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No Evidence for Displacement of Wintering Red-breasted Geese *Branta ruficollis* (Pallas, 1769) (Anseriformes) at a Wind Farms Area in Northeast Bulgaria: Long-term Monitoring Results

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Abstract: While broadly considered "environmentally friendly", being a clean source of renewable energy, wind farms are not without potentially adverse effects on environmental features, notably on birds. The conservation status of the Red-breasted Goose *Branta ruficollis* (RBG) has changed from endangered in the past to vulnerable in 2015. At present, the hinterland of the western Black Sea coast, including Bulgaria, is one of the main wintering grounds of RBG, where flocks co-exist in the same region with around 200 wind turbines. We hypothesise that the operation of wind parks has caused displacement of wintering geese. However, according to the results of our study, RBG are using the same territory in the same number but distributed in smaller flocks. Our findings do not indicate displacement of RBG from traditional feeding grounds but are associated with the changes in the property of the land in Bulgaria and fragmentation of the crop fields, including those of wheat, which is the main feeding resource of RBG in winter. Our study provides no evidence for a displacement effect of wind turbines and describes the opportunistic strategy of wintering of RGB in the area in the last 20 years.

Key words: wintering birds, wind turbines, displacement, vulnerable species

Introduction

Harnessing wind energy is a rapidly increasing method of energy production around the globe, as governments encourage the development of renewable "clean" sources to counter the emission of "greenhouse gases" and their effect on climate change. Terrestrial (onshore) wind farms are at the forefront of this trend because they are relatively cheap to construct and the technology is relatively well advanced.

While broadly considered "environmentally friendly", by being a clean source of renewable energy, wind farms are not without potentially adverse effects on environmental features, notably on birds. Such potentially adverse effects on birds primarily include fatalities through collision with rotating turbine blades, disturbance leading to the displacement of birds from feeding, drinking, roosting or breeding sites (effectively a form of habitat loss) and turbines presenting a barrier to flight movements, thereby preventing access to areas via those movements or increasing energy expenditure to fly around the turbine locations (Drewitt & Langston 2006, Hötker *et al.* 2006, Madders & Whitfield 2006, Rees 2012). Both disturbance at potentially favoured terrestrial

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locations and the barrier effect (disturbance at potentially favoured aerial routes) may be considered as different forms of displacement. Geese, along with swans and smaller wildfowl, are considered to be especially sensitive to being displaced by the presence of wind turbines (Langston & Pullan 2003, Stewart *et al.* 2007, Madsen & Boertmann 2008, Rees 2012) and so can be prevented from using feeding, drinking and (or) roosting sites by disturbance (Rees 2012).The perceived sensitivity of this group of birds to the presence of novel tall structures in the landscape, in the form of wind turbines, may be due to these birds typically occupying open landscapes (Rees 2012). Consequences of such displacement in preventing use of feeding areas may result in birds' energy budgets being compromised, with potential effects on individual survival and population status.

In a recent review, Rees (2012) concluded that non-breeding geese and swans could be displaced by 100-600 m from feeding areas around the nearest terrestrial turbine (see also Pedersen & Poulsen 1991, Kruckenberg *et al*. 1996, Larsen & Madsen 2000, Drewitt & Langston 2006, Fijn *et al*. 2012, Harrison & Hilton 2014). Recorded terrestrial displacement distances are therefore variable (Drewitt & Langston 2006) and birds have been recorded feeding within turbine arrays in two studies (reviewed by Rees 2012). That geese and swans have, at least in some studies, routinely come close to wind turbines, is also evident in that they have been recorded (albeit infrequently) as victims of collision with turbine blades (Rees 2012); this is evident because collisions and displacements are mutually exclusive events (Madders & Whitfield 2006, Whitfield & Coupar 2008). The infrequency of such collision victims may refer more to the pronounced ability of geese to avoid collision with wind turbine blades at relatively close proximity (Fernley *et al.* 2006, SNH 2013; see also Fijn *et al*. 2012) rather than a lack of exposure to potential collision through systematic displacement of birds away from the immediate presence of turbines (as largely inferred by the review of Rees 2012).

There are further studies of this group of birds involving the barrier effect, an effect which also involves an adverse behavioural reaction to the presence of turbines and includes disruption of commuting flights between (e.g.) terrestrial roost and feeding sites or migratory flights. Some of these studies indicate that geese usually fly around a wind farm's infrastructure and that this displacement reaction is often pronounced as regards both the numbers of birds involved and the distances from turbines (Plonczkier & Simms 2012, Rees 2012). Other studies implying much lower and potentially inconsequential diversionary flight behaviour (Hötker *et al.* 2006, Masden *et al.* 2010) have also been considered as evidence of a barrier effect (Rees 2012). Recent analyses on the energetic consequences of barrier effects on individuals and their implications for populations suggest that population-level impacts are far more likely with disruption of regular and frequent commuting flight routes rather than turbines leading to deviations in infrequent migratory flight pathways (Masden *et al*. 2009, 2010).

Research on the effects of wind farms on all birds, not just geese, has struggled to keep pace with the rapid expansion of the wind energy industry (Madders & Whitfield 2006, Whitfield & Coupar 2008, Rees 2012) and several reviews refer to weaknesses of existing research and highlight the need for more published studies on the displacement of large wildfowl (Drewitt & Langston 2006, Stewart *et al.* 2007, Whitfield & Coupar 2008, Rees 2012). Such research involves a shortage of Before-After-Control-Impact (BACI) studies (Drewitt & Langston 2006, Whitfield & Coupar 2008, Rees 2012), a shortage of more simple Before-After (BA) studies whose duration is greater than one year in BA wind farm construction (Rees 2012) and studies that consider the possibility of "large-scale displacement" (Rees 2012).

The Red-breasted geese *Branta ruficollis* (Pallas, 1769) (RBG) were first time registered in significant number in Southern Dobrudzha in 1961 and in the study region in 1964 (Donchev 1967, Michev 1968). Since then, this is the primary wintering area for this vulnerable species. This study focuses on RBG because: (i) the species is classified as Vulnerable by the International Union for Conservation of Nature (IUCN) and as a priority species by several other international conservation instruments (Cranswick *et al*. 2012); (ii) the threat to RBG posed by wind farms on their wintering grounds is considered high (Cranswick *et al*. 2012) although this threat is noted as being primarily from collision mortality; and (iii) because of the RBG conservation status, recent historical information is available, which comprises the distribution of RBG in the study area before the construction of wind turbines (Dereliev 2000). This, together with six years of post-operation observations associated with the wind power development (see Material and Methods) provided unique set of records on the effects of wind farms on the vulnerable RBG.

The present study addresses some of these research gaps by reporting on observations in an area with recently developed wind parks and their vicinity in northeast Bulgaria. In this region, several species of geese overwinter; notably, numerically, the Greater white-fronted goose *Anser albifrons* but also the RBG, the Greylag goose *Anser anser*, the Lesser white-fronted goose *Anser erythropus* and a few other vagrant species (e.g. Burfield & Bommel 2004, Cranswick *et al*. 2012).

