ECOLOGIA BALKANICA
2019, Vol. 11, Issue 1 June 2019 pp. 51-62

Density of Grey Partridge (Perdix perdix Linnaeus, 1785) Population in Sakar Mountain (SE Bulgaria) and the Effect of Weather and Habitats

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Abstract. The breeding density of the Grey Partridge in Sakar Mountain is 1.23±0.19 (1-1.53) breeding pairs/km^2. The brood size is 11.9±3.87 (3-21) ind./successful breeding pair. The breeding density of the grey partridges in the study area has been marked by peaks over several years, which are preceded by an increase in the average brood size. The reproductive success is 2.97 young per adult bird. There is a significant positive correlation between the brood size and the number of days with rainfall in July. There is a significant moderate positive correlation between the brood size and the area of the sunflower crops.

Key words: breeding density, demographic parameters, agricultural crops, open habitats, habitat variables.

Introduction

The decline of biodiversity in open habitats predominantly with agricultural land is a fact in Europe. Populations of common species similar to those of the Grey Partridge (*Perdix perdix*) decrease with the intensification of agricultural practices (Bro *et al*., 2000; Donald *et al*., 2001; Verhulst *et al*., 2004; Vickery *et al*., 2004; Kuijper *et al*., 2009; Faragó *et al*., 2012; Birdlife International, 2016). As a result of the changes in their habitat structure, the European population of Grey Partridge has been decreasing since the mid-1950s (Potts, 1986; Potts & Aebischer, 1994; Meriggi *et al*., 2002). The species is included in SPEC 3 with an unfavorable conservation status in Europe (Tucker & Heath 1994; Aebisher & Kavanagh, 1997) and is Least Concern (LC) according to Birdlife International, (2016).

In Bulgaria the Grey Partridge was numerous in the 19th and the beginning of the 20th centuries in all the plain and semi-mountainous parts of the country. After 1985 there was a decrease in the population density (Gerasimov & Mitev, 2007). At present, it is under the regime of Conservation and Regulated Hunting (Bulgarian Biodiversity Act, Annex 4).

A number of studies have established relations between certain weather factors and the population indices of Grey Partridge populations in different regions of Europe (Faragó, 1998; Milanov, 1998; Donald *et al*., 2001; Aebisher & Ewald, 2004; Rosin *et al*., 2010; Barbazyuk & Chibilyov, 2017). They show differences in the effect of the same factors in different parts of the areal of the Grey Partridge. Probably the relationship

between the weather factors and the population variables is compounded by the influence of other environmental factors. This makes the study of these interactions complicated and often difficult to understand (BIBBY *et al.*, 1998).

During the recent decades, there has been an increasing focus on the impact of agricultural practices on the Grey Partridge population in open habitats (MERIGGI *et al.*, 1992; PANEK, 1997; AEBISHER & POTTS, 1998; DE LEO *et al.*, 2004).

The aim of this study is to establish the dynamics of the density of the Grey Partridge on the territory of the Sakar Mountain (SE Bulgaria) and to determine the impact of weather elements and some habitat variables on the demographic parameters of the population.

Materials and Methods

Study area

Sakar is a low mountain in Southeastern Bulgaria. It is enclosed by the rivers Maritsa, Sazlijka, Tundzha and Sinapovska (STOYCHEV, *et al.*, 2008) (Fig.1).The relief is hilly and slightly folded. The climate is Continental-Mediterranean. The average annual temperatures are between 8 and 13.5^{0}C. The annual rainfall is 500-900 mm, with winter maximum and summer autumn minimum. The snow cover is at least the same amount as in all other areas of Bulgaria (KOPRALEV, 2002). The natural vegetation is represented by xerothermic Oak forest, which in most of the mountain has been replaced with arable land and secondary vegetation represented by Christ Thorn (*Paliurus spina-christi*) mixed with Jasminum (*Jasminum fruticans*) and xerothermic grass formations with a predominance of Belize (*Dichantieta ischaemi*) (BONDEV, 1991; GRUYCHEV, 2014, perss. com.).

