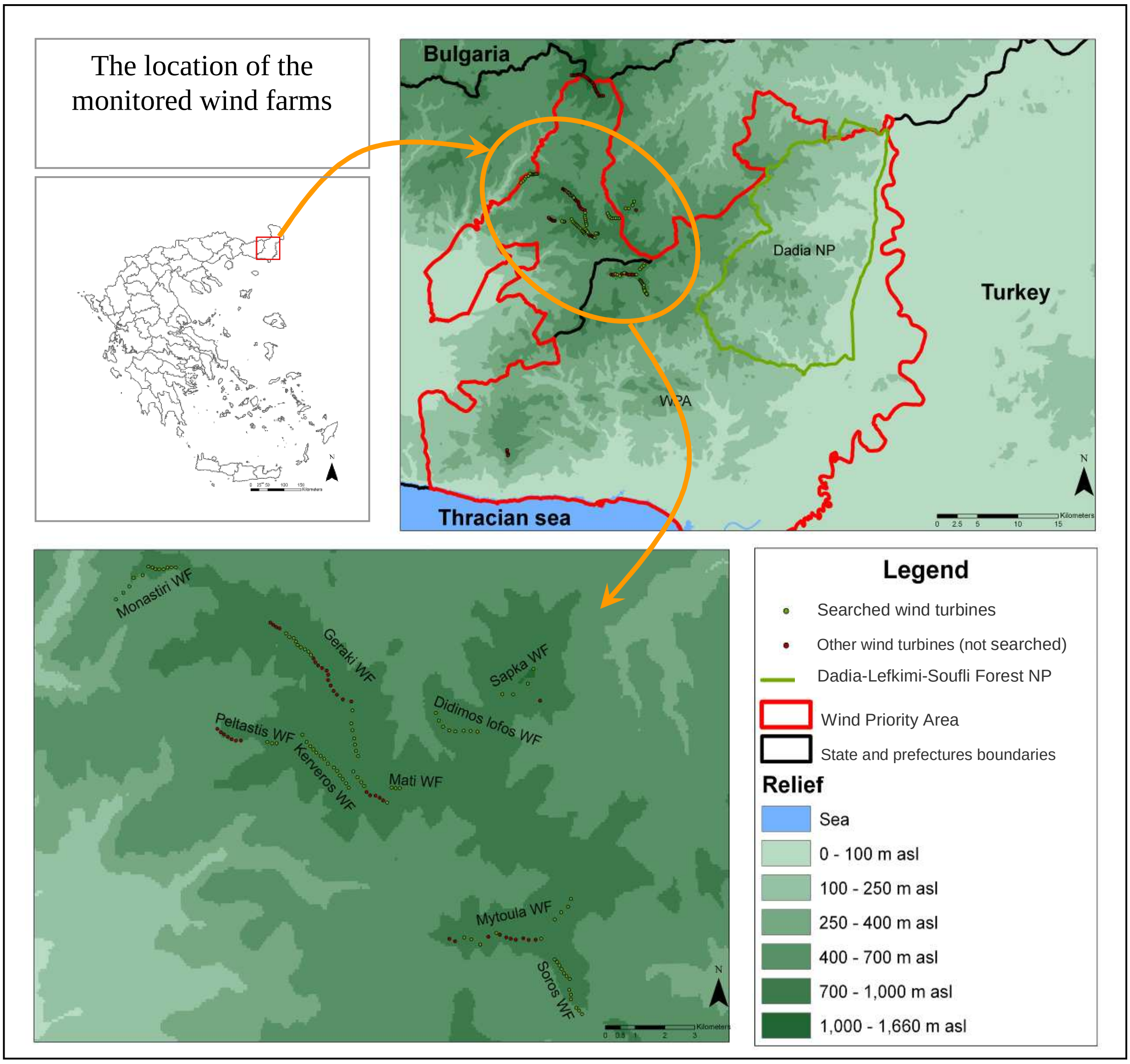
2. STUDY AREA

The study area is located in Thrace, in the border area between the Rhodope and Evros prefectures, in northeastern Greece. It is characterised by small mountains and forested hills stretching along long ridges. The area is acknowledged for its high ornithological interest, since it is used for nesting, wintering or as a migrating corridor by rare territorial birds of prey. It is situated on the north-west of the Dadia-Lefkimi-Soufli Forest National Park, originally established due to its great diversity of birds of prey. The park holds the last breeding population of Black Vulture in the Balkans (Skartsi *et al.* 2008).

Map 1 Study area



In total, 88 out of the 163 (54 %) operating wind turbines (WTs), at nine of the 11 operating wind farms (WFs) in the area were monitored. The nine WFs are hereafter called:

- **Didimos Lofos (D):** 8 wind turbines
- **Geraki (T)**: 42 wind turbines
- **Kerveros (K)**: 14 wind turbines
- **Mati (MA)**: 3 wind turbines
- **Monastiri (MO)**: 13 wind turbines
- **Mytoula (M)**: 19 wind turbines
- **Peltastis (P)**: 10 wind turbines
- **Sapka (X)**: 5 wind turbines
- **Soros (S)**: 13 wind turbines

These names reflect a terminology specific to WWF studies. WT models in each wind farm varied in their technical characteristics (Table 1).

Table 1 Wind turbines operation characteristics

	Wind Farm code	Height (m)	Rotor diameter (m)	Rotation period	Max. Chord (m)	MW
Nec micon 52/900KW	T, S, MA, MO	44	52	22.4/14.9 rpm	2.25	0.9
Rokas Bonus 1.3MW	K, P	50	62	19/13 rpm	3	1.3
Vestas 2MW	M, D, X	60	90	16.7/19	3.5	2
N50R46 - IEC I (80)	MO	44	52	22.4/14.9 rpm	2.25	0.8

3. METHODS

3.1. Intensive carcass surveys

We proceeded with changing the survey intensity because of the concerns raised among researchers with regards to the possibility of losing carcasses due to human and scavenger removal activity in the area. Large pieces of carcasses (e.g. Griffon vulture) appeared to disappear very quickly from obvious locations on the platforms of wind turbines, while smaller pieces belonging to the same carcass situated in less obvious locations remained in the area for much longer, even for months (Cárcamo *et al.* 2011). During the same study, one Griffon Vulture plastic ring without any bird remains was found below a wind turbine. This suggests that scavengers may not be the only “agent” removing carcasses from the wind farm area and that humans may be involved. This possibility has already been acknowledged by Atienza *et al.* (2008) who report that people working at wind farms hide carcasses and this is probably because they think that their job might be at risk if birds die at wind farms. Hiding carcasses, however, leads to an underestimation of bird mortality rate obtained from the monitoring plans (Atienza *et al*. 2008*).* Consequently, a concern about impacts of potential human induced carcass removal on the estimated value of mortality (underestimation) was entirely justified.

The possibility of missing carcasses – especially small ones – due to removal by scavengers is also high in the study area and may lead to underestimated avian mortality rates (Barrios & Rodriguez 2004). Correction factors were previously derived to account for this bias (Cárcamo *et al*. 2011). Nevertheless, reducing the time between each searching effort appeared to be the best approach to reduce this bias. The study was therefore first planned to be carried out on a daily basis, but due to logistic reasons it was initially conducted over five and later over six days per week.

3.1.1. Field techniques

The study took place between the 3rd of August 2009 and the 4th of August 2010 and was based on searching surveys. During the winter, carcass searches did not take place from 31/12/09 to 06/01/10, from 09/01/10 to 11/01/10, from 14/01/10 to 11/02/10, from 13/02/2010 to 15/02/2010, 18/02/10, 21/02/10, 28/02/10 and from 06/03/10 to 11/03/10 due to the roads leading to the study sites being blocked by snow and ice. In addition, due to national celebrations and holidays, the carcass searches did not take place on the following dates: 28/10/09, 24/12/09 - 27/12/09, 29/12/09, 25/03/10, 01/04/10 - 05/04/10 and 24/05/10.

The survey was based on searching activities carried out by two teams each consisting of two searchers. The teams were in the field five days per week (Monday to Friday) until October 2009 and than six days per week (Monday to Friday and Sundays), since extra staff was available from 12/10/09. Carcass searches were conducted in the morning and in the afternoon alternatively. Starting times varied depending on seasonal day light. Morning starting times varied from 6:00 am in summer to 7:30 am in winter, and afternoon starting times varied between 10:30 am in winter and 12:00 pm in summer.

Each wind turbine was systematically searched: a circular sample plot of at least 50 m radius was searched around each turbine, with the turbine as the centre of the plot. At each visit and turbine, observers first scanned the platform holding the wind turbine by car. They then divided the rest of the plot into two parts (half circles) and each part was searched on foot, starting from the same point and following opposite directions. If general, each half circle was searched by zigzags, but the actual way of searching often varied among wind turbines depending on the different topography and vegetation cover. When observers encountered obstacles such as rocks, bushes, trees or other, they searched them carefully. In cases where steep slopes were found within the plot, binoculars were used to scan the area. However, it could happen that some parts of the plot were not accessible for searching due to dense vegetation or other reasons.

On the plate of the turbine, carcasses of all kinds of animals that had possibly died due to an interaction with the wind turbine were a target, including passerines and bats. However, outside the platform, observers focused only on birds of prey.

During carcass searches, searchers carried with them equipment which included:

- GPS device
- digital camera
- binoculars
- maps of the wind farms
- measuring tape
- plastic bags
- plastic gloves
- old newspapers (to wrap small carcasses)

All carcasses found were uniquely labelled, placed into bags (or if fresh in newspaper to allow better preservation) and frozen for future reference. A copy of the data sheet for each carcass was stored with the carcass at all times. Data recorded included species, sex, age (when possible), date and time collected, location (GPS coordinates), condition, and any comments that could help future data analysis. All casualties were photographed as found on site prior to collection.

