Between conflict and reciprocal habituation: Human-wild boar coexistence in urban areas

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HIGHLIGHTS

- Wild boar (*Sus scrofa* WB) synurbization creates interactions and conflict with humans.
- Human response to WB synurbization is determinant for conflict perception.
- Five clusters in attitude towards WB were identified among 1956 Barcelona citizens.
- Lay-knowledge, emotions and experience determined perception and attitudes towards WB.
- Perception and attitudes towards WB ranged from sensitization to mutual habituations.

GRAPHICAL ABSTRACT
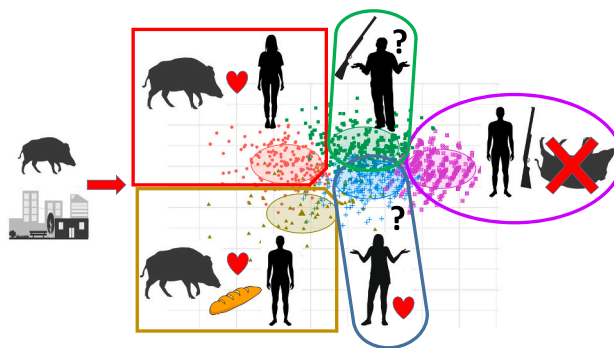
ARTICLE INFO

ABSTRACT

Urbanization is an ongoing global environmental change. Wildlife may respond using anthropized environments and resources, which is known as synurbization, creating human-wildlife interactions. Wild boar (*Sus scrofa*) populations have become common in urban areas, including the metropolitan area of Barcelona. Humans respond to wild boars in urban environments either habituating, with lower conflict perception and higher wild boar acceptance, or sensitizing, with reduced tolerance towards wild boars. Since citizen response influences conflict management, this study analysed the drivers of human responses, which should allow adopting socially-accepted measures to manage synurbic wild boar populations. Interviews to 1956 Barcelona citizens were performed, grouping the response variables to score citizen and urban characteristics, as well as citizen lay-knowledge, emotions, experiences, and perception of wild boar. Five citizen clusters were identified: cluster 1 (3.3 %), highly habituated and active wild boar feeder; cluster 2 (11.3 %), habituated to wild boars with positive feelings; cluster 3 (19.8 %), not habituated nor sensitized, willing to maintain urban wild boar populations;

cluster 4 (29.1 %), sensitized and concerned, defending to reduce wild boar; and cluster 5 (40.1 %), highly sensitized and proposing to reduce or even eliminate wild boar. Positive attitudes associated wild boar to aesthetic value, closeness to nature and sympathy, and were more frequent in young citizens with urban background and high education, animal lovers habituated to wild boar through contact without negative experiences. Conversely, negative attitudes were concerned about city fouling, safety or health, accepted lethal management measures, and were more frequent in older citizens with rural background, lower education, low contact with wild boar or sensitized through negative experiences. We document for the first time the sensitization and reciprocal habituation of humans to wild boar in urban areas. The identification of the drivers of citizen attitudes towards urban wildlife should be useful to design socially-accepted management measures.

1. Introduction

Urbanization is among the main ongoing global environmental changes, and it is predicted to continue and increase in the future (United Nations, 2018). Synantropic mammal species take profit from anthropized environments and resources, and the resulting human-wildlife interaction is responsible for economic and material costs associated with mitigation and prevention of conflicts, such as damage to landscape and gardens, fouling of public spaces and noise, raiding of garbage bins, traffic accidents, attacks to pets and/or people, and increased zoonotic risk (Castillo-Contreras et al., 2022a; Castillo-Contreras et al., 2022b; Darwich et al., 2021; Fernández-Aguilar et al., 2018; Luniak, 2004; Nyhus, 2016; Shen et al., 2023; Wang et al., 2019). Wild boar (*Sus scrofa*) abundance has increased and its distribution range has expanded in the last decades as a consequence of lack of predators, and human depopulation of rural areas with the consequent forest encroachment, among other factors (Massei et al., 2015; Shen et al., 2023). Such spread has been accompanied by an increase of wild boar presence in the suburban environment of European cities such as Barcelona, Berlin, Budapest, Genova and Warsaw, where wild boar has become an urban exploiter, developing specific phenotypic features (Cahill et al., 2012; Castillo-Contreras et al., 2018; Castillo-Contreras et al., 2021; Hagemann et al., 2022; Licoppe et al., 2013; Stillfried et al., 2017a; Stillfried et al., 2017b; Piana et al., 2024). The metropolitan area of Barcelona in Spain is a densely populated area, with 16,339 human inhabitants/km^2 (Idescat, 2024), and includes the Collserola Natural Park (CNP), a natural area hosting an increasing wild boar population (González-Crespo et al., 2018). Wild boar behavioural plasticity, food availability and environmental and urban planning have favoured wild boar presence in the urban area of Barcelona. Consequently, contact between humans and synurbic wild boars is frequent in the suburban areas of Barcelona (Cahill et al., 2012; Castillo-Contreras et al., 2018; Castillo-Contreras et al., 2021; Conejero et al., 2019; González-Crespo et al., 2018; González-Crespo et al., 2023).

Values, emotions, and cognition or lay-knowledge contribute to construct human perception of wildlife, as well as the associated moral values and the consequent support or opposition to lethal management measures (Batavia et al., 2021; Hovardas and Stamou, 2006; Jacobs, 2012; Jacobs et al., 2012; Jacobs et al., 2014; Jacobs and Vaske, 2019; Lute and Gore, 2019; Murata et al., 2019; Skogen, 2003). Beyond this basis, human-wildlife interactions further contribute to define human-wildlife coexistence and human perception of wildlife-related conflict (Conejero et al., 2019; Nyhus, 2016; Piana et al., 2024; Shen et al., 2023). Non-traumatic contact with wild boar minimizes the perception of human-wild boar conflict (HWBC), increasing the habituation of citizens to this species, resulting in increased tolerance to wild boar presence (Conejero et al., 2019; Dickman, 2010). On the other hand, wild boar-related negative incidents (i.e., traffic accidents, attack on pets and people) drive to sensitization and decreased tolerance to wild boar (Conejero et al., 2019; Shen et al., 2023). When the perceived costs involving wild boars overcome the eventual perceived benefits, negative perceptions determine human attitudes: the more incidents suffered or experienced, the more negatively wild boar presence is perceived (Conejero et al., 2019; Kansky and Knight, 2014). In Barcelona, HWBC is

more likely in the districts bordering CNP, where wild boar presence is more habitual and, consequently, human-wild boar contact and interactions are more likely, direct and frequent (Arregui, 2023; Broz et al., 2021; Castillo-Contreras et al., 2018; González-Crespo et al., 2018; González-Crespo et al., 2023).