According to the recent review (Rees 2012), one should expect that feeding geese should be displaced by the presence of wind turbines in this area of Bulgaria. Moreover, the studies of Larsen & Madsen (2000) and Madsen & Boertmann (2008) in Denmark indicate that geese are less tolerant to the presence of taller turbines and those grouped in clusters (rather than "strings" or lines of turbines). Rees (2012) highlighted these factors (tall turbines, arranged in clusters) as potentially increasing the extent of displacement. All these allegations have been included in the models recently developed in order to predict relation between feeding and distances to the different elements of the landscape in the study area (Harrison & Hilton 2014). The wind farms constructed in the period 2004–2012 in northeast Bulgaria should, therefore, present a major landscape source of disturbance for geese because most of the operating turbines are taller than those in the Danish studies (Larsen & Madsen 2000, Madsen & Boertmann 2008). We should consequently anticipate rather dramatic evidence of displacement due to constructed wind parks in this area of coastal Dobrudzha, beyond that documented in previous studies. The study area would therefore be a prime candidate for causing a large-scale displacement effect in northeast Bulgaria (Rees 2012).

Due to wind farms infrastructure, with an expectation of large-scale displacement as a feeding area and obstacle to flight activity under the barrier effect, we hypothesise that the operation of wind farms has caused the displacement of wintering RBG and other geese. To test this working hypothesis, we made several predictions, which vary according to the presumed nature of displacement, the spatio-temporal mode of these tests and the available data. At each prediction's examination, we progressively build increasingly rigorous testing of the validity of the working hypothesis.

- Prediction 1: During the operation of wind turbines geese do not fly through the wind farms (e.g. Plonczkier & Simms 2012).

- Prediction 2: During the operation of turbines geese do not feed within the territory of wind farms (e.g. Larsen & Madsen 2000, Rees 2012);

- Prediction 3: The operation of wind turbines has caused a reduction in the total and peak number of feeding geese compared to the same area before construction of turbines.

Regular field surveys have investigated the spatial and temporal distribution of the wintering RBG within this area in the period before any wind turbine to be constructed (Dereliev 2000). The results of the winter monitoring of geese in the area with wind farms are also published (Zehtindjiev *et al*. 2009, Zehtindjiev & Whitfield 2010, 2011, 2012, 2013, 2014). The massive amount of data collected up to now allow comparison of the number as well as spatial distribution of geese wintering in the same area and test of above-listed hypotheses in regard to the displacement effect of already operating wind farms on the wintering RBG.

This study presents for the first time comparative analysis of spatial distribution and numbers of RBG in the wind farm territory in five seasons before construction and six winter seasons after construction of the turbines. The available information is analysed in order to assess the impacts of the wind farm on the wintering vulnerable RBG population.

Materials and Methods

Study species

Red breasted geese breed in Arctic Russia, primarily on Taimyr, Yamal, Gydan and adjacent peninsulas, migrating through Russia to Kazakhstan and then west, through southern Russia, to the northern and western Black Sea coasts. Major part of the species populations currently winters in Bulgaria, Romania and Ukraine (Cranswick *et al*. 2012). The wintering distribution was markedly different until the late 1960s when most of the birds wintered along the western coast of the Caspian Sea (Cranswick *et al*. 2012). Red-breasted geese were first time registered in Southern Dobrudzha on December 8, 1961 (Michev 1968) and in the region of Shabla Lake February 6-8, 1964 (Donchev 1967). According to Dereliev & Simeonov (2015), RBG is a passage migrant and winter visitor around the lakes Shabla and Durankulak, sometimes in Srebarna Lake and Burgas lakes (Fig. 1). Sporadically, it winters in reservoirs within the country and the valley of the Danube. Until the end of the 1960s, there were single birds and small flocks of 20-30 individuals (Ivanov & Pomakov 1983). Between 1969 and 1985, its numbers varied widely, up to 16,566 individuals in January 1980 (Ivanov & Pomakov 1983, Michev *et al.* 1983). Between 1986 and 1995, the numbers had a maximum of 59,206 individuals (Michev & Profirov 1997) and in the period 1997–2005 they were between 14,266 and 67,795 individuals (up to 71% of the world population, see Dereliev 2006). Migration counts suggest a recent increase in the breeding population of the species (Rozenfeld 2011) which highlighted the need of careful evaluation of the quantitative data available from the counts in winter. Moreover, the evidences for range expansion support the increase in the number of RBG world population. The species is irregularly wintering in Greece, mainly Evros Delta (Cranswick *et al*. 2012). It winters fairly regular in Turkey (Cranswick *et al*. 2012). Its increase at the Black Sea coast presumably at least partly reflects a shift from wintering grounds further east. Overall trend is unclear (Cramp & Simmons 2004, Bird Life International 2016).

The reason for this major shift in the wintering distribution was considered the change in agricultural crops around the Caspian Sea from wheat to cotton (Dereliev 2006, Cranswick *et al*. 2012). However, it obviously cannot explain the subsequent continuation of the expansion of the wintering range. Within the current wintering range, where almost all feeding grounds are agricultural, winter wheat is the preferred crop for RBG (Hulea 2002, Sutherland & Crockford 1993). Red breasted geese are highly itinerant in their choice of feeding areas between and within winters (Dereliev 2000, Cranswick *et al*. 2012) and this itinerancy contributes to difficulties in estimating the population trends, although counts in the late 2000s suggest a world population of about 44,000–57,000 (Cranswick *et al*. 2012, Rozenfeld 2011). The species' mobility may be partly explained, at least at a local scale, by the availability of winter wheat. Other local factors affecting distribution may also include several sources of disturbance, from hunters and farmers to weather (Cranswick *et al*. 2012, Simeonov & Possardt 2012). The severity of winter weather can apparently also influence distribution on a larger scale (Cranswick *et al*. 2012). Recent satellite tagging of individuals has confirmed that wintering birds are extremely mobile on a day-to-day basis in their choice of feeding areas (Simeonov & Possardt 2012). Hence, wintering RBG show a high degree of itinerancy in their movements that are substantially unpredictable (Simeonov & Possardt 2012) even though probably related to many potential influences. As RBG typically associate with other geese species, in particular the more numerous greater white-fronted geese (GWFG), it follows that the same unpredictability in occurrence and itinerancy also applies to GWFG (see Dereliev 2000).

Study site and visual observations protocol

The study covered an area of northeast Bulgaria close to the Black Sea coast known as coastal

