Effect of supplementary food on age ratios of European turtle doves (*Streptopelia turtur* L.)

G. Rocha & P. Quillfeldt

Rocha, G. & Quillfeldt, P., 2015. Effect of supplementary food on age ratios of European turtle doves (*Streptopelia turtur* L.). *Animal Biodiversity and Conservation*, 38.1: 11–21.

Abstract

*Effect of supplementary food on age ratios of European turtle doves (*Streptopelia turtur *L.).*— Many farmland birds have difficulties finding sufficient food in intensely managed agricultural ecosystems, and in more extensively worked landscapes they are often attracted to human–induced dietary sources. European turtle doves *Streptopelia turtur* feed on seeds collected on the ground, and are readily attracted to supplementary provided grain at feeding stations. Supplementary feeding is a common management practice on hunting estates around the world. This study was conducted in 40 hunting estates located in central west Spain: 20 sites where supplementary food was provided to attract turtle doves and 20 control sites without feeding stations. At sites with supplemental feeding, the field age ratio was 20% higher and the hunted age ratio was 33% higher than at control sites, indicating a positive effect of the food supplementation of the breeding success around supplemented sites. Both the amount of food provided per day and the amount of time where supplemental food was given (20–120 days) were positively correlated with the field age ratio and, less strongly, with the hunted age ratio. These data suggest that providing extra food can increase the breeding success of this species when the amount provided is sufficiently large and when supplementary food is provided early in the breeding season. However, hunting pressure was also higher at supplemented sites. Future studies should therefore closely monitor the positive and negative effects in order to ascertain which management practices will ensure the viability of these important European turtle dove populations.

Key words: Age–ratio, Hunting, Management, *Streptopelia turtur,* Food supplementation

Resumen

*Efecto de la alimentación complementaria en la razón de edad de la tórtola europea (*Streptopelia turtur *L.).*— Son numerosas las aves de los hábitats agrícolas que tienen dificultades para encontrar suficiente alimento en los ecosistemas agrícolas intensivos y que, en los hábitats explotados de forma más extensiva, suelen ser atraídas por las fuentes antrópicas de alimento. La tórtola europea, *Streptopelia turtur*, se alimenta de semillas que se hallan en el suelo y es atraída inmediatamente por los cereales que se aportan como complemento a los comederos. El aporte complementario de alimento es una práctica habitual en la gestión de los cotos de caza de todo el mundo. Este estudio se realizó en 40 cotos de caza ubicados en el centro y el oeste de España: 20 zonas en las que se aportó alimentación complementaria para atraer a las tórtolas y 20 zonas de control sin comederos. En las zonas con alimentación complementaria, las razones de edad en el campo y en las aves cazadas fueron, respectivamente, un 20% y un 33% más elevadas que en las zonas de control, lo que indica que la alimentación complementaria tiene un efecto positivo en el éxito reproductivo en torno a las zonas con aporte de alimento complementario. Tanto la cantidad de alimento suministrado por día como el período en el que se aportó (20-120 días) se correlacionaron positivamente con la razón de edad en el campo y, con menos intensidad, con la razón de edad en las aves cazadas. Estos datos sugieren que el suministro de alimento extra puede aumentar el éxito reproductivo de esta especie si la cantidad aportada es suficientemente abundante y si se empieza a proporcionar a principios de la temporada de cría. No obstante, la presión cinegética también fue mayor en las zonas con aporte de alimento complementario, por lo que sería necesario analizar minuciosamente los efectos positivos y negativos de dicho aporte con vistas a determinar qué prácticas de gestión garantizarán la viabilidad de estas importantes poblaciones de tórtola europea.

ISSN: 1578–665 X
eISSN: 2014–928 X

Palabras clave: Razón de edad, Caza, Gestión, *Streptopelia turtur*, Alimento complementario

Received: 24 VI 14; Conditional acceptance: 17 X 14; Final acceptance: 18 I 15

Gregorio Rocha, Dept. of Agro–forestry Engineering, Univ. of Extremadura, Avda. Virgen del Puerto 2, 10600 Plasencia, Cáceres, Spain.– Petra Quillfeldt, Inst. für Tierökologie und Spezielle Zoologie, Justus Liebig Univ. Gießen, Heinrich–Buff–Ring 38, 35392 Gießen (Germany).

Corresponding author: Gregorio Rocha. E–mail: gregorio@unex.es

Introduction

The availability of food is a principal parameter determining breeding success in animals. The lack of an adequate food supply often leads to birds abandoning their brood, brood reduction, and poorer condition of offspring (Martin, 1987). Food supplementation therefore has consistent effects on parameters of breeding success in birds, such as earlier laying, larger clutch size, and accelerated population growth (reviews by Boutin, 1990; Schoech & Hahn, 2007). The use of supplemental feeding as a positive tool in species conservation has been consistently recommended (Schoech et al., 2008), although some unwanted effects may appear (Martínez–Abrain & Oro, 2013). In the case of some gallinaceous game species in Europe (pheasant *Phasianus colchicus* and quail *Coturnix coturnix*), supplementary feeding at hunting estates can influence the proportion of juveniles to adults, through an increase in reproductive success (Draycott et al., 2005; Díaz–Fernández et al., 2013). However, this practice may be negative if the hunting bag is not thoroughly controlled, because it can increase the hunting pressure excessively (Rocha & Hidalgo, 2001).

Although the distribution area of European turtle doves *Streptopelia turtur* is wide, they are restricted to warm, lowland areas, which are often agricultural areas (Cramp, 1985). In recent decades, the European turtle dove has experienced a widespread decrease both in population density and in its area of distribution (Tucker & Heath, 1994; Jarry, 1997; Browne et al., 2005). This decline has led to its inclusion as Vulnerable in the Red Book of Vertebrates of Spain (Blanco & González, 1992; Madroño et al., 2004). As a result of this, and being a hunted species in an unfavorable demographic situation, this species is the subject of a management plan by the European Commission (Boutin, 2001; Lutz & Jensen, 2007). On the Iberian peninsula, the breeding population has declined significantly, by 29.3% between 1998 and 2012 (SEO/BirdLife, 2013), and this decline has been particularly marked since 2008.

