Characteristics of wild boar (*Sus scrofa*) habituation to urban areas in the Collserola Natural Park (Barcelona) and comparison with other locations

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Abstract

*Characteristics of wild boar (*Sus scrofa*) habituation to urban areas in the Collserola Natural Park (Barcelona) and comparison with other locations.*— The parallel growth of urban areas and wild boar populations in recent years has increased the presence of this species around cities and in suburban areas, often leading to conflict with local people. In the Collserola Natural Park, situated within the metropolitan area of Barcelona, wild boar have become habituated to humans and urban settings because of direct feeding by local residents. Their attraction to these areas due to an abundance of anthropogenic food sources is especially strong during the warmer summer season when foraging conditions are poorer in their natural woodland habitat; the number of captures of habituated wild boar in peri–urban areas is significantly correlated with mean monthly temperatures. Habituated boar are primarily matriarchal groups, whereas adult and sub–adult (>1 year) males are significantly less represented than in non–habituated boars. In Collserola, habituated sub–adult and adult females are significantly heavier than their non–habituated counterparts and these weight differences increase with age; in the > 3 year–old age class they may be 35% heavier. Conflicts generated by the presence of wild boar in peri–urban areas are complex, and the responses by authorities are similarly diverse and often exacerbated by ambivalent public attitudes, both towards wild boar presence and applied mitigation measures. By 2010, at least 44 cities in 15 countries had reported problems of some kind relating to the presence of wild boar or feral pigs.

Key words: Habituation, Human–wildlife conflict, *Sus scrofa*, Urbanisation, Wild boar.

Resumen

*Características de la habituación de jabalíes (*Sus scrofa*) a las áreas urbanas en el Parque Natural de la Sierra de Collserola y comparación con otros lugares.*— El crecimiento paralelo de las zonas urbanas y de las poblaciones de jabalíes durante los años recientes ha significado un aumento de la presencia de esta especie en las proximidades de las ciudades y de las áreas suburbanas donde a menudo representan una fuente de conflicto con las personas. En el Parque Natural de la Sierra de Collserola, situado en el área metropolitana de Barcelona, el jabalí se ha habituado a las personas y a las áreas urbanas como consecuencia de la alimentación directa por parte de vecinos. Su atracción a dichas áreas debido a una abundancia de alimento de origen antropogénico es especialmente fuerte durante los veranos cálidos cuando las condiciones tróficas son peores en su hábitat forestal natural; el número de capturas de jabalíes habituados en áreas periurbanas está significativamente correlacionado con las temperaturas medias mensuales. Los jabalíes habituados son principalmente grupos matriarcales, mientras que los machos adultos y subadultos (> 1 año) están significativamente menos representados, a diferencia de lo que se observa en los no habituados. En Collserola, las hembras adultas y subadultas habituadas pesan significativamente más que las hembras no habituadas y las diferencias de peso entre ellas incrementan a mayor edad; las > 3 años pueden pesar un 35% más. Los conflictos generados por la presencia de jabalíes en áreas periurbanas son complejos, y las respuestas por parte de las autoridades son también diversas y a menudo exacerbadas por unas actitudes ambivalentes por parte del público, tanto en lo que se refiere a la presencia del jabalí como a las medidas de mitigación aplicadas. Hasta el 2010, por lo menos 44 ciudades de 15 países habían registrado problemas de algún tipo relacionado con la presencia de jabalíes, o cerdos asilvestrados.

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Palabras clave: Habituación, Conflicto, *Sus scrofa*, Urbanización, Jabalí.

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Introduction

The rapid expansion of urban areas means that metropolitan landscapes are becoming increasingly significant from the perspective of wildlife ecology. Apart from the direct loss of habitat which occurs as a result of urban sprawl, there has been a dramatic increase in the contact zone between urban areas and wildlife habitat, often referred to as the wildland–urban interface (Radeloff et al., 2008). Such interfaces usually occupy more land than the built urban/suburban area itself, thus affecting wildlife habitat and human–wildlife interactions over an ever increasing surface area (Zhang et al., 2008). Although many species of wildlife are negatively affected by urbanisation processes (McDonald et al., 2008), others, particularly so–called generalist species, are capable of successfully exploiting habitat at the wildland–urban interface and even thrive in highly artificial urban greenspace and gardens. In recent times, racoons (*Procyon lotor*), fox squirrels (*Sciurus niger*), and coyotes (*Canis latrans*) have become established in metropolitan areas of Canada and the United States (Gehrt, 2007), while red fox (*Vulpes vulpes*) frequently occupy urban areas (Harris & Smith, 1987; König, 2008).

Likewise, wild boar (*Sus scrofa*) populations are currently expanding worldwide both in distributional range and in numbers in many countries where they are present, either as a native or non–native species. Wild boar population dynamics are often dictated by the abundance or scarcity of pulsed resources, such as mast seeding by oak (*Quercus* spp.) and beech (*Fagus* spp.) trees (Bieber & Ruf, 2005). Nevertheless, this species has benefitted from changes in traditional agro–silvo–pastoral landscapes which have removed the limitations that hitherto existed for population growth. Among other factors, the loss of predators, the intensification of agricultural practices, supplementary feeding, the deliberate release by hunters, and even global warming (Geisser & Reyer, 2005) all have contributed to increased abundance of wild boar. Previously confined mainly to rural, forested, mountainous, and similar natural areas with low human presence, in recent years wild boar have become increasingly habituated to urban areas (Kotulski & König, 2008).

