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Raptor Journal 2025, Vol. 19: 75–83. DOI: 10.2478/srj-2025-0008
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Wintering raptors in lowland farmland of north-western Italy: a second distance sampling survey twenty years later

Zimovanie dravých vtákov v nížinnej poľnohospodárskej krajine severozápadného Talianska: druhé líniové vzorkovanie, dvadsať rokov neskôr

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Abstract: Diurnal raptors and the great grey shrike (*Lanius excubitor*) wintering in the lowland farmland of north-western Italy were surveyed again after 20 years, during the winters of 2020/2021 and 2021/2022. Data were collected using roadside car transects, and perpendicular distances of birds from the transect lines were recorded to estimate wintering raptor densities. Ten species (9 raptors) were observed, but only two species, the common buzzard (*Buteo buteo*) and the common kestrel (*Falco tinnunculus*), were recorded frequently enough to allow reliable density estimates. Extensive rice fields in the north-eastern part of the study area supported high densities of common buzzards, with estimates ranging between 1 and 2 individuals per km². Although occurring at lower densities (~ 0.5 individuals per km²), the common kestrel showed a broader habitat tolerance and appeared less dependent on specific agricultural landscapes. The estimated wintering population of common buzzards in the lowland farmland of the Piemonte region, an area covering approximately 5,700 km², was slightly higher than that recorded 20 years earlier, ranging between 4,000 and 5,000 individuals. For the common kestrel, the estimated wintering population in the same area was around 2,500 individuals (1,800–3,500). However, the total wintering populations of both species in the whole region were certainly much larger, because they are also widespread during winter in hilly and mountainous areas.
Overall, the results highlighted the importance of rice fields for wintering common buzzards, suggested stability in the raptor community, and advocated for broader adoption of distance sampling methods for effective large-scale bird surveys.

Abstrakt: Po 20 rokoch bolo v poľnohospodárskej nížine severozápadného Talianska opäť sledované zimovanie dravých vtákov a strakoša veľkého (*Lanius excubitor*). Výskum prebiehal počas zím 2020/2021 a 2021/2022. Údaje boli zbierané metódou cestných transektov. Hustota zimujúcich dravých vtákov bola odhadnutá na základe kolmých vzdialenosti vtákov od transektových línií. Pozorovaných bolo desať druhov (9 dravých vtákov), ale len dva druhy, myšiak lesný (*Buteo buteo*) a sokol myšiar (*Falco tinnunculus*), boli zaznamenané v dostatočnej početnosti, aby bolo možné spoľahlivo odhadnúť ich hustotu. Rozsiahle ryžové polia v severovýchodnej časti študovanej oblasti podporovali vysokú hustotu myšiakov lesných, s odhadmi v rozmedzí 1 až 2 jedincov na km². Sokol myšiar vykazoval širšiu toleranciu biotopov a zdá sa menej závislý od špecifickej poľnohospodárskej krajiny, hoci sa vyskytoval v nižšej hustote (~ 0,5 jedincov na km²).
Odhadovaná zimujúca populácia myšiaka lesného v nížinných poľnohospodárskych oblastiach regiónu Piemonte, ktoré pokrývajú približne 5700 km², bola o niečo vyššia ako populácia zaznamenaná pred 20 rokmi a pohybovala sa v rozmedzí 4000 až 5000 jedincov. V prípade sokola myšiara bola odhadovaná zimujúca populácia v tej istej oblasti približne 2500 jedincov (1800 – 3500). Zimujúce populácie oboch druhov v celom regióne však boli určite oveľa väčšie, pretože oba druhy sa v zime vyskytujúaj v kopcovitých a horských oblastiach.
Celkovo výsledky zdôraznili význam ryžových polí pre zimovanie myšiakov lesných, naznačili stabilitu v spoločenstve dravých vtákov a podporili širšie uplatňovanie metód vdialenostného vzorkovania pre efektívne veľkoplošné prieskumy vtáctva.

Key words: road counts, distance sampling method, density, common buzzard, common kestrel

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Acknowledgements: We thank Romeo Nicolini, Gloria Ramello, Federico Pino, and Pier Giuseppe Meneguz for their help in the field, and Kelsey Horvath, who kindly revised the English. Suggestions and corrections of referees and the editor greatly improved the manuscript.

