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# Long term population trends in different habitats of two Sparrow species: House Sparrow and Tree Sparrow


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**RESUMEN**

Las áreas urbanas están en constante crecimiento, lo que puede afectar a las poblaciones de aves debido a las alteraciones que causan las actividades humanas. Según los últimos censos nacionales, las poblaciones de gorrión común y gorrión molinero están en descenso. En este estudio hemos intentado evaluar la tendencia poblacional durante más de dos décadas usando datos de estaciones de anillamiento científico, así como determinar los parámetros poblacionales y reproductivos en relación a la estructura del hábitat. Hemos analizado los datos y confirmado la decreciente tendencia en estas dos especies. Sin embargo, el gorrión molinero mostró un patrón diferente en cuanto a selección de hábitat de lo que se había predicho en un principio. Además, la productividad permaneció estable en las localidades de muestreo y durante los años de estudio.

**ABSTRACT**

Urban areas are constantly increasing, which can cause an effect in bird populations since human activities lead to nature alterations. Populations of House sparrow and Tree sparrow have been decreasing in Spain according to the later national censuses. In this study we tried to assess the population trend over more than two decades using ringing stations data, as well as determine the population and breeding parameters in relation to habitat structure. We analysed data and confirmed the decreasing trend in the two species. However, Tree sparrows showed a different pattern of habitat selection than predicted. Furthermore, the productivity remained stable over sampling sites and years.

**PALABRAS CLAVE**

Gorrión común, *Passer domesticus,* Gorrión molinero, *Passer montanus*, tendencia poblacional, hábitat, productividad.

**KEY WORDS**

House sparrow, *Passer domesticus*, Tree sparrow, *Passer montanus*, population trends, habitat, productivity.

## INTRODUCTION

The increase of urbanized areas impacts on biodiversity by reducing the available habitat or fragmenting it (Fahrig, 2003; Dri *et al,* 2021). Urban environments can differ from natural ones in several ways. The microclimate that big cities generate is advantageous for many species, usually the generalist ones. The heat island effect implies that cities usually have higher temperatures in their central areas than in the outskirts, mostly after the sun sets from all the heat the ground absorbs (Seress & Liker, 2015). This not only alters the phenology of different species but also their ability to survive hard winters, increasing its fitness (Chace & Walsh, 2004). Urban areas provide great amounts of food for species, up to the point there is usually a constant supply, due to the supplementary feeding that occurs in urban areas (Tryjanowski *et al,* 2015). In addition, there are low levels of predation since urban areas generally lack natural predators. This implies that there are more weak competitors than in more rural areas, where stronger competitors are dominant (Anderies *et al,* 2007).

Nonetheless, feral cats are highly present in urban and suburban areas, which can cause individual losses or sub-lethal effects such as behavioural changes that can lead to a reproductive decrease or less food intake (Lepczyk *et al,* 2004; Beckerman *et al,* 2007). Pollution is another factor to take into consideration: society is constantly releasing chemicals which damage water, atmosphere, and ground (Khan & Ghouri, 2011). Urban areas are more populated, resulting in more pollution than in rural ones (Khatri & Tyagi, 2015).

Birds in cities are often in contact with humans. The disturbance created by people to these animals changes considering the species (bigger species display stronger alert behaviour at longer distances than smaller species) but it usually causes a decrease in foraging time, reproduction and parental care (Blumstein *et al,* 2005).

Productivity is usually defined as the number of offspring a population produces each season. Productivity numbers may change depending on different factors which can affect both adult and juvenile numbers. For instance, the direction a nest faces (Hooge *et al*, 1999) or its height (Tordoff *et al*, 1997) could determine the rearing success of the chicks. In the same way, the amount of available food for nestlings would affect their chances of survival (Summers-Smith, J.D., 2003). Therefore, productivity can be used as a proxy of population composition changes.

Among all urban bird species that share habitat with humans, Sparrows are a representative group due to its large distribution along the planet and vast number of species. They are deeply connected to human structures as well as to their activities.

