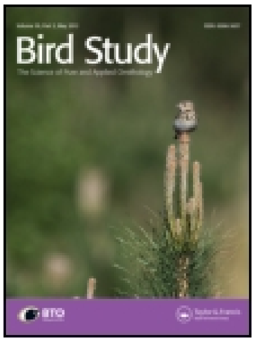

Bird Study

ISSN: 0006-3657 (Print) 1944-6705 (Online) Journal homepage: http://www.tandfonline.com/loi/tbis20

Road transects as a large-scale census method for raptors: the case of the Red Kite Milvus milvus in Spain

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Bird Study (1997) **44,** 155–165

Road transects as a large-scale census method for raptors: the case of the Red Kite *Milvus milvus* in Spain

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The reliability of road transects as a census method for wintering and breeding Red Kites was studied in Spain. Road transect data were compared with censuses of wintering populations made by roost counts and of breeding populations made by a combination of nest searching and detection of territorial pairs. The variation in population density explained a high percentage of the variance of abundance indices provided by road transects during winter (> 90%) and breeding seasons (85%). The estimation of densities from distances to the transect did not provide more accurate results than unadjusted counts. On the contrary, strip counts may consistently bias population estimates in species that are attracted by roads, or may provide unpredictably unrealistic results when the number of observations is low. Winter roost counts made in areas of high breeding density apparently underestimated the real populations, because resident Red Kites usually do not use roosts, and this was detected through the results obtained in road transects. No clear effect was found of forest cover on the detectability of Red Kites, probably due to their selection of open areas for hunting. Road transects seem to be a reliable method to estimate the numbers of Red Kites, and probably of other species of similar habits and size.

Several methods of estimating the size of bird populations have been thoroughly investigated in the past.[1,2] However, census of raptor populations poses special problems and the techniques used to census other groups of birds are often inappropriate for raptors.[3] The only methods considered to be valid to census raptor populations are those involving direct counts, specifically the detection of nests or occupied territories.[2,3] Methods involving indirect estimates, that have proved useful for many groups of vertebrates, have been little developed for raptors.

Direct counting of nests or territories may be unsuitable to census some raptor species. In the case of the Red Kite in Spain, its wide distribution, the variety of habitats used, the relatively low detectability of nests and a shortage of manpower make such a census impracticable. The problems are greater in winter, as Red Kites are not tied to a territory at this time,[4] and may be very mobile depending on the weather or on the availability of food.[5]

Road transects have often been used to obtain density indices to study regional abundances, seasonal changes in populations, population trends or habitat selection.[6–8] Craighead & Craighead[9] showed that road transects could also be useful to estimate raptor populations whenever a previous pilot study is made relating 'real' population sizes to the abundance indices provided by road transects. However, the techniques to estimate densities of birds from line transects by recording the distances of the observed individuals to the transect line[10] have rarely been applied to road transects.[11,12] Millsap & LeFranc[13] tested the accuracy of several census methods based on road transects, by using static models

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of perched raptors, and concluded that unadjusted counts provided the most precise results. Nevertheless, as the authors acknowledged, the validity of their results is limited, because in road transects flying raptors are much more commonly observed than perched birds, especially in the case of Red Kites (pers. obs.).

The road transect method could be appropiate to census Red Kites, as this was one of the raptors most commonly reported in previous studies using this method, both in winter[14,15] and during the breeding season.[16,17] However, road transects do not appear to have been used to estimate population size in this species. Most raptor studies using road transects do not include an assessment of the reliability of the method[11,12] and very few have compared abundance indices from road transects with other independent estimates of population.[9] This paper presents the results of a study designed to assess the validity of road transects to census Red Kites.

Results from road transects are compared with estimates of population size obtained by roost counts (winter) and by direct counts of nests/territories (breeding season). Given that it is not clear to what extent strip counts are better than unadjusted counts,[13] the reliability is compared of two different methods of estimation: with or without strips at the sides of the line transect.

