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Monitoring of a community of breeding birds in an agroecosystem with high environmental heterogeneity

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Abstract - An agroecosystem with high environmental heterogeneity located in the low Veronese Po plain (Italy) was monitored over a seven-year period, from 2013 to 2019. In the study area three transects representative of three types of environment were selected: arboreal-shrubby hedge, cultivated land, and linear wood. Using a line transect method, five visits were made in each breeding season. For each habitat type, the following indices were calculated: Richness, Relative species frequency, I.K.A., Abundance and Density of territorial males, and Shannon Diversity. A total of 39 breeding species were registered. Whittaker's diagrams highlighted the presence of high levels of richness and diversity in the linear wood and arboreal-shrubby hedge environments. The cultivated area hosts species considered as bioindicators of highly extensive agricultural environments. The characteristics of the arboreal-shrubby hedge seemed optimal to support a well-structured and stable bird community, and some typical species of hedges such as *Sylvia communis* and *Luscinia megarhynchos* had reached I.K.A. comparable to the highest recorded in Italy. The trends of the main parameters of all three communities did not show statistically significant fluctuations in the years of sampling. The results show a high degree of general ecological interest and conservation importance of the study area, also in comparison of other similar Italian agroecosystems, since we found 14 breeding species of high conservation concern, among which three included in Annex 1 of the 2009 Directive / 147 / EC.

Key-words: Abundance/Biomass Comparisons, arboreal-shrubby hedge, biodiversity indices, farmland birds, Whittaker plots.

INTRODUCTION

Agricultural intensification, including removal of the hedgerows and treerows, has led to widespread declines in farmland biodiversity over the last century (Donald et al. 2001, Newton 2004, Donald et al. 2006, Reif et al. 2008, Vorisek et al. 2010). Hedges are important structural elements of the landscape; they provide important services, and have a crucial role in maintaining a stable balance in agricultural ecosystems. The hedge is an important micro-habitat for plant and animal species, in particular for the birds that use it to nest, feed on berries, fruits and insects, as a perch for singing and defending the territory, to hunt their prey, to hide from predators, as a shelter from adverse weather conditions and as a roost site (O'Connor 1984; Osborne 1984). The hedges and arboreal rows also act as ecological corridors for the fauna and significantly increase the biodiversity of the areas in which they are present (Groppali 1991, Groppali 2000); for woodland birds they can allow training meta-populations among isolated forests and woodlots (Davies & Pullin 2007; Gilbert-Norton et al. 2010). Many authors that have studied the bird communities of rural areas underline the impor-

tance of hedges (Hinsley & Bellamy 2000, Genghini et al. 2003) and the structural complexity of habitats (Bűchs 2003, Calvi et al. 2018) for avian biodiversity and for the conservation of farmland specialists (Brambilla et al. 2003, Brambilla 2019). In Italy there are some works concerning in particular hedges and linear woods located along waterways within agroecosystems (Capello & Boano 2010, Angelici et al. 2012); most of the investigations however, were carried out within a year or a single breeding season. This work shows the results of a 7-year monitoring concerning the breeding bird community of a rural area particularly suitable for birds due to its high environmental heterogeneity. The study site it is part of an area of the low Po plain which was reported in the past for its ornithological interest (Dini et al. 1988); quantitative data on breeding assemblages however, had not been investigated yet. The results of quantitative medium-term studies on these types of environment can be compared with those of more degraded rural areas and provide useful management and conservation indications. The objectives of this investigation were: to study the parameters of the breeding bird communities over the years; to monitor the populations of some farmland specialists, as Skylark *Alauda arvensis*, Western Yellow Wagtail *Motacilla flava*, Red-backed Shrike *Lanius collurio*, Common Nightingale *Luscinia megarhynchos*, Common Whitethroat *Sylvia communis*, Corn Bunting *Emberiza calandra*, Ortolan Bunting *Emberiza hortulana*; to provide useful data for comparisons with other areas and to evaluate any changes in the bird community over time. A further objective was to study the level of stress experimented by the bird assemblages following the Abundance/Biomass Comparisons approach (Magurran 2004) to understand the ecological processes taking place in this area and to obtain useful information at management and conservation level.