Among wildlife, habituation is defined as the loss of fear response to the presence of humans after repeated, non–consequential encounters (Herrero et al., 2005; McNay, 2002; Wieczorek–Hudenko & Decker, 2008). However, conflicts arise when the species' presence overlaps both in time and space with human activity and their activities become an annoyance to residents (Loker & Decker 1998). Such conflicts are varied, ranging from general nuisance to more serious issues such as disease transmission, increased risk of traffic accidents, or even attacks on humans (Hubbard & Nielsen, 2009; Storm et al., 2007; Timm et al., 2004; White & Gehrt, 2009).

Wild boar have become very abundant in the province of Barcelona (NE Spain) over the last two decades, with an eight–fold increase in annual hunting bag returns between the 1986 and 2005 seasons (fig. 1). This increase has coincided with a rapid rise in the human population in the province, which has increased from just over 4.5 million to 5.5 million, and an intense period of sprawling urbanisation (fig. 1). However, hunting has been forbidden in the area covered by the Barcelona city municipality for more than 20 years, and groups of wild boar in the adjacent Collserola Natural Park (fig. 2) have become increasingly habituated to human presence over the last 10 years, especially in peri–urban areas located beside this and other nearby cities (fig. 3). Habituation of wild boar has largely been motivated by direct feeding by people and is also facilitated by the proximity of densely vegetated areas close to the city limits (Llimona et al., 2007). This habituation leads to frequent conflicts for neighbours, park managers, and city authorities due to damage caused to gardens and landscaped areas, as well as fear of attacks and collisions with vehicles. In this study we aimed to identify the main environmental factors associated with habituation incidence in the Collserola Natural Park (Barcelona, NE Spain), and to investigate potential differences in relation to sex, age, and weight between habituated and non–habituated wild boar. We describe the characteristics, consequences, and management implications of wild boar habituation to urban areas near the Park, and contextualise the increasing presence of wild boar and feral swine in peri–urban situations in other countries.

Study area

The Collserola Natural Park (41° 25' 52" N, 2° 4' 45" E) is a Natura 2000 site situated in the middle of the Barcelona Metropolitan Area (fig. 2). It comprises 36 municipalities with a population of 3.2 million people and a population density of over 5,000 inhabitants per km^2 (INE 2011). Collserola occupies ~9,000 ha of mountainous (60–512 m a.s.l.) Mediterranean scrub and woodland (60%), with declining agriculture and intense urban and infrastructure pressure on its periphery. Wild boar numbers have increased in Collserola since the early 1980s, and the population has been estimated to be about 800 individuals (density ~11 boar/km^2) based on hunting returns in recent years (Cahill et al., 2012). The hunting of wild boar is permitted in ~50% of available habitat, and on average about 100 wild boar are killed there each year by hunters (annual range of 61–192 captures for 2004–2011). Hunting occurs either via large battues (drive hunts with hunters placed at fixed positions and teams of dogs used to flush the boars) carried out between October and February, or with special permits authorised for damages throughout the year (fig. 4; Cahill et al., 2012). Further details on the study area and on the demography and biology of wild boar in Collserola may be found in Cahill et al. (2003) and Cahill & Llimona (2004), and on the specific peri–urban metropolitan context of Collserola's wildlife in Llimona et al. (2005, 2007).

Material and methods

We define habituated wild boar in this study as individuals that are clearly accustomed to or indifferent to

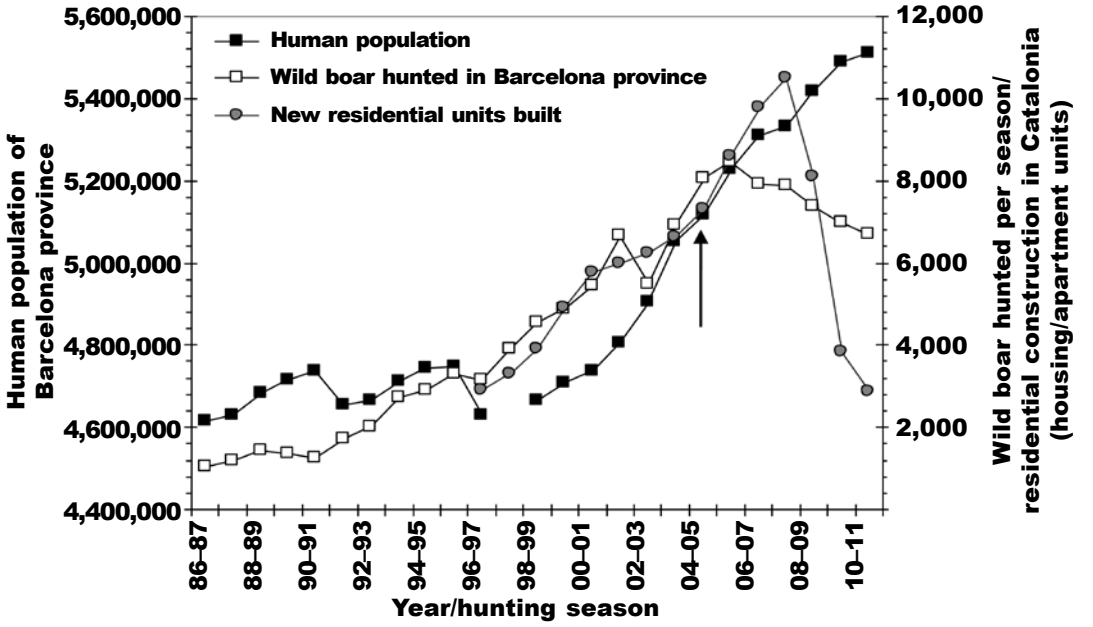

Fig. 1. Trends in human population growth (left ordinate) and the number of wild boar hunted per season in the province of Barcelona from 1986 to 2010, and residential construction in Catalonia since 1990 (right ordinate). Data from INE (2011), the Territorial Service of the Government of Catalonia, and http://www20.gencat.cat/portal/site/ptop. The vertical arrow marks the year in which the systematic live capture of habituated wild boar began in Collserola.