METHODS

Estimates of wintering populations

Wintering populations of Red Kites were estimated by roost censuses in 16 study areas (Table 1, Fig. 1) during the winters (November to February) of 1991–92, 1992–93 and 1993–94. These areas were previously selected on the availability of observers and the presence of a roost. Detailed descriptions of the study areas are given in Viñuela.[18] These areas were surveyed during two to four weeks before the census by local observers, so the locations of several roosts were known in advance. Roosts were located by following individuals exhibiting directional flights from two to three hours before sunset. Triangulation of flight lines of different individuals proved to be a good method to predict the location of roosts.[18] Often the real roosts were not encountered first, but preroosting sites where kites gathered before entering roosts.[18] The censuses were made at weekends, with teams of 15–60 observers. Known roosts were censused by teams of one to three people, from two to three hours before sunset until complete darkness, as

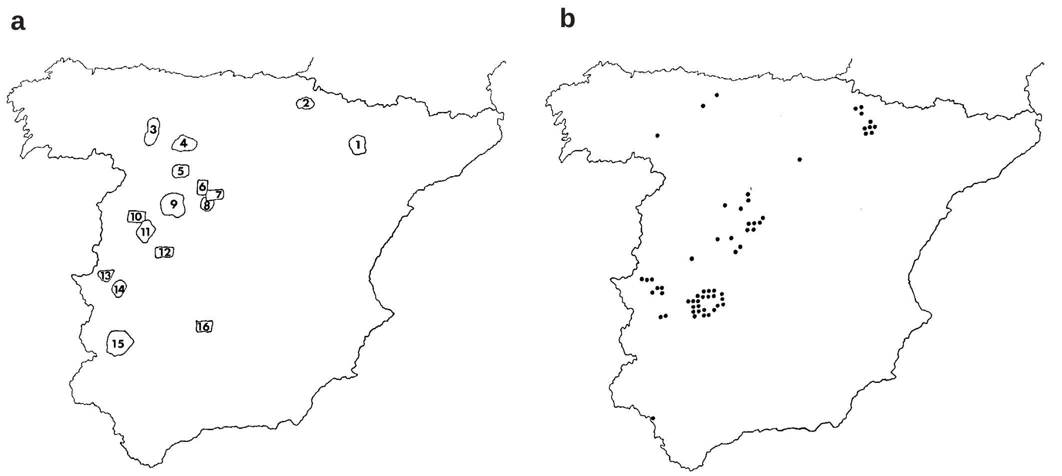

Figure 1. Distribution of the study areas sampled during winter (a) and 10 × 10 km squares sampled during the breeding season (b). 1, Huesca; 2, Pamplona; 3, León; 4, Palencia; 5, Valladolid; 6, Cuéllar; 7, Cantalejo; 8, Segovia; 9, Madrigal; 10, Matilla; 11, Guijuelo; 12, Tietar; 13, Brozas; 14, Cáceres; 15, Zafra; 16, Alcudia.

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Table 1. Winter roost census of Red Kites in Spain (1991–94). Repeated counts refer to two counts of the same roosts on consecutive days; single counts refer to those roosts that were censused on only one day.

Study area	*Area (km^2)*	*No. of roosts*	*Repeated counts*	*Single counts*	*P*	*WD*	*BD*
Pamplona	487	4	271–310	–	285.5	0.586	0.15
Zafra	1661	9	314–278	378	674	0.406	0
Palencia	1313	11	442–453	207	654.5	0.498	0
Madrigal	1453	12	1145–1165	503	1658	1.141	0.03
Guijuelo	754	11	369–359	311	675	0.895	0.29
León	1097	12	994–1012	364	1367	1.246	0
Cáceres	565	4	482–390	199	635	1.124	0.07
Brozas	538	4	–	290	290	0.539	0.21
Huesca	907	9	644–659	131	782.5	0.862	0.02
Segovia	400	9	950–794	–	872	2.18	0.56
Matilla	750	6	176–122	59	213	0.284	0.34
Tietar	600	1	–	185	185	0.308	0.15
Alcudia	500	2	–	100	100	0.2	0.04
Cuellar	600	2	–	183	183	0.305	0.21
Cantalejo	600	8	–	484	484	0.806	0.11
Valladolid	600	4	–	200	200	0.333	0
Total	12 925	109	5611–5420	3594	9258.5	0.716	0.136

P, Estimated population: average of repeated counts plus single counts; WD, winter population density (no. of kites/km^2); BD, nesting population density (no. of kites/km^2), estimated from data of the National Census (1994).

Red Kites often entered the roosts around dusk or even some minutes after sunset. Other teams surveyed the rest of the study area divided in plots of 10–50 km^2 to find further roosts. The size of the area surveyed varied depending on the availability of volunteers and the density of roosts. Censuses were repeated on two consecutive days (repeated counts in Table 1) but not all the roosts could be counted on both days (single counts in Table 1), in some cases due to lack of manpower, in others because the roost was found on the second day of census. For one to three days after the census, the area was surveyed daily to confirm that no roost was overlooked on a census day. Only in two study areas were two small roosts (< 15 individuals) found after a census. These censuses provided conservative population estimates because some individuals may not attend roosts (including most resident Red Kites, see below). However, given the size of the study areas and the large numbers of Red Kites found (Table 1), it seems reasonable to think that few were overlooked. Furthermore, very similar counts were obtained on the two consecutive days of census (Table 1), confirming that the estimates were reasonably accurate.