Introduction

Road surveys by car while driving at slow speed are among the most common methods to count diurnal raptors, especially in open habitats and in winter seasons, as noted from the first papers of Nice (1934) and Leopold (1942) up to present days (Fuller & Mosher 1987, McClure et al. 2021). From these counts, we obtain an index of the relative abundance usually expressed as birds per kilometre, but not an estimate of density (birds per unit area).

Comparisons of these indices of abundance among areas, times, and/or different species could be made only assuming similar sighting probabilities, although assumptions rarely meet for species of various sizes and detectability or in habitats with different vegetation cover (Burnham et al. 1981); moreover detection probability could even change between years in the same habitat/area (Andersen et al. 1985).

The road surveys also show a considerable variation in methodology, including vehicle speed, times of day and year, number of observers, and transect width, so it would be recommended that road count practitioners record information that affects the detectability of raptors, thus enabling detection corrected estimates allowing reliable comparisons within and among monitoring programs (McClure et al. 2021).

Comparisons of density estimates avoid these problems, but generally require labour-intensive methods, usually applicable only to limited areas and territorial birds, such as territory mapping. Another way to obtain density estimates of wintering raptors over large areas may be provided by the "distance sampling method" described in depth by the monographs of Buckland et al. (1993, 2015). Distance sampling consists of line transects with the registration of the perpendicular distance from the line of the objects of interest (Burnham et al. 1981) or point counts measuring the radial distance from the observer to the objects (Reynolds et al. 1980, Buckland 1987).

Even if the underlying theory is the same, and point counts are conceptually like line transects for which the lines have zero length, points are less robust to monitor scarce species than are transects, because some time is spent moving from one point to another point instead of counting birds along the complete transect. The variance of the count is also greater with points than with transects because of mathematical reasons (Buckland et al. 1993).

Despite their potential usefulness, the above methods were rarely applied until now to raptor density estimation (McClure et al. 2021), especially in Europe (but see Boano & Toffoli 2002, Nikolov et al. 2006, Baltag et al. 2013, Steven et al. 2019).

As previously (Boano & Toffoli 2002), we decided to use the line transect method and investigate the same area of the western Po plain after twenty years, with the scope to show eventual changes in the guild of wintering raptors and of the densities of the commonest species.

Materials and Methods

Study area

The study area encompasses two distinct zones within the Po River plain, corresponding to the geographically separated western and north-eastern sectors, which differ in dominant land use, maize cultivation in the west and rice fields in the northeast. The western plain includes relatively high habitat heterogeneity, with humid meadows, small fallow fields, scattered poplar plantations, and remnants of natural woodlots, largely due to poorer soil quality and lower agricultural productivity (IPLA 1982). In our previous study (Boano & Toffoli 2002), these heterogeneous zones were treated as separate habitats. However, over the past two decades, such features declined markedly in both extent and continuity. Humid meadows decreased by approximately 50%, and poplar plantations by over 90% in surface area (www.sistemapiemonte.it). For the current analysis, these areas have been merged with the rest of the western plains, just as we have merged the south-eastern plains, where wheat is the predominant crop, with the western area, as the two share similar land-use characteristics. Maize cultivation is also common in this zone, particularly near the Po River.

The north-eastern sector is mainly occupied by rice monoculture, and the heathlands of the northernmost area,

once quite extensive and considered a separate habitat in the previous work (Boano & Toffoli 2002), have been greatly fragmented and largely converted into rice fields.
Counts were carried out over two consecutive winters: from 8 January to 25 February 2021 (winter 2020/2021), and from 3 December 2021 to 19 February 2022 (winter 2021/2022).

The average minimum temperatures in January and February 2021 (-1.3°C and +1.8°C, respectively) were higher than those recorded in the same months of 2022 (-2.5°C and -1.1°C) (www.arpa.piemonte.it).
Sampling was stratified (Sutherland 1996) by winter and prevailing rural landscape structure.