3.1.2. Selected study wind turbines

The sample of wind turbines for this intensive survey was selected in July 2009, after examining the data obtained with regards to bird use and fatalities by Cárcamo *et al.* (2011). Data analysis through our Access and GIS database was performed to determine wind farm areas more frequently used by birds of prey. Selection of wind turbines was therefore based on the results of this anaysis combined with locations where dead birds had been found. In table 2 the following surveyed wind farms and wind turbines are presented (see also Appendix IV):

Table 2 Wind farms and wind turbines (WTs) monitored in the study (between 3/8/2009 and 04/8/2010)

Wind Farm	Code	Total number of WTs per wind farm	Number of monitored WTs per wind farm	Codes of monitored WTs
Didimos Lofos	D	8	8 (100%)	D1-D8
Geraki	T	42	21 (50%)	T5-T13, T26-T36, T42
Kerveros	K	14	14 (100%)	K1-K14

Mati	MA	3	3 (100%)	MA1-MA3
Monastiri	MO	13	13 (100%)	MO1-MO13
Peltastis	P	10	3 (30%)	P8-P10
Mytoula	M	19	9 (47%)	M3-M5, M7, M15-M19
Sapka	X	5	4 (80%)	X1-X4
Soros	S	13	13 (100%)	S1-S13
TOTAL		127	88 (70%)	

3.1.3. Data collected

The following data were always recorded on the protocol (Appendix III protocol Wind Farm monitoring, new carcass searches):

- Searchers' names
- Date
- Searching site (wind farms)
- Starting and ending time of searching activity
- Starting and ending time of searching for each wind farm
- Wind turbines searched

In case that a carcass was found the following data were recorded:

- ID of the carcass found (number code)
- Time the carcass was found
- The carcass condition and/or a description of its state
- The species was identified if possible
- The age was recorded if possible
- The sex was recorded if possible
- The site (wind turbine)
- GPS coordinates of the carcass position were taken (if there was more than one piece, the GPS position was taken for every piece)
- The distance and direction to the closest turbine was measured (if there was more than one piece, distance and direction to the closest turbine were measured for each one, as well as the distance between the carcass pieces)
- The direction from the turbine base
- The time of death was estimated if possible (but is not necessarily reliable)
- The estimated cause of death (wind turbine)
- Photos of the incident were taken, as described in the Table 3, before the carcass was removed or touched

Table 3 Photo protocol for carcasses found

✓ Close ups of the carcass from all sides and of each carcass piece, if the carcass was cut in more than one piece.
✓ Clear ups of both sides of the wing, head, bill and other parts of the bird potentially providing information about the species, the age or the sex of the carcass.
✓ Close ups of injuries e.g. injured bill, broken wing, etc.
✓ Photos showing the position of the bird in relation to the closest wind turbine.

3.2. Mortality estimation

The total number of avian fatalities was estimated for all birds of prey (including Black Vulture) and for Black Vulture separately, using the observed number of fatalities during the study period and the following correction factors: the proportion of carcasses that remained in the study area during the scavengers' removal trials and the searcher efficiency rate. Both correction factors were obtained during previous WWF studies (Cárcamo *et al.* 2011). To estimate mortality two equations were used.

Annual mortality rate (m) per turbine was estimated by (Equation I):

$$\mathbf{m} = \frac{\bar{\mathbf{c}}}{\hat{\boldsymbol{\pi}}}$$

where (Erickson *et al*. 2003)

$$\boldsymbol{\pi} = \begin{cases} \dfrac{\mathbf{t*p}}{\mathbf{I}} & \text{if } \mathbf{I} > \mathbf{t} \\ \mathbf{p} & \text{if } \mathbf{I} < \mathbf{t} \end{cases}$$

c - observed number of fatalities
π - an estimation of the probability a carcass is available to be collected during a fatality search (probability it is not removed by a scavenger or by other methods), and is detected (probability of detection).
p - estimated searcher efficiency rate

t - estimated carcass removal time
I - average interval between searches

Another formula (Equation II) used to determine the total number of collision fatalities (N-estimated) was:

N-estimated= Na*Cz*Cp*Ce (Everaert and Stienen 2007)

where
Na - number of collision fatalities detected
Cz - correction factor for search area (*Cz* = 100/z, where z is the proportion of total surface that was actually searched)
Cp - correction factor for scavenging (*Cp* = 100/p, where p is the proportion of birds not removed by predators during the scavenging trials)
Ce - correction factor for search efficiency (*Ce* = 100/e, where e is the proportion of birds found by observers)

3.3. Seasonal changes in mortality

Because data were not normally distributed, the *Kruskal–Wallis* test (Field 2005) was used to test for differences in the mean number of carcasses found across seasons. The test was performed for two groups of carcasses :

1. Birds of prey (including Black Vulture)
2. Only passerines

The test was not performed on other bird species of which carcasses were found (Chukar partridge *Alectoris chukar,* Woodcock *Scolopax rusticola, etc.)* because of inadequate sample size.

Seasons were defined as:

- Autumn: 23rd September to 21st December
- Winter: 22nd December to 20th March
- Spring: 21st March to 20th June
- Summer: 21st June to 22nd September

4. RESULTS

Monitoring was conducted for 251 days in total. A total of 2134 hours and 33 minutes were spent searching for carcasses (Figure 1).

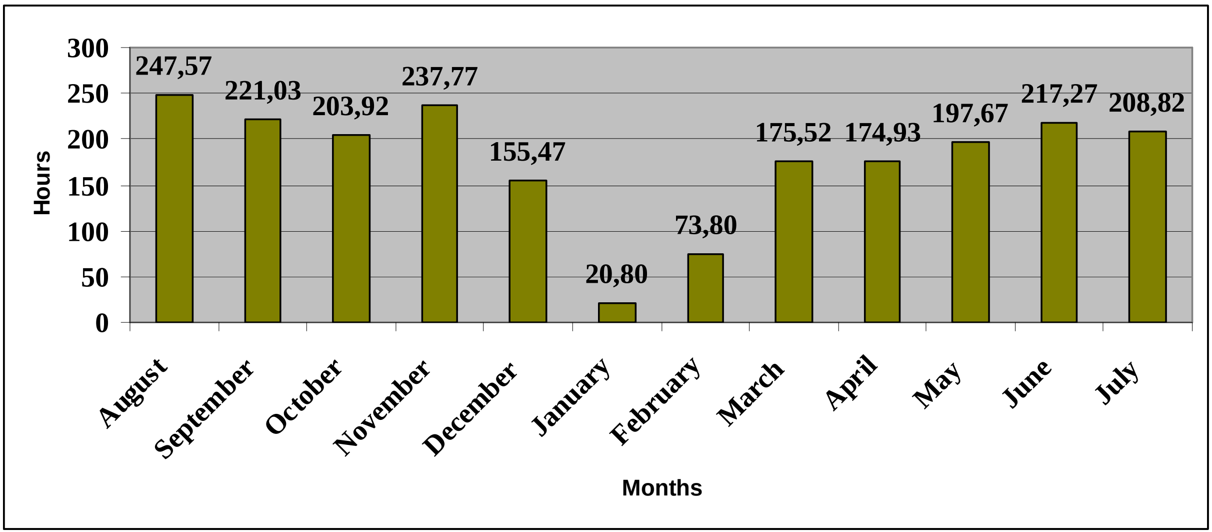


Figure 1 Monthly distribution of hours spent for carcass surveys

4.1. Intensive carcass surveys

A total of 82 bird fatalities (9 specimens of birds of prey) from at least 25 species (5 species of birds of prey) were found at the study area and were attributed to wind turbine collisions. The most common bird of prey fatality belonged to the Common Buzzard (*Buteo buteo*) with a total of 3 fatalities (Table 4). The most common passerine found dead was the House Martin (*Delichon urbica*), with a total of 25 fatalities, followed by Woodlark (*Lullua arborea*) with 17 fatalities (Table 5). It should be added that power transmission lines were not monitored, however one electrocuted Hooded Crow (*Corvus corone cornix)* was found under power lines in Monastiri Wind Farm, about 100 m away from the nearest WT.

In addition to dead birds, a total of 186 bats from at least 11 species were found (Table 6; Georgiakakis & Papadatou 2011). Data on dead bats are reported in detail in Georgiakakis and Papadatou (2011). Their report focuses on the impacts of wind farms specifically on bats.

In Tables 4, 5 and 6, the following terms are used to describe the condition of the carcasses:

- *Intact*: carcass which is completely intact, not badly decomposed, no sign of having been fed upon by predator or scavenger
- *Scavenged*: Entire carcass that shows sign of having been fed upon by predator or scavenger
- *Portion of a carcass:* Carcass not complete
- *Feathers:* No part of the carcass, only feathers

Table 4 Birds of prey fatalities detected in the study area over the course of 1 year (August 2009-August 2010).