While conflicts related to urban wildlife in densely human-populated areas require specific management measures, such as control of anthropogenic food resources and live-capture and euthanasia (Barasona et al., 2013; Castillo-Contreras et al., 2018; Castillo-Contreras et al., 2021; Conejero et al., 2022; González-Crespo et al., 2018; Massei et al., 2011; Torres-Blas et al., 2020), people attitudes may determine public acceptance and must therefore be considered by managers and policy-makers when establishing management plans (Arregui, 2023; Broz et al., 2021; Liordos et al., 2017; Whittaker et al., 2006). The negative perception of control measures by residents and citizens adds technical and social difficulties to the success and efficiency of conflict management (Conejero et al., 2022; Jacobson et al., 2014; Liordos et al., 2017). In particular, the attribution of human emotions or cognizance to individual animals may result in public refusal of targeted strategies such as live-capture and euthanasia (Benvenuti, 2016; Scheele et al., 2015), which challenges the traditional approaches to wildlife management in urban environments (Manfredo et al., 2020; Nettles et al., 2021). Management actions including sensitization and conservation policies focusing solely on education of lay-knowledge are likely to fail in gaining public acceptance (Emre Can and Macdonald, 2018). Instead, information about underlying cultural, social, and emotional drivers may better forecast potential controversies and foster the acceptance of specific management measures (Nyhus, 2016).

Since public perception of synurbic wild boar determines the feasibility and success probability of management measures, managers must know such perceptions and their drivers, in order to be able to plan and implement tailored publicly accepted management measures also addressing these perception drivers. Therefore, the objective of this study is to investigate the citizen perceptions of synurbic wild boar, HWBC, and the acceptance of the associated management measures, as well as the emotions, beliefs, lay-knowledge, and experiences driving such perceptions and acceptance, in Barcelona, Spain.

The hypothesis is that emotions, beliefs, lay-knowledge, social background, and previous experiences regarding synurbic wild boar in the city of Barcelona will determine wild boar perception, ranging from acceptance and even active wild boar feeding, on the one hand, to aversion and reluctance, on the other hand. In turn, such perception will correlate with rejection and support of lethal management measures for urban wild boar, respectively.

2. Materials and methods

2.1. Study area

This study was carried out in the municipality of Barcelona (Catalonia, northeastern Spain), which has an extension of 10,135.3 ha and a human population of 1,620,3430 inhabitants in 2018, when the field study was carried out, and 1,655956 in 2023 (Idescat, 2024). Five of the ten districts of Barcelona, namely Nou Barris (NB), Horta-Guinardó

(HG), Gràcia (G), Sarrià-Sant Gervasi (SSG) and Les Corts (LC), border the CNP (Fig. 1). Those districts, referred to from now on as Peripheral Districts (PD), are frequented by wild boars, which coexist with citizens. Conversely, the five remaining districts of Barcelona, namely Sant Andreu (SA), Sant Martí (StM), Ciutat Vella (CV), Eixample (E) and Sants-Montjuïc (SM), referred to as Core Districts (CD) from now on, do not limit with CNP and are consequently less visited by wild boars (Castillo-Contreras et al., 2018; González-Crespo et al., 2023). The CNP is an 8295-ha protected area (Fig. 1) hosting an increasing wild boar population founded from the surrounding rural wild boar populations through mostly unidirectional migration (González-Crespo et al., 2018; Hagemann et al., 2022).

2.2. Questionnaire design and scores

A standardized survey was designed to obtain data on citizen features, behavioural reactions towards wild boar, experience on coexistence with wild boar, assumed wild boar-related emotions, and previous lay-knowledge, as well as perception and attitude towards wild boar, HWBC, and public management actions (Tables S1 and S2). Informed consent for the anonymous use of the information gathered was obtained before starting each survey, and agreement was granted trough participation in the survey. The questionnaire was divided in two main sections. The first part regarded the surveyed citizen, and was further subdivided in citizen range (i.e., living and working districts within Barcelona), citizen characteristics (gender, occupation, childhood background, formation, age), and citizen behaviour (eating habitats, animal likeness, previous threat by wild boar). The second section of the questionnaire regarded citizen relationship with wild boar, including perception of HWBC and lethal management measures; attitudes and perceptions towards wild boar; citizen lay-knowledge about wild boars; and experiences originated from citizen coexistence with wild boars (Tables S1 and S2). From the information obtained in the last subsection of the questionnaire (experiences originated from citizen coexistence with wild boar), two citizen scores were calculated: a Perception of Incidence Score [PIS] (i.e.: wild boar-related incidents suffered; see Table S2 for more detail) and a citizen habituation to wild boar presence score (ratio between wild boar sighting frequency and PIS). Therefore, citizens were characterized with 42 variables: 30 responses to questions, two citizen scores, and ten characteristics of the district where the questionnaire took place (Tables S1, S2, and S3; Idescat, 2024).