House Sparrow (*Passer domesticus*) is considered to be a well-adapted species to urban and suburban areas and it has a great ability to respond to stress in these sites (Chávez-Zichinelli *et al,* 2010). It is not very selective in terms of habitat and diet. However, it directly depends on human activities, so they are usually found in human inhabited areas. This species can be typically found in barns, vegetated patches and residential areas, especially where gardens are present (Chamberlain *et al*, 2007). Such places provide them with cavities to nest (in buildings) as well as enough food provisioning to feed their nestlings (insects in parks) (Summers-Smith, 1988). House sparrow used to be really abundant, but it has decreased markedly in the last decades (De Laet and Summers-Smith, 2007; Brichetti *et al.* 2008). This phenomenon has been reported not only in the countryside (Siriwardena *et al,* 1998) but also in urban environments (Klok *et al,* 2006; Robinson *et al,* 2005). Population of House sparrow in Spain has had a 18% decrease in the last 25 years according to national censuses (Murgui, 2022), even though the distribution range over the country has remained almost the same.

Whereas Tree sparrow (*Passer montanus*) is thought to be related to wetland habitats (Field & Anderson, 2004; García-Navas & Sanz, 2012). It is regarded as a more natural species, not so-well adapted to cities as the House sparrow (Zhang *et al,* 2008), preferring parks or suburban areas when in cities, distancing from places such as main roads or commercial centres (Zhang & Zheng, 2010).
Tree sparrow has overgone changes in population in European cities since the 20th century, when it started to colonize urban areas (Tomiałojć, 2012). It has been expanding across Europe, but there is evidence that some countries have had declining trends in the last few years (Jokimäki *et al,* 2021). In Spain, decreasing

numbers have been reported for this species for the last two decades (SEOBirdLife, 2013; Birdlife International, 2017).

There is no evidence of negative interactions between the two species. Moreover, House sparrow tends to disappear from locations where Tree sparrow cannot be found (Vepsäläinen *et al,* 2005).

The aim of the present study is to determine whether there is a generalized population decrease in both House sparrow and Tree sparrow in Spain that would reflect a global trend not influenced by local conditions, or if population declines are more restricted phenomena caused by regional or local factors such as a decrease in productivity in some geographic areas or by the difference in habitat structure. To attain that goal, we used ringing and productivity data from different Constant Effort Ringing Stations (CES) at different habitats during the same breeding periods and temporal scales. In this way, it is possible to compare population tendencies at different locations undergoing different selective pressures, which can result in differential population effects. We have studied: i) population trends across Spain for 27 different locations over a 25-year period and ii) the productivity index in those locations.

According to the literature, both species are decreasing their number so we predict that there will be a decline in the number of birds captured over the 25 year period under study. We also expect that House sparrows will be more frequent in urban areas since they are well adapted to cities and human activities, whilst Tree sparrow, as it is considered a non urban species, will be associated with more natural areas.

In addition, since there seems to be an overall reduction in the population of Spanish sparrows, we predict that productivity will be affected, so we will find decreasing productivity numbers.

## MATERIALS & METHODS

We recorded data from a 27 scientific ringing stations' network (Figure 1, Table 1) during the breeding season with regular trapping intervals following standardized Constant Effort Site (CES) protocols. The number and locations of the mist nets, as well as their technical characteristics, are constant among years and within localities. Accordingly, this sampling technique provides information on breeding population trends, and allows the identification of changes in juvenile and adult proportions, thus permitting estimates of variation in productivity over years and long-term trend assessment. The data analysed was provided by two different CES programs: PASER (SEO/BirdLife, Bermejo and Palomino 2007) and EMAN (Aranzadi, Arizaga *et al,* 2020). Both programs operate during the breeding period (April-July) with 10 sampling days in periods no longer than 10 days apart.

To determine how urbanization affected sparrow population, we characterized habitat in a 1 $km^2$ plot around each ringing station with different parameters: vegetation, buildings, pavement and water following Liker *et al,* 2008. A grid containing 100 cells of 100 m x 100 m was plotted over a satellite picture and a percentage (0-100%) of the previous parameters (vegetation, buildings, pavement and water) was assigned to each cell. As two different observers analysed different ringing stations, a repeatability test was carried out (r=0.9993) thus enabling to merge both scores.

To assign an urbanization index to each ringing station, we performed a principal component analysis (PCA). Component 1 of the PCA (PC1) was interpreted as the urbanization index (eigenvalue = 2.7320; explained variance = 0.6830; factor loadings: vegetation = -0.5671, buildings = 0.5821, pavement = 0.5827, water = -0.0057). Thus, higher scores in PC1 were related to more urbanized areas whilst lower scores were related to more natural areas (Table 1).