European turtle doves feed primarily on the seeds of weeds (Murton et al., 1964; Dias & Fontoura, 1996), especially at the start of the breeding season when seeds of cultivated plants are not yet available (Jiménez et al., 1992). Some studies suggested that late in the breeding season cereal seeds become available and then play a larger role (Jimenez et al., 1992; Browne & Aebischer, 2003).

On the Iberian peninsula, the European turtle dove is hunted from the second half of August to the first half of September, *i.e.* the late breeding season and the post–breeding migration. The hunting of this species is carried out using the 'fixed location' method, which takes advantage of birds passing to feeding areas such as crops and natural pastures, where they are shot at by a row of hunters. The European turtle dove plays an important role in Extremadura, where it is considered one of the main game bird species of this hunting season (Hidalgo & Rocha, 2001). However, there are as yet no studies on the economic value of this activity.

Many hunters and estate managers use supplementary food to attract and concentrate the birds (Rocha & Hidalgo, 2001). Such supplementation consists of seed mixes of various oleaginous or leguminous cereals scattered throughout the crops or natural pastures. The feeding stations usually occupy an area of between 0.2 and 5.0 hectares, although they can be larger. Currently, over 70% of the estates that hunt European turtle doves during August–September in Extremadura operate this kind of hunting management (Rocha, own data).

Food supplementation on the hunting estates can start 1 to 4 months before the hunting season (Rocha, own data). At sites with early supplementation, this covers most of the breeding season of the European turtle dove. Thus, food supplementation could influence the population dynamics of this species during the breeding season, including changes in abundance, breeding success, feeding ecology and migratory phenology.

It is known that a greater amount of food available on the estates attracts the European turtle dove since they are killed in greater numbers when extra food is provided (Rocha & Hidalgo, 2002). However, it is unknown to what extent supplemental food affects the productivity of the populations.

The main objectives of this work were to summarize data on quantity and duration of the food supplementation at hunting estates and to study how this game management practice influences reproductive success. Specifically, we tested whether the breeding success of the European turtle doves was influenced by the supplemental feeding at hunting estates by comparing the age ratio of populations of post–breeding aggregations in the second half of August. Observations of age ratios are a widely used method to estimate breeding success in birds (*e.g.,* Wagner & Stokes, 1968; Newton, 2001; Flanders–Wanner et al., 2004; Peery et al., 2007). Although observations of age ratios in the field do not provide a direct measure of productivity, they have proven to be a useful technique because they are relatively easy to apply, yet they avoid time–consuming and potentially harmful nest searches.

Methods

Study species

The European turtle dove is a migratory species that winters in the African Sahel and breeds in large parts of Europe, Asia and North Africa (Cramp, 1985).

In the Iberian peninsula, its main habitats are the areas populated by holm oaks (*Quercus ilex* L.) and cereal cultivation, where they present densities of some 2.3 birds/10 ha (Muñoz–Cobo, 2001). In the central and western part of the Iberian peninsula they nest among small to medium sized oaks, in a mix of natural pasture and cultivated habitats (Peiró, 1990; Rocha & Hidalgo, 2002). In these areas, they can reach densities of up to 10.5/10 ha (Santamaría, 2007). They also inhabit open areas with scattered trees and shrubs, riverine forests and orchards, and they are very scarce in coniferous woodlands, scrubland and all across the thermo–Mediterranean (Díaz et al., 1996). The study area has traditionally been one of the principal nesting territories of the European turtle dove in Spain (Rocha & Hidalgo, 2002).

Study sites

The study area is located in the region of Extremadura, in the central–western Iberian peninsula (fig. 1). This region has a rich biodiversity. More than 30% of the territory is included in the *Natura 2000* ecological network (Fernández, 2004; Junta de Extremadura, 2012) and 80% of the territory is subject to hunting rights (Lázaro, 2004).

The predominant habitat on the hunting estates is the *dehesa*: open managed parkland used for livestock grazing within a savanna–like woodland of evergreen *Quercus* trees, mainly *Q. ilex* (holm oak) and *Q. suber* (cork oak). The *dehesa* is intermixed with cropland and Mediterranean woodland and scrub (Díaz et al., 1997).

The use of feeding stations for hunting had been banned in Extremadura since 2007 (included) (Junta de Extremadura, 1991, 2007, 2008), but not in the surrounding regions. Despite being banned, 62% of estate managers where hunting takes place added supplementary food during the season 2004/2005 (Hidalgo & Rocha, 2006). This hunting management is frequently used because it increases the number of birds hunted (Hidalgo & Rocha, 2001).

During the spring and summer of 2009, 40 hunting estates with *dehesa* habitats were selected throughout the region where the European turtle dove has been hunted traditionally. These estates were split in two groups according to the provision or not of supplemental food. In the first group, hunting management involved consistently adding supplementary food year after year, dispersed throughout the crops and natural pastures (group with extra food added). Supplemental food was composed of mixtures of crop seeds: wheat (*Triticum aestivum* L.), sunflower (*Helianthus annuus* L.) and vetch (*Vicia sativa* L.). The estates with feeding stations always provided the same amount of food every year, and for the same duration of time. In the control group, no supplementary food was added to the environment and the birds fed on seeds from crops and natural pastureland (group without extra food added).

The size of the estates did not differ between supplemented and control sites (mean ± sd: 661.5 ± 132.9 ha; *t*–test: t_{38} = –0.84, P = 0.41). The mean number of hunters per estate (± sd) was 11.8 ± 2.6, and did not differ between supplemented and control sites (*t*–test: t_{38} = –0.71, P = 0.48). There are no data on movements of turtle doves in Spain, but in two English populations, the mean foraging distances for radio–tagged doves were 450 m and 1,400 m (Browne & Aebischer, 2003). The sites in our study area were over 10 km distant from each other (fig. 1). We thus assume that the population recorded at each site was mainly local.

Data collection

The following data were collected at supplemented sites: the amount of food added (in kilos) and the duration (in days) of the food supplementation until the beginning of the hunt. These data were freely provided by estate staff in charge of the food supplementation. Age ratios were estimated as an indicator of the breeding success by counting the number of young birds observed after the breeding season (in the second half of August), compared to the total number of adults (young/adults), just before the beginning of the migratory season (Cramp, 1985).