2.3. Data collection

From May 4th to July 23rd, 2018, eight trained pollsters interviewed 1956 passers-by across the ten districts of Barcelona (Tables S1 and S2). The number of wild boar presences in the urban area of Barcelona reported to the local police (Castillo-Contreras et al., 2018), the wild boar reactive capture interventions required (Torres-Blas et al., 2020), and the number of wild boars captured in the urban area from January 1st until December 31st 2018 were used as proxies for the actual wild boar presence (Castillo-Contreras et al., 2018; González-Crespo et al., 2023). The local socio-economic and landscape-related variables (unemployment rate, At Risk of Poverty or Exclusion -AROPE- rate, number of residents, human density, and land uses) for 2018 were obtained from public repositories (Table S3; Ajuntament de Barcelona, 2020; Idescat, 2024).

2.4. Statistical analysis

A Principal Component Analysis (PCA) was performed to create and sort the main factors determining citizen attitudes towards wild boar (Macci et al., 2012), using a correlation matrix ($n = 1956$) to describe the relationship between: 1) citizen characteristics and experiences towards wild boar; 2) district characteristics, citizen habituation score, and PIS; and 3) citizen emotions, lay-knowledge and acceptance of management measures to mitigate HWBC. The values missing on the dataset were replaced by the median of the corresponding variable for quantitative variables. Citizen emotions (sympathy, closeness to nature, and aesthetic enjoyment of wild boar), lay-knowledge (wild boar-related risk perception and agreement on wild boar fouling the city), and habituation towards wild boar were selected as the six active variables used to characterize citizen attitudes. A Hierarchical Clustering on Principal Components (HCPC) was performed on the PCA output to identify citizen clusters regarding attitudes towards wild boar. Because the dataset was based on multidimensional scales, dissimilarity was calculated using Euclidean distances, computing the distances among individuals and balancing the influence of each data measurements applying Ward's agglomeration criterion on HCPC (Husson et al., 2010).

All the data processing and statistical analyses were performed in R software (R Core Team, 2017). The dataset was processed and exploratory analyses were performed using the packages "readxl" (Wickham and Bryan, 2019) and "dplyr" (Wickham et al., 2021). The packages ggplot2 (Wickham et al., 2016) and "GGally" (Schloerke et al., 2018) were used in the correlation analyses. The Catdes function of the
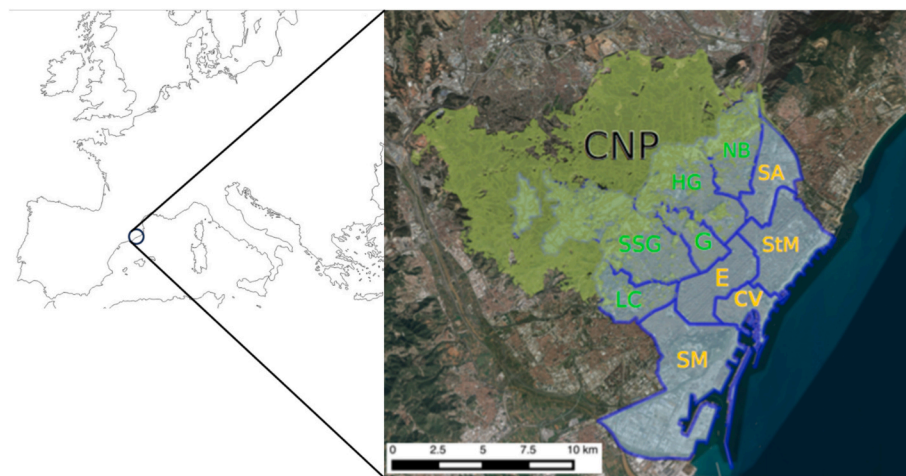

Fig. 1. Study area. Collserola Natural Park (CNP) surface including surrounding urban green areas is shown in pear colour; area and edges of the ten districts of Barcelona appear in blue; References to Peripheral Districts (PD), namely Nou Barris (NB), Horta-Guinardó (HG), Gràcia (G), Sarrià-Sant Gervasi (SSG) and Les Corts (LC) are typed in bright green; References to Core District (CD), namely Sant Andreu (SA), Sant Martí (StM), Ciutat Vella (CV), Eixample (E) and Sants-Montjuïc (SM) are typed in yellow.

FactoMineR package (Lê et al., 2008) was used to detect differences (at a 90 % confidence level) on categorical variables between the two district categories (Core and Peripheral). The PCA was performed through the PCA function of the same FactoMinerR package. The "fviz" function from the "factoextra" package (Kassambara and Mundt, 2020) was used to visualize the output correlation between the explanatory variables of the PCA, as well as their position and contribution with respect to Principal Components 1 and 2. The HCPC function from the FactoMineR package was used for the clustering analysis, including v.test to detect statistically significant differences between the mean values of each cluster and the overall mean (Aluja et al., 2018; Lê et al., 2008; Husson et al., 2010). V-measure is an entropy-based measure, computed as the harmonic mean of cluster scores, which explicitly measures how successfully the criteria of homogeneity and completeness have been satisfied (Rosenberg and Hischberg, 2007).

3. Results

3.1. Citizen features, experiences towards wild boar and acceptance of management measures

Most respondents lived in urban environments during their childhood (72.9 %), held high school graduates (39.8 %) and expressed affinity towards animals (77.4 %). Most had never (48.1 %) or only once (25.0 %) seen a wild boar, while 5.6 % claimed seeing wild boar daily or weekly. Forty-two out of 1956 citizens (2.2 %) had fed wild boar at least once, and four (0.2 %) did it frequently.