MATERIAL AND METHODS

Study area

The survey was carried out in an agricultural area located in the low Veronese Po plain (Italy) at an average altitude of 11 m a.s.l. in the municipal area of Cerea (VR) (45° 09' N; 11° 24' E) (Fig. 1). A path representative of the environmental characteristics of the agroecosystem was chosen. The clear change in the type of environment observed along the path led us to divide it into three consecutive transects 50 meters away from each other (Fig. 1). The small fraction of overlap between them (less than 5%) has not significantly influenced the census, since the aforementioned environmental differences have facilitated the detection of territories and their attribution to the different communities. Overall, the buffer of the transects encompass an area of 31.18 ha and hosts no human settlements and rural buildings. The transects were:

Canal Bianco Transect (CB): 1310 m long route located on the right bank of the Canal Bianco channel. On the embankment there is a spontaneous arboreal-shrubby hedge with prevalence of *Salix alba* and presence of *Salix cinerea*, *Populus alba*, *Crataegus monogyna*, *Sambucus nigra*. The average width of the hedge is 6.5 meters. The transect includes a narrow belt of arable land and grass verges (10%). On the bank there is still a narrow strip of marsh vegetation with *Carex* sp. and *Phragmites australis*.

Cultivated Land Transect (CL): 990 meters long route that crosses a cultivated area furrowed by a dense network of ditches on whose banks there are strips of marsh vegetation with *Typha* sp., *Carex* sp. and some isolated *Salix* sp. During the study period, the crops occupied on average the following fractions of agricultural land: corn (40 %), wheat (25%), soy (15%), sunflower (10%), sugar beet (5%). Among the crops, grass verges are left (5%).

Tartaro Wood Transect (TW): 660 meters long route located on the bank of the ancient course of the Tartaro river. On the embankment there is a multilayered linear wood with an average width of 18 meters and an age of 25 years. The dominant species, in order of decreasing frequency are: *Crataegus monogyna*, *Acer campestre*, *Cornus sanguinea*, *Corylus avellana*, *Carpinus betulus*, *Quercus robur*, *Alnus*

glutinosa, *Fraxinus excelsior* (Comunian & Pozzani 1997). The transect includes a narrow strip of marsh vegetation dominated by *Phragmites australis* (5%) and arable lands (5%).

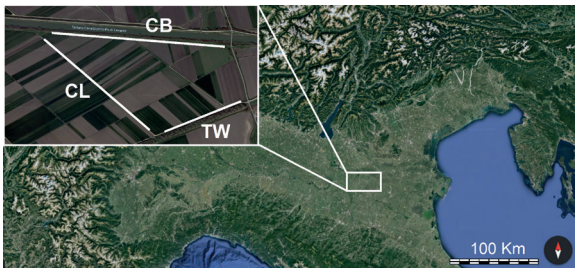

Figure 1. Geographical location of the study site and position of the linear transects within the area (inset). CB: Arboreal-shrubby hedge; CL: Cultivated Land; TW: Linear wood (modified from Google Earth).

Protocol and data analysis

The monitoring focused on the breeding bird species, considered among the most significant for the evaluation of the ecological characteristics of the natural environments (Temple & Wiens 1989). The censuses were conducted with the linear transect method (Järvinen & Väisänen 1976, Bibby et al. 2000) where the observer walked at a constant speed along the transect, recording all contacts of reproductive individuals within a buffer of 100 m. Species with crepuscular or nocturnal activity (e.g. *Strigiformes*) were not considered except the Long-eared Owl *Asio otus*. Particular attention was paid to recording activities useful to define the presence of territorial males. All the species surveyed showed a high and almost uniform detectability (Boulinier et al. 1998). The censuses were carried out in the morning from 6.30 to 8.30 in good weather conditions, in the years 2013-2019. Each transect was surveyed 5 times from March to June, to match the peak of breeding activity of sedentary, short migrants and summer visitor species (Brotons et al. 2004, Spina & Volponi 2008a, Spina & Volponi 2008b). We recorded all the observation of males with territorial behaviour; for each year, the highest number of territories of a species from the five surveys was used as a measure of its abundance in the transect. We then derived the average number of territorial males over the years. For each transect and for each breeding season, the following parameters were detected:

1) Species Richness (S_{tot}), i.e. the total number of species sampled;

2) Relative species frequency (pi), i.e. the ratio between the number of individuals of the i-th species and the total number of individuals in the assemblage. A species with pi ≥ 0.05 was considered dominant (Turcek 1956);

3) I.K.A. or number of territorial males/km (Ferry & Frochot 1958);

4) Abundance (Ab) or number of territorial males surveyed for each individual species;

5) Shannon Diversity Index (H') (Shannon & Weaver 1963), calculated as $H' = -\Sigma (p_i) (\ln p_i)$, where p_i is the proportion of individuals of the community belonging to the i-th species out of the total of individuals of all species.