Two macro-habitats were defined as follows:
Mixed crops: areas characterised by intensive agriculture, predominantly maize, but also wheat, meadows, and soybeans. This habitat covers most of the western and south-eastern plains, with an estimated area of 4,200 km².
Rice fields: This area, located North of the Po River and between the Dora Riparia and the Ticino rivers, is dominated by intensively managed, almost treeless rice fields, interspersed only occasionally with isolated poplars or oaks, and includes a single 4 km² wooded patch. In the northernmost portion, more recent rice field expansion has occurred at the expense of the heathland of ancient pastoral origin. The total surface of this habitat is approximately 1,500 km².

Based on our previous work and the considerations of Buckland et al. (1993), we selected the linear transect method, taking note of the transect length, species observed and perpendicular distances between the transect line and each observed bird. To obtain unbiased and representative estimates of densities realised by raptors in the whole area, according to Buckland et al. (1993, 2015), it is necessary to respect some conditions, in particular: the detection probability of the birds on the transect line should be 1; perpendicular distances of the observed birds from the transect are correctly estimated; the transect is allocated randomly with respect to the distribution of birds.

The first is the most crucial assumption of the method: the lack of detection of some individuals just on (or very nearby) the transect line irremediably biases the results; on the contrary, the method explicitly allows some animals to go undetected away from the transect line. In practice, it is necessary to ascertain that no birds fly away from the transect line undetected. This condition is not very difficult to obtain in open country with medium to big raptors like common buzzard (*Buteo buteo*), but may be a common cause of problems with little or more elusive species flying away well before being seen from the approximating observer, like Eurasian sparrowhawk (*Accipiter nisus*) or merlin (*Falco columbarius*).

All the authors alternated between the roles of observer and driver and the accuracy of the observations and measures was improved with a slow speed (15 to 40 km/h) and using a rangefinder like binoculars LEICA Geovid 7 X 42 BDA (precision of ±1 m; range 25–1000 m) and LEICA Rangemaster 1200 that estimate the distances with a laser telemeter (precision of ±1 m; range 10–1200 m). The distances of birds under 10 m were paced or visually estimated. Birds flying away from the line due to the approaching car were measured at the distance they were first seen. A few birds flying independently from our approach were recorded when they came abeam of the observer's car. All the birds observed were counted without truncation distance, and, due to the open habitat, we saw birds up to 650 and, exceptionally, up to 850 m. We carried out the counts mainly by covering secondary and dirt roads and avoiding main roads, on days of low work traffic.

The observation effort was 416 km in the first winter and 546 km in the second, subdivided into transects of variable length according to routes and macro-habitats, averaging about 10 km each, and are reported in the map (Fig. 1). We included in transects the little country towns under 2 km of crossing due their relatively high frequencies in the area.

During the observation period, the birds were wintering, and there was no noticeable movement. Raptors, even in winter, are territorial, so we did not observe clusters of birds, and all the observations were independent of each other.

We counted mainly from 10:00 to 15:00, as in winter the daytime in our region is relatively short, and at 16:00–16:30 the night is descending; and in the morning, fog conditions frequently occur. In each stratum, we made observations in the same hourly period.

Analysis of densities with the program DISTANCE was limited to the species with more than 60 observations, thus possible only for the common buzzard and the common kestrel (*Falco tinnunculus*). Data were right-truncated at 480 m to reduce the effect of data having an extended tail, especially for common buzzards, so we excluded 5% of common buzzard and 2.5% of common kestrel observations.

We adopted three analytical approaches based on the principles of Distance Sampling (Buckland et al. 1993): (a) **Conventional Distance Sampling (CDS)** with a *pooled detection function*, assuming identical detection