Seven citizens (0.4 %), all from PD, hunted wild boar. While most respondents considered that wild boar cause problems because their population is not adequately managed (45.5 %) or that wild boar represent a threat in urban areas (35.6 %), only 75 (3.8 %) perceived wild boar as a threat for themselves. PIS was 0 for most respondents (95.2 %), meaning lack of incidences with wild boars, ranged between 1 and 2 for 86 citizens (4.4 %), and was above 3 only for three citizens (0.2 %). The most frequent incidents were traffic accidents (1.5 %), intromission in property (1.0 %) and attacks on people (0.7 %) or pets (0.6 %). Voluntary feeding, citizen habituation to wild boar presence, PIS, and actual incidences with wild boar in the district were positively correlated ($p < 0.05$, Fig. 2). Frequent wild boar feeders perceived wild boar as likable, with pleasant aesthetic value and low threat perception (Fig. S1).
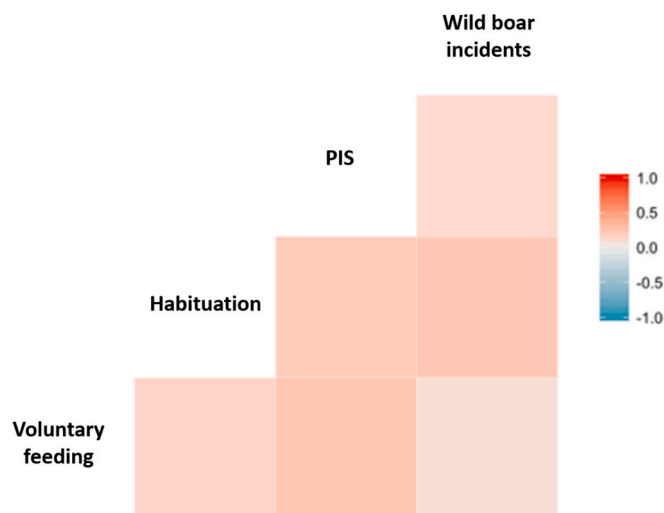

Fig. 2. Correlation plot of variables including voluntary feeding, citizen habituation to wild boar presence, total perception of wild boar-related incidents suffered by the passer-by (PIS) and number of citizen calls to the Local Police of Barcelona as a proxy to wild-boar related incidents. The colour scale represents the correlation coefficient among variables.

Lethal methods were disapproved as management for urban wild boar populations by nearly 44 % of the respondents, while approximately one third (37.7 %) supported maintaining wild boar populations as they are, a quarter (25.2 %) would accept ethical sacrifice but not hunting, and the remaining 11.1 % defended moving them all away from the city. The complete results of the surveys are presented in Table S2.

3.2. Differences among districts

The comparison of quantitative and categorical variables between PD and CD are shown in Fig. S1 and Tables S4 and S5. All the indicators of actual wild boar presence, human-wild boar contact and incidences, citizen habituation, and PIS were significantly higher in the PD, while problem perception was higher in the CD (Tables S3 and S4). According to the v.test results, while in PD maintaining the urban wild boar population was more defended than in CD ($p < 0.05$), the CD respondents were significantly more prone to remove wild boar than in PD ($p < 0.001$) (Table S5).

Tables S6 and S7 show the values for the quantitative and categorical variables of the PD, respectively. Both the indicators of actual wild boar presence and the social economic indicators were heterogeneous among the PD. While G and LC had lower values of wild boar presence and habituation scores similar to CD, HG, NB and SSG concentrated wild boar incidences and had the highest score in citizen habituation, with higher associated management measures and costs in HG and SSG. Wild boar feeding was highest in SSG, where higher school education level was found together with G. The AROPE rate was higher than the mean in NB and lower in G, LC, and SSG (Table S6). Regarding management, eradicating or reducing urban wild boars was supported above the mean in LC and G, respectively. Conversely, maintaining the wild boar population had more support in HG and SSG, the two districts with more presence of the species (Table S7).

3.3. Principal component analysis (PCA)

The PCA provided six Principal Components (Dim) adjusted through quantitative variables based on human-wild boar coexistence (habituation), citizen emotions (sympathy, closeness to nature and aesthetics) and lay-knowledge (fouling the city and perception of health or risk issues) regarding wild boar. The two first dimensions included 31 variables, explaining altogether the 58.7 % of the variance (Table 1, Fig. 3). The first component (Dim1, eigenvalue = 2.49) explained 41.5 % of the variance, with the highest positive contributions from emotions such as aesthetics, closeness to nature, and sympathy, and negative contributions from two lay-knowledge perceptions, namely considering wild boar detrimental for the city and as a threat for public health and safety. Dim2 (eigenvalue = 1.03) explained 17.2 % of the variance, with the highest positive contributions of the same two lay-knowledge perceptions as Dim 1 (considering wild boar detrimental for the city and as a threat for public health and safety) and the highest negative contributions of habituation and frequency of wild boar sighting (Table 1, Fig. 3).

3.4. Citizen clustering towards wild boar

The HCPC identified five citizen clusters according to their emotions, lay-knowledge, experiences, and habituation towards wild boar presence in urban areas (Tables 2, S8, and S9 and Fig. 4).

Cluster 1 included the smallest proportion of respondents (3.3 %), significantly more frequent in neighbourhoods with lower human density from the PD. These citizens had high contact and were habituated to wild boar presence, approved maintaining urban wild boar populations, had the highest rate of urban wild boar voluntary feeding, and experienced the highest rate of wild boar incursions into their properties.

Cluster 2 included 11.3 % of the citizens surveyed, mostly from the PD and the most habituated to wild boar presence, who had mean contact with wild boar, declared as animal lovers and preferred

Table 1
Quantitative and qualitative variables describing the Dimensions 1 (Dim1) and 2 (Dim2). Correlation coefficients are given for the quantitative variables and r-square (r^2) for the qualitative variables. The quantitative variables with the highest positive and negative contributions to Dim1 and Dim 2 are indicated in bold.