The roosts were censused by one of the following three methods, in order of preference: (1) counts of perched birds, the most reliable method for roosts located in thin patches of deciduous trees; (2) counts of birds entering the roost, more suitable for thick forest patches, whenever birds entered the roost from few directions (often the birds entered the roosting site following two or three flight-lines, often only one, due to the gathering in preroosting sites near the roost); and (3) counts of flushed birds, in roosts in evergreen trees where birds had entered from many directions. Red Kites usually flush one or more times from the roost before finally settling. These movements usually involve most of the roosting individuals flushing simultaneously. Preliminary comparisons of the three methods showed that they provided similar results but that counts of flushed birds tended to underestimate real numbers, so this method was used when it was the only suitable option for a given roost.[18] Populations in each study area were estimated as the average of repeated counts added to single counts (Table 1).

Estimates of breeding populations

Estimates of the number of territorial pairs were obtained for a total of 61 10 × 10 km squares scattered across the range of the species (Fig. 1). Squares were selected on the availability of observers and on the prior knowledge of at least one breeding pair. The numbers in some of the squares were known before the census and data were provided by several local collaborators.

The rest of the squares were sampled during April to July (mainly May to June) of 1992–94 by a combination of nest searching by foot and detection of occupied territories by standardized observations from high points,[18] the two most reliable methods to estimate the size of populations of breeding raptors.[3,19] Preliminary assessment of these two methods showed that both provided similar estimates[18] so, depending on the percentage of forest cover of each square, one of the two methods was used preferentially (nest searching in deforested areas, observation in heavily forested squares).

Young and non-breeding Red Kites usually gather in favourable areas, sometimes in relatively large numbers (15–20 individuals), often associated with regular and abundant food sources such as rubbish tips.[18] Most of these areas also held important breeding populations. In such places the populations of young/non-breeders were estimated from counts in roosts or feeding concentrations, but only in squares where their presence was evident from observation of concentrations unrelated to breeding pairs. Population in each square was estimated as the number of breeding pairs × 2 plus the estimated number of young/non-breeders.

Road transects

Road transects were conducted concurrently with the censuses of breeding and wintering birds within each study area, following the guidelines provided by previous studies.[3,20] Adverse weather conditions (rain, fog, snow) were avoided. Transects were driven from two hours after sunrise to one to two hours before sunset, at an approximate speed of 40 km/h, stopping the car to identify individuals but not including new birds not previously seen. Preliminary work indicated that 40 km of transects were sufficient to census 100 km^2. In winter, road transects were driven within an area including all roosts censused. The outer limit of the area surveyed by road transects was determined by the mean distance between roosts, so that the distance from each roost to the outer edge of the sampled area was approximately the same as the mean distance between roosts. This was an attempt to overcome the problem that roosts near the edge of the sampling area might have included birds foraging outside the study plot.

The road transect method was designed to detect concentrations of birds. When two or more kites were seen over the same area, the car was stopped to determine the reason for the concentration (rubbish tip, roost, etc.) and to census all the birds present in the area.

The detectability of birds may vary depending on the habitat sampled.[1] Forest cover could reduce detectability of raptors.[13] Hence, the percentage of forest cover within 1 km of the transects (the estimated maximum distance of detection for this species, see below) was estimated in each study area.

Two methods were assessed to estimate populations from road transect data: (1) unadjusted counts: an index of relative density (IRD), defined as number of birds seen per 100 km of transect,[21] was calculated for each study area; (2) strip counts:[10] all observations of isolated birds were assigned to six strips 100-m wide at each side of the transect. The maximum distance of observation was estimated to be a little over 1 km.[18] Observations at distances greater than 600 m were scarce and were removed from the analyses ('truncation' of the tail of the distribution[10]). Strip counts were analysed with the program DISTANCE.[22] A half-normal model was the detection function that best fitted the distance data (Akaike's information criterion). For these analyses, only the areas personally surveyed were included, to assess the reliability of the method under optimal conditions (sampling by one person, as the estimates of distances by different people may introduce serious biases[10]).