Species	Date	Carcass condition/description	Closest wind turbine	GPS E/N	Distance to the turbine
Falconiformes					
Common Buzzard *Buteo buteo*	05/08/09	Intact with broken right wing, open wound on belly	MA1	00657931 04555587	8.70 m
Hawk species *Accipiter* spp.	20/08/09	Feathers, quite a lot	D6	00660319 04557430	40 m
Short-toed Eagle *Circaetus gallicus*	24/08/09	Feathers	S12	00664109 04548263	45 m
Western Marsh-harrier *Circus aeruginosus*	28/08/09	Intact but wound just above the tail, cut across stomach	T8	00654683 04560368	49 m from T8 90 m from T9
Eurasian Sparrowhawk *Accipiter nisus*	11/10/09	Intact	X3	00663822 04551642	12.65m
Black Vulture *Aegypius monachus*	04/03/10	Found dead on 08/04/10, but it was observed alive some days before. It was wounded on one toe of the right leg, both legs had cut off or broken nails (wingtag 53, ring H71) and the tail was cut off.	Dichalo near Sapka, X3	00660713 04560546	2088 m
Common Buzzard *Buteo buteo*	09/04/10	Intact fresh	M4	00660605 04550560	29.50 m
Common Buzzard *Buteo buteo*	07/05/10	Portion of carcass	S8	00663852 04548924	19.10 m
Short-toed Eagle *Circaetus gallicus*	18/07/10	Portion of a carcass, fresh, tail and legs are missing	S2	00656253 04555902	22.30 m

The dead Black Vulture (Table 4 and Picture 1) was found under special circumstances. An injured but still alive vulture was found on 04/03/10 by a local shepherd, but unfortunately nobody was informed at the time. A month later, the shepherd reported the incident to local people who in turn informed WWF on 08/04/10, when the Black Vulture had already died. A bird with the wing tag number 53 and the plastic ring coded H71 (bird tagged and ringed by WWF team) was found dead at a distance of 2000 m from and at an altitude approximately 200m below the nearest wind turbine. X-ray plaques were obtained showing no evidence of shooting. The bird had an injury on one toe of its heavily swollen right leg and both legs had claws cut off or broken, while its tail was cut off. These findings suggested a collision of the bird with a wind turbine. Barrios & Rodriguez (2007) reported that this type of injuries due to collision with wind turbines occurred with lower frequencies (around 20% of all type of injuries) than for instance broken or sheared off wings (around 66% of all type of injuries). The injured bird died probably because it was unable to fly or eat.

Picture 1 Dead Black Vulture found

Table 5 Other birds' fatalities

Species	Date	Carcass condition/description	Closest turbine	GPS E/N	Distance to the turbine
Galliformes					
Chukar *Alectoris chukar*	26/03/10	Intact	X2	00661992 04558654	1.52 m
Charadiformes					
Eurasian Woodcock *Scolopax rusticola*	12/01/10	Intact	MO5	00677509 04526286	10.30 m
Gull species *Larus* spp.	04/03/10	Feathers	P8	00653698 04557058	44.30 m
Cuculiformes					
Common Cuckoo *Cuculus canorus*	14/05/10	Intact	M4	00660558 04550564	18.80 m
Apodiformes					
Common Swift *Apus apus*	12/08/09	Intact	K5	00656072 04556181	12.30 m
Common Swift *Apus apus*	30/07/10	Intact, very fresh	T7	00654600 04560542	10.55 m
Piciformes					
Woodpecker species *Dendrocopos* spp.	13/08/09	Feathers	D8	00660788 04557434	1.85 m
Middle Spotted Woodpecker *Dendrocopos medius*	04/09/09	Feathers	D8	00660783 04557428	0.75 m

Passeriformes					
House Martin *Delichon urbica*	03/08/09	Intact	X2	00661968 04558672	no data
Mistle Thrush *Turdus viscivorus*	04/08/09	Intact	S1	00690084 04549426	22.50 m
House Martin *Delichon urbica*	04/08/09	Intact	M15	00662924 04550608	11.40 m
House Martin *Delichon urbica*	04/08/09	Scavenged	M15	00662954 04550591	22.04 m
House Martin *Delichon urbica*	05/08/09	Scavenged	M15	00660861 04550394	27.60 m
House Martin *Delichon urbica*	10/08/09	Intact	M16	00663354 04551224	19.20 m
House Martin *Delichon urbica*	11/08/09	Intact & warm, broken wing	M16	00663348 04551247	14.20 m
House Martin *Delichon urbica*	11/08/09	Intact, with blood (still wet) and broken wing, in a bad condition	M16	00663345 04551220	17.56 m
Red-Backed Shrike *Lanius collurio*	12/08/09	Scavenged	T6	00654469 04560570	0.80 m
House Martin *Delichon urbica*	13/08/09	Fresh	M16	00663350 04551248	18.50 m
House Martin *Delichon urbica*	17/08/09	Scavenged, broken wing & head eated	S10	00663925 04548599	8 m
House Martin *Delichon urbica*	17/08/09	Intact	K5	00656065 04556156	33 m
House Martin *Delichon urbica*	17/08/09	Intact	K5	00656069 04556163	10 m
Willow Tit *Parus montanus*	17/08/09	Intact	T20	00655772 04559205	62 m
House Martin *Delichon urbica*	17/08/09	Intact	T32	00656761 04556646	19 m
House Martin *Delichon urbica*	21/08/09	Intact	K9	00656185 04555956	34 m
House Martin *Delichon urbica*	25/08/09	Scavenged, head eaten	X2	00661960 04555956	30.80 m
Eurasian Skylark *Alauda arvensis*	31/08/09	Scavenged, wasp fed upon it	D3	00659627 04557596	4.45 m
Blackbird *Turdus merula*	31/08/09	Scavenged	S9	00663906 04548755	1.30 m
House Martin *Delichon urbica*	31/08/09	Scavenged, relatively fresh, without eyes	S2	00663495 04549813	21.30 m
Blackcap *Sylvia atricapilla*	28/09/09	Broken, scavenged	M4	00660347 04550574	14.60m
Winter Wren *Troglodytes troglodytes*	30/09/09	Intact	D4	00659835 04557489	5.90 m
Woodlark *Lullula arborea*	01/10/09	Portion of carcass	MO7	00649840 04562834	24.50 m
Woodlark *Lullula arborea*	05/10/09	Scavenged	K2	00656384 04555738	5.58 m
Woodlark *Lullula arborea*	18/10/09	A bit scavenged	T8	00655377 04556753	12.05 m

Blackbird *Turdus merula*	25/10/09	Portion of carcass	K5	00656072 04556170	12.90 m
European Robin *Erithacus rubecula*	24/11/09	Feathers, scavenged	T12	00655080 04560079	36.30 m
Woodlark *Lullula arborea*	26/02/10	Intact	T7	00654622 04560516	4.45 m
Woodlark *Lullula arborea*	03/03/10	Fresh / intact	S10	00663928 04548608	4.50 m
Song Thrush *Turdus philomelos*	12/03/10	Fresh/ Intact	MO4	00650236 04562759	39.40 m
Song Thrush *Turdus philomelos*	12/03/10	Intact / big injury	MO4	00650230 04562772	35.10 m
Woodlark *Lullula arborea*	12/03/10	Intact not fresh	MO11	00649078 04562159	49.30 m
Blackbird *Turdus merula*	15/03/10	Portion of carcass	D4	0659819 4557457	23.10 m
Blackbird *Turdus merula*	22/03/10	Feathers	X2	00661983 04558630	20.73 m
Woodlark *Lullula arborea*	23/03/10	Intact	MO12	00648897 04562001	12.40 m
European Robin *Erithacus rubecula*	31/03/10	Intact	M4	00660611 04550581	33.20 m
Woodlark *Lullula arborea*	06/04/10	Intact	MO10	00649248 04562494	10.90 m
Sardinian Warbler *Sylvia melanocephala*	07/04/10	Intact	MO7	00649882 04562815	33 m
Blackbird *Turdus merula*	07/04/10	Feathers	MO8	00649733 04562865	17.80 m
Bunting species *Emberiza* spp.	07/04/10	Feathers	MO9	00649218 04562499	15.90 m
Woodlark *Lullula arborea*	09/04/10	Intact	S1	00663368 04549928	12.10 m
Woodlark *Lullula arborea*	15/04/10	Intact	T32	00656762 04556633	12 m
Blackcap *Sylvia atricapilla*	21/04/10	Intact	D7	00660566 04557478	23.30 m
Northern Wheatear *Oenanthe oenanthe*	26/04/10	Intact	K7	00655784 04556404	10.40 m
Northern Wheatear *Oenanthe oenanthe*	26/04/10	Intact	K9	00655507 04556619	20.50 m
Woodlark *Lullula arborea*	30/04/10	Portion of carcass	P8	00653739 04557023	58.30 m
House Martin *Delichon urbica*	14/05/10	Scavenged	M15	00662935 04550592	8 m
Woodlark *Lullula arborea*	16/05/10	Intact	T42	00657784 04555119	33 m
Woodlark *Lullula arborea*	19/05/10	Intact	T30	00656694 04557016	20.20 m
Woodlark *Lullula arborea*	19/05/10	Intact	K2	00656393 04555720	5.10 m
Woodlark *Lullula arborea*	19/05/10	Intact	T35	00656872 04555720	15.20 m

Red-Backed Shrike *Lanius collurio*	21/05/10	Intact	T9	00654747 04560301	17.73 m
Woodlark *Lullula arborea*	07/06/10	Scavenged	MO9	00660333 04557470	1.40 m
Woodlark *Lullula arborea*	16/06/10	Intact	M7	00661417 04550803	14.60 m
Northern Wheatear *Oenanthe oenanthe*	20/06/10	Scavenged	D3	00659966 04557620	0.95 m
House Martin *Delichon urbica*	12/07/10	Intact, with broken head	M15	00662974 04550602	38.40 m
House Martin *Delichon urbica*	14/07/10	Scavenged, half of the body	M15	00662961 04550609	26.60 m
House Martin *Delichon urbica*	14/07/10	Scavenged	M15	00662971 04550575	44.50 m
House Martin *Delichon urbica*	16/07/10	Intact	M19	00663968 04551871	26.40 m
House Martin *Delichon urbica*	18/07/10	Intact	M16	00663355 04551228	6.80 m
House Martin *Delichon urbica*	25/07/10	Fresh	X3	00661986 04558631	29.26 m
House Martin *Delichon urbica*	28/07/10	Intact	M16	00663396 04551250	12.80 m
House Martin *Delichon urbica*	29/07/10	Fresh	S1	00663247 04550199	12.60 m
House Martin *Delichon urbica*	04/08/10	Scavenged	K7	00655781 04556896	12.25 m
Unidentified birds					
Bird unid.	04/09/09	Bunch of black feathers-wing, probably from *T. merula*	T8	00654702 04560433	9.10 m

Table 6 Detected bats' fatalities.