Quantitative variables (correlation coefficients)	Dim1	Dim2	Qualitative variables (r^2)	Dim1	Dim2
Aesthetics	**0.76****	0.21**	Ideal solution for HWBC	0.17**	0.01**
Closeness to nature	**0.73****	0.15**	Borough survey	0.14**	0.21**
Sympathy	**0.70****	0.18**	Working district	0.05**	0.05**
Problem level	0.37**	0.30**	Working area	0.03**	0.02**
Borough unemployment	0.12**	0.16**	District survey	0.02**	0.05**
Borough population	0.10**	0.13**	Student	0.01**	0.00*
Age	0.09**	0.11**	District of residence	0.02**	0.07**
District urban parks area	0.07**	0.11**	Sex	–	0.01**
Borough density	0.07**	0.15**	Type of district (PD or CD)	–	0.02**
District density	0.06**	0.11**			
Home garden	−0.05*	−0.14**			
Sighting of wild boar eating in city	−0.05*	−0.34**			
District forestry area	−0.07**	−0.19**			
Wild boar-related incidences	−0.08**	−0.16**			
Captured wild boar	−0.10**	−0.15**			
Wild boar reactive capture interventions	−0.10**	−0.15**			
Voluntary feeding of wild boar	−0.11**	−0.09**			
Wild boar sighting frequency	−0.14**	**−0.52****			
Animal affinity	−0.21**	−0.07**			
Habituation	−0.33**	**−0.65****			
Risk for health/ security	**−0.62****	0.48**			
Fouling the city	**−0.63****	**0.52****			

HWBC = human-wild boar conflict; PD=Peripheral district; CD=Core district.
* $p < 0.05$.
** $p < 0.01$.

Fig. 3. Correlation circle on principal components (Dim) with the active variables used for the Principal Component Analysis (PCA). The colour scale according Cos^2 indicates the quality of representation of the variable on the Dim. The *x* axis is Dim1 and the *y* axis is Dim2. Citizen emotions, lay-knowledge and habituation score towards wild boar are forming a proportionally correlated triangle star on three axes.

maintaining the urban wild boar population in Barcelona. They rejected lethal control, even if required for public health or safety concerns. They found wild boar aesthetically likable, sympathetic, not dangerous, and clean.

The citizens in cluster 3 (19.8 % of the respondents) had mean contact with urban wild boars and were not habituated nor sensitized, although they declared as animal lovers and perceived wild boar as a likable animal that made them feel closer to nature. Citizens in cluster 3 had not extreme attitudes against or in favour of lethal control measures.

Cluster 4 included a fourth of the interviewed citizens (25.5 %), containing the higher proportion (29.1 %) of the citizens surveyed in the CD, and 27.8 % of the citizens choosing reducing wild boar population. Cluster 4 was mainly composed by elder citizens, who did not coexist with wild boar and perceived it as a safe and clean animal. As for cluster 3, citizens in cluster 4 had not extreme attitudes against or in favour of lethal control measures.

Finally, cluster 5 included 40.1 % of the respondents and particularly more than half of the NB district residents surveyed (51.6 %). Despite
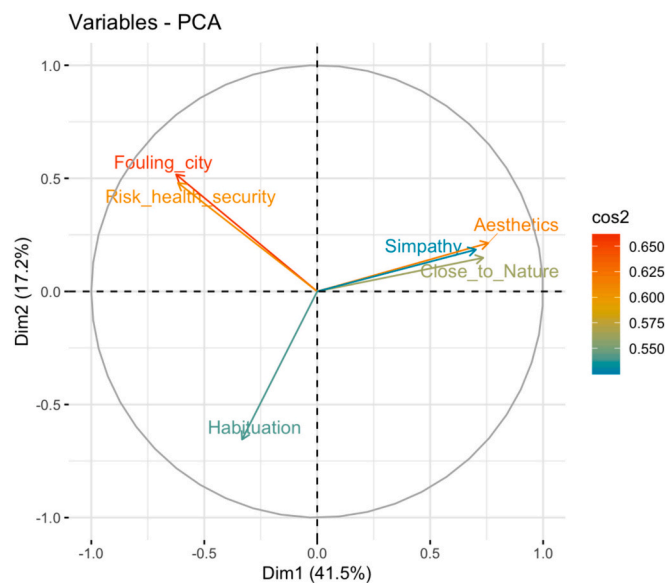
only having mean contact with wild boar lower than clusters 1 and 2, the citizens in cluster 5 were the most sensitized to HWBC, defended lethal methods to manage urban wild boar populations, and perceived wild boar as an unpleasant animal. These citizens also believed that wild boar poses a risk for human health and safety. A previous experience of vehicle collision with wild boar was also significantly more frequent in cluster 5.

The v.test found significant relationships between the citizen clustering and wild boar voluntary feeding, citizen habituation to wild boar presence, and number of wild boar veterinary interventions. Thus, voluntary feeding was negatively associated with cluster 5 ($p < 0.001$) and positively associated with clusters 1 ($p < 0.001$) and 2 ($p < 0.05$). Although a higher degree of human-wild boar coexistence was only found in cluster 1 citizens ($p < 0.001$), citizen habituation to this coexistence was positively associated with both clusters 1 ($p < 0.001$) and 2 ($p < 0.05$), and negatively associated with clusters 3 ($p < 0.05$), 4 ($p < 0.001$) and 5 ($p < 0.001$). Regarding district differences on the public cost of wild boar management measures, a higher number of removed wild boar in veterinary interventions in the district was associated with cluster 1 ($p < 0.001$) and 2 ($p < 0.001$) surveyed districts, while a lower number of removed wild boar was associated with cluster 4 ($p < 0.001$) surveyed districts.

Fig. 5 shows the paths leading to the construction of perception of wild boar, HWBC, and acceptance or rejection of lethal management measures in the clusters identified in the present study. Thus, the citizens in the CD with low contact with wild boar (clusters 3 and 4) based their attitudes solely on lay-knowledge and emotions, whereas in the PD, the contact and interaction with wild boar added experiences to the formation of specific attitudes (clusters 1, 2, and 5; Tables 2, S8, and S9; Figs. 4 and 5).

Table 3 shows the main features, emotions, beliefs, and experiences related with HWBC perception and acceptance of lethal management measures, which are correlated (Fig. 3). Positive attitudes were more frequent in young citizens from the PD with urban background and high education, habituated to wild boar through contact without negative experiences and high affinity for animals. Conversely, older citizens with a rural background, lower education, higher acceptance of hunting,

Table 2
Main features of the citizen clusters.