The Sakar ornithofauna is represented by 253 bird species, which characterizes the mountain as one of the richest and most important bird areas in Bulgaria (STOYCHEV *et al.*, 2008).

Field methods

The breeding density was determined by linear transects and the reproduction of a male partridge song during March – May (Fig.1). In July – September, the brood size and the number of successfully breeding pairs were estimated once again in the same transects. A dog (typical German wirehaired pointer) was used in each transect to reduce the likelihood of errors. This method is suitable for species that are easily recognizable but at the same time mobile and in low density (BIBBY *et al.*, 1992). The field visits were during the first three hours after sunrise and the last three before sunset when the activity of the Grey Partridge was the greatest. The average length of the transects was 3.96±1.73 (1.5 – 7) km, and the strip width was 100 m. This was the average distance between the dog and the observer, as well as the distance reached by the sound of the playback device. The breeding density was determined by the maximum number of pairs reported in each transect for all observations in March – May, and it was subsequently calculated over an area of 1 km^2 (BIBBY *et al.*, 1992). The average brood size was calculated by the number of fledglings per adult pair. In cases where one adult bird was observed, the number of the fledglings was once again calculated per adult pair (only the number of successfully breeding pairs has been taken into account). The reproductive success of the population was calculated as the number of fledglings per adult partridges, including non-breeding or unsuccessfully nesting birds. The brood production rate (BPR) is a percentage of pairs reproducing successfully (ROSIN *et al.*, 2010).

Weather

Climate data for each year were collected from the nearest weather stations in the surveyed area (Svilengrad, Elhovo, Kolarovo). Then we calculated the average monthly temperatures; minimum and maximum monthly temperatures; monthly rainfall amounts; number of days with

rainfall; monthly number of days with snow cover.

Habitat variables

Data on the habitat variables in the transects surveyed were collected every year during the entire study period. For each transect, the areas occupied by different agricultural crops (wheat, barley, triticale, sunflower, rapeseed, tobacco) in their percentage distribution were determined, as well as the percentage of orchards, shrubs, meadows, and pastures.

Statistical analyses

We compared the density in each year using the Kruskal-Wallis test. We used a Pearson product moment correlation to establish the associations among all weather and habitat variables. In the second order, we used the uncorrelated variations to relationships among weather, habitats, and population variables. We separately tested the density and brood size with the weather and habitat variables with partial product correlations. All statistical procedures were performed using PAST (HAMMER *et al.*, 2001).

Results and Discussion

The breeding density is 1.23±0.19 (1-1.53) breeding pairs/km^2 (Fig. 2). The breeding density of the grey partridges in the study area has been marked by peaks over several years, which are preceded by an increase in the average brood size (Fig. 3). The density in September is 15.4±6.14 (9-37) ind./km^2. It follows the trend of peaks and dips similar to the breeding density of the species.The brood size is 11.9±3.87 (3-21) ind./successful breeding pair. The reproductive success is 2.97 young per adult bird. The breeding density during 2017-2018 was higher than that during the previous years (Kruskal-Wallis chi square = 5.54; $p<0.01$). There is a significant positive correlation between brood size and breeding density in the following year ($r=0.657$; $n=50$; $p<0.001$). The two variables follow the same trend. The average BPR is 51.14±7.59 (33.3 – 60%) and there is no relationship between it and the annual breeding density and brood size ($r=-0.28$; $n=10$; $p=0.43$).

The partial correlation shows that there is a significant positive correlation between the brood size and the number of days with rainfall in July ($r=0.63$; $t=2.31$; $p=0.04$) (Fig. 4). No reliable dependences between breeding density, brood size, and other weather variables were found (Table 1).

There is a significant moderate positive correlation between the brood size and the area of the sunflower crops ($r=0.317$; $p=0.025$) (Fig. 5, Table 2).

No other significant relationships between population and habitat variables were found.

