



# Urban wild boars prefer fragmented areas with food resources near natural corridors



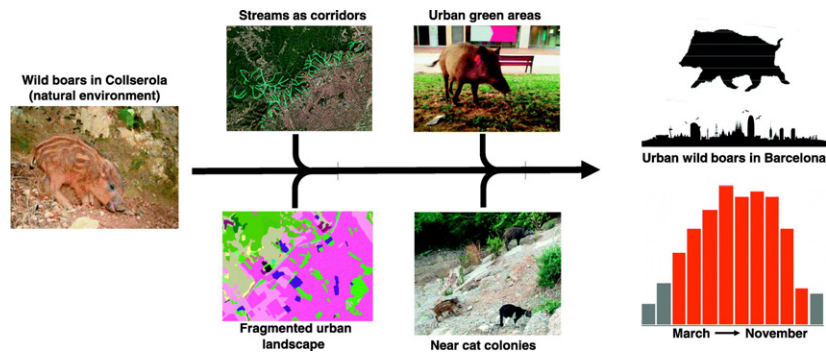
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## HIGHLIGHTS

- Urban wild boars appear close to streams, which might act as corridors.
- Fragmentation, urban green areas and pet food are related to wild boar presence.
- Most wild boar enter into the city between March and November.
- Management measures derived from this study are currently being applied in Barcelona.
- The methodology can be applied to other cities with wild boar presence.

## GRAPHICAL ABSTRACT



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## ABSTRACT

Wild boar populations are expanding throughout the world and intruding into periurban and urban areas. In the last years, wild boar has colonized several European cities, including our study area, the city of Barcelona. It is required to identify the main factors driving wild boar into urban areas prior to establish management measures. We built Boosted Regression Trees (BRT) using 3148 wild boar presences registered in the urban area of Barcelona from 2010 to 2014 to identify the variables correlated with these presences. The variables analysed included proxies for distance to source population, urban food resources, climate and urban habitat structure. Wild boars enter the urban area from close natural habitat using corridors such as streams, preferably in fragmented urban environment, looking for food such as urban green areas or dry pet food from cat colonies. Wild boar presence is higher in spring possibly due to the births of piglets and the dispersion of yearlings during that season, and also when natural resources in the Mediterranean habitat fail to satisfy the nutritional requirements of the wild boar population during the summer season. Management measures derived from this study are currently being applied in the city of Barcelona, including vegetation clearings in the wild boar entrance areas and an awareness campaign aimed at reducing the anthropogenic food availability for wild boars. The methodology used can be applied to other cities with wild boar or even other wildlife species issues. The comparison between the factors attracting wild boars into different urban areas would be helpful to understand the global phenomenon.

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## 1. Introduction

Wild boar populations are geographic and demographically increasing throughout the world as a result of socio-economic and ecological changes, such as natural forest regeneration, increased anthropogenic food resources, limited hunting and translocations (Massei et al., 2011; Sáez-Royuela and Tellería, 1986; Snow et al., 2017). The movement ecology of wild boar, together with its high diet plasticity and high prolificacy, have also contributed to the worldwide spread of wild boar populations (Morelle et al., 2015). As a consequence of these human-induced changes and natural features of the wild boar, the interaction between wild boars, humans and the environment have increased, namely crop damages, road traffic accidents, increased risk for shared diseases including zoonoses, altered food webs and damage to some plant and animal species (Massei et al., 2011).

This way, wild boar has been acting as a native invader, spreading within their historical range, reaching extreme abundances and producing severe effects on other species (Carey et al. 2012). The concept “native invader” was introduced by Simberloff (2011) to refer to a species that has become invasive in its own native distribution range, but has not been widely applied to wild boar yet. However, it is a clear example of a human-wildlife conflict, where management strategies applied try to mitigate the symptoms rather than address the causes, and then both social and political challenges arise (Carey et al. 2012).

The easy access to food and water, the absence or insufficient hunting pressure and the expanding urbanization into the forested areas occupied by wild boar have similarly favoured its intrusion into periurban and urban areas (Licoppe et al., 2013). Rivers and roads act as corridors which facilitate wild boar occurrence in these areas (Licoppe et al., 2013). The risks and disturbances associated with the wild boar presence in urban environments include, apart from traffic accidents, damages to street furniture, parks and private gardens, and ransacking of rubbish bins and containers. They can also share diseases with pets and humans (Meng et al., 2009) and may occasionally attack people (Cahill et al., 2012).