Post–breeding age ratios are a common tool to estimate the reproductive productivity in monitoring programmes. Age ratios can be obtained easily and economically, while avoiding biases due to disturbance at the nest in sensitive species such as turtle doves. In the present study, age ratios were measured using two different methods based on the proportion of young to adult birds among live birds observed in the field (termed 'field age ratio') and birds killed during the hunt (termed 'hunted age ratio'), respectively.

The field age ratio was obtained by observation, from a hidden fixed position, of live birds perched, where the difference between young and adult birds could be directly ascertained as they gathered in post–reproduction groups or 'aggregates'. Field age ratios have been successfully used in work on this species in Andalucía (SEO/BirdLife, 2002). Field age ratios are important parameters when trapping methods influence the age ratio sample of the population (*e.g.,* Domènech & Senar, 1997). Hunted age ratios of turtle doves were determined in Morocco, where they were found to depend largely on reproductive productivity and hunting pressure (Hanane, 2009). To determine the 'field age ratio', we conducted observations once in each estate, from between 2 and 10 days before the hunt started. Post–reproduction groups were observed and counted in all 20 supplemented sites. However, in the control group, data were obtained from 11 of the 20 sites because post–reproduction groups were not located in the remaining nine estates. On the 11 estates, post–reproduction groups were found at feeding sites such as harvested fields, where food can be found but is not as concentrated as at supplemented sites. On observation days, one person per estate occupied an observation point (hidden) before the birds began to arrive (at dawn). This point was located near the feeding area, so that the birds were seen at a distance of 20–40 m. The observer remained there for 30 min recording the birds that came with a telescope 20–40 x, differentiating young and adult birds by identifying the presence or absence of the 'collar'. The 'collar' is a distinctive feature of the neck plumage of adult European turtle doves. It is composed of feathers that form black and white bands (Cramp 1985; Sáenz de Buruaga et al., 2001). Young European turtle doves usually have no collar, although some juveniles birds hatched from early broods may have a partial collar. Thus, birds with partial collars were always considered juveniles. Double counting was avoided by using the data of the birds recorded in the peak of simultaneous concentration. A total of 982 birds were observed (773 at supplemented sites and 209 at control sites).

The 'hunted age ratio' was determined at supplemented and control sites during the first hunting weekend in 2009 (22–23 August), in order to ensure that all of the hunted individuals belonged to the local

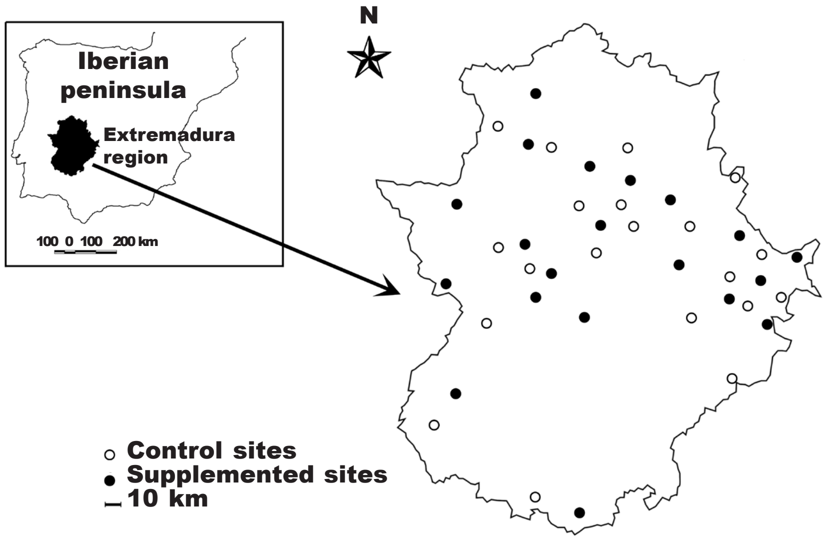

Fig. 1. Location of the region of Extremadura on the Iberian peninsula and distribution of the estates.

Fig. 1. Localización de la región de Extremadura en la península ibérica y distribución de los cotos.

breeding population and not to passing migratory populations which appear from the north from September onwards and mix with the local populations (Fernández & Camacho, 1989; Rocha & Hidalgo, 2002).

Each estate was visited on the day of the hunt in order to count the young and adult birds shot, as well as the number of hunters involved. The ratio of young to adult birds, obtained at the end of the hunt, is a simple parameter used previously on the Iberian peninsula (Gutiérrez, 2001). In total, 4,132 killed birds were observed (3,154 in the group with extra food and 987 in the group without extra food).

Data analysis

Data analyses were carried out in the R environment (R Development Core Team, 2013). Normality was tested using Kologorov–Smirnoff tests and Q–Q plots. Means were compared using unpaired Student's *t*–tests. General linear models were used to analyze the influence of the quantity of supplementary food and the time it was available on the field on hunted age ratios. This relationship was visualised with contour plots produced with the function vis.gam from the R package mgcv. A general lineal model was used to compare the correlations between field and hunted age ratios between the supplemented and control sites, by defining hunted age ratio as dependent, supplement (yes/no) as factorial predictor and field age ratio as covariate. The models were initially carried out with two–way interaction terms, but these were removed as they did not reach statistical significance. We used Mann Whitney *U*–tests to compare the number of turtle doves killed per hunter and day on the estates with extra food and those without extra food. All tests were two–tailed.

Results

Differences between supplemented sites and control sites

The mean field age ratio (fig. 2) based on the observation of post–breeding aggregates was significantly higher at supplemented sites (mean ± sd: 1.61 ± 0.19) than in control sites (1.43 ± 0.27; *t*–test: $t_{29} = -2.13$, $P = 0.04$). The mean hunted age ratio at supplemented sites (1.84 ± 0.22) was also significantly higher (*t*–test: $t_{38} = -6.83$, $P < 0.001$) than at control sites (1.38 ± 0.19).

The hunted age ratio was correlated with the field age ratio, but the regression functions differed between supplemented sites and controls (fig. 3; linear model: $F_{1,28} = 21.8$, $P < 0.001$; effect of field age ratio: $F_{1,28} = 7.9$, $P = 0.009$).

At control sites, the hunted age ratio did not vary significantly from that obtained from the killed bird count (paired *t*–test: $t_{10} = 0.8$, $P = 0.422$). At supplemented sites, in contrast, the field age ratio was lower than the hunted age ratio (1.61 ± 0.19 *vs.* 1.84 ± 0.22; paired *t*–test: $t_{19} = -3.52$, $P < 0.001$).