Community parameters were calculated using the PAST 3 software (Hammer et al. 2001). To verify the occurrence of significant differences in terms of S_{tot} and H' over the years, the Spearman coefficient for ranks (r_s) was used (Fowler & Cohen 1986). We also adopted a dominance/diversity approach by using Whittaker plots (Whittaker 1965, Krebs 1999, Magurran 2004, Magurran & Mc Gill 2011), were species relative frequencies are represented as a function of the species rank. Such analyses have been widely used in avian ecology to explore the bird response to patchy and disturbed environments (Wiens 1989, Battisti et al. 2008). We ranked all species recorded in each habitat type from the most to the least abundant. The curve shapes are indicative of the evenness of assemblages and suggest the presence of underlying processes that determine the revealed patterns (Magurran 2004). These diagrams explicit the ratio of frequency among species, either calculated only on individuals (rank/abundance diagrams) or on individuals and biomass contemporarily (Abundance/Biomass Comparisons or ABC curves, Warwick 1986). In the rank/abundance diagrams more elevated curves represent the less diverse assem-

blages; in ABC curves, different slopes, shape and/or trend in curves provide information on the stress suffered by species assemblages (Magurran 2004, Benassi et al. 2009). Frequency curves relative to the abundance indicate a distribution of the spatial niche of the species; differently, biomass curves indicate the flow of energy in the assemblage according to the trophic resources used by species (Begon et al. 1986, Magurran 2004). In undisturbed communities, usually a high number of low abundant species is observed, and only one or two of them are dominant in terms of biomass; this has the effect of elevating the biomass curve relative to abundance curve. In contrast, highly disturbed assemblages are expected to have a few species, mostly ecologically "generalist" with very large numbers of individuals but, since these species are usually small bodied, they do not dominate the biomass. In such circumstances the abundance curve lies above the biomass curve. Intermediate conditions are characterized by curves that overlap and may cross several time (Magurran 2004). The weights of the birds were derived in part from measurements made by the Author in the ringing station of the Palude Brusà (Cerea-VR), located about 9 km away from the study area and in part from the literature (Cramp 1998, Brichetti & Fracasso 2003, Brichetti & Fracasso 2004, Brichetti & Fracasso 2006, Brichetti & Fracasso 2007). To construct the ABC curves, the average density of territorial males (number of territories/10 ha), and the standing crop biomass as total weight of the territorial males in the assemblage (g/10 ha) were calculated (Salt 1957).

RESULTS

During the 7-year study, a total of 39 breeding bird species were registered (Tab. ESM1). For two other species, Eurasian Sparrowhawk *Accipiter nisus* and Common Kestrel *Falco tinnunculus*, although breeding within the study area, it was not possible to precisely define the territories. On average, 59 (52-68) territorial males belonging to 34 species were found in the arboreal-shrubby hedge habitat; in the linear wood 31 (21-44) territorial males belonging to 29 species and 14 (10-19) territorial males belonging to 13 species in the cultivated area were observed. Richness in arboreal-shrubby hedge ranged from 17 to 26 (mean 22.9; SD 3.4), in cultivated land from 5 to 10 (mean 8.1; SD 2.1), in linear wood from 13 to 23 (mean 19.3; SD 3.9) (Tab. ESM2). The dominant species in the arboreal-shrubby hedge were: Nightingale, Common Whitethroat, Marsh Warbler *Acrocephalus palustris*, Magpie *Pica pica*, Cetti's Warbler *Cettia cetti*, Wood pigeon *Columba palumbus*, Blackcap *Sylvia atricapilla* and Moorhen *Gallinula chloropus*; in the cultivated area were: Yellow Wagtail, Skylark, Mallard *Anas platyrhynchos*, Magpie, Northern Lapwing *Vanellus vanellus*, Carrion Crow *Corvus corone*; in the linear wood were: Wood Pigeon, Magpie, Nightingale, Blackcap, Carrion Crow, Great Tit *Parus major*, Mallard, Cuckoo *Cuculus canorus*, and Moorhen (Tab. ESM1). The highest values of I.K.A. of territorial males were reached by Nightingale and Common Whitethroat in the arboreal-shrubby hedge, by Yellow Wagtail and Skylark in the cultivated environment, and by Wood Pigeon and Magpie in the linear wood (Tab. ESM1). In the diversity/dominance diagram it can be noted that the relative abundance curve of the cultivated environment has a great slope (Fig. 2).