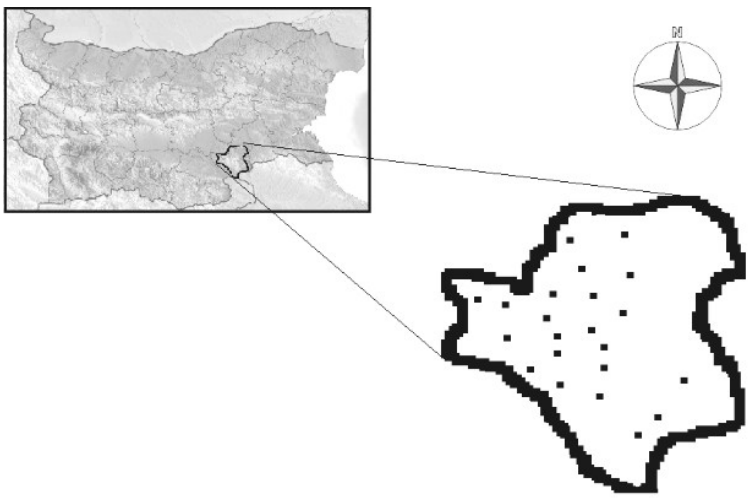

Fig. 1. Study area and distribution of transects in grey partridge habitats.

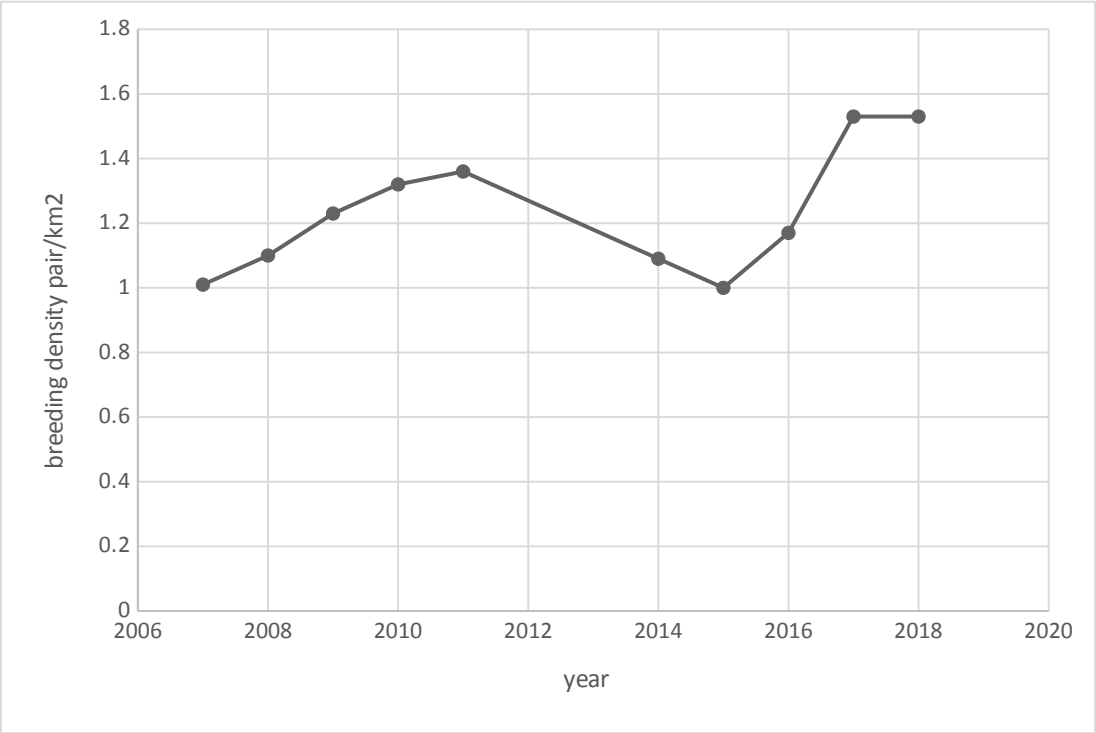

Fig. 2. Dynamics of breeding density in Sakar Mountain by the period 2007-2018 (between 2012 and 2014 data is missing).