The total number of birds killed per hunter varied significantly between groups (Mann–Whitney *U*–test: $Z = -4.17$, $P < 0.001$). At supplemented sites, an average of 12.74 ± 9.52 European turtle doves per hunter per day were killed (n = 3,154), while the average was 3.91 ± 4.54 at control sites (n = 978).

Age ratio variation within supplemented sites

The quantity of supplementary food added annually ranged from a minimum of 300 kg to a maximum of

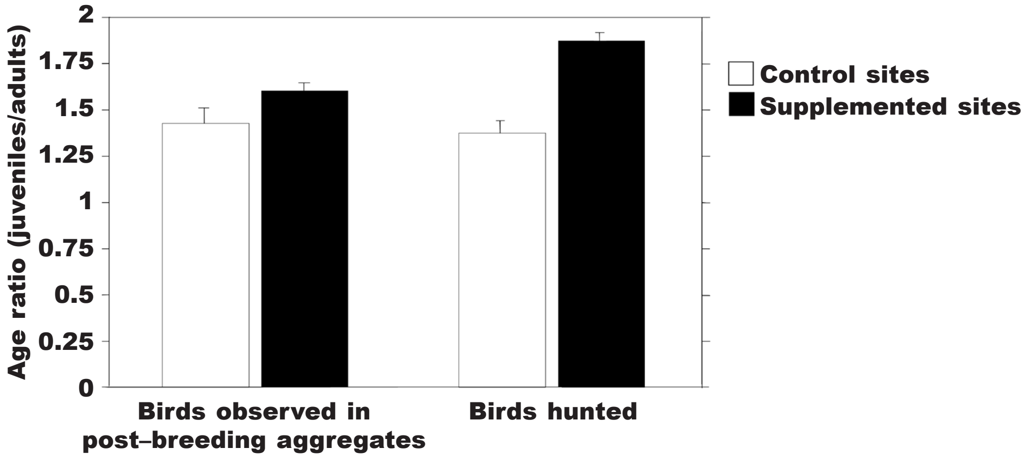

Fig. 2. Field age ratio (observed in post–reproduction aggregates) and hunted age ratio in estates with food supplementation and control sites in Extremadura, Spain, in late August 2009 (mean and standard error).

Fig. 2. Razón de edad obtenida en el campo (observada en agregados posreproductores) y razón de edad en las aves cazadas, en cotos con aporte de alimento complementario y en las zonas de control en Extremadura, en España, a finales de agosto de 2009 (media y error estándar).

1,300 kg (mean ± sd: 785 ± 275 kg). The contribution of food, from when it was added until the beginning of the hunt, had a range of 100 days, with a minimum of 20 to a maximum of 120 days (72 ± 30 days). The amount of food supplied was greater when food was supplied over a longer time ($R^2 = 0.567$, $P < 0.001$). Therefore, daily supplement rates were calculated and included as predictor variables in GLMs.

The daily amount of food provided and the duration of the supplementation correlated positively with the field and hunted age ratios (table 1, fig. 4). Together, the amount and duration of the supplementation explained 47 and 31% of the variation in field and hunted age ratios, respectively (fig. 4). The correlation coefficient was higher for field age ratios ($R^2 = 0.408$) than for hunted age ratios ($R^2 = 0.227$).

Discussion

The present data suggested a positive influence of food supplementation on the number of juveniles present at the end of the breeding season, suggesting a higher breeding success. A higher percentage of juveniles hunted, compared to field observations close–by, suggests that juveniles behave less cautiously at feeding sites or have a slower escape response than the more experienced adult birds.

Effects of food supplementation on post–breeding age ratios

The effect of artificial feeding on the turtle dove age ratio had previously been investigated over a longer period including postnuptial migration (Rocha & Hidalgo, 2001). In the present study, in contrast, age ratio was analyzed before the onset of migration.

The hunted and field age ratios at supplemented sites in the present study were higher than in Andalusia, where they ranged from 1.15 to 1.25 (Gutiérrez, 2001). This could be explained by the positive effect of the increased availability of food, availability being a limiting factor in the dry ecosystems of these latitudes from May to September, *i.e.* during the breeding season. In this respect, Rocha & Hidalgo (2002) found that European turtle doves largely depend on the *dehesa* zones of cereal cultivation during the breeding season. This type of habitat is highly suitable because it provides abundant food and quiet and protected nest sites for the birds (Santamaria, 2007). In recent decades, the acreage used in the region for cereal cultivation has decreased notably (*e.g.,* 1,500,000 ha since the 1980s across Spain; Olona, 2014), while cereal production has increased due to the agricultural intensification put in place by the Common Agricultural Policy of the European Union (Alés, 1996; Naredo, 1996; Robson, 1997). The loss has especially affected less intensively managed and marginal areas, which were a very suitable habitat for European turtle doves. Therefore, the increased age ratio of the European turtle dove in areas where supplementary food was added could be considered a response to the lack of naturally available food due to the scarcity of crops.

Several studies highlight the susceptibility of this species to agricultural changes (increased intensity, changes in crops, pesticide use, etc.), both in breeding areas and wintering quarters (Browne & Aebischer, 2004; Browne et al., 2005; Wilson & Cresswell, 2006; Eraud et al., 2009). Supplementary feeding could be used as a management tool to contribute to mitiga-

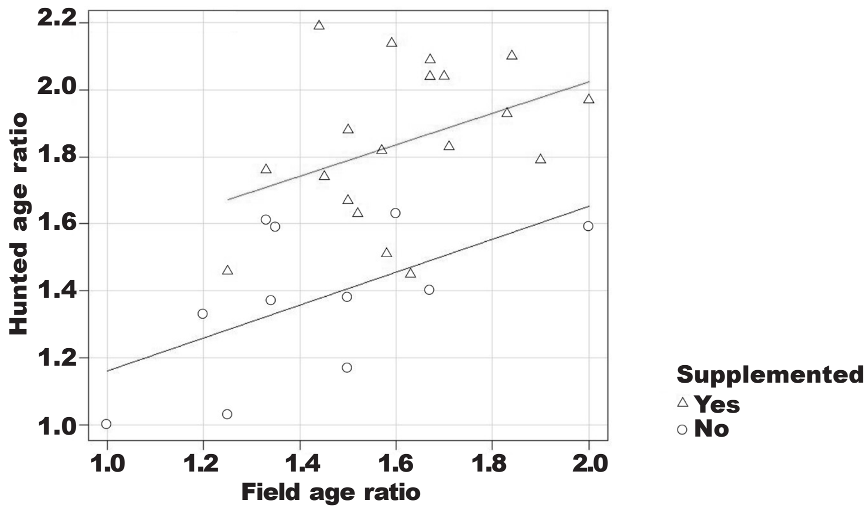

Fig. 3. Relationship between field age ratio and hunted age ratio of European turtle doves in 20 estates with food supplementation and 11 control sites in Extremadura, Spain, in late August 2009. No field age ratio could be established for the remaining nine control sites because no post–breeding aggregations were located at these sites in the days preceding the late–August hunt.