Fig. 1. Tendencias de crecimiento de la población humana (eje de ordenadas izquierdo) y el número de jabalíes cazados por temporada en la provincia de Barcelona entre 1986 y 2010, y de construcción de viviendas en Cataluña desde 1990 (eje de coordenadas derecho). Datos del INE (2011), los Servicios Territoriales de la Generalidad de Cataluña y http://www20.gencat.cat/portal/site/ptop. La flecha vertical indica el año en que se inició la captura sistemática en vivo de jabalíes habituados en Collserola.

human presence and usually do not flee from people. Live capture of habituated wild boar in urban areas of Collserola has been carried out on a regular basis by park wardens using tranquiliser darts since 2004 to address complaints either from residents, local police, or other authorities. Wardens dart habituated wild boar during daylight at close range (~5–15 m) with Zoletil® 100 (VIRBAC S.A., Spain), an anaesthetic mixture of tiletamine and zolazepam (see Fournier et al. (1995) for its use on wild boar), applied using a JM Special rifle (DAN–INJECT ApS, Denmark). It is usually possible to capture most or all of the members of sounders located in urban areas on a first attempt, and if not, they are captured on subsequent visits given that groups quickly return to the same site in the urban area. At present, most wild boar captured are subsequently euthanized. We gathered biometric data from captured boar and estimated age class based on tooth eruption sequences (Monaco et al., 2003). We also collected comparable data from wild boar mortality from different causes (*e.g.,* hunting and road kills).

We correlated the number of wild boar captured in urban areas with mean monthly maximum temperatures and means of total monthly rainfall using values from local meteorological data available online (http://www.fabra.cat/meteo/dades/dades.html). In order to obtain information regarding foraging conditions in natural areas of Collserola, we gathered relevant data during seasonal plot surveys carried out between September 1998 and December 2004. We assessed acorn availability, soil rooting conditions, and wild boar rooting activity at 27 fixed 3 m x 3 m plots located in different woodland areas within Collserola Natural Park. We evaluated soil rooting conditions through calculation of a simple index based on soil humidity and compactedness both at the surface layer and at 10 cm depth, and this index takes values between 0 (poorest conditions) and 1 (optimal conditions). The specific methodology applied in surveying these seasonal plots is detailed further in Cahill et al. (2003) and Cahill & Llimona (2004). We used official data on motorway traffic through Collserola as an indicator of monthly human presence for 1997–2007 from http://www20.gencat.cat/portal/site/ptop. For statistical analysis, we used Chi–squared, *t*–tests, and one–way ANOVA to evaluate comparisons of proportions and means and Spearman's Rank correlation coefficient for the analysis of linear correlations between variables (Zar, 1984). Where mean values are quoted these are provided with their corresponding standard errors.

Fig. 2. Location of the Collserola Natural Park beside the city of Barcelona.

Fig. 2. Situación del Parque Natural de la Sierra de Collserola al lado de la ciudad de Barcelona.

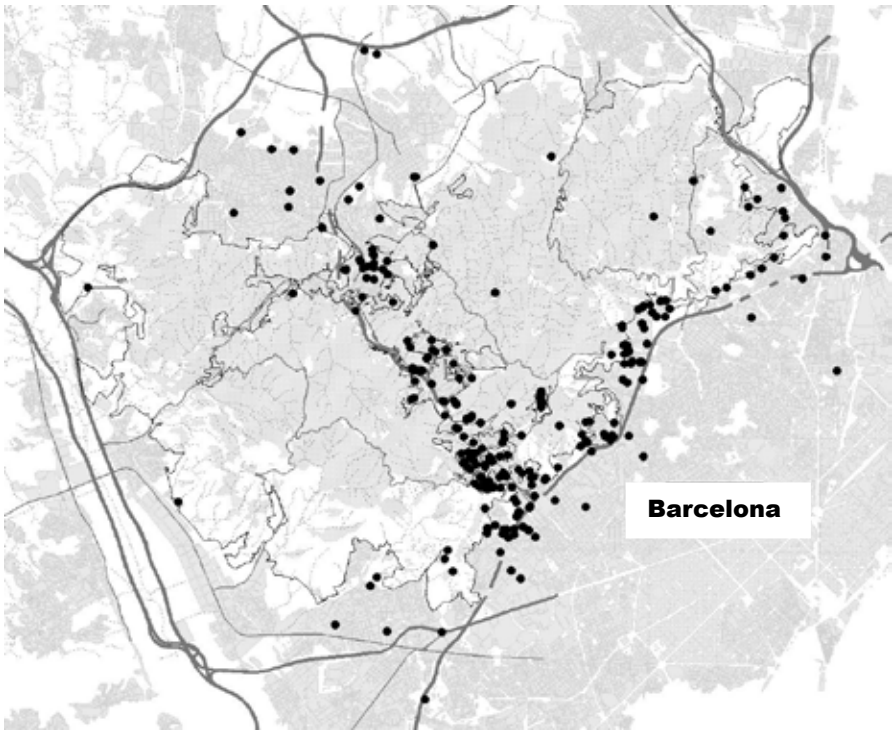

Fig. 3. Locations of incidents concerning the presence of wild boar in peri–urban areas of the Collserola Natural Park and its surroundings.