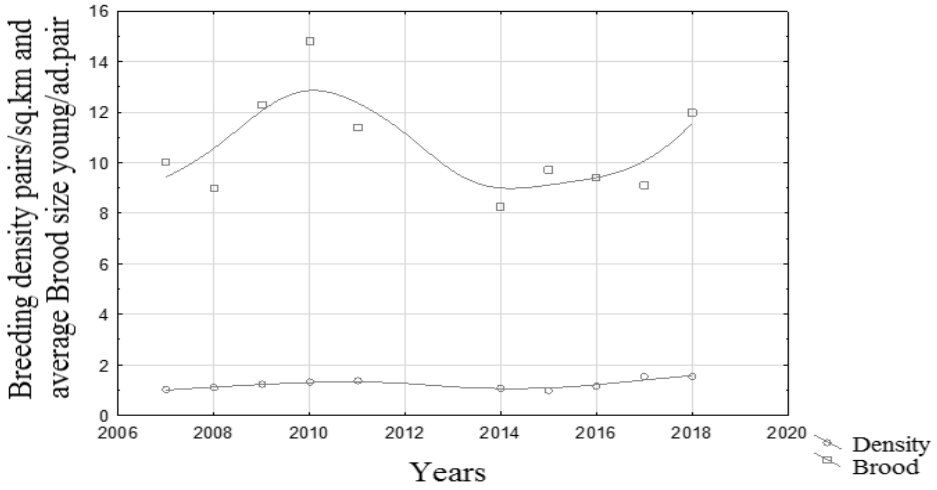

Fig. 3. Dynamics of brood size and breeding density (pair/km^2) of Grey Partridge in Sakar Mountain in period 2007-2018 years. (in figure was seen average brood size from every year and average annual breeding pairs per km^2).

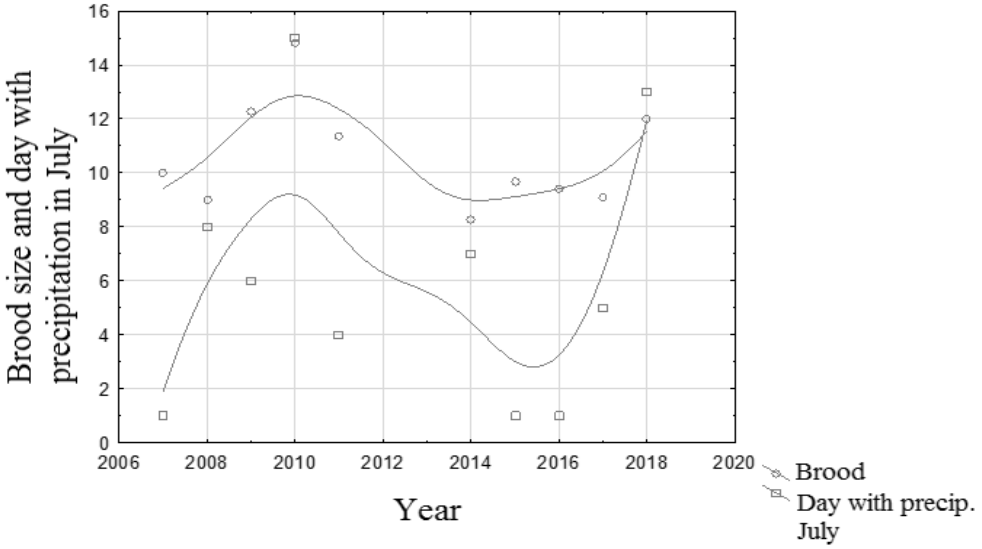

Fig. 4. Brood size vs. day with precipitation July in study area by the study period. (ordinate values are given as distance weighted of least squares).

Table 1. Partial correlation between weather variable and density and brood size.