Fig. 3. Relación entre la razón de edad en el campo y en las aves cazadas de tórtola europea en 20 cotos con aporte de alimento complementario y 11 zonas de control en Extremadura, en España, a finales de agosto de 2009. No se pudieron obtener las razones de edad en el campo para las nueve zonas de control restantes porque no se localizaron agregados postreprodutores en estos sitios en los días precedentes a la caza de finales de agosto.

ting the decline of biodiversity produced by recent changes in European agricultural and livestock uses (Potts, 1997; Krebs et al., 1999; Donald et al., 2000). Likewise, planting cereal crops has been proposed as a management tool in addition to supplementary food supply, both in spring and in summer, in order to guarantee sufficient food during the breeding season and to increase productivity of the species (Rocha, 2007; Gutiérrez–Bermejo, 2009; Rocha et al., 2009). The survival rate during the first year of life of this species is very low, around 36% (Calladine et al., 1997); therefore, such measures would be effective provided they are not over–compensated by too high a hunting pressure. Mortality from hunting on breeding populations should not exceed the breeding capacity of the species. This would ensure the sustainability of the population in spite of hunting, since it would allow the annual return of birds to their breeding quarters because of the possible breeding philopatry of this species (Cramp, 1985).

Field *vs.* hunted age ratio

Regarding the methodology used to assess age ratios, the field and hunted age ratios did not differ significantly at control plots, while at supplemented sites, a greater proportion of young birds were counted when using data from the hunt as opposed to data from direct observation. Thus, supplementation resulted in about 20% higher field age ratios, but up to 33% higher hunted age ratios. One plausible explanation for these differences may lie in the poorer escape response and lack of experience of the juveniles,

Table 1. Influence of food supplementation on the field and hunted age ratio, assessed using generalized linear models.

Tabla 1. Influencia del aporte de alimento complementario en la razón de edad en el campo y en las aves cazadas, utilizando modelos lineales generalizados.

GLM predictor	$F_{1,19}$	t	P
Dependent: field age ratio			
Days supplemented	15.1	5.0	0.001
Supplement/day (kg)	6.4	2.5	0.022
Dependent: hunted age ratio			
Days supplemented	4.7	2.2	0.043
Supplement/day (kg)	7.2	2.7	0.016

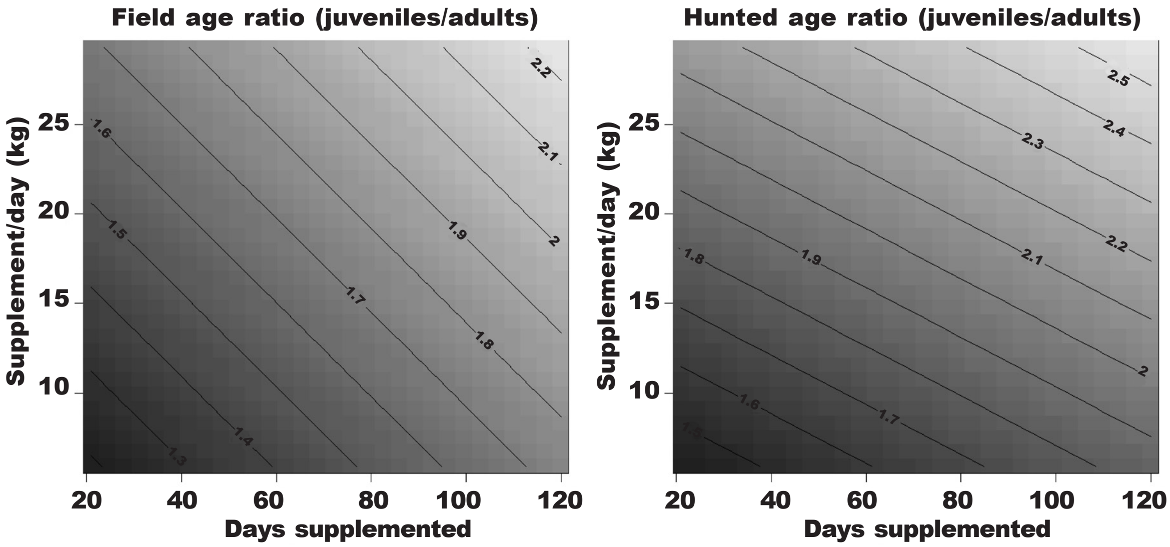

Fig. 4. Contour plot of fitted values for the age ratios.

Fig. 4. Gráfico de los valores ajustados para las razones de edad.

which are not so skilled in flight and encounter the shots of the hunters for the first time. Thus, juveniles would be killed more easily than the adults, artificially raising the ratio of young to adult birds. However, in areas with supplemental feeding, an increased hunting pressure could also partially explain the results here presented. Since the hunted age ratio was consistently larger than the field age ratio (a more reliable but more time–consuming method), an adjustment factor could be established to estimate breeding success from hunting bags. According to the present data of supplemented sites, hunted age ratios should be adjusted by a factor of 0.87 to obtain values similar to field age ratios. This correction factor would be useful for future studies.

A previous study in Extremadura reported a higher proportion of young to adult birds killed on estates with supplementary food than in control sites during the migratory period (Rocha & Hidalgo, 2001). The larger proportion of young birds shot at supplemented sites might have a negative effect on the renewal of the population, leading to an ageing population and therefore the disappearance of breeding populations in the medium to long term (Rocha & Hidalgo, 2001).