In the last years, wild boar has colonized the urban and periurban environment in several European cities, including Barcelona, Berlin, Budapest, Genoa and Warsaw (Licoppe et al., 2013). In Barcelona, the wild boar enters the city mainly from the bordering Collserola massif, a natural area where wild boar presence was anecdotal in the 80s. Since then, and in accordance with the global trends, Collserola wild boar population has increased to reach a density over nine wild boars per 100 ha (Minuartia, 2016). This increase may have been favoured by the increased urbanization inside the massif and therefore the increased anthropogenic food available for wild boars (domestic rubbish, vegetable material from parks and gardens, pet food and direct feeding). This might also have attracted wild boar into periurban and urban areas during periods of scarcity (Cahill et al., 2012).

Alternative approaches based on integrated landscape and social management are necessary to reduce wild boar populations (Cahill et al., 2003). Moreover, to specifically deal with wild boar presence in urban areas it is required to identify the main drivers, in order to establish management measures to reduce their attractiveness. Although several studies have investigated the factors related to a species presence or distribution, only a few focus in urban wild species, and to the authors' knowledge no study has tried to identify the factors favouring wild boar presence in urban areas.

The aim of this study is identifying the factors determining the presence of wild boars inside the urban area, considering the distance to the source population, climate, food resources and urban habitat structure, to provide scientific knowledge allowing the implementation of management measures. Since wild boar adaptation to urban environments is widespread and increasing, both the analytical approach performed and the results might be useful for other urban areas where wild boar is or will shortly be conflictive.

## 2. Material and methods

### 2.1. Study area

The study area is the municipality of Barcelona (Catalonia, NE Spain) (Fig. 1), which has a 10,100 ha area and a human population of 1,600,000 inhabitants (Institut d'Estadística de Catalunya, 2016). The urban area of Barcelona spreads between the Mediterranean seashore (SE) and the border with the Collserola massif (NW), and between the Besòs (E) and Llobregat (W) rivers. Barcelona landscape is mostly urban but green spaces represent a 35.3% (3611 ha) of the city surface, including the Collserola surface which falls within the city limits. Excluding this part of the massif, green areas represent an 18.1% (1850 ha) of Barcelona surface. Despite the existence of several large parks, the 84% of urban green spaces are less than half hectare in size and are, in general, isolated (Ajuntament de Barcelona, 2013).

Collserola massif is an 11,000 ha natural area belonging to the Catalan coastal mountain range with an abundant wild boar population (Departament d'Agricultura Ramaderia Pesca i Alimentació, Generalitat de Catalunya, 2015). It is a hilly area, altitude ranging between 60 and 512 m above sea level. It is completely surrounded by human infrastructures and receives about two million visitors yearly (Consorci del Parc Natural de la Serra de Collserola, 2016). Collserola has a Mediterranean climate; mean annual temperature is 15 °C (average temperature is rarely below 5 °C in winter, and around 21 °C in summer). The annual average rainfall is over 620 mm with two wet seasons, autumn and spring (October, 83.1 mm; May, 60.4 mm), and a dry summer period (July, 10.6 mm) (Consorci del Parc Natural de la Serra de Collserola, 2016). Mediterranean pine forests dominated by *Pinus halepensis* (40%) and sclerophyllous woodlands with *Quercus ilex* (15%) cover a large part of the massif, but Mediterranean and sub-Mediterranean scrubs also represent an important part of the vegetation (24%) (Pérez-Haase and Carreras, 2012).

### 2.2. Data collection

The Metropolitan Police registered the location and date of 3148 wild boar presence in the urban area of Barcelona from 2010 to 2014. A wild boar presence means that a minimum of one wild boar was present in the public street at a certain time, alive, wounded or dead (after a car accident, for instance). Most of the sightings were reported by citizens through a phone call to the local emergency number. The wild boar presences were processed to avoid pseudo-replication, retaining only one presence if two or more data occurred within 500 m from each other within a two hour frame. Therefore, only 2621 (1.4 observations/day on average) of the 3148 presences registered were finally included in the analysis. Fig. 1 shows a map of Barcelona municipality with the refined wild boar presences.

### 2.3. Data creation and modelling

We created wild boar pseudoabsences as a random sample of locations to compare the presences with, following Barbet-Massin et al. (2012). Both wild boar presences and pseudoabsences were characterized with factors accounting for climate, distance to source population, urban food resources and habitat structure. Table 1 shows the predictor variables constructed for the analysis. We used QGIS v2.8.1 (Meng (Quantum GIS Development Team, 2015) and Fragstats v4.2.1. (McGarigal et al., 2012) softwares.

Before modelling, we used R software (version 3.1.3; R Development Core Team, 2015) to perform an exploratory analysis following the protocol proposed by Zuur et al. (2010), checking for multicollinearity amongst the explanatory variables by calculating Pearson's correlation coefficients. When the variables were highly related (coefficient  $\geq 0.7$ , Dormann et al., 2013), only one was retained for model construction (Table 1).

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