Cluster	1	2	3	4	5
Citizens (%)	3.3	11.3	19.8	29.1	40.1
Main districts	Into PD, not in CD	Into PD, not in CD	–	Not in PD	–
Citizen characteristics	Male citizens, animal-lover, high formation, unemployed	Young, animal-lover, high formation, students and unemployed	Students, animal lover	Urban childhood, aged citizens, low formation, employed	Rural childhood, no students, animal hater, employed
Coexistence with WB	High	Mean	Mean	No	Mean
Habituation to WB	Highly habituated	Habituated	Not sensitized nor habituated	Sensitized	Highly sensitized
Experience with WB	Voluntary feeder, high PIS (no traffic incident)	Voluntary feeder	No incidences	No incidences	No voluntary feeding, low PIS (only traffic incident)
HWBC perception	Very low	Low	–	–	High
Emotions towards WB	Expression of positive emotions on sympathy, closeness to nature and aesthetics	Highest expression of positive emotions on sympathy, closeness to nature and aesthetics	High expression of positive emotions on sympathy, closeness to nature and aesthetics	–	High expression of negative emotions on sympathy, closeness to nature and aesthetics
Beliefs towards WB	Low concern on risk for health/security and fouling the city	No concern on risk for health/security and fouling the city	High concern on risk for health/security and fouling the city	No concern on risk for health/security and fouling the city	Highest concern on risk for health/security and fouling the city
Preferred solution	WB population maintenance	WB population maintenance	WB population maintenance	WB population reduction	WB population reduction and elimination
Acceptance of lethal management measures	No	No	–	–	Yes
Cost of management measures	Very high	High	–	Low	–
Landscape measures	High percentage of forestry areas	High percentage of residential, forestry areas	–	Low percentage of residential and forestry areas and high percentage of urban parks	–

CD: Core Districts; HBWC: human-wild boar conflict; PD: Peripheral Districts; PIS: Perception of Incidence Score; WB: wild boar.
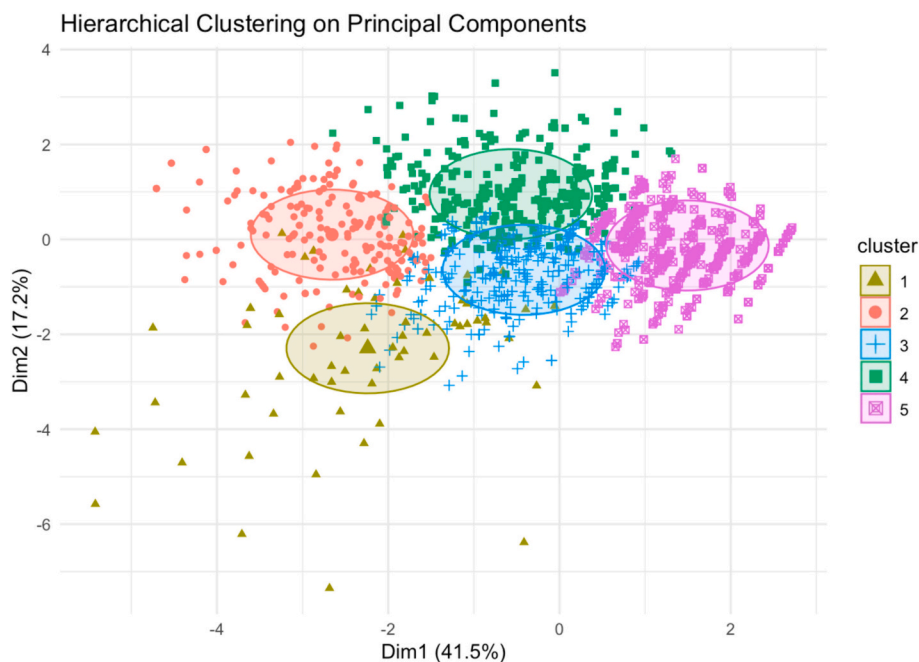

Fig. 4. Hierarchical Clustering on Principal Components (HCPC) on PCA results.

either with low contact with wild boar leading to concern about city fouling and/or health/security risk or sensitized to wild boar through contact with negative experiences (mainly traffic accidents), had the most negative perception of wild boar, higher HWBC perception and the highest acceptance of lethal measures.

4. Discussion

This study identifies the main clusters in citizen perception and attitudes towards synurbic wild boars, the associated HWBC, and the potential management measures, as well as their main social drivers. Human attitudes towards wild boar and the derived human-wildlife conflicts were determined by past experiences, emotions, and lay-knowledge, and linked to cultural perceptions and socio-economic
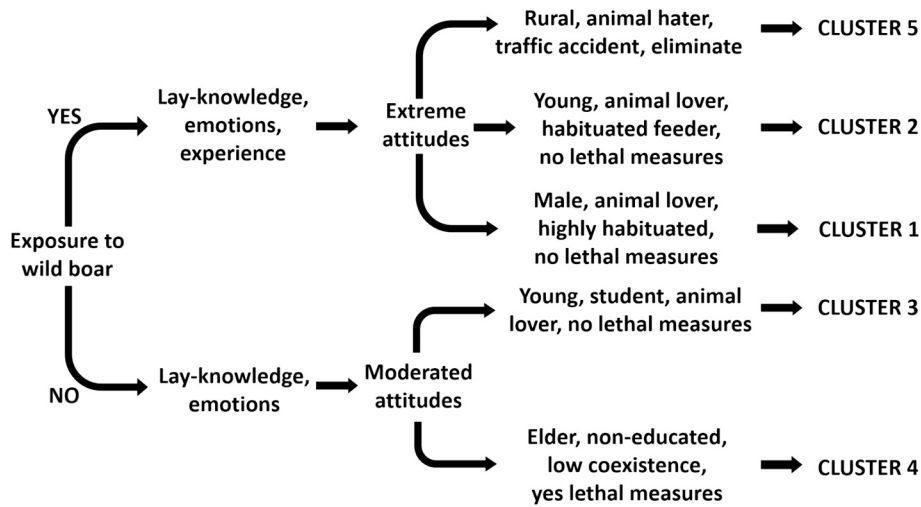
Fig. 5. Lay-knowledge, emotion, and experience paths and socio-economic features leading to the construction of perception of wild boar, human-wild boar conflict, and acceptance or rejection of lethal management measures in the clusters identified in the present study. The belonging of citizens to a cluster is the result of the drivers leading to each cluster.