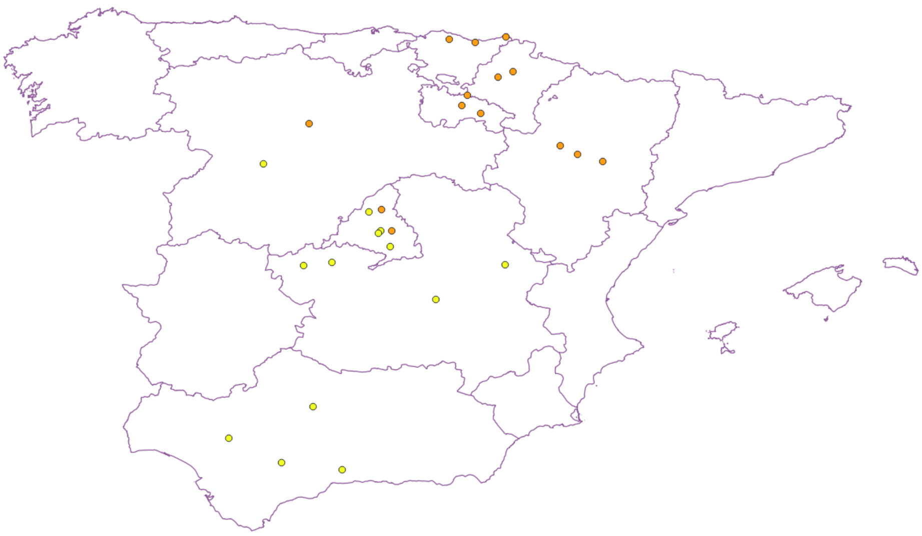

Figure 1: Location of CES across Spain. In yellow those from the PASER program, in orange those from the EMAN program.

Table 1: Sampling locations with their respective coordinates, urbanization index and active period of time in order of urbanization.

| Station name | Town | Latitude | Longitude | Urbanization index | Data range |
|---|---|---|---|---|---|
| Parque del Alamillo | Sevilla, SE | 37º23'00 | -5º57'00 | 4.1964 | 2001-2009 |
| Jardín Botánico UCM | Madrid, M | 40º26'00 | -3º43'00 | 3.5131 | 2011-2021 |
| La Murtera | Oda, CU | 39º58'00 | -1º50'00 | 3.4190 | 1999-2009 |
| Embalse la Portiña | Talavera de la Reina, TO | 39º57'00 | -4º50'00 | 2.8300 | 2000-2007 |
| Parque del Oeste | Madrid, M | 40º28'00 | -3º41'00 | 2.3658 | 1995-2016 |

| | | | | | |
|---|---|---|---|---|---|
| Barrutibasoko Lezkadia | Gautegiz-Arteaga, BI | 43º19'0" | -2º40'0" | 0.4869 | 2010-2019 |
| La Tejera | Nalda, RI | 42º20'0" | -2º29'0" | 0.3534 | 2015-2020 |
| Jaizubia | Hondarribia, GI | 43º21'0" | -1º49'0" | 0.2796 | 2010-2020 |
| Laguna de Manjavacas | Mota del Cuervo, CU | 39º27'00 | -2º52'00 | 0.1331 | 2011-2016 |
| Barajas | Paracuellos del Jarama, M | 40º28'11" | -3º31'37" | -0.5088 | 2019 |
| Río Guadalix - Embalse de Pedrezuela | Guadalix de la Sierra, M | 40º47'9" | -3º40'42" | -0.6537 | 2019-2020 |
| Mejana del Casetón | Sobradiel-Utebo, ZA | 41º44'0" | -1º1'0" | -0.7962 | 2017-2020 |
| Ubagua | Riezu-Muez, NA | 42º45'13" | -1º56'33" | -0.8099 | 2019-2020 |
| Loza | Loza, NA | 42º50'0" | -1º43'0" | -0.8176 | 2012-2021 |
| La Nava | Fuentes de Nava, PA | 42º4'0" | -4º45'0" | -0.8440 | 2013-2020 |
| Las Cañas | Viana, NA | 42º29'0" | -2º24'0" | -0.8694 | 2013-2021 |
| Las Minas | San Martín de la Vega, M | 40º14'00 | -3º33'00 | -0.8802 | 1995-2021 |
| Autillos | Pina de Ebro, ZA | 41º30'0" | -0º23'0"' | -0.8892 | 2017-2019 |

