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SURVEY METHODS FOR RED-LEGGED PARTRIDGE *(ALECTORIS RUFA)* IN OLIVE GROVES IN SOUTHERN SPAIN

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ABSTRACT

In 1996-1998, we compared three survey methods (nest mapping, beat counts and driven line transects) and four density estimates or indices of red-legged partridges, Alectoris rufa, *in a 9.5-km² olive,* Olea europaea, *grove in Málaga (Southern Spain), during three study periods (February-March, August and October). Nest mapping has been used only in February-March, and was based on intensive searches for nests in a 1.3-km² study plot, and for unpaired birds in the olive grove. Beat counts involved 30-50 people beating the entire study plot, and line transects 2 people driving a car along a 19-km long transect through the grove. Beat counts and line transects did not differ in their estimates of density (between 13.2 and 36.0 partridges per km² in February-March, and between 44.4 and 81.3 in August/October). Nevertheless, the driven line transect method is the best in terms of accuracy and effort (7.4 ± 1.2 men-hours per study period* vs *70 ± 4.4 for the beat count method and 308 ± 12 for the nest mapping method), but requires a level of skill beyond most Andalusian game managers (gamekeepers, hunters and landowners). For such people the most practical method is a index of kilometric abundance (*IKA *= number of sightings per km along the driven line transect) standardized to give absolute density D according to the relationship* D *= 20.11 + 9.93* IKA *(*R^2 *= 0.87,* p *= 0.006). This relationship can only be used for olive groves and in the above-mentioned density ranges.*

I. INTRODUCTION

Survey methods are basic tools for managing wildlife (SUTHERLAND, 1996), and estimating population sizes and harvest rates of game species (TAPPER, 1988). Some studies of red-legged partridge, *Alectoris rufa,* survey methodology are available. FARTHOUAT (1981), in southern French agrosystems, considered the strip census more efficient in open areas than in closed ones, in which he recommended the use of a dog. PÉPIN and BIRKAN (1981) compared total and strip census in intensively cultivated cereal-based French agroecosystems and recommended the first as a reference method. PÉPIN (1983) reviewed methods such as territory mapping, capture-mark-recapture, the use of a decoy and some indices of abundance. RICCI (1989) proposed the use of an index of kilometric abundance (IKA) in French vineyards and orchards and adjusted a regression of density at IKA, estimated by means of total counts. BRUN *et al*. (1990) tested edge walking in French *bocages* and considered it an efficient tool. NADAL *et al.* (1992) worked mainly on orchards and irrigated lands in the north of Spain and recommended driven transects for biotopes with sparse and low-height vegetation and for large areas with high densities of partridges. BORRALHO *et al.* (1996) studied driven line transects and strip transects in mixed farmlands with shrublands in Portugal. They made a comparison with the territory mapping method and recommended distance sampling as the most efficient and accurate method.

Olive, *Olea europaea,* groves did not cover much of the territory in the area studied in any of these works. Olive groves are farmlands in which there is a sparse and low-height herbaceous layer and no shrubs. In this way, although olive groves are like open habitats, a pseudo-forest structure makes the groves similar to closed ones thus reducing visibility. Estates with olive tree plantations are large enough to make the use of absolute efficient methods for closed habitats difficult and expensive, whereas the use of an index of abundance and other relative but accurate methods for open areas could fall into biased density estimations.

The olive is a dominant crop in Southern Spain and other areas of the Mediterranean basin. In Andalusia (Southern Spain) it occupies 13,530 km^2 (15% of the Andalusian area), equivalent to 52% and 91% of the wooded and the protected areas, respectively (JUNTA DE ANDALUCÍA, 1997). The social and economic importance of the olive is high in Andalusian rural lands, as has been made clear by the polemic caused by the reform of the olive groves proposed by the European Union. Olive groves host characteristic communities of wintering birds in autumn and of nesting birds in spring (MUÑOZ-COBO, 1992; RUIZ and MUÑOZ-COBO, 1998), and are subject to a high annual erosion rate owing to agricultural work (PASTOR *et al.*, 1997). Recently, BORRALHO *et al.* (2000) have suggested that olive groves constitute an important source habitat for red-legged partridges in the Mediterranean basin when these plantations are farmed extensively. The size of these groves in Southern Spain and the economic value of the red-legged partridge as additional farm income both justify the search for a reliable and efficient counting method as an aid to partridge management in this habitat.

In this study we tested three survey methods for counting red-legged partridges in homogeneous and continuous olive groves: a variant of territory mapping here called nest mapping, beat counts, and driven line transects, and four density estimates or indices, including the index of kilometric abundance.