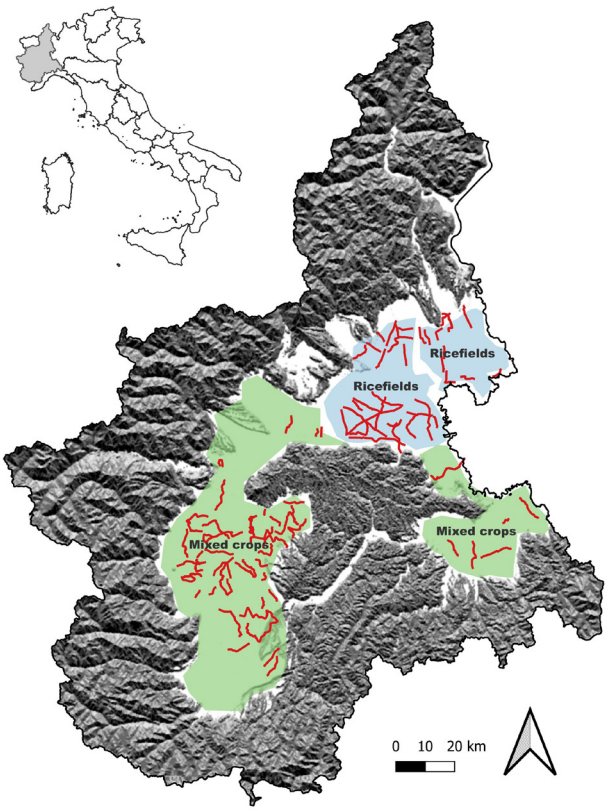

Fig.1. The study area in the western Po Plain in Italy with transects driven/sampled during the two study winters (red lines) and the two studied macro-habitats: mixed crops (green) and ricefields (azure).
Obr. 1. Sledovaná oblasť v západnej časti Pádskej nížiny v Taliansku s transektmi, ktoré boli prejdené/vzorkované počas dvoch študovaných zím (červené čiary), a dva študované makrohabitaty: zmiešané plodiny (zelená farba) a ryžové polia (azurová farba).

probability across all surveys; (b) **CDS with stratified detection functions**, where each stratum corresponded to one of the two macro-habitats (mixed crops and rice fields) in each winter season; (c) **Multiple-Covariate Distance Sampling (MCDS)**, incorporating covariates expected to influence detectability: habitat stratum (HAB), month of observation (MTH), and observer identity (OBS).

Detection functions were fitted using both the half-normal and the hazard-rate key functions, with cosine, simple polynomial, or Hermite polynomial adjustment terms. The most parsimonious model was selected based on Akaike's Information Criterion (AIC (Burnham & Anderson 1992, Laake et al. 1993).

To compare density estimates among macro-habitats and years, we used the program CONTRAST (Hines & Sauer 1989), a chi-square analysis with multiple comparisons, which enables statistical comparison of multiple parameter estimates, provided their associated variances. The null hypothesis is that there is no difference among the tested estimates.

Results

We counted 504 raptors plus 11 great grey shrikes (*Lanius excubitor*) subdivided by species, seasons and areas as shown in Table 1. Common buzzards, common kestrels, peregrine falcons (*Falco peregrinus*) and great grey shrikes were observed mainly when perching or waiting for food. Red kites (*Milvus milvus*), hen harriers (*Circus cyaneus*), marsh harriers (*Circus aeruginosus*), Eurasian sparrowhawks, northern goshawks (*Astur gentilis*), and merlins were usually spotted in flight. Excluding the common buzzard and common kestrel, the only two species generating a sufficient number of observations to allow an analysis of density, the indices of abundance (ind./km) of all other species was generally low, about one per 100 km for peregrine falcon, red kite, sparrowhawk, and great grey shrike, or even less (Table 1).

Common buzzard density

All the tested models supported half-normal key functions with cosine adjustment terms (Table 2). According to AIC, the best - supported model was MCDS with detection function differentiated across strata (habitats and years), and observers as factor covariate. We used the estimates from this unpooled analysis for the subsequent generation of density estimates (Table 3).

The DISTANCE analysis of transects conducted during the first winter showed a relatively lower density than the second winter (Table 3). We observed a marked difference between macro-habitats during both winters, with densities in rice fields about two to four times greater than in mixed crops. The selected model gave an effective strip half-width, the distance from the transect line at which as many individuals are overlooked as recorded, of 210 m and the average probability of detection was estimated to be 0.44 (CV = 4.11%).

A contrast analysis (Hines and Sauer, 1989) rejected the null hypothesis of no differences in the density estimates among the four strata (χ^2 = 55.874, df = 3, P < 0.001). Similar results were obtained when comparing densities between the two macro-habitats, by pooling data across different years (χ^2 = 50.864, df = 1, P < 0.001), or during winters, by pooling densities within each macro-habitat (χ^2 = 10.536, df = 1, P = 0.001).