| | | | | | |
|---|---|---|---|---|---|
| Cortijo de Auta | Riogordo, MA | 36º55'00 | -4º16'00 | -0.9939 | 1997-2007<br>2019-2020 |
| Rio Salado | Almargen, MA | 37º1'00 | -5º10'00 | -1.0148 | 2000-2007 |
| Motondo | Orio, GI | 43º16'0" | -2º17'0" | -1.0825 | 2010-2020 |
| Arroyo Samburiel | Manzanares el Real, MA | 40º45'00 | -3º52'00 | -1.1403 | 2002-2009 |
| Soto del Rincón Falso | Pastriz, ZA | 41º36'0" | -0º45'0"' | -1.1800 | 2017-2019 |
| La Higueruela | Santa Olalla, TO | 40º00'00 | -4º25'00 | -1.2186 | 1995-2009 |
| Santa Eulalia | Arnedo, RI | 42º13'0" | -2º12'0" | -1.2621 | 2012-2020 |
| La Veguilla | Córdoba, CO | 37º51'00 | -4º42'00 | -1.3021 | 2002-2009 |
| Dehesa de Castrillo | Toro, ZA | 41º28'00 | -5º26'00 | -1.3142 | 1999-2004 |

A total number of 5080 records of House sparrows and 2553 records of Tree sparrow were analysed. Birds were marked and dated as juvenile (hatched individuals from that breeding season) or adults (breeding individuals) following Demongin, 2016. In order to standardize effort, since not all ringing stations set up the same number of mist nets, an *index of captures* was calculated by dividing the number of individuals / meters of mist net.

We performed generalized linear mixed models (GLMM, lmer library in R: linear mixed-effects model) to determine differences in the capture index.  We used the *urbanization index* and *year* as covariates and *ringing station* as random factor.

To analyze changes in productivity in all those years, we created a *productivity index* by subtracting the number of adults to the number of juveniles per year. (*Productivity index*: juveniles - adults). A negative index would indicate a higher number of adults, a positive one, more juveniles and 0 would indicate an equal number of both age groups. We performed another set of GLMM with *productivity* as a response variable, *year* and *urbanization index* as covariates and *ringing station* as a random factor.

## RESULTS

### Population trends

Both Sparrow species are associated with urban environments, we found a significant decrease in the capture index for both House sparrow ($p<0.0000$) and Tree sparrow ($p=0.0037$) over the study period (1995-2021) (Figure 2, Table 2).