Species	Date	Carcass condition/description	Age	Sex	No of turbine	GPS E/N	Distance to closest turbine
Hypsugo savii	05/08/09	Intact	J	M	P9	00653893 04557076	5.70 m
Nyctalus leisleri	05/08/09	Scavenged	Ad/Ts	M	T6	00654473 04560566	0.85 m
Pipistrellus pipistrellus	05/08/09	Scavenged	Ad/Ts	U	T6	00654473 04560566	3.75 m
Hypsugo savii	05/08/09	Scavenged	J	U	T6	00654473 04560566	2.45 m
Pipistrellus pipistrellus	05/08/09	Intact	Ad/Ts	F	T33	00656625 04556133	4.40 m
Hypsugo savii	05/08/09	Scavenged	J	M	MA1	00657914 04555588	3.50 m
Hypsugo savii	05/08/09	Scavenged	Ts/Juv?	U	MA3	00658179 04555577	6 m

Hypsugo savii	05/08/09	Scavenged	J	U	X4	00662651 04559525	1.50 m
Nyctalus leisleri	05/08/09	Intact, on the road to the WT	Ad/Ts	M	S1	00663345 04549949	38.10 m
Hypsugo savii	06/08/09	Scavenged, without flesh, dried out	Ad/Ts	F	MA3	00658174 04555556	15.20 m
Pipistrellus pipistrellus	06/08/09	Intact	Ts/Juv?	U	D7	00660543 04557436	26 m
Pipistrellus kuhlii/pipistrellus/ pygmaeus	07/08/09	Portion of carcass	U	U	X1	00661637 04558684	9.20 m
Hypsugo savii	07/08/09	Scavenged	J	M	D1	00659383 04558071	28.55 m
Hypsugo savii	07/08/09	Scavenged, ants on it	J	U	D1	00659375 04558077	34.50 m
Hypsugo savii	07/08/09	Scavenged	Ts/Juv?	U	D2	00659490 04557786	13.70 m
Hypsugo savii	07/08/09	Intact	J	F	K12	00655177 04556979	2.10 m
Pipistrellus pipistrellus	07/08/09	Scavenged	Ts/Juv?	M	K11	00655280 04556852	8.70 m
Hypsugo savii	10/08/09	Scavenged	J	M	K3	00656268 04555861	12.80
Nyctalus leisleri	11/08/09	Intact, dried out	Ad/Ts	U	M18	00663844 04551669	no data
Pipistrellus pipistrellus/pygmaeus	12/08/09	Intact	Ad/Ts-m	F	D7	00660545 04557482	26.40 m
Pipistrellus pipistrellus	12/08/09	Scavenged	Ad/Ts	U	T42	00657768 04555106	23.90 m
Hypsugo savii	14/08/09	Intact	Ad/Ts	F	M16	00663362 04551226	17.30 m
Pipistrellus pipistrellus	26/08/09	Intact	Ad/Tm	F	K4	00656160 04555986	10 m
Pipistrellus pipistrellus	31/08/09	Scavenged	Ad/Ts	M	D8	00660770 04557436	14.85 m
Hypsugo savii	31/08/09	Very bad, full of ants	Ad/Ts	U	S11	00664047 04548410	6 m
Nyctalus leisleri	03/09/09	Half eaten, very dry, (scavenged)	Ad/Ts	U	K13	00655048 04557079	41 m
Nyctalus leisleri	04/09/09	Intact	Ad/Ts	M	M5	00660878 04550410	6.10 m
Nyctalus leisleri	04/09/09	Intact	Ad/Ts	F	K13	00655067 04557089	16.20 m
Nyctalus leisleri	04/09/09	Intact	Ad/Ts	F	K12	00655173 04556964	9.20 m
Nyctalus leisleri	04/09/09	Scavenged	Ad/Ts	M	K5	00656088 04556149	7.80 m
Nyctalus leisleri	04/09/09	Scavenged	Ad/Ts	M	K3	00656277 04555907	35.30 m
Nyctalus leisleri	07/09/09	Intact	Ad/Ts	M	T5	00654364 04560689	7.30 m
Pipistrellus nathusii	07/09/09	Scavenged	Ad/Ts	M	P8	00653728 04557046	34.30 m

Nyctalus leisleri	07/09/09	Intact	Ad/Ts	M	K13	00655059 04557075	13.10 m
Nyctalus noctula	07/09/09	Intact	Ad/Tm	F	K9	00655514 04556643	10.10 m
Nyctalus leisleri	14/09/09	Intact	Ad/Ts	F	MA1	00657914 04555590	3 m
Nyctalus noctula	14/09/09	Fresh, intact	Ad/Ts	M	K3	00656270 04555868	2.60 m
Nyctalus leisleri	14/09/09	Fresh, intact	Ad/Ts	M	K3	00656270 04555868	2.20 m
Nyctalus leisleri	14/09/09	Fresh, intact	Ad/Ts	F	K14	00654953 04557271	27.72 m
Nyctalus leisleri	14/09/09	Fresh, intact	Ad/Ts	F	K14	00654927 04557309	23 m
Pipistrellus pipistrellus	14/09/09	Fresh, intact	Ad/Ts	M	K14	00654927 04557309	22 m
Pipistrellus nathusii	14/09/09	Fresh, intact	Ad/Ts	F	K14	00654927 04557310	27 m
Pipistrellus nathusii	14/09/09	Scavenged, only skeleton and some wing remains	Ad/Ts	U	P10	00654033 04557027	30.60 m
Nyctalus noctula	15/09/09	Scavenged, half eaten	Ad	U	T28	00656579 04557483	12.60 m
Nyctalus leisleri	15/09/09	Intact	Ad/Ts	F	T5	00654363 04560691	8 m
Nyctalus leisleri	15/09/09	Intact	Ad/Ts	M	K13	00655058 04557076	12 m
Nyctalus noctula	16/09/09	Intact	Ad/Ts	F	K5	00656096 04556158	10.40 m
Nyctalus noctula	16/09/09	Intact	Ad/Ts	F	S1	00663352 04549945	29 m
Pipistrellus nathusii	17/09/09	Scavenged, only skeleton and wings	Ad/Ts	M	M7	00661421 04550783	4.20 m
Pipistrellus nathusii	17/09/09	Scavenged, crushed by car	Ad/Ts	U	X4	0662649 04559508	6 m
Pipistrellus pipistrellus	17/09/09	Intact	Ad/Ts	F	K13	00655060 04557079	16.90 m
Vespertilio murinus	18/09/09	Scavenged	Ad/Ts-m	M	M5	00660842 04550414	33.10 m
Nyctalus noctula	18/09/09	Intact, broken wing	Ad/Ts	F	K12	00655179 04556967	6.40 m
Nyctalus noctula	18/09/09	Intact, broken wing	Ts/Juv?	F	MO12	00648903 04561998	10.54 m
Pipistrellus pipistrellus/pygmaeus	24/09/09	Scavenged	Ad/Ts	U	X4	00662630 04559542	23.10 m
Pipistrellus pipistrellus	24/09/09	Intact	Ad/Ts	F	X3	00662456 04559033	26.60 m
Nyctalus leisleri	24/09/09	Scavenged	Ad/Ts	F	M3	00660346 04550623	25.70 m
Pipistrellus nathusii	30/09/09	Intact	Ad/Ts	F	T7	00654611 04560543	10.10 m
Pipistrellus pygmaeus	01/10/09	Scavenged	Ad/Ts	M	M4	00660577 04550579	21.20 m

