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SPARROW PLAGUES IN EXTREMADURA (WESTERN SPAIN) OVER FOUR CENTURIES (1501-1900): A SPATIO-TEMPORAL ANALYSIS OF RECORDS FROM HISTORICAL ARCHIVES

LAS PLAGAS DE GORRIONES EN EXTREMADURA (OESTE DE ESPAÑA) DURANTE CUATRO SIGLOS (1501-1900): UN ANÁLISIS ESPACIO-TEMPORAL DE REGISTROS EN ARCHIVOS HISTÓRICOS

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Summary.—Some bird species can cause crop damage but the historical variation in the incidence of such events is poorly documented. We analyse the spatio-temporal variation of damage attributed to sparrows (*Passer domesticus, P. hispaniolensis* and/or *P. montanus*) at a regional scale in Extremadura (western Spain) over four centuries (1501-1900). Textual data were extracted from historical documentary sources using over 12,000 Books of Accords (*Libros de Acuerdos*) belonging to 203 municipal archives. Sparrow agricultural damages were estimated from reported actions to control sparrow populations and two simple indices were constructed to analyse the spatial (PI_M) and temporal (PI_Y) variation in sparrow plagues. We used these indices to fit geostatistical models and analyse time curves. We found 251 accords reporting sparrow plagues, distributed across 236 years and involving 47 municipalities. Most of these reports (97.2%) were mandatory impositions (*repartimientos*) on residents to deliver a certain number of dead sparrows within a fixed period, under penalty of a fine or imprisonment. Results show a significant spatio-temporal variation in sparrow plagues, which we

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tentatively relate to dynamic environmental and agroecological factors. The spatial index showed high values ($PI_M > 4$) in certain cereal-producing areas, among which *La Raya* zone located in western Badajoz province was the best example. The temporal index reached maximum values ($PI_Y = 7.3$) in the mid 18th century (1741-1770), probably because this was a milder period (within the so-called Little Ice Age) coinciding with increased food availability for birds. In addition, we also examine some sociopolitical, economic and historical features that could have shaped the plague indices. We particularly discuss the normative and legislative developments (e.g. mandatory impositions), the municipal activity itself (affected by wars and other historical events) and the bird conservation interest (which flourished during the final quarter of the 19th century). We conclude that textual data-based indices provide a suitable historical perspective of the agricultural impact of sparrows in Extremadura and of human perceptions of them.

Key words: geostatistics, history of agriculture, Little Ice Age, mandatory impositions of birds, municipal Books of Accords, *Passer*, protection of useful birds.

RESUMEN.—Algunas especies de aves pueden causar daños a los cultivos pero su variación histórica no está bien documentada. Aquí se analiza la variación espacio-temporal de los daños atribuidos a los gorriones (*Passer domesticus*, *P. hispaniolensis* and/or *P. montanus*) a escala regional en Extremadura (oeste de España) durante cuatro siglos (1501-1900). Los datos textuales se obtuvieron de fuentes documentales históricas, usando casi 12.000 Libros de Acuerdos de 203 archivos municipales. Los daños agrícolas de los gorriones se estimaron a partir de las acciones de control ejercidas contra sus poblaciones, calculando dos índices simples para analizar la variación espacial (PI_M) y temporal (PI_Y) de las plagas. Los índices se usaron para ajustar modelos geoestadísticos y analizar curvas temporales. Se encontraron 251 acuerdos sobre plagas de gorriones repartidos en 236 años e implicando a 47 municipios. La mayoría de esos acuerdos (97,2%) fueron repartimientos a los vecinos imponiendo la entrega obligatoria de un número de gorriones muertos en un período determinado, bajo pena de multa o cárcel. Los resultados mostraron una variación espacio-temporal significativa en las plagas de gorriones, la cual se relacionó tentativamente con factores ambientales y agroecológicos. El índice espacial mostró valores altos ($PI_M > 4$) en algunas zonas cerealistas, entre las que La Raya, al oeste de Badajoz, fue el mejor ejemplo. El índice temporal alcanzó valores máximos ($PI_Y = 7,3$) a mediados del siglo XVIII (1741-1770), probablemente por ser un período más templado (dentro de la llamada Pequeña Edad de Hielo) junto con una mayor disponibilidad de alimento para las aves. También se examinaron algunos factores sociopolíticos, económicos e históricos que podrían haber influido en los índices de plaga. En particular discutimos el desarrollo normativo y legislativo (p.ej. los repartimientos), la propia actividad municipal (dependiente de guerras y otros avatares históricos) y el interés por la conservación de las aves (que floreció en el último cuarto del siglo XIX). Se concluye que los índices basados en datos textuales aportaron una perspectiva histórica adecuada del impacto de los gorriones en Extremadura y de la percepción humana sobre ellos.

Palabras clave: geoestadística, historia de la agricultura, Libros de Acuerdos municipales, *Passer*, Pequeña Edad del Hielo, protección de aves útiles, repartimientos de aves.