Fig. 3. Localización de los incidentes relacionados con la presencia de jabalíes en áreas periurbanas del Parque Natural de la Sierra de Collserola y de sus alrededores.

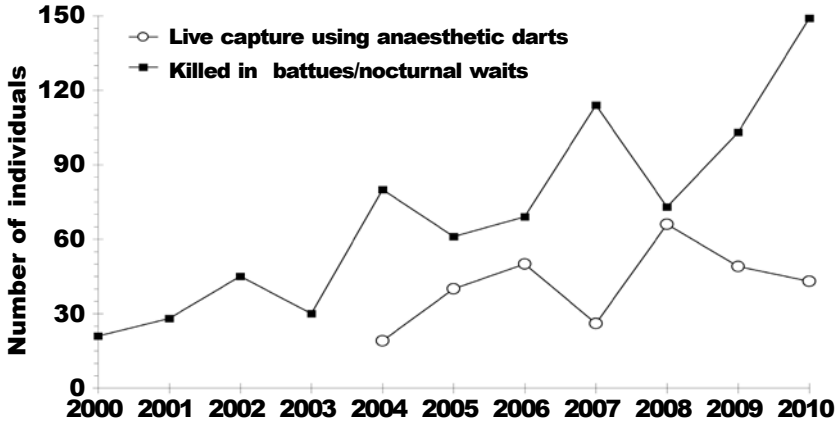

Fig. 4. Number of *non–habituated* wild boar killed by hunters (■) and *habituated* wild boar (○) captured by park wardens using tranquilizer darts in the Collserola Natural Park each year since 2000. (Data are calendar year totals.)

Fig. 4. Número de jabalíes no habituados capturados por cazadores (■) y de jabalíes habituados (○) capturados por guardas del parque mediante dardos anestésicos en el Parque Natural de la Sierra de Collserola cada año desde el 2000. (Los datos son totales para cada año.)

Table 1. Seasonal mean values of the rooting suitability index, the percentage of plot rooted, and acorn density at fixed plots monitored in Collserola between September 1998 and December 2004, with corresponding *p*–values of Tukey HSD post–hoc multiple comparisons.

Tabla 1. Valores medios mensuales del índice de condiciones para hozar, del porcentaje de parcela hozada y de la densidad de bellotas en parcelas fijas muestreadas en Collserola entre septiembre de 1998 y diciembre de 2004, y los valores correspondientes de p *de comparaciones múltiples post–hoc realizadas mediante la prueba HSD de Tukey.*

Season	Mean	S.E.	N plots	Summer	Autumn	Winter
Rooting suitability index						
Spring	0.389	0.015	135	$p = 0.000$	$p = 0.000$	$p = 0.000$
Summer	0.249	0.017	194	–	$p = 0.000$	$p = 0.000$
Autumn	0.466	0.011	216		–	$p = 0.840$
Winter	0.481	0.009	160			–
Plot rooted (%)						
Spring	1.259	0.568	135	$p = 0.721$	$p = 0.917$	$p = 0.257$
Summer	0.699	0.263	194	–	$p = 0.226$	$p = 0.010$
Autumn	1.597	0.290	216		–	$p = 0.514$
Winter	2.280	0.373	160			–
Acorn density (per m^2)						
Spring	2.655	1.028	135	$p = 0.735$	$p = 0.939$	$p = 0.098$
Summer	0.669	0.300	194	–	$p = 0.274$	$p = 0.002$
Autumn	3.747	1.223	216		–	$p = 0.199$
Winter	7.304	2.153	160			–

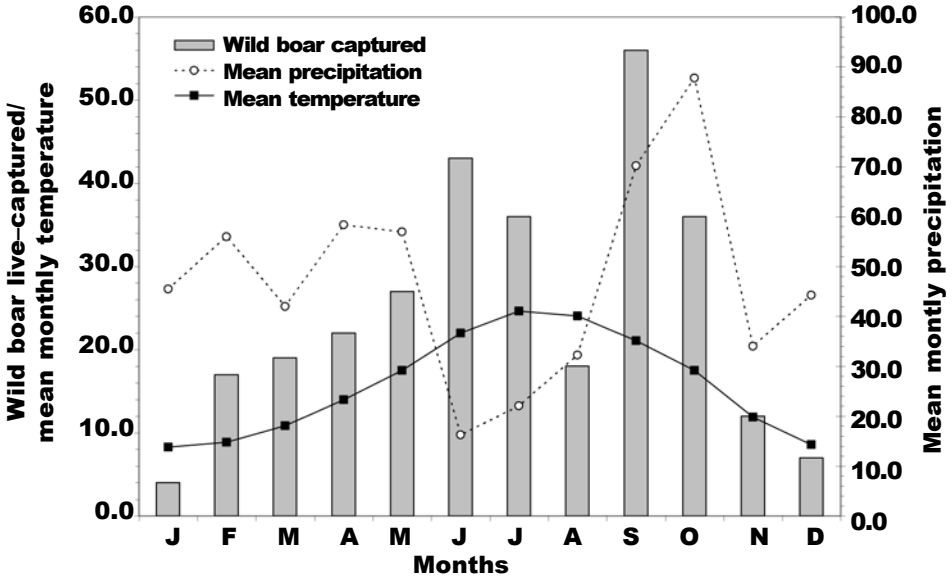

Fig. 5. Total number of wild boar live–captured per month in peri–urban areas of Collserola in relation to mean monthly temperature (in ºC, solid line and squares) and mean monthly precipitation (in l/m^2, dotted line and circles) between 2004 and 2010.