Tab.1. Total number of raptors and shrikes (n) observed in the two winter study seasons, subdivided into the two macro-habitats, with the sampling effort for each winter and habitat reported as the length of the transects in kilometres ("Km").
Tab.1. Celkový počet dravých vtákov a strakošov (n) pozorovaných v dvoch zimných sezónach štúdie, rozdelených do dvoch makrohabitatov, s úsilím vzorkovania pre každú zimu a habitatom uvedeným ako dĺžka transektov v kilometroch („Km").

	Winter 2020/2021						Winter 2021/2022						Total	
	Mixed crops		Rice fields		Total		Mixed crops		Rice fields		Total			
	Km 262		Km 154		Km 416		Km 372		Km 164		Km 546		Km 962	
Species	**n**	**n/km**	**n**	**n/km**	**n**	**n/km**	**n**	**n/km**	**n**	**n/km**	**n**	**n/km**	**n**	**n/km**
Common buzzard	64	0.24	77	0.5	141	0.34	71	0.19	162	0.99	233	0.43	374	0.39
Common kestrel	28	0.11	16	0.1	44	0.11	23	0.06	15	0.09	38	0.07	82	0.09
Eurasian sparrowhawk	3	0.01	0	-	3	0.01	8	0.02	3	0.02	11	0.02	14	0.01
Peregrine falcon	3	0.01	2	0.01	5	0.01	4	0.01	3	0.02	7	0.01	12	0.01
Red kite	1	0	6	0.04	7	0.02	1	0	2	0.01	3	0.01	10	0.01
Marsh harrier	0	-	4	0.03	4	0.01	0	-	3	0.02	3	0.01	7	0.01
Hen harrier	0	-	3	0.02	3	0.01	0	-	0	-	0	-	3	0
Northern goshawk	0	-	1	0.01	1	0	0	-	0	-	0	-	1	0
Merlin	1	0	0	-	1	0	0	-	0	-	0	-	1	0
Great grey shrike	3	0.01	1	0.01	4	0.01	7	0.02	0	-	7	0.01	11	0.01

Common buzzard density was variable over the winters and macro-habitats; however, the values obtained in this study are quite comparable to those obtained during the previous survey of the winter 1999/2000 (Fig. 2). Finally, from our density estimates, we can get for the entire sampled area 4,009 (2,965–5,422) birds in the winter 2020/2021 (overall mean 0.70 individuals per km^2) and 5,221 (4,061–6,719) in the winter 2021/2022 (mean = 0.92).

Common kestrel density

Despite being the second most abundant species, the common kestrel had much lower encounter rates than the common buzzard, and we were unable to collect a sufficient number of observations (i.e. more than sixty) for each different strata (macro-habitats and winters). As for the common buzzard, all the models supported half-normal key functions with cosine adjustment terms. The analyses showed no difference in detection rate by strata, and the model selection procedure indicated the pooled CDS model as the best (Table 4). All models with covariates were discarded according to the AIC. So we calculated the densities in the two habitats and winters from this model, and obtained very similar densities in each stratum (Table 5). This model gave an effective strip half-width of 97 m, and the average probability of detection was estimated to be 0.20, Coefficient of Variation = 10.24%.

Tab. 2. Common buzzard: model-selection results. Models are sorted by AIC (Akaike's Information Criterion). Model: CDS = conventional distance sampling, MCDS = multiple-covariates distance sampling; Covariates: HAB = Habitats, MTH = months, OBS = observers. N par. = number of parameters; ΔAIC = difference in AIC between the candidate model and the model with the lowest AIC.
Tab. 2. Myšiak lesný: výsledky výberu modelu. Modely sú zoradené podľa AIC (Akaikeho informačného kritéria). Model: CDS = konvenčné vzorkovanie vzdialenosti, MCDS = vzdialenostné vzorkovanie s kovariátmi; Kovariáty: HAB = biotopy, MTH = mesiace, OBS = pozorovatelia. N par. = počet parametrov; ΔAIC = rozdiel v AIC medzi kandidátskym modelom a modelom s najnižším AIC.