The aims were to evaluate which method is the most appropriate (easy to use, accurate, and efficient) for game estates where olives are the main crop, and to assess the relationship between IKAs and "absolute" densities (taking the beat count results as reference). Game species management in Andalusia is seldom carried out by highly qualified personnel (with the exception of public land and protected nature reserves, managed by technical personnel from the public administration). The managers are usually the owners of the private estates, the hunters themselves, or the gamekeepers. Thus, an ideal survey method for partridges in this habitat should not only be efficient and accurate, but also easy to carry out.

II. MATERIAL AND METHODS

II.1. STUDY AREA

The field study was carried out between February 1996 and March 1998 on a 15.5-km^2 private game estate called 'La Camorra', located in the province of Málaga (Southern Spain). Scrub covered 20% of the area and was concentrated on a calcareous hill which maximum height was 796 m. Typically, the scrubland vegetation comprised degraded holm oak (*Quercus rotundifolia*) woodland, dominated by *Olea europaea* var. *sylvestris*, and *Pistacia lentiscus* (NIETO *et al.*, 1991). The cultivated area occupied 12.4 km^2 of the plain and included patches of natural vegetation. The main crop was the olive (9.5 km^2; 62% of the total estate area). Olive trees are grown 10-15 m apart in a square grid, giving a density of 70-80 trees per ha. Other existing crops included cereals, sunflowers, almonds, and grapes. In the olive groves, the ground cover changed during the year, with sequential associations of *Diplotaxis* sp., *Raphanus* sp., *Amaranthus* sp., *Heliotropium* sp., and *Convolvulus* sp. (GARCÍA and CANO, 1995).

II.2. SURVEY METHODS AND DATA COLLECTION

We estimated the red-legged partridge density three times per year. This frequence is recommended by LUCIO (1989) to obtain partridge harvest planning. Surveys were carried out: a) in February or March, before the breeding period and after the last hunting season (pre-reproductive density); b) in late July/early August, which is related to chick productivity after the breeding period (post-reproductive density); and c) in early October, before the new hunting season (pre-harvest density).

Nest mapping

We used the nest-mapping method only for the February/March period. Nest mapping is a variety of the territory mapping method (GIBBONS *et al.*, 1996). It consists in an intensive search for nests in a plot. The method has been used especially in tree crops such as fruit trees, where the nests are easily found due to the agricultural work (GIL-DELGADO and BARBA, 1987). Here, a study plot of 1.3 km^2 of continual and homogeneous olive grove was chosen. 14% of the olive grove studied was beaten, which fits the minimum territory requirements recommended by PÉPIN and BIRKAN (1981). Farming work requires the inspection of every olive tree, to cut it down or to eliminate chemically or mechanically the herbaceous vegetation. Thus, most of the existing nests are usually found every year. In this case, with the help of the gamekeeper and the rural workers, the nests were found after hatching, between June and July, during the elimination of the herbaceous vegetation. A smaller percentage of nests with eggs was located before June, during pruning and ploughing the soil just around the olive trunks. The search for nests was also carried out on the edges of the plot. The method does not increase the loss of nests which are, in any case, caused by farming work and which have been estimated at about 50% of the nests (DUARTE and VARGAS, 1998). This method allowed us to use valuable and difficult-to-obtain data.

Density in February (D_{Feb}, number of individuals per km^2) was calculated using the following formula:

$$D_{Feb} = \frac{(Tn - Sn) * 2}{Pa} + Nr$$

where: Tn = total number of nests present in the study plot; Sn = total number of second nestings present in the study plot; Pa = the study plot area (1.3 km^2); and Nr = non-reproducing population (partridges/km^2).

It is assumed that each nest is equivalent to two reproducing adults. The non-reproducing population was estimated as the unpaired individuals' density, which was sampled through an intensive search throughout the entire olive tree area (9.5 km^2) before nesting (unpaired) and after hatching (covey of bachelors) between February and May. The intensive search consisted of driven transects with two persons mapping the location of each isolated individual contacted. When the number of such individuals did not increase with new samplings, we stopped the search. To determine the nests with second nestings or replacement ones, three criteria were followed: 1) nesting size smaller than 9 eggs (BIRKAN, 1990); 2) proximity to a nest with a greater nest size and not hatched; 3) direct field observation. The position of each nest was obtained with a portable Global Position System that was later converted to 1:10,000 scale cartography to locate each nest in the mapped study plot.

Beat counts

Beat counts were the reference method (PÉPIN and BIRKAN, 1981) and were performed during the same periods and in the same plot as for nest mapping. 30-50 people participated in each beating, distributed among four flanks: two lines of mobile side observers, one line of background observers, and one line of beaters with no dogs. They walked, never losing visual contact with each other, with a separation of 20-25 m between adjacent beaters. Smaller separations between beaters were not necessary because olive groves are habitats with scarce herbaceous cover. The run was 1.5 km long, and the width of the progression line was 900 m, fitting a representative sampling area of 1.3 km^2 (the same as for nest mapping). Each of the beaters noted the time, location, and direction of each encounter. With these data, we generated a spatial and time map of the contacts obtained during the beating, which allowed us to calculate the minimum number of different contacts and the possible maximum one. The minimum was estimated as the total number of partridges contacted and taken out of the beaten area limits. The maximum one was the minimum plus those sighted partridges estimated as possible double contacts. The final partridge density assessed for each beating was estimated as a range of the two numbers in the beaten surface and expressed as partridges per km^2.