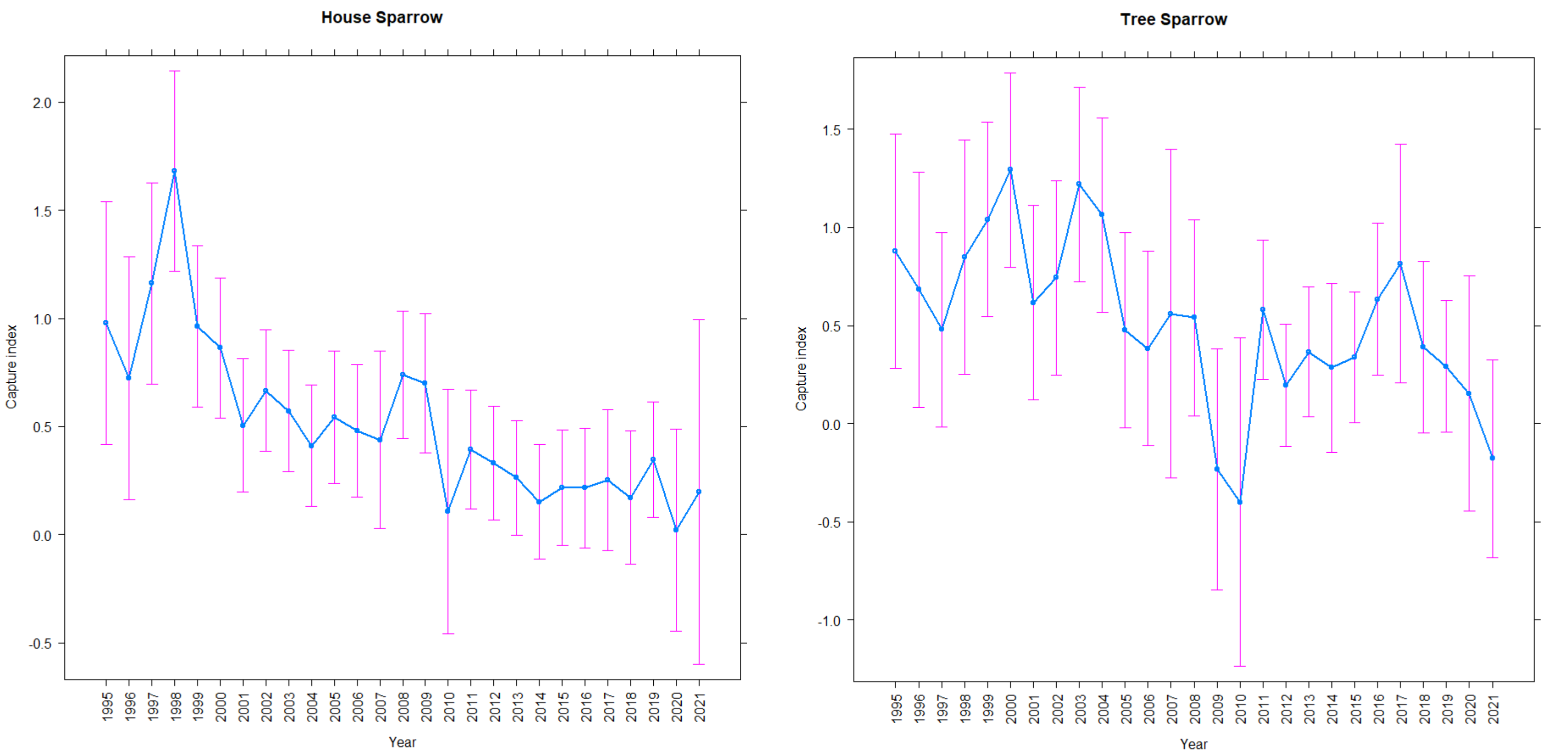


Figure 2: Capture index for *House sparrow* (A) and *Tree sparrow* (B) over the study years.

However, we found close to significant differences for House sparrow between the urbanization index and the captures (p=0.0683). Capture index increased in more urbanized areas than in natural ones (Figure 3, Table 2). In the case of Tree sparrow, we found strongly significant differences in the capture index in relation to urbanization (p=0.0043) (Figure 3, Table 2).