Pipistrellus pipistrellus	01/10/09	Scavenged	Ad/Ts	M	K14	00654925 04557293	18.40 m
Nyctalus leisleri	05/10/09	Scavenged	Ad/Ts	F	K6	00655968 04556235	20.10 m
Nyctalus leisleri	05/10/09	Scavenged	Ad/Ts	U	K5	00656071 04556145	21.80 m
Nyctalus leisleri	07/10/09	Intact	Ad/Ts	M	M18	00663819 04551650	14.80 m
Pipistrellus pipistrellus	11/10/09	Intact	Ad/Ts	M	X4	00662658 04559597	12.65 m
Nyctalus leisleri	11/10/09	Cut in half	Ad/Ts	M	X2	00661982 04558634	20 m
Nyctalus leisleri	12/10/09	Intact	Ad/Ts	M	P10	0065407 04557035	14.80 m
Nyctalus leisleri	12/10/09	Scavenged	Ad/Ts	M	K10	00655377 04556754	23.20 m
Nyctalus leisleri	21/10/09	Intact	Ad/Ts	M	P9	00653887 04557073	13.10 m
Pipistrellus pipistrellus/pygmaeus	22/10/09	Intact	Ad/Ts	M	X4	00662449 04559527	8.60 m
Nyctalus leisleri	25/10/09	Intact	Ad/Ts	M	MA1	00657904 04555588	5.75 m
Pipistrellus pipistrellus/pygmaeus	29/10/09	Intact	Ad/Ts	M	X2	00661995 04558653	10.15 m
Pipistrellus nathusii	29/10/09	Intact	Ad/Ts	M	X1	00661637 04558644	44.60 m
Pipistrellus sp	29/10/09	Alive, with a broken wing, rehabilitated	U	U	X4	00662661 04559495	0 m
Nyctalus leisleri	15/11/09	Intact, with broken wing	Ad/Ts	M	M16	00663347 04551234	11.50 m
Pipistrellus nathusii	16/11/09	Intact	Ad/Ts	F	MA2	00658052 04555580	3.70 m
Pipistrellus nathusii	17/11/09	Intact	Ad/Ts	F	M3	00660338 04550608	29.70 m
Pipistrellus pipistrellus/pygmaeus	23/03/10	Intact	Ad/Ts	F	T6	00654478 04560565	9.30 m
Pipistrellus nathusii	24/03/10	Intact	Ad/Ts	M	M15	00662974 04550574	38 m
Pipistrellus nathusii	08/04/10	Intact	Ad/Ts	F	MA2	00658054 04555525	54.40 m
Pipistrellus nathusii	08/04/10	Intact	Ad/Ts	M	MO4	00650269 04562821	24.50 m
Pipistrellus nathusii	16/04/10	Intact	Ad/Ts	M	K2	00656404 04555751	19.20 m
Pipistrellus nathusii	19/04/10	Intact	Ad/Ts	F	M5	00660907 04550396	28.70 m
Pipistrellus nathusii	21/04/10	Intact	Ad/Ts	F	D7	00660562 04557472	20 m
Pipistrellus nathusii	22/04/10	Intact	Ad/Ts	M	M17	00663588 04551476	3.70 m
Pipistrellus nathusii	25/04/10	Intact	Ad/Ts	F	M16	00663343 04551256	13.52 m

Pipistrellus pipistrellus	25/04/10	Intact	Ad/Ts	M	D5	00660070 04557460	26.10 m
Pipistrellus pipistrellus/pygmaeus	03/05/10	Intact	Ad/Ts	F	MO7	00649876 04562845	10.50 m
Nyctalus leisleri	04/05/10	Intact	Ad/Ts	F	K1	00656456 04555581	5.20 m
Pipistrellus pipistrellus/pygmaeus	04/05/10	Intact	Ad/Ts	F	K1	00656472 04555576	10.38 m
Nyctalus leisleri	04/05/10	Intact	Ad/Ts	M	K14	00654930 04557312	22 m
Pipistrellus nathusii	04/05/10	Scavenged	Ad/Ts	F	MO6	00649992 04562808	7.60 m
Nyctalus leisleri	05/05/10	Intact	Ad/Ts	M	K6	00655938 04556266	8.90 m
Nyctalus leisleri	05/05/10	Scavenged	Ad/Ts	F	K2	00656408 04555723	14.90 m
Nyctalus leisleri	07/05/10	Intact	Ad/Ts	F	K2	00656378 04555690	34.90 m
Nyctalus leisleri	11/05/10	Intact	Ad/Ts	M	K14	00654953 04557270	25.05 m
Nyctalus leisleri	11/05/10	Intact	Ad/Ts	M	K14	00654862 04557167	36 m
Nyctalus leisleri	11/05/10	Intact	Ad/Ts	M	K14	00654932 04557311	28.06 m
Pipistrellus pipistrellus/pygmaeus	12/05/10	Intact	Ad/Ts	M	D8	00660779 04557449	15.75 m
Hypsugo savii	12/05/10	Intact	Ad/Ts	M	X2	00662092 04558488	12.92 m
Pipistrellus pipistrellus/pygmaeus	12/05/10	Intact	Ad/Ts	M	P9	00653890 04557041	4.45 m
Hypsugo savii	13/05/10	Scavenged	Ad/Ts	U	MO12	00648898 04562001	11.70 m
Nyctalus leisleri	13/05/10	Intact	Ad/Ts	M	K14	00654937 04557305	26.70 m
Nyctalus leisleri	13/05/10	Intact	Ad/Ts	M	K14	00654941 04557267	14.40 m
Nyctalus leisleri	19/05/10	Intact	Ad/Ts	M	K14	00654929 04557317	32.30 m
Pipistrellus pipistrellus/pygmaeus	19/05/10	Intact	Ad/Ts	U	K6	00655974 04556323	45.10 m
Hypsugo savii	30/05/10	Intact	Ad/Ts	M	S2	00663430 04549818	6.30 m
Pipistrellus nathusii	31/05/10	Scavenged	Ad/Ts	M	K13	00655057 04557092	8.40 m
Pipistrellus nathusii	01/06/10	Scavenged	Ad/Ts	M	P9	00653868 04557072	27.20 m
Pipistrellus pipistrellus/pygmaeus	01/06/10	Scavenged	Ad/Ts	M	T26	00656598 04558170	12.30 m
Nyctalus leisleri	03/06/10	Intact	Ad/Ts	M	K14	00654922 04557309	31 m
Pipistrellus nathusii	04/06/10	Scavenged	Ad/Ts	M	K9	00655523 04556606	12.75 m

Pipistrellus nathusii	04/06/10	Scavenged	Ad/Ts	M	D6	00660329 04557470	10.30 m
Pipistrellus nathusii	08/06/10	Intact	Ad/Ts	M	M15	00662972 04550585	39.30 m
Pipistrellus nathusii	09/06/10	Intact	Ad/Ts	M	M3	00660345 04550460	7 m
Pipistrellus pipistrellus	09/06/10	Intact	Ad/Ts	M	X4	00662645 04559259	7.90 m
Pipistrellus nathusii	09/06/10	Intact with broken wing	Ad/Ts	M	MO1	00650638 04562853	15.95 m
Nyctalus leisleri	09/06/10	Intact	Ad/Ts	M	T26	00656598 04558154	9.10 m
Pipistrellus pygmaeus	10/06/10	Scavenged	Ad/Ts	M	D8	00662645 04559528	6.40 m
Nyctalus leisleri	11/06/10	Scavenged	Ad/Ts	M	D3	00659638 04557578	3.25 m
Pipistrellus pygmaeus	11/06/10	Scavenged	Ad/Ts	M	X1	00661631 04558661	11.50 m
Nyctalus noctula	13/06/10	Intact	Ad/Ts	M	S13	00664227 04548204	10.70 m
Pipistrellus nathusii	13/06/10	Intact	Ad/Ts	M	X4	00662638 04559523	9.10 m
Nyctalus leisleri	13/06/10	Intact	Ad/Ts	M	K14	00654927 04557265	5.30 m
Nyctalus leisleri	13/06/10	Intact	Ad/Ts	M	K14	00654921 04557263	9 m
Pipistrellus nathusii	13/06/10	Intact	Ad/Ts	M	K7	00655782 04556381	5.45 m
Pipistrellus pipistrellus	13/06/10	Intact	Ad/Ts	M	K4	00656186 04556007	22 m
Nyctalus noctula	14/06/10	Intact	Ad/Ts	M	D7	00660583 04557458	22 m
Pipistrellus pipistrellus/pygmaeus	14/06/10	Scavenged	Ad	M	X3	00662486 04559000	12.60 m
Nyctalus leisleri	14/06/10	Intact	Ad/Ts	M	MO3	00650370 04562849	5.57 m
Nyctalus leisleri	14/06/10	Intact	Ad/Ts	M	K14	00654899 04557206	8.50 m
Pipistrellus nathusii	14/06/10	Intact	Ad/Ts	M	K13	00655056 04557081	13.20 m
Pipistrellus pipistrellus/pygmaeus	14/06/10	Intact	Ad/Ts	M	K5	00656070 04556165	15.70 m
Nyctalus leisleri	15/06/10	Intact	Ad/Ts	M	K14	00654928 04557309	36.90 m
Pipistrellus pipistrellus	15/06/10	Scavenged	Ad/Ts	F	MO11	00649013 04562191	8.25 m
Pipistrellus pipistrellus/pygmaeus	15/06/10	Intact	Ad/Ts	M	MO5	00650119 04562781	3.14 m
Pipistrellus pipistrellus/pygmaeus	16/06/10	Intact	Ad/Ts	M	K12	00655182 04556978	3.76 m
Nyctalus leisleri	16/06/10	Intact	Ad/Ts	M	MO4	00650213 04562900	4 m