RESULTS

Wintering season

The frequency distributions of IRDs and population densities during winter did not differ significantly from normal (Kolmogorov–Smirnov test, P = 0.22 and P = 0.75, respectively), so parametric tests on untransformed variables have been used. The results of the roost censuses and road transects are summarized in Tables 1 and 2. Population densities estimated from roost censuses within each study area were strongly correlated with the number of birds seen in concentrations during the road transects (r = 0.85, n = 16, P < 0.001), with the IRDs excluding birds seen in concentrations (r = 0.65, n = 16, P < 0.007) and with the IRDs including birds seen in concentrations (r = 0.88, n = 16, P < 0.001). The best fitting model was a linear regression of IRDs with birds seen in concentrations ($F_{1,14}$ = 46.19, P < 0.001, R^2 = 0.77). However, the constant of this regression was not significant (t = –1.09, P = 0.29). A new regression line adjusted to the origin provided a more satisfactory fit ($F_{1,14}$ = 107.7, P < 0.001, R^2 = 0.88, Fig. 2).

There was an effect of the size of breeding populations on the results of winter road transects: the areas with large breeding populations provided relatively high IRDs (Fig. 2). This may be explained by the differential use of roosts by resident and wintering birds. Because residents rarely use communal roosts[23] (see Discussion), roost censuses probably underestimated the real populations in areas used simultaneously during winter by resident and wintering birds. The breeding populations within each area sampled during the winter (Table 1) were estimated from the data gathered in the national census of Red Kites made during the spring of 1994 and the linear regression of IRDs on population densities obtained during the breeding season (see below). The ratio IRD/winter population density (estimated from roost counts) was positively correlated with the breeding population density within each area (r = 0.55, n = 16, P = 0.025). A new estimate of winter population density was calculated by adding the population estimate obtained from roost counts to the estimate of the breeding population. A new regression adjusted to the origin using this last estimate of

Table 2. Results of winter road transects made within the roost census areas (see Table 1). For each study area the distance driven in km, the number of Red Kites observed isolated or in concentrations (three or more individuals over the same area) and the indices of relative density (IRD, no. of kites seen/100 km) are given.

Study area	*Distance driven (km)*	*No. of birds isolated*	*No. of birds in concentrations*	*IRD-1*	*IRD-2*
Pamplona	250.5	59	65	23.8	49.5
Zafra	465.5	80	41	17.2	25.6
Palencia	491	100	199	20.4	60.9
Madrigal	540	173	231	32	74.8
Guijuelo	323	101	209	31.3	95.9
León	500	191	269	38.2	92
Cáceres	170	60	153	35.3	125.3
Brozas	137	67	11	48.9	56.9
Huesca	476.5	91	146	19.1	49.7
Segovia	133.5	143	324	107.1	349.8
Matilla	250.1	166	17	66.4	73.2
Tietar	170.1	10	0	5.87	5.87
Alcudia	138	6	0	4.35	4.35
Cuellar	206.8	67	100	32.4	80.7
Cantalejo	239.3	184	61	76.9	102.4
Valladolid	256	48	18	18.75	25.78
Total	4783	1546	1844	32.2	70.88

IRD-1, Including only isolated individuals; IRD-2, including isolated individuals and concentrations.

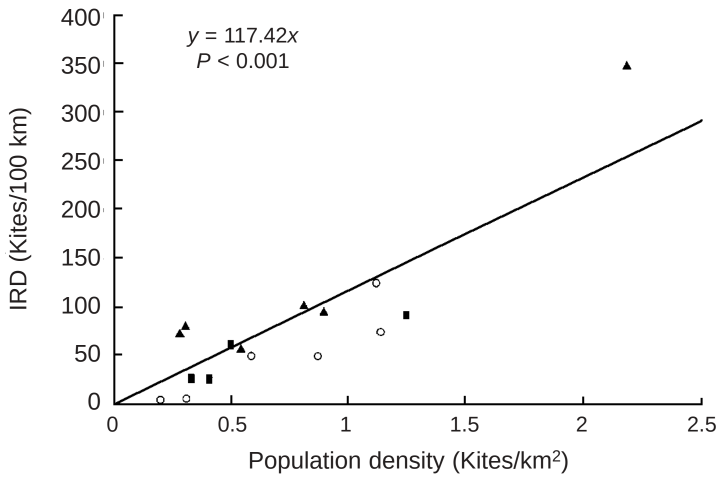

Figure 2. Linear regression adjusted to the origin (non-significant constant excluded) of IRDs (no. of kites/100 km) obtained from road transects, including the birds seen in concentrations, on the winter population densities calculated from roost censuses (Table 1). ❍, Areas where Red Kites do not breed; ■ , areas where Red Kites breed in low density (average of < 5 pairs/square of 10 × 10 km); ▲, areas of high breeding density (> 5 pairs/square).

density was even more significant than the previous one ($F_{1,14} = 182.6$, $P < 0.001$), explaining 92.4% of the variance in IRDs. Using this estimate of density, the ratio IRD/population density was no longer correlated with breeding population density ($r = 0.41$, $n = 16$, $P > 0.1$), or with the surface of forest cover within each study area ($r = 0.27$, $n = 16$, $P = 0.31$), although study areas were selected to obtain a sample with varied forest cover (between 5 and 63% of the surface sampled by road transects).