Model	Covariates	N Par.	AIC	ΔAIC
MCDS	OBS	4	1224.52	0
CDS (stratified detection function)		6	1226.1	1.57
MCDS	HAB+OBS	5	1226.11	1.59
MCDS	OSS+MTH	6	1227.86	3.33
MCDS	HAB+OBS+MTH	7	1229.33	4.8
CDS (pooled detection function)		2	1230.84	6.32
MCDS	HAB	2	1237.44	12.92
MCDS	HAB + MTH	4	1238.56	14.04
MCDS	MTH	3	1239.18	14.66

Tab. 3. Common buzzard: summary of the results of the DISTANCE analysis according to the model MCDS with covariate OBS. k = samples (transects); L = total transects length; n = number of individuals counted; n/L = encounter rate; SE = standard error; CV% = Coefficient of Variation %; D = Density estimates (expressed as individuals per km^2); 95% LCL = 95% lower coefficient limit; 95%; UCL = 95% upper coefficient limit.
Tab. 3. Myšiak lesný: zhrnutie výsledkov analýzy DISTANCE podľa modelu MCDS s kovariátom OBS. k = vzorky (transekty); L = celková dĺžka transektov; n = počet spočítaných jedincov; n/L = miera výskytu; SE = štandardná chyba; CV% = koeficient variácie %; D = odhad hustoty (vyjadrený ako počet jedincov na km^2); 95 % LCL = 95 % dolná hranica koeficientu; 95 %; UCL = 95 % horná hranica koeficientu.

Winter	Macro habitat	k	L (km)	n	n/L	SE (n/L)	%CV (n/L)	D (ind./km^2)	SE (D)	CV% D)	95% LCL (D)	95% UCL (D)
2020/21	mixed crops	31	262	63	0.24	0.03	13.69	0.57	0.08	14.29	0.43	0.77
2020/21	rice fields	27	154	69	0.45	0.07	15.31	1.07	0.17	15.85	0.77	1.47
2021/22	mixed crops	36	372	71	0.19	0.03	14	0.45	0.07	14.59	0.34	0.61
2021/22	rice fields	18	164	152	0.93	0.1	10.26	2.21	0.24	11.05	1.76	2.77

Moreover, the contrast analysis (Hines & Sauer 1989) among the four density estimates did not show any statistical differences ($\chi^2 = 2.722$, df = 3, $P = 0.436$). For this reason, we used the global estimate of 0.44 (SE = 0.08) birds for km^2 for the entire sampled area to estimate a wintering population of about 2,508 (95% CIs = 1,767–3,534).

Discussion

The raptor species composition was found to be similar to the result of the survey made 20 years ago with a similar sampling effort (Boano & Toffoli 2002). The biggest difference was that we found quite a good number of marsh harriers, due to a larger sample of transect routes in the rice field area and probably an increase in winter visitors. The species experienced a moderate increase in wintering individuals in Italy (Zenatello et al. 2014). All the other recorded raptor species showed an encounter rate that was not substantially different and generally very low. The only two species with a number of records that allowed the possibility of calculating the densities were the common buzzards and the common kestrels. This pattern is common over a wide area in European agro-ecosystems (Ševcík 1995, Mülner 2000, Nemček 2013).

Also, for common buzzard and common kestrel, our estimates should refer to the limited areas along the transect roads, but we think that the estimates could be considered good approximations of the densities typical of the whole investigated area. The agricultural landscape of the region shows great homogeneity.

Moreover, the selected transects were mainly secondary roads, irregularly crossing the entire area and representing a common feature of the territory, and the effective strip half-width was very large.