Nyctalus leisleri	17/06/10	Intact	Ad/Ts	M	K14	00654936 04557267	10.40 m
Hypsugo savii	17/06/10	Intact	Ad/Ts	M	M5	00660876 04550441	17.51 m
Eptesicus serotinus	17/06/10	Intact	Ad/Ts	M	M15	00662925 04550599	7.67 m
Nyctalus lasiopterus	20/06/10	Intact	Ad/Ts	M	D8	00660803 04557432	12.50 m
Pipistrellus nathusii	21/06/10	Scavenged	Ad/Ts	M	M16	00663354 04551248	7.10 m
Nyctalus leisleri	21/06/10	Scavenged	Ad/Ts	M	K14	00654960 04557273	29.4 m
Hypsugo savii	29/06/10	Alive, with a big hole in the wing. Rehabilitated and released	U	U	MO9	00649586 04562622	16.50 m
Nyctalus leisleri	30/06/10	Intact	Ad/Ts	M	D8	00660802 04557429	19.10 m
Pipistrellus pipistrellus	01/07/10	Intact	Ad/Ts	F	T30	00660801 04557430	15.70
Hypsugo savii	02/07/10	Intact	Ad/Ts	M	K4	00656167 04556004	9.60 m
Pipistrellus pipistrellus	02/07/10	Intact	Ad/Ts	M	K3	00656267 04555863	7.80 m
Nyctalus leisleri	04/07/10	Scavenged	Ad/Ts	M	MO6	00649971 04562809	15.93 m
Nyctalus noctula	05/07/10	Scavenged	Ad/Ts	M	D2	00659505 04557792	9.10 m
Hypsugo savii	06/07/10	Intact	Ad/Ts	M	D8	00660785 04557450	7 m
Nyctalus leisleri	07/07/10	Intact	Ad/Ts	M	D6	00660324 04557464	12.94 m
Pipistrellus pipistrellus	07/07/10	Intact	Ad/Ts	M	K3	00656280 04555855	10.80 m
Hypsugo savii	11/07/10	Intact	Ad/Ts	M	K7	00655774 04556340	7.20 m
Pipistrellus pipistrellus/pygmaeus	12/07/10	Scavenged	Ad/Ts	M	X1	00661605 04558651	15.60 m
Hypsugo savii	12/07/10	Intact	Ad/Ts	M	D8	00660777 04557429	13.60 m
Nyctalus leisleri.	12/07/10	Intact	Ad/Ts	M	K1	00654921 04557268	6 m
Nyctalus leisleri	12/07/10	Intact	Ad/Ts	M	K1	00654920 04557270	3 m
Nyctalus leisleri	12/07/10	Portion of carcass	Ad/Ts	M	K2	00656383 04555716	39 m
Pipistrellus pipistrellus/pygmaeus	13/07/10	Intact	Ad/Ts	M	M16	00663329 04551219	29.50 m
Pipistrellus pipistrellus/pygmaeus	13/07/10	Intact	Ad/Ts	M	X3	00662469 04559008	12.15 m
Pipistrellus pipistrellus	13/07/10	Scavenged	Ad/Ts	M	D6	00660321 04557475	9.30 m

Nyctalus leisleri	14/07/10	Intact	Ad/Ts	M	K12	00656271 04555869	8.80 m
Pipistrellus nathusii	14/07/10	Intact	Ad/Ts	M	S10	00663930 04548595	11.75 m
Pipistrellus pipistrellus/pygmaeus	14/07/10	Scavenged	Ad/Ts	F	S9	00663926 04548746	5.05 m
Pipistrellus pipistrellus	14/07/10	Scavenged	Ad/Ts	M	X4	00662666 04559511	18.20 m
Hypsugo savii	14/07/10	Intact	Ad/Ts	M	X4	00662667 04559520	17 m
Pipistrellus pygmaeus	14/07/10	Intact	Ad/Ts	M	X4	00662664 04559523	14.70 m
Pipistrellus nathusii	14/07/10	Scavenged	Ad/Ts	M	X4	00662660 04559527	9.40 m
Pipistrellus pygmaeus	15/07/10	Scavenged	Ad/Ts	M	K2	00656409 04555708	2.70 m
Pipistrellus pipistrellus	15/07/10	Scavenged	Ad/Ts	?	X4	00662662 04559519	13.30 m
Pipistrellus pipistrellus/pygmaeus	15/07/10	Scavenged	Ad/Ts	F	X4	00662661 04559517	12.30 m
Pipistrellus pipistrellus/pygmaeus	16/07/10	Intact	Ad/Ts	M	MA3	00658187 04555575	10.10 m
Pipistrellus pipistrellus/pygmaeus	16/07/10	Intact	Ad/Ts	M	K3	00656255 04555906	3.20 m
Pipistrellus nathusii	18/07/10	Portion of a carcass	Ad/Ts	M	M3	00660340 04550628	19.50 m
Pipistrellus nathusii	21/07/10	Intact	Ad/Ts	M	M3	00660348 04550622	16 m
Nyctalus leisleri	27/07/10	Intact	Ad/Ts	M	K3	00656261 04555874	7.50 m
Hypsugo savii	27/07/10	Intact	Ad/Ts	M	S11	00664031 04548401	14.70 m
Pipistrellus pipistrellus/pygmaeus	27/07/10	Intact	Ad/Ts	M	X4	00662652 04559528	13.90 m
Pipistrellus nathusii	28/07/10	Scavenged	Ad/Ts	M	MA1	00657912 04555579	1.80 m
Pipistrellus pipistrellus	28/07/10	Intact	Ad/Ts	M	K9	00655530 04556647	22.50 m
Pipistrellus pipistrellus/pygmaeus	28/07/10	Intact	Ad/Ts	M	MO12	00648884 04561988	11.30 m
Pipistrellus pipistrellus/pygmaeus	30/07/10	Intact	Ad/Ts	F	K3	00656276 04555885	24.60 m
Hypsugo savii	01/08/10	Scavenged	Ad/Ts	M	S4	00663645 04549560	25.10 m
Nyctalus leisleri	01/08/10	Intact	Ad/Ts	M	P8	00653733 04557081	32.60 m
Hypsugo savii	04/08/10	Scavenged	Ad/Ts	?	P8	00653737 04557055	20.40 m

4.2. Assessment of risk posed by each wind farm and each wind turbine

Certain wind farms and in particular a number of wind turbines appeared to have stronger impact on birds and bats than others. This is seen by the differences in number of fatalities recorded (Tables 7 and 8). The highest number of bird and bat fatalities occurred in Kerveros (76 fatalities or 28.4% of the total fatalities, Table 7), followed by Mytoula, Sapka, Didimos Lofos and Geraki (41, 31, 28, 28 fatalities or 15.3%, 11.6%, 10.4%, 10.4% of the total fatalities respectively, Table 7).

Table 7 Total of bird and bat fatalities per wind farm (WF)

Wind farm name	Number of wind turbines monitored/WF	Number of bird and bat fatalities	Percentage of total fatalities (%)
Didimos Lofos	**8**/8	28	10.4
Geraki	**21**/42	28	10.4
Kerveros	**14**/14	76	28.4
Mati	**3**/3	10	3.7
Monastiri	**13**/13	24	8.9
Mytoula	**9**/19	41	15.3
Peltastis	**3**/10	12	4.5
Sapka	**4**/5	31	11.6
Soros	**13**/13	18	6.7
Total	**88**/127	268	100

Table 8 Total of bird and bat fatalities detected per wind turbine (WT). WTs with a stronger impact are marked in red (i.e. one bird of prey or more than 10 fatalities in total)

Wind Turbines	Birds of prey	Other bird species	Bats	Total
D1	0	0	2	2
D2	0	0	2	2
D3	0	2	1	3
D4	0	2	0	2
D5	0	0	1	1
D6	1	0	3	4
D7	0	1	4	5
D8	0	2	7	9
Total Didimos lofos	1	7	20	28
T5	0	0	2	2
T6	0	1	4	5
T7	0	2	1	3
T8	1	2	0	3
T9	0	1	0	1
T10	0	0	0	0

T11	0	0	0	0
T12	0	1	0	1
T13	0	0	0	0
T20	0	1	0	1
T26	0	0	2	2
T27	0	0	0	0
T28	0	0	1	1
T29	0	0	0	0
T30	0	1	1	2
T31	0	0	0	0
T32	0	2	1	3
T33	0	0	1	1
T34	0	0	0	0
T35	0	1	0	1
T36	0	0	0	0
T42	0	1	1	2
Total Geraki	1	13	14	28
K1	0	0	4	4
K2	0	2	5	7
K3	0	0	9	9
K4	0	0	3	3
K5	0	4	4	8
K6	0	0	3	3
K7	0	2	2	4
K8	0	0	0	0
K9	0	2	3	5
K10	0	0	1	1
K11	0	0	1	1
K12	0	0	5	5
K13	0	0	7	7
K14	0	0	19	19
Total Kerveros	0	10	66	76
MA1	1	0	4	5
MA2	0	0	2	2
MA3	0	0	3	3
Total Mati	1	0	9	10
MO1	0	0	1	1
MO2	0	0	0	0
MO3	0	0	1	1
MO4	0	2	2	4
MO5	0	1	1	2
MO6	0	0	2	2
MO7	0	2	1	3
MO8	0	1	0	1

MO9	0	2	1	3
MO10	0	1	0	1
MO11	0	1	1	2
MO12	0	1	3	4
MO13	0	0	0	0
Total Monastiri	0	11	13	24
M3	0	0	5	5
M4	1	3	1	5
M5	0	0	4	4
M7	0	1	1	2
M15	0	7	3	10
M16	0	6	5	11
M17	0	0	1	1
M18	0	0	2	2
M19	0	1	0	1
Total Mytoula	1	18	22	41
P8	0	2	4	6
P9	0	0	4	4
P10	0	0	2	2
Total Peltastis	0	2	10	12
X1	0	0	3	3
X2	0	4	3	7
X3	1	1	3	5
X4	0	0	15	15
Sapka WF *	1	0	0	1
Total Sapka	2	5	24	31
S1	0	3	2	5
S2	1	1	1	3
S3	0	0	0	0
S4	0	0	1	1
S5	0	0	0	0
S6	0	0	0	0
S7	0	0	0	0
S8	1	0	0	1
S9	0	1	1	2
S10	0	2	1	3
S11	0	0	2	2
S12	1	0	0	1
S13	0	0	0	0
Total Soros	3	7	8	18
Overall total	9	73	186	268

- One Black Vulture was found on 04/03/10, 2000 m away from the nearest wind farm (Sapka).