At 11 control sites, a total of 121 juveniles and 81 adults were observed (a mean of 11.0 juveniles and 8.0 adults per estate). In comparison, a total of 477 juveniles and 296 adults were observed at 20 supplemented sites (a mean of 23.9 juveniles and 14.8 adults per estate). These observation numbers are 2.2 times higher on supplemented sites for juveniles and 1.9 times higher for adults, suggesting a positive effect on breeding turtle dove populations.

However, this positive effect would be counteracted if the hunting pressure at the supplemented estates was even higher in relative terms. At the 11 control sites with observation data, a total of 410 juveniles and 281 adults were hunted (a mean of 37.3 juveniles and 25.5 adults per estate). In comparison, a total of 2021 juveniles and 1,133 adults were observed at 20 supplemented sites (a mean of 101.1 juveniles and 56.7 adults per estate). These numbers for the hunting pressure were 2.7 times higher on supplemented sites for juveniles and 2.2 times higher for adults. Based on these numbers, an increase of 2.2 (positive effect of supplementary feeding) would be counteracted by a decrease of 2.7 (negative effect of increased hunting pressure) for juveniles, thus suggesting a stronger negative effect on breeding turtle dove populations than the gain by supplemental feeding. A similar reasoning applies to adults, where an increase of 1.9 (positive effect of supplementary feeding) would be counteracted by a decrease of 2.2 (negative effect of increased hunting pressure). It has been mentioned in previous studies that increased pressure from hunting could cause serious problems for the species (Lucio & Purroy, 1992; Purroy, 1995, 1997; Rocha, 2007; Gutiérrez–Bermejo, 2009). The present data support this point of view. The average number of birds killed per hunter per day was 3 times higher on supplemented sites than on control sites. Similar figures have been recorded previously in Extremadura, where the average in other years has reached up to 4 times more (Rocha & Hidalgo, 2001). However, our methods (a single observation period per estate) were not ideal, and the relative population numbers given here are therefore tentative and should be monitored more closely to ascertain which of the two opposing effects exerts a greater influence.

Additional factors may also need to be taken into account. For example, the species is also hunted in non–breeding zones, such as the open fields of cereals and sunflowers in the southern half of Extremadura (and other areas of Iberian peninsula), where the European turtle dove is only hunted in migratory passage (Puerta, 2011). A negative effect through overhunting of young birds is expected on the migratory populations from western and central Europe (Rocha & Hidalgo, 2001).

Effects of the annual amount of food added and the duration of its availability

On the estates where a greater amount of extra food was added, a higher age ratio was observed, and this relationship was stronger for the field age ratio than for the hunted age ratio (table 1).

The field age ratio was especially strongly explained by the duration of the addition of food, suggesting that supplementation early in the breeding season had a particularly positive effect on the breeding success. European turtle doves can have up to three successive breeding attempts, and a longer supplementation would thus support early and late breeding attempts alike. In contrast, less variability was explained in the hunting age ratios by the amount of food added. This suggests that more variability in the hunting age ratios was explained by unknown factors that may also impact on the ratio of young to adult birds killed. These unknown factors could be related, among other things, to the variation in the hunting pressure applied on the estates, as occurs with other hunted species, such as the Woodcock (*Scolopax rusticola*) (Fadat, 1981). Hunting pressure may vary from estate to estate depending on variables such as the distance between hunters and the distance from the posts to the feeding zones, (the shorter the distance, the higher the pressure). These distances could facilitate or hinder the capture of young and adult birds, thereby affecting a greater variability in the proportions obtained. A further issue is the variety in the levels of marksmanship (shooting efficiency) between hunters from estate to estate.

By providing food from the beginning of June to the end of August, managers and hunters would assure the existence of food readily available for most of the feeding period of the chicks, from the eggs being hatched to their first flight and their preparation for migration.

These measures could also serve to avoid a possible reduction in the breeding season as occurred in the UK, decreasing the number of broods and causing a drop in the species' reproductive rates (Browne & Aebischer, 2004). These authors consider that agricultural intensification over the second half of the 20th century has caused a clear change in feeding habits of turtle doves by decreasing the availability of wildflower seeds (probably due to extended herbicide use, disappearance of uncultivated land, degraded field edges, etc.). This could be the ultimate reason why food supplementation could be successful in increasing productivity.

Where turtle doves are hunted, however, over–exploitation of the breeding populations of the species is possible despite, or even helped by, supplementation due to its effects as bait. This will depend on the level of extraction that the hunt exerts on the populations: we thus suggest that hunting pressure needs to be carefully controlled for this migratory species due to its vulnerability (Madroño et al., 2004). It is also possible that migratory populations suffer from the negative effects of increased hunting at supplemented sites. In any case, we do not know to what extent the positive effects on productivity can be offset or even reversed by the effect of increased hunting pressure at supplemented sites for both breeding and migratory populations.

To limit the adverse effects of this practice in Extremadura, since 2008, the addition of extra food is permitted only when the hunters are situated more than 200 meters from the edge of the area where the food is added (Junta de Extremadura, 2008). Furthermore, the distance between hunting posts has been limited to 50 meters and a quota of 15 European turtle doves/hunter/day (reduced to 10 European turtle doves/hunter/day since 2011) has been established. In this study we did not analyse the distances between hunters and the distance between hunters and feeding stations but it would be interesting to know if these variables effectively reduce the hunting pressure.

Acknowledgments

We thank the owners of the hunting estates for kindly allowing us to work on their property. We also acknowledge the assistance of the guards and hunters who participated in recording data at the observation posts and on the hunts.

References

Alés, E. E., 1996. Cambios en el paisaje del suroeste de España: nuevos escenarios de conservación para la fauna amenazada. *Quercus,* 121: 35–39.

Blanco, J. C. & González, J. L. (Eds.), 1992. *Libro Rojo de los Vertebrados de España*. ICONA, Madrid.

Boutin, S., 1990. Food supplementation experiments with terrestrial vertebrates: patterns, problems, and the future. *Canadian Journal of Zoology*, 68(2): 203–220.

Boutin, J. M., 2001. Elements for a Turtle Dove (*Streptopelia turtur*) management plan. *Game Wildlife,* 18: 87–112.