Observations of Red Kites made during the road transects with respect to the sampling strips showed the typical biased distribution reported in other studies[10] (Fig. 3), confirming that detectability declined with distance from the transect. The frequency of observations was lower in the 100–200 m strip than in the 0–100 m strip, but this could be an effect of the

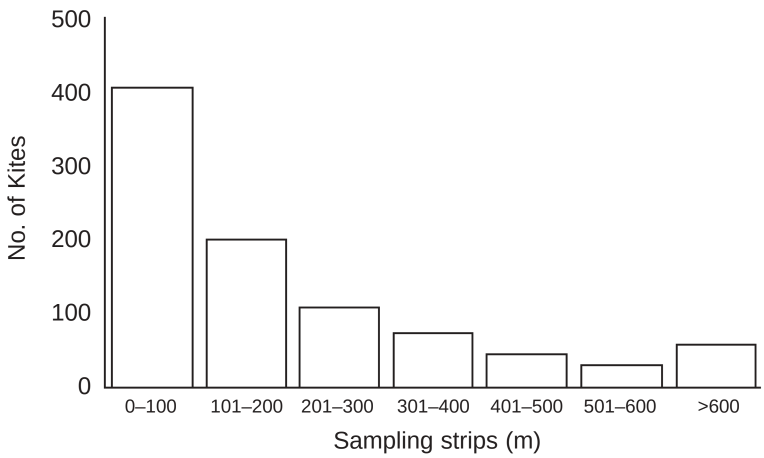

Figure 3. Distribution of observations of Red Kites made during road transects in sampling strips 100-m wide at each side of the transect. Data from winter 1992–93 in the areas of roost census.

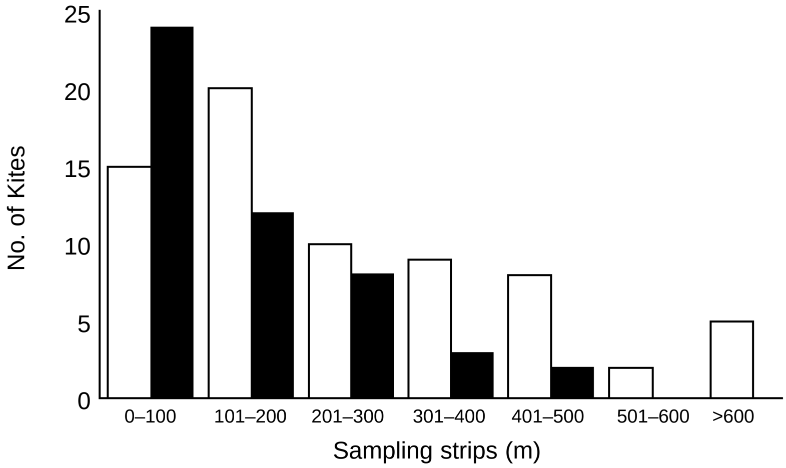

Figure 4. Distribution of observations of Red Kites in sampling strips at each side of the line of transect for areas with low forest cover (< 10%, white bars) and areas with higher forest cover (> 10%, shaded bars). Data from transects in main wintering area (central northern plateau) obtained during January to February 1992.

attractiveness of roads for Red Kites (see Discussion) and no reduction was found in detectability between 100 and 200 m in the more open areas (Fig. 4) commonly used by wintering Red Kites.[14] Population densities estimated from strip counts were not significantly correlated with 'real' densities (roost counts and estimated breeding populations pooled) (r = 0.13, n = 9, P = 0.74). These estimates of density did not include the individuals observed in concentrations. However, as shown above, the inclusion of these individuals in the estimates of density may be vital to obtain realistic estimates. The assignment of birds seen in concentrations to sampling strips was complicated, especially when large flocks were encountered, so a different approach to the problem was considered. The density of individuals seen in concentrations was estimated as $N/(K \times 2 \times D)$, where N = number of birds observed in concentrations, K = distance driven (km) and D = maximum distance of observation (1 km). This value was added to the density index described above but the correlation with real population densities was still non-significant (r = 0.5, n = 9, P = 0.17), while this subsample of real densities was significantly correlated with the index of density in concentrations (r = 0.73, n = 9, P = 0.024) and with IRDs (r = 0.82, n = 9, P < 0.01). The ratio 'population density estimated from distances/real population densities' was not correlated with the percentage of forest cover (r = 0.18, n = 9, P = 0.63).