INTRODUCTION

Some bird species are known to cause crop damage and their harmful effects have been reported worldwide from historical times and even from the beginning of agriculture (Jones, 1972; Bucher and Bedano, 1976; Wright *et al.*, 1980; Dhindsa and Saini, 1994; Huber *et al.*, 2002; Contreras *et al.*, 2003; Tracey *et al.*, 2007; De Mey *et al.*, 2012; Monge, 2013). In the Iberian Peninsula, the main species accused of damaging

crops belong to the families Passeridae, Corvidae, Sturnidae, Gruidae and Turdidae (Bernis, 1989a, 1989b; Sánchez-Guzmán *et al*., 1993; Tellería *et al*., 1999; MAPA, 2001; Martí and Del Moral, 2003; SEO/BirdLife, 2012). Some studies have shown that birds such as sparrows (Passeridae) have been perceived as problematic since at least the late Middle Ages (Carreres, 1946; Zamora, 2004). Regrettably, the impact of bird plagues and their crop damages in the past are not well documented, since the historical information available is very scattered in the scientific literature, often included within collateral studies of a diverse nature, and quite heterogeneous as a result of the diverse documentary sources.

Ferrero-García *et al*. (2014) applied a novel approach to study the bird species reported as harmful in Extremadura (western Spain) over four centuries (1501-1900). Spanish Municipalities have recorded in their archives, and particularly in their Books of Accords (the so-called *Libros de Acuerdos*; BAs hereafter), the impact of the most important agricultural pests, birds included, to promote appropriate control measures in the exercise of their jurisdiction. Such ornithological information presents major documentary advantages: it is reliable and verified (official public documentation), homogeneous and geographically delimited (produced by each municipality), ongoing and regular in time (municipal sessions are held throughout the year), it covers an extended historical period (the BAs originated in the late Middle Ages and are still used today) and, above all, these textual data are amenable to quantification and statistical analysis (Torres-Vila and Sánchez González, 2007).

Analysing vernacular bird names used in the Books of Accords, Ferrero-García *et al*. (2014) were able to document between 13 and 16 bird genera reported as harmful, belonging to eight families: Passeridae, Columbidae, Corvidae, Alaudidae, Phasianidae, Emberizidae, Turdidae and Gruidae. Sparrows were by far considered to be the most harmful birds, figuring within about 70% of the accords recorded. These authors also show that the Spanish vernacular names *gorriones*, *pardales*, *gorriatos* and *gurriatos* are closely associated in Extremadura with the following species of the genus *Passer*: the house sparrow *P. domesticus*, the Spanish sparrow *P. hispaniolensis* and to a lesser extent, the Eurasian tree sparrow *P. montanus*. Moreover, these authors revealed that the sparrows actually damaged some crops –mainly cereals– that were staples for human subsistence during a period characterised by low agricultural yields. It follows that this constraint would explain the perception of sparrows as authentic pests. Ferrero-García *et al*. (2014) also recall how this negative perception of sparrows was reflected in Spain; in hunting laws, law treatises, emerging ornithological researches and even popular books, and how such attitudes only began to change during the second half of the 19th century.

In the present work we expand these results by analysing the spatial distribution and temporal variation in Extremadura over four centuries (1501-1900) of sparrow plagues or, put more precisely, of the human perception of sparrows as potential pests. We then discuss the environmental and agroecological factors potentially involved in the spatio-temporal incidence of sparrow plagues, considering also other relevant socioeconomic, administrative and historical factors, including the emergence of novel conservation measures in the second half of the 19th century. To our knowledge, this is the first time that bird plagues –and more generally agricultural plagues– have been studied at a regional scale through the rigorous quantification and statistical analysis of textual data extracted from historical documentary sources.

MATERIAL AND METHODS

Documentary sources and data acquisition

The main documentary sources were the municipal Books of Accords (BAs). The BAs consist of the agreements (ordered by sessions) adopted by municipalities regarding matters within their legislative, executive and judicial jurisdiction, including those related to crop pest damage –bird damage included– and measures for pest control. In a number of cases, especially if BAs were lacking, raw data compilation was improved with ancillary information from other municipal archive files if available (e.g. account books, reports, provisions, decisions, writs, ordinances and miscellaneous papers). The BAs are an indispensable tool for the study of regional, district and local history, especially in rural areas (Torres-Vila and Sánchez-González, 2007).

We reviewed almost 12,000 BAs (more than a million pages) each including one year's accords, belonging to 190 municipalities within the current boundaries of Extremadura (i.e., about half of the existing municipalities). The sample studied was complemented with 13 additional municipalities, given their historical interest and/or geographical position, located in six of the seven neighbouring provinces, namely: Santa Olalla del Cala (Huelva); Alanís, Guadalcanal and El Real de la Jara (Sevilla); Belalcázar (Córdoba); Almadén and Chillón (Ciudad Real); Oropesa and Torralba de Oropesa (Toledo); La Alberca, Béjar and Ciudad Rodrigo (Salamanca); as well as Elvas (Alentejo) in Portugal (fig. 1). In most historical archives the original BAs were consulted and the relevant agreements photographed for later transcription, which was especially necessary with paleographic texts in older BAs. Digital reproductions of BAs were also used where available online or on disk. The *reading effort* (i.e., the number of BAs consulted) was increased in those municipalities that conserved older documentation (usually historic towns) and in those geographical areas where there was evidence of recurrent bird plagues.