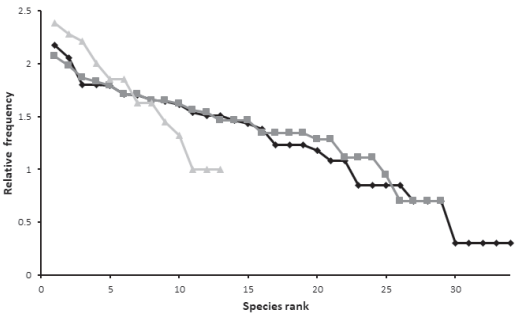

Figure 2. Dominance/diversity diagrams (Whittaker plots) of the breeding bird assemblages found in three habitat types. CB (rhombuses); CL (triangles); TW (squares).

Analyzing the Abundance/Biomass Comparison curves (Fig. 3) it is noted that, in the linear wood and arboreal-shrubby hedge graphs, the biomass curve

almost always exceeds that of abundance, and there is always a clear gap between them. In the diagrams of the cultivated land, the curve of the biomass is in some places below those of the abundance, to then overcome it.

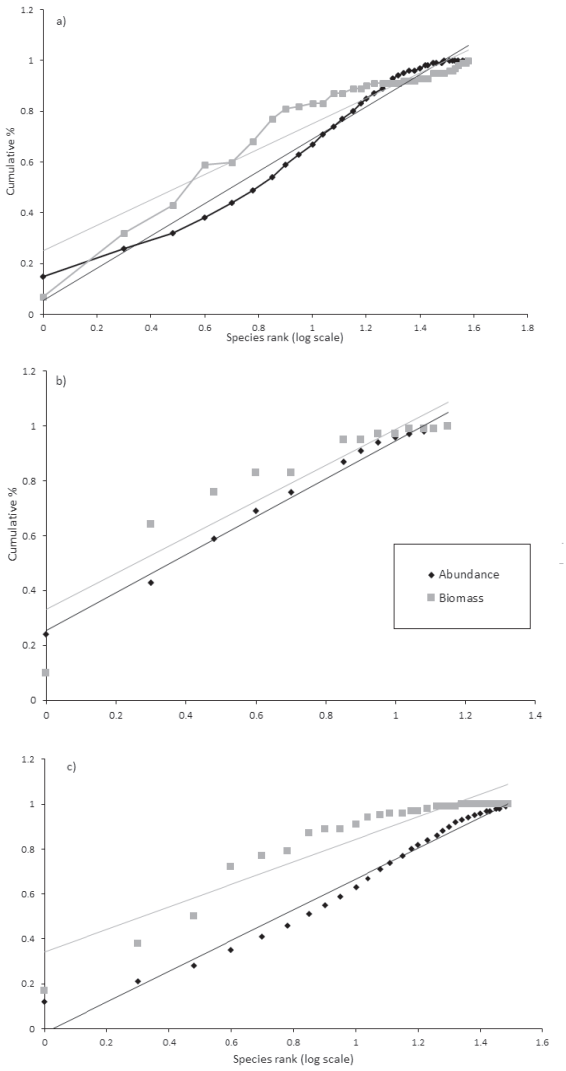

Figure 3. Abundance-biomass comparison (ABC) curves of the CB (Arboreal-shrubby hedge) (a), CL (Cultivated Land) (b); and TW (Linear wood) (c) bird assemblages. Along the x axis, the species rank (log scale) from the most to the least important in terms of either number of territorial males or biomass is reported; on the y axis the cumulative relative frequency calculated as percentage for breeding species biomass (squares) and abundance (rhombuses). Average values for the period 2013-2019 were used, both for the number of individuals and for biomass.

The trends of the main parameters of the three communities, despite some fluctuations, generally indicate a fairly constant trend in the study period (Fig. 4). The most marked oscillations are noted in the arboreal-shrubby hedge community richness and abundance indices (Fig. 4), and in the Shannon Diversity index of the cultivated land (Fig. 4). However, none of the parameters showed statistically significant variation over the years (Tab. 1).