Variables	Density		Brood	
	r	p	r	p
T May	0.07	0.85	0.30	0.39
T June	0.15	0.68	-0.08	0.82
T July	-0.21	0.56	-0.42	0.23
Precip. May	-0.34	0.33	-0.60	0.07
Precip. June	-0.16	0.67	-0.23	0.53
Precip. July	0.37	0.29	0.49	0.15
T Jan	-0.51	0.14	-0.15	0.68
T Feb.	-0.32	0.36	-0.39	0.26
T Mar.	-0.17	0.65	-0.79	0.06
Precip. Jan	-0.27	0.44	-0.02	0.96
Precip. Feb	0.18	0.62	0.69	0.06
Precip. Mar.	-0.12	0.75	-0.11	0.77

min. T Jan.	-0.50	0.14	-0.13	0.71
min. T Feb.	-0.25	0.49	-0.14	0.70
min. T Mar.	-0.21	0.57	-0.66	0.07
Day snow Jan	0.34	0.34	0.53	0.12
Day snow Feb.	0.26	0.47	0.94	0.07
Day snow Mar.	0.54	0.11	0.80	0.06
day with prec. may	-0.41	0.24	-0.27	0.46
day with prec. june	0.40	0.25	0.10	0.79
day with prec. july	0.52	0.12	**0.63**	**0.04**

In the past, the Grey Partridge was a numerous species in Bulgaria. In the 1930s, the average annual shooting ranged between 225 and 230 thousand individuals. In 1942-43 it dropped sharply to less than 50 thousand birds per year (BOTEV, 1962). These data show a decrease in the population in the middle of the past century. This reduction has been sustained since 1985, and the latest data from the beginning of the new century report decreasing trends of the population (GERASIMOV & MITEV, 2007).

The breeding density in this study is lower than the one estimated in parts of Northern Bulgaria in the middle of the past century – 14.4 ind./km^2 (BOTEV, 1962). The same author reported a density of single pairs/km^2 in single cases in Northern Bulgaria. The breeding density in the Sakar Mountain is even lower than the one established in some parts of the Thracian Plain (MILANOV, 1991, pers. comm; ANGELOV, 2017, pers. comm.).

The density of the Grey Partridge in the present study is lower than the average observed in a number of European countries (KUGELSCHAFTER & RICHARZ, 2001; SÁLEK *et al.*, 2004; BRO *et al.*, 2005; ROSIN *et al.*, 2010; BRO *et al.*, 2014) but it is close to the one estimated in the mountainous habitats of Greece (ALEXIOU *et al.*, 2005) and some parts of the Czech Republic (SÁLEK *et al.*, 2002), Poland (PANEK, 2006), and Spain (PURROY & PURROY, 2016) as well as certain regions of France (BRO *et al.*, 2005). The dynamics of the breeding density is similar to the one established by earlier studies (POTTS & AEBISHER, 1994) and no decreasing trends have been observed within the survey period. The annual breeding density is influenced by the brood size in the previous year, similar to the results reported by ROSIN *et al.*, (2010). Compared to the neighboring regions of Bulgaria, the density of the Grey Partridge during this study in September yielded results close to the ones in several mountains in Greece (ALEXIOU *et al.*, 2005) and lower than the ones in certain areas of Macedonia (MALETIC *et al.*, 2013). Probably

this is due to the capacity of the habitat in the Sakar Mountain.

The brood size (11.9) is similar to the one in Northern Bulgaria from the middle of the past century – 7 young/ad. ind. (BOTEV, 1962) but it is higher than the one reported for the Thracian Plain (Central South Bulgaria) - 7.3 young/ad. pair (ANGELOV, 2017, perss. com.). The large brood size in this study probably results from the lower breeding density. The reproductive success is negatively correlated with the spring density (MONTAGNA & MERIGGI, 1991). The reproductive success in this study is 2.97 young per adult partridge and is similar to the one established in South Bulgaria in the 1990s (MILANOV, 1991, perss. com.). Despite the relatively high brood size and reproductive success, the breeding density of the Grey Partridge remained relatively low during the survey period. This result could be due to differences in the habitat quality or more significant losses leading to a lower density of partridges.