Data analysis

We used two indices to model the intensity of sparrow damage (namely *sparrow plagues*): 1) the spatial variation among municipalities (PI_M), and 2) the temporal variation among years (PI_Y). Both PI_M and PI_Y are simple indices representing relative frequencies, so that their values range between 0 and 100%.

For the spatial analysis, PI_M was calculated for each of the 203 municipalities studied as: $PI_M = 100\ Yp / Ye$ where Yp = the number of years with at least one sparrow plague in a given municipality, and Ye = the number of years with available data for that municipality (i.e. sample size).

The spatial variation in PI_M was analysed with geostatistical techniques by using ArcGIS software (version 10.1, ESRI Inc., Redlands, CA, USA). We calculated PI_M values both for the whole study period and for each century (16^{th}, 17^{th}, 18^{th} and 19^{th} centuries). We then modelled the spatial ocurrence of sparrow plagues using the geographical position of the municipalities as the explanatory variable. The surface area of each municipality was calculated using tools of the module ArcToolbox in ArcGIS and the centroid of each polygon was used to model intra-zonal variation. The geographic coordinate system used was datum WGS 1984 projected in the UTM zone 30N. Interpolation analyses to predict PI_M values at locations without data were conducted with the Geostatistical Analyst extension of ArcGIS by using radial basis functions (RBF). The RBF methods are exact interpolators that enable a surface to be created

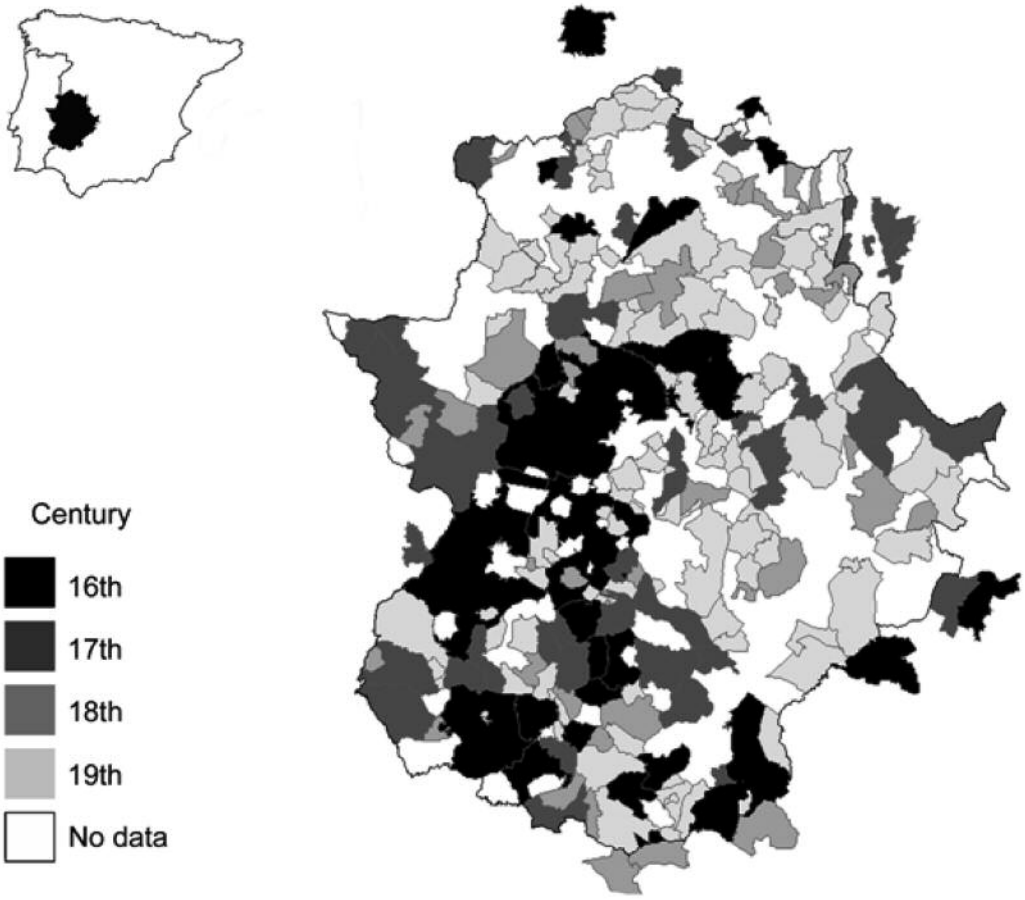

FIG. 1.—Municipalities of Extremadura and neighbouring municipalities (n = 203) used in the spatio-temporal analysis of sparrow (Passeridae) plagues. The antiquity of the available documentary sources is also indicated for each municipality.
[Municipios de Extremadura y municipios vecinos (n = 203) utilizados en los análisis espacio-temporales de las plagas de gorriones (Passeridae). La antigüedad de las fuentes documentales disponibles se indica también para cada municipio.]

that captures global trends and picks up local variation. A number of splines with tension and multiquadric RBF were fitted to the spatial database and cross-validation was used to select the best function (Johnston *et al*., 2001). After cross-validation to estimate the optimal parameters controlling the surface smoothness for each RBF, root-mean-squared prediction errors were lower than 2.5 in all cases, so that models and their associated parameters predicted the measured values very accurately. A set of map layers was finally generated with the ArcGIS ArcMap module (Moral, 2003).