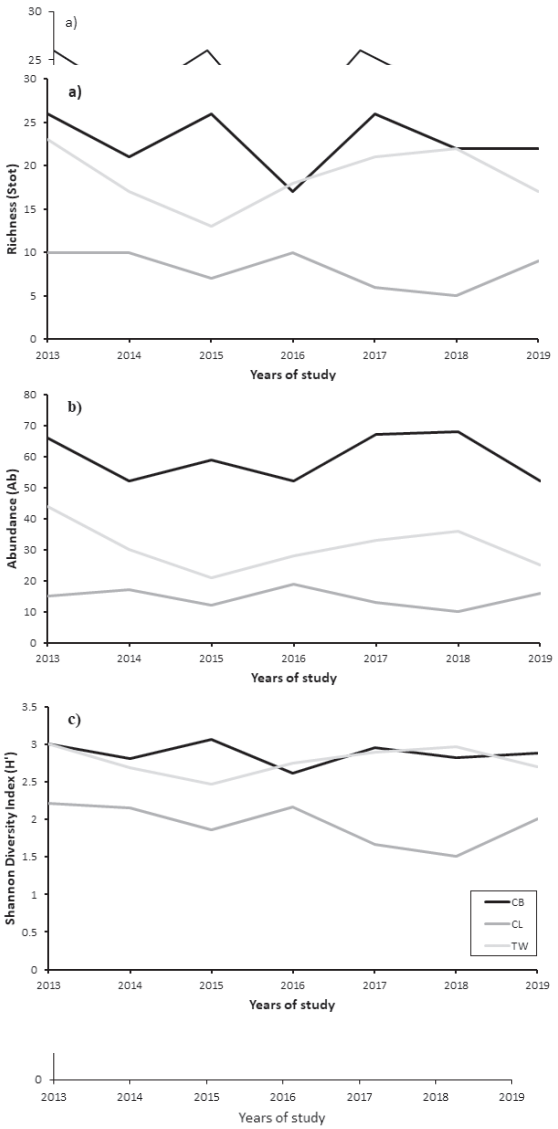

Figure 4. Trends of Richness (a), Abundance (b) and Shannon Diversity (c) resulted for the 7 year census at the CB, CL, and TW bird assemblages.

Table 1. Results of the Spearman Rank test (rs; P-value) for trend changes over the years of the main parameters of the CB, CL and TW bird assemblages.

Parameter	**CB** r_s, P-value	**CL** r_s, P-value	**TW** r_s, P-value
S_{tot}	- 0.12 P = 0.78	- 0.57 P = 0.16	- 0.08 P = 0.84
Ab	0.14 P = 0.72	0.28 P = 0.50	- 0.25 P = 0.55
H'	- 0.21 P = 0.60	- 0.64 P = 0.11	0.00 P = 0.97

DISCUSSION

Although it is not possible to make a statistical comparison between the three communities due to the different length of the transects, we can note that the communities of the linear wood and the arboreal-shrubby hedge are richer and more biodiverse than that of the cultivated area. Whittaker's diagrams in fact highlight a good degree of richness and diversity in arboreal-shrubby hedge and linear wood environments. In the Abundance/Biomass Comparison diagrams the cultivated land pattern is quite similar to that typical of communities consisting of a few species with high abundance, small in size, opportunistic and linked to degraded environments (Andrén 1994, Bellamy et al. 1996, Magurran 2004). Early-cumulating curves may indicate that the resources are used by few species with a broad spatial niche. However, it is noted that the biomass curve in some sections exceeds that of abundance; this suggests that the cultivated area is not excessively degraded. The curves of the linear wood and the arboreal-shrubby hedge, on the other hand, are typical of communities formed by a large number of species with low relative abundance, more ecologically demanding and with greater body biomass. Those habitats are therefore capable of supporting more species either in the space-level (more niche available for a greater number of species), or the trophic-energetic level (more resources and more potential species with high body size and total biomass) (Benassi et al. 2009). The habitat of the arboreal-shrubby hedge community has the most diverse vegetation structure among the three types: hedges, marsh vegetation, crops and grass verges. It is in younger a phase of the ecological succession than the linear wood, and it is more stressed due to man-made extemporaneous coppicing and to sheep grazing. This environment hosts ecotonal and generalist species which thus justify the high average richness value. We note however that even in the most stressed environments, such as cultivated land and, to a lesser extent, the arboreal-shrubby hedge, we found species considered as biondicators of highly extensive agricultural environments (Morelli et al. 2014) many of which included in the Farmland Bird Index: Northern Lapwing, Skylark, Yellow Wagtail, Red-backed Shrike, Common Whitethroat, Ortolan Bunting and Corn Bunting (Brambilla et al. 2009a, 2009b, Rete Rurale Nazionale LIPU 2015a, 2015b, Brambilla et al. 2016a). This favorable situation is in all probability linked to the type of management of the area: first of all, a discrete diversification of crops is maintained, which positively affects the presence of birds by increasing the number of trophic niches available (Fuller & Wilson 1995, Redhead et al. 2018, Sirami et al. 2019). A certain vegetation heterogeneity, also favourable to birdlife, is maintained with the preservation of grass verges, swathes of marsh and shrub vegetation on the banks of the moats (Benton 2003, Genghini et al. 2003, Vickery & Arlettaz 2012, Brambilla 2019). In addition, the dense network of ditches with constant water supply exerts a strong attraction on farmland birds and water-related species such as Northern Lapwing (Arnold 1983). With regard to the trends of the various indices, it is noted that the linear wood community denotes the greatest stability