Fig. 5. Número total de jabalíes capturados cada mes en las áreas periurbanas de Collserola en relación con las temperaturas medias mensuales (en ºC, línea continua con cuadrados) y precipitación media mensual (en l/m^2, línea discontinua con círculos) entre 2004 y 2010.

Results

The mean index of soil suitability for rooting activity was significantly different between seasons ($F_{3,696}$ = 4.28, p < 0.0001), with poorest conditions in summer and best conditions in winter (table 1). The mean percentage surface area of plots that was rooted by wild boar also varied between seasons ($F_{3,696}$ = 3.23, p < 0.05), again being lowest in summer and highest in winter (table 1). Likewise, mean acorn density varied between seasons ($F_{3,696}$ = 4.33, p < 0.005), being lowest in summer and highest in winter (table 1).

A total of 293 habituated wild boar were captured live and removed from urban areas of Collserola between 2004 and 2010 (fig. 4), representing a mean of 42 ± 5,9 animals captured per year (range: 19–66). Live captures of habituated wild boar tended to be concentrated during the warmer months of the year, especially between May and October (fig. 5), and the monthly total of such captures was significantly correlated with mean monthly temperatures (r_s = 0.771, p < 0.005, n = 12, data from 2004–2010 inclusive). In contrast, there was no correlation between the number of incidents and mean monthly precipitation during this same period (fig. 5, r_s = 0.133, p = 0.68, n = 12). Fewer captures were recorded in August, despite the high mean temperature for this month (fig. 5). Lower human presence in the Collserola area during August is indicated by data from the E–9 toll motorway which runs through the park, with 47% less traffic than in the other months of the year ($F_{1,11}$ = 6.371, p < 0.0001: ~16,000 vehicles/day in August and minimum–maximum range for the remaining months between ~28,000 in January and ~33,000 vehicles/day in November). In contrast, there was a sharp increase in wild boar captures during the month of September, which may reflect residents' return from holidays. When total captures for the months of August and September (n = 74) are averaged, thus adjudicating 37 captures to each month, the overall relation between monthly temperature and captures of habituated wild boar is strengthened (r_s = 0.912, p < 0.001, n = 12).

Groups of habituated wild boar were comprised almost entirely of adult females accompanied by sub–adults and piglets, whereas adult male boars were less frequently encountered in urban areas (fig. 6). Among habituated males, adults and sub–adults (over 1 year old) comprised a significantly lower proportion (31.2%) of individuals than those in an accumulated sample of non–habituated males in which 64.3% were more than 1 year old (χ^2 = 15.86, p < 0.001, n = 64 habituated and 84 non–habituated individuals). In the case of females, the proportions of individuals over 1 year old among habituated (48.9%) and non–habituated (62.4%) wild boar were not significantly different (χ^2 = 3.21, p = 0.07, n = 90 habituated and 85 non–habituated).

Habituated wild boar females were significantly heavier than non–habituated females in all age classes > 1 year old, and weight differences between them increased in older age classes (table 2). On

Table 2. Mean weights (kg) of different age classes of habituated and non–habituated male and female wild boar in Collserola. *T*–test values and corresponding significance levels (*p* value) are indicated for appropriate *t*–test comparisons of means between habituated and non–habituated animals. Sample sizes are indicated in brackets following means and standard errors.

Tabla 2. Pesos (kg) medios de las distintas clases de edad de jabalíes machos y hembras habituados y no habituados en Collserola. Se indican los valores de test t *y sus niveles correspondientes de significado (valores de* p*) para las comparaciones de promedias entre animales habituados y no habituados. El tamaño de las muestras se indica entre paréntesis después de los valores promedios y sus errores estándar.*

	Males				Females			
	Habituated		Non–habituated		Habituated		Non–habituated	
0–6 months								
	15.66	2.04 (24)	13.44	1.41 (18)	14.15	1.93 (20)	15.16	1.06 (26)
	t = –0.836 p = 0.408				t = 0.485 p = 0.630			
6–12 months								
	37.19	2.85 (9)	30.98	1.54 (11)	33.44	2.35 (20)	24.58	2.04 (6)
	t = –2.014 p = 0.059				t = –1.979 p = 0.059			
1–2 years								
	53.63	3.27 (16)	48.02	2.18 (40)	53.99	2.60 (27)	42.77	1.96 (26)
	t = –1.396 p = 0.168				t = –3.428 p = 0.001			
2–3 years								
	84.03	4.92 (3)	71.71	7.42 (7)	65.47	3.62 (11)	51.75	1.60 (13)
	t = –1.02 p = 0.338				t = – 3.657 p = 0.001			
> 3 years								
	85.30	7.10 (2)	80.25	7.14 (6)	83.34	4.75 (7)	61.78	3.71 (13)
	t = –0.375 p = 0.720				t = –3.507 p = 0.003			

average, habituated females were 26.2%, 26.5% and 34.9% heavier than non–habituated individuals in the 1–2 year, 2–3 year and 3 year+ age classes, respectively. Habituated female wild boar that were 6–12 months old were also heavier than non–habituated females, although this weight difference was marginally non–significant, while there was no significant difference between them in the 0–6 month old age class (table 2). Habituated males also weighed more than non–habituated males in all age classes. However, unlike females, these differences were not statistically significant, being only marginally non–significant in the 6–12 month age class.