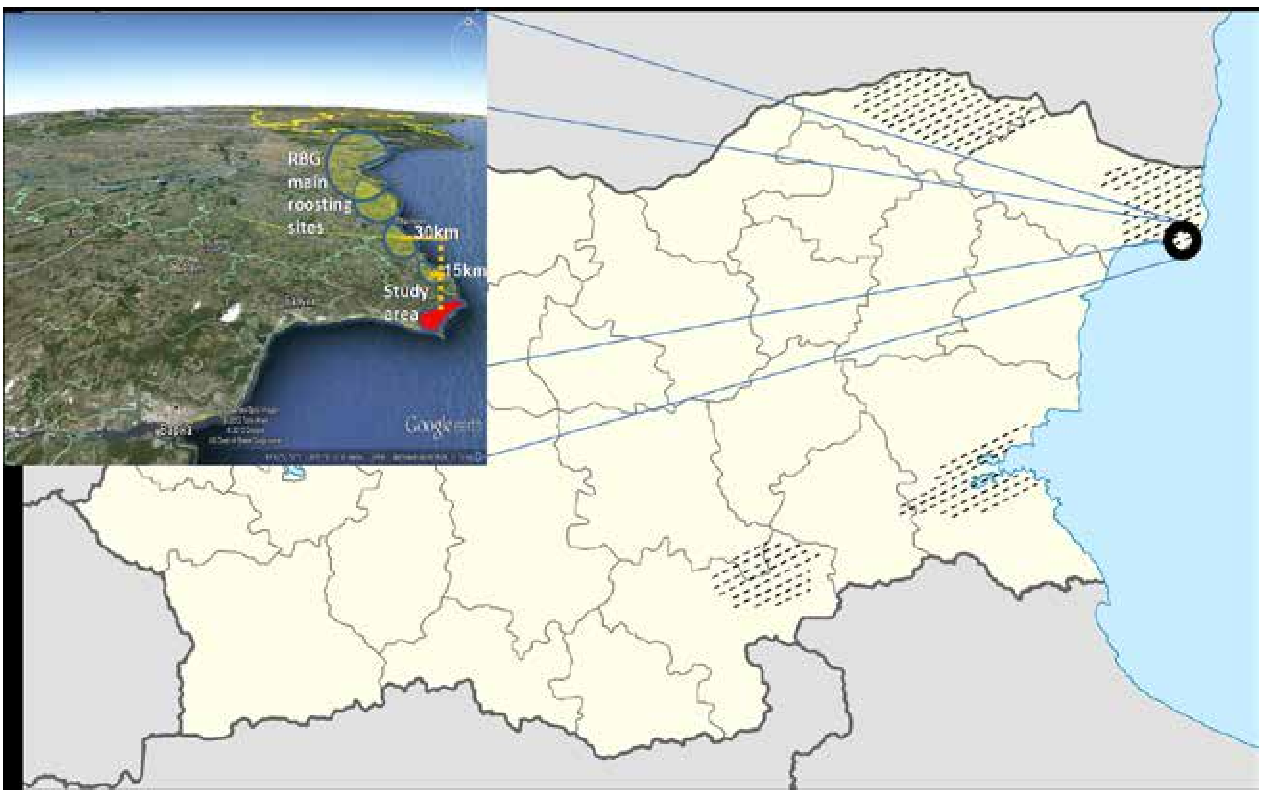

Fig. 1. Winter distribution of RBG in Bulgaria (according to the Red Data Book of Bulgaria) and the study area location (left upper corner)

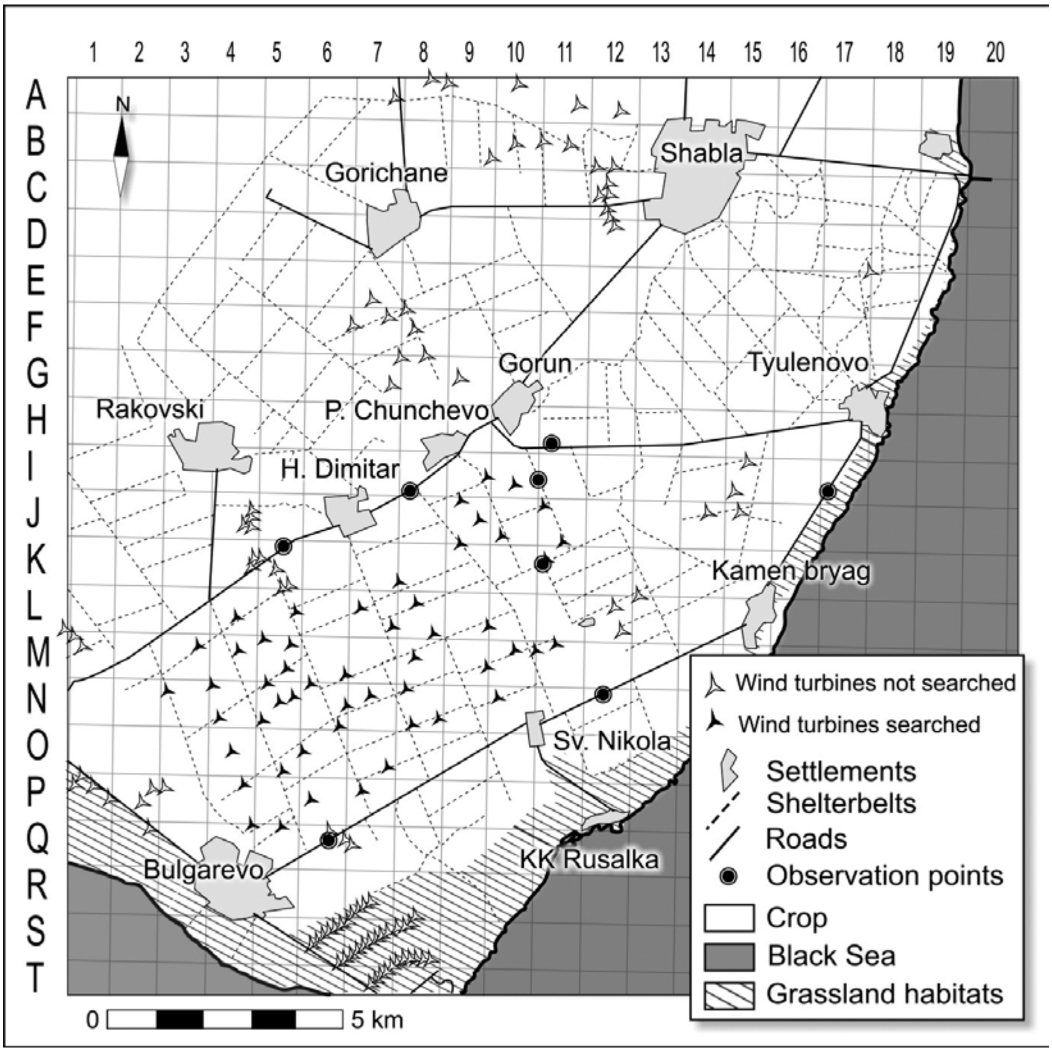

Fig. 2. Location of the observation points (black dots) and operating wind turbines in the study area. The numbers and letters present the grid applied to this study area

Dobrudzha where 146 wind turbines were constructed in the period 2004-2010 (Fig. 2). The area consists mainly of arable land of various crops, crossed by roads and shelter belts. The distances between the turbines vary between 300 and 600 m. In order to collect comparable information between the seasons on the large scale movements of the wintering RBG and their habits, the surveys were set up to cover an area wider than one specific wind park territory and adjacent agricultural fields in the period 2008–2014 (Fig. 2).

The study included the same survey period every winter between 1st December and end of March 2008–2014, covering the period of the most intense movements of wintering geese in the region of northern Bulgarian Black Sea coast (Dereliev 2000). During the visual surveys, the following records of birds were noted by observers:

- Species and (if possible) sex and (or) age.
- Number of geese in the flock.
- Distance from observer.
- Direction from the observation point.
- Altitude.
- Direction of flight (flight path).
- Behaviour (notably flight behaviour) concerning existing wind farm constructions.
- Supplementary behavioural observations.
- Weather conditions.

Direct visual surveys of all passing birds were made from daily vantage points around the study area (Fig. 2). Point counts were performed by scanning the sky in all directions over the study area from sunrise till sunset.