over time of all the parameters, while the arboreal-shrubby hedge and cultivated land communities have greater oscillations. In the case of the hedge, there is a decrease in the richness, diversity and abundance indices in 2016 (Fig. 4), which highlights the damage to the community caused by the cutting of part of the hedge that occurred during the reproductive period. Overall, however, the substantial stability of trends in community indices seems to confirm a situation of ecological stability and resilience of the environments investigated, certainly favoured by the high degree of environmental heterogeneity of the study area. From the comparison of our results with those of other studies carried out in Italy in similar environments (Tab. ESM3) we can see that the richness and diversity of the hedge community are very similar to those found in the Cuneo-Turin Po plain by Capello & Boano (2010), in hedges lined up along waterways. The value of richness of our cultivated area is much higher than that detected by Malavasi (2001) in the low Modena Po plain not far from the study area, and it is comparable to that observed by Carpegna et al. (2018) in a much wider cultivated countryside (about 390 ha) of the Piedmont Apennines, although a higher diversity value was recorded in the latter. Our richness, on the other hand, is lower than those found by Angelici et al. (2012) in a wider and protected agroecosystem (321 ha) within the Tevere-Farfa Nature Reserve (RM) (Mari 2004). With regard to the community of the linear wood, the values of richness and diversity are similar to those found in the riparian forest of the aforementioned Tevere-Farfa N.R., and those of an autochthonous forest surrounded by crops in the eastern Po-Veneto plain (Nardo 2002). Considering our study area as a single large ecosystem globally, it is interesting to note that the total richness of species and the average diversity (S_{tot} = 39; H' = 2.53) are similar to those found about thirty years ago in a traditional Val Belluna (BL) agroecosystem (S_{tot} = 38; H'= 3.22) (Cassol & Dal Farra 1993). We therefore conclude that, despite not having an environmental quality comparable to protected and wider ecosystems (e.g. Tevere-Farfa N.R.), the study area as a whole has interesting ecological characteristics comparable with those of other rural areas, some of which managed in the past with traditional methods. We also believe that the arboreal-shrubby hedge is particularly interesting from the ornithological and ecological point of view. According to Genghini (1994), 49 birds of 20 different species per kilometer can live in a mature hedge made up of various deciduous plants, and Ravussin & Mellina (1980) in a tree-shrub windbreak hedge of the same width as ours (6.5 meters), counted 40 breeding pairs per kilometer belonging to 13 species. In our hedge an average of 42 territorial males per kilometer were registered, belonging to 34 species. We therefore think that structural characteristics of investigated hedge (width, length, presence of trees) are optimal to support a well-structured and stable bird community (Arnold 1983, Green 1994, Mac Donald & Johnson 1995, Hinsley et al. 1999). The interest of the study area also is underlined by the presence of 14 breeding species of high conservation concern, 3 of which listed in the Annex I of the Birds Directive (2009/147 / EC) (Tab. ESM1). Some of these species were once common in our countryside and today are in decline in Italy and overall in Europe (Massa & La Mantia 2010, Vorisek et al. 2010, Rete Rurale Nazionale & Lipu 2015a, 2015b, Gustin et al. 2016). Among the farmland bird species, the Common Whitethroat has reached a high I.K.A. in the hedge habitat (5 territorial males per kilometer), comparable with that recorded in similar Italian environments: 5 singing males / 0.5 km along the Po in the province of Mantova (Grattini N. in Brichetti & Fracasso 2010); max 4-5 pairs/km in hilly bushes in the provinces of Forlì-Cesena (Ceccarelli 2011); 0.3-4.4 contacts in the reproductive period/km in the Tuscan-Emilian Apennine National Park (Campedelli et al. 2019). As for the Nightingale, a high frequency was found in the arboreal-shrubby hedge environment. The fair width of the hedge, the presence of numerous trees and the proximity to a large stream, probably have positively influenced the choice of this habitat. The I.K.A. found (6.3 territorial