Browne, S. J. & Aebischer, N. J., 2003. Habitat use, foraging ecology and diet of Turtle Doves *Streptopelia turtur* in Britain. *Ibis*, 145(4): 572–582.

– 2004. Temporal changes in the breeding ecology of European turtle doves *Streptopelia turtur* in Britain, and implications for conservation. *Ibis,* 146(1): 125–137.

Browne, S. J., Aebischer, N. J. & Crick, H. Q. P., 2005. Breeding ecology of Turtle Doves *Streptopelia turtur* in Britain during the period 1941–2000: an analysis

of BTO nest record cards. *Bird Study*, 52: 1–9.
Calladine, J. R., Buner, F. & Aebischer, N. J., 1997. The summer ecology and habitat use of the Turtle Dove: A pilot study. *English Nature Research Reports*, 219: 87.
Cramp, S. (Ed.)., 1985. *The birds of the western Paleartic. 4*. Oxford University Press, Oxford.
Dias S., Fontoura A. P., 1996. A dieta estival da rôla-brava (*Streptopelia turtur*) no sul de Portugal. *Revista Florestal,* 9: 227–241.
Díaz, M., Asensio, B. & Tellería, J. L., 1996. *Aves Ibéricas. I No Paseriformes (*J. M. Reyero Ed.). Madrid.
Díaz, M., Campos, P. & Pulido, F. J., 1997. The Spanish dehesas: a diversity in land–use and wildlife. In: *Farming and Birds in Europe. The Common Agricultural Policy and its Implications for Bird Conservation*: 178–209 (D. J. Pain & M. W. Pienkowski, Eds.). Academic Press, London.
Díaz–Fernández, S., Arroyo, B., Casas, F., Martinez–Haro, M. & Viñuela, J., 2013. Effect of Game Management on Wild Red–Legged Partridge Abundance. *PLoS ONE*, 8(6): e66671.
Domènech, J. & Senar, J. C., 1997. Trapping methods can bias age ratio in samples of passerine populations. *Bird Study*, 44(3): 348–354.
Donald, P. F., Green, R. E. & Heath, F., 2000. Agricultural intensification and the collapse of Europe's farmland bird populations. *Proceedings of the Royal Society London*, 268: 25–29.
Draycott, R. A. H., Woodburn, M. I. A., Carroll, J. P. & Sage, R. B., 2005. Effects of spring supplementary feeding on population density and breeding success of released pheasants *Phasianus colchicus* in Britain. *Wildlife Biology*, 11: 177–182.
Eraud, C., Boutin, J. M., Riviere, M., Brun, J., Barbraud, C. & Lormee, H., 2009. Survival of Turtle Doves *Streptopelia turtur* in relation to western Africa environmental conditions. *Ibis*, 151: 186–190.
Fadat, C., 1981. Age ratio des tableaux de chasse de bécasses (*Scolopax rusticola*). Signification biologique et utilisation pour la bonne gestion des populations bécassières. *Bull. Mens. ONC. No. Sp. Scien. Techn.,* Nov. 1981*:* 141–172.
Flanders–Wanner, B. L., White, G. C. & Mcdaniel, L. L., 2004. Validity of prairie grouse harvest–age ratios as production indices. *Journal of Wildlife Management*, 68(4): 1088–1094.
Fernández, A., 2004. La Red Natura 2000 en Extremadura. *Foresta*, 27: 89–99.
Fernández, L. & Camacho, M., 1989. Determinación de status de la Tórtola Común *Streptopelia turtur*. ICONA, Informe inédito, Madrid.
Gutiérrez, J. E., 2001. Les populations de tourterelles des bois en Andalusie. *Faune Sauvage*, 253: 36–43.
Gutiérrez–Bermejo, L. F., 2009. Tórtolas, causas del declive y cómo gestionarlas. *Trofeo, caza y conservación*, 470: 42–47.
Hanane, S., 2009. Variabilité spatio–temporelle des âges ratios chez la Tourterelle des bois *Streptopelia turtur* dans les plaines du Souss et du Tadla (Maroc). *Go–South Bull*., 6: 124–127.
Hidalgo, S. J. & Rocha G., 2001. Valoración de la presión cinegética sobre la Tórtola Común en Extremadura. *Naturzale*, 16: 157–171.
– 2006. *Seguimiento de la actividad cinegética sobre la tórtola común en la Media Veda de los años 2005 y 2006.* Junta de Extremadura, Informe Técnico, Mérida.
Jarry, G., 1997. Turtle Dove *Streptopelia turtur*. In: *The EBCC Atlas of European Breeding Birds: Their Distribution and Abundance*: 390–391 (W. J. M. Hagemeijer & M. J. Blair, Eds.). T and AD Poyser, London, UK.
Jiménez, R. Hodar, J. A., & Camacho, I., 1992. La alimentación estival de la Tórtola Común *Streptopelia turtur* en el sur de España. *Gibier Faune Sauvage*, 9: 119-126.
Junta de Extremadura, 1991. Ley 8/1990, de 21 de diciembre, de Caza de Extremadura. *Diario Oficial de Extremadura (14–1–1991)*, 2: 1–28.
– 2007. Orden de 14 de junio de 2007 por la que se establecen los períodos hábiles de caza durante la temporada 2007/2008 y otras reglamentaciones especiales para la conservación de la fauna silvestre de la Comunidad Autónoma de Extremadura. *Diario Oficial de Extremadura (23–6–2007)*, 72: 11162–11182.
– 2008. Orden de 17 de julio de 2008 por la que se establecen los periodos hábiles de caza durante la temporada 2008/2009 y otras reglamentaciones especiales para la conservación de la fauna silvestre de la Comunidad Autónoma de Extremadura. *Diario Oficial de Extremadura (18–7–2008)*, 139: 19700–19732.
– 2012. Superficie de las áreas protegidas de Extremadura. http://www.extremambiente.es. (Accessed on 23 June 2014).
Krebs, J. R., Wilson, J. D., Bradbury, R. B. & Siriwardena, G. M., 1999. The second silent spring? *Nature*, 400: 611–612.
Lázaro, I., 2004. La caza en Extremadura. *Foresta*, 27: 144–151.
Lucio, A. & Purroy, F. J., 1992. Caza y conservación de aves en España. *Ardeola*, 39(2): 85–89.
Lutz, M. & Jensen, F. P., 2007. Management Plan for Turtle Dove *Streptopelia turtur*, 2007–2009. European Commission. *Office for Official Publications of the European Communities*, Luxembourg. http://ec.europa.eu/environment/nature/conservation/wildbirds/hunting/docs/turtle_dove.pdf. (Accessed on 23 June 2014).
Madroño, A., González, C. & Atienza, J. C. (Eds.), 2004. *Libro Rojo de las Aves de España*. Dirección General para la Biodiversidad, SEO/BirdLife, Madrid.
Martin, T. E., 1987. Food as a limit on breeding birds: a life–history perspective. *Annual Review of Ecology and Systematics*, 18: 453–487.
Martínez–Abraín, A. & Oro, D., 2013. Preventing the development of dogmatic approaches in conservation biology: A review. *Biological Conservation*, 159: 539–547.
Muñoz–Cobo, J., 2001. Tórtola Común (*Streptopelia turtur*). In: *Libro Rojo de los Vertebrados Amenazados de Andalucía* (A. Franco & M. Rodríguez (Coord.). Consejería de Medio Ambiente, Junta de Andalucía, Sevilla.