Discussion

Several factors have coincided in facilitating the initial habituation of wild boar to urban areas and human presence in Collserola. In Mediterranean areas, and specifically as is shown in this study, food is scarcer in natural woodland habitat during the months of summer drought, mainly because foraging conditions are poorer as a result of the hardening of the soil. Also, during this period there is a scarcity of forest food sources, such as oak mast, which play an important role in wild boar demographics (Massei et al., 1996, 1997; Cahill & Llimona, 2004). Indeed, during the summer nocturnal feeding activity of wild boar in the Collserola mountains is concentrated on more humid, generally northern facing slopes, and in valley ravines and by streams, whereas feeding activity is almost non–existent during this season on the drier forest slopes that cover most of the surface area of the park (Cahill et al., 2003). Thus, wild boar might be expected to venture into peri–urban areas in search of anthropogenic food sources during summer if food is scarce in adjacent woodland areas. In this regard, mean monthly temperature appears to be a good correlate of habituation incidence in Collserola, unlike precipitation which is much more variable and irregular.

Anthropogenic food sources in peri–urban areas are varied and can be abundant. In addition to direct feeding, unintentional (indirect) feeding is also important, either through food left out for domestic pets or discarded rubbish, and also via irrigated lawns, gardens, and other landscaped areas such as golf courses or ceme-

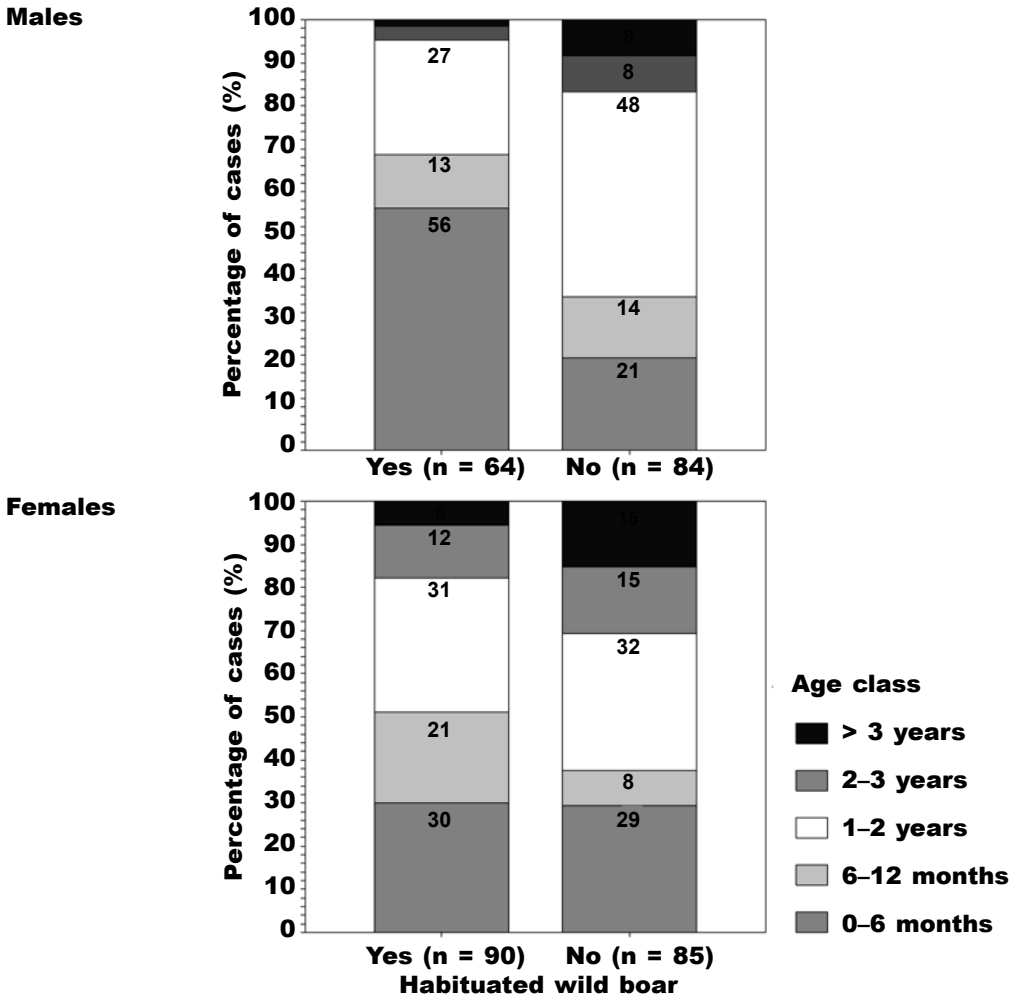

Fig. 6. Proportions of age classes represented among habituated and non–habituated male and female wild boars in the Collserola Natural Park. Data from 2004 to 2008.