The visual point surveys were supplemented by itinerant surveys throughout the wind farm area and surrounding agricultural fields, made as-and-when birds were seen to enter the area or its vicinity, and at least daily. Itinerant surveys were undertaken pri-

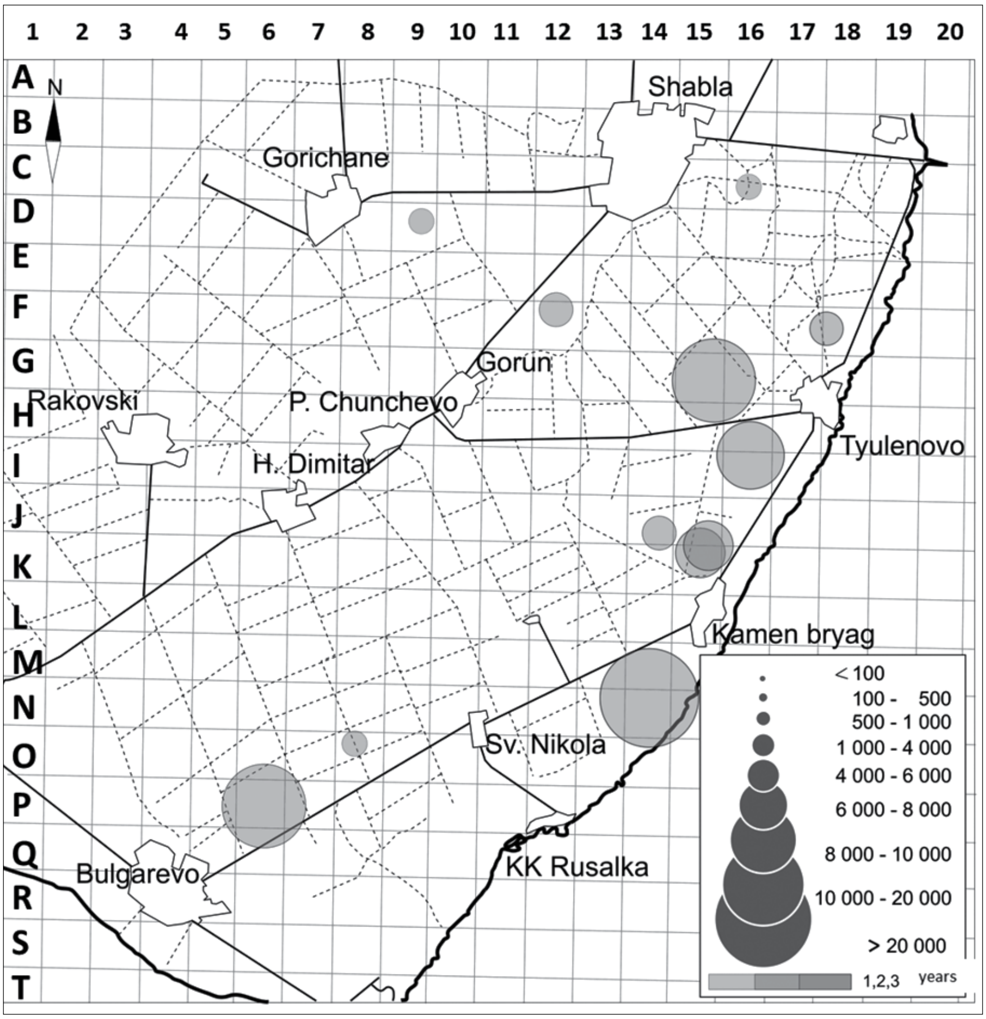

Fig. 3. Distribution of feeding RBG in the investigated territory as observed in winter periods between 1995 and 2000

marily to count and identify birds to species on the ground, thereby allowing the numbers of wintering geese feeding in wind farm territory and its environs to be ascertained. The overall number of birds per species was obtained by collating counts made simultaneously from at least three observation points. All observers were qualified specialists carrying out surveys of bird migration for many years.

Methods were essentially the same in all winter surveys. Data were collected within study area that encompassed an area in a several wind parks with 146 operational wind turbines and their vicinity. An area of consistent effort across winters was searched frequently for collision victims under 52 turbines once per week (Fig. 2). The study encompassed the whole period when geese were recorded in the study area, during all six winters when turbines in this area are constructed. Detailed observations and visits on the feeding grounds of the geese were made daily. In all cases when feeding RBG were observed in close distance to the operating turbines the shortest distances to the nearest turbines were measured. Only feeding RBG were used for comparative analysis of the flock size.

Statistical approach and standardization of the quantitative spatial data

The quantitative data on spatial distribution of RBG was digitalized in a standard grid of 20×20 squares (1 x 1 km) in order to compare model based on the numbers given in the report by Dereliev (2000) and data collected during current study based on six years post-construction period.

In order to test for significant difference between pre-construction and post-construction periods, we compared the maximum number of RBG observed to feed on the same areas per winter season, using *t*-test for independent samples. The variable was Box-Cox-transformed prior to analysis to achieve a normal distribution. Additionally, a nonparametric Mann-Kendall statistical test (R package "trend" in the R v. 3.2.3) was used to test for time

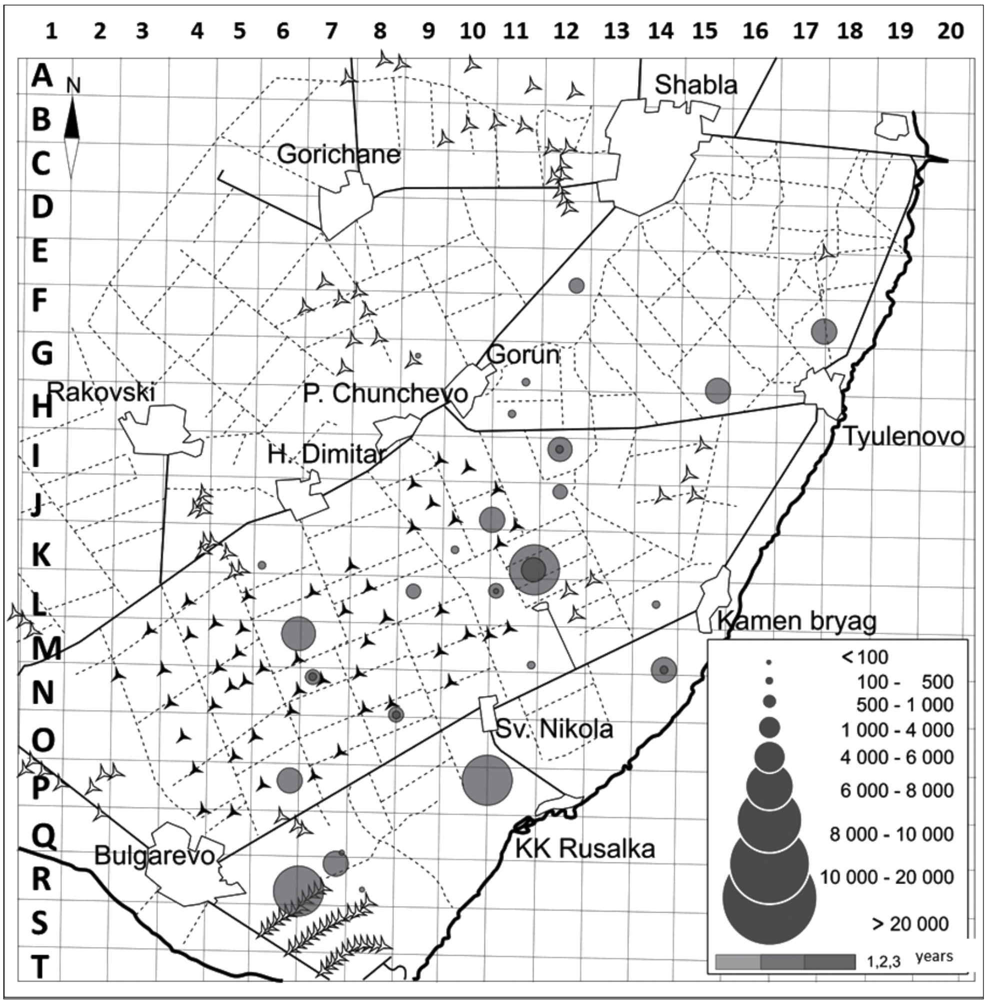

Fig. 4. Distribution of feeding RBG in the investigated territory as observed in winter periods between 2008 and 2014

series trend in both total number of feeding RBG and the mean number of RBG per flock. Mann-Kendall test was used as a non-parametric test for zero slope of the linear regression because data were not normally distributed and because of data variability issues, such as missing values in the period of record and outlier data (Gilbert 1987). One-tailed tests were used to detect a decreasing trend. All data analyses were performed using the software Statistica 8 for Windows (StatSoft, Tulsa, OK, USA) and R (version 3.2.3) statistical package (R Development Core Team 2015).