Murton, R. K., Westwood, N. J. & Isaacson, A. J., 1964. The feeding habits of the Wood Pigeons *Columba palumbus*, Stock Dove *Columba oenas* and Turtle Dove *Streptopelia turtur*. *Ibis*, 106: 174–188.
Naredo, J. M., 1996. *La evolución de la Agricultura en España (1940–1990)*. Universidad de Granada, Granada.
Newton, I., 2001. An alternative approach to the measurement of seasonal trends in bird breeding success: a case study of the bullfinch *Pyrrhula pyrrhula*. *Journal of Animal Ecology*, 68: 698–707.
Olona, J., 2014. *Economía de la agricultura española. Evolución y tendencias*. Quasar Consultores, Zaragoza, Spain.
Potts, G. R., 1997. Cereal farming, pesticides and grey partridges. In: *Farming and Birds in Europe. The Common Agricultural Policy and its Implications for Bird Conservation*: 150–177 (D. J. Pain & M. W. Pienkowski, Eds.). Academic Press, London.
Peiró, V., 1990. Aspectos de la reproducción de la Tórtola Común *Streptopelia turtur* en Madrid. *Mediterránea serie Biológica*, 12: 89–96.
Peery, M. Z., Becker, B. H., Beissinger, S. R. & Burger, A. E., 2007. Age ratios as estimators of productivity: testing assumptions on a threatened seabird, the marbled murrelet (*Brachyramphus marmoratus*). *The Auk*, 124(1): 224–240.
Puerta, D., 2011. Tórtolas en Extremadura. Las que llegarán del norte. *Trofeo, caza y conservación*, 496: 52–64.
Purroy, F. J. (Ed.), 1995. La tórtola común. *La Garcilla*, 94: 22–23.
Purroy, F. J. (Coord.), 1997. *Atlas de las Aves de España (1975–1995)*. SEO/BirdLife, Lynx Edicions, Barcelona, Spain.
Robson, N., 1997. The evolution of the Common Agricultural Policy and the incorporation of environmental considerations. In: *Farming and Birds in Europe. The Common Agricultural Policy and its Implications for Bird Conservation*: 43–78 (D. J. Pain & M. W. Pienkowski, Eds.). Academic Press, London.
Rocha, G., 2007. Criterios de calidad en la gestión cinegética de especies migratorias. In: *Criterios para la Certificación de la Calidad Cinegética en España:* 75–80 (J. Carranza & J. M. Vargas, Eds.). Servicio de Publicaciones de la Universidad de Extremadura, Cáceres.
Rocha, G. & Hidalgo, S. J., 2001. Incidencia del uso de reclamos alimenticios sobre la Tórtola Común. *Naturzale*, 16: 147–155.
– 2002. *La Tórtola Común (*Streptopelia turtur*): Análisis de los factores que afectan a su status*. Servicio de Publicaciones de la Universidad de Extremadura, Cáceres.
Rocha, G., Merchán, T. & Hidalgo, S. J., 2009. Gestión de la tórtola común y la paloma torcaz. In: *Gestión cinegética en los ecosistemas mediterráneos*: 255–285 (J. Carranza & M. Sáenz de Buruaga, Eds.). Consejería de Medio Ambiente, Junta de Andalucía, Sevilla.
Sáenz de Buruaga, M., Lucio, A. & Purroy, F. J., 2001. *Reconocimiento de sexo y edad en especies cinegéticas*. EDILESA, León.
Santamaría, A., 2007. Análisis de la abundancia reproductora de las principales especies cinegéticas y su aprovechamiento en media veda, en varios acotados de la provincia de Cáceres. Proyecto Fin de Carrera, Universidad de Extremadura, Plasencia.
Seo/BirdLife, 2002. *Seguimiento de las poblaciones de aves fringílidas de interés canoro y de la tórtola común en Andalucía durante la temporada 2002*. Documento Técnico, Junta de Andalucía, Sevilla.
– 2013. *Resultados del programa Sacre de SEO/BirdLife*. SEO/BirdLife. Madrid. http://www.seguimientodeaves.org/ESPECIOS/docs/ESPECIES/3280_RES_SP.pdf. (Accessed on 23 June 2014).
Schoech, S. J. & Hahn, T. P., 2007. Food supplementation and timing of reproduction: does the responsiveness to supplementary information vary with latitude?. *Journal of Ornithology*, 148(2): 625–632.
Schoech, S. J., Bridge, E. S., Boughton R. K., Reynolds S. J., Atwell, J. W. & Bowman, R., 2008. Food supplementation: a tool to increase reproductive output? A case study in the threatened Florida Scrub–Jay. *Biological Conservation*, 141(1): 162–173.
Tucker, G. M. & Heath, M. F., 1994. *Birds in Europe: Their conservation status*. BirdLife Conservation Series No. 3. BirdLife International, Cambridge, UK.
Wagner, F. H. & Stokes. A. W., 1968. Indices to overwinter survival and productivity with implications for population regulation in pheasants. *Journal of Wildlife Management*, 32: 32–36.
Wilson, J. M. & Cresswell, W., 2006. How robust are Palaearctic migrants to habitat loss and degradation in the Sahel? *Ibis*, 148: 789–800.