The most harmful wind turbine was K14 (Kerveros) with 19 bird and bat fatalities, followed by X4 (Sapka), M16 (Mitoula) and M15 (Mitoula) with 15, 11, 10 bird and bat fatalities respectively (Table 8).

4.3. Mortality estimation

To estimate the mortality of all birds of prey and of the Black Vulture separately, correction factors were adopted from Cárcamo *et al*. (2011) as it was mentioned earlier in the methods section.

Searcher efficiency correction factor (p) was 0.66 [SE(*p*) = 0.027, CI 90%: 0.61-0.70]

The average length of time a carcass remained in the trial area before it was removed was 23 days [SE(t) = 3.71, CI 90%: 18.15-30.38]

Because searching activities occurred every day, the intervals between carcass searches were shorter than estimated average carcass removal time. It was assumed that all carcasses were found and consequently scavengers' removal rate was not used.

When Equation I was applied (Erickson *et al*. 2003), estimated mortality was:

Birds of prey: m = 13.64
Black Vulture: m = 1.52

The adjusted mortality rate was: 0.15 birds of prey/turbine/year
0.02 Black Vultures/turbine/year

Following Everaert and Stienen (2007) (Equation II), the mortality was:

Birds of prey: N = 15.26
Black Vulture: N = 1.67

The adjusted mortality rate consequently was: 0.173 birds of prey/turbine/year
0.02 Black Vultures/turbine/year

Similar mortality rates were found in Carcamo *et al.* (2011), where mortality rate of birds of prey was estimated as 0.152 bird per turbine per year. Drewitt & Langston (2006) report that many wind farms result in low apparent levels of mortality, but even these levels may have significant consequences for species with a long life expectancy and low productivity, especially species of conservation concern. In future construction plans, mortality rates should be considered in relation to the number of wind turbines being proposed.

4.4. Seasonal changes in mortality

The highest numbers of dead birds of prey were found during the spring and summer months (respectively 3 and 5 fatalities, Figure 2), although no statistical differences were detected among seasons (*Kruskal–Wallis* test, X^2= 3.6, *df* = 3, non significant). The non significant result may be due to the low sample size.

- Autumn: 1 bird
- Winter: 0 bird
- Spring: 3 birds
- Summer: 5 birds

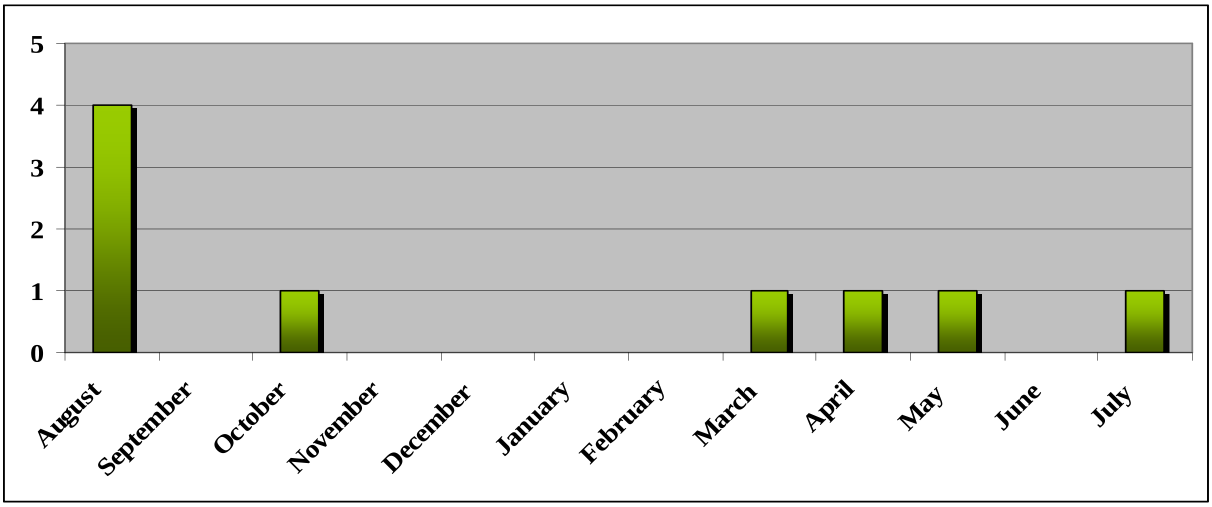


Figure 2 Total numbers of dead birds of prey found per month

The highest numbers of dead passerines were also found during the spring and summer months (respectively 22 and 31 fatalities, Figure 3), although no statistical differences were detected among seasons (*Kruskal–Wallis* test, X^2= 5.68, *df* = 3, non significant).

- Autumn: 7 birds
- Winter: 6 birds
- Spring: 22 birds
- Summer: 31 birds

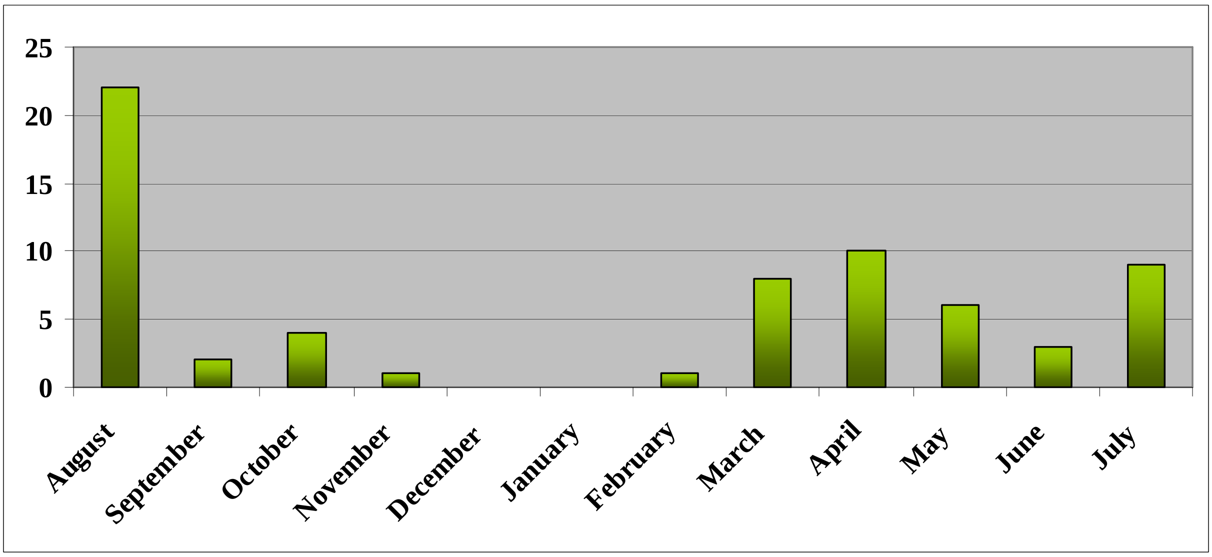


Figure 3 Total numbers of dead passerines found per month

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Effects of wind farms on birds of prey in Thrace

Of all birds found dead by collisions with wind turbines, nine were birds of prey. Three out of the five birds of prey species found dead are listed as“Endangered (Black Vulture), “Vulnerable” (Western Marsh Harrier) or “Near Threatened” (Short-toed Eagle) in the Greek Red Data Book of Threatened Animals (Legakis & Maragou 2009, cf.Appendix I). Black Vulture in Greece is of particular concern as it belongs to the last breeding colony in the Balkans and because it is a long-lived species with low productivity, hence difficult to recover from population declines. Consequently, additional mortality caused by wind turbines may threaten its population on regional, national and international levels.

Estimated mortality rates of all birds of prey (0.152 to 0.173 birds per year per turbine) are comparable to those reported in other studies (Barrios & Rodriguez 2004, Cárcamo *et al.* 2011). Although the mortality rate per turbine may seem ostensibly low, overall collision rates may increase when the number of wind turbines gets larger (Farfán *et al*. 2009). It is worth mentioning that the carrying capacity of the large part of Thrace (including our study area) has been established at 480 standard wind turbines (960MW in total). Langston & Pullan (2003) stated that even relatively small increases in mortality rates may be significant for populations of some birds, especially large, long-lived species with generally low annual productivity and slow maturity, notably so when already rare. It should be taken into consideration that both the observed number of bird of prey fatalities recorded (9 inds.) and the Black Vulture fatalities recorded (1 ind.) are slighty lower than the estimated total mortality (13.64 and 15.26 birds of prey, and 1.52 and 1.69 Black Vulture). More than one “mortality estimation equation” should be used in order to have a more integrated representation of the estimated mortality.

It is worth to mention that after this study period on 10/10/10, adult Black Vulture remains (many feathers) were found in Kerveros wind farm, around 100 meters away from the closest wind turbine (K12). This finding was not included in the mortality estimation presented in this study.

Patterns of birds of prey mortality did not seem to be affected by migration. Most dead individuals belonged to resident species or vultures that visited the area regularly for foraging, rather than species occurring during migration.

There were differences in bird mortality recorded between wind farms. For instance, no birds of prey were found dead in three wind farms (Peltastis, Monastiri, Kerveros), but in a previous study one collision fatality (Griffon Vulture) was reported in Kerveros (Cárcamo *et al.* 2011*).* Some wind farms seemed to pose a greater threat to birds of prey than others. Collision risk depends on a range of factors, one of which is related to wind farm topography. The location of a wind farm site can be crucial. Particular topographic features may be used for lift by soaring species that can result in bird collisions with a wind turbine under adverse weather conditions (Drewitt *et al.* 2006).