Driven transects

During the weeks previous to and following each beating, at least four driven line transects were carried out in a four-wheel-drive car avoiding the edges of the groves to reduce biases due to edge effect (McCOLLIN, 1998). These transects which were carried out in the entire olive grove covered at least 19 km (for 9.5 km^2 of groves), allowing us to fit the minimum transect length per area (2 km/km^2) as suggested by RICCI (1989). None of the samples matched the criterion of BURNHAM *et al.* (1980) and BIBBY *et al.* (1992), of at least 40 contacts per transect. This was inevitable in the prebreeding period (i.e., in February or March), since an increase in the length of the census route would also have increased the likelihood of double contacts. Nevertheless, all samples comprised $\geq$ 19 individual sightings, which agrees with SHERMAN *et al.* (1995) for computing non-spurious estimates.

The speed of progression was 5-10 km/hr, and all the surveys were carried out by at least two persons (one being the driver) covering both sides of the progression line. The passengers and the driver who were previously trained in the estimation of visual distances in the same olive groves used tape-measured distances to previously located features in the field. We avoided performing the surveys at farming labour time (especially at dawn) due to the great activity of people and tractors in the olive grove, as this could have induced biases in the results, thus reducing precision. Therefore, the transects were driven during the three hours before dusk. All individual partridge sightings and their perpendicular distance to the progression line was visually recorded. Visual distance estimation is faster than other methods and avoids triggering a response movement of undetected birds (BORRALHO *et al.*, 1996). In the case of coveys (> 1 individual), the perpendicular distance from the perceived cluster's geometric centre to the line was recorded. Distance estimation was helped by the relative position of the partridges to the olive trees which are planted in linear squares of 12 m^2 (mean distance between olives = 11.85, SE = 0.12, n = 223 trees sampled). We adopted these squares (12-m cut points) as default grouping classes. The use of grouping distance classes for partridge surveys with line transect methods is recommended by BORRALHO *et al.* (1996), because of the loose structure of the clusters and in order to agree with the line transect theory.

For each survey period, a line transect density estimation (BURNHAM *et al.*, 1980; BUCKLAND *et al.*, 1993) and an average IKA (FERRY and FROCHOT, 1958) were obtained. For the line transect estimations we used DISTANCE 3.5 for Windows software (THOMAS *et al.*, 1998), fitting the best detection model (Akaike's information criterion). The default analysis consisted in individuals as sighting units, the grouping classes mentioned above after pooling empty classes, and untruncated perpendicular distance data. This is the line transect analysis recommended by BORRALHO *et al.* (1996) for red-legged partridge. Coveys as sighting units and truncating of distance data were rejected due to the density estimates having less precision and less accuracy, respectively, as shown by these authors. In each survey period, the IKA was estimated as the total number of partridges sighted per driven kilometer. This index was used to represent the trends of the population across the study period and to explore its relationships with the reference density. No counts were carried out either in February 1996 nor after March 1998, so there is no IKA nor line transect density estimation for these periods.

II.3. STATISTICAL METHODS

To test whether the methods give parallel density variations, Pearson's correlation analysis was performed between density estimations by means of beat counts and line transects. An ANCOVA (TABACHNICK and FIDELL, 1996) was used to explore how the seasons can affect the relationship between densities and IKAs. If a significant covariance is found, one can expect the same relationships across seasons and pool the data. The relationship between the IKAs and the reference density (beat counts) was explored with a linear regression of the density on the mean IKA values (McCAFFERY, 1976; RICCI, 1989). A midrange was estimated for each beat count range estimation using a normal distribution (SOKAL and ROHLF, 1995).

A field effort for each method was evaluated as the men-hours consumed per survey period (BORRAHLO *et al.*, 1996), taking into account the total number of men and days employed and the time (hours) spent in pre-survey preparation, data collection, and data analyses.

All means are given with their standard errors.

III. RESULTS

III.1. NEST MAPPING

In 1996 we did not find any unpaired individual or covey of single birds. In the following nesting seasons 7 and 8 non-reproducing individuals were found, at a density of 0.74 and 0.85 partridges/km^2, respectively. The calculation of the absolute February densities according to this method indicated 13.8, 30.0 and 37.8 partridges per km^2 in 1996, 1997 and 1998 respectively (Table I).