Results and Discussion

Numbers and distribution of RBG in the period 1990–2000 before construction of wind turbines

Same observation protocol as one in post construction period was applied in the period 1995–2000, with one major difference in the frequency of the surveys, which were made twice per month in the period between 1 November and the end of March (Dereliev 2000).

According to the report by Dereliev (2000), the territory covered by our study was visited four out of five winter seasons, with variations in the number of feeding geese between 2 and 25000 individuals (Table 1 in the Appendix). RBG have been observed in 10 locations for the four winters when feeding flocks have been registered in the study area (Fig. 3). Only in one of the locations, feeding RBG have been observed in two winters. This fact is explained in the report by Dereliev (2000) by the rotation of the crops and opportunistic character of RBG in the area of the two lakes Durankulak and Shabla.

Numbers and distribution of RBG in the period 2008–2014

RBG were registered in 85 days during 6 years of the monitored period. RBG used the territory in all 6 winter seasons between 2008 and 2014. The median arrival and departure of RBG in the study area was calculated as 8th January and 20th February, respec-

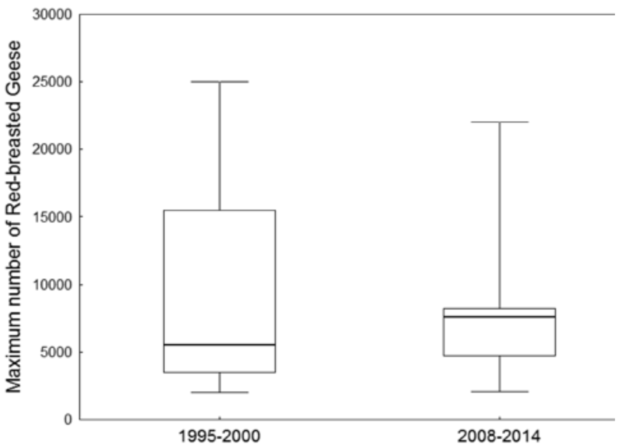

Fig. 5. Comparison of the maximum number of feeding RBG per season in the study area in pre-construction period 1995–2000 and after construction of 146 wind turbines. Box and whisker plots indicate median, interquartile ranges, and min/max values of the distribution

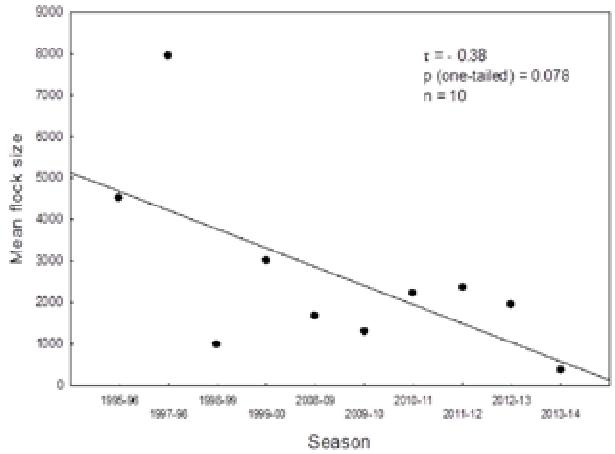

Fig. 6. Trend in the mean flock size of the RBG in the period between 1995 and 2014 according to data published in Dereliev (2000) and our observations in the study area

tively. Maximum number of RBG observed every winter varied between several hundreds and almost 25000 individuals (Fig. 4). Extremes of the observed numbers of RBG have been registered in two winters, with numbers over 8000 RBG per day and once with absolute number of over 22000 RBG per day. Comparison of the maximum numbers observed before and after construction of turbines in the area is presented in Fig. 5 and in the Appendix.

Table 1. Minimal distances between feeding RBG and nearest wind turbine measured during the monitoring 2008–2014

No	Date	Distance (m)
1	25.12.2012	90
2	27.12.2012	51
3	27.12.2012	59
4	24.12.2012	93
5	24.12.2012	77
6	24.12.2012	58
7	24.12.2012	30
8	24.12.2012	78
9	24.12.2012	196
10	02.01.2013	100
11	02.01.2013	30
12	02.01.2013	18
13	03.01.2013	80
14	03.01.2013	150
15	04.01.2013	100
16	04.01.2013	80
17	05.01.2013	100
18	05.01.2013	100
19	04.01.2013	80
20	04.01.2013	60
21	05.01.2013	80
22	06.01.2013	90

RBG number comparison between pre- and post-construction periods

The maximum number of RBG observed feeding in the study area in pre-construction and post-construction periods did not differ significantly ($t(8) = -0.2$, p (one-tailed) = 0.42, Fig. 5). There was no support for the prediction that the operation of wind turbines had caused a reduction in the number of feeding geese in the area with operational turbines compared with the same area before wind turbines construction (Mann-Kendall $S = 7$, Kendall's tau = 0.156, p (one-tailed) = 0.3). In support of this result, we have observed feeding RBG in close distances to the operating wind turbines (Table 1).Throughout 10 winter seasons between 1995 and 2014, a non-significant decreasing trend in the mean flock size of RBG was detected (Mann-Kendall $S = -17$, Kendall's tau = – 0.378, Sen's slope = – 319.9, p (one-tailed) = 0.078, Fig. 6).

The investigated territory was monitored in six consecutive winters in 2008-2014. In order to find whether there are arguments indicating adverse effect of the constructed turbines on the wintering RBG, we have applied before and after approach in a comparative analysis of the numbers, dynamics and spatial distribution of wintering RBG. For the comparative analysis and statistical test of our hypotheses, we have also investigated all published monitoring reports from the operational wind parks in the study area (Zehtindjiev *et al*. 2009, Zehtindjiev & Whitfield 2010, 2011, 2012, 2013, 2014). All these reports as well as previous studies at the national scale have demonstrated strong influence of the environmental factors such as ambient temperature and