Regarding the temporal analysis, PI_Y was calculated for each of the 400 years studied as: $PI_Y = 100\ Mp / Me$ where Mp = the number of municipalities reporting sparrow

plagues in a given year, and Me = the number of municipalities with available data for that year (i.e. sample size).

In order to aid the interpretation of the temporal variation in PI_Y, we averaged PI_Y values by natural decades. Significant differences between decades within centuries (or for the total sample) were tested with the Kruskal-Wallis test by using SYSTAT software (version 10.0, Systat Software, Richmond, CA, USA).

Results

Sample size and agreement typology PI_M

We found 251 accords reporting sparrow plagues, covering 236 years and originating from 47 municipalities (table 1), so that some BAs included more than one accord on sparrow plagues per year. Nearly a quarter of the municipalities studied (47 of 203, 23.2%) reported at least one sparrow plague during their history (table 1). As would be expected given the vagaries of history, the greater antiquity of the target BAs within the period studied (1501-1900), the fewer municipal archives and BAs available (table 1). No information on sparrows in the 16th century was found so this century was not represented (fig. 2). Another 41 agreements citing unspecified birds (mentioning *pájaros* or similar words with small spelling variations) were not considered in this study since they could not certainly be attributed to sparrows (Ferrero-García *et al*., 2014).

Of the 251 agreements reporting sparrows, 244 (97.2%) were related to the so-called *repartimientos*, that is, mandatory impositions on the town or village inhabitants to capture and deliver a predetermined number of dead birds (or their equivalent in eggs, chicks or nests) to the municipal Authorities within a strict time period, under penalty of a fine or imprisonment. In a number of municipalities, such mandatory impositions were equitably divided between residents depending on their job/activity (farmer, labourer, farmhand), income/rent (size and

Table 1

Summary of the studied sample by centuries, indicating the number of Books of Accords, municipalities, agreements and years. The percentage of municipalities reporting sparrow plagues is also given. *[Resumen de la muestra estudiada por siglos, indicando el número de Libros de Acuerdos, municipios, acuerdos y años. También se señala el porcentaje de municipios con plagas de gorriones.]*

Century	16th	17th	18th	19th	Total
Number of Books of Accords studied	507	1604	2805	6863	11779
Number of municipalities studied	25	71	98	190	203
Number of municipalities reporting sparrow plagues	0	10	25	33	47
Percentage of municipalities reporting sparrow plagues	0	14.1	25.5	17.4	23.2
Number of agreements reporting sparrow plagues	0	26	115	110	251
Number of years with reported sparrow plagues	0	25	107	104	236