Breeding success and BPR fall within the range of those established in other European populations (MERIGGI *et al.*, 1992; PANEK, 1997; PANEK, 2006; ROSIN *et al.*, 2010). In the present study, there is no relation between BPR and the population variables. In other similar studies, BPR varies between 28 and 75% and decreases with the increase in population density (PANEK, 1997). BPR is smaller in hand-reared partridges than in the present study and bears no relationship to breeding density (ROSIN *et al.*, 2010). In our study, there are no large differences in the breeding density during the study period, which is the probable reason for the lack of any significant relations between BPR and breeding density. Over the past 2 years, the breeding density has been higher, which could lead to a decrease of BPR in the future.

Weather elements can have a direct and indirect impact on the populations of hand-reared birds (ROSIN *et al.*, 2010). Heavy rains may have an adverse impact on the clutch size and chick survival rate. Females often abandon their nests after torrential rains and strong winds, especially when they are nesting in cereals (BRO *et al.*, 2000). Heavy winters and cold springs can reduce the spring population density (MONTAGNA & MERIGGI, 1991; ROTELLA *et al.*, 1996; GABBERT *et al.*, 1999). Cold weather in spring may slow the growth of vegetation and lead to poor hiding of nests and large losses (MERIGGI *et al.*, 1990). During our study, no extreme amounts of precipitation were reported. The location of the Sakar Mountain determines the minimum precipitation in spring and summer as well as the high summer temperatures (KOPRALEV, 2002). In some Mediterranean countries, high summer temperatures tend to reduce breeding success and increase the risk of predation in adult birds (VILLANÙA *et al.*, 2005). The frequent rainfall in small amounts in spring and summer contributes to the growth of the grass and the better hiding of the nests. In addition, hatchlings' shelters are increasing, which is the possible cause of a relation between brood size and the number of days of precipitation in July. Although a number of studies on the Grey Partridge point at winter and spring temperatures, rainfall and other factors affecting the demographic parameters of the Grey Partridge (MERIGGI *et al.*, 1990; MONTAGNA & MERIGGI, 1991; ROTELLA *et al.*, 1996; GABBERT *et al.*, 1999; BRO *et al.*, 2000; ROSIN *et al.*, 2010), we have not found any other weather elements impacting the Grey Partridge population. This is due to the relatively warm winters and high average temperatures in the studied area, or the influence of other factors affecting the Grey Partridge populations.

The relationship between brood size and the percentage of sunflower crops is probably associated with the availability of shelter and better food supply in August and September compared to other parts of the habitats. The agricultural structure has a significant impact on the real growth rate of Grey Partridge populations. The reproductive success rises with an increase of spring crops and autumn wheat in the partridges' habitats (MILANOV, 1991, perss.

com). Turkey-corn and sunflower crops were used as shelters by partridges in Northern Bulgaria (BOTEV, 1962). Cereal crops are harvested in August and September, at which time the hay-mowed meadows are low in vegetation and a large part of the habitats are open. The sunflower crops remain one of the areas offering shelter and food in the study area.

There are two possible approaches for analyzing the impact of habitats on the demographic parameters of grey partridges. The brood size and reproductive success are directly related to the breeding density (MONTAGNA & MERIGGI, 1991; PANEK, 1997; BRO *et al.*, 2003). A decrease in breeding success with increased breeding density is a result of competition for limited food resources or nesting grounds. Lower brood size and reproductive success may also be due to the use of lower quality habitats. Both possible approaches have been described with regard to bird populations (RODENHOUSE *et al.*, 1997; FERNANDEZ *et al.*, 1998; MILCHEV & KOVACHEV, 2000; KRÜGER & LINDSTRÖM, 2001; BRO *et al.*, 2003). The arable land has a relatively small area of mosaic distribution in the surveyed area (rarely exceeding 200 dka) and there are stripes of hedgerows. The percentage of sunflower crops is positively correlated with the cereal crops but the relationship was not significant ($r=0.1$, $p=0.4$). Sunflower crops are negatively correlated with the percentage of pastures ($r=-0.61$, $p<0.001$). Probably the sunflower crops are good sites in habitats in the summer.