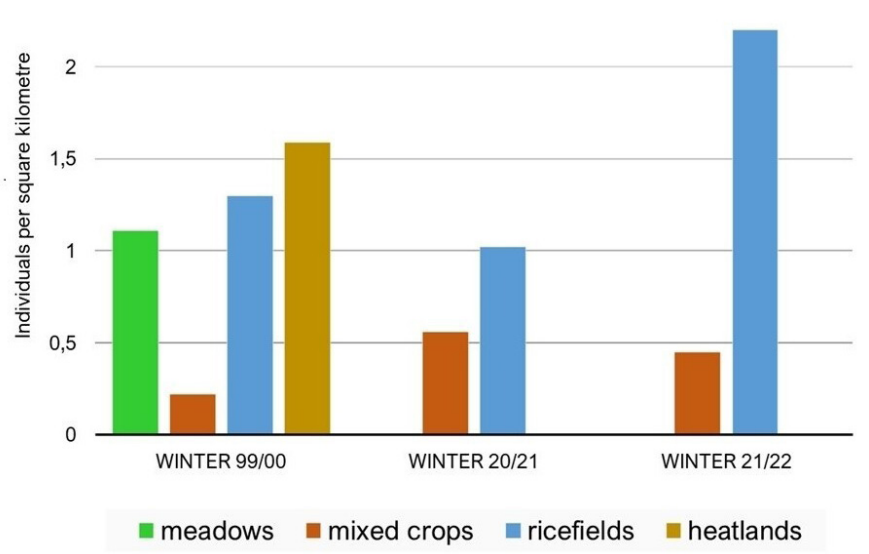

Fig 2. Common buzzard density estimate comparisons among the two studied macro-habitats and the two study winters, including the data for 1999/2000 taken from Boano & Toffoli (2002). For the winters 2020/2021 and 2021/2022, the surfaces of the remaining "meadows" and "heatlands" were respectively included in the "mixed crops" and in the "rice fields" (see study area paragraph).
Obr. 2. Porovnanie odhadov hustoty myšiaka lesného medzi dvoma študovanými makrohabitatmi a dvoma sledovanými zimami, vrátane údajov za rok 1999/2000 prevzatých z Boano & Toffoli (2002). Pre zimy 2020/2021 a 2021/2022 boli plochy zostávajúcich „lúk" a „vresovísk" zahrnuté do „zmiešaných plodín" a „ryžových polí" (pozri Study area).

Tab. 4. Common kestrel: model-selection results. Models are sorted by AIC (Akaike's Information Criterion). Model: CDS = conventional distance sampling, MCDS = multiple-covariates distance sampling; Covariates: HAB = macro-habitats, MTH = months, OBS = observers. N par. = number of parameters; ΔAIC = difference in AIC between the candidate model and the model with the lowest AIC.
Tab. 4. Sokol myšiar: výsledky výberu modelu. Modely sú zoradené podľa AIC (Akaikeho informačného kritéria). Model: CDS = konvenčné vzorkovanie vzdialenosti, MCDS = vzorkovanie vzdialenosti s viacerými kovariátmi; Kovariáty: HAB = makrohabitat, MTH = mesiace, OBS = pozorovatelia. N par. = počet parametrov; ΔAIC = rozdiel v AIC medzi kandidátskym modelom a modelom s najnižším AIC.

Model	Covariates	N Par.	AIC	ΔAIC
CDS (pooled detection function)		4	216.49	0
CDS (stratified detection function)		5	219.55	3.06
MCDS	OBS+MTH	6	222.9	6.41
MCDS	HAB+OSS+MTH	7	224.71	8.22
MCDS	OBS	4	226.21	9.72
MCDS	HAB+MTH	4	227.14	10.65
MCDS	HAB+OBS	5	228.05	11.56
MCDS	HAB	2	228.85	12.36
MCDS	MHT	3	228.95	12.46

The data confirmed the importance of the region's rice fields at a national level for the wintering common buzzards: the encounter rate (birds/km) was well over that of other Italian regions and of many Mediterranean countries (Sarà 1996, Boano & Toffoli 2002).

The lower temperature in January and February 2022 could account for the higher density of common buzzards observed in the second winter in the study area, particularly in the rice fields, while they remained more stable in mixed crops. Buzzard abundance in winter is often associated with lower temperatures (Baltag et al. 2013) and/or the availability of prey, which in turn is influenced by climate and agricultural practices (Laber & Zuna-Kratky 2005). Variation in prey abundance likely also played a significant role, though recent studies on rodent density and raptor prey in the area are lacking. The only existing information comes from stomach content analysis of common buzzards caught in our study area in January (Moltoni 1937), which revealed that the commonest prey were rodents (*Arvicola, Micromys*), reptiles (*Natrix*) and frogs (*Rana*).

Therefore, the current common buzzard's overall wintering population of the investigated area appeared relatively stable, though a bit higher, in comparison with that of 3,180 (2,690–3,760) obtained on 4,700 km^2 (i.e. mean = 0.68 inds./km^2) of the same area without the south-eastern plains in the winter 1999/2000 (Boano & Toffoli 2002).