Fig. 6. Proporción de clases de edad representadas entre jabalíes habituados y no habituados de ambos sexos en el Parque Natural de la Sierra de Collserola. Datos del período 2004 a 2008.

teries. Such feeding opportunities encourage daytime activity and subsequently a loss of fear of people. As a consequence, wild boar behaviour surpasses mere *habituation,* which is defined more by indifference (Wieczorek–Hudenko & Decker, 2008). Indeed, boars are positively attracted to peri–urban areas, and in Collserola for example they frequently root up areas of grass in city parks and turn over large domestic rubbish bins to obtain food. The greater mean weight of habituated female wild boar compared to non–habituated individuals here evidences the importance of such resources for this species.

Lactating sows have high energy requirements, and protein can also be a limiting nutrient for milk production (Barrett, 1978). In his study on the feral hog at the Dye Creek Ranch in California, Barrett (1978) found that most lactating feral sows showed poor body condition during summer, and that piglet mortality was greatest during this period. Also, starvation was aggravated during poor mast periods and it increased the vulnerability of mortality due to causes such as accidents or predation (*op. cit.*). As such, it is important to emphasize that Mediterranean–type drought conditions can limit the reproductive performance of sows (Fernández–Llario & Carranza, 2000), and consequently the attraction towards readily accessible anthropogenic food sources is strong. For example, in the Mediterranean climate of California, Barrett (1982) found that during the critical hot dry summers, feral hogs that foraged in irrigated pastures of the Sacramento Valley showed greater reproductive success, higher growth rates, and lower juvenile mortality than hogs which remained in the nearby mountain foothills characterised by oak–dominated (*Quercus* spp.) habitats. Similarly, any alleviation of

the drought–induced depression of reproductive performance through artificial feeding will also inevitably result in greater densities of wild boar in peri–urban Mediterranean areas.

To date, few studies have investigated the presence of wild boar in or close to urban areas, and most of these have dealt with aspects relating to the incidence of zoonoses (Jansen et al., 2007; Nidaira et al., 2007; Schielke et al., 2009). Wild boar in urban areas are more than just a nuisance and may pose risks of disease transmission to humans (Meng et al., 2009). For example, some urban areas now known to have problems with wild boar are also located adjacent to large standing water bodies, as is the case in Berlin, Singapore, or Florida, where contamination of water may increase the risk of infection by *Escherichia coli* (Jay et al., 2007) or *Leptospira* sp. Stauffer (2010) reported that 22.9% of 192 people who had participated in an adventure race in Florida that involved swimming in open waters presented symptoms of Leptospirosis, with three of them requiring hospitalisation. Florida has a very large feral boar population, estimated at > 500,000 animals (Giuliano, 2011). Their distribution overlaps vast extensive residential urban developments in the midst of wetlands. Proximity of wild boar to domestic pets could also increase the risk of *Toxoplasmosis gondii* in relation to cats (Richomme et al., 2010), or *Echinococcus granulosus/multilocularis* (Boucher et al., 2005; Martín–Hernando et al., 2008) in relation to dogs. It is therefore important that the authorities are aware of such potential risks, though not necessarily alarmed, given that some of these risks already exist in peri–urban areas due to other wildlife such as rodents.

Although few data are available in the scientific literature on the extent of wild boar presence in urban areas, there are frequent reports in media sources regarding this problem in various cities. We undertook a non–exhaustive search using the following keywords with Google: 'wild boar', 'wild/feral pig', '*Sus scrofa*', 'jabalí', 'sanglier', 'wildschwein', 'cinghiale', in combination with 'city', 'town', 'street', 'urban', 'neighbourhood', 'residential', 'ciudad', 'ville', 'stadt' and 'città'. We found that, up until 2010, at least 44 cities or towns in 15 countries (Belgium, China, France, Germany, India, Israel, Italy, Japan, Korea, Poland, Singapore, Spain, United Kingdom, United States and Romania) had reports of incidents concerning wild boar/pigs. These figures are probably conservative given the limitations of this search (*e.g.,* no searches were done in languages such as Russian, Chinese, or Japanese). Of these cities, 36.4% had experienced just one or two incidents, while the majority (63.6%) had already reported several or many cases. Many cities reporting problems concerning habituated wild boar, such as Genoa (Italy), Haifa (Israel), or San José, California (U.S.), are also located in regions with a Mediterranean or a subtropical climate, and appear to be characterised by similar patterns of dry summers combined with anthropogenic food–rich peri–urban landscapes. Nevertheless, cases of wild boar habituation are also found in cooler, temperate regions (*e.g.,* Germany, Poland, UK, Japan) where snow cover or frozen soil can impede rooting activity in winter in a similar way to drought conditions in summer in Mediterranean areas.

Food scarcity could indeed be a powerful driving force behind wild boar habituation, but other factors may be important. Despite important biogeographic differences between cities that have problems with habituation, most are commonly characterised by narrow gradients at the urban–rural interface, often typified by direct contact between urban and forested or densely vegetated areas, as for example in Kobe (Japan) or Berlin (Germany), where frequent problems occur with wild boar (Kobe City, 2012; Kotulski & König, 2008). Habituation in Collserola has coincided with a period of rapid growth in the wild boar population, which possibly saturated available natural habitat and thereby led to immigration into surrounding peri–urban areas. However, this same period was also characterised by important urban expansion in the area (fig. 1). Under this situation, wild boar populations and sprawling urbanisation were on a collision course which materialised as initial cases of habituation during the early 2000s, and later intensified as chronic conflicts requiring specific management strategies (Cahill et al., 2012).