III.2. BEAT COUNTS AND DRIVEN TRANSECTS

February/March minimum densities obtained by beat counts varied from 13.2 to 31.4 partridges per km^2, and maximum densities from 21.9 to 36.0 (Table II). In August/October figures varied between 44.4 and 75.1 for the minimum and between 52.9 and 81.3 for the maximum ones (Table II).

Distance distributions of contacts and related detection functions (Figure 1) were used to estimate the densities from line transect data (Table III). These density estimations are significantly correlated with densities obtained by beat counts (r = 0.98, P < 0.001).

The partridge abundances expressed by three parameters (density estimates and IKA) measured by the two survey methods show the same trends throughout the studied periods (Figure 2). The abundance in February (prebreeding period) seems to have increased over the entire study period.

III.3. THE IKA RELATIONSHIP TO DENSITY

A significant covariance was found between reference densities and IKAs over the seasons (ANCOVA, n = 6, F = 31.56, df = 2, P < 0.01); therefore, the data were pooled. A significant relationship was found between the IKAs

TABLE I

February densities (partridges/km²) of red-legged partridges, *Alectoris rufa*, obtained by nest mapping in a 1.3 km² study plot, and by intensive search for unpaired individuals in a 9.5 km² olive grove, including the study plot, in Málaga (Southern Spain). $D_{Feb} = \frac{(Tn - Sn) * 2}{Pa} + Nr$ **, where Pa = 1.3 km².**

TABLEAU I

Densités (perdrix/km²) de perdrix rouges, *Alectoris rufa*, en février 1996-1998 obtenues par la cartographie de leurs nids dans une zone échantillon de 1,3 km² et par des recherches intensives d'individus non-appariés effectuées dans une oliveraie de 9,5 km² (incluant la zone échantillon), à Málaga (au sud de l'Espagne).

Parameter / *Paramètre*	1996	1997	1998
Number of nests in the study plot (Tn) *Nombre de nids dans la zone d'étude (Tn)*	11	27	28
Nests determined as second nesting ones (Sn) *Nids identifiés comme étant des secondes pontes (Sn)*	2	8	4
Number of pairs in the study plot (Tn - Sn) *Nombre de couples dans la zone échantillon (Tn – Sn)*	9	19	24
Non-reproducing population density (Nr) *Densité de la population non-reproductrice (Nr)*	0	0.74	0.85
Density in February (DFeb) *Densité en février (DFeb)*	13.8	30.0	37.8

TABLE II

Densities (partridges/km², minimum-maximum) of red-legged partridges, *Alectoris rufa*, obtained by beat counts in a 1.3 km² study plot of a 9.5 km² study area of olive groves in Málaga (Southern Spain) at three periods of the years 1996, 1997 and 1998.

TABLEAU II

Densités (perdrix/km², minimales-maximales) de perdrix rouges, *Alectoris rufa*, obtenues lors des comptages en battue effectués dans une zone échantillon de 1,3 km² incluse dans une oliveraie de 9,5 km² à Málaga (au sud de l'Espagne) pendant trois périodes (février-mars, août et octobre) au cours des années 1996, 1997 et 1998.

Year	Density (partridges/km²) (minimum-maximum)		
	February-March	August	October
1996	13.2-21.9	55.8-71.7	54.3-58.6
1997	27.9-30.9	75.1-81.3	44.4-52.9
1998	31.4-36.0		