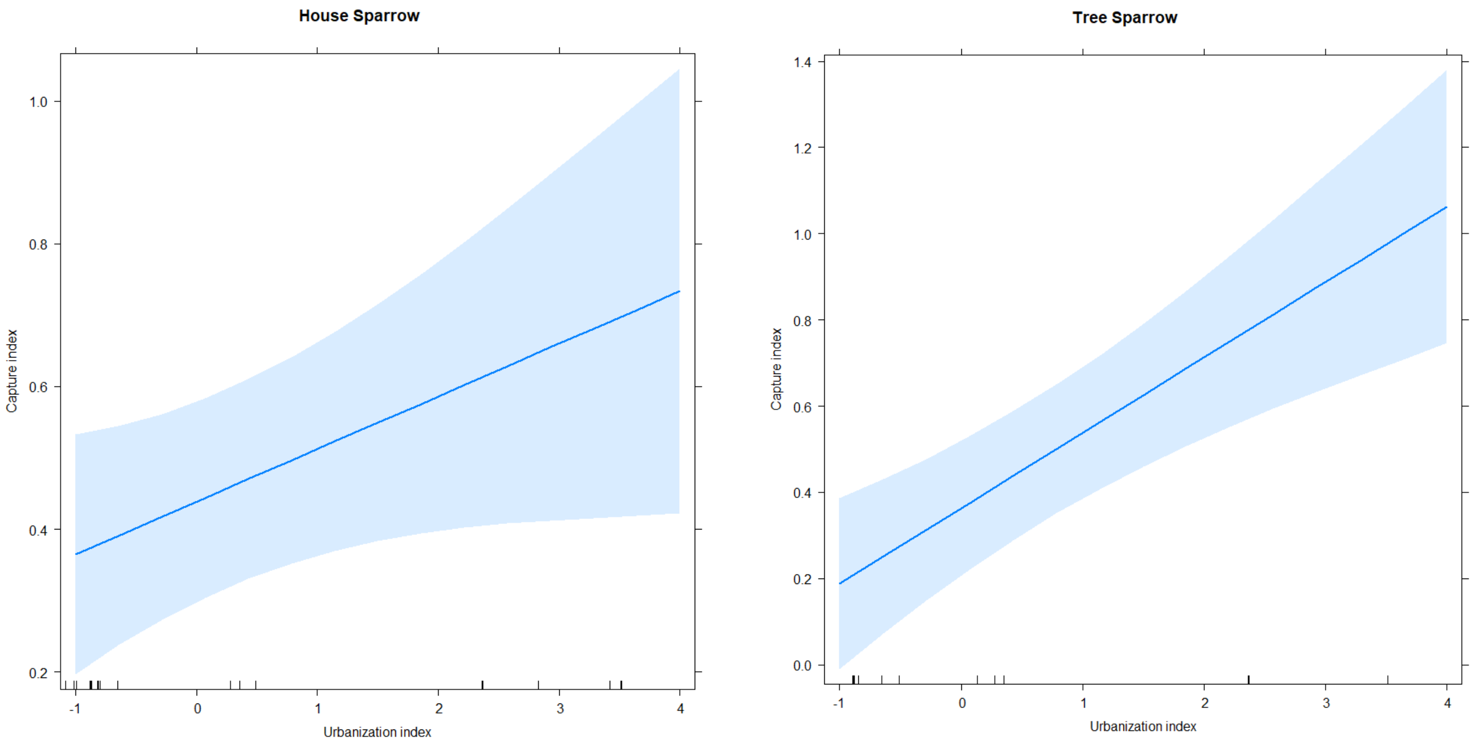


Figure 3: Capture index for *House sparrow* (A) and *Tree sparrow* (B) according to the urbanization index.

## Productivity

Interestingly, we found no significant differences in productivity among the years neither in House sparrow (p=0.1872) nor in Tree sparrow (p=0.1479) (Table 2, Figure 4). Similarly, there were no significant differences in productivity depending on the urbanization index the ringing station was characterized with (for House sparrow p=0.7627; for Tree sparrow p=0.8851) (Table 2, Figure 5).

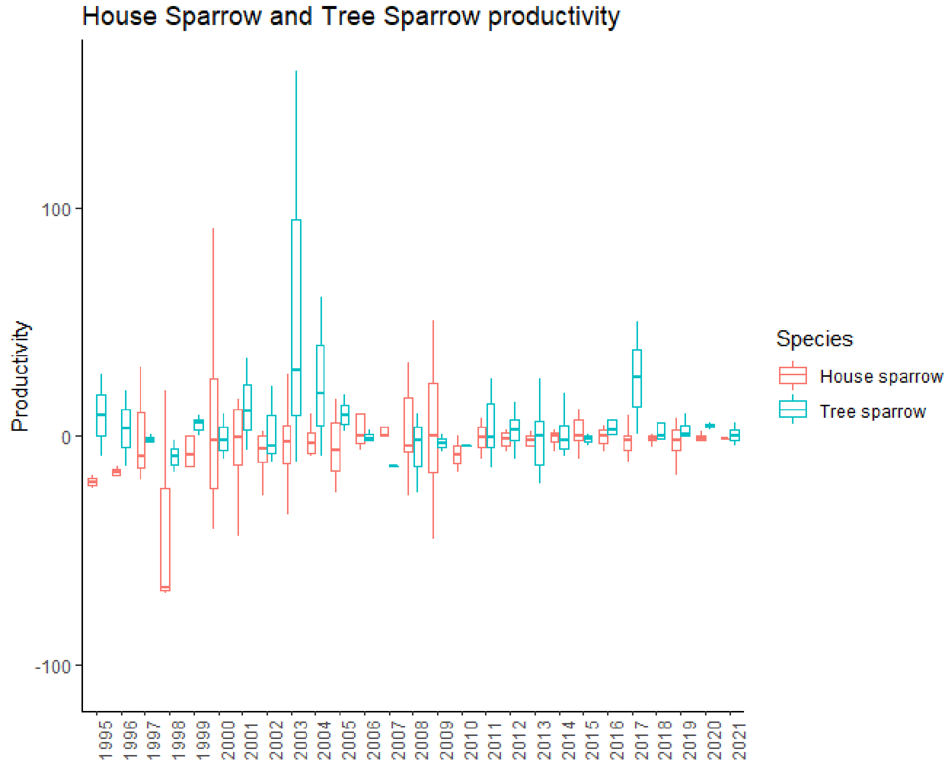


Figure 4: Productivity index for *House sparrow* and *Tree sparrow* over the study years period.