Landscape characteristics were shown to have a significant influence on the location of incidents relating to habituated wild boar in Collserola (Llimona et al., 2007). Contrast–weighted edge density values for sharp contrast gradients between urban and densely vegetated habitat, such as woodland, were significantly higher at known incident locations than in random locations. However, no differences were found in the case of soft gradient edge values corresponding to urban areas in contact with more openly vegetated habitat (*op. cit.*). Similarly, other parts of Spain that have experienced rapid urban expansion, such as Las Rozas (Madrid), have also recorded cases of habituation by groups of wild boar, especially during or after drought periods (López et al., 2010).

Nevertheless, it is clearly the availability of anthropogenic food sources that attracts wild boar to peri–urban areas. Benign attitudes of urban residents towards wild boar have facilitated their habituation, either directly encouraging their presence by intentional feeding, or simply through indifference (habituation of people to boars). However, for some people the presence of wild boar is a nuisance because of the damage they ultimately cause to gardens, golf courses and , parks, as well as their rooting in rubbish bins and the spreading of garbage. Wild boar can be a danger to traffic on city streets, and they occasionally cause significant disruption on major roads around Collserola. Some residents are fearful of possible attacks on children or pets, and although few attacks are reported in relation to habituated wild boar in urban areas, non–habituated wild boar can be dangerous to people and are known to cause injuries and even fatalities in rural areas of northern and central India (Chauhan et al., 2009). As such, not all residents look favourably on the presence of wild boar in urban areas. In Berlin, wild boar have been frequenting peri–urban areas for the past two decades (Georgii et al., 1991) and as their numbers have increased sharply they are now considered as a serious nuisance. Kotulski & König (2008) carried out a survey on attitudes of Berliners towards wild boar

and found that 23% of residents objected to their presence, 37% were in favour and 36% had ambivalent opinions. Despite the fact that 44% of people believed the numbers of wild boar should be reduced, 67% of these were against lethal removal methods.

Massei et al. (2011) gave an extensive review of the diverse options currently available to control populations of wild boar/pigs. However, the ambivalent opinions of residents complicate the implementation of efficient management strategies for dealing with this species in urban areas. In cities where problems have arisen with habituated wild boar, implemented management options range from hunting with firearms to removal using live capture (darting and cage–traps), to public awareness campaigns, to doing nothing. In Collserola for example, live capture using tranquiliser darts is currently the usual method of removing habituated wild boar from urban areas. Recently, however, trial attempts were made by the authorities responsible for hunting to kill habituated wild boar in peri–urban areas using expert bow hunters equipped with modern bows and arrows. However, within less than a week of announcing this control method, it had to be withdrawn due to opposition pressure from the public, highlighting the difficulties in implementing apparently technically valid control options. Although archery is considered the preferred hunting method for controlling deer in urban areas of some U.S. states, such as Connecticut (Kilpatrick et al., 2002; Kilpatrick & LaBonte, 2007), its use in hunting in Europe is more restricted, and perhaps less culturally accepted by urban dwellers. In a study of residents' acceptance of solutions to wildlife conflicts, invasive and lethal solutions were in fact more highly accepted than had been expected by wildlife managers (Loker et al., 1999). Nevertheless, suburban residents were also more likely to accept non–lethal management actions (*op. cit.*).

In early cases in Collserola, attempts were made to relocate habituated wild boar several kilometres away from the urban areas where they had been causing problems. However, radiotracking of these individuals showed that they quickly returned to the exact same places where they had been captured. Indeed, previous research on translocating feral hogs in California has shown that groups need to be moved to suitable habitat at least 15–20 km away in order to avoid their returning (Barrett, 1978; Lewis, 1966). Subsequently, some problem animals from Collserola were sent to enclosed private estates, but now most habituated wild boar captured using tranquilizer darts are subsequently euthanized, although again, public opinion is often against this. Drive hunting (with dogs) of wild boar is carried out in forested areas of Collserola, and although it may be tempting to conclude that increased hunting reduces habituation incidence (fig. 4), in peri–urban areas such control methods may be impracticable, or they may meet with opposition from the public and land–owners (Storm et al., 2007). Given this situation, live–capture methods, either using tranquiliser darts or trap–cages, will continue to play an important role in removing specific problem individuals or sounders. It is important to stress in public relations that these methods are quick and humane in removing animals.

Given the limitations of efforts to reduce human–wild boar conflicts solely through lethal methods aimed at population suppression (Honda & Kawauchi, 2011), specific alternative measures are also required to prevent and mitigate habituation in order to alleviate the growing incidence of conflicts in urban areas. In Collserola, emphasis is placed on prevention through public awareness campaigns. Specifically, public education is required on the eco–ethological consequences of feeding wild boar, as well as on the ultimate destiny of most habituated individuals (capture and euthanasia). Nevertheless, other preventive measures are also required: the possibility of fines has been introduced by city councils to dissuade direct feeding, and the landscaping of peri–urban green space needs to be adapted to make it less attractive to wild boar, for example by reducing the irrigation of grassy areas. Domestic rubbish bins should be designed so that they are inaccessible to wild boar, as should feeding points destined for domestic pets. Improved fencing is also necessary in many private gardens as well as suburban parks to impede wild boar access. Also, the maintenance of more open vegetation (*e.g.,* native dry grasslands) adjacent to peri–urban areas may also help to reduce wild boar presence. Once again, public education is also required in order to gain maximum acceptance of such mitigation measures.

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