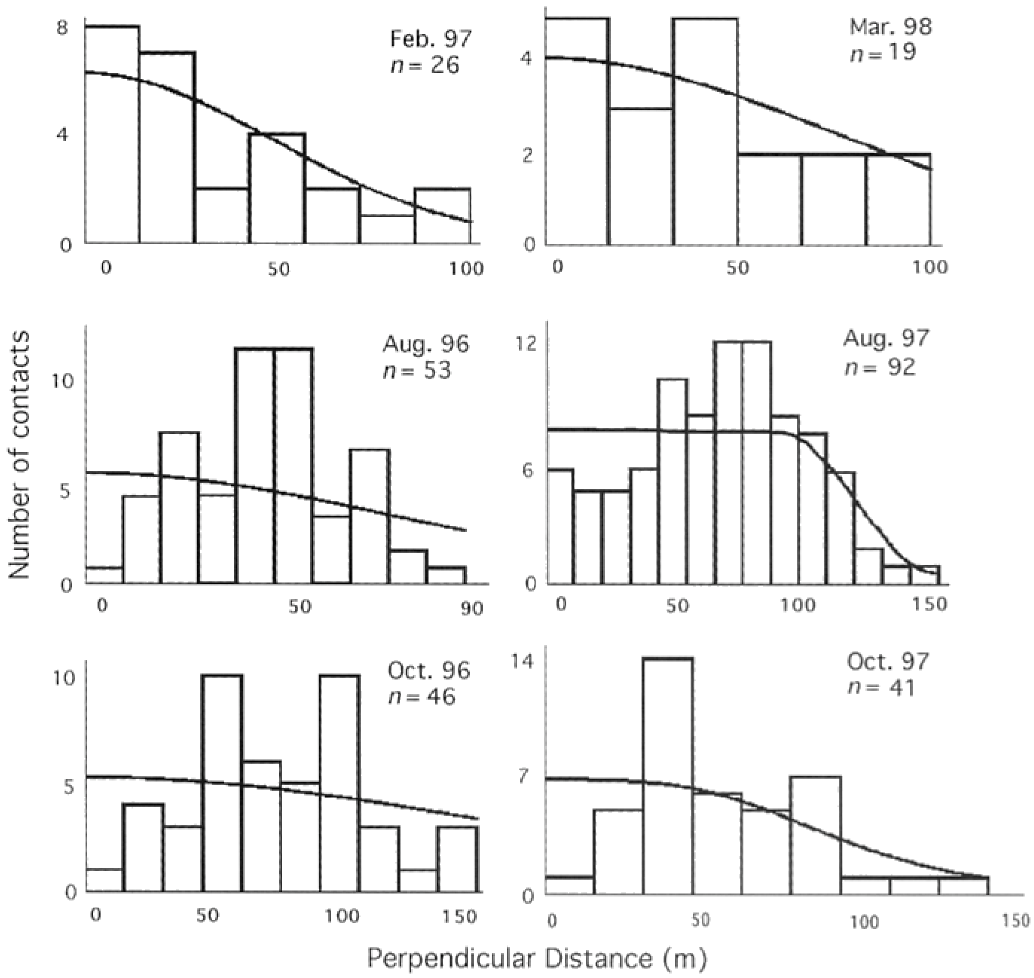

Figure 1: Perpendicular distance distributions of contacts (numbers) of red-legged partridges, *Alectoris rufa*, sighted along 19-km driven line transects in a 9.5-km² olive grove in Málaga (Southern Spain) in 1996-1998, and related detection functions (detection probabilities, not to scale). *n* = number of contacts of individuals.

Figure 1 : Distributions des distances perpendiculaires (m) des contacts avec les perdrix rouges, *Alectoris rufa*, obtenus le long de 19 km de transects dans une oliveraie de 9,5 km² à Málaga (au sud de l'Espagne) en 1996-1998, et fonctions de détection déduites (la représentation des probabilités de détection n'est pas à l'échelle). *n* = nombre de contacts avec les individus.

and the estimated densities through the beat counts (Figure 3), where $D = 20.11 + 9.93\ IKA$ ($R^2 = 0.87$, p = 0.006).

III.4. THE FIELD EFFORT

For the intensive search for unpaired individuals and nests, a total of 339 km, 112 days, and 469.5 hours were spent by two men during the entire study period. For one survey and two men, the mean figures were: 110 ± 2.3 km, 10 ± 1 days, and 154 ± 6 hours.

TABLE III

Density estimates (partridges/km², mean ± SE) and indices of kilometric abundance (IKA = number of sightings of individuals per km) of red-legged partridges, *Alectoris rufa*, obtained by 19-km driven line transects in a 9.5-km² olive groves in Málaga (Southern Spain) in 1996-1998. Densities were estimated using the formulae in BURNHAM *et al.* (1980) and BUCKLAND *et al.* (1993).

TABLEAU III

Nombres d'observations d'individus, densités estimées (individus/km², moyennes ± erreur type) et indices kilométriques d'abondance (IKA = nombre d'observations d'individus au km) de perdrix rouges, *Alectoris rufa*, obtenus en parcourant en voiture, en 1996-1998, 19 km de transects dans une oliveraie de 9,5 km² à Málaga dans le sud de l'Espagne. Densités : d'après formules mathématiques de BURNHAM *et al.* (1980) et BUCKLAND *et al.* (1993).

Survey	Number of sightings of individuals	Density (mean ± SE)	IKA
February 1997	26	28.6 ± 1.4	1.77
March 1998	19	32.6 ± 2.1	1.06
August 1996	53	53.4 ± 5.4	3.58
August 1997	92	65.2 ± 5.7	6.05
October 1996	46	42.5 ± 4.2	3.11
October 1997	41	40.4 ± 4.6	3.53