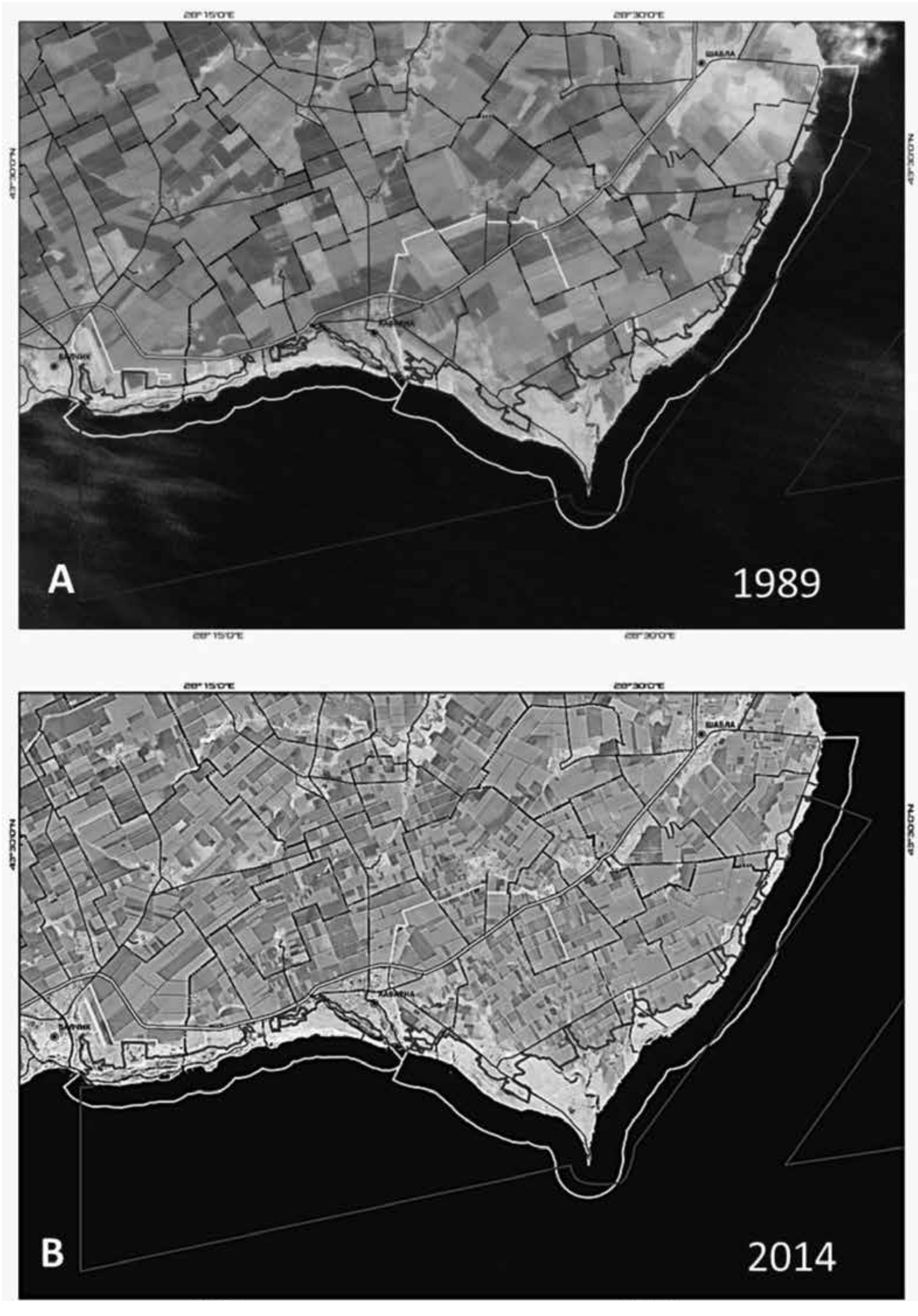

Fig. 7. Satellite images of the study area in the winter of 1989 (A) and 2014 (B)

snow coverage on the abundance of RBG in the study area (Dereliev 2000). Extreme cold months were observed in NE Bulgaria mainly in 1970s, 1980s and late 1990s (Chenkova & Nikolova 2015). Therefore, some higher numbers may be expected in the first period of our study between 1995 and 2000. According to the available meteorological data, there is no trend of lower temperatures as well as precipitations, which could be associated with the period covered by our study (Chenkova & Nikolova 2015) and therefore all observed numbers of geese presented here can be considered as representative in respect to potential variations due to temperature fluctuations between winters in 10 years of the study period.

Our first prediction that during the operation of wind turbines geese do not fly through wind farms (as suggested by Plonczkier & Simms 2012) was not supported by the results of this study. The recent data from the area with operating wind turbines, compared to data of Dereliev (2000), show equal or even more use of the area after the wind turbines have been constructed and become operational. We do not know if the records by Dereliev (2000) from 1995–2000 in the same area are from periods when preferred crop availabilities for geese were more or less favourable than during our contemporary studies associated with area with wind turbines. We can surmise, however, based on the concerns expressed by Cranswick *et al*. (2012), on a potential shift in financial rewards for 'cash crops' through the accession of Bulgaria to the European Union (in 2007), that any change will probably have been more likely detrimental to the presence of RBG and other geese than beneficial.

The second prediction that the RBG do not feed within the territory of wind farms (as suggested by Larsen & Madsen 2000 and Rees 2012) also was not confirmed by the results of our study. While it is difficult to ascribe an alternate particular cause to this possible shift in increasing use of area with operating wind turbines over last 10 years, one salient factor may be that RBG prefer feeding areas that are close to roost sites (Sutherland & Crockford 1993) and that, since Dereliev's (2000) studies, these have increasingly not involved the "traditional" freshwater lakes to the north of area where wind turbines are constructed now. This may indicate (albeit anecdotally) that the wind turbines are not a substantial obstacle to geese seeking feeding areas, although we suggest that it is not that wind turbine areas should be considered attractive but that it provides an area where geese can feed in greater safety from hunting pressure.

Hunting is a major threat to RBG, especially due to their association with GWFG (Cranswick *et al*. 2012). RBG is protected throughout its range but either indirectly, through its association with legal quarry species such as GWFG, or directly, through hunters flouting or being ignorant of legislation, it is apparent that several thousands are probably shot each year across the non-breeding range (Rozenfeld 2008, Cranswick *et al.* 2012). Cranswick *et al.* (2012) indicates that in Bulgaria alone this might be between 3 and 5% of the RBG population wintering in Bulgaria annually. Despite the direct losses of birds killed, the disturbance effect of shooting is liable to have considerable indirect effects on survival rates, by affecting birds' energy budgets, and access to vital resources such as feeding grounds, roost sites and freshwater (Cranswick *et al*. 2012). An apparent increasing trend in wintering in northeast Bulgaria geese is number of sleeping on the sea birds rather than freshwater lakes because of the hunting pressure (Dereliev 2000).

Our last prediction that operation of wind turbines has caused a reduction in the number of feeding geese compared with the same area before construction of wind turbines is not confirmed by the statistical tests and it is carefully considered in the following comparative analysis. Five out of ten registered feeding locations were the same used by RBG in 1995–2000 and in 2008–2014. Five other locations, where RBG were feeding in the post-construction period, were located in the much "deeper" agricultural territories, which were not covered by the monitoring of Dereliev (2000) (Fig. 3, 4). These five new locations might be overlooked in the pre-construction period because of much less frequent surveys (Dereliev 2000) and lack of inner roads, which are available now. Anyway, the total number of the feeding locations in post-construction period significantly increased and feeding RBG were observed in all 19 fields (Fig. 4).