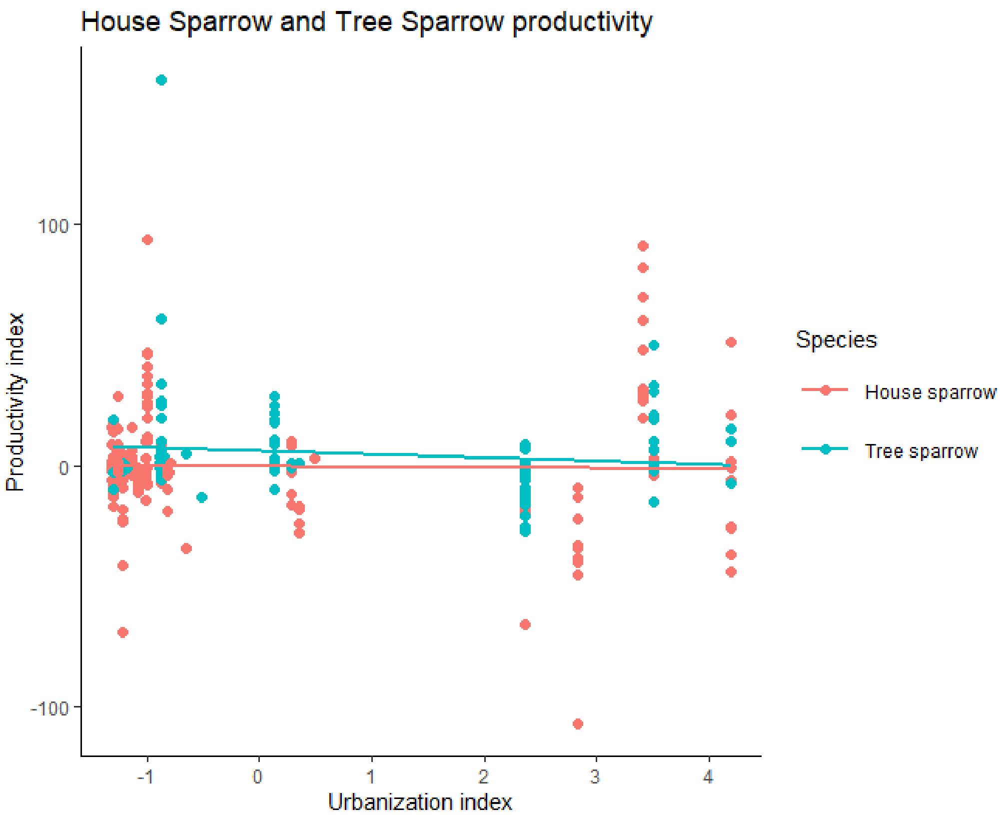


Figure 5: Productivity index for *House sparrow* and *Tree sparrow* according to the urbanization index.

Table 2: Generalized linear mixed models. P-values marked in bold indicate significance (p<0.05)

| HOUSE SPARROW | | Estimate | SE | F | Df | p |
|---|---|---|---|---|---|---|
| Population trends | **Intercept** | 0.9550 | 0.2846 | 11.2266 | 1 | **0.0010** |
| | **Urban index** | 0.0738 | 0.0378 | 3.8047 | 1 | 0.0683 |
| | **Year** | -0.0171 | 0.3236 | 2.9104 | 26 | **0.0000** |
| | | | | | | |
| Productivity | **Intercept** | -15.9132 | 12.4865 | 1.6213 | 1 | 0.2047 |
| | **Urban index** | 0.0941 | 2.3035 | 0.0942 | 1 | 0.7627 |
| | **Year** | 4.5000 | 16.1885 | 1.2715 | 26 | 0.1872 |

| TREE SPARROW | | Estimate | SE | F | Df | p |
|---|---|---|---|---|---|---|
| Population trends | **Intercept** | 0.7432 | 0.3013 | 5.9202 | 1 | **0.0177** |
| | **Urban index** | 0.1749 | 0.0412 | 16.5448 | 1 | **0.0043** |
| | **Year** | -0.1950 | 0.4059 | 2.3302 | 26 | **0.0037** |
| | | | | | | |
| Productivity | **Intercept** | 11.3803 | 14.1087 | 0.6329 | 1 | 0.4291 |
| | **Urban index** | 0.2997 | 1.9202 | 0.0224 | 1 | 0.8851 |
| | **Year** | 3.4740 | 17.4493 | 1.3893 | 26 | 0.1479 |

## DISCUSSION

Our long-term study of Spanish House sparrows and Tree sparrows strongly suggests a continuous decline in populations of both species over the study years, not only in highly urbanized areas but also in the more natural ones. Although different limiting factors could influence the decrease of the urban population, our data indicate that it is not related to a decrease in productivity in any particular area.