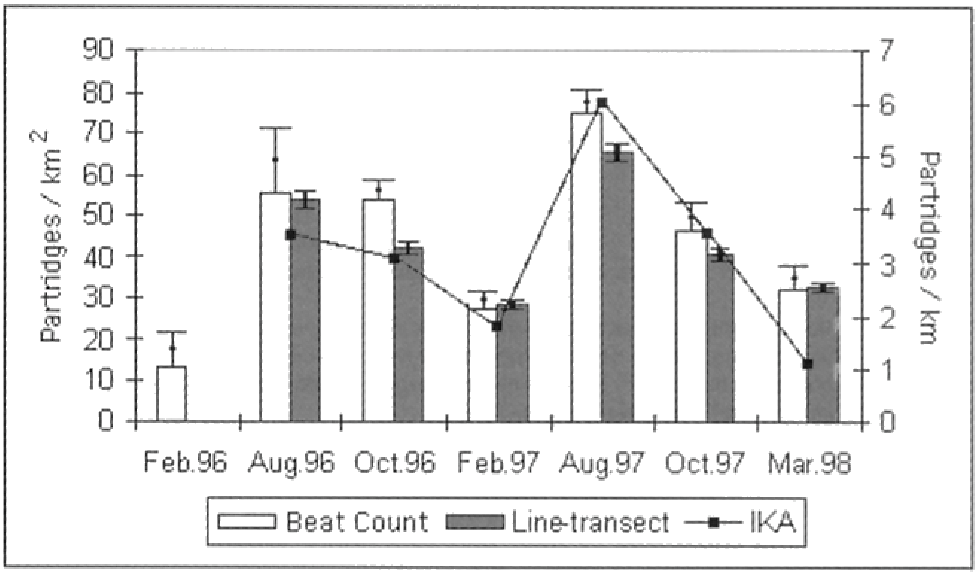

Figure 2: Comparison of trends of a red-legged partridge, *Alectoris rufa*, population in a 9.5-km² olive grove in Málaga (Southern Spain) in 1996-1998, expressed as densities (partridges per km²) estimated from beat counts (minimum-maximum) and driven line transects (mean + SE), and as IKAs (partridges per km) measured by driven line transects.

Figure 2 : Comparaison des tendances d'évolution d'une population de perdrix rouges, *Alectoris rufa*, dans une oliveraie de 9,5 km² à Málaga (au sud de l'Espagne) en 1996-1998, exprimées soit à partir des densités (nombre de perdrix au km²) obtenues après comptages en battue (minimum-maximum), ou calculées après transects parcourus en voiture (moyenne + erreur type), soit à partir d'IKAs (nombre de perdrix au km) mesurées sur ces mêmes transects.