Two Short-toed Eagle fatalities were recorded at the same wind farm (Soros). These are of great concern, because ten new wind turnbines (3 MW) have been constructed along the same ridge and will start operating in the following year.

The Black Vulture found dead about 2000 meters away from Sapka wind farm, raised concerns about birds probably being killed by wind turbines, but dying away from the surveyed area. This type of bias has been referred to as crippling bias by Smallwood *et al.* (2007), who report that some unknown number of birds survive long enough to die outside the search area, and some unknown number likely survive for extended periods, though exhausted by their injuries. This is supported by our findings: the Black Vulture found is the second bird that dies under such circumstances in the area; a Griffon Vulture was first found dead in 2008 due to a collision with a wind turbine slightly further than 2000 meters away from the nearest wind turbine (Cárcamo *et al.* 2011). In addition, after this study period one alive Griffon Vulture was found with sheared off wing due to a collision with a wind turbine. The bird was detected on 27/11/10 in Geraki wind farm, 130 meters away from the closest wind turbine (T18). The vulture was exhausted and unable to fly. This finding was not included in the number of collision incidents presented in this study.

Cárcamo *et al.* (2011) reported that the Common Buzzard population may have been severely affected by the operation of the wind farms in Thrace. The discovery of three Common Buzzard fatalities may support this assumption, confirming high mortality of the species. In accordance with other researchers (Pearce-Higgins *et al.* 2009), buzzard populations may be significantly affected by wind farms. Wind turbines killing birds might lead to reduction of local populations and their productivity in the area.

In our daily monitoring, the effect of removal by scavengers and humans seem to have been kept low. In comparison to the previous study carried out in a much less intensive manner (Cárcamo *et al.* 2011), the numbers of bird and especially bat collision fatalities detected significantly increased. Hence, reducing intervals between searches appeared to be a better approach to reduce the bias resulting from scavenger and human activities. This is also acknowledged by other researchers, for example in Johnston *et al.* (2010) who report that most carcasses searches likely underestimate mortality if not conducted daily.

5.2. Conservation implications and recommendations

Our findings suggest that existing wind farms in Thrace contribute to an increase in mortality of both birds and bats. Among the fatalities were species that are considered endangered or vulnerable. The biological significance of the fatalities at wind turbines needs to be investigated. It is essential to understand the effect wind turbine-caused mortality has on bird and bat populations by conducting population viability studies.

There is an urgent need to extend the study on other wind turbines in Thrace, to assess more accurately the impact of wind farms on birds and bats. Carcass surveys, if possible on a daily basis, should be carried out at the already operating wind farms as well as those which will start operating in the future in order to monitor both short- and long-term effects on bird and bat populations. The greater the precision of mortality estimation, the better wildlife managers may assess the extent of wind farm impacts on bird populations which will assist them in defining appropriate mitigation measures to reduce those impacts.

The observers' detection efficiency trials and the scavengers removal trials should be carried out for both birds and bats. The trials ought to account for topography, vegetation and season, separatly at every wind farm (Erickson 2004), in order to correct the potential bias which can result in underestimation of collision mortality. In addition, according to Flint *et al*. (2010) even if carcass surveys are conducted daily, when carcass removal rates are high, the adjustment for scavenging will have a substantial influence on estimates of total mortality. An estimation of carcass persistence rate for 24 hours (1 day) is an important parameter in the whole analysis of scavenging effect.

In addition, it would be essential to gather accurate weather data during the study period (wind strength and direction, air temperature, humidity etc.). Collision risk is greatest in poor flying conditions, such as low temperature, very strong wind, rain and fog (Madders & Whitfield 2006). These parameters need to be incorporated into collision risk assessments.

A substantial number of passerine and bat corpses were found (65 birds and 186 bats). Mortality changed seasonally in passerines with more birds found dead in certain seasons. This is particularly obvious for Woodlark and may be related to the reproductive behaviour of this species. In addition, many House Martins were found dead near certain WTs, within a short period in summer. Future impact assessment studies should consider the impact of wind farms on both these taxonomic groups.

Only wind turbines were checked during this study and electric power transmission lines were not monitored. However, one electrocuted Hooded Crow (*Corvus corone cornix*) was found during the searching activities. Two Black Vultures and one Golden Eagle were found dead under power lines in the area, not related to wind farms. Although these findings were not related to the present study, they raised concerns about the risks associated to the increasing number of power lines connected to wind farms in the area. Electric power lines may have important impacts on bird populations. Therefore, any future investigations should take into account the potential impacts of overhead power lines and other infrastructure related to wind farms in addition to the impacts of wind turbines themselves, as it is currently done.

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7. APPENDICES

Appendix I. Birds found dead at monitored wind farms and their IUCN status (http://www.iucnredlist.org/apps/redlist, 2010)

IUCN Red Data List:
EN - Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern, DD – Data Deficient, NE – Not Evaluate
EU bird directive:
Annex I: The mentioned species are subject to specific conservation measures
Annex II: The mentioned species can be hunted under specific conditions

Birds of prey			**Conservation status of the species**		
Species or taxonomic group	**Scientific name**	**Total fatalities**	**IUCN Red List**	**Greek Red Data Book**	**EU Birds Directive**
Black Vulture	*Aegypius monachus*	1	NT	EN	Annex I
Short-toed Eagle	*Circaetus gallicus*	2	LC	NT	Annex I
Sparrowhawk	*Accipiter nisus*	1	LC	NE	Not listed
Accipiter spp.	*Accipiter spp.*	1	LC	NE	-
Common Buzzard	*Buteo buteo*	3	LC	NE	Not listed
Western Marsh Harrier	*Circus aeruginosus*	1	LC	VU	Annex I
OTHER BIRDS			**Conservation status of the species**		
Species or taxonomic group	**Scientific name**	**Total fatalities**	**IUCN Red List**	**Greek Red Data Book**	**EU Birds Directive**
House Martin	*Delichon urbica*	25	LC	NE	Not listed
Mistle Thrush	*Turdus viscivorus*	1	LC	NE	Annex II part B
Blackbird	*Turdus merula*	5	LC	NE	Annex II part B
Song Thrush	*Turdus philomelos*	2	LC	NE	Annex II part B
Woodlark	*Lullula arborea*	17	LC	LC	Annex I
Eurasian Skylark	*Alauda arvensis*	1	LC	NT	Annex II part B
European Robin	*Erithacus rubecula*	2	LC	NE	Not listed
Common Swift	*Apus apus*	2	LC	NE	Not listed
Red-Backed Shrike	*Lanius collurio*	2	LC	NE	Annex I
Willow Tit	*Parus montanus*	1	LC	NE	Not listed
Bunting species	*Emberiza spp.*	1	-	-	-
Blackcap	*Sylvia atricapilla*	2	LC	NE	Not listed
Sardinian Warbler	*Sylvia melanocephala*	1	LC	NE	Not listed
Winter Wren	*Troglodytes troglodytes*	1	LC	NE	Not listed
Northern Wheatear	*Oenanthe oenanthe*	3	LC	NE	Not listed
Eurasian Woodcock	*Scolopax rusticola*	1	LC	NE	Annex II part A
Gull species	*Larus spp.*	1	-	-	-
Common Cuckoo	*Cuculus canorus*	1	LC	NE	Not listed
Chukar	*Alectoris chukar*	1	LC	NE	Annex II part B
Middle Spotted Woodpecker	*Dendrocopos medius*	1	LC	LC	Annex I
Woodpecker species	*Dendrocopos spp.*	1	LC	-	-
Aves	Bird unidentified	1	-	-	-

Appendix II. Bats found dead at study wind farms and their IUCN Red List status (http://www.iucnredlist.org/apps/redlist, 2010)

BATS			Conservation status of the species	
Species Name or taxinomic group	**Scientific name**	**Total fatalities**	**IUCN Red List**	**Greek Red Data Book**
Lesser Noctule	*Nyctalus leisleri*	57	LC	LC
Nathusius' Pipistrelle	*Pipistrellus nathusii*	35	LC	DD
Savi's Pipistrelle	*Hypsugo savii*	26	LC	LC
Common Pipistrelle	*Pipistrellus pipistrellus*	22	LC	DD
Noctule	*Nyctalus noctula*	10	LC	DD
Pygmy Pipistrelle	*Pipistrellus pygmaeus*	5	LC	DD
Particoloured Bat	*Vespertilio murinus*	1	LC	DD
Pipistrelle species	*Pipistrellus pipistrellus/pygmaeus*	26	LC	DD
Pipistrelle species	*Pipistrellus kuhlii/pipistrellus/pygmaeus*	1	LC	LC/DD
Greater Noctule bat	*Nyctalus lasiopterus*	1	NT	VU
Serotine bat	*Eptesicus serotinus*	1	LC	LC
Bats	Bats unidentified.	1		
Total No. of bats		186		

Appendix III. Protocol used in the carcass surveys

Wind Farm Monitoring 2009-2010
New Carcass Searches

Date	Researchers
Start time	Sites
End time	Interruption

Site	Start-End times	Windmills searched (e.g. T30, T31, T32…)	Comments

In case you find a carcass of a large raptor or a vulture, don't remove it and call the office. For the rest that you find:

ID	Carcass condition / description	Species	Age	Sex	Site/ Turbin plot	GPS	Distance to closest turbin	Direction from turbine base	Estimated time of death	Estimated cause of death	No photo taken	Comments

Carcass condition:
- Intact: carcass which is completely intact, not badly decomposed, no sign of been fed upon by predator or scavenger
- Scavenged: Entire carcass that shows sign of been fed upon by predator or scavenger
- Portion of a carcass
- Feathers

Appendix IV. Location of the nine wind farms and codes