The observed increase of the feeding localities in the post-construction period can also indicate fragmentation of the feeding habitats. During our study, we did not observe any difference in behaviour of RBG while feeding in proximity to wind turbines or shelterbelts. The distance to the nearest turbine when RBG were present in the fields with turbines varied between 30 and 196 m, with an average of 80 m (Table 1). If this result would be extrapolated according to the number of constructed turbines, it would cover an area of 1.95 hectares. The total available fields usually planted in annual base with wheat and potentially available feeding grounds for RBG in the study area are over 24000 hectares. Therefore the direct impact of constructed turbines involves 0.007% of the available in the studied territory feeding grounds. The observed decreased size of the RBG flocks in the entire period from 1995 till 2014 coincided with the fragmentation of the feeding grounds leading to the smaller fields available for concentration of RBG. The size of the fields in the period covered by our study dramatically decreased in the beginning of 1990s after restitution of the private property in Bulgaria (Fig. 7A, B). In the literature, this significant change was never considered as a factor and therefore has never been associated with the dynamics of flock sizes and numbers of RBG, wintering in coastal Dobrudzha, despite of the primary importance of feeding resources in the area. The wheat is the main and traditional crop in the region before the changes in the land property as well as in a subsequent period. The only change was the size of the fields, which reflected into the reduction of the flock sizes of RBG, which opportunistic feeding behaviour is known (Gill 1996).

This study raises the need for additional investigations on the drivers for such pronounced variation in the recorded intensity of displacement of non-breeding geese at terrestrial feeding areas. This important issue, integral to being able to predict impacts of proposed wind farms, has been barely broached in previous studies or their reviews, with the notable exceptions of Madsen & Boertmann (2008) and, especially, Fijn *et al.* (2012).

In addition, we observed similar numbers of feeding RBG in the same feeding grounds before and after intensive development of wind energy in the region. There was no evidence of any collisions of geese with constructed in the area wind turbines. Over 6 years of systematic collision monitoring in the biggest wind park in the area, there was no reported case of mortality of any geese species caused by collision with turbines, including RBG (Zehtindjiev *et al.* 2009, Zehtindjiev & Whitfield 2010, 2011, 2012, 2013, 2014).

In conclusion, from the data obtained in the periods much earlier than any wind turbines were constructed in the study area and now, there is no evidence for displacement of vulnerable RBG in their wintering grounds in NE Bulgaria.

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References

BirdLife International 2016. Species factsheet: *Branta ruficollis*. Downloaded from http://www.birdlife.orgon 04/03/2016.

Burfield I. & van Bommel F. 2004. Birds in Europe: Population Estimates, Trends and Conservation Status. BirdLife International. 374 p.

Chenkova N. & Nikolova N. 2015. Air temperature and precipitation variability in northeastern Bulgaria on the background of climate change. *Thermal Science*, **19** (Supplement 2): 381-390.

Cramp S. & Simmons K. E. L. 2004. BWPi: Birds of the Western Palearctic interactive (DVD-ROM). Sheffield, Bird Guides Ltd.

Cranswick P.A., Raducescu L., Hilton G. M. & Petkov N. 2012. International Single Species Action Plan for the conservation of the Red-breasted Goose (*Branta ruficollis*). AWEA Technical Series no. 46.

Dereliev S. 2000. Results from the monitoring of wintering geese in the region of lakes Durankulak and Shabla for the period 1995-2000. BSBCP & BSPB/BirdLife Bulgaria, Sofia. 88 p. Unpublished report (In Bulgarian).

Dereliev S. G. 2006. The Red-breasted Goose *Branta ruficollis* in the new millennium: a thriving species or a species on the brink of extinction. – In: Boere G. C., Galbraith C. A. & Stroud D. A. (eds.): Waterbirds around the world. Edinburgh, UK, The Stationery Office. 619-623.

Dereliev S. & Simeonov P. 2015. Red-breasted Goose *Branta ruficollis* (Pallas, 1769). In: Golemansky V. *et al*. (eds.): The Red Book of Bulgaria, Vol. 2 Animals. Sofia, Institute of Biodiversity and Ecosystem Research at the Bulagarian Academy of Sciences and Ministry of Environment and Water of Bulgaria. 252.

Donchev S. 1967. A contribution to the study of the waterfowl in Bulgaria. *Izvestiya na Zoologicheskiya Institut s Muzey*, **23**: 79-95.

Drewitt A. L. & Langston R. H. W. 2006. Assessing the Impacts of Wind Farms on Birds. *Ibis* **148**: 29-42.

Fernley J., Lowther S. & Whitfield P. 2006. A review of goose collisions at operating wind farms and estimation of the goose avoidance rate. Report, Natural Research Lim., West Coast Energy, Hyder Consulting.

Fijn R. C., Krijgsveld K. L., Tijsen W., Prinsen H. A. & Dirksen S. 2012. Habitat use, disturbance and collision risks for Bewick. *Wildfowl* **62**: 97-116.

Gilbert R. O. 1987. Statistical Methods for Environmental Pollution Monitoring. New York, John Wiley & Sons, Inc. 336 p.

Gill J. A. 1996. Habitat choice in pink-footed geese: quantifying the constraints determining winter site use. *Journal of Applied Ecology* **33**(4): 884–892.

Harrison A. L. & Hilton G. M. 2014. Fine-scale distribution of geese in relation to key landscapeelements in coastal Dobrudzha, Bulgaria. Preliminary report, WWT Slimbridge, 28 p.

Hötker H., Thomsen K.-M. & Jeromin H. 2006. Impacts on biodiversity of exploitation of renewable energy sources: the example of birds and bats – facts, gaps in knowledge, demands for further research, and ornithological guidelines for the development of renewable energy exploitation. Bergenhusen,Michael-Otto-Institut im NABU.

Hulea G. D. 2002. Winter Feeding Ecology of the Red-breasted Goose (*Branta ruficollis*). PhD thesis. University of East Anglia, UK.

Ivanov B. E. & Pomakov V. A. 1983. Wintering of the Red-breasted Goose (*Branta ruficollis*) in Bulgaria. *Aquila* **90**: 29-34.

Kruckenberg H., Jaene J. & Bergmann H.-H. 1996. Rastphanologie und Raumnutzung der Wildganse am Dollartim Winter 1994/1995 (Staging-numbers and distribution of wild geese at Dollard Bay, NW-Germany, in winter 1994/1995). –*Vogelkundliche Berichte aus Niedersachsen*, **28** (2): 63-74.

Langston R. & Pullan J. 2003. Windfarms and Birds: An Analysis of the Effects of Windfarms on Birds, and Guidance on Environmental Assessment Criteria and Site Selection Issues. Report by BirdLife International and Royal Society for the Protection of Birds (RSPB). 58 p.

Larsen J. K. & Madsen J. 2000. Effects of wind turbines and other physical elements on field utilization by pink-footed geese (*Anser brachyrhynchus*): A landscape perspective. *Landscape Ecology* **15** (8): 755-764.

Madders M. & Whitfield D. P. 2006. Upland raptors and the assessment of wind farm impacts. *Ibis* **148** (Suppl. I): 43-56.

Madsen J. & Boertmann D. 2008. Animal behavioral adaptation to changing landscapes: spring-staging geese habituate to wind farms. *Landscape Ecology* **23:** 1007-1011.

Masden E. A., Haydon D. T., Fox A. D., Furness R. W., Bullman R. & Desholm M. 2009. Barriers to movement: impacts of wind farms on migrating birds. *ICES Journal of Marine Science* **66**: 746–753.

Masden E. A., Haydon D. T., Fox A. D. & Furness R. W. 2010. Barriers to movement: modelling energetic costs of avoiding marine wind farms amongst breeding seabirds. *Marine Pollution Bulletin* **60:** 1085-1091.