Table 3
Summary of the main features, lay-knowledge, and experience determining perception of human-wild boar conflict (HWBC) and acceptance of lethal measures by the Barcelona citizens.

	Low HWBC perception, rejection of lethal management	High HWBC perception, support of lethal measures
Features		
Age	Young	Old
Education	High	Low
Background	Urban	Rural
Origin	PD	CD / PD
Emotions and beliefs		
Lay-knowledge	Aesthetic, nature, sympathy	City fouling, health / security risk
Animal relationship	Animal lover	Animal hater
Experiences		
Wild boar contact	Habituated	No contact / Sensitized
Interaction	No incidences / Pleasant contact	No incidences / Traffic accident

factors. These factors have already been reported as determinant in the construction of human perception of wildlife and for conservation (Batavia et al., 2021; Broz et al., 2021; Emre Can and Macdonald, 2018; Jacobs and Vaske, 2019; Lute and Gore, 2019; Nettles et al., 2021; Piana et al., 2024).

Although the cultural determinants and socio-economic factors related to each cluster contributed to construct wild boar perception, particularly in absence of coexistence, the gradient of human-wild boar coexistence determined differences in the factors contributing to the construction of the perception of urban wild boar (Broz et al., 2021; Nyhus, 2016; Piana et al., 2024). Thus, fear and increased HWBC perception, resulting in the acceptance of lethal control methods, could be related with the lower coexistence and interactions with wild boar of citizens from CD (clusters 3 and 4), where sensitized profiles predominated (McCleery et al., 2014; Piana et al., 2024). Conversely, interaction experience with wild boar participated in the construction of attitudes of citizens from PD (clusters 1, 2, and 5), where habituated profiles where more common. According to the dual-process theory (Groves and Thompson, 1970), human responses to a repeated stimulus are unstable and shift is expected to occur either in an incremented (sensitization) or decreased (habituation) response to the stimulus (Jacobson et al., 2014;

Nettles et al., 2021; Pascual-Rico et al., 2021; Soulsbury and White, 2015). Thus, coexistence without associated negative experiences led to low HWBC perception and human habituation to wild boar presence and interaction in urban environments (clusters 1 and 2), resulting in disapproval of lethal management measures (Adams, 2016; Conejero et al., 2019; Massei et al., 2011; Piana et al., 2024; Rosell and Llimona, 2012). This supposes a process of reciprocal habituation of synurbic wild boar to urban environment and anthropic resources (Castillo-Contreras et al., 2018; Castillo-Contreras et al., 2021; Pascual-Rico et al., 2021; Hagemann et al., 2022) and habituation of citizen to presence and interaction with wild boar, which is reported here for the first time. To date there is scarce research considering habituation as a bidirectional process, involving changes both in wildlife and in human relational habits (Arregui, 2023).

Conversely, traumatic experiences induced citizen sensitization towards risks on human health and safety, and hence increased HWBC in cluster 5, resulting in negative attitudes towards urban wild boar and a higher acceptance of lethal control measures (Çevik, 2014; Conejero et al., 2019; Pascual-Rico et al., 2021). However, sensitization patterns can be difficult to identify because of the complexity inherent to human attitudes, emotions and personal experiences (Adams, 2016; Bath, 1998; Nyhus, 2016). Thus, the relationship between negative experiences and increased HWBC perception was not direct and straightforward, since the citizens in cluster 5, sensitized towards wild boar, scored lower PIS than citizens in cluster 2, habituated to wild boar. Citizens in cluster 5 pointed at traffic accidents as their main concern regarding wild boar, conversely to citizens in clusters 1 and 2. Therefore, traffic accidents were apparently more traumatic and determinant of higher HWBC concern than other negative experiences (Conejero et al., 2019; Madden and McQuinn, 2014; Nyhus, 2016; Rosell and Llimona, 2012; Rodríguez-Morales et al., 2013; Soulsbury and White, 2015; Zuberogoitia et al., 2014). Conversely, in rural environments plant damage was more influential in determining tolerance towards wildlife than vehicle collisions, despite the latter being a more frequent and common concern (Storm et al., 2007).

Since most of the surveyed citizens (95.2 %) had not experienced incidents involving wild boars, agreeing with previous reports from other contexts (Lewis et al., 2019; Manipady et al., 2006; Nyhus, 2016; Piana et al., 2024), other factors such as emotions, socio-economic, and cultural background probably participated in the habituation or sensitization processes of the citizens (Pascual-Rico et al., 2021; Piana et al., 2024). Age and education participated in determining HWBC perception and acceptance of lethal management measures, with young student

animal-loving citizens (cluster 3) communicating lower HWBC perceptions and acceptance of lethal management measures than elder lower-educated citizens (cluster 4). Thus, the highly sensitized citizens in cluster 5 had a higher rural background and lower school education than the younger and higher educated students of clusters 1 and 2, who reported positive feelings towards wild boar. Similar differences in citizen attitudes towards wildlife conditioned by specific personal characteristics have been previously reported (Blanco and Cortés, 2009; Frank, 2016; Sakurai et al., 2013; Slagle and Bruskotter, 2019).