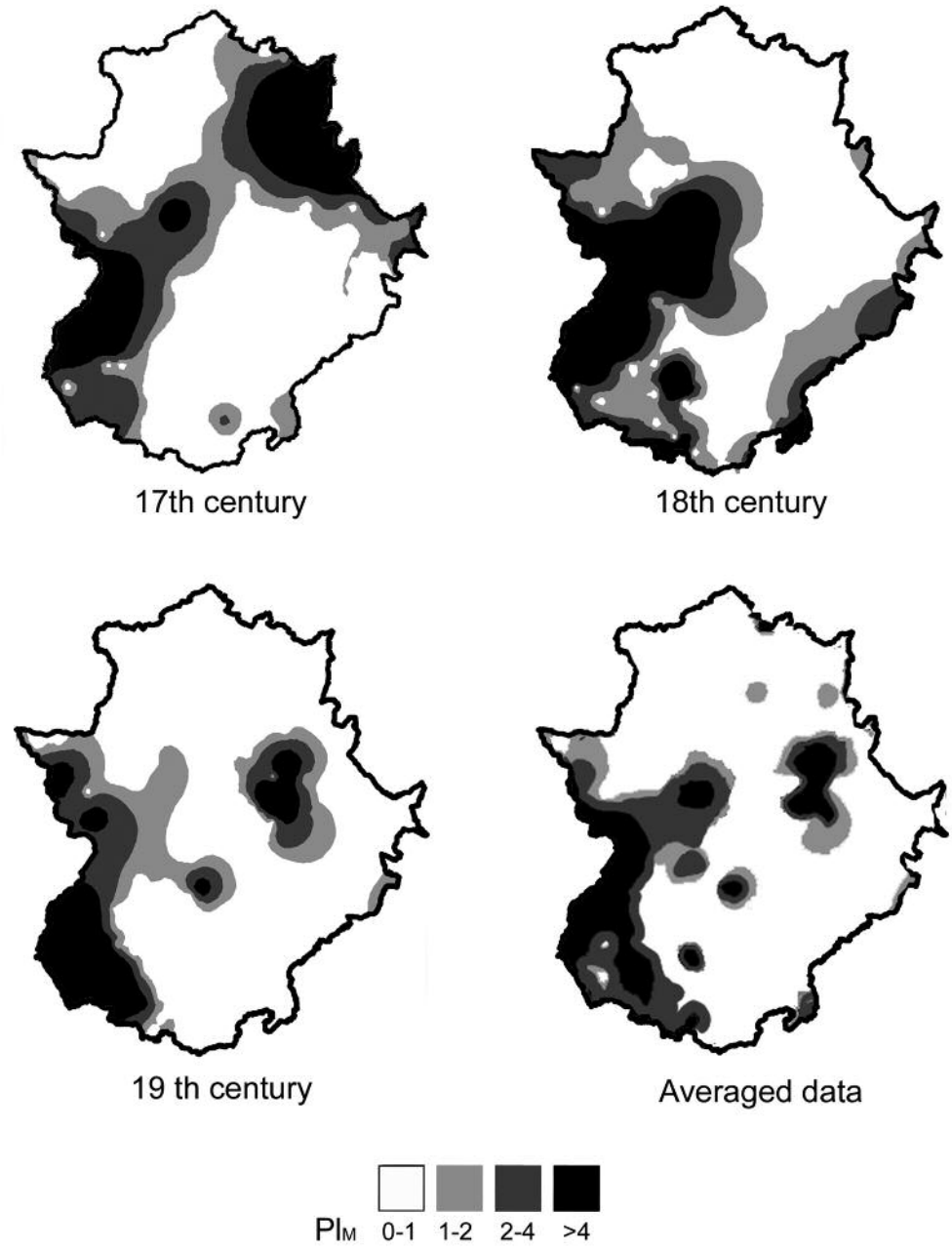

FIG. 2.—Spatial variation of sparrow (Passeridae) plagues in Extremadura in the 17th, 18th and 19th centuries (and averaged data) according to the plague index PI_M. The geostatistical analyses were computed using radial basis functions (RBF) with ArcGIS software.
[Variación espacial de las plagas de gorriones (Passeridae) en Extremadura en los siglos XVII, XVIII y XIX (y datos promediados) según el índice de plaga PI_M. Los análisis geoestadísticos se computaron usando funciones de base radial (FBR) con el software ArcGIS.]

number of oxen owned, cultivated land area) and even civil status (widows often benefited from a reduction). The remaining seven agreements (2.8%, 7 of 251) concerned prizes for voluntary delivery of sparrows or preventing damage to house roofs.

Spatial variation of sparrow plagues (PI_M)

Sparrow incidence (as indicated by PI_M values) proved to be more or less consistent over centuries in some areas (fig. 2). Very high values ($PI_M > 4\%$) occurred in all centuries in the western area of Badajoz province bordering Portugal (covering the so-called *La Raya* zone). This area takes in several municipalities including at least in part (from north to south) Valencia de Alcántara, La Codosera, Albuquerque, Badajoz, Elvas (Portugal), Olivenza, Almendral, Cheles, Alconchel, Barcarrota, Villanueva del Fresno and Jerez de los Caballeros. In the 17th and 18th centuries high values ($PI_M = 2$-4% or higher) also occurred in a belt of territory extending westwards across the municipalities of La Roca de la Sierra and Puebla de Obando, as far as the south of Cáceres province; this belt expanded greatly during the 18th century to include Mérida and nearby municipalities. In the 18th and 19th centuries sparrow incidence also expanded towards southwestern Badajoz province, reaching very high values ($PI_M > 4\%$) in Jerez de los Caballeros, Fregenal de la Sierra and some other adjacent municipalities; in the 18th century the sparrow incidence also extended towards the centre of Badajoz province, reaching Valencia del Ventoso, Zafra and Los Santos de Maimona. There were also other areas with high incidence values ($PI_M = 2$-4% or higher) but where sparrows occurred less consistently over time. They included: 1) in the 17th century, an area in eastern Cáceres province centred on Navalmoral de la Mata and extending towards the lands of Oropesa in Toledo; 2) also in the 17th century, a small island-shaped area in the Campiña Sur zone at Llerena, in southeastern Badajoz province; 3) in the 18th century, a narrow and irregular strip on the eastern border of Badajoz province, from La Siberia in the north (extending towards Chillón and Almadén in Ciudad Real) and crossing La Serena, to reach the Campiña Sur zone at Azuaga in the south (and extending towards Alanís and Guadalcanal in Sevilla); and 4) in the 19th century, two island-shaped areas: the first quite a large expanse in the lands of Trujillo in Cáceres province, centred on Aldeacentenera, Herguijuela, Zorita and Conquista de la Sierra, and extending northwards as far as Belvís de Monroy and southwards to Logrosán and Madrigalejo, reaching the Guadiana river valley; the second a smaller area in central Badajoz province in the Guadiana river valley (Mérida and Villagonzalo districts) (fig. 2).