Michev T. 1968. New data for the ornithofauna of Srebarna Nature Reserve, South Dobrogea. *Izvestiya na Zoologicheskiya Institut s Muzey* **27:** 13-21.

Michev T. & Profirov L. 1997. Midwinter numbers of the Red-breasted goose (*Branta ruficollis*) in Bulgaria. *Branta* (Sofia), **2:** 10-14.

Michev T., Nankinov D., Ivanov B. & Pomakov V. 1983. Midwinter numbers of wild geese in Bulgaria. *Aquila*, **90:** 45-54.

Pedersen M. & Poulsen E. 1991. [Impact of a 90m/2MW wind turbine on birds: Avian response to the implementation of the Tjaereborg Wind Turbine at the Danish Wadden Sea]. *Danske Vildtundersoegelser* **47**: 44 p. (In Danish, English summary).

Plonczkier P. & Simms I. C. 2012. Radar monitoring of migrating pink-footed geese: behavioural responses to offshore wind farm development. Journal of Applied Ecology 49 (5): 1187-1194.

Rees E. C. 2012. Impacts of wind farms on swans and geese: a review. *Wildfowl* **62**: 37-72.

Rozenfeld S. 2008. Red-breasted Goose in Russia: conservation bottlenecks. Presentation at the Life/AEWA Red-breasted Goose Workshop, 26-28 February 2008, Constanta, Romania.

Rozenfeld S. 2011. The number of Red-breasted Geese (*Branta ruficollis*) and Lesser White-fronted Geese (*Anser erythropus*) on the migration routes in 2010. *Goose Bulletin* **12**: 8-14.

Simeonov P. & Possardt E. 2012. First successful satellite tracking of Red-breasted Geese *Branta ruficollis*. *Goose Bulletin* **14:** 18-26.

SNH 2013. Guidance: Avoidance rates for wintering species of geese in Scotland at onshore wind farms. Available online at http://www.snh.gov.uk/docs/A916616.pdf

Stewart G. B., Pullin A. S. & Coles C. F. 2007. Poor evidence-base for assessment of wind farm impacts on birds. *Environmental Conservation*, **34** (1): 1–11.

Sutherland W.J. & Crockford N. J. 1993. Factors affecting the feeding distribution of red-breasted geese *Branta ruficollis* wintering in Romania. *Biological Conservation* **63**: 61-65.

Whitfield D. P. & Coupar A. M. 2008. Effects of terrestrial wind farms on birds and upland habitats. – In: Galbraith C.A. & Baxter J.M. (eds.): Energy and the Natural Heritage. Edinburgh, TSO Scotland, 205-220.

Zehtindjiev P. & Whitfield D. P. 2010. Monitoring of wintering geese in the AES Geo Energy Wind Park "Sveti Nikola" territory and the Kaliakra region in winter 2009/2010. Available online at http://www.aesgeoenergy.com/site/Studies.html

Zehtindjiev P. & Whitfield D. P. 2011. Monitoring of wintering geese in the AES Geo Energy Wind Farm"Sveti Nikola" territory and the Kaliakra region in winter 2010/2011. Available online at http://www.aesgeoenergy.com/site/Studies.html

Zehtindjiev P. & Whitfield D. P. 2012 Monitoring of wintering geese in the AES Geo Energy Wind Farm "Sveti Nikola" territory and the Kaliakra region in winter 2011/2012. Available online at http://www.aesgeoenergy.com/site/Studies.html

Zehtindjiev P. & Whitfield D. P. 2013 Monitoring of wintering geese in the AES Geo Energy Wind Farm "Sveti Nikola" territory and the Kaliakra region in winter 2012/2013. Available online at http://www.aesgeoenergy.com/site/Studies.html

Zehtindjiev P. & Whitfield D. P. 2014 Monitoring of wintering geese in the AES Geo Energy Wind Farm "Sveti Nikola" territory and the Kaliakra region in winter 2013/2014. Available online at http://www.aesgeoenergy.com/site/Studies.html

Zehtindjiev P., Gash M., Evans T. & Percival S. 2009.The monitoring of the wintering geese in the AES Geo Energy Wind Park "Sveti Nikola" territory and the Kaliakra region in winter 2008/2009. Available online at http://www.aesgeoenergy.com/site/Studies.html

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Appendix. Quantitative data of Red-breasted goose (*Branta ruficollis*) in the study area.

Table 1. Numbers of the observed feeding Red-breasted Geese in the study area in 1996–2000. Source: Dereliev (2000)

Date	Numbers
02.03.1996	4000
17.03.1996	5000
25.01.1998	10
08.02.1998	25000
08.02.1998	15000
09.02.1998	2000
10.02.1998	6000
11.02.1998	9000
11.02.1998	5000
12.02.1998	1510
06.01.1999	2
01.02.1999	2000
15.01.2000	5
15.01.2000	6000

Table 2. Numbers of the observed feeding Red-breasted Geese in the study area in 2009–2014. Source: present study

Date	Numbers	Date	Numbers
10.01.2009	3800	17.02.2011	1305
11.01.2009	7700	22.02.2011	1696
12.01.2009	500	27.02.2011	20
16.01.2009	830	08.01.2012	15
18.01.2009	80	09.01.2012	25
20.01.2009	1050	10.01.2012	75
27.01.2009	940	11.01.2012	90
29.01.2009	105	12.01.2012	80
01.02.2009	65	13.01.2012	60
09.01.2010	253	14.01.2012	60
11.01.2010	4	15.01.2012	60
12.01.2010	70	17.01.2012	15
21.01.2010	8	18.01.2012	100
22.01.2010	2421	22.01.2012	150
25.01.2010	1036	24.01.2012	260
26.01.2010	2037	25.01.2012	210
27.01.2010	596	26.01.2012	30
28.01.2010	1042	27.01.2012	45
29.01.2010	645	28.01.2012	340
30.01.2010	7194	29.01.2012	1600
01.02.2010	607	30.01.2012	1180
02.02.2010	145	31.01.2012	860
03.02.2010	87	19.02.2012	20900
04.02.2010	4794	20.02.2012	22000
05.02.2010	50	21.02.2012	3880
06.02.2010	920	05.01.2013	940
07.02.2010	1077	07.01.2013	1570
09.02.2010	8260	09.01.2013	1570
10.02.2010	200	10.01.2013	3240
12.02.2010	116	11.01.2013	2360
13.02.2010	260	12.01.2013	50
14.02.2010	10	13.01.2013	3680
18.02.2010	195	14.01.2013	4250
19.02.2010	150	15.01.2013	2950
02.01.2011	289	16.01.2013	940
03.01.2011	1893	17.01.2013	1120
04.01.2011	325	18.01.2013	1732
15.01.2011	31	19.01.2013	1940
01.02.2011	7518	20.01.2013	2295
02.02.2011	7180	21.01.2013	1616
07.02.2011	2385	22.01.2013	3268
12.02.2011	1949	23.01.2013	2630

Table 2. Contginued

Date	Numbers
24.01.2013	4020
26.01.2013	1570
27.01.2013	4750
28.01.2013	1060
29.01.2013	395
30.01.2013	943
31.01.2013	650
05.02.2013	480

Date	Numbers
09.02.2013	441
27.01.2014	100
28.01.2014	1040
29.01.2014	440
01.02.2014	1000
02.02.2014	240
03.02.2014	50
04.02.2014	2100

Date	Numbers
05.02.2014	100
07.02.2014	15
09.02.2014	27
10.02.2014	54
27.02.2014	200
28.02.2014	40
29.02.2014	49