Additionally, the presence of wild boar in the PD and their interaction with humans are heterogeneous and influenced by environmental and urban factors (Bieber and Ruf, 2005; Castillo-Contreras et al., 2018; González-Crespo et al., 2023; Piana et al., 2024), leading to variability in the related costs (Dickman, 2010; Nyhus, 2016). While wild boar presence and HWBC were higher in SSG, HG and NB as compared to LC and G, citizens in the two later districts were more sensitized towards HWBC. These differences can be compared, at a different scale, to the differences between the CD and PD, with citizens in LC and G lacking positive emotional feelings raised from non-conflictive experiences and relying more on lay-knowledge concerns with sanitary and safety risks posed by wild boar, increasing in these two districts the support to reducing or eliminating the urban wild boar populations (Adams, 2016; Bath, 1998; Bruskotter et al., 2009; Piana et al., 2024; Slagle and Bruskotter, 2019). Between these two districts, higher HWBC perception and more radical position against wild boar was found in LC, with lower education level, AROPE rate, and population density than G. Moreover, even among the three PD with higher wild boar presence and incidences (SSG, HG and NB), sensitization was positively correlated with education level and negatively correlated with AROPE rate and human population density. The district with higher education level, population density and lower AROPE rate (SSG) had a more negative perception of urban wild boar and a stronger HWBC perception than HG, which in turn had also higher values for these indicators than NB. The lower effort and cost of wild boar management measures in NB than in HG and SSG despite the similar wild boar incidences and HWBC among the three districts could be explained by the higher AROPE in NB leading to higher social concern and efforts for other unsolved social and economic struggles (Nilon, 2014; Nyhus, 2016). This supports the existence of patterns of poverty and social inequality that link current HWBC with local socio-economic and cultural variables (Kaltenborn et al., 2006; Nilon, 2014).

4.1. Policy implications

The current and most feasible, effective, and efficient management of urban wild boars includes the control and reduction of anthropogenic food resources, including food from stray cat colonies, as well as both reducing the source population through hunting or other methods and removing conflictive wild boars in urban environments through live-capture and euthanasia (Barasona et al., 2013; Castillo-Contreras et al., 2018; Conejero et al., 2022; Cox and Gaston, 2018; González-Crespo et al., 2018; Massei et al., 2011; Torres-Blas et al., 2020). However, the human dimension is essential to implement such measures and address HWBC, since reducing anthropogenic food resources requires active citizen participation and lethal management measures must be socially accepted and approved (Broz et al., 2021; Conejero et al., 2019; Liordos et al., 2017; Nilon, 2014; Pascual-Rico et al., 2021: Piana et al., 2024; Shen et al., 2023; Slagle and Bruskotter, 2019).

However, emotionally-based human behaviours such as wild boar feeding by citizens are unlikely to change through rational cost-benefit motivations alone (Emre Can and Macdonald, 2018; Jacobson et al., 2014; Madden and McQuinn, 2014; Sun, 2015). Moreover, conflict mitigation may be more difficult among citizens with limited education or specific historical or cultural attributes predisposing to conflict (Adams, 2016; Nyhus, 2016). Consequently, arguments targeting the specific values for each reluctant social cluster must be integrated into awareness campaign messages (Conejero et al., 2019; Cox and Gaston,

2018; Jacobson et al., 2014; Sakurai et al., 2013). Social and cultural research on the factors promoting citizen habituation and sensitization of human-wildlife relations in urban areas could help to properly manage urban wildlife (Nilon, 2014; Slagle and Bruskotter, 2019; Zhang et al., 2014). In the long term, youth education could improve wildlife knowledge and increase environmental awareness, by addressing concerned attitudes derived from lay-knowledge misconceptions (George et al., 2016; Zhang et al., 2014).

Identifying the main drivers of the human dimension of HWBC provided a potentially useful quantitative and qualitative assessment of citizen attitudes, and allowed to disclose not only the animal habituation, but also the reciprocal process of habituation of humans to wildlife. This methodology could be applied in other human-wildlife interactions contexts, by addressing the specific cultural, social and psychological aspects (Bath, 1998; Kansky and Knight, 2014; Nettles et al., 2021). A local sociological analysis of citizen emotions, attitudes, lay-knowledge and experience conditioning management actions, including public acceptance of required measures, should increase management specificity and success (Jacobson et al., 2014; Sakurai et al., 2014; Whittaker et al., 2006).

5. Conclusions

This study reports for the first time reciprocal habituation between humans and synurbic wild boar through frequent and regular contact without negative interactions. On the other hand, low human interaction with wildlife and negative experiences, particularly traffic accidents, boost HWBC perception and increase acceptance of lethal control measures. Beyond reciprocal habituation and sensitization, in the absence of contact and/or negative experience, formation, cultural background, and socio-economic variables are the main contributors to create HWBC perception and acceptance or rejection of management measures. These factors should therefore be also considered in both awareness campaigns and specific management measures. Since socio-economic variables and cultural aspects orient emotions, perceptions, experiences, attitudes, and acceptance of management measures, the new approaches need to include social inequality and cultural variability in HWBC management. Beyond the specific context of synurbic wild boar in Barcelona, the common drivers of habituation and sensitization of humans to synurbic wildlife will allow the application of both the methodology used and the results obtained to other human-wildlife conflict scenarios. Education on a broad conceptual framework, including new technical approaches and ecological processes, should aim at increasing human knowledge of urban wildlife, in order to face HWBC in urban areas. This could orient citizen attitudes towards higher understanding and increased social and environmental responsibility.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2024.173258.

CRediT authorship contribution statement

Carles Conejero: Data curation, Formal analysis, Investigation, Methodology, Writing – original draft. **Carlos González-Crespo:** Formal analysis, Investigation, Methodology, Writing – review & editing. **Jaume Fatjó:** Conceptualization, Methodology, Writing – review & editing. **Raquel Castillo-Contreras:** Data curation, Investigation, Writing – review & editing. **Emmanuel Serrano:** Formal analysis, Software, Writing – review & editing. **Santiago Lavín:** Data curation, Project administration, Writing – review & editing. **Gregorio Mentaberre:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Supervision, Writing – original draft, Writing – review & editing. **Jorge R. López-Olvera:** Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

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