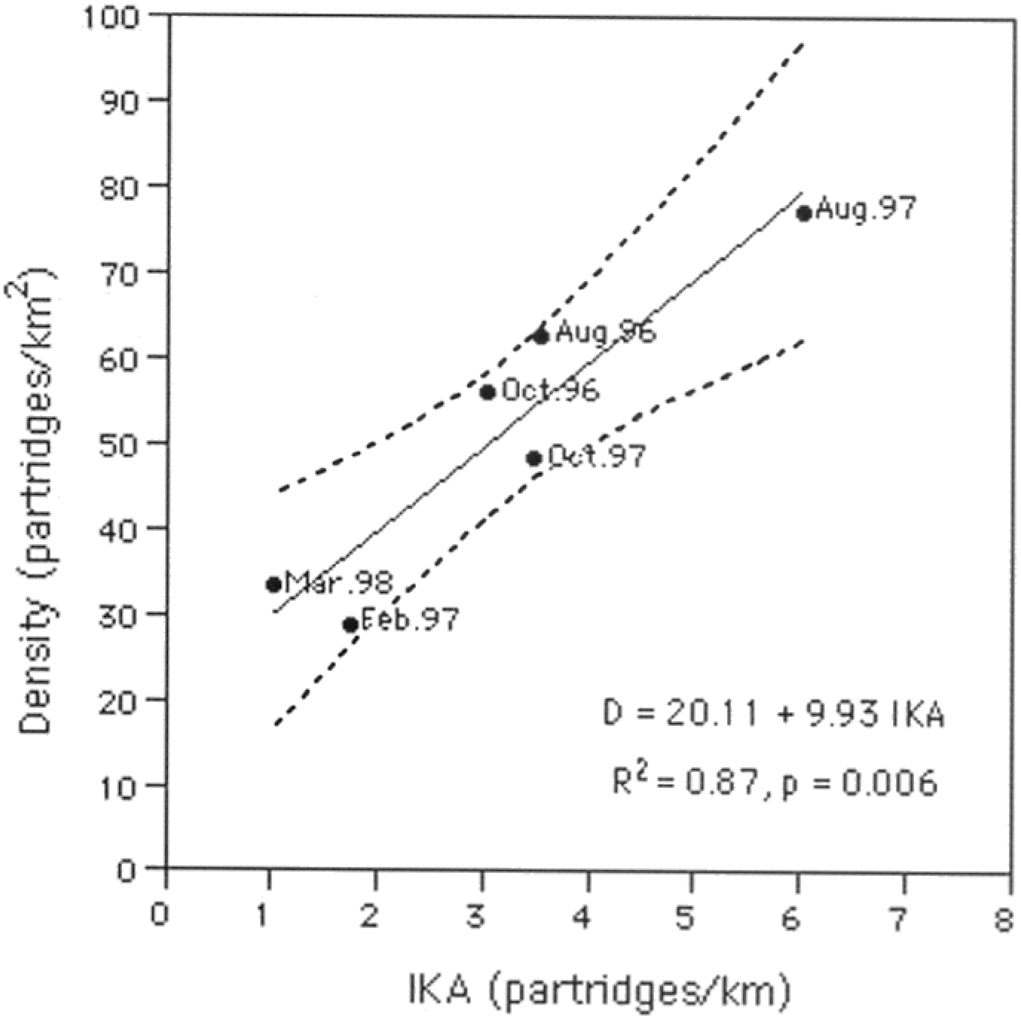

Figure 3: Regression line between IKAs (partridges per km) measured along 19-km driven line transects and densities (partridges per km²) obtained by beat counts in a 1.3-km² study plot, for red-legged partridges, *Alectoris rufa*, in a 9.5-km² olive grove in Málaga (Southern Spain) in 1996-1998.

Figure 3 : Droite de régression des IKAs (perdrix au km) mesurés en parcourant des transects linéaires de 19 km de long, sur les densités (perdrix au km²) obtenues par comptages en battues sur une zone échantillon de 1,3 km², pour les perdrix rouges, *Alectoris rufa,* d'une oliveraie de 9,5 km² à Málaga (au sud de l'Espagne) en 1996-1998.

A total of 272 people collaborated in seven beat counts. For the total of the beatings, the time spent was 14 days and 12.6 hours. Means per period were 2 days, 1.8 ± 0.6 hours, and 38.9 ± 7.3 men.

A total of 135.5 km were driven by two men along 31 line transects during 25.9 field hours. Mean figures per period and two men were: 19.3 ± 1.7 km, 4.3 ± 1.5 transects, and 3.7 ± 0.6 field hours.

Therefore, taking the mean figures per period and the number of involved men into account, nest mapping was the method with the highest effort, consuming 308 ± 12 men-hours, while beat counts consumed 70 ± 4.4 men-hours, and the line transects consumed 7.4 ± 1.2 men-hours per survey period.

IV. DISCUSSION

IV.1. LIMITATIONS OF NEST MAPPING

Nest mapping is influenced by the spatial structure and demographic status of the population. Landscape heterogeneity, habitat quality, and carrying capacity condition the demography of a species (DUNNING *et al.*, 1992) and determine the population's spatial structure (KNIGHT and MORRIS, 1996) in habitat patches differing in abundance and productivity (MORRIS, 1992). The year 1996 was the end of four years of drought. Since then, there has been a growth in herbaceous vegetation and, therefore, greater availability of food and shelter, an improvement in habitat quality, and an increase in the carrying capacity (LUCIO, 1990; MILANOV, 1998). This has been shown by the partridge population increase from 1996 to 1998. However, increases of carrying capacity can promote heterogeneity and irregular distribution of resources (DHONDT, 1991) causing different death, birth, and fertility rates among subpopulations (WILLSON, 1974). In partridges, density-dependent brood production (PANEK, 1997), polygamy and replacement or second nestings, will probably increase in optimal patches (POTTS, 1986; RANDS, 1988). In the suboptimal patches, the non-reproducing fraction of the population should increase, as happened in 1997 and 1998 during the study. Further, the recruitment rate of the red-legged partridge is inversely related to the increase in the adult population (RANDS, 1987). Adults occupy the resources of the optimal patches and displace the yearlings towards suboptimal ones, the existence of unmated yearlings being more frequent in habitats with improved carrying capacity (GREEN, 1983). These spatially-dependent demographic processes influence the results of the nest mapping method and make it more difficult to apply because the field effort increases as the need for more demographic data increases.

In February, the estimated density may be biased by the assumption that one nest is equal to one pair, for at least five reasons: 1) the existence of double nestings (GREEN, 1984), i.e., males hatching in additional nests; 2) the presence of polygamous males, frequent in environments with a high density of partridges in spring (RICCI, 1985); 3) the existence of territory overlap, also high in environments with increasing abundance (RICCI, 1985), allows to confuse first nestings with replacement ones; 4) dispersion after February (GREEN, 1983); and 5) the predation on adults in their nests (REYNOLDS *et al.*, 1992). During 1997 and 1998 some reproducing trios were observed although it was not possible to determine which nests they were occupying. Neither can we discard the existence of double nestings nor the existence of polygamous males or territory overlap. The predation on hens during hatching is usual, so dead individuals have probably been included into the density estimation. Even though nest predation rates were estimated, it would be difficult to determine which nest the dead hen comes from without the use of some kind of tag. The dispersal process, that appears to occur between February and March in Mediterranean environments (BORRALHO *et al.*, 1997), might bias density estimations leading to overestimations. Furthermore, dispersion and nest predation rates are density- and habitat-quality dependent (GREEN, 1983; POTTS, 1980; RICCI *et al.*, 1990) and change between years with different climatology and carrying capacity. Applying correction factors to the method to allow for these demographic process is not possible without increasing the field effort, which is already high enough. Therefore, the method is biased by other population processes not taken into consideration. The nest mapping method introduces biases, requires great field effort and qualified personnel for sampling demographic data, and is dependent on the timing of farm work regarding finding the nests. The method is not appropriate as a management tool and its use is not recommended.