Temporal variation of sparrow plagues (PI_Y)

The PI_Y index showed large fluctuations over time even between consecutive years, with values exceeding 10% in ten years concentrated in the 18th century (fig. 3). A Kruskal-Wallis test shows significant differences between decades within centuries (17th: $H_9 = 35.56$, $P < 0.001$, 18th: $H_9 = 28.84$, $P < 0.001$, 19th: $H_9 = 29.14$, $P < 0.001$) as well as across the whole period studied (16th-19th centuries: $H_{39} = 195.05$, $P < 0.001$). The analysis of means by decades also highlights some interesting trends (fig. 3). There was a progressive increase in the PI_Y index from the early 18th century over seven decades (1701-1770), with values higher than $PI_Y = 5\%$ in the last three decades (1741-1770), to finally reach an absolute maximum ($PI_Y = 7.3$). In the period 1791-

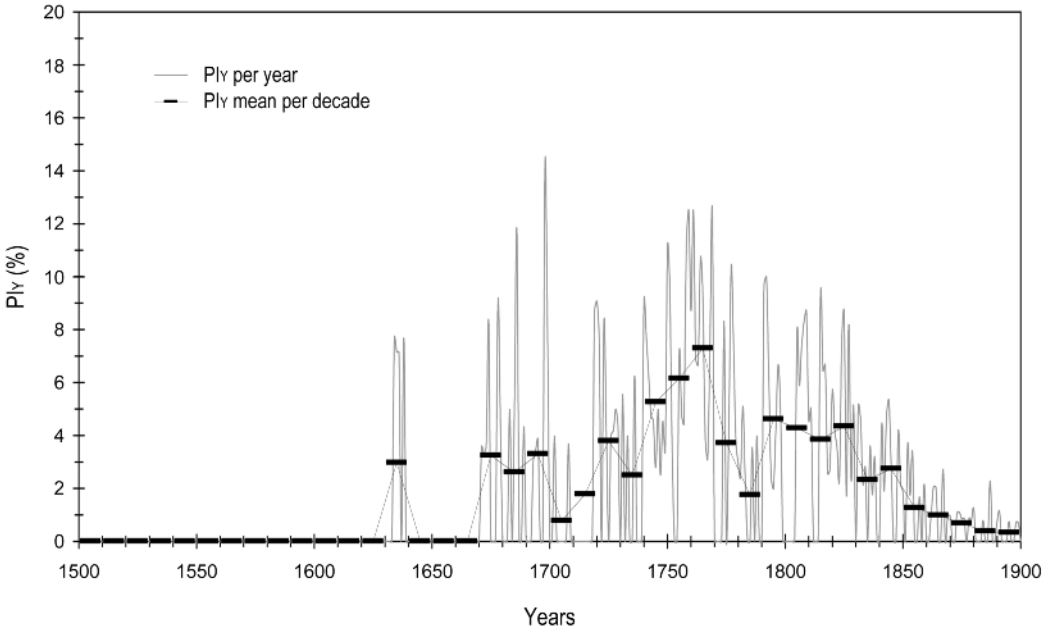

FIG. 3.—Temporal variation of sparrow (Passeridae) plagues in Extremadura during the 16th to 19th centuries according to the plague index PI_Y.
[Variación temporal de las plagas de gorriones (Passeridae) en Extremadura durante los siglos XVI a XIX según el índice de plaga PI_Y.]

1830 there were high and relatively constant means by decades (PI_Y = 3.8-4.6) and in the period 1671-1700 a similar plateau occurred with slightly lower values (PI_Y = 2.6-3.3).

On the other hand, the lack of any accords concerning sparrow plagues from 1501 to 1634, and again from 1641 to 1670, is remarkable. This extended period of more than a century and a half was only interrupted in the 1630s when the first sparrow plagues were documented in Cáceres and Oropesa. The very low PI_Y values in the final two decades of the 19th century are also noteworthy (PI_Y < 0.5%). These minimum values occurred after a gradual decline over seven decades (1831-1900) in which all years had PI_Y < 6 %, a trend accentuated during the second half of the 19th century, during which PI_Y < 4% in all years.

DISCUSSION

The results show that sparrows have been more abundant in a number of areas of Extremadura in historical times. The underlying ecological factors regulating population dynamics are difficult to explain, although greater food availability and favourable local climate should be considered as essential.