The density estimates were still lower than those obtained with intensive searches or mapping methods in some Central European countries, as Germany and France, mainly reported in general handbooks (Glutz & Bauer 1980 and references therein, Yeatman-Berthelot 1991, Wuczyński 2003), and not easily comparable with ours. However, considering only the estimates obtained with comparable distance sampling methods, the common buzzard densities found in our study area score among the highest obtained in Europe (Boano & Toffoli 2002,

Tab. 5. Common kestrel: summary of the results of the DISTANCE analysis with the CDS Model Half Normal+cosine, detection global, data right truncated at 480 m. k = samples (transects); L = total transects length; n = number of individuals counted; n/L = encounter rate; SE = standard error; CV% = Coefficient of Variation %; D = Density estimates (expressed as individuals per km^2); 95% LCL = 95% lower coefficient limit; 95% UCL = 95% upper coefficient limit.
Tab. 5. Sokol myšiar: zhrnutie výsledkov analýzy DISTANCE s modelom CDS Half Normal+cosine, globálna detekcia, údaje skrátené na 480 m. k = vzorky (transekty); L = celková dĺžka transektov; n = počet spočítaných jedincov; n/L = miera výskytu; SE = štandardná chyba; CV% = koeficient variácie %; D = odhad hustoty (vyjadrený ako počet jedincov na km^2); 95 % LCL = 95 % dolná hranica koeficientu; 95 % UCL = 95 % horná hranica koeficientu.

Winter	Macro habitat	k	L (km)	n	n/L	SE (n/L)	%CV (n/L)	D (ind./km^2)	SE (D)	CV% D)	95% LCL (D)	95% UCL (D)
2020/21	mixed crops	31	262	28	0.11	0.03	26.52	0.55	0.16	28.43	0.31	0.97
2020/21	rice fields	27	154	15	0.1	0.03	27.31	0.5	0.15	29.16	0.28	0.9
2021/22	mixed crops	36	372	23	0.06	0.01	20.58	0.32	0.07	22.99	0.2	0.5
2021/22	rice fields	18	164	14	0.09	0.03	29.59	0.44	0.14	31.31	0.23	0.83
Pooled	pooled	112	952	80	0.08	0.01	13.21	0.44	0.08	17.68	0.31	0.63

Nikolov et al. 2006, Baltag et al. 2013, Panuccio et al. 2019), except for those found in some winters in middle Austria, reaching 3–4 inds./km^2 (Laber & Zuna-Kratky 2005).

Our results confirmed that common kestrel detectability declines more rapidly than that of common buzzards with increasing distance (Panuccio et al., 2019), as indicated by the lower effective strip half-width for common kestrels (97 m) compared to buzzards (210 m). This difference likely accounts for the absence of observer effects on common kestrel detectability. Nonetheless, the distance sampling method, which accounts for varying detectability, still indicates a lower abundance of common kestrels than common buzzards, even if the first species is apparently more evenly distributed across winter habitats. Also during the breeding season, common kestrels have been shown to be more widespread and better adapted to a larger variety of landscape types (Butet et al. 2022). Our findings indicated that this also remains the case in winter, despite the higher abundance of common buzzards.

The lower detectability and density of the common kestrel made it more challenging to obtain an adequate sample for distance analysis with this level of field effort. Therefore, it is unsurprising that our winter density estimate is the first for the study region, and one of the few for Europe based on methods that consider the detection probability (Burhnam et al. 1981). For comparison, the average value of 0.44 inds./km^2 (± 0.08 SE) found in Piedmont seems to be intermediate between the values found by Panuccio et al. (2019) in Sicily (0.75 ± 0.10 SE) and in Crete (0.26 ± 0.04 SE).

Finally we emphasize that the line transect method, which is unfortunately not still widespread in raptor-surveys in Europe, if correctly applied in open agricultural habitat, can generate, with a moderate effort, good results for the most familiar and widespread species, like the common buzzard and common kestrel, and should be used for future raptor surveys to provide more rigorous comparisons of density and abundance estimates over time and large areas. To obtain an acceptable sample to calculate the density of other scarcer wintering raptors, an effort 4–5 times greater would be required. Larger samples could allow more detailed environmental analyses even for the commonest species. Further, gathering precise information on the abundance of available prey species in the study area would be helpful.

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Received 5.6.2025
Accepted: 24.8.2025