IV.2. BEATINGS AND LINE TRANSECTS AS SURVEY METHODS

The beatings carried out here are similar to those described by PÉPIN and BIRKAN (1981) and are considered a reliable and absolute method in farming environments. According to these authors, overestimations in a beat count may be due to double contacts and underestimation of the beaten area. These authors proposed the drawing of a contact map to alleviate the bias of the double contacts, which has been put into practice here. Likewise, the beating area has been calculated with the greatest possible accuracy and the sampling bias has been minimized by using a greater number of beaters. We carried out only one beat count per survey period and rejected doing this again because this would considerably have increased both the field effort and the budget. With a same field effort as the one applied, we could have carry out several beats in a plot of smaller size, but this plot would not significantly have represented the whole studied grove area. Nevertheless, the size of the beaten plot fits the required minimum area size.

Beat counts are not affected by the differential selection of the habitat, the openness of the populations, the existence of non-reproducing or polygamous individuals, and double or replacement nestings. It is a method that reflects the real population size in a more accurate manner than nest mapping. However, although its field effort is smaller than the one applied in nest mappings, it is still high since the beatings involve a large number of men helping to carry them out, and both pre-survey preparation tasks and data handling are time consuming. These are the reasons that make this method unprofitable unless a large budget is available and absolute counts needed.

The density estimates obtained by line transects are accurate, since they fit those obtained by beat counts, and require the smallest field effort, as previously assessed by BORRALHO *et al.* (1996). However, as has also been referred to by these authors, line transect methods seem to underestimate density in brood-rearing periods, and in the present case, also in the autumn period. Nevertheless, the principal advantage of the method is that it needs detectability correction models, which is also a disadvantage because of the difficulty to get these. It is unlikely that hunters, gamekeepers or private estate owners could understand and apply this type of analytical methodology. In this sense, line transects are only advisable for highly qualified game managers and researchers for whom the method must be considered efficient to count partridges in olive groves.

IV.3. IKAs AND MANAGEMENT IMPLICATIONS

The use of IKAs in estimating population trends has been criticized by RATTI *et al.* (1983) who suggested the use of methods that correct the problem of visual detectability likelihood. Nevertheless, according to GREENWOOD (1996), an index is preferable to a unreliable density estimate, since simple methods like the one carried out to get IKAs (driven line transects) are not based on assumptions which are sometimes difficult to support. Therefore, this index is a good tool for population monitoring (BIBBY *et al.*, 1992). Using IKAs has some advantages: 1) the IKA includes every individual sighted; 2) it is easy to calculate, even by unqualified personnel; 3) the method requires little field effort (not many people) and is not too time-consuming (the same as line transects); 4) it can be carried out by gamekeepers simultaneously with their usual tasks; 5) it can also be carried out by the hunters themselves, by involving them in game management tasks and is a useful tool when used wisely; and 6) it is proposed for use only in a homogeneous habitat (olive groves), avoiding problems of differential visibility in heterogeneous ones.

The existence of a good fit between the IKAs and the reference densities suggests that the IKA is a good estimator of the abundance of partridges in olive groves. Furthermore, the IKA is not affected by important biases in detectability, given the scarcity of herbaceous vegetation among the olive trees. The majority of sightings are within the first hundred nearest meters to the progression line, which gives an exponential drop in detectability with distance. This circumstance avoids the risk of biases introduced by the most distant individuals.

Nevertheless, the measurement of the IKA in olive groves has certain limitations (GREENWOOD, 1996). First, the census routes can only be followed in homogeneous olive groves to avoid edge effect, and the results are not comparable to those obtained in other environments. Second, the use of the relationship found between IKAs and densities must be restricted to the interval between the calculated maximum and the minimum IKAs. Above or below these values the validity of the equation cannot be guaranteed. Third, the relationships of IKAs and densities may only be true for the area and habitats used in the original surveys. Nevertheless, olive groves are very homogeneous environments in the Mediterranean basin, because these plantations are subject to standardized farming techniques (CALATRAVA, 1997). Thus, it is assumed that the results are generalizable for this crop.

We conclude that the driven line transect method providing adjusted IKAs to the regression line is a recommended survey method for the managing task usually carried out by hunters or gamekeepers. However, for research or more technical purposes, line transect density estimates are preferable, especially when time and budgets are limited. Beat count appears to be the most accurate method for density estimation although it is expensive regarding field effort because of the needed number of people. Nest mapping must be rejected as survey method.

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