In the Iberian Peninsula, the diets of the house and Spanish sparrows are largely based on plant material, especially seeds and cultivated grains (Alonso, 1985; Sánchez-Aguado, 1986; Bernis, 1989b). The Eurasian tree sparrow is less reliant on cultivated than on wild seeds (Sánchez-Aguado, 1986). Nevertheless, almost all species of the genus *Passer* can aggregate in flocks and cause damage to crops (Bernis, 1989b). However,

in recent years numerous studies have detected a significant decline in certain European bird species, including the house sparrow (Ferrero-García *et al.*, 2014 and references therein). Extensive agriculture in Extremadura did not change much during the centuries studied with herbaceous crops, mainly cereals, prevailing (Rodríguez, 1985; Hernández and Pulido, 2004, 2005). It is interesting that the regions affected by sparrow plagues in Extremadura coincide precisely with areas of cereal crops, most of which still remain today: La Raya, Trujillo and Cáceres plains, Mérida, Tierra de Barros, Campo de Arañuelo, lands of Oropesa, La Siberia and Campiña Sur. The best example occurs in western Badajoz province (La Raya), where the occurrence of sparrow plagues has extended from historical times to the present. Thus, in the late 20th century there were numerous complaints from farmers concerning crop damage by the Spanish sparrow (Prieta, 2003). Regarding the house sparrow, it has been suggested that its overabundance in central Europe during the 18th-19th centuries was promoted by human activities (Herrmann and Woods, 2010). In Extremadura, the area with the highest winter abundance of this species at present is again La Raya (SEO/BirdLife, 2012). These two sparrow species are most probably those that damaged crops in Extremadura during the 17th-19th centuries (Ferrero-García *et al.*, 2014). Circumstances may have been different in the past, but the above assumption is further supported by the fact that Extremadura currently harbours the largest breeding population of the Spanish sparrow and much of the house sparrow population in Spain (Carrascal and Palomino, 2008).

Maps showing the spatial distribution of sparrow damages were calculated for each century, so they are not confused by the large interannual variation observed in sparrow population densities within centuries. For example, the remarkable population growth of the Spanish sparrow in Extremadura in the late 20th century occurred after the species had become restricted to the Zújar river valley (eastern Badajoz province) during the 1960s and 1970s (Martí and Del Moral, 2003). The huge interannual fluctuations in Spanish sparrow populations had already caught the attention of ornithologists and it has been suggested that this species may have had a greater presence in the Iberian Peninsula in the past (Alonso, 1997). Both the house sparrow and the Eurasian tree sparrow also exhibit lesser but still significant population fluctuations (Tellería *et al.*, 1999).

The highest historical incidence of sparrow plagues within the period studied occurred in the mid 18th century (*c.* 1741-1770), coinciding with a slightly warmer period within the cold period termed the Little Ice Age (LIA), which took place in Europe between the early 14th century and the mid-19th century. In the Iberian Peninsula, the coldest LIA episodes occurred in the 17th century (De Castro *et al.*, 2005), with maximum glacial expansion between the late 17th century and the early 18th century (González Trueba *et al.*, 2008), the climate becoming milder in the mid-18th century (González Trueba *et al*, 2005; Fagan, 2008). It is well known that low temperatures and associated factors (ice, snow, insufficient food) negatively affect bird species (Newton, 1998), especially those of smaller body size (Senar and Borras, 2004). For example, adverse weather conditions may cause high mortality in some Spanish populations of the Eurasian tree sparrow (Cordero and Salaet, 1990) whereas house sparrow survival increases in mild winters (Senar and Copete, 1995). It has also been suggested that milder weather, among other factors, may account for the late 20th century population explosion of the Spanish sparrow in Extremadura (Prieta, 2003).

The temperature increase in the mid 18th century has also been put forward to explain the proliferation of the mediterranean locust

Dociostaurus maroccanus (Alberola, 2012) that affected Extremadura and Spain in 1754-1757 (Azcárate, 1997; Torres-Vila and Sánchez-González, 2007; Mas, 2012). More benign temperatures favouring the proliferation of insects (particularly locusts and other acridids) could in turn provide an additional feeding resource for sparrows. In fact, acridid species contribute significantly to the diet of Spanish sparrow chicks in some Portuguese populations (Marques *et al*., 2003). Moreover, in the 18th century, agriculture in Extremadura experienced some expansion of certain crops, including cereals (Sánchez Salazar, 1988). In conclusion, we suggest that the greater abundance of sparrows in the mid 18th century could be the result of favourable weather and increased food availability.

In addition, other non-environmental factors could have shaped the incidence of sparrows (as measured by plague indices) both in space and time. The most important additional factors that we have detected are: the normative and legislative development over time, the municipal activity itself and the bird conservation interest, which we discuss below.