The decreasing situation of the two species could be due to many different factors, since there seems to be no single reason that explains the observed situation entirely. It is true that cities provide some benefits for species, like a constant food supply (Tryjanowski *et al,* 2015), however, there must be a cause for such decline. Some authors have pointed out the disappearance of favourable habitat (Shaw *et al,* 2008) and lack of breeding sites (Chamberlain *et al,* 2007) to be one of the reasons.

In relation to the absence of breeding locations, both species lean toward using the space under roof tiles in order to nest (Šálek *et al*, 2015) in urban areas. It was shown by Shaw *et al*, 2008 that more sparrows can be found in low socioeconomic status locations than in wealthy areas since construction flaws are almost non-existent in affluent regions, making it more difficult for them to nest. To compensate for the lack of nesting spaces, nest-boxes are usually suggested. Interestingly, Tree sparrows do use nest-boxes but House sparrows are more indifferent, only using them in some cases where sub-optimal nesting sites were lost (Węgrzynowicz, 2012).

In addition, a descending number of feeding resources such as arthropods in cities may be associated with the decreasing trend of Sparrows, since nestlings feed on them (Summers-Smith, 2009; Murgui & Macias, 2010), a lower quantity of insectivore diet could lead to a reduced lifespan for the juveniles.

Competition with other species (Cooper *et al,* 2007) could also be a reason leading to the population decrease, due to the use of similar resources and aggressive behaviours to defend them, like invasive species e.g. Monk parakeets (Freeland, D. B., 1973; Appelt *et al,* 2016). Predators are another factor to take into consideration, even though cities cannot compare to natural areas when talking about predators, feral cats and free-ranging domestic cats are one of the main causes of biodiversity loss in urban areas (Jessup, 2004; Lepczyk *et al,* 2004; Beckerman *et al,* 2007).

Another key point is contamination of the environment, such as electromagnetic radiation (Balmori and Hallberg, 2007), additives in fuels (Summers-Smith, 2007), or pollution in the system (atmosphere, ground and water) (Khan & Ghouri, 2011).

Probably a combination of these factors, and/or others unidentified, is causing the observed decline.

At the same time, Tree sparrows were thought to inhabit more natural areas (Zhang *et al,* 2008), but our research shows how captures increase with the more urbanized ringing station locations in contrast to what we had previously predicted.
House sparrows are more aggressive than Tree sparrows (Cordero & Senar, 1990), excluding the last ones from favourable nest-sites, which could mean that due to the decrease of House sparrow population, an increase of the Tree sparrow population in urban areas may occur. Nonetheless, Tree sparrows are influenced by human activity, preferring urban places where it is not so crowded and where they can find a great portion of vegetation. In cities they prefer places where they can find natural resources, as well as holes in low buildings to nest (Zhang & Zheng, 2010). We could say that the increasing urban population of Tree sparrows we can see in our results would rather inhabit more natural areas within urban cities, for instance private gardens in residential places (Šálek *et al,* 2015).

Our data also show that, even with decreasing trends in population, productivity does not change neither along the years nor along the urbanization index. This means that whatever is causing the declining trend in House sparrow and Tree sparrow populations, it affects both adults and juveniles. Fitness would be reduced since individuals do not live as long as before, meaning they would have less offspring.
Related to the invariable productivity, birds breeding seasons are longer in urban areas than in natural ones (Chamberlain *et al*, 2009), having more time then to lay more eggs, compensating for their potentially shorter lifespan.

## CONCLUSIONS

According to national censuses, and in view of the arguments above, we can conclude that House sparrow and Tree sparrow populations are decreasing in Spain. There is no known cause for this event but it seems that there are multiple factors involved. Not only that, Tree sparrows (that used to settle in more natural areas) unexpectedly seem to be now expanding to cities and urban areas, again we are not aware of the reason why but it could be related to the occupancy of empty niches due to the decrease of House sparrow numbers. However, our data show how productivity remains the same over the study years and locations, which means that the cause of the decline in both populations seems to affect not only adults but also juveniles.

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