Breeding season

The frequency distributions of population sizes and IRDs for breeding populations were very skewed towards low densities/IRDs and differed significantly from a normal distribution (Kolmogorov–Smirnov test, P < 0.001 for both variables). Log-transformation was used to normalize the variables. The population estimates in each square and the IRDs obtained from road transects were strongly correlated. The most significant model, explaining 88% of the variance in IRDs, was a linear regression adjusted to the origin (the constant was non-significant) on the variables logarithmically transformed (Fig. 5). The ratio IRD/estimated population for each square was not correlated with the percentage of forest cover (r = -0.24, n = 23, P = 0.28, only the squares sampled personally have been included).

The distributions of frequencies of distances from squares where fewer than four individuals were observed during road transects did not converge with any detection function, or the analyses provided unrealistic densities, and these squares have not been included in subsequent analyses. The densities estimated

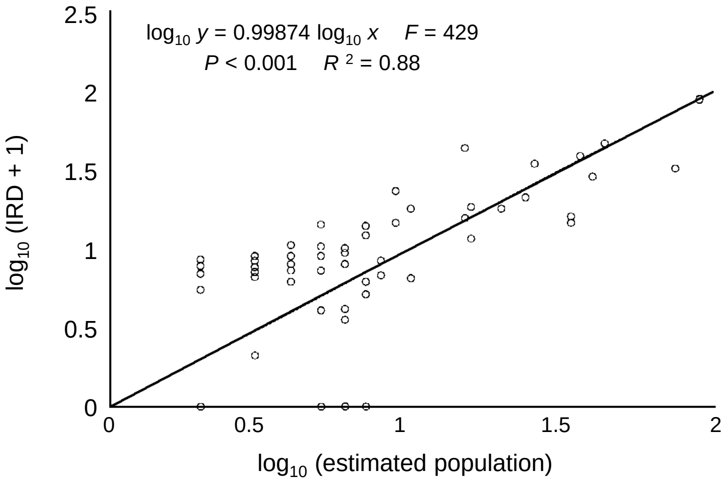

Figure 5. Linear regression adjusted to the origin of IRDs on estimated breeding populations (no. of pairs × 2 plus estimated number of young/non-breeding individuals). Variables log-transformed.

from distances to the transect were higher than real densities (paired *t*-test, t = 2.3, n = 16, P = 0.035) and both variables were strongly correlated (linear regression with log-transformed variables, $F_{1,14}$ = 25.3, n = 16, P < 0.001) (Fig. 6). The ratio 'population densities estimated from distances/real densities' was not correlated with the percentage of forest cover (r = 0.22, n = 16, P = 0.41).

A stepwise regression analysis was performed including population densities estimated from territory/nest location as the dependent variable, and the IRDs and estimates from strip counts as independent variables. Only IRDs entered the final model ($F_{1,14}$ = 39.9, P < 0.001).

DISCUSSION

Population densities explained a high percentage of the variance in IRDs during winter (> 90%) and nesting (> 85%) censuses. Road transects seemed to be sufficiently accurate to detect the presence of resident birds

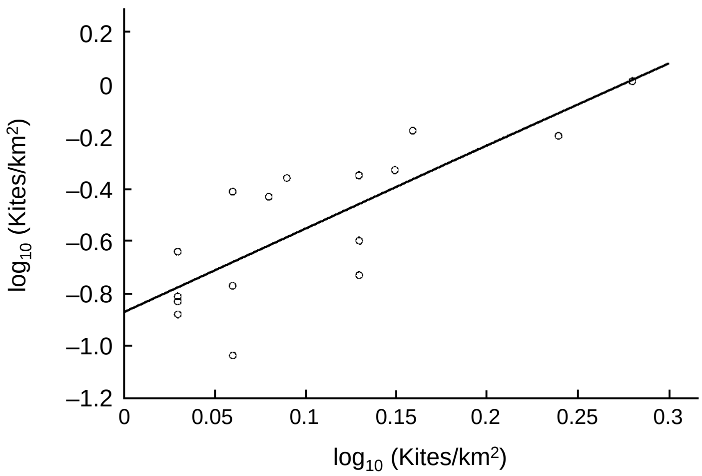

Figure 6. Linear regression of population estimates obtained by the distribution of distances to the line of transect on nesting population densities (as in Fig. 5). Variables log-transformed.