No similar quantitative studies exist for other regions but the available information implies that the historical situation in the rest of Spain should be very similar to that observed in Extremadura. Mandatory impositions of bird culls (mainly of sparrows) were common in the 17th-19th centuries in many Spanish provinces, such as Álava (López, 1957), Córdoba (Arjona and Estrada, 1977), Albacete (Gómez and Cebrián, 1987), Huelva (De Vega, 1990), Jaén (Torres, 2005) and Málaga (García Guillén, 2009). Conversely, references to crop damage by birds are less frequent prior to the 17th century. The few references we have been able to document do not mention mandatory impositions, but rather incentives in the form of prizes, such as in Murcia in the 14th and 16th centuries (Zamora, 2004) and Valencia in the 15th century (Carreres, 1946). This suggests that the absence of accords on sparrow plagues before the 1630s in Extremadura, could reflect the lack of local (and national) norms concerning mandatory impositions to control birds (Ferrero-García *et al*., 2014). In fact, no historical legislation related to control of harmful birds has been documented. We suggest that the first municipal edicts of bird culls became gradually widespread from the early 17th century by emulating the impositions against locust plagues established by the pioneering Law of 1593, promulgated under the reign of Felipe II (NRLE, 1805, book VII), a provision whose crucial importance (principally for crop protection) has been highlighted many times (EUIEA, 1920; Márquez, 1963; León, 2005; Peris, 2008). An agreement of 7 May 1638 from the Council of Cáceres regarding a mandatory cull of sparrows (the first documented in Extremadura) supports this idea. In order to counter damage to barley and wheat crops, the Council ordered the killing of sparrows "in the manner and with the expense usually used to kill the locust" ("*en la forma y con el horden y costa que se suele matar la langosta"*).

The sociopolitical situation may also have influenced plague indices, by diverting municipal activity towards other matters and even by interrupting it (Ferrero-García *et al*., 2014). The best –and most tragic– example we found are the wars. For instance, in Úbeda (Jaén) the mandatory sparrow culls were interrupted during several years as a result of the war in the early 18th century (Torres, 2005). In the same manner, the long conflict between Portugal and Spain (1640-1668), one of the most destructive of European history that century, greatly affected Extremadura (García Barriga, 2008) and could have been responsible for the zero values of the plague index detected for 1641-1670 in our study. Similarly, the atypically low values (PI_Y = 0.8%) found in the 1700s

could be explained by the scarcity of accords due to the disastrous effects of the Spanish Succession War in Extremadura (Muñoz, 1948; Sánchez Rubio, 2010).

Lastly, the bird conservation interest could also influence the plague indices. A gradual and positive societal change in attitudes to birds could be involved in the progressive decline in PI_Y values from 1830s onwards. Such a decline took place despite both the slight increase in cereal cultivation in that period (Hernández and Pulido, 2005) and the milder weather during the second half of the 19th century, when the LIA had already ended (De Castro *et al*., 2005).

In the early 19th century, the Spanish legislation still reflected the need to eliminate sparrows; for instance hunting regulations (*Ordenanza de Caza de 1804*) and people show the same negative attitude (Torres-Vila *et al*., 2009; Ferrero-García *et al*, 2014). Mandatory quotas of birds to prevent crop damage were customary and nearly compulsory for municipal Councils (Ferrero-García *et al*., 2014). In the 1840s, coinciding with the transition from the Old Regime to the Liberal State, people begin to recognise that such practices should be curtailed, being considered more typical of an oppressive administration rather than one interested in agricultural development (Ortiz de Zúñiga, 1841). In fact, the hunting regulations adopted in 1834-1837 were based on more democratic principles (Nieto, 2001).

Interest in the conservation of insectivorous birds increased during the second half of the 19th century, when the first norms for wildlife preservation were adopted in many European countries (eg. Ferrero-García, 2013). In Spain, hunting legislation (*Ley de Caza de 1879*) established some general protection measures, which were expanded and developed in 1896 (Torres-Vila *et al*., 2009; Ferrero-García, 2010, 2011; Casado, 2013). Lengthy negotiations carried out from 1868, with the participation of leading naturalists, experts and European politicians, came to fruition in the 1902 International Convention for the Protection of Useful birds to Agriculture, signed in Paris on 19 March 1902 (van Heijnsbergen, 1997; Bowman *et al*., 2010; Ferrero-García, 2013, 2014), in which Spain was also involved (Ferrero-García, 2012b). In addition, such institutions as the *Sociedad Valenciana de Agricultores* in 1866 (Azcárate, 1997), and such eminent scientists and technicians as M. P. Graells, A. García Maceira and J. Arévalo Baca in the 1880s, encouraged the protection of insectivorous birds, including the Passeridae (Ferrero-García, 2012a; Balset, 2012; Ferrero-García *et al*., 2014). Even the daily press echoed the need to defend sparrows (La Vanguardia, 1886). It is noteworthy that these positive developments increased during the late 19th century, precisely the period in which the lowest plague indices were recorded in our study. In Spain, despite initial debates, the laws on the protection of useful fauna finally included –albeit partly– the Passeridae (Torres-Vila *et al*., 2009; Ferrero-García *et al*., 2014). In Extremadura, also during the last quarter of 19th century, some authorities, such as Agustín Salido, Civil Governor of the Badajoz province, promoted measures for bird preservation (Torres-Vila *et al*., 2009) and several municipalities established additional protection norms (Ferrero-García *et al*., 2014). Therefore, we suggest that from the 1830s onwards the new Liberal State could begin to reduce the old practice of mandatory bird culls, a trend that would increase progressively throughout the late 19th century as a result of new environmental awareness. Although it has been suggested that the real impact of the pioneering conservation laws and conventions was very limited (Ferrero-García, 2010; Bowman, 2014), our results suggest that the first conservation standards adopted in Extremadura and Spain had "useful" consequences for the preservation of some bird species.

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