In some studies the breeding density is in a positive correlation with the percentage of vineyards, shrubs, hedgerows, wood strips, small orchards among arable land and habitat heterogeneity (MERIGGI *et al.*, 1992; PANEK & KAMIENIARZ, 2000). In our study, the percentage of arable land is relatively constant, while at the same time the breeding density varies within a small interval. This is also the reason why there are no statistically significant dependences and in this case the quality of the habitat allows this population size of Grey Partridges.

The quality of the habitats of hunting species is determined by the Ordinance for inventory and planning in forest areas. The present study is an important step towards the precise estimation of the capacity of Grey Partridge habitats in Bulgaria.

Table 2. Partial correlations between habitat variables, density and brood size.

Variables	Density		Brood	
	r	p	r	p
cereal crop	0.64	0.06	0.53	0.09
sunflower	0.13	0.21	0.32	0.02
rapiseed	0.88	0.06	0.14	0.21
orchard	0.81	0.06	0.31	0.14
tobacco	0.49	0.12	0.18	0.29
shrubs	0.15	0.20	0.80	0.06
meadows	0.47	0.13	0.72	0.06
pastures	0.50	0.09	0.19	0.18

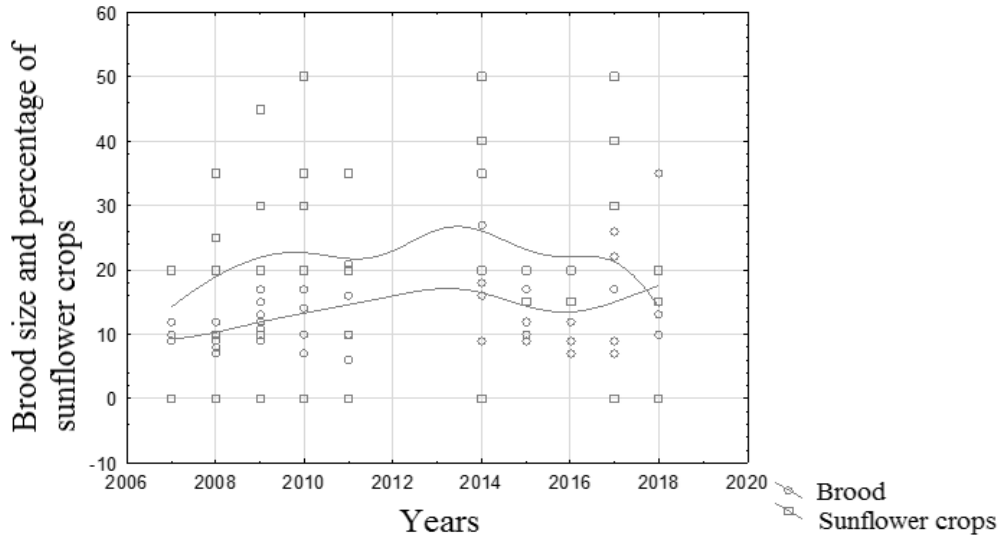

Fig. 5. Brood size vs. sunflower crops coverage in study transects by years (ordinate values are given as distance weighted of least squares).

Conclusions

The density of the Grey Partridge in the present study is lower than the average observed in a number of European countries. The dynamics of the breeding density is similar to the one established by earlier studies and no decreasing trends have been observed within the survey period. The annual breeding density is influenced by the brood size in the previous year. The large brood size in this study probably results from the lower breeding density. In the present study, there is no relation between brood production rate and the population variables. Although a number of studies on the Grey Partridge point at winter and spring temperatures, rainfall and other factors affecting the demographic parameters of the species, we have not found any other weather elements impacting the Grey Partridge population. The relationship between brood size and the percentage of sunflower crops is probably associated with the availability of shelter and better food supply in August and September compared to other parts of the habitats. The agricultural structure has a significant impact on the real growth rate of Grey Partridge populations.

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Received: 12.02.2019
Accepted: 15.04.2019

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University of Plovdiv Publishing House