during winter, even though these often represented a small proportion of winter populations (Table 1). Resident Red Kites in Spain do not enter winter roosts but continue using the territories and roosting sites used in the nesting season[4,23] (pers. obs.). The only exceptions seem to be pairs nesting at high elevations that may move to lower areas in winter (pers. obs.; F. Compaired, pers. comm.). Indeed, during winter roost censuses made in areas of high breeding population density, observers trying to find new roosts were often misled by resident pairs roosting alone in their nesting territories; this never occurred in areas without breeding populations.

Population densities and abundance indices were normally distributed in winter but were strongly biased to low values in the breeding season. Most of the squares sampled during the breeding season had mid to low population densities (< 5 pairs/square) and only a few cases of high population density were found (maximum of 42 pairs/square). This probably reflects the present nesting dispersion of Red Kites in Spain: a rare or scarce raptor in most areas but breeding semi-colonially when conditions, especially absence of marked persecution[24] and abundance of favourable nesting habitat and food supply,[18,25] favour high breeding density. The high numbers of wintering birds in Spain (around 60 000[26]) are probably distributed more regularly than breeders, so many areas of mid-population density may be found in Spain. Furthermore, only areas where the presence of roosts was previously known were selected for winter censuses, thus discarding very low density areas that could have biased the sample in the same direction as the breeding season.

Unadjusted counts (IRDs) were more strongly correlated with real densities than the estimates of density obtained from strip counts, especially for winter data. Millsap & LeFranc[13] tested the accuracy of several census methods based on road transects, by using static models of perched raptors, and reached a similar conclusion; they found that unadjusted counts provided the most precise results. For spring data, density estimates obtained from strip counts were strongly correlated with real densities but the method tended to overestimate population densities. A basic premise to estimate population densities from distance data is that the spatial distribution of individuals is independent of the transect.[10] However, Red Kites are attracted by roads where they scavenge small animals killed by cars[25,27] (pers. obs.) and this would explain the overestimation of densities in the nesting season. The main prey of Red Kites in Spain during late autumn/early winter are Field Voles *Microtus arvalis*, but they switch to carrion in late winter.[28] Voles are often caught in road ditches because they use this undisturbed ground to excavate their burrows[29,30] (pers. obs.). Red Kites should be attracted by roads preferentially during early winter, whereas during late winter they would be more commonly observed near carrion.[28] Winter censuses covered all the wintering season, so some counts were made when kites were often using roads as hunting grounds whereas others were performed when they were not so attracted by them. Furthermore, some of the roost censuses were made in Northern Spain, where Field Voles are abundant, and others in Southern Spain, where Red Kites have different feeding habits.[30] These facts could explain the poor correlation between estimates obtained from strip counts and real population densities for winter data. Caution is strongly recommended when using strip counts to estimate populations of raptors (or other birds) that may be attracted by roads, where they may find prey or perches (e.g. Common Kestrels *Falco tinnunculus* or Buzzards *Buteo buteo*). In addition, strip counts were not a useful method in squares where numbers of Red Kites observed were low (< 4). IRDs from transects performed simultaneously by two different observers differed little[18] whereas the results provided by strip counts may differ greatly between observers.[10]

No effect was found of forest cover on detectability. Red Kites are hunters of open areas and rarely use forests.[18,25] Most observations were of flying, presumably hunting, birds. In such a species, forest cover may not have so marked an effect on detectability, simply because they rarely use very forested areas. In more heavily forested areas they could more often use roadside clearings for hunting. This could explain why the detectability apparently decreased more abruptly in forested areas than in open areas (Fig. 4), while no correlation was found between the degree of forest cover in every study area and the reliability of transects (measured as the ratio IRD/estimate from roost or breeding censuses).

Road transects seemed to be a useful method to census Red Kites but caution must be used when applying the method in areas of low population density.[16] Road transects during the breeding season failed to detect birds in some squares where the species was scarce (1–3 pairs/square) (Fig. 5). In this kind of area, surveys by road transect might be complemented with other methods of census.

ACKNOWLEDGEMENTS

This is a contribution to the project 'Status of the Red Kite in Spain', financed by the RSPB and coordinated by the Spanish Ornithological Society (SEO). Colin Bibby, Ian Evans and Scott Stoleson provided useful suggestions on previous drafts of the manuscript. Alfredo Ortega coordinated the roost census and drove the road transects during the winter of 1993–94. A. Balmori, L. Bejarano, A. Bueno, R. Bueno, J.M. Colorado, J. Elósegui, J. Fernández, J. García González, E. Gómez Crespo, J. Gómez Labrador, F. Grajera, GURELUR, S. Hidalgo, F. Jubete, P. López Avila, M. López de Carrión, P. Martín, A. Onrubia, R. Palomo, P.L. Ramos and G. Sierra made the preliminary surveys of roosts and coordinated roost censuses.

The following collaborated in the roost censuses or provided data from breeding populations: D. Abel Schaad, A. Acha, C. Aguilar, M. Alberdi, J.C. Albero, J.M. Alonso Rubio, M. Andrés Moreno, T. Andrés Ponga, C. Antolín, S. Antón, R. Aquilué, A. Arbulu, I. Arizón, C. Astrain, M.I. Avery, M. Aymerich, C. Azkona, V. Baglione, M. Barcenilla, P. Barguin, A. Barón, M.A. Blanco, M.A. Blasco, O. Borrego, A. Calderón, J. Calzada, A. & A. Cameo, J. Caminero, C. Caminos, D. Campion, M. A. Campos, J.M. Canudo, R. Carbonell, S. Casado, M. Coca, F. Compaired, T. Córcoles, G. Costas, R. Cowie, J. Crespo, J.M. Crespo, M. Cuesta, M.A. Cuesta, J.I. Deán, E. de Juana, M. del Castillo, R. de la Peña, I. de la Riva, M. de Pedro, P.C. Díaz, E. Donoso, C. Equinoa, A. Escribano, A. Espinosa, M.J. Estévez, A. Etxeberria, I. Fagundo, I. Fajardo, J.I. Fernández Aransay, C. Fernández de Celis, P. Fernández Llario, A.B. Fernández Salegui, P. Fernández, J. Ferrer, R. Fuente, F. J. Galvache, E. García, F. García, M. García, F. J. García González, L. Gómez Moreno, R. Gómez Valmaestre, A. González de Castro, F. González, M. González Vélez, J. C. Guerra, C. Gutierrez Expósito, D. Guzmá, J.A. Hernández Blanco, G. Hernández Cordero, R. Hernández, M.A. Herrera, F. Hiraldo, L. Hurtado, A. Iglesias, E.L. Iglesias, A. Ibarrola, M.C. Illanes, R. Johnston, D. Lanaspa, P. Lauzurica, J. Lavedán, J.M. Lenguas, A. León, I. Lerga, A. Lezaun, I. López Pérez, A. Lora, Y.M. Lorenzana, M. Losfabios, A. Maestre, C. Manzano, R. Marco, A. Martín, X. Martín, E. Martín Serrano, J.M. Martín Zancajo, I. Martínez de Morentín, M. Martínez Duchel, R. Mellado, T. Merchán, F.M. Mesonero, R. Millán, A. Mir, M. Monge, J.D. Moreno, E. Morey, C. Muñoz, A. Muriel, A. Núñez, P. Ollero, J. Orduña, L. Otero, D. Pain, J.C. Palermo, J.A. Palomo, D. Pando, E. M. Pedraza, J. Peña, E. Pérez Balsalobre, Y. Pérez Chirinos, M.F. Pérez Escrivá, T. Pérez Jaranta, M. Pérez Zahonero, T. Pérez, L. Picazo, V. Pividal, T.A. Ponga, J.C. Pons, C. Pradel, J.F. Ramírez, F. Ramírez Villares, M.A. Ramiro, B. Revenga, E. Revilla, F. Reyes, M.J. Rincón, T. Rincón, J.L. Robledo, J.A. Robles, J.J. Robles, J.L. Robles, G. Rocha, E. Rodríguez Paíno, A. Rodríguez Pérez, E.A. Rodríguez Sánchez, H. Roldán, J. Rubio Casado, L. Salguero, A. Sánchez (AMA-Extremadura), J. Sánchez, L. Sánchez, E. Sánchez Airas, C. Sánchez-Alonso, J. Sánchez Poveda, J. Sanz-Zuasti, J. Sears, A. Senosiaín, I. Sim, C. Sunyer, A. Toledo, A. Torralba, J. M. Traverso, J.C. Usieto, F. Vallés, A. Valverde, A. Velando, J.A. Velasco, J. Vilches, L. Villacorta, C. Villar, F. Yago, R. Yustos and F.J. Zalba.

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(MS received 28 March 1996; revised MS accepted 22 October 1996)