males/km) is among the highest recorded in Italy in the last 20 years in similar environments: max 10-17 pairs/km in the coastal strip of the provinces of Forlì-Cesena and Ravenna (Cacciato & Ceccarelli 2011); 3.1 singing males/km in a stretch of the Secchia river in the province of Mantova (Grattini N. in Brichetti & Fracasso 2008); 4.4 singing males/km (Capello & Boano 2010). Conversely, the Skylark, a typical species of agroecosystems which has undergone a strong numerical contraction since the 1970s both in Italy and throughout Europe (Busche 1989, Browne et al. 2000, BirdLife International 2004, Massa & Lamantia 2010, Campedelli et al. 2012, Rete Rurale Nazionale & Lipu 2015a), has reached in the cultivated area an average frequency of 2.7 territorial males/km, much lower than the maximum levels found in the plains in Italy: 4.1-8.2 pairs/km in provinces of Ravenna and Forlì-Cesena (Ceccarelli & Gellini 2011). The frequency found is however noteworthy, since in Veneto the species is in strong regression in terms of range and density compared to the early 1990s (Associazione Faunisti Veneti 2013) and since the species generally avoids areas excessively rich in hedgerows, from which predators can better control the hunting territory (Moles & Breen 1995, Sparks et al. 1996). The Western Yellow Wagtail, whose Italian populations are considered to be in moderate decline (Campedelli et al. 2012), in our cultivated area has reached an average I.K.A. of 3.4 territorial males/km, while the maximum frequency in Italy is 13 pairs/km, recorded in cultivated plains in the province of Ravenna (Casadei 2011). The Northern Lapwing and the Corn Bunting reach very low frequency in the study area, despite being still fairly well represented in the surrounding countryside. The Red-backed Shrike and the Ortolan Bunting have become rare now, in particular the latter, whose populations are undergoing a dramatic decline in Europe (Lipu & WWF 1999, Vickery et al. 2014, Brambilla et al. 2016a) and only in limited areas of Mediterranean Europe, including central Italy, seems to be slightly increasing (Brotons et al. 2008, Pruscini et al. 2013). We can conclude that this study confirms the importance of arboreal-shrubby hedges and linear woods for the quality of agricultural ecosystems, since they provide valuable ecosystem services for agriculture; indeed, these natural elements are able to host rich bird communities, made up of species that could be considered antagonists of crop pests (e.g. Barbaro et al. 2017, Assandri et al. 2018, Garcia et al. 2018), possibly contributing to limiting the use of pesticides, which in turn is known to directly and indirectly affects the possibility of survival and the reproductive success of birds (e.g. Campbell et al. 1997, Tuck et al. 2014, Calvi et al. 2018). Thanks to its general ecological importance, and the presence of bird species of conservation interest, the study area is in our opinion worthy of official forms of protection. The future goal will therefore be to extend the monitoring to a wider area, focusing on species of conservation concern, and then to identify a homogeneous area that can be proposed as a ZPS according to the "Birds Directive" 2009/147/EC. In any case, our hope is that this work will be useful to raise awareness in people in general, and in farmers, technicians and public authorities, on the importance of protecting the biodiversity of agroecosystems, that should be conceived as the association not only of cultivations, but also of wild species and of various ecosystem units, a real "eco-mosaic" in which the individual components support and protect each other, creating the conditions to better withstand the impact exerted from various environmental stresses (